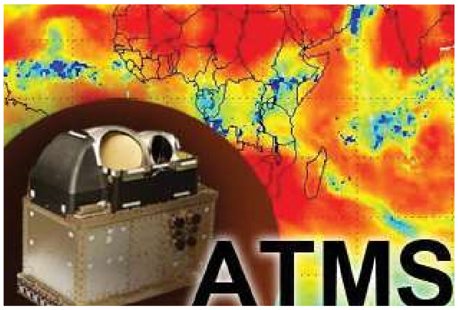

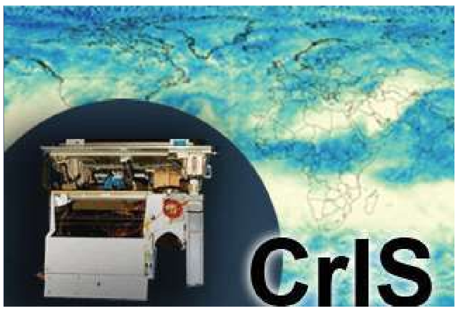

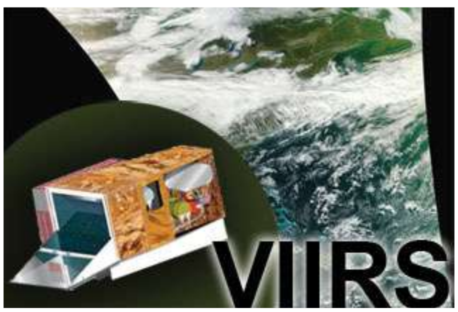

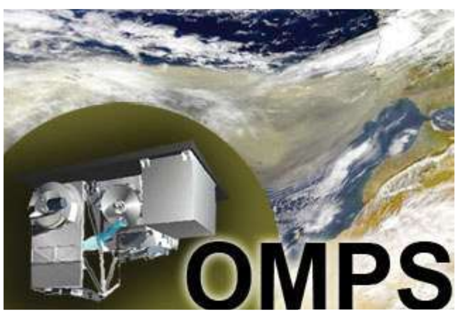

NOAA Workshop on JPSS Life-Cycle Data Reprocessing to Advance Weather and Climate Applications

Workshop on

JPSS Life-Cycle Data Reprocessing to Advance Weather and Climate Applications

National Oceanic and Atmospheric Administration

National Environmental Satellite, Data, and Information Service
Center for Satellite Applications and Research (STAR)

Hosted by the University of Maryland Earth System Science Interdisciplinary Center, College Park, MD

May 17-18, 2016

Workshop Organized by
Fuzhong Weng, Lihang Zhou, and Tom Atkins of STAR and Shubha Barriga of ERT, Inc.

Report Preparation
Compiled by Raju Datla, ERT, Inc.
Edit and Layout by Rebecca DeVost, ERT, Inc.

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2016 NOAA Workshop on JPSS Life-Cycle Data Reprocessing to Advance Weather and Climate Applications

Introduction

On May 17 and 18, 2016, the Center for Satellite Applications and Research (STAR) of the National Environmental Satellite, Data, and Information Service (NESDIS) held a workshop for experts across NESDIS/STAR, the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the Naval Research Laboratory (NRL), and NOAA-cooperative institutes and industry partners to maximize Joint Polar Satellite System (JPSS) data applications through Sensor Data Record (SDR) and Environmental Data Record (EDR) reprocessing. The JPSS preparatory mission Suomi National Polar-orbiting Partnership (SNPP), with the Visible Infrared Imaging Radiometer Suite (VIIRS), the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), and the Ozone Mapper/Profiler Sensor (OMPS) on board, has been providing valuable data and lessons learned on anomalies and their resolution for algorithm improvement. Reprocessing using mature algorithms will ensure that all JPSS satellite data, starting with SNPP from the beginning of the time series through the JPSS life cycle, will be consistent on a common reference frame with known uncertainty. The workshop proceeding will be available for forward planning of algorithm upgrades for the 2017 JPSS-1 launch.

Dr. Fuzhong Weng, Chief of the Satellite Meteorology and Climatology Division (SMCD), the SDR Domain Chair, and the SDR ATMS Lead; Ms. Lihang Zhou, JPSS STAR Program Manager; Dr. Tom Atkins of STAR; and Ms. Shubha Barriga of ERT, Inc. organized the two-day workshop, which was hosted by the University of Maryland Earth System Science Interdisciplinary Center at University Research Court, College Park, Maryland. Nearly 70 technical staff and associates connected with SNPP and JPSS at various branches of NOAA and NASA participated in the workshop. There were seven sessions, with presentations by invited speakers1 and discussions. Various speakers addressed the importance of reprocessing of SNPP data during the course of the workshop. Following the opening session, SNPP on-orbit performance and sensor data anomalies were discussed in Session 2. SNPP data user experiences and recommendations for further improvements were discussed in Sessions 3 and 4. Improved and advanced calibration and validation algorithms for reprocessing applications were discussed in Session 5. Potential impacts of the reprocessed SNPP data on NOAA operations were discussed in Session 6. Session 7 included a final discussion on the issues, challenges, and next steps for baseline approaches, schedules, and plans for SDR and EDR reprocessing. As a summary of the workshop, the benefits of SNPP reprocessing, and the action plan and milestones are presented below.

Importance of Reprocessing

The SNPP instruments are performing very well on orbit and the algorithms are very stable and nearing maturity. However, there has been quite a change in the data products—SDR and EDR—since the SNPP launch five years ago. The products were in various levels of maturity during these years as the data moved through beta, provisional, and then validated stages. The purpose of this workshop, therefore, was to discuss data reprocessing in an effort to bring all data in the time series to the fully validated level. Reprocessing, also referred to as "science reprocessing," is the use of validated mature algorithms to regenerate the SDR time series of SNPP onwards for the JPSS life cycle and thereby regenerate the EDR, again using mature algorithms, for weather and climate applications.

Various perspectives on the importance of reprocessing were presented by the workshop speakersThe presentations and discussion across the board established the need for reprocessing for accurate, reliable, and consistent data and products for users. The benefits of reprocessing are summarized as follows:

1 The individual presentations can be found on the NOAA Web site http://www.star.nesdis.noaa.gov/star/meeting_JPSS2016_LDRW.php.

- Many user applications expect long-term consistency of data product quality for reliable interpretation of trends observed with data products (land, atmosphere, and ocean).
- Product maturity and validation schema from beta, provisional, and validated maturity progressively proves that each data product meets the product quality requirements.
- Consistent, long-term product quality metrics (e.g., Accuracy, Precision, and Uncertainty [APU], achieved through re-processing, are crucial to set up a baseline for further advancement of observational data records.
- Reprocessing will contribute to improved reanalysis schemes that merge data from many different observations through data assimilation to attain reliable global trends.
- Reprocessing using best science and most matured algorithms provides useful inputs for essential climate variables (ECVs) and critical CDRs.

JPSS Reprocessing Action Plan

STAR will have a system of 72 nodes, similar to Wisconsin's Liam Grumley approach, with each node having 24 CPUs. The server, named Bamboo, is used to do bench tests, the results of which are as follows: the SDR reprocessing time for one year of ATMS data is 5 hours, CrIS is roughly one day, and OMPS is about three hours for the nadir profiler (ND) and 18 hours for Total Column. The total time required to process one year of SNPP data is currently 10 days. Dr. Weng projected that once the full capacity is built, the required time will be cut to 2 days. The goal is to accomplish complete reprocessing of one year of ATMS/CrIS/VIIRS/OMPS data by January 2017.

Milestones

2016

May	Complete the benchmark tests for reprocessing SDR datasets (done).
June	Complete the reprocessing of 5 years ATMS SDR data (done).
August	Complete reprocessing of 5 years of CrIS SDR data (done).
October	Complete the reprocessing of 1 year of OMPS SDR data.
November	Complete the reprocessing of 1 year of VIIRS SDR data.

2017

January	Complete the analysis of reprocessed ATMS/CrIS/OMPS SDR data.
March	Publish articles on quality improvements of Suomi NPP reprocessed SDR (R-SDR) data in AMS journals.

Introduction

1

On May 17 and 18, 2016, the Center for Satellite Applications and Research (STAR) of the National Environmental Satellite, Data, and Information Service (NESDIS) held a workshop for experts across NESDIS/STAR, the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the Naval Research Laboratory (NRL), and NOAA-cooperative institutes and industry partners to maximize Joint Polar Satellite System (JPSS) data applications through Sensor Data Record (SDR) and Environmental Data Record (EDR) reprocessing. The JPSS preparatory mission Suomi National Polar-orbiting Partnership (SNPP), with the Visible Infrared Imaging Radiometer Suite (VIIRS), the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), and the Ozone Mapper/Profiler Sensor (OMPS) on board, has been providing valuable data and lessons learned on anomalies and their resolution for algorithm improvement. Reprocessing using mature algorithms will ensure that all JPSS satellite data, starting with SNPP from the beginning of the time series through the JPSS life cycle, will be consistent on a common reference frame with known uncertainty. This workshop proceeding will be useful for forward planning of algorithm upgrades for the 2017 JPSS-1 launch.

Dr. Fuzhong Weng, Ms. Lihang Zhou, and Dr. Tom Atkins of STAR and Ms. Shubha Barriga of ERT, Inc. organized the two-day workshop, which was hosted by the University of Maryland Earth System Science Interdisciplinary Center at University Research Court, College Park, Maryland. There were seven sessions, with presentations by invited speakers[1] and discussions. The opening remarks are summarized in Section 2. The session on understanding SNPP on-orbit performance and sensor data anomalies is summarized in Section 3. As part of preparing for JPSS-1 launch and post-launch activities, Section 4 summarizes the SNPP data user experiences and recommendations for further improvements. Section 5 summarizes the improved and advanced calibration and validation algorithms for reprocessing applications. The potential impacts of the reprocessed SNPP data on NOAA operations are discussed in Section 6. The discussion on the issues, challenges, and next steps for baseline approaches, schedules, and plans for SDR and EDR reprocessing are summarized in Section 7.

1 The individual presentations can be found on the NOAA Web site http://www.star.nesdis.noaa.gov/star/meeting_JPSS2016_LDRW.php. Only the highlights are summarized in this report. Acronyms used in this report can be found in URL: http://www.star.nesdis.noaa.gov/jpss/acronyms.php.

Opening Session

2

Dr. Fuzhong Weng

Chair

Dr. Fuzhong Weng—Chief of the Satellite Meteorology and Climatology Division (SMCD), the SDR Domain Chair, and the SDR ATMS Lead—welcomed everyone, observing that it was the right time to have the workshop, as the SNPP instruments are performing very well on orbit and the algorithms are very stable and nearing maturity. However, there has been quite a change in our data products, SDR and EDR, since the SNPP launch five years ago. The products were in various levels of maturity during these years as we moved through beta, provisional, and then validated stages of 2015, as shown in **Figure 1.1**. In other words, 2014 data is not at the same level as that from 2015. Therfore, the purpose of this workshop was to discuss data reprocessing in an effort to bring all data in the time series to the fully validated level. Dr. Weng also observed that STAR should be fully prepared for the SNPP follow-on JPSS-1 launch in the coming year and, as such, the inputs and discussions in the workshop would help set the requirements, plans, and schedules for the JPSS life cycle data reprocessing.

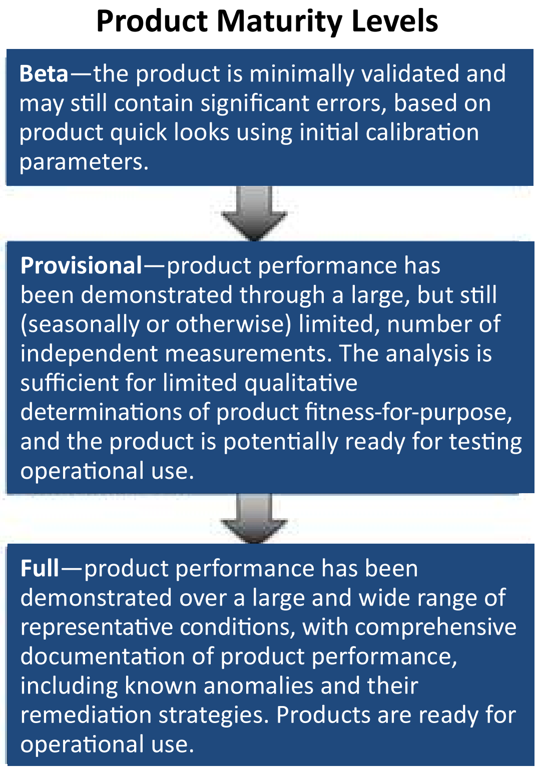


Figure 1.1: Product maturity levels: beta, provisional, and full.

2.1 Importance of Reprocessing

Following Dr. Weng's welcoming remarks, Dr. Michael Kalb, Acting Director of STAR; Dr. Mitchell Goldberg, NOAA JPSS Program Scientist; Dr. Jeffrey Privette, Deputy Director of the Center for Weather and Climate; and Ms. Lihang Zhou, JPSS STAR Program Manager also gave opening remarks for the workshop, presenting various perspectives on the importance of reprocessing for JPSS calibration and validation.

Reprocessing, also referred to as "science reprocessing," is the use of validated mature algorithms to regenerate the SDR time series of SNPP onwards for the JPSS life cycle and thereby regenerate the EDR, again using mature algorithms, for weather and climate applications. Dr. Michael Kalb, in his opening remarks, pointed out that it is a kind of retrospective analysis based on experience gained. Since the launch of SNPP, there have been improvements in data handling, calibration/validation methodologies, anomaly detection, and the development of new tools and capabilities. The purpose of the reprocessing is to extract the value from the past, to propagate it into the future, and to build a foundation for reference data sets. The lessons learned from this activity are to be applied to the full JPSS.

Presenter

Ms. Lihang Zhou

JPSS STAR Program Manager

Ms. Lihang Zhou highlighted the recommendations of expert bodies such as the JSTAR Annual Science Team (2015) for reprocessing to be undertaken. She emphasized that the JPSS system and instrument calibration stability requirements dictated by L1 Requirements Document Supplement[2 3] (L1RDS–14, L1RDS–92) and the long-term stability for product generation radiometric accuracy requirement from the Ground System Requirements Document (GSRD Vol 2) can only be satisfied through the JPSS life cycle reprocessing.

Another perspective on reprocessing is that it both ensures accurate and reliable products and satisfies the NOAA/NESDIS 2016 Strategic Plan[4]. This comment was referring to NESDIS' commitment for ensuring data quality and accuracy, and its goal to be a trusted source for near-real-time applications and retrospective information. An example was given about users accessing archived data in order to perform a retrospective study of how the forecasting of Hurricane Sandy in 2012 could have been improved. Users should be able to trust that the archived data is accurate, reliable, and consistent. The JPSS reprocessing is confined to S-NPP, J-1, and J-2 and should naturally be a line item of calibration/validation-funded activity. (Dr. Goldberg, Session 1)

The need for reprocessing to generate consistent data for creating Climate Data Records (CDR) was emphasized by Dr. Privette at the National Centers for Environmental Information (NCEI). The process of generating CDRs involves merging together data from multiple missions and it is absolutely necessary that the data from each mission be consistent. In fact, staff at NCEI do not develop new algorithms. Instead, they use the reprocessed SDR, which is considered to be a fundamental CDR, and the validated mature algorithms obtained from reprocessing for CDR generation. NCEI sustains 32 CDRs of various climate variables and, currently, many of them rely on reprocessed data from legacy sensors such as AVHRR, AMSU, and HIRS. NCEI plans to extend these CDRs with reprocessed VIIRS, ATMS, and CrIS records. (Dr. Privette, Session 1)

In session 7, Dr. Paul Digiacomo, Chief, Satellite Oceanography & Climatology Division; Dr. Ivan Csiszar, Chief, Environmental Monitoring Branch; and Dr. Ralph Ferraro, Chief, Satellite Climate Studies Branch also presented their perspectives based on their EDRs and the need for reprocessing.

From Oceans' perspective, the need for reprocessing has been expressed by various Line Offices—National Weather Service (NWS), National Marine Fisheries Service, National Oceanic Research, and Oceanic and Atmospheric Research—to have consistent, fit-for-purpose quality and a long-term series of satellite observations to fulfill their mission and the broader NOAA mission. Along those lines, reprocessing is essential for the production of science-quality time series data of satellite observations and is expected by satellite data product user communities, both within and external to NOAA. They consider reprocessing not as a luxury, but as essential to meeting their requirements. (Dr. DiGiacomo, Session 7)

From the Land EDR reprocessing perspective, there is also an ongoing transition of the land EDRs to Enterprise products that better meet critical end users' needs, such as

2 http://www.jpss.noaa.gov/assets/pdfs/technical_documents/level_1_requirements_supplement.pdf.

3 https://elibrary.gsfc.nasa.gov/_assets/doclibBidder/tech_docs/10.%20JPSS%20Ground%20System%20 Requirements%20Document%20470-00067%20-%20Copy.pdf.

4 http://www.nesdis.noaa.gov/pdf/strategic_plan/the_nesdis_strategic_plan_2016.pdf.

the NCEP/EMC land team. The goal is to reprocess the data record with the new enterprise algorithms, also taking advantage of the opportunity for accelerated and comprehensive product validation through the availability of multiple years of consistent data. Dependencies on upstream SDR and EDR products are critical and there needs to be strong interaction between the various product teams in the testing, evaluation and preparation for full reprocessing. Through reprocessing and the enterprise redesign of the products, improved integration into more generic multi-sensor, multi-mission systems, such as Land Product Characterization System (LPCS), is possible. Once the enterprise products are available, they will be evaluated and likely integrated within LPCS. Once in the LPCS, the products will be directly comparable with other similar data and products, currently MODIS and Landsat. (Dr. Csiszar, Session 7)

From the Precipitation/Hydrology perspective, reprocessing is important for several reasons. The first is the need for a continuous, consistent time series from the primary NOAA satellites as interim records. Two first-tier users of these interim records are the National Weather Service forecast offices and the National Centers for Environmental Prediction. If a weather forecaster is trying to make a forecast analog of how a storm today resembles a storm that occurred two years ago using a precipitation rates product, he or she needs consistency to analyze the corresponding data. It is not going to be of help to him or her if the precipitation rates are different due to the algorithm changing from one year to the next. However, it will be beneficial if he or she can rely on a consistent time series using the current algorithm. The second reason is the data use for test bed activities. For example, there is a hydrometeorology test bed to do winter and spring experiments. Satellite products are being considered for infusion into the experiments. The products must be consistent in order for the test bed to be able to compare them with their other products. Dr. Ferraro stated that he has been working with Dr. Kalb at STAR in running their big stream National Water Model for the National Water Center—a big player in terms of hydrology at the NWS. Again, consistent precipitation and snow cover information is required to feed these models. They refer back one to two years to spin the model and they need consistent data which can only be provided by reprocessing. (Dr. Ferraro, Session 7)

The benefits of reprocessing are summarized below: (Ms. Zhou, Session 1)

- Many user applications expect long-term consistency of data product quality for reliable interpretation of trends observed with data products (land, atmosphere, and ocean).
- Product maturity and validation schema from beta, provisional, and validated maturity progressively proves that each data product meets the product quality requirements.
- Consistent, long-term product quality metrics (e.g., Accuracy, Precision, and Uncertainty [APU], achieved through re-processing, are crucial to set up a baseline for further advancement of observational data records.
- Reprocessing will contribute to improved reanalysis schemes that merge data from many different observations through data assimilation to attain reliable global trends.
- Reprocessing using best science and most matured algorithms provides useful inputs for essential climate variables (ECVs) and critical CDRs.

In summary, the presentations and discussion across the board has established the need for reprocessing for accurate, reliable, and consistent data and products for users. Algorithms demonstrated through reprocessing will be used for forward planning of J1 upgrades. NESDIS/STAR, with the expertise on satellite algorithms and calibration/validation, will coordinate with NCEI and other stakeholders on the research-to-operations of the JPSS products reprocessing. (Ms. Zhou, Session 1)

As Dr. Kalb expressed, "there is a research element in reprocessing and it supports operations as well. You may or may not note its current value but the idea here is that we are trying to ensure the future value of the data and the investments we made in the mission (JPSS)."

2.2 JPSS Mission within NESDIS Ground Enterprise

Ms. Heather Kilcoyne, JPSS segment Program Manager, Office of Satellite Ground Services (OSGS), presented the overall status of the NESDIS ground enterprise in connection to the JPSS mission. The strategy of NESDIS' ground enterprise is to manage all ground systems through OSGS and support planning and future investments to create an integrated ground enterprise (IGE) enabling integrated processing, distribution, and access to products produced by NOAA and partner missions. One way of doing this is via enterprise algorithms. The same algorithm can be applied to all data, instituting processes into the ground system that are identical across satellite platforms. For example, one does not have to learn new vocabulary and new processes working with JPSS or GOES-R. The purpose is to foster greater efficiency and lower costs through common services and logistics.

The OSGS role in the NESDIS Ground Enterprise is shown as three missions. Mission 1 sustains current capabilities of legacy satellite systems. Mission 2 enables the completion of JPSS and GOES-R ground systems and their transition to sustainment. Mission 3 creates the IGE based on Ground Enterprise Architecture Services (GEARS). Currently, SNPP is flying on Block 1.2 of the OSGS ground system. Block 2.0 will be released soon and J-1 is projected to be on it. The purpose is to produce products to get the data to the users to enable improved forecasts. The real JPSS management of ground developments will transition from NASA to NOAA after the development of Block 3.0, projected notionally to be in 2019. As far as JPSS is concerned, the testing and development of early enterprise components (ESPDS and CLASS) that will provide product processing for JPSS-1 is being completed. The details on ESPDS and CLASS are provided below.

2.2.1 Environmental Satellite Processing and Distribution System (ESPDS)

It is the goal of the program to transition the Environmental Satellite Processing Center (ESPC) from mission-specific subsystems into an integrated enterprise system capable of meeting the requirements of both existing and future satellite ground processing systems. This includes developing and sustaining ingest, processing (NDE), and distribution (PDA) of elements for environmental satellite data mission needs.

2.2.2 Comprehensive Large Array-data Storage System (CLASS)

It provides long-term, secure storage of NOAA-approved data, information, and metadata and enables access to these holdings through both human and machine-to-machine interfaces. It provides capabilities in three primary functional areas: Ingest, Archival Storage, and Access. As an enterprise system, CLASS provides common services for acquisition, security, and project management for the IT system supporting NOAA archives, consolidating redundant, stand-alone, legacy archival storage systems; and relieving data owners of archival system development and operations issues (Heather Kilcoyne, Session 1).

Understanding SNPP Instrument On-Orbit Performance and Sensor Data Anomalies

3

Dr. Tom Atkins

Chair

Identifying and understanding anomalies is the most important component in advancing an algorithm to maturity. The SNPP satellite transmits raw instrument data—Level 0 data, called Raw Data Records (RDRs)—to the Command, Control, and Communications Segment (C3S), which is then routed to the Interface Data Processing Segment (IDPS). The IDPS processes the RDRs using the latest version of operational algorithms to create SDRs, which are subsequently processed into EDRs. The IDPS then transmits RDRs, SDRs, and EDRs to NOAA's CLASS (referred to earlier in Section 2.2.2) for archiving and distribution. Anomalies occuring at the sensor level are identified at the IDPS level, while some may be missed again at the IDPS level. In some instances, new anomalies can be introduced at the IDPS level due to operational algorithm problems. Therefore, a third level of screening for anomalies is performed by the STAR Integrated Calibration/Validation System (ICVS). The ICVS provides on-orbit instrument performance monitoring, both in real-time and long-term, and also provides trending of calibration/validation (cal/val) product quality.

Dr. Tom Atkins, of NOAA/NESDIS/STAR, chaired the session, which included six speakers: Mr. Wael Ibrahim and Ms. Michelle Hoover of the JPSS Common Ground System (JPSS/CGS - Raytheon[5]); Dr. Ninghai Sun and Dr. Jason Choi of NOAA/NESDIS/STAR; Dr. Viha Nguyen of NESDIS' Office of Satellite and Product Operations (OSPO); and Mr. Cole Rossiter of the NOAA JPSS Office (NJO) Algorithm Management Project (AMP). Their presentations are summarized in the following sections.

3.1 IDPS-identified Anomalies in SNPP RDR/SDR/EDRs

Presenters

Dr. Wael Ibrahim
Ms. Michelle Hoover

JPSS CGS

Dr. Wael Ibrahim and Ms. Michelle Hoover presented the IDPS perspective of anomalies that could occur either upstream at the sensor level or within IDPS. Many of these anomalies are resolved within IDPS and some are in the process of being resolved in order to update algorithms for reprocessing. All in all, they suggested that CGS IDPS has acquired operational experience since the SNPP launch and can contribute tremendously to: 1. understanding SNPP anomalies that occur during reprocessing and supporting program readiness for both JPSS-1 launch and post-launch activities; 2. developing baseline approaches, schedules, and plans for SDR and EDR reprocessing; and 3. developing new or identifying "reuse" tools to support SDR and EDR reprocessing.

Dr. Ibrahim provided the following examples of anomalies that occurred upstream of IDPS that required IDPS updates.

1. OSPO operations communicated that CrIS sensor packets were missing due to data link issues. They were later recovered as repaired RDRs, which then resulted in the generation of repaired SDRs. The repaired SDRs were then executed in parallel with real-time SDRs. IDPS identified the data quality issues and updated the

5 Raytheon – Intelligence, Information and Services (IIS) is the contractor providing support for the JPSS CGS for NOAA.

standard operating procedure to enforce serial tasking of CrIS SDR processing. In Block 2, the CrIS SDR CMO design was updated to fix this issue.

2. The CrIS SDR was produced with FILL values and further investigation revealed that the rotation angles in the four-minute engineering packet were in micro-radians whereas the IDPS code is expecting them to be in radians. Also, the time stamp bias field was defined as an unsigned integer, while the actual field was supposed to be a signed integer to handle negative numbers. The IDPS CrIS code was updated and the anomalies were resolved.
3. The OMPS Total Column Mapper/Nadir Profiler (TC/NP) CAL RDRs were truncated when the sensor was commanded to send more images than the allowed number in the IDPS ING algorithm. To resolve the problem, the code was updated to increase the number of images allowed.
4. An analysis of ATMS's first image after launch revealed inconsistencies and an investigation revealed that the ATMS PCT that was used was an old version and not the latest version. The correct "updated" version of the PCT was delivered to OPS.

The following were some examples of anomalies that occurred within IDPS.

I. Anomalies due to inherently known issues in the IDPS design that would result in lower-quality products:
    1. Anomaly related to repaired science RDR granule with ATMS, CrIS, or VIIRS: According to design, an SDR granule uses, as input, multiple RDRs, i.e., core RDR and cross-granule RDRs. As an example, an ATMS RDR granule <i> is an input to SDR granules <i-1>, <i>, and <i+1>. However, a repaired ATMS granule <i> will only trigger one repaired ATMS SDR granule (<i>) and not the other two (<i-1> and <i+1>) SDR granules. When a whole swath of granules was examined, it was determined that this affected the quality of the output.
    2. Anomaly due to missing spacecraft Attitude/Ephemeris (S/C ATT&EPH) packets in an RDR granule: If the volume of the packets was below a CFG threshold, this RDR granule would still be used as an input to create a corresponding GEO granule with TLE being used to mend the gap caused by the missing S/C ATT&EPH packets. According to design, if that S/C Diary RDR granule was repaired later (when the missing packets were redelivered to IDPS), that repaired S/C Diary RDR granule would not trigger a repaired GEO granule.

II. Anomaly related to leap second insertion: The leap second event was known to happen at the end of June 2012. The file was updated on July 1, 2012 but, due to a miscommunication, IDPS did not take advantage of that updated file until three days later. For those three days, the SNPP data products had a small known defect due to the impact of the 1-sec difference on the various time-dependent calculations. The leap second insertion has to be coordinated ahead of time between Observatory and Ground (C3S/IDPS) systems. As a lesson learned, it was handled well in the subsequent leap second insertion at the end of June 2015.

III. Anomaly due to table insertion into IDPS DMS with wrong effectivity: Effectivity means there is a start/end time stamp in the file name that is used as a means to query DMS searching for the required input files. If multiple versions of the requested input file exist, the DMS query will return a unique result based on the provided required effectivity. If an incorrect effectivity is used in inserting the table into the DMS, the product that is requesting that table based on the product-provided effectivity will not be able to find that table version, which may cause it to use a different version or even fail to process.

IV. Anomaly in VIIRS Aerosol ADR 4962 in Mx6.5: An early build Mx6.4 IDPS was found to be erroneous as it caused the aerosol retrievals to be unrealistic even in areas where it should not be erroneous, such as confidently cloudy conditions. IDPS collaborated with the Aerosol team to devise, test, and implement a fix in the following build Mx6.5.

The SNPP lessons learned were presented by Ms. Hoover. A perspective on how to accelerate reprocessing was presented from a factory production point of view. Repeated and excessive reprocessing was occurring in order to quickly correct issues for the IDPS releases. A solution was found in using Jenkins, which can run on Linux, to automate ADL. This change has lightened the load greatly on the IDPS software team. The algorithm chain runs were scripted, thereby reducing the overhead of running graphical user interfaces or the ADL TK runner. Many issues were resolved by reviewing the configuration of the system and SW architecture. Ms. Hoover concluded by saying that there are plenty of enhancement opportunities at IDPS to help reprocessing.

3.2 ICVS-identified Anomalies

Presenters

Dr. Ninghai Sun
Mr. Jason Choi

NESDIS/STAR

Dr. Ninghai Sun and Mr. Jason Choi presented the ICVS-identified anomaly events of SNPP instruments ATMS and CrIS, and VIIRS and OMPS respectively. The ICVS-identified anomaly events were classified as being of two types: (1) sensor level; and (2) algorithm and ground processing level. Sensor-level anomalies that produce data gaps or inaccurate RDRs cannot be resolved by reprocessing while the algorithm and ground processing level anomalies can be resolved via reprocessing. The improvements for ICVS were listed as being planned for each of the instruments in order to enhance the capability of monitoring sensor performance based on lessons learned from SNPP.

Dr. Sun demonstrated, via ICVS data analysis that uses SI-traceable instrument performance evaluation methods[6,7], that ATMS and CrIS are performing very well. The plots of the long-term noise equivalent differential temperature (NEdT) for ATMS and the noise (NEdN) for CrIS showed stable performance compared to specifications. Similar stable performance of VIIRS and OMPS compared to requirements has been reported by Mr. Choi. The ICVS web site presents the performance monitoring data for ATMS, CrIS, VIIRS, and OMPS using graphical plots[8]. Dr. Sun elaborated the two types of anomaly events of ATMS. The sensor level anomalies impact the Raw Data Record (RDR). The reprocessing of Sensor Data Record (SDR) during these anomaly events cannot improve the SDR further as the anomalies impacted the RDR itself. Examples of anomalies in this category are listed as follows.

- Sensor operating in safe mode causes data gaps.

6 Tian, Miao, Xiaolei Zou, and Fuzhong Weng. "Use of Allan Deviation for Characterizing Satellite Microwave Sounder Noise Equivalent Differential Temperature (NEDT)." *Geoscience and Remote Sensing Letters, IEEE* 12.12 (2015): 2477-2480.

7 Chen, Yong, Fuzhong Weng, and Yong Han. "SI traceable algorithm for characterizing hyperspectral infrared sounder CrIS noise." *Applied optics* 54.26 (2015): 7889-7894.

8 http://www.star.nesdis.noaa.gov/icvs/index.php

- Sensor drive main motor current anomaly causes calibration target degradation and the Field of View (FOV) angle variation.
- Radio-Frequency Interference (RFI) caused signal loss results in data gaps and quality degradation.

On the other hand the anomalies identified in the ATMS ground processing system or the calibration algorithm updates can be fixed in reprocessing. Examples of SDR quality improvements in this category are listed as follows:

- The updates of Temperature Data Record (TDR) to SDR conversion since launch.
- The updates of lunar intrusion detection and correction.
- The updates of non-linearity coefficients in the calibration equation.

Also, the full radiance processing update in the next version of ground processing system (IDPS code) will dramatically improve the SDR quality. Examples of ATMS anomalies caused by the ground processing system, which were fixed by improving the ground processing, are shown. The ATMS warm target range error for Channel 6 is illustrated in **Figure 3.1**. There was an error in the PCT table during April and early May of 2014. As a result, Warm Target readings could not pass the validation test by the calibration quality flag (QF 20) and data was missed. Once the range error was corrected in the PCT table, calibration data passed through validation test and the quality of the SDR improved to normal.

Another example discussed for SDR quality improvement was the lunar intrusion detection and correction algorithm upgrade (IDPS MX8.3). It fixed the IDPS coding error and also improved the logic. The lunar intrusion detection is now based on the geometry model as implemented successfully in the operational code. The contaminated cold counts are replaced by the most recent cold counts unaffected by lunar intrusion

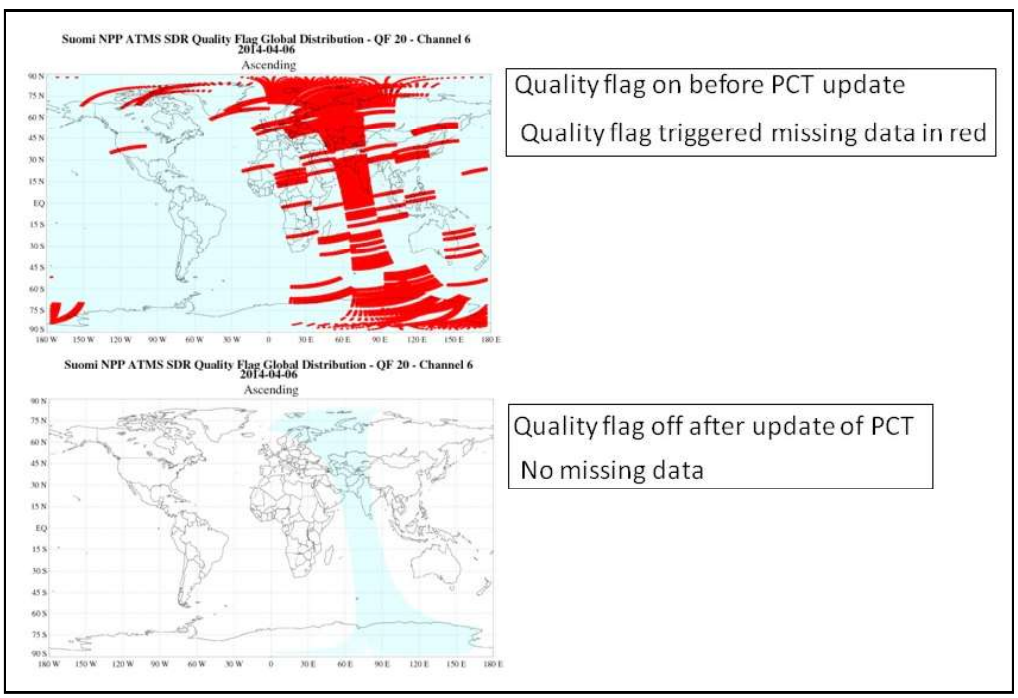


Figure 3.1: Correction of the calibration target valid range error resulted in the improvement of SDR.

instead of replacing with Fill values. The consistency check is allowed and data gaps are prevented.

Dr. Sun also discussed the anomaly events of CrIS classifying as sensor based and ground processing system or calibration algorithm based. The CrIS sensor based anomalies that cannot be fixed are data gaps caused by sensor switching to safe mode in operation or caused by orbital correction and calibration maneuvers. Examples of anomalies in the ground processing system that were fixed in the IDPS upgrades are discussed. The geolocation quality flag was triggered more often in the ground processing due to an error in the IDPS software. It was fixed in the software upgrade IDPS MX7.1 on July 10, 2013 and **Figure 3.2** shows the quality flag triggered less after that date. However, in IDPS MX7.1 update, a more strict check was applied on RDR quality which resulted in increase of RDR invalidity as shown in **Figure 3.3**. Such anomalies in ground processing can be fixed using final software update in reprocessing.

Mr. Choi discussed the VIIRS anomaly events as follows. The sensor level anomalies that cause data gaps are not fixable. Also, the data gap anomalies due to single board computer (SBC) lock-up events that can't be fixed by reprocessing are listed in **Figure 3.4**. Over the VIIRS lifetime, there were 10 SBC lock-up events causing data gaps.

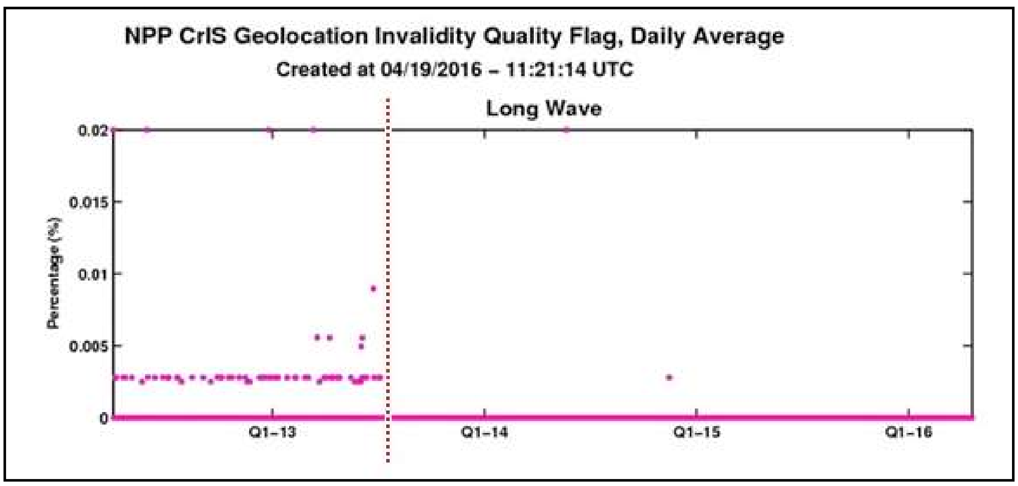


Figure 3.2: CrIS anomaly due to geolocation invalidity quality flag.

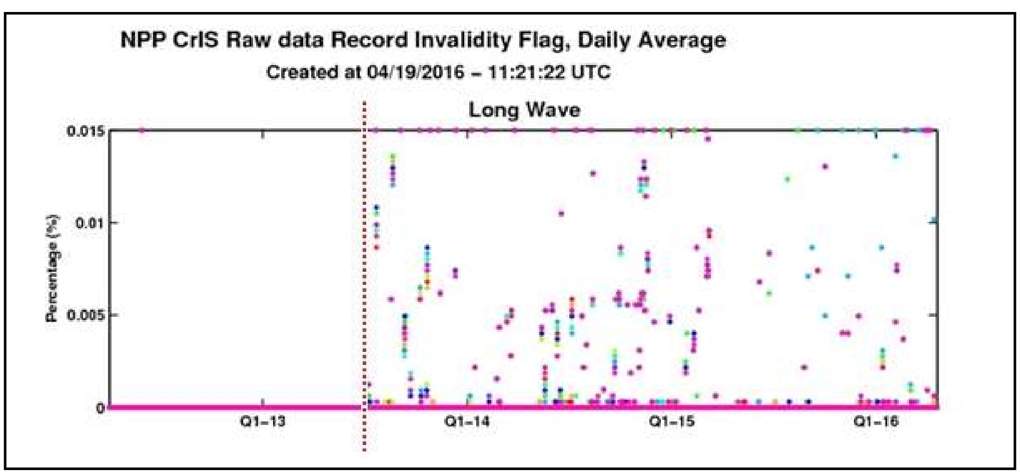


Figure 3.3: CrIS anomaly due to RDR quality flag.

SNPP VIIRS Single Board Computer (SBC) Lock-Up Events				
Event #	**Date**	**Start Time**	**End Time**	**Duration**
1	11/25/2011	16:36	N/A	N/A
2	2/10/2012	04:43	08:56	4:13
3	2/18/2012	04:14	12:00	7:17
4	3/10/2012	04:03	14:03	10:00
5	3/28/2012	04:22	11:25	7:03
6	11/22/2012	16:32 (11/22/2012)	01:26 (11/23/2012)	8:54
7	2/4/2014	17:38	21:35	3:37
8	8/8/2014	14:20	18:50	4:30
9	9/26/2014	18:25	18:35	0:10
10	10/9/2014	17:22	19:31	2:09

Figure 3.4: VIIRS data gap due to single board computer lock-up events at the sensor.

The reason is unknown, although high energy particle hits could cause such events. However, there was no SBC lock-up event since 10/9/2014.

An example of the anomaly that can be fixed by reprocessing is shown in **Figure 3.5**. The operational fast track updates of the "F" factors had sudden changes in year 2014 caused by the H-factor estimation errors up to 1.5 percent. The H-factor is directly related to the F-factor. The forward H-factor fit failed to predict the future trend which resulted in a sudden change in SDR product (F factor).

The anomalies in OMPS are discussed at the Sensor level and at the ground processing system level. The sensor level anomalies due to changes in CCD temperature, electron-

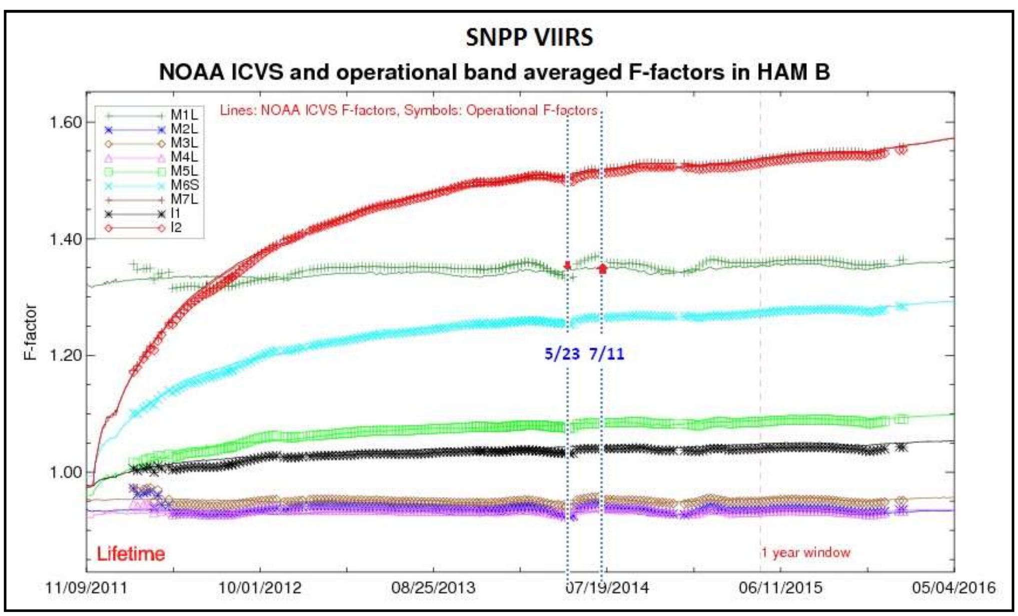


Figure 3.5: Sudden "F" factor changes in certain VIIRS channels due to sudden changes in the H-factor.

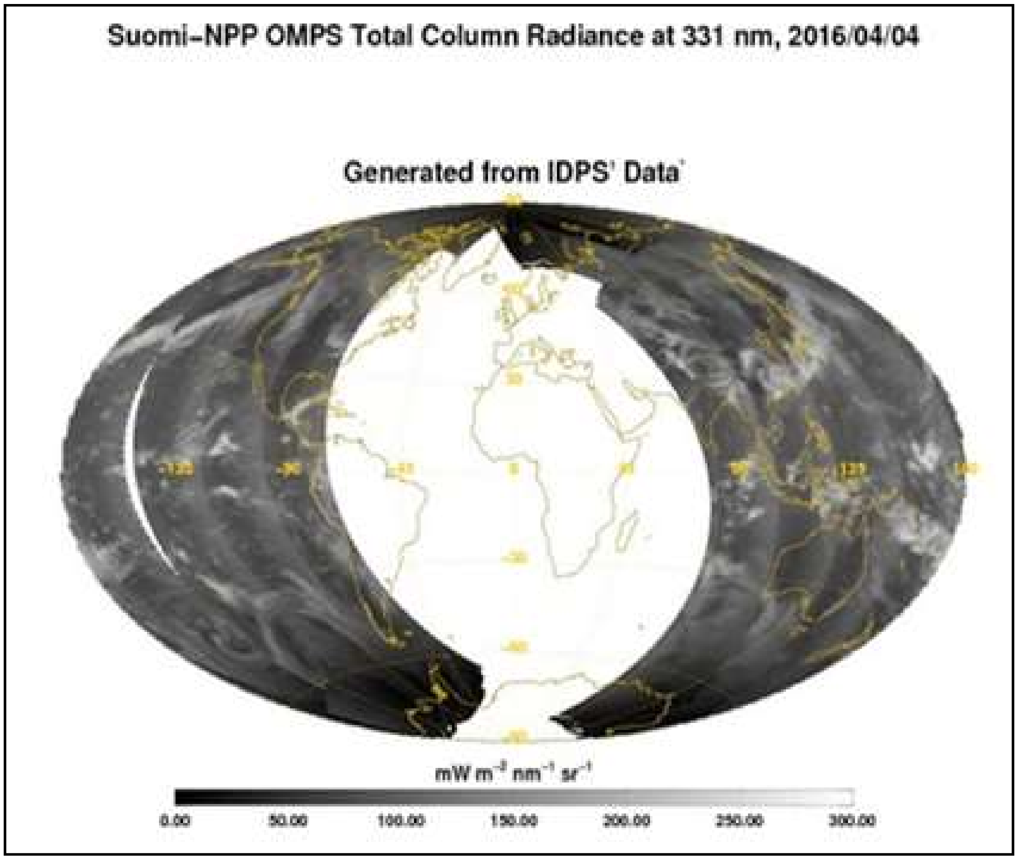


Figure 3.6: OMPS anomaly caused by accidentally uploading an incorrect LUT table.

ic bias, and degradation of the instrument optics cannot be fixed. The ground processing system level anomalies discussed are as follows. The corrections to the software completed as part of Mx6.7 in 2013 removed the negative smear in OMPS earth view. The dark calibration anomalies are captured by monitoring the dark data every day every orbit and performing statistical analysis of the weekly data to identify week to week variations. Anomalies due to light contamination are captured in this process.

Another example of an OMPS anomaly caused at the ground processing system level is shown in **Figure 3.6**. An incorrect LUT table was accidentally uploaded and as a result, the earth view radiance is shown with many NAN values and so part of the image is blank. ICVS is implementing the fast, near real time monitoring algorithm to closely watch the SDR products and prevent similar anomalies to happen. The use of the earth view radiance quality flag, monitoring of NAN values and zeros, and other fill numbers in the SDRs are accomplished in the algorithm.

3.3 ICVS-LITE Status and Recommendations on ICVS-Lite Development

Presenter

Dr. Viha Nguyen

NESDIS OSPO

Dr. Viha Nguyen presented the current status and recommendations on ICVS-Lite development. ICVS has been identified as one of the important tools for data quality monitoring by the OSPO Data Quality Engineers (DQEs) to support OSPO real time operations. OSPO decided to develop ICVS capability with the help of STAR for SNPP real time monitoring by DQEs. OSPO chose to host the new capability, which they named ICVS-Lite, on the Government Resource for Algorithm Verification, Independent Test, and Evaluation (GRAVITE) system, as it provides the real-time data access, computing powers, redundancy, and secured environment necessary to support operations. Nguyen demonstrated that substantial progress has been made to integrate Block 2.0-compliant ICVS-Lite packages into GRAVITE. The most useful modification recommended for ICVS-Lite development was to use standard a configuration file in each module to define path names of input, output, and intermediate data directions. The benefits would be a faster and simpler integration process and data that could be separated from code, thus improving manageability and efficiency. Other changes recommended that would facilitate the ICVS-Lite integration process are as follows:

1. Provide advance notification of changes that will be coming to ICVS-Lite, including new commercial of the shelf (COTS) products.
2. Coordinate with the STAR ICVS Web developer to update the ICVS-Lite web page (i.e., csv files) to be consistent with any new module delivered.
3. Provide information from the STAR subversion that describes the differences between STAR ICVS and ICVS-Lite.
4. Add a capability to disseminate email alerts about anomalies.
5. Reduce the size of files and specify which intermediate files are to be kept for the life of the mission and which can be cleaned up. This will avoid exceeding GRAVITE storage capacity and prevent the deletion of files that should be saved.

3.4 Synoptic Report on SNPP Events and Anomalies

Presenter

Mr. Cole Rossiter

NOAA JPSS

Mr. Cole Rossiter discussed the Data Product History (DPH)[9] task at NJO/AMP. The DPH is a comprehensive list of planned activities and anomalies, beginning with SNPP launch, in October 2011, through the present. The DPH is maintained as an Excel spreadsheet, with the purpose being to serve as an immediate reference of SNPP events as needed for reprocessing. At present, the NOAA STAR team has access to the spreadsheet but it was Rossiter's intention that going forward, it should be as widely accessible to users as possible. That access will allow others to contribute to the data by editing it as necessary as well as adding any missed events.

Rossiter demonstrated the DPH spreadsheet in Excel, shown in **Figure 3.7**, which includes a tab for a Master List of all anomalies and planned events that have occurred as well as individual tabs for the ATMS SDR, the CrIS SDR, the OMPS Nadir Profiler SDR, the OMPS Total Column SDR, the VIIRS SDR, and VIIRS NCC Imagery—all products that IDPS is fully responsible for going forward. The master list includes the event title and description, the date of the event, the time it occurred, and the ending time, as well as the instruments affected, from where that information was retrieved, a CCR number, if applicable, and any additional notes that could be of use to the users. Rossiter pointed to the most recent event in the master list page that happened on the morning of the workshop at 2:56 UTC, May 17th: a roll maneuver for the VIIRS lunar calibration. Rossiter gave the sources for the information, as shown in **Figure 3.8**.

9 Update for the report: The DPH is updated and maintained on a weekly basis. It can be accessed on eRooms at https://jpss-erooms.ndc.nasa.gov/eRoom/JPSSGround/GroundAlgorithms/0_a92d1. Weekly updates are also sent to Lori Brown at STAR who incorporates them into an identical spreadsheet that is maintained on the STAR ICVS website: http://www.star.nesdis.noaa.gov/icvs/AnomalyHistory.php. If you have any events or anomalies you think should be incorporated into the DPH please send them to Cole Rossiter at cole.rossiter@noaa.gov.

Event	Date	Time (UTC)	End (UTC)	Instrument(s)	Retrieved from:	CCR	Notes
CrIS SSM SEU (12)	04/07/16	19:30		C	C/V Leads Archive		8s loss of dat
VIIRS DNB Calibration	04/07/16	1:43	16:56	V	C/V Leads Archive		
Star Tracker Lunar Intrusion Test	04/11/16	18:18		NACOV	C/V Leads Archive		12 minutes w
ATMS 1552 Bus Safe Mode Event	04/14/16	4:35	12:06	A	C/V Leads Archive		During conta series of erro 1553 Packet E there is no ev issue. The pr the problem, UTC. No ATM to begin seei
ATMS Daily Scan Drive Reversals Stopped	04/15/16			A	C/V Leads Archive		
Roll Maneuver for VIIRS Lunar Calibration	04/17/16	11:38	11:50	NACOV	MN022678, GO-CAM, C/V Leads Archive		
VIIRS FSW_x4017 Upload	04/19/16	13:01	21:48	V	MN022679, GO-CAM, C/V Leads Archive		
VIIRS Scan Sync Error (62)	04/23/16	4:17	4:19	V	NPP Tech Memo on VIIRS Telescope Sync Loss		
OMPS Solar Calibration	04/27/16	14:58	6 orbits	O	C/V Leads Archive		Reference Dif
OMPS Solar Calibration	04/30/16	3:52	2 orbits	O	C/V Leads Archive		LP Solar Refe
ATMS Manual Command Scan Drive Reversal	05/05/16	14:46	14:52	A	ESPC Ops Report		
VIIRS DNB Calibration	05/06/16	1:01	16:15	V	C/V Leads Archive		
ATMS Manual Command Scan Drive Reversal	05/06/16	14:26	14:30	A	ESPC Ops Report		
ATMS Manual Command Scan Drive Reversal	05/09/16	16:53	16:58	A	ESPC Ops Report		
ATMS Manual Command Scan Drive Reversal	05/10/16	16:33	16:38	A	ESPC Ops Report		
ATMS Manual Command Scan Drive Reversal	05/11/16	16:14	16:19	A	ESPC Ops Report		
ATMS Manual Command Scan Drive Reversal	05/12/16	17:38	17:43	A	ESPC Ops Report		
ATMS Manual Command Scan Drive Reversal	05/13/16	15:35	15:40	A	ESPC Ops Report		
Roll Maneuver for VIIRS Lunar Calibration	05/17/16	3:56	4:08	NACOV	C/V Leads Archive		

DPH Brief | Master List | ATMS | CrIS | OMPS NP | OMPS TC | VIIRS | VIIRS NCC Imagery

Figure 3.7: Template of the Data Product History (DPH) spreadsheet.

- **WRS Full Report Mission Notices (MNxxxxxx)**
  - My eRooms > Ground Operations and Support > WRRP > Weekly WRS Full Reports
- **NPP Annual Trending Reports (NPP ATR)**
  - My eRooms > JPSS Flight Operations and Support > NPP > Trending > MOT Annual Trending Reports
- **NPP Monthly Trending Reports (NPP MTR)**
  - My eRooms > JPSS Flight Operations and Support > NPP > Trending > MOT Monthly Trending Reports
- **NPP Tech Memo on VIIRS Telescope Sync Loss**
  - Maintained on the OPS LAN
- **Cal/Val Leads Archive (C/V Leads Archive)**
  - Updated weekly by Cole Rossiter, maintained by Jeff Weinrich, AMP/STAR Cal/Val Lead
- **ESPC Ops Report**
  - Automatic email updates from Mission Ops about on-orbit anomalies and maneuvers
- **NOAA CLASS JPSS Mission Notice Archive**
  - Can order mission notices from anytime after launch

Figure 3.8: Information sources for the DPH.

Rossiter stated that the three most important sources of information are the WRS Full Report Mission Notices, the SNPP Annual Trending Report and Monthly Trending Reports, and the NPP Tech Memo on VIIRS Telescope Sync Loss. The Full Report Mission Notices, saved in eRooms and updated on a weekly basis, are stored along with the mission notice number and any notes that were included in those mission notices. The Annual Trending Reports, from 2013 through the present, and Monthly Trending Reports, from launch through the present, are kept up to date in a separate eRooms managed by the Mission Operations Support Team (MOST) as a source of information. The third source is the NPP Tech Memo on VIIRS Telescope Sync Loss, which is maintained on the OPS LAN by the NOAA OSPO SNPP Engineering Team. Rossiter himself performs the on-orbit updates on a weekly basis, which are then archived in the Cal/Val Leads Google Drive, which is maintained by AMP/STAR Cal/Val Lead, Jeff Weinrich. A fifth source is the Environmental Satellite Processing Center

(ESPC) Operations (Ops) report, which is disseminated by email each time there is an anomaly or upcoming planned event. One can also retrieve mission notices from the CLASS archive.

During the second part of the presentation, the SNPP information that is archived for various planned events, numerous calibrations, algorithm and table updates, and common and major anomalies were discussed. As an example of the type of information archived under planned events/maneuvers, the ATMS Scan Drive reversal is shown in **Figure 3.9** with the full description of the maneuver.

Finally, Rossiter discussed the most recent major anomaly: the ATMS 1553 Bus anomaly, described in **Figure 3.10**. The other examples of archived information can be seen in Rossiter's presentation[10]

ATMS Scan Drive Reversals

- **Purpose:** Delay ATMS Scan Drive degradation
- **Instrument(s) Affected:** ATMS
- **History:** ATMS was designed to scan back-and-forth but the ground software wasn't designed to handle the reverse scan data so it was decided that ATMS would scan in one direction. When the ATMS scan drive motor current began to spike last year it was decided to begin once-a-day reversals for 6 reverse scans (16 seconds) above 70° Northern latitude.
- **Daily Scan Reversals began:** 24 August 2015
- **Daily Scan Reversals ended:** 15 April 2016 due to the ATMS 1553 Bus Anomaly. Manually commanded reversals began every weekday on 5 May 2016. Reversals are commanded during a Svalbard contact. Because they are manually commanded they last for 15 reverse scans (60-90 seconds).
- **Impact:** No ATMS science data during reverse scan. Larger impact due to manual commanding.

Figure 3.9: ATMS planned maneuver of scan drive reversal.

ATMS 1553 Bus Anomaly

- **Root Cause:** The root cause appears to be a problem with the Flight Software that is unique to the scan drive reversal. Northrup Grumman was able to reproduce the anomaly on the EDU but is still reviewing the data and has not provided a recommendation for how to resolve this issue.
- **Instrument(s) Affected:** ATMS
- **Occurred:** 14 April 2016
- **Impact:** During the daily ATMS scan reversal a routine ATMS instrument reset command tripped off a series of errors culminating in the instrument going into safe mode (starting with a 1553 Packet Error). There is no evidence to suggest that this was caused by a mechanical scan drive issue. The problem was verified on the following orbit. After some work to diagnose the problem, spacecraft engineers returned ATMS to nominal operation at 12:06 UTC. No ATMS SMD data will be available from this event.

Figure 3.10: SNPP ATMS 1553 Bus anomaly.

10 http://www.star.nesdis.noaa.gov/star/meeting_JPSS2016_LDRW.php.

SNPP Data User Experiences and Recommendations for Future

4

The SNPP data user experiences were presented in two sessions. The first session was devoted to the experiences of the real-time data users of SNPP for numerical weather prediction (NWP) and its effect on NWP in cases of data gaps. This session is summarized in section 4.1. The second session was devoted to experiences encountered during the development of the SNPP data products at STAR. This session is summarized in section 4.2.

4.1 SNPP Real-Time Data Users

Dr. Mitchell Goldberg

Chair

Dr. Mitchell Goldberg chaired the session, which included four speakers: Dr. Andrew Collard of the National Weather Service (NWS) National Centers for Environmental Prediction (NCEP); Dr. Heather Lawrence of the European Center for Medium-range Weather Forecasts (ECMWF), UK; Dr. Bill Campbell of the Naval Research Laboratory (NRL); and Dr. Krishna Kumar of the Joint Center for Satellite Data Assimilation (JCSDA). Their presentations are summarized in the sections below.

4.1.1 Evaluations of SNPP Data and Impacts on Forecasts

Presenter

Dr. Andrew Collard

NWS NCEP

Dr. Andrew Collard focused on assimilating the CrIS and ATMS data into an operational weather prediction model. The NWS/NCEP considers itself a part of the cal/val effort at STAR and obtaining the data as soon as it was available was important for their mission. As the CrIS and ATMS data were received as buffer in real time, NCEP was able to use them very quickly. This high-quality ground-based instrument characterization data, such as the instrument spectral response functions, allowed for timely forward model development. The antenna temperatures contained in the ATMS data files were used and the performance was assessed relative to that of AMSU-A/MHS on NOAA-19. The comparisons were shown based on first-guess (FG) departure statistics (observed radiances minus those calculated from a 6-hour forecast) for the NCEP common Gridpoint Statistical Interpolation (GSI) assimilation system. Nigel Atkinson, of the UK's Met Office, developed the AAPT FFT-based code to re-map and, in the process, spatially average the AMSU-A-like ATMS channels to a common field of view of 3.3^0. This was to reduce the noise on the temperature sounding channels and also allow the 5.2^0 FOV channels 1 and 2 to be consistent with other AMSU-A-like channels, as those channels were used for cloud detection. Special attention was paid to remove data gaps and bad data, as they can affect the surrounding points in the re-mapped product.. Collard presented the data in **Figure 4.1** as the comparison between AMSU-A and ATMS FG departure statistics. Following the remapping, the ATMS noise characteristics were much improved. It can also be seen that the ATMS scan dependent bias is much smaller than that of AMSU-A. (the remapped data is shown as green points in the top section of the graph). However, striping that appeared in ATMS channel 10 was being investigated. The equivalent AMSU-A channel 9 showed comparatively less striping. The striping artifact in the data can introduce correlated errors that are larger than the signal for some upper-atmospheric channels and for this reason only scan position 5 was assimilated to try to mitigate this effect. On the whole,

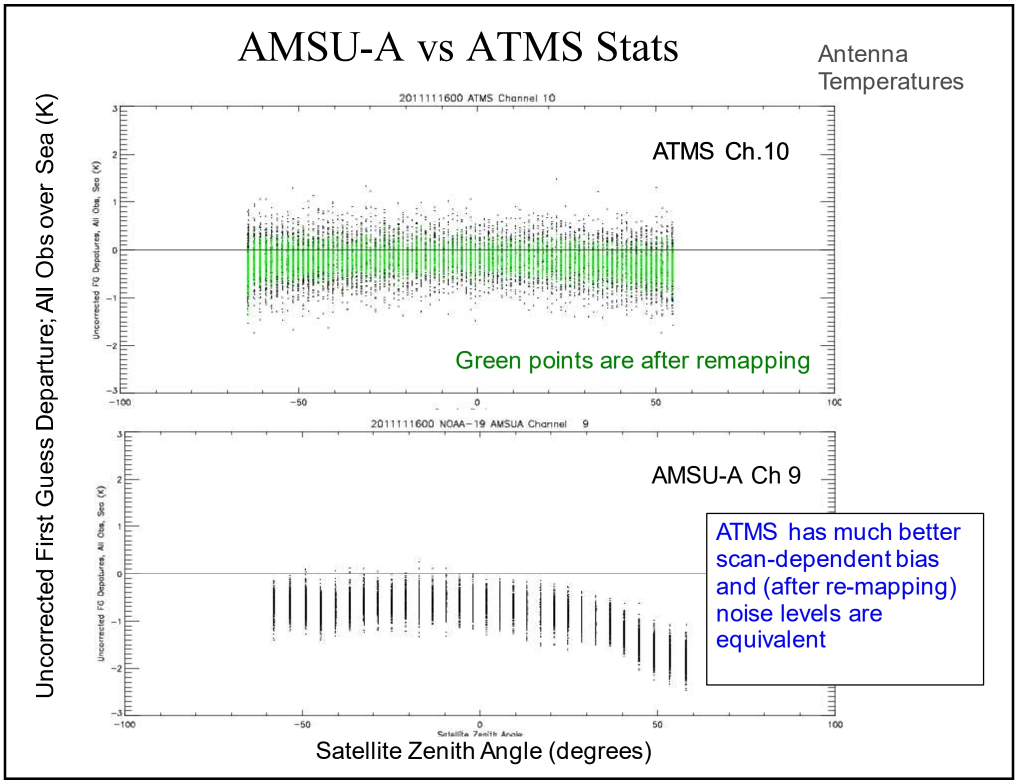


Figure 4.1: Comparison between AMSU-A and ATMS FG departure statistics.

ATMS observations were of good quality and ATMS and AMSU-A are very equivalent in their impact on forecasts.

With regard to CrIS data, 399 channels from the original 1,305 channels with spectral resolutions ranging from 0.625 cm-1 to 2.5 cm-1 were received (the full set of 2,211 full-spectral resolution (FSR) channels will be received when operationally available). Eighty-four channels ranging from 672.5 cm-1 to 1095.0 cm-1 are operationally assimilated which were identified as being useful for inferring for temperature, cloud, CO2, and surface properties. Channels sensitive to trace gases and solar radiation were excluded. The water vapor channels will be included once the correlated observation error term has been added to the algorithm. The comparison of CrIS, AIRS, and IASI FG departure statistics are shown in **Figure 4.2**. The CrIS instrument noise was much lower; in the important CO_2 band, it was well below 0.2K. However, the CrIS, AIRS, and IASI were very close in their impacts.

Dr. Collard concluded that while CrIS and ATMS data are valuable contributions for the NCEP global model, how to optimally use the data from these instruments is still in the discovery phase at NWS/NCEP. Specifically, a number of projects were undertaken to improve the use of CrIS radiances, including improved error specification, cloud-cleared radiances, and direct cloudy radiance assimilation.

Presenter

Dr. Heather Lawrence

ECMWF, UK

4.1.2 Operational Near Real-Time (NRT) Data from SNPP at ECMWF

Dr. Heather Lawrence spoke about the assimilation of ATMS and CrIS data at ECMWF. The ATMS data was assimilated operationally in 2012. While the data quality was good, two differences stood out when compared to AMSU-A. The first was

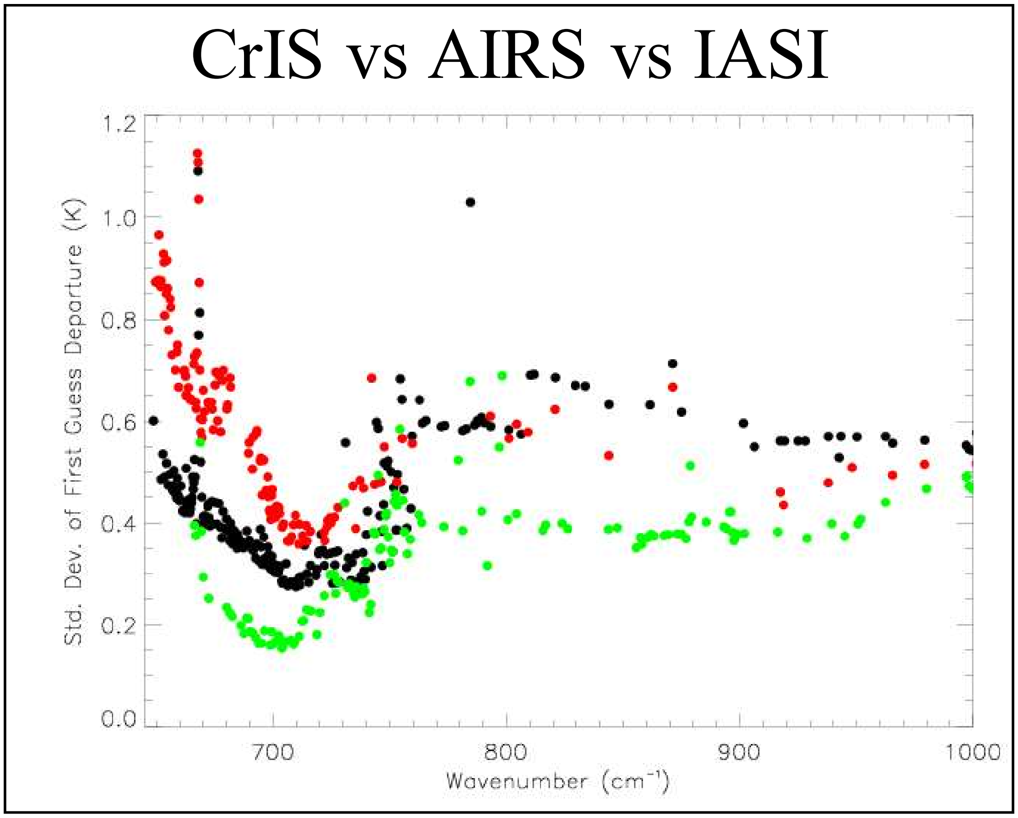


Figure 4.2: Comparison of CrIS, AIRS, and IASI FG departure statistics.

striping, which can be seen clearly in **Figure 4.3** in the observation minus background chart. The second difference was the inter-channel error correlations for temperature sampling channels, which made assimilation more complicated. Such correlations were not present in AMSU-A, as shown in the right side of Figure 4.3. They assimilated ATMS following 3x3 averaging and received some positive impacts on their forecasts, as shown in the bottom of Figure 4.3. The values were below Zero and ATMS had a positive impact on the day by day forecast especially for Day 1 and Day 2.

Lawrence discussed de-striping analysis done on a dataset provided by NESDIS that covered January 1st to February 14, 2013. The de-striping algorithm[11] was applied. An improvement for temperature sounding channels was seen in the maps of observation minus background statistics for de-striped minus original. However, for the window and humidity channels, new artifacts in the data were seen that were suspected to be caused by some geo-physical features; coastlines or clouds that hit the scan line. The de-striping algorithm might consider these features as stripes to be removed and introduce them as artifacts. The change in the standard deviation (o-b) was shown in **Figure 4.4**. There was a reduction of standard deviation (o-b) for temperature sounding channels 6 to 15 by about 5%. There was an increase in the humidity sounding channels, which was suspected to be due to the artifacts discussed earlier or due to clouds. For future instruments, Lawrence stressed that avoiding the striping through appropriate instrument design would be the best solution.

11 Ma, Y. and X. Zou, 2015: Striping noise mitigation in ATMS brightness temperatures and its impact on cloud LWP retrievals. J. Geophy. Res., 120, 6634-6653.

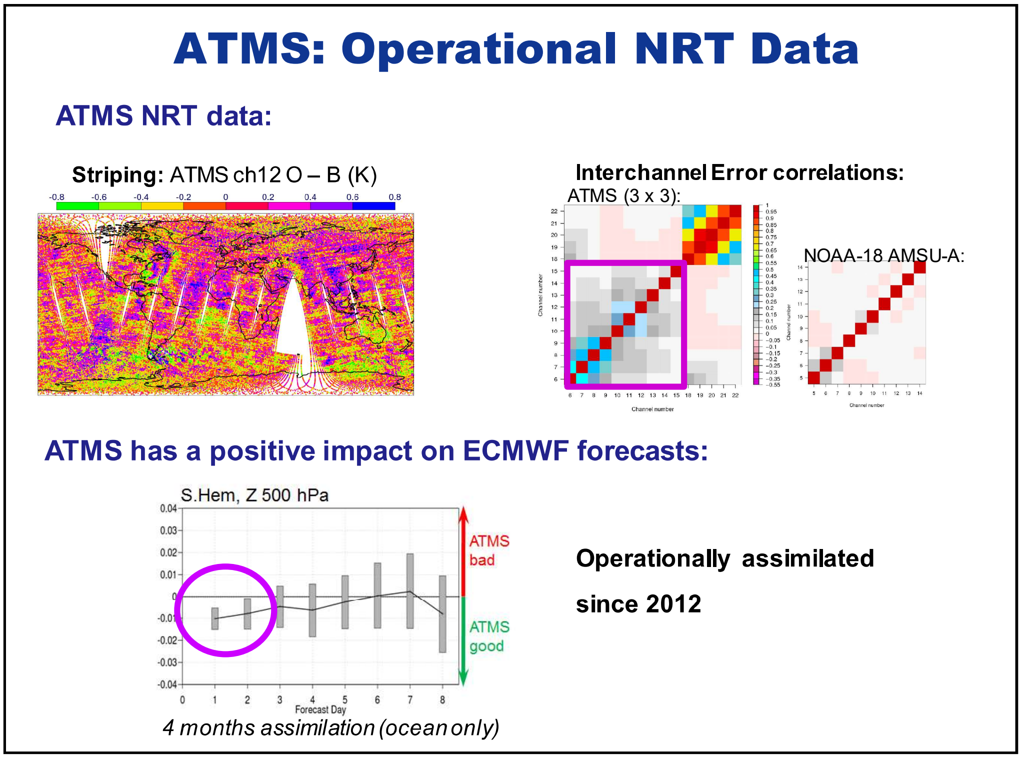


Figure 4.3: Operational NRT data from SNPP ATMS at ECMWF.

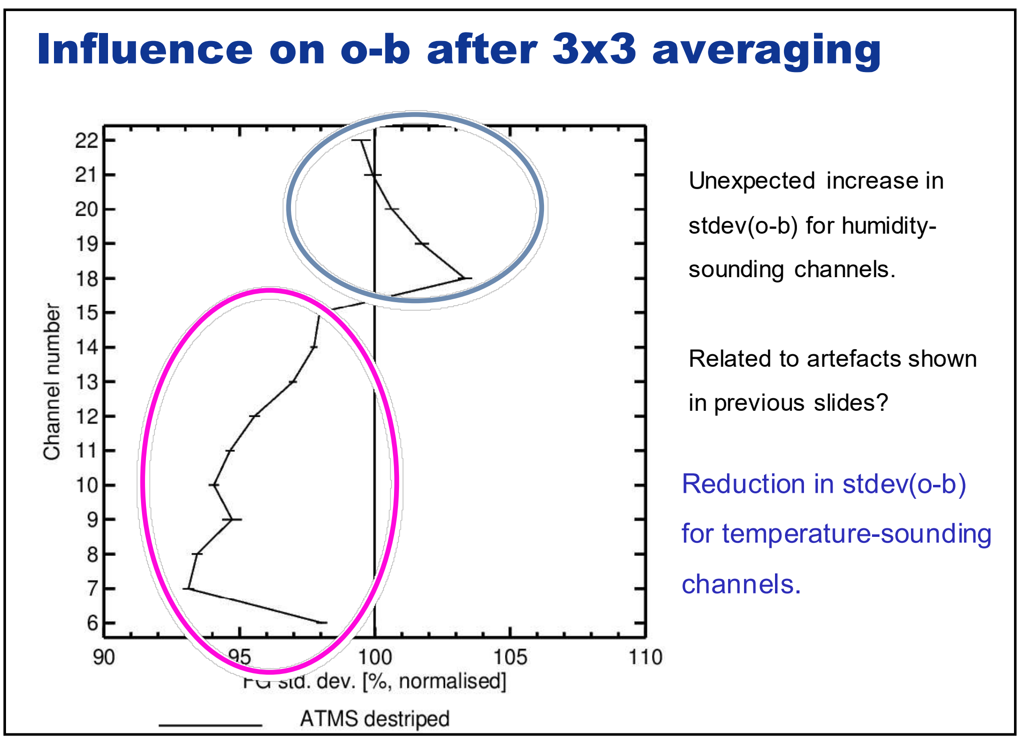


Figure 4.4: De-Striping Effect on the Temperature, Window, and Humidity Channels of ATMS.

Lawrence also briefly presented CrIS data, as analyzed by her colleague Dr Reima Eresmaa at ECMWF. The CrIS data has been assimilated into ECMWF forecasts since January of 2015. A significant upgrade—increasing the number of channels from 77 to 117—was in process and Dr Eresmaa was applying a new observation error covariance matrix that would have off-diagonal terms to account for inter-channel error correlations, considered to be very important for hyper-spectral sounders. The impact of adding CrIS into the forecast model is shown in **Figure 4.5**. The two plots at the bottom—ATMS and AMSU-A—showed improvements when CrIS data was added. Also shown, on the bottom right of the figure, are improved forecasts scores with active wind in the southern hemisphere at 500 hPa, as a function of the forecast day.

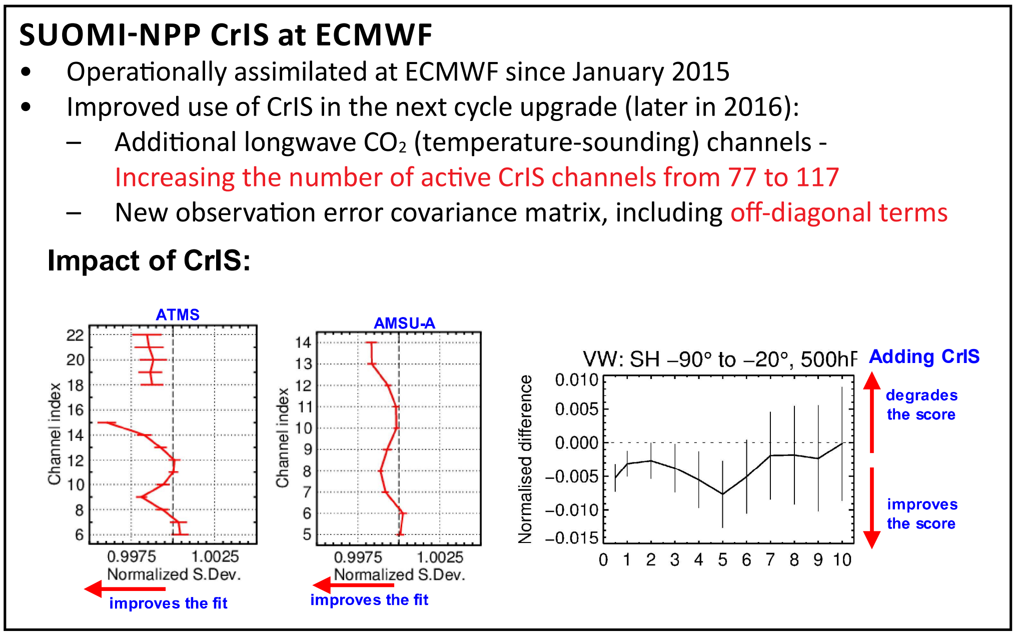


Figure 4.5: The impact of including CrIS improves forecasts at ECMWF.

The conclusion was that adding CrIS data had a positive impact on ECMWF forecasts.

Lawrence showed a wish list for reprocessed SNPP data for their work at ECMWF:

1. ATMS data with lunar intrusions flagged and corrections applied for the entire time series;
2. Collocated imager data[12] along with CrIS data to assist with cloud detection, as with IASI; and 3. The VIIRS AMV dataset from prior to 2014.

Lawrence finished by presenting ongoing work of the GAIA-CLIM project. This project is a collaboration between 15 different institutes within Europe, including ECMWF and the Met Office, with the goal of using reference in-situ data such as the GRUAN radiosonde network to aid the calibration/validation of new satellite instruments[13]. As part of this project, data from the JPSS-1 ATMS instrument will be evaluated at ECMWF and the Met Office using the short-range forecasts from these institutions. Simultaneously the GRUAN data will be used to give estimates of the errors in the ECMWF and Met Office short-range forecasts, both in model space (temperature and

12 Eresmaa, R., 2014: Imager-assisted cloud detection for assimilation of Infrared Atmospheric Sounding Interferometer radiances, Q. J. Roy. Meteorol. Soc., 140, 2342-2352.
13 www.gaia-clim.eu.

humidity) and in radiance space, which should help to provide uncertainty estimates on the calibration/validation of these new satellites.

4.1.3 ATMS and CrIS Assimilation at Naval Research Laboratory

Presenter

Dr. Bill Campbell

NRL

Dr. Bill Campbell showed the current Navy Global Environmental Model (NAVGEM)-based Naval Research Laboratory (NRL) Atmospheric Variational Data Assimilation – Accelerated Representer System (NAVDAS–AR) observation sensitivity in **Figure 4.6**. The plot is a 24-hour forecast error norm reduction and ATMS and CrIS are two very large contributors, as shown on the left, and very important for NAVGEM. The middle and right side of the figure represent the plots of channel-by-channel contributions of ATMS and CrIS, respectively. Their impact was very beneficial.

Campbell presented the process for data assimilation from these sensors. Basically, there can be four types of observation errors in the data. The first is instrument error that, while usually uncorrelated, is not always, as in the case of ATMS. The second error type is incorrectly mapping operator errors in interpolation to errors in the radiative transfer model. The third is quality control, especially for IR, due to cloud and precipitation screening. Pre-processing and bias correction may also have errors. The fourth error type is in data representation due to sampling or scaling. Campbell presented the use of Desroziers[14] method of estimating the covariance matrix of correlated errors and the results for ATMS and CrIS based on this method. The striping exhibited in Channels 5, 6, 7, and 8 was shown. The striping error was correlated in time and, as such, correlated both in space and channel to channel. Taking into account the correlated error would correct some of the striping.

The results of correlations in ATMS channels are shown on the right side of **Figure 4.7**. The moisture channels (18 to 22) are highly correlated, as are temperature channels 4 and 5, circled in red. The results of error of standard deviations in the analysis are shown on the right side of the Figure 25. The red curve is the error of standard de-

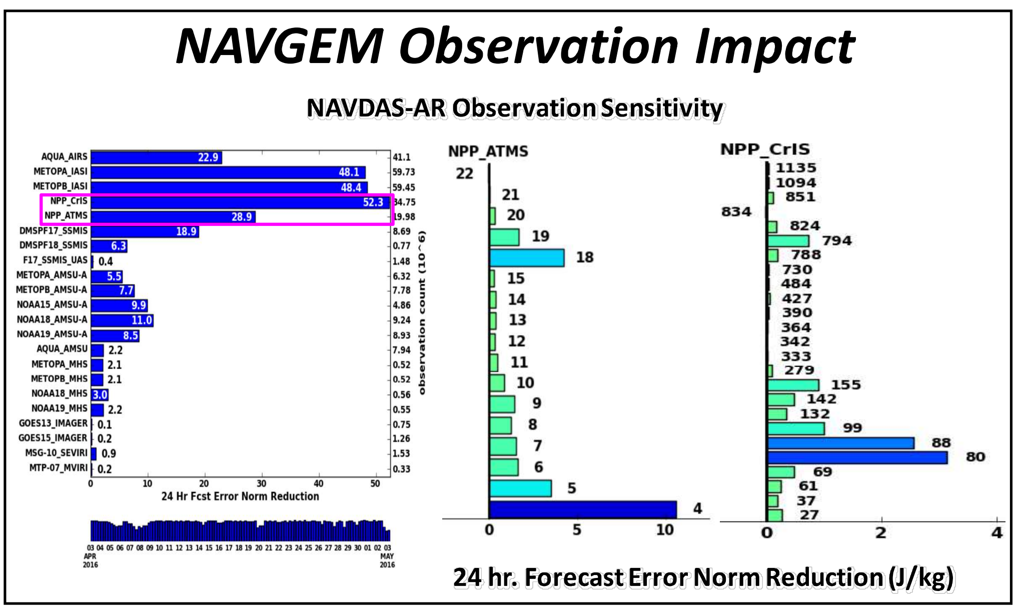


Figure 4.6: Analysis of accounting correlated error in ATMS channel by channel.

14 Desroziers, G., L. Berre, B. Chapnik and P. Poli, 2005: Diagnosis of observation, background and analysis-error statistics in observation space, Q. J. R. Meteorol. Soc., 131, 3385–3396.

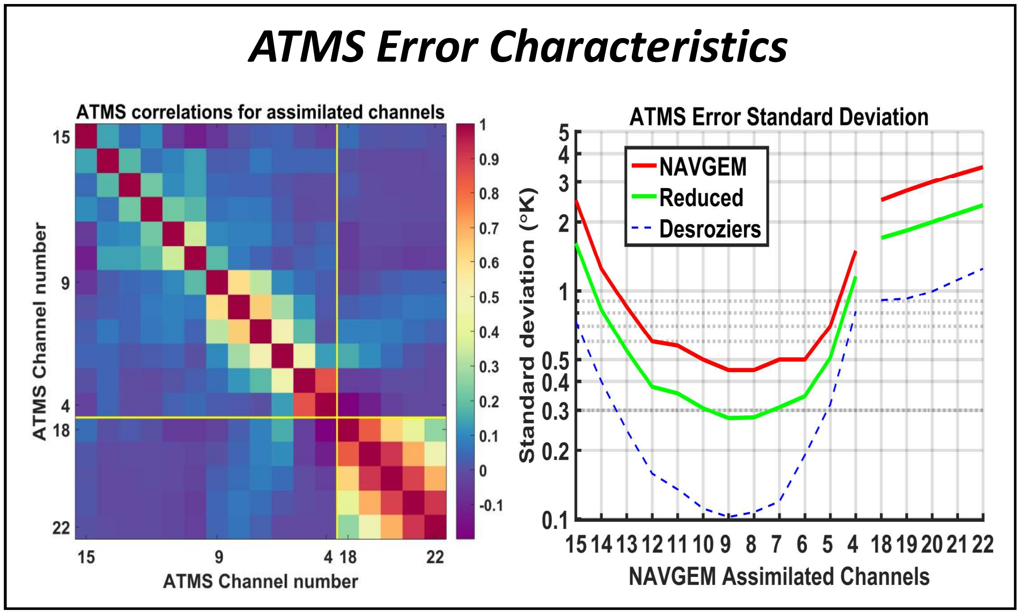


Figure 4.7: ATMS correlations for assimilated channels and the Error standard deviation.

viations that was assumed in NAVGEM prior to accounting for correlated errors. The dashed curve shows the result of error in standard deviations in applying Desroziers' method for accounting correlated errors. Campbell noted that the standard deviations in the dashed curve were much lower and may not be realistic. The green line was considered a compromise between the red curve of the NAVGEM model and the dashed curve of the Desroziers' method. The results of an experiment comparing the NAVGEM model (red curve = control run) and the ATMS model that accounted for just the vertically-correlated error (green curve) in the channels are shown. The improvement in the forecast, even up to five days, at all pressures was robust. The improvement occurred in the northern hemisphere, the tropics, and the southern hemisphere. Merely assimilating the correlated ATMS model data compared to the baseline showed a very positive result.

Campbell presented such an analysis on CrIS data as well. **Figure 4.8** shows the 120 assimilated CrIS channels, the positive impact of which was shown previously, in Figure 23. In summary, Campbell concluded that SNPP ATMS and CrIS data provides significant positive impact in the NAVGEM system. Accounting for correlated errors from ATMS and CrIS data yielded an unexpectedly large forecast benefit. NRL plans to implement, test, and transition correlated errors for ATMS, CrIS, and other satellite instruments in the future.

The attendees had a discussion regarding the potential impact to forecasts should reprocessed data (following de-striping) be provided. Campbell stated that it should have a beneficial impact, and even more so if the striping correlation is removed at the source and any remaining correlations are able to be remedied by the Desroziers' method.

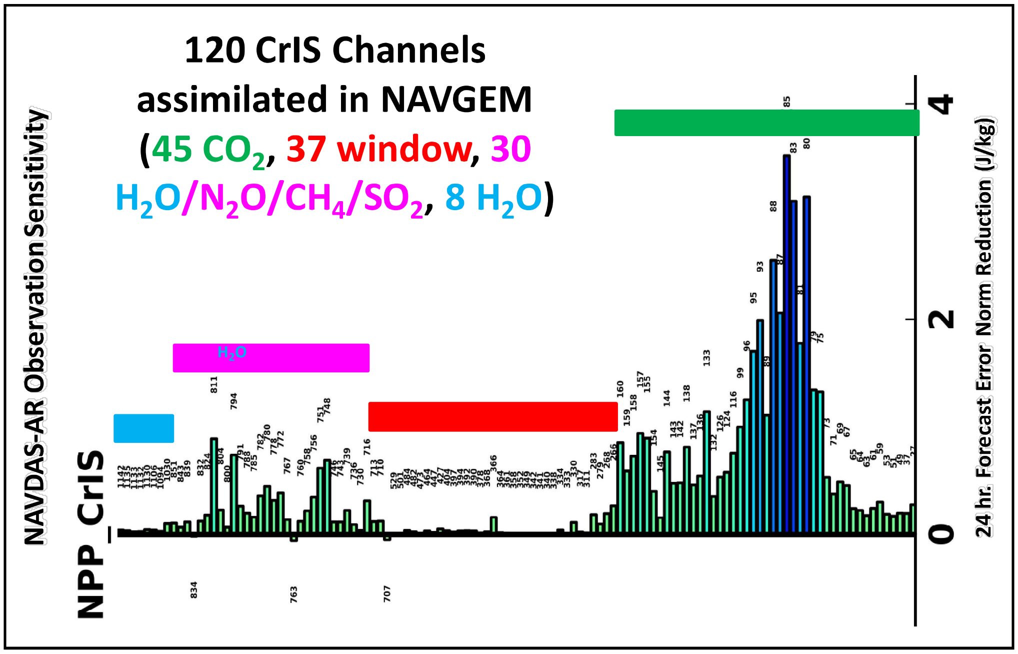


Figure 4.8: CrIS channel assimilation in NAVGEM.

4.1.4 Results of Data Denial Experiments at the Joint Center for Satellite Data Assimilation

Presenter

Dr. V. Krishna Kumar

JCSDA

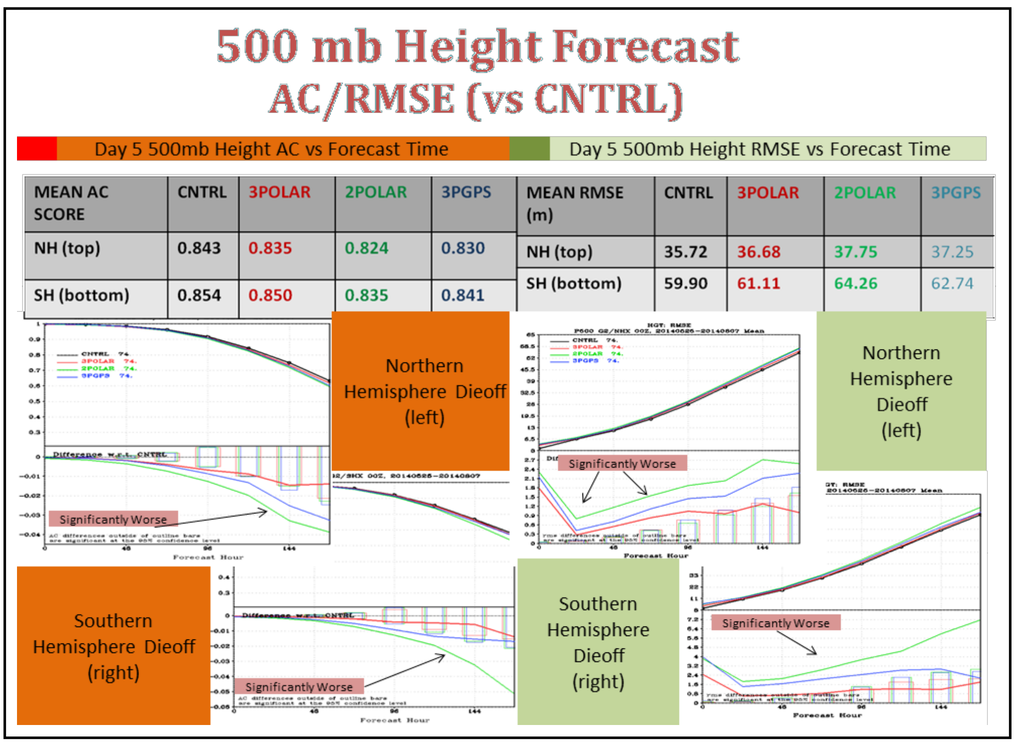
Dr. V. Krishna Kumar, of the Joint Center for Satellite Data Assimilation (JCSDA), presented the data denial experiment, where the objective was to assess the impact of potential JPSS data gaps on global NWP forecast performance. The data employed from the global observing system (GOS) polar-orbiting satellite constellation—comprised of all polar-orbiting satellites from DoD, NOAA, NASA, and JPSS—was primarily from three orbits: early morning, mid-morning, and afternoon. The best case scenario, used as the control (CNTRL) group in the experiment, occurs when all data is available. In this case, while data is being collected from JPSS, as the primary satellite, data is also being collected from secondary satellites. Secondary satellites are degrading satellites still in operation but beyond their expected lifetime such as afternoon satellites N18 and N19. One data denial case in the experiment was the three polar satellite case, when all secondary satellite data was unavailable, leaving only the early morning F18, the mid-morning METOP-B, and the afternoon JPSS satellite (SNPP) data. The exception here is that the MODIS IR winds are also assimilated, as a proxy for the VIIRS IR winds that have yet to be implemented in the operational system. The second case—the two polar satellites case—occurred upon the loss of the JPSS complete afternoon orbit, when only the F18 and METOP-B were available. They also considered the 3PGPS case: similar to the three polar satellite case but with the added loss of the Global Positioning System Radio Occultation (GPSRO) data poleward of ±24º latitude since it is expected that the COSMIC-2 low inclination constellation will provide more dense observations in the tropics.

The 2015 NOAA operational model, with the NOAA Global Data Assimilation System (GDAS) and the NOAA Global Forecast System (GCAS), was used for the experiment. The period chosen was one season—May 15, 2014 to August 7, 2014 (summer season capturing Hurricane Arthur). A 10-day spin up period was allowed and a 7-day

(168 hours) NOAA GFS forecast was analyzed. The results are summarized in **Figure 4.9,** where the 500 mb height forecast anomaly correlation (AC) is shown on the left side and the root mean square error (RMSE) is shown on the right side for both the northern and southern hemispheres. The two satellite case, where there was no JPSS afternoon orbit data, has the largest degradation: 0.824 compared to the CNTRL of 0.843 and the three polar case of 0.835. The color-coded Dieoff curves showed the same trend for both the northern and southern hemispheres.

Drs. Boukabara, Garrett, and Kumar, of NESDIS and JCSDA, devised a new method to compute a normalized score by looking at all the experiments—CNTRL, three-polar satellite, two-polar satellite, and 3PGPS—as well as the overall AC and RMSE.[15] The description of the method is shown in **Figure 4.10**. Based on a consolidated score, the CNTRL experiment resulted in the most accurate forecast skill, followed by the three-polar experiment and then the 3PGPS, which was denying some of the extra tropical observations from the GPSRO. The two-polar experiment had the lowest score, as shown in **Figure 4.11**.

In summary, the overall forecast quality is degraded significantly when quasi-redundant (secondary satellite) polar data is removed. The secondary orbits proved to be important in terms of forecast skill and should not, therefore, be considered as secondary. The 3PGPS case suffered degraded forecast skill, but not as significantly as the two polar satellite case, where the afternoon satellite data was removed.



MEAN AC SCORE	CNTRL	3POLAR	2POLAR	3PGPS
NH (top)	0.843	0.835	0.824	0.830
SH (bottom)	0.854	0.850	0.835	0.841

MEAN RMSE (m)	CNTRL	3POLAR	2POLAR	3PGPS
NH (top)	35.72	36.68	37.75	37.25
SH (bottom)	59.90	61.11	64.26	62.74

Figure 4.9: The AC and the RMSE shown for the data denial experiment.

15 Boukabara, S. A, K. Garrett, and V. K. Kumar (Monthly Weather Review, doi:10.1175/MWR-D-16-0013.1).

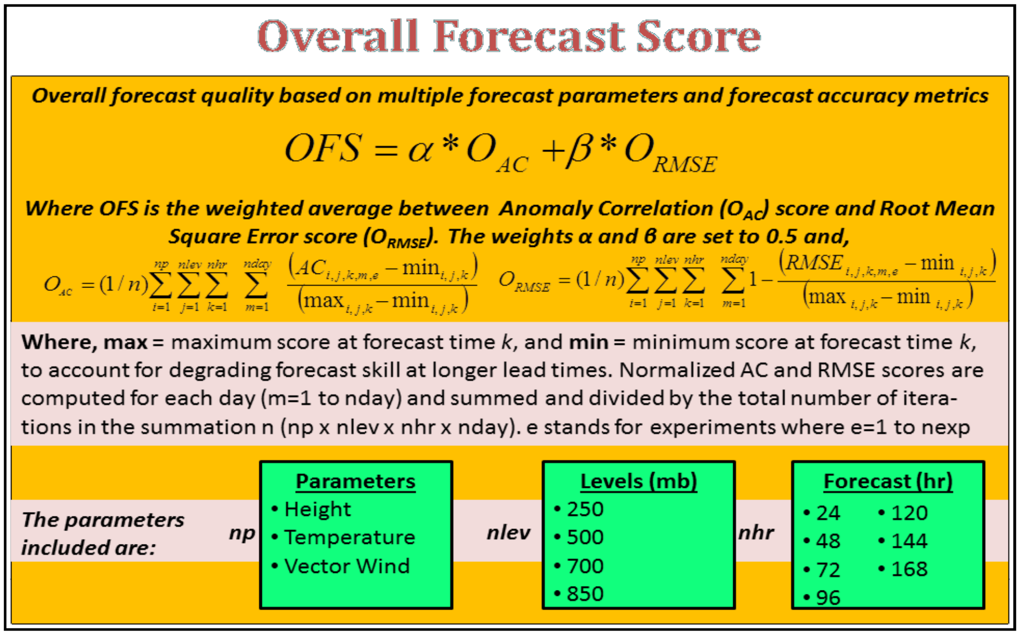


Figure 4.10: New method developed by JCSDA to compute the overall forecast score.

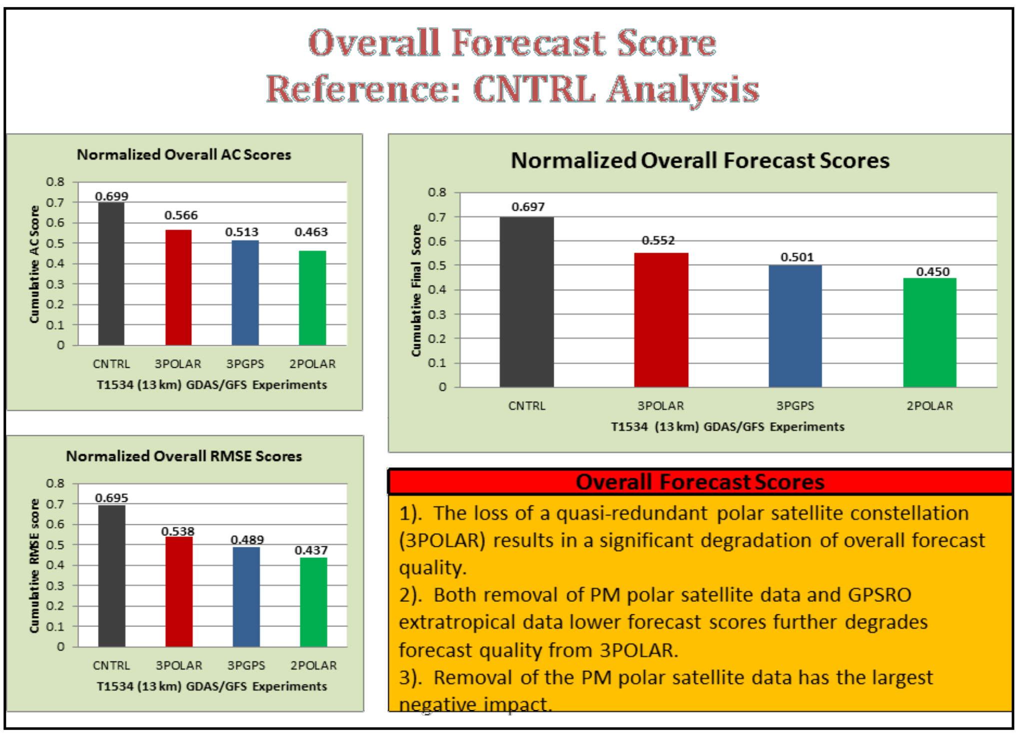


Figure 4.11: Overall forecast scores using the JCSDA method.

When asked whether the new computation method is being developed by JCSDA for the community and, if so, when it would be available, Kumar replied that it is JCSDA's intention to offer this contribution to the community, that they are working on it to make it more user friendly for computation and comparison of different methods, and that it would be available following its validation by different metrics.

4.2 Users of SDR, EDR Updates and Reprocessed Data

Dr. Changyong Cao

Chair

Dr. Changyong Cao, Chief of the Satellite Calibration and Data Assimilation Branch at NOAA/NESDIS/STAR, chaired the session, which included seven speakers: Dr. Jack Xiong of the VIIRS Characterization Support Team (VCST) at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC); Dr. Junqiang Sun of NOAA/NESDIS/STAR; Dr. Ivan Csiszar, Chief of the Environmental Monitoring Branch of NOAA/NESDIS/STAR; Dr. Glen Jaross of the OMPS Nadir Team at NASA GSFC; Dr. Craig Long of National Weather Service (NWS)/Climate Prediction Center (CPC); Dr. Larry Flynn of NOAA/NESDIS/STAR; and Dr. Mark Liu from NOAA/NESDIS/STAR. Their presentations are summarized in the following sections.

4.2.1 Evaluation and Improvements of SNPP VIIRS SDR

Presenter

Dr. Jack Xiong

NASA GSFC

Dr. Jack Xiong reviewed the VIIRS on-orbit performance, the NASA VCST contribution towards SDR improvements, and VIIRS future effort. He also answered a question from Dr. Ivan Csiszar of NOAA/NESDIS/STAR by providing details about the difference between NASA's Land Science Investigator-led Processing System (SIPS)-generated SDR and the IDPS-generated SDR. There are two data processing streams for VIIRS. The data processing stream through IDPS produces EDRs to meet NOAA's operational needs, especially those of the NWS. The other data processing stream is handled at NASA by the VIIRS Land Product Quality Assessment through Land SIPS[16], which produces Earth System Data Records (ESDR) for the science community. The details are given at the end of the section.

4.2.1.1 VIIRS On-orbit Calibration Configuration

Figure 4.12 shows the on-orbit calibration activities of VIIRS' reflective solar bands (RSB) with the solar diffuser (SD), the solar diffuser stability monitor (SDSM), and the space view (SV) port to view space for background subtraction and to view the moon for RSB calibration, as well as the blackbody for the thermal emissive band (TEB) calibration. It also shows the rotating telescope aft (RTA) optics and the half angle mirror (HAM). The RTA and HAM rotate to view the calibrators and measure the earth radiance.

4.2.1.2 VIIRS On-orbit Performance

1. The SD degradation since the day of launch, October 28th 2011, has been monitored by SDSM and is shown in **Figure 4.13**. The left side graph y-axis is the factor H_{SDSM}. It illustrates the ratio of the SD reflectance at any day shown on the x-axis to its original value at launch. The degradation was measured by the eight narrow band filtered detectors of SDSM. The degradation plots are color coded and correspond to the eight filtered detector center wavelengths, ranging from 412nm to 926nm. The degradation is larger at shorter wavelengths and currently slowly varying. The right side graph presents the averages of the relative standard deviation of each detector measurement. The maximum is for detector 1 at 0.074% and

16 http://www.star.nesdis.noaa.gov/star/documents/meetings/2015JPSSAnnual/dayFour/14_Session7c_Devadiga_LandSIPS.pdf.

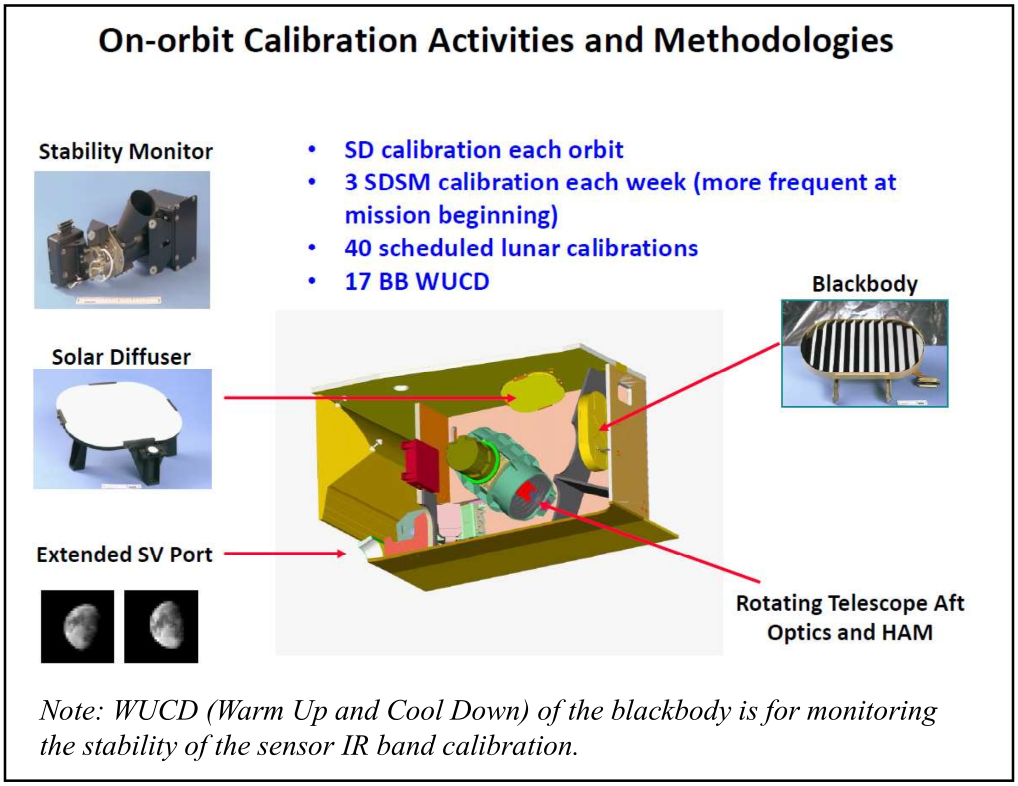


Figure 4.12: VIIRS front-end optics, on-orbit calibrators, and calibration events to date.

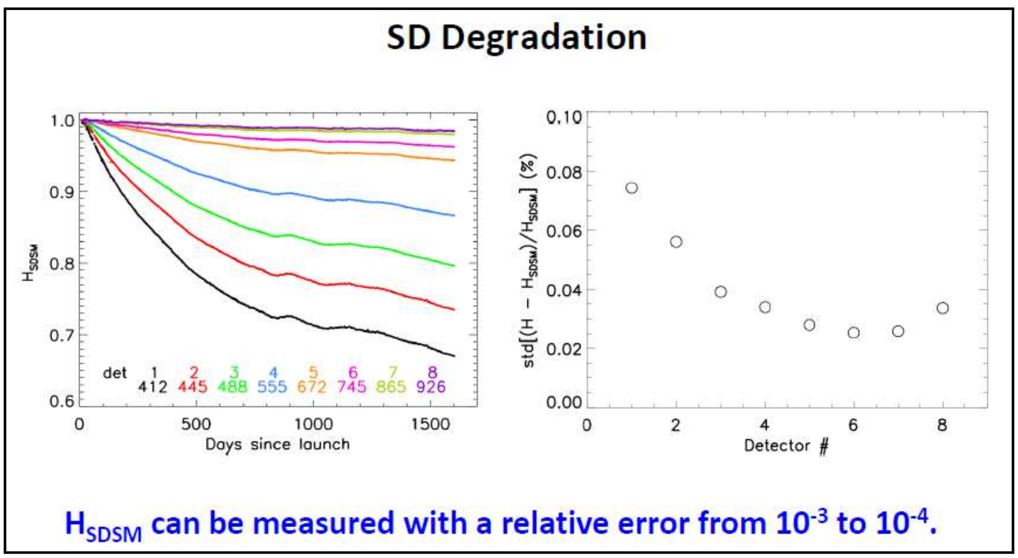


Figure 4.13: SD degradation monitored by SDSM.

the minimum is for detector 6 at 0.026%. The graph shows that the relative error in H_{SDSM} measurement is very low.

2. The blackbody performance meets requirements and is very stable, as shown by the long-term daily average trend of within a few mK. The scan-by-scan short-term stability is 20mK for temperature average and 40mK for individual thermistors. The blackbody uniformity meets the requirement of 30mK.
3. The RSB calibration using the SD compared to the calibration using the moon through the space view have a difference of less than 1% and moon view is being

used to correct the SD-based calibration. However, both methods show agreement in tracking the degradation.

4. The Thermal Emission Band (TEB), both mid-wave and long-wave, IR responses show excellent stability in time and the change is less than 1% over four years.
5. The signal-to-noise ratio (SNR) for all channels is excellent and exceeds requirements.
6. The VIIRS sensor spatial performance has proven over the years to be very stable, as has been assessed by using the band-to-band registration (BBR) derived from lunar observations.
7. The impact of the wavelength-dependent RTA optics degradation on the relative spectral response (RSR) of channels has been assessed and is shown in **Figure 4.14**. There is a large impact on the Day Night Band (DNB) RSR as it has a large bandwidth, as shown on the left side of the figure with the arrow pointing down. The modulation on the RSR changed from year to year due to RTA degradation. The impact on bands with narrow bandwidths and small out-of-band responses is minimal. However, the RSR modulation can be seen in channels M1 and M7 RSR, as shown on the right side of the figure with the arrow pointing to the right. The out-of-band response for these bands gets modulated.

Changes and SDR Improvements

1. A methodology was developed to use both the yaw maneuver and a small portion of regular on-orbit data to determine the SDSM screen relative transmittance () at a fine angular scale, as shown in **Figure 4.15**. The transmittance values measured pre-launch (PL_LUT) were found to be not adequate and yaw maneuvers were undertaken to get the SDSM screen transmittance data on orbit. The data, however, had to be acquired within a very short window of time to avoid being skewed due

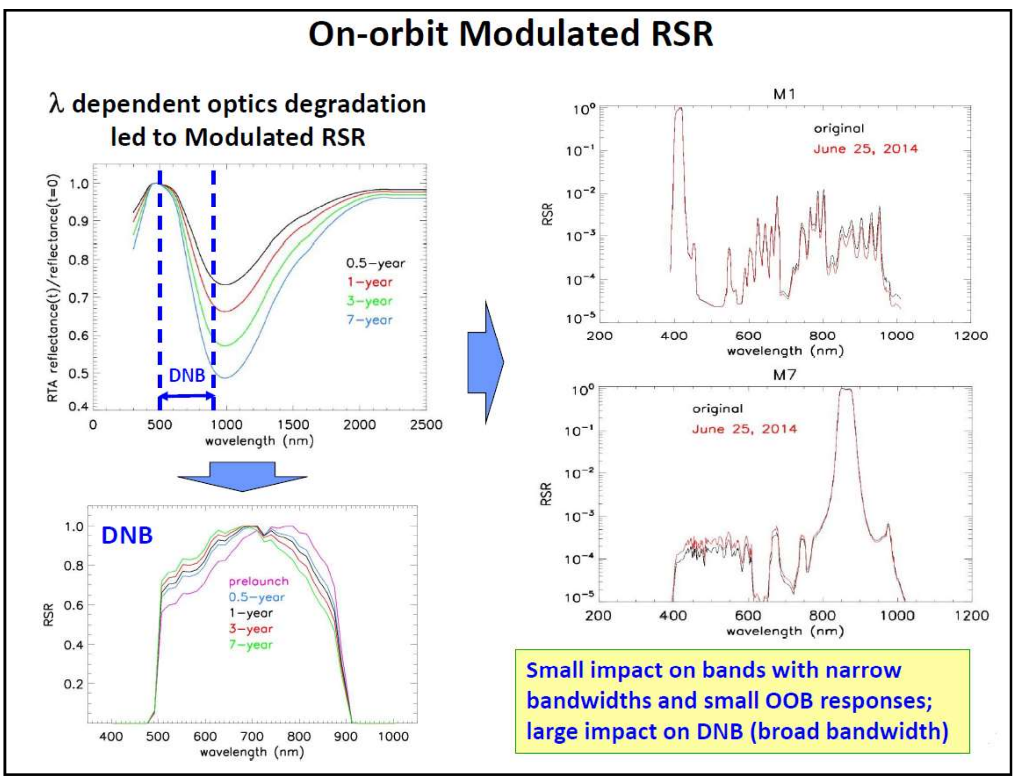


Figure 4.14: RTA optics degradation impact on DNB and other bands.

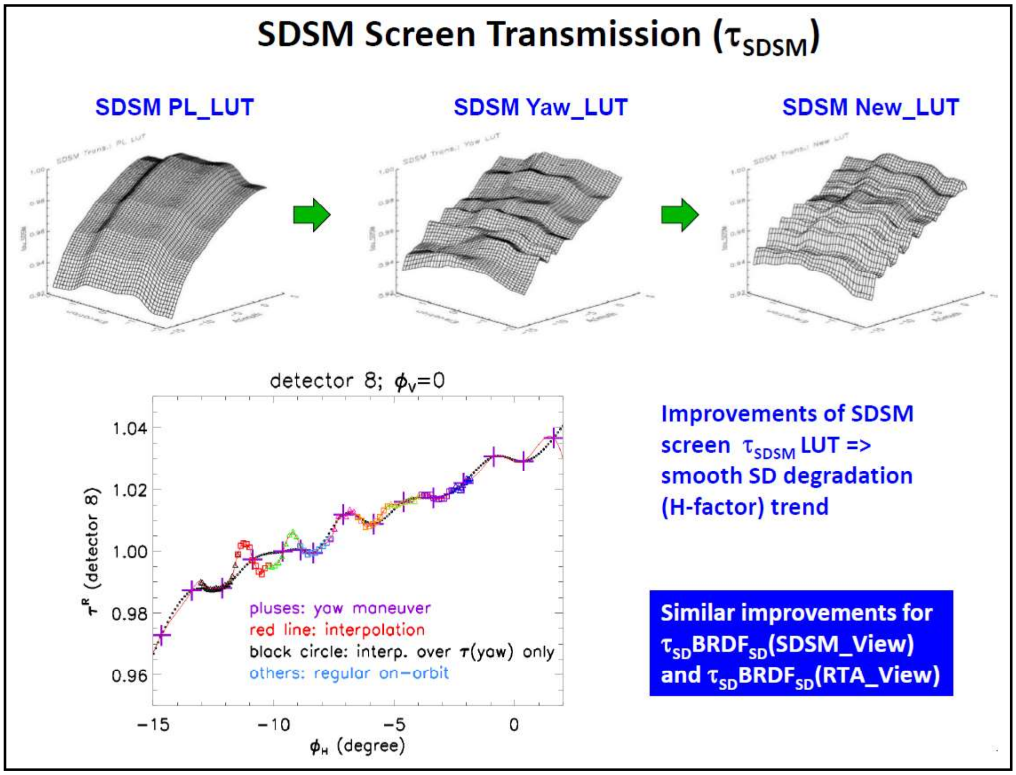


Figure 4.15: Improvement of SDSM screen transmission determination methodology.

to drift and the solar angles could not be covered to a finer scale. The use of regular on-orbit data to fill the gaps of the yaw maneuver data significantly improved the SD Bi-directional Reflectance Distribution Function (BRDF) degradation "H" factor curves[17].

2. Similar improvements were made for the SD screen transmission and $BRDF_{SD}$ SDSM view, () using both yaw maneuver and on-orbit data[18], and the SD screen transmission and $BRDF_{SD}$ RTA view () using yaw maneuver data[19], as mentioned in Figure 4.15.
3. As a result of the above improvements, the following changes were made:
   a. The extrapolation of H to the mission beginning is revised, as shown in **Figure 4.16**.
   b. The observations of the dependence of the H factor on the solar azimuth angle have been taken into account. The assumption of negligible angular dependence is found to be invalid for large BRDF degradation[20].
   c. The H factor is modeled to cover SWIR wave lengths[21].

17 Lei, N., X. Chen, and X. Xiong, 2016: Determination of the SNPP VIIRS SDSM screen relative transmittance from both yaw maneuver and regular on-orbit data. IEEE Tran. of. Geosc. and Remote Sens.. 54, 1390 - 1398.

18 Lei, N., and X. Xiong, 2015: Estimation of the accuracy of the SNPP VIIRS SD BRDF degradation factor determined by the solar diffuser stability monitor. Proc. SPIE - Earth Obs. Sys. XX, 9607, 1-18.

19 Lei, N., and X. Xiong, 2015: Impact of the angular dependence of the SNPP VIIRS solar diffuser BRDF degradation factor on the radiometric calibration of the solar bands. Proc. SPIE - Earth Obs. Sys. XX, 9607, 1-13.

20 Lei, N., K. Chiang, and X. Xiong, 2014: Examination of the angular dependence of the SNPP VIIRS solar diffuser BRDF degradation factor. Proc. SPIE - Earth Obs. Sys. XIX, 9218, 1-13

21 Lei, N. and X. Xiong, 2015: Determination of the SNPP VIIRS solar diffuser BRDF degradation factor over wavelengths longer than 1 µm. Proc. SPIE - Earth Obs. Sys. XX, 9607, 1-9.

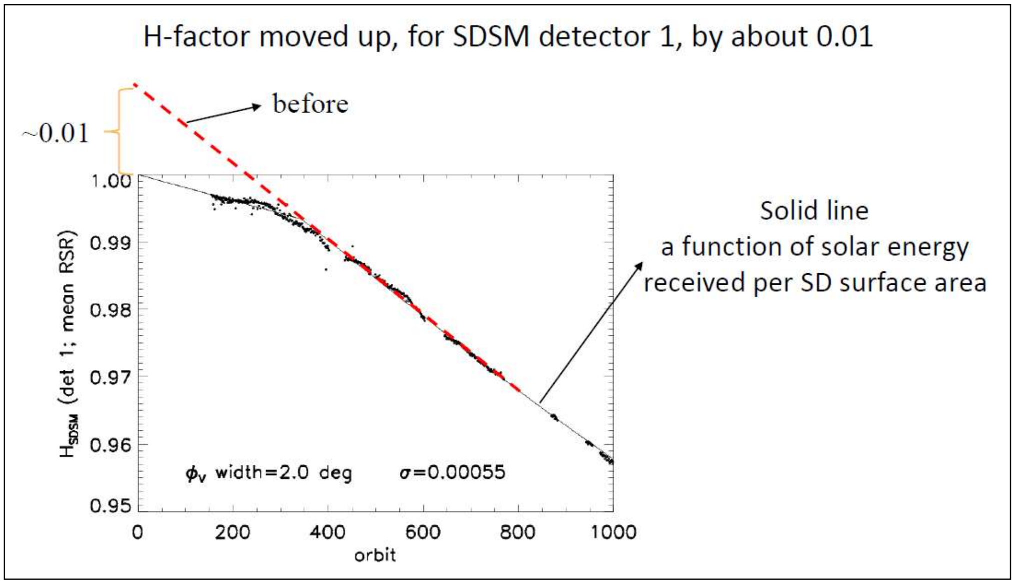


Figure 4.16: Improvement H-factor normalization.

   d. The H factor for the RTA view has been determined using lunar trending[22].
4. In early 2014, with the assistance of the Aerospace Corporation, the NASA SNPP VIIRS geo-location group found that there is an error in the solar vectors in the SDR Common Geo library. The uncorrected solar vectors resulted in as much as a 0.2-degree error in the solar angle and, thus, an H-factor error as large as 0.005. Since then, the corrected solar vectors have been produced and used in the improvements mentioned above and the computations of the F- and H- factors.
5. The DNB offsets and stray light correction have been improved for forward processing as follows:
   a. The DNB offsets are now derived from the BB observations as they are found to be lower than the offsets derived from ocean view at night, due presumably to lunar shine.
   b. The weighted average of the "same" day look-up table (LUT) from previous years are provided to derive the stray light correction LUT as it resulted in better performance as shown in **Figure 4.17**.

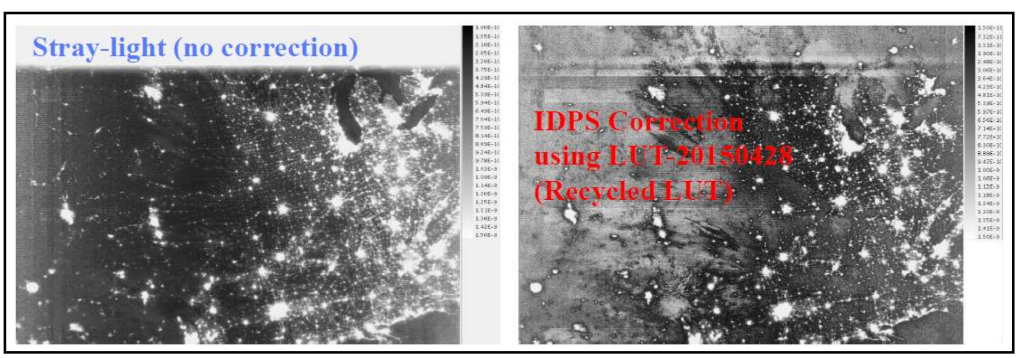


Figure 4.17: DNB stray light correction for forward processing LUT (Day 2016-04-08 GMT 08:24:21 original/IDPS corrected image).

22 Same as footnote 4.

4.2.1.3 VIIRS Future Effort

1. Continue to work closely with other calibration teams and provide support in the following areas:
   a. VIIRS on-orbit calibration activities and enhancements
   b. SDR algorithm and LUT improvements
   c. SDR and EDR quality evaluation
2. Monitor changes in responses versus scan-angle (RVS), which is currently tracked using Earth View data at different angles of incidence
3. Support L1B V2.0 as follows:
   a. Apply weighted average of individual BB thermistors
   b. Implement uncertainty index

4.2.1.4 SIP-generated SDR and L1B at NASA

Dr. Xiong provided the information shown in **Figure 4.18**, **Figure 4.19,** and **Figure 4.20,** referring to a question mentioned at the beginning of this section regarding the SIP-generated SDR and L1B at NASA.

4.2.2 Improvement of VIIRS SNPP SDR for Ocean Color EDR Science Quality Reprocessing

Presenter

Dr. Junqiang Sun

NESDIS/STAR

Dr. Junqiang Sun focused on the ocean color (OC) user perspective of VIIRS SNPP data. For OC _Environmental Data Record (EDR) products, the ocean bands (primarily M1 – M7 but also, to a lesser extent M8 – M11) are expected to be calibrated to within 0.1-0.2% uncertainty (stability requirement). OC bands are RSB bands, and the sensor on-orbit performance specification for them is only 2% uncertainty. A serious challenge arose that required the OC researchers to further analyze the RSB calibration data at a very fundamental level of instrument and optics in order to develop a methodology to improve the SDR whereby these bands could meet the OC requirement. The methodology, labeled "Hybrid methodology," was then developed, and the results from the subsequent 4.5 years showed a stability level of 0.1-0.2% in the reprocessed SDR. OC products reached maturity status in March 2015 using the improved LUTs. The step-by-step evolution of the Hybrid methodology is reviewed below.

4.2.2.1 The Evolution of the Hybrid Methodology for RSB SDR Improvement

1. The VIIRS on-board calibrators and front end optics were shown previously in Figure 4.12. The 2012 SNPP yaw maneuver data, along with the prelaunch measurements of the SD Screen (SDS) transmission (Vignetting Function [VF]) and the SD Bidirectional Reflectance Factor (BRF), were analyzed further to determine the absolute form of BRF-VF product (BVP) for each of the RSB and the SDSM detectors. The absolute form of the SDS VF can also be obtained from the RSB and SDSM detectors using the yaw maneuver data. The results showed that the BVP for an RSB is independent of the RSB detector, gain status, and HAM mirror side, and can be expressed as a quadratic expression of solar angle dependence[23].
2. The SDSM sun view responses and SD view responses in SD/SDSM calibration events in the two and a half years since launch were also carefully analyzed. The full illumination sweet spot was selected for SD calibration in order to provide

23 Sun, J. and M. Wang, 2015: On-orbit characterization of the VIIRS solar diffuser and solar diffuser screen. *Appl. Optic.*, **54**, 236 - 252.

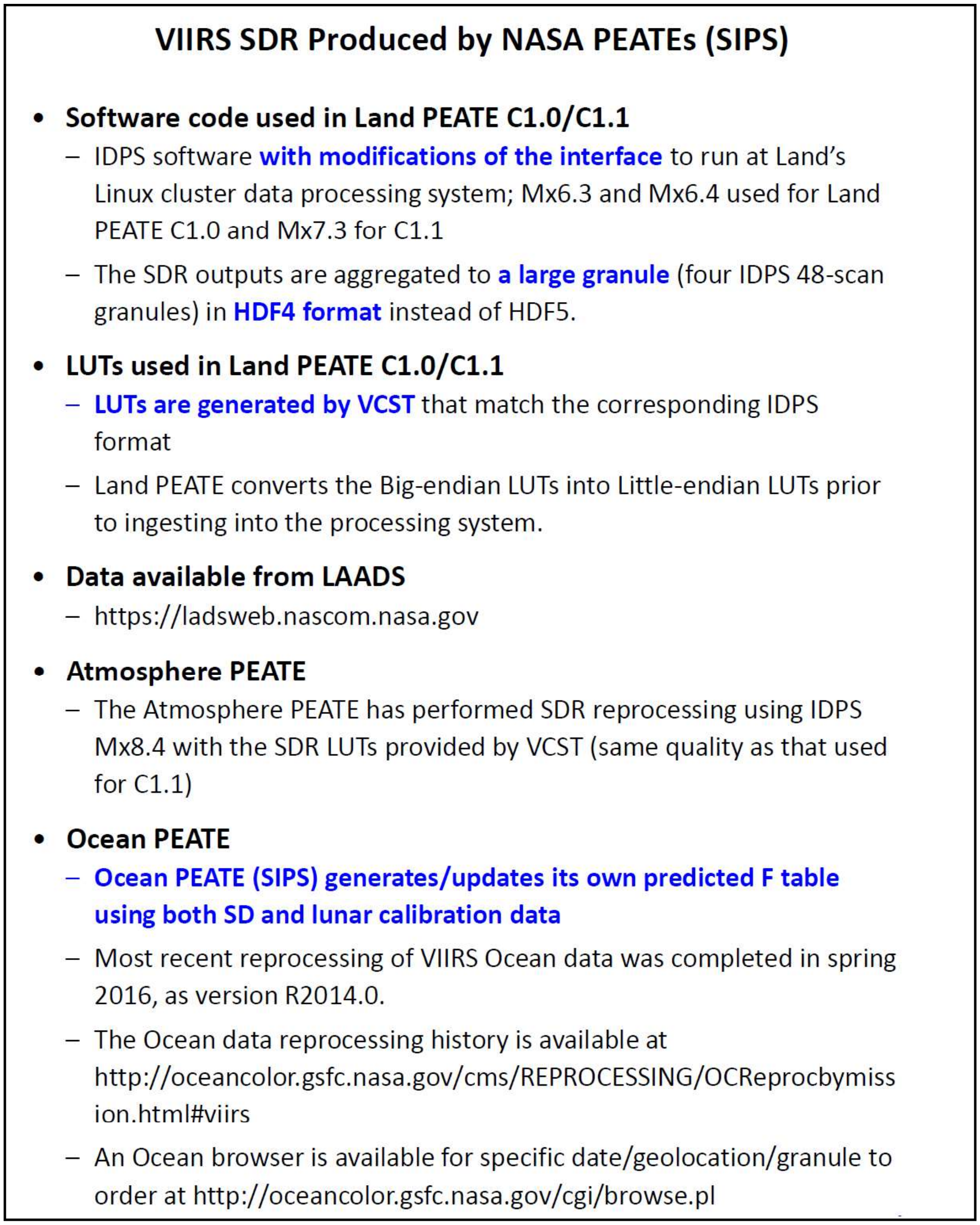


Figure 4.18: NASA SIPS generation of SDR.

a consistent and optimal number of valid data samples with which to aid in the reduction of sample noise due to either a lack of or inconsistent samples. The application of the above results[24] in determining the degradation factor H, using the two and a half years of calibration data, showed significant improvement in the smooth variation in degradation, effectively removing the seasonal oscillations, as shown in **Figure 4.21**.

3. The time-dependent RSR, due to VIIRS Fore optics degradation, as shown previously in Figure 4.14, is also addressed by the OC group to correct for the changes in out-of-band contribution in the SD calibration of each OC RSB. Also, further

24 Sun, J. and M. Wang, 2014: Visible infrared imaging radiometer suite solar diffuser calibration and its challenges using a solar diffuser stability monitor. *Appl. Opt.,* **53,** 8571-8584.

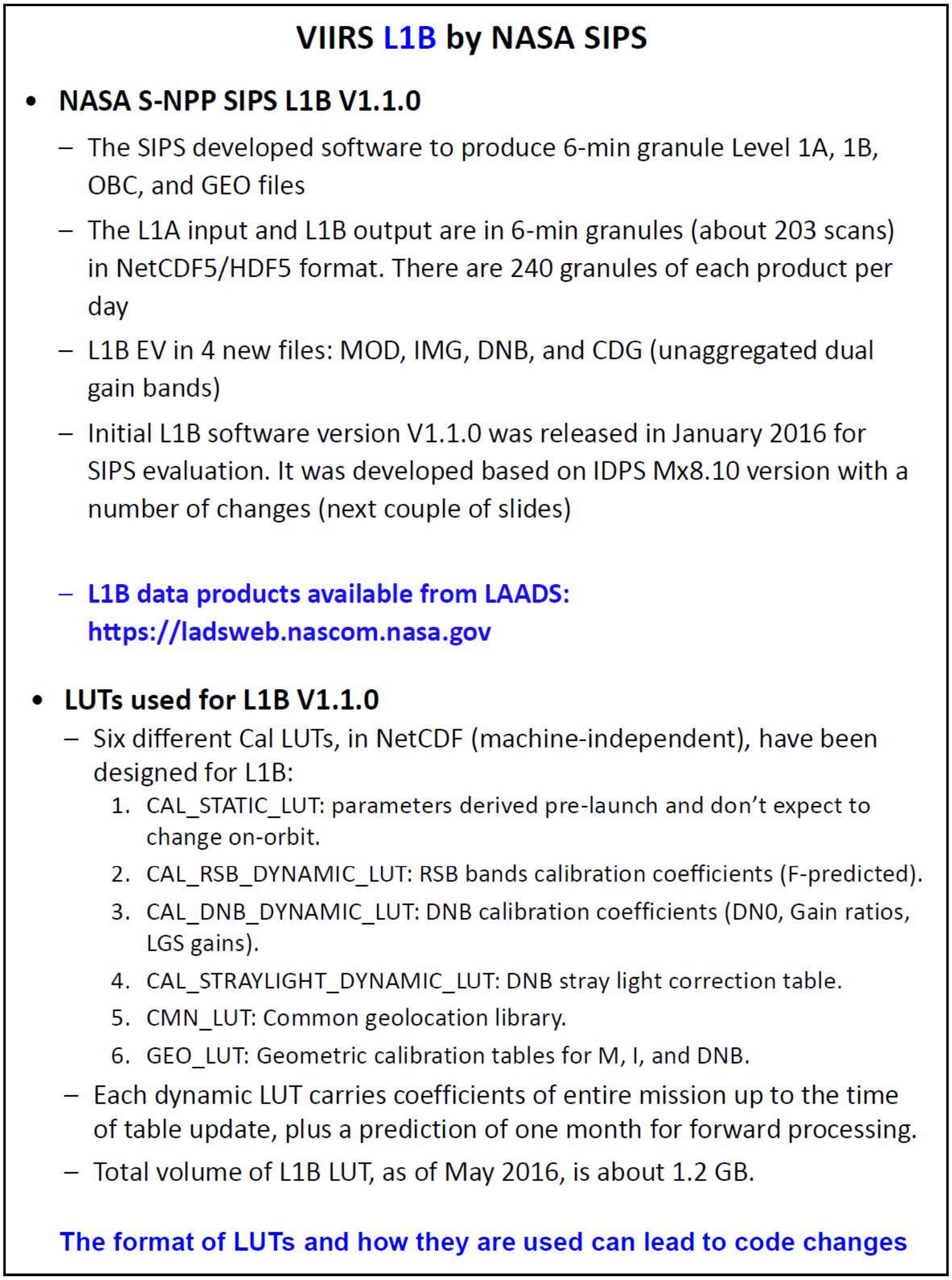


Figure 4.19: NASA SIPS-generated L1B.

analysis revealed that the SD degrades non-uniformly[25] with respect to the incident angles for the outgoing directions toward the RTA and the SDSM. Since the difference between the two outgoing directions is much larger than the range of the incident directions, the SD/SDSM-based calibration methodology introduces a systematic drift based on the degradation of the SD. Lunar calibrations scheduled as part of VIIRS operations offered the way to track the drift[26], as the moon is

25 Sun, J. and M. Wang, 2015: On-orbit calibration of the Visible Infrared Imaging Radiometer Suite reflective solar bands and its challenges using a solar diffuser, *Appl. Opt.*, **54**, 7210-7223.

26 Sun, J., X. Xiong, J. Butler, 2012: NPP VIIRS on-orbit calibration and characterization using the

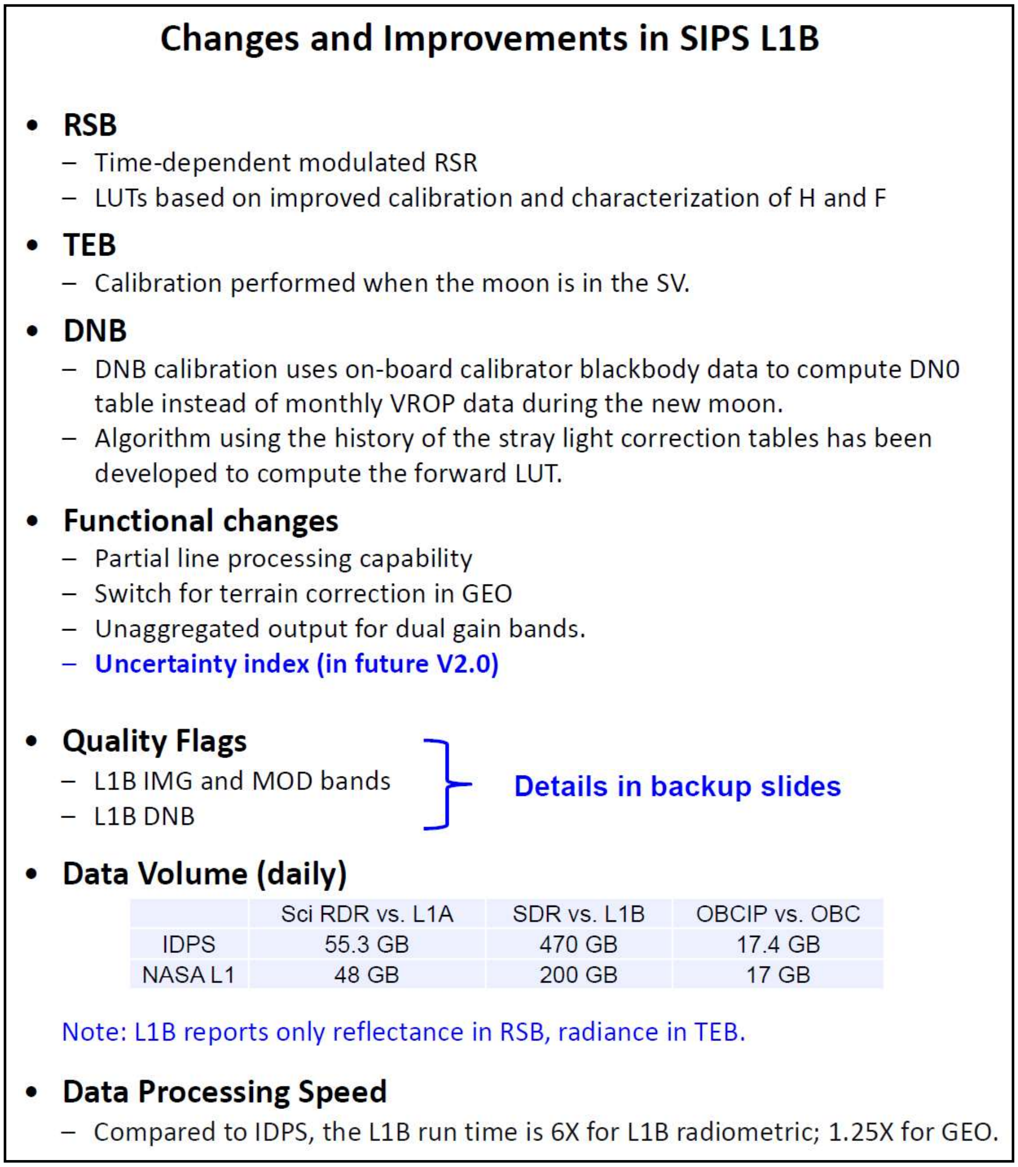


Figure 4.20: NASA SIPS L1B improvements.

very stable in its reflectance. Therefore, lunar-based calibration has been proven to provide an accurate long-term baseline for the successful restoration of the core calibration methodology. The new look-up tables, which combine the coefficients from the SD-based and lunar-based calibrations have been shown to produce the optimal result with an estimated (relative) uncertainty of 0.2%. This hybrid approach is also made possible due to inherent design feature for VIIRS that allows the moon and the SD to be viewed by the RSB at the same angle of incidence[27]. The non-uniformity of degradation, the lunar and SD-based calibration factors (F) over time were shown in **Figure 4.22**. The hybrid methodology and the resulting calibration coefficients for OC bands M1 – M4 were shown in **Figure 4.23**.

Moon. Proc. SPIE, 8510, 85101I.

27 Sun, J., and M. Wang, 2015: Radiometric calibration of the visible infrared imaging radiometer suite reflective solar bands with robust characterizations and hybrid calibration coefficients. Appl. Opt., 54, 9331 - 9342.

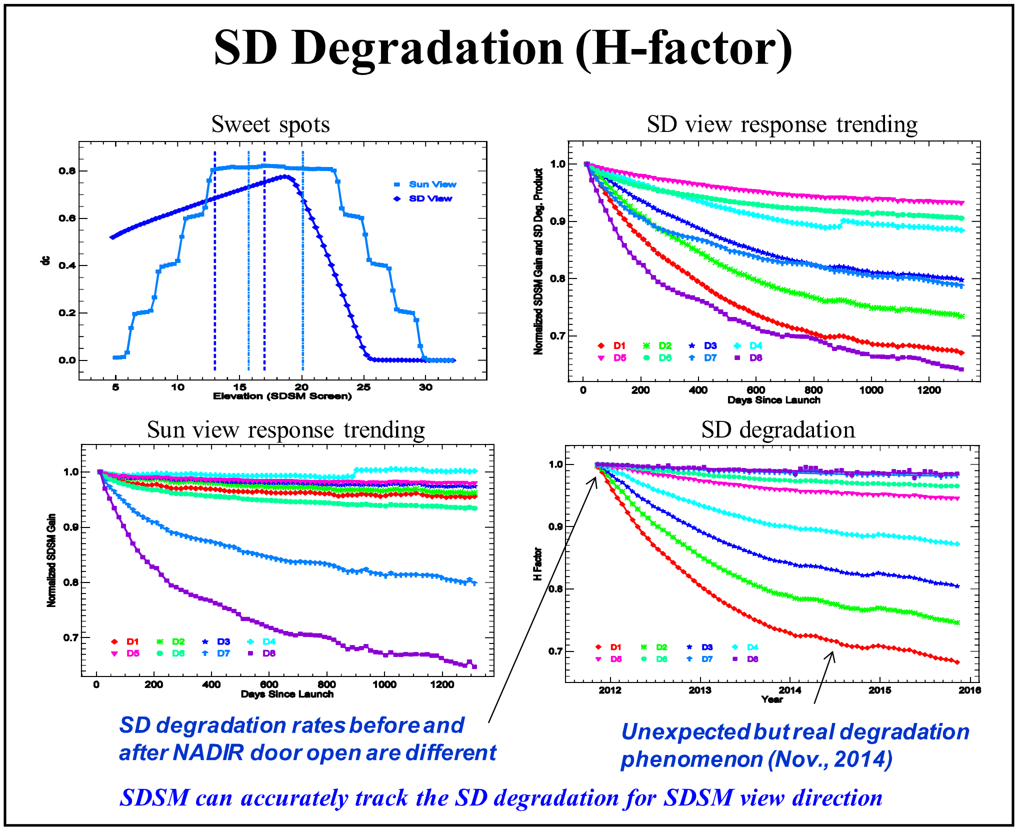


Figure 4.21: Sweet spot selection, SD view and SDSM view response trending, and SD degradation.

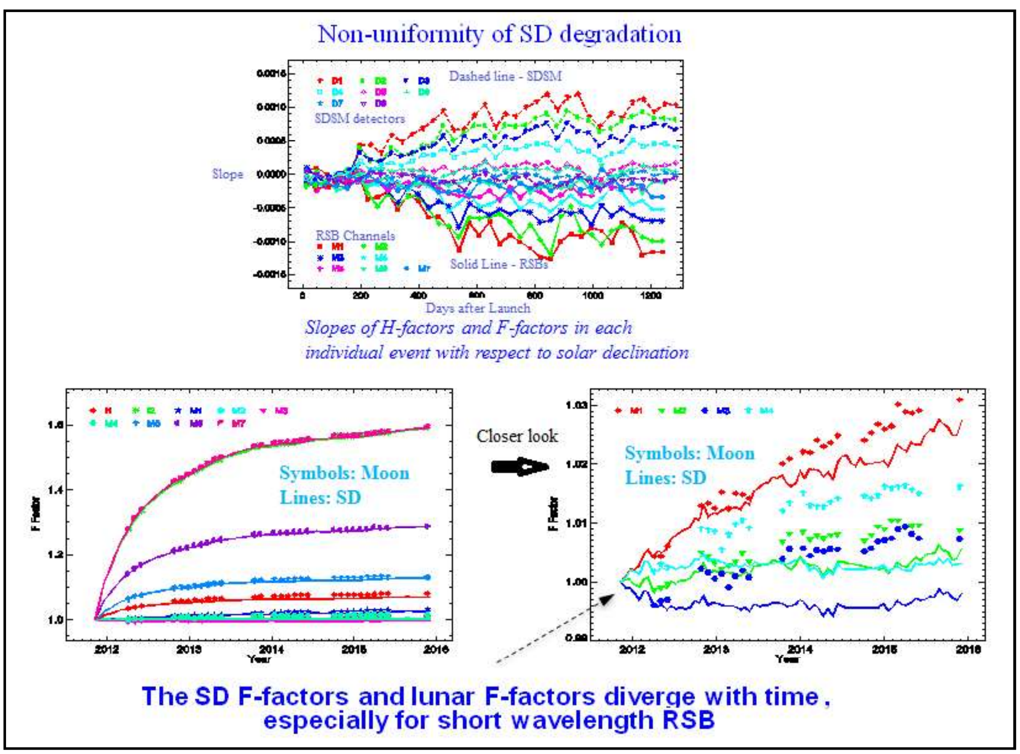


Figure 4.22: Non uniformity of SD degradation, SD and Lunar F factors.

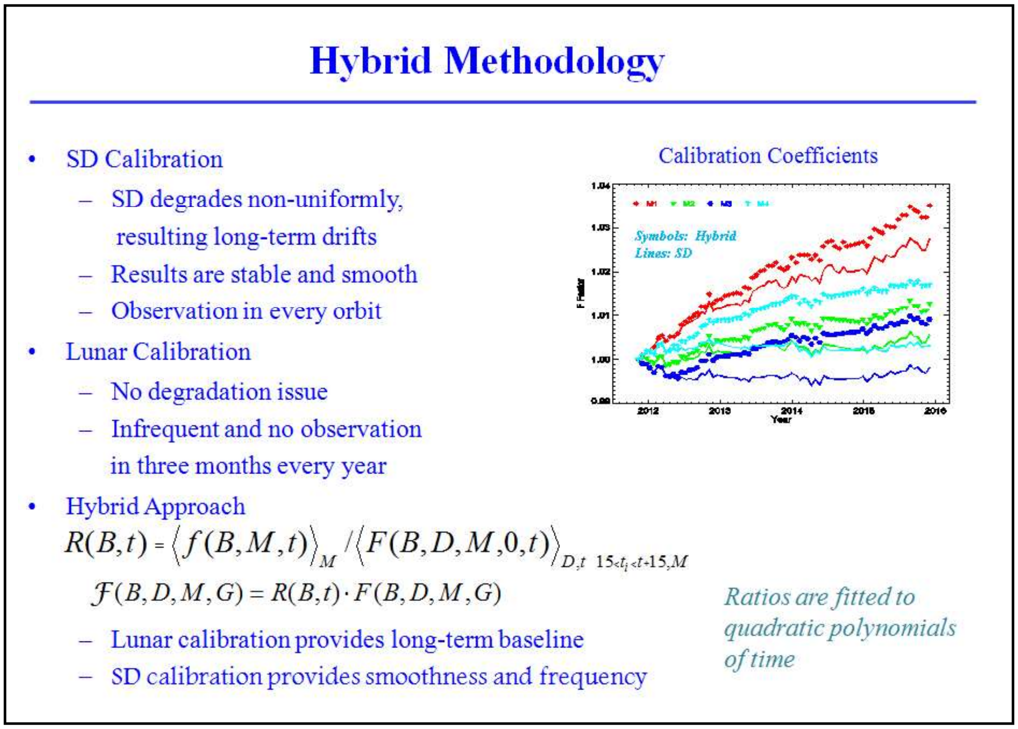


Figure 4.23: Hybrid methodology and Calibration coefficients for bands M1, M2, M3, and M4.

4.2.2.2 Improvements in OC Products[28]

1. The hybrid calibration coefficients were first applied in September 2014. NOAA OC products produced with the hybrid calibration coefficients met the goals of the validated maturity in March 2015.
2. Final LUTs were derived in December 2015 and are being used for final EDR reprocessing as well as science quality OC products going forward.

4.2.2.3 Dr. Sun's Answers to Audience Questions

1. *Question:* The GSICS has new lunar model. Are you going to use it or are you happy with the model you are using?
   Answer: I have my own model. If GSICS lunar model works better, I will happily use it for reprocessing.

2. *Question:* What input will you be using for reprocessing OC EDR?
   Answer: The applied SDR generated by the OC group using the hybrid model for calibration will be used for reprocessing and generating OC EDR.

3. *Question:* Have you ever compared your H and F with that of IDPS?
   Answer: The OC results are simply different from the IDPS results due to all the reasons, and more, that have been mentioned. This includes long-term drift, early mission discrepancies, large random and spurious anomalies, significant seasonal fluctuations, and certainly greater noise.

28 Sun, J., and M. Wang, 2016: VIIRS reflective solar bands calibration progress and its impact on ocean color products. Remote Sensing Journal. 8, 194, 1-20.

4.2.3 Evaluation of SNPP Land EDRs

Presenter

Dr. Ivan Csiszar

NESDIS/STAR

Dr. Ivan Csiszar of NOAA/NESDIS/STAR presented the land products status and the four and half years of experience acquired while improving them to maturity and readying them for reprocessing. The land products represent a diverse group of complex algorithms. The overlapping key issues are listed below.

4.2.3.1 Key Users

1. First and foremost is the clear need for a proper "climate" baseline. There is no climate record at present. It is for this reason that an NCEP partner has requested that STAR complete the reprocessing, thereby creating a baseline for the analysis effort that can then be used to create a climate record.
2. The enterprise algorithm development is strongly linked to reprocessing. The reason is that land products are not a part of the original risk reduction package. The design of the land products for the enterprise solutions is in the final stage. The development and transition to operations is in the agenda.

4.2.3.2 Key Issues

1. The performance of the upstream products impacts the processing of land products, such as.
   a. The accuracy of the upstream variables (i.e., the cloud mask, the aerosol, the snow mask, and the SDR calibration);
   b. Traceability, data anomalies, and data gaps of the delivered variables; and
   c. The accuracy and setting up of quality flags.
2. The experience with current operational products in terms of accuracy, content, traceability, and user-friendliness is very important. The lack of user-friendliness for some of the products is driving the redesign of the land products for the enterprise solutions.
3. Reprocessing is to be considered in the context of implementing the enterprise algorithms. The impact of the change in upstream products is to be evaluated to determine the readiness for enterprise products and the adequacy of reprocessing. A realistic schedule is to be developed for reprocessing based on the dependencies. Retrospective reference test datasets are needed for evaluation before full reprocessing.
4. Reprocessing is also an opportunity to accelerate the confirmation of validation and maturity stages of the new enterprise products. Long-term monitoring is necessary to ensure sustainment of product quality. The elements of the J1 calibration/validation plans are to be coupled where possible with the reprocessing validation plans.

4.2.3.3 Examples of SNPP Experience

1. The land surface reflectance is shown in **Figure 4.24** as an example of the impact of the SDR quality flag. The red and green on the left panel were not retrieved in IDPS processing due to a quality flag. The NASA equivalent processing shows on the right panel that those quality flags have been ignored and the data looks good. Therefore, the accuracy of the quality flag needs to be critically examined to ensure proper processing of pixels.

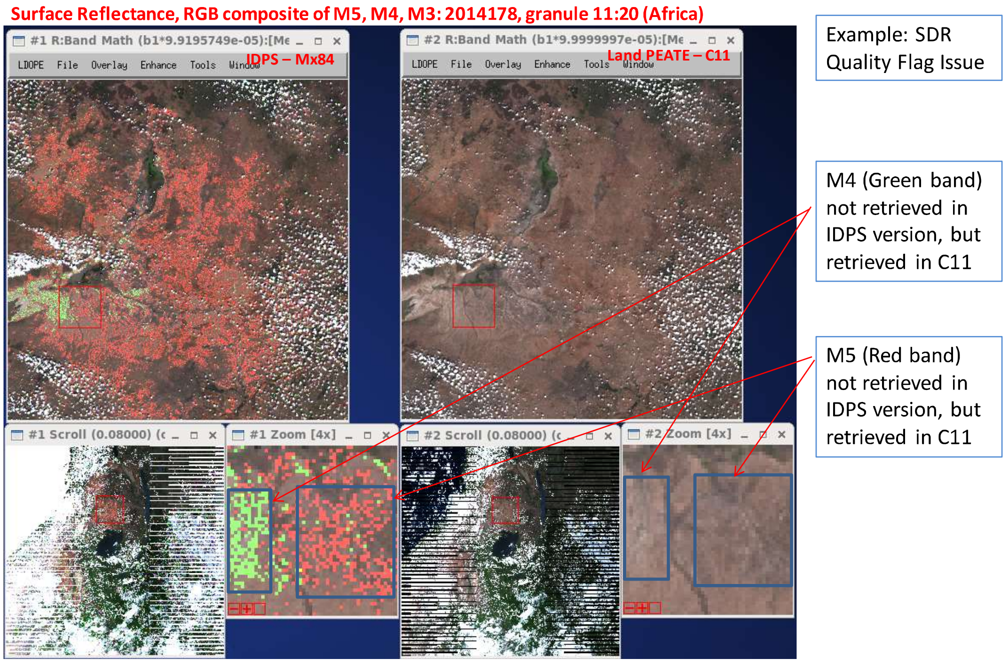


Figure 4.24: The example of the surface reflectance of a land surface using NOAA IDPS processing vs NASA C11 processing.

2. Although the IDPS operational Vegetation Index (VI) EDR has undergone some helpful improvements, it is in the wrong format for enterprise algorithms. The IDPS was in granule format while the user requirement is in gridded format, which will be addressed in reprocessing. The SDR had the following additional quality flags implemented in Mx8.4 (IDPS algorithm) for the VI EDR:
   a. Snow/ice
   b. Adjacent clouds
   c. Aerosol quantity
   d. Cloud shadow

   The snow and cloud shadow quality flag analysis/validation is shown in **Figure 4.25**. Adjacent cloud flag and the aerosol quantity flag impacts are shown **Figure 4.26**. Block 2.0 VI EDR algorithms include the Top-of-Canopy (TOC) NDVI data layer, an additional quality flag, and an improved definition of product high quality. The data from all atmospheric conditions is processed for the VI product and the user is given the choice to use the quality flag or not.
3. The IDPS algorithm improvements for the Land Surface Albedo (LSA) product and the Land Surface Temperature (LST) are presented[29] in detail as part of lessons learned corresponding to each update. For example, the LSA had three LUT updates. The latest update corrects an error in the previous LUT that caused the underestimation of albedo results. It also improves the quality of desert albedo retrievals. Similarly, the LST IDPS product quality had improved when the SDR changed to reach validated maturity.
4. The EDR team's feedback helped to identify errors in the SDR code which primarily impacted the IDPS Active Fire product. For example, at the beginning of the data record, an error in the SDR code resulted in good, but spurious agreement between MODIS and Suomi NPP VIIRS fire counts, which the EDR team identi-

29 Refer to http://www.star.nesdis.noaa.gov/star/meeting_JPSS2016_LDRW.php for the full presentation.

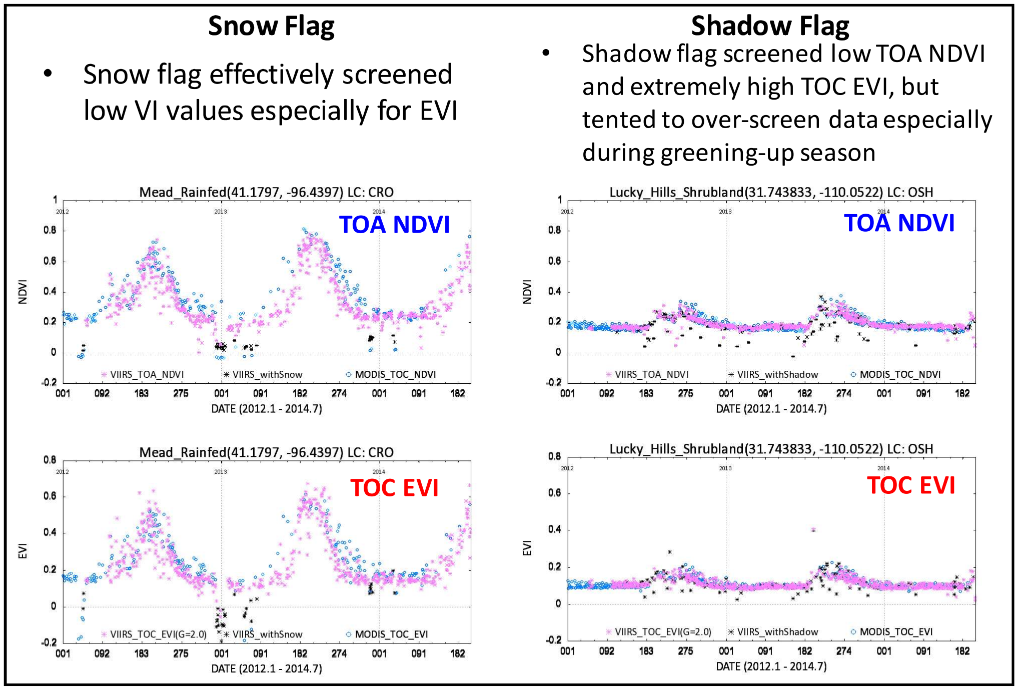


Figure 4.25: Time series analysis of Snow Flag and Shadow Flag impact in screening data.

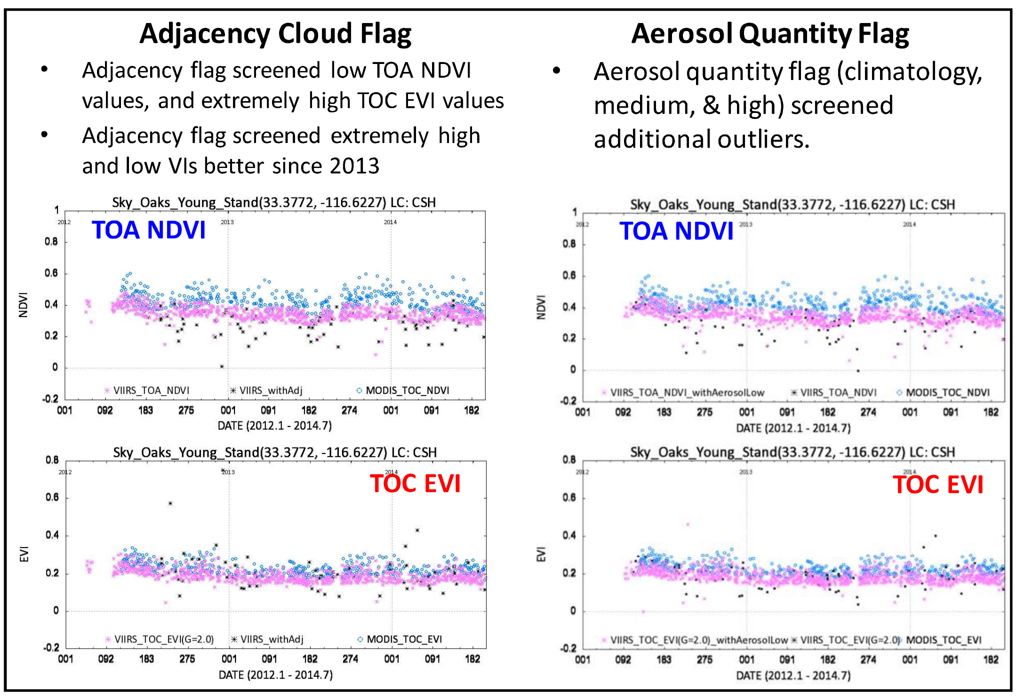


Figure 4.26: Time series analysis of Adjacency Cloud Flag and Aerosol Quantity Flag.

fied as an anomaly. Once the error in the SDR code was fixed, the fire pixel counts were in agreement with the expectation.

5. The active fire code history revealed several issues due to the incorrect gain setting in the dual-gain VIIRS M13 "fire" band. It is very important that the right gain setting be used when the data set is reprocessed. As the effect of lunar intrusion is

seen in the Active Fire product, the data and the flight software updates handling the lunar intrusion should be critically analyzed.

6. The surface type product is created as an externally generated data set and the real retrieval is the global composite. The Science Team changed the decision tree algorithm to a spectral vector machine algorithm and the global composite product is shown in **Figure 4.27**, which is very good and it will be produced annually.

4.2.3.4 Summary

- Land products reached validated (Stage 1) maturity for the current operational products, primarily IDPS, but also NDE Green Vegetation Fraction (GVF).
- Impacts of upstream SDR and EDR products are significant and quality flags and auxiliary data layers are critical. The test data sets allow for accelerated validation/verification as needed.

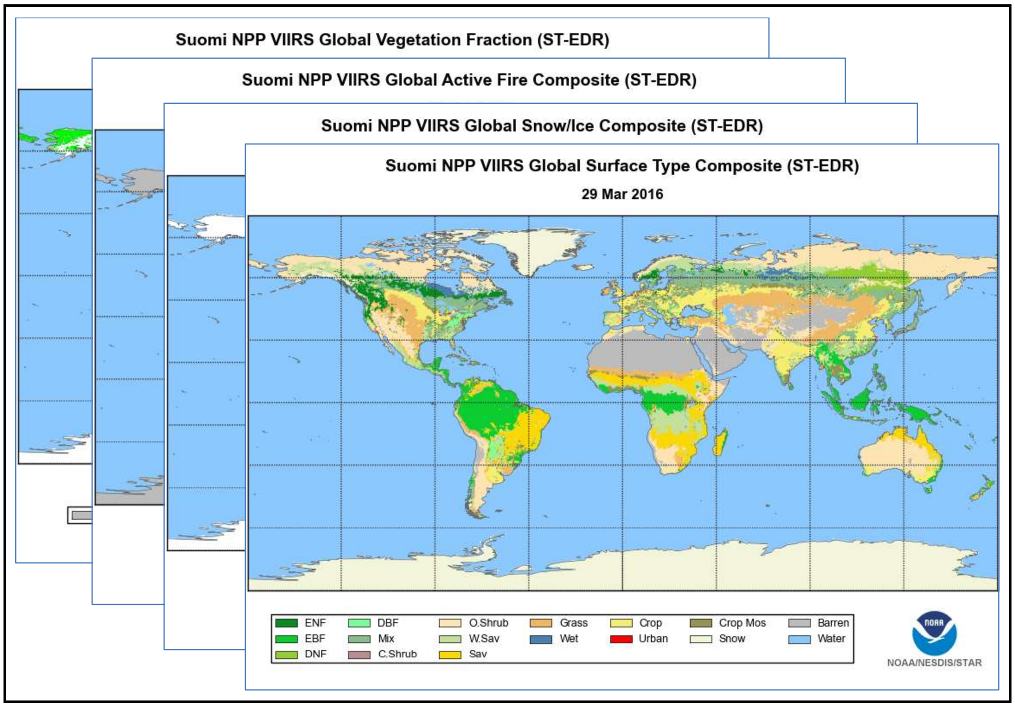


Figure 4.27: Global composite product will be generated annually.

4.2.4 Evaluation of Current SNPP OMPS Calibration and SDR Performance at NASA

Presenter

Dr. Glen Jaross

NASA GSFC

Dr. Glen Jaross of NASA's OMPS NADIR team presented the status of the NASA OMPS SIPS-generated SNPP OMPS NASA SDR product that is similar to the NOAA OMPS SDR. The instruments in the OMPS sensor suite are the Nadir Mapper (NM), Nadir Profiler (NP) and the Limb Profiler (LP). The NASA OMPS team began reprocessing the OMPS data by making needed improvements in the calibration of the instruments. These improvements are also addressed at the operational NOAA SDR. The following is the summary of the presentation.

1. The NM radiances are found to compare well with the Radiative Transfer (RT) Model. The NM radiance data was also found to agree with NASA Ozone Mapper

Instrument (OMI) data from the Aura satellite mission within 1%, the best that can be expected of these instruments.

2. The wavelength registration is determined by the regression analysis of OMPS measurements and synthetic solar spectrum based on the band pass function of the OMPS. The fractional difference between the measured and synthetic spectrum in the case of NP is typically plus or minus a percent and it was considered good. In the case of NM, the solar measurements are made at the northern terminator that provided a static wavelength registration. The Fraunhoffer lines are used in the Earth view data that have time dependence in the orbit, which introduced a bias of around 0.03 nm based on solar measurements that is corrected in both NASA and NOAA SDR products. However, there are known deficiencies in those corrections.
3. The stray light in NM is analyzed and the algorithm is improved. A single image of the NM two-dimensional Charge Coupled device (2D CCD) is shown in the top of **Figure 4.28**. The axes of the image are horizontal for the Wavelength spectral pixel index and vertical for the cross-track spatial pixel index ozone measurement. Based on the NM design, there should be no sensitivity for incoming photons for wavelengths below the line marked 89121 (pixel index). The prelaunch grating ghost model in the algorithm corrected this stray light and the current operational product is shown in the left of the second line of images. The image still shows plenty of signal (red) in the short wavelength region. In fact, the gray area in the image means negative counts. The model is over-correcting the stray light and the percentage error in the operational product is estimated to be eight percent or higher in the short wavelength region. The reevaluation of the ghost characterization improved the stray light model as shown in the image on the right side in the second line. The stray light is close to zero around 300 nm and residual percentage is in the plus or minus one or two percent.

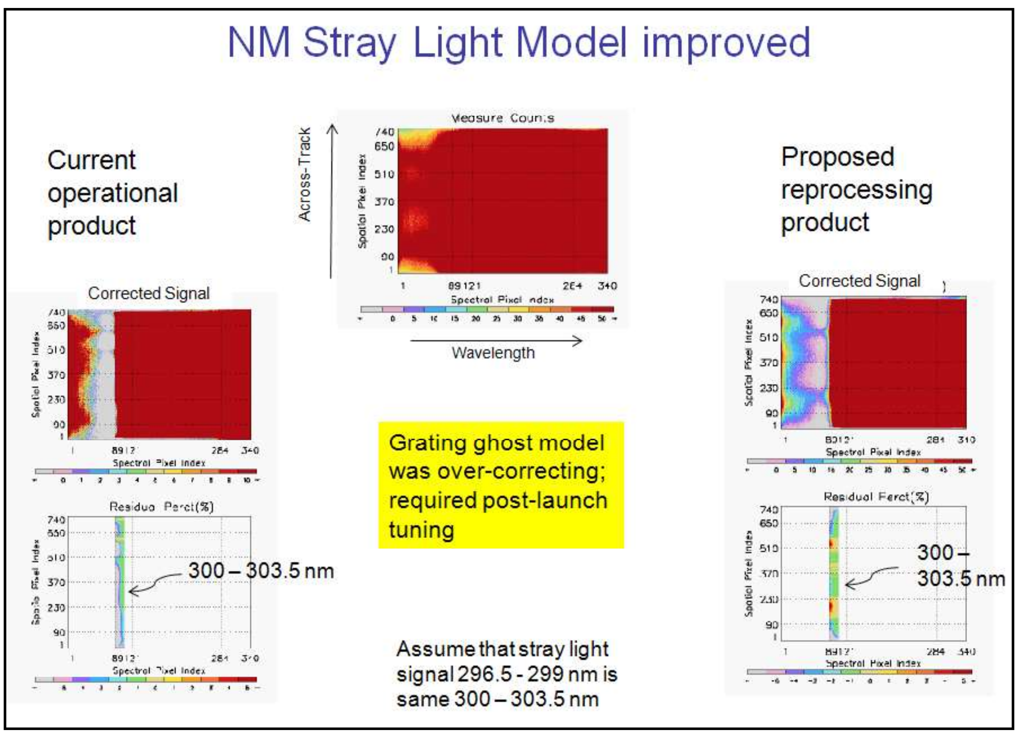


Figure 4.28: Improvement of NM stray light model.

4. The stray light correction in the operational product NP is found to be not performing as well as the NOAA-19 Solar Backscatter Ultraviolet (SBUV) instrument. However, the error is small and the NP stray light algorithm is considered to meet specifications.
5. The comparison of OMPS sun-normalized radiances to a RT model that uses the ozone and temperature profiles from the Microwave Limb Sounder (MLS) instrument data is shown in **Figure 4.29**. Several calibration improvements for OMPS were made in its dichroic wavelength region (300 – 310nm). The dichroic filter splits the signal between the NM and the NP in this spectral overlap region of 300 – 310 nm, where both instruments measure the radiance, but the sensitivity drops rapidly for both of them. The left graph shows the current operational production. The error is estimated to be 2 to 3% for NP (blue) at 300 nm and a similar error for NM (green) at 310 nm. After a number of radiometric, wavelength, band pass, and stray light corrections were made, the right graph shows the expected errors. The NM slow period shown with a dashed line in the graph was attributed to an error in the surface reflectivity in the RT model. The error in the RT model is estimated to be 2 to 3% based on ice radiances. Once adjusted, the NM will flatten out and will look very much like NP in the graph.
6. The solar diffuser degradation based on the four and half years of data was analyzed and found to be less than 1% at the very short wavelengths and is not considered for time-dependent calibration adjustment for reprocessing.

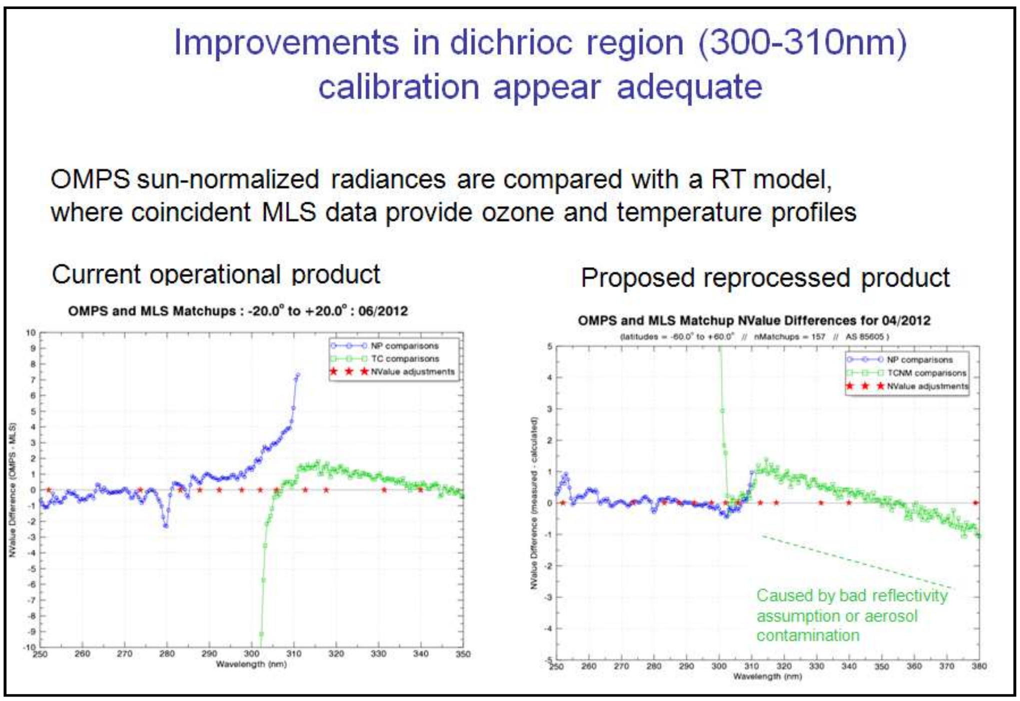


Figure 4.29: NM and NP radiometric calibration in the dichroic region (300 – 310 nm).

4.2.5 OMPS EDR Product Assessments

Presenters

Dr. Craig Long

NWS CPC

Dr. Larry Flynn

NESDIS/STAR

Dr. Craig Long and Dr. Larry Flynn took turns sharing their presentations, which are summarized below. The presentations included material and results from members of the NASA and NOAA OMPS Teams[30].

4.2.5.1 OMPS Data Users

Dr. Long presented the use of OMPS data at the Climate Prediction Center (CPC) and NCEP. Both operational and reprocessed data products are used. Operationally, the OMPS data are used by NCEP and the international weather centers for assimilation into weather prediction models for ozone forecasts and the UV index. A recent application arose at the Air Weather Forecast center to alert pilots flying through their tracks when stratospheric intrusions of ozone occur that can raise the amount of ozone in the cabin. The OMPS data illuminates where the intrusions are and helps pilots avoid regions with high ozone levels. The CPC uses operational products to monitor the size of the ozone hole on a daily basis.

Reprocessed ozone products are used by the CPC for long-term monitoring of ozone anomalies. Monthly anomalies relate the circulation to temperatures. When there is warm polar circulation, there is no ozone depletion. When there is cold polar circulation, there is no stratospheric warming. The ozone layer reacts differently when there is stratosphere warming. The anomalies help to monitor the ozone depletion in the atmosphere due to greenhouse gases and anthropogenic chlorine and bromine chemicals. The ozone variation due to climate change, by the CO_2 and water vapor affects, is monitored. There is a long time series of continuous ozone observation—37 years—by SBUV(/2) instruments flown on Nimbus 7 through NOAA 19, which will be continued with OMPS data to create the long-term climate data record (CDR). Trends in ozone layer from 1979 to present are shown in **Figure 4.30**. There is depletion trend before 1995 and recovery since 1996. The maps such as Figure 4.30 are possible due to reprocessed data and as long as there is an OMPS-type instrument on orbit.

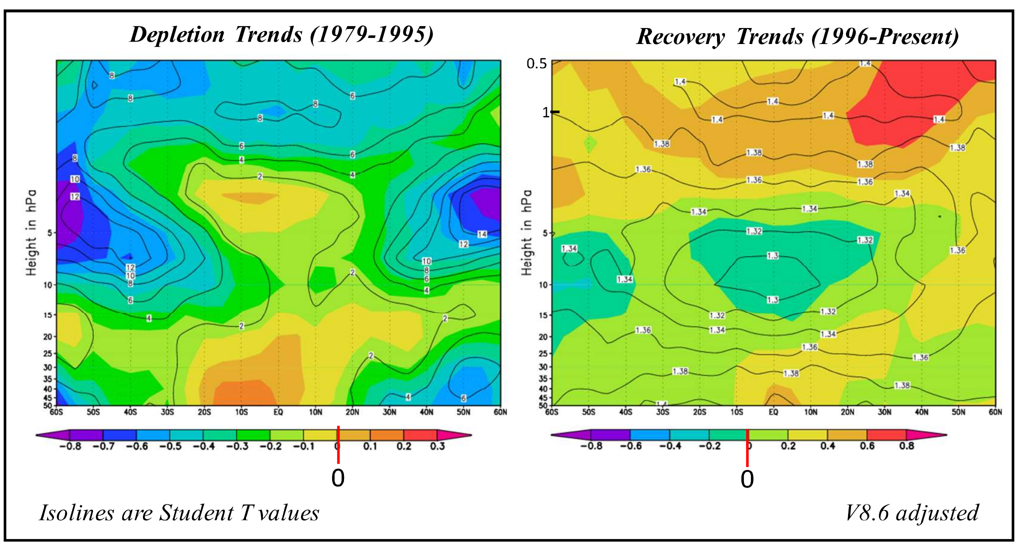


Figure 4.30: Trends of ozone in the vertical (Regression Model).

30 In Particular, Chunhui Pan provided much of the SDR analysis.

4.2.5.2 OMPS Algorithm Maturity

Dr. Flynn presented the OMPS algorithm maturity and readiness for reprocessing, focusing mainly on the reprocessing of OMPS data. The version 8 Heritage algorithms' EDR performance and V8 reprocessing are described below.

Version 8 EDR Performance

- The Version 8 Total Column Ozone (V8TOz) and the Ozone Profile (V8Pro) algorithms are the heritage and enterprise algorithms for nadir backscatter ultraviolet (BUV) observations.
- They are regularly run on OMPS SDRs offline at STAR (NCDC Project) and are being implemented at NDE for operational processing.
- The algorithms are applied to create ozone CDRs from the reprocessed measurements made by the TOMS and SBUV(/2) series of instruments and follow-on sensors (OMI, OMPS).

V8 Reprocessing

- When a new set of SDRs becomes available, the existing system can reprocess it with the V8TOz and V8Pro at the rate of 1 month/day.
- A sample reprocessing of 4 weeks per year (one per season) and of some individual chasing orbits can be used to check the calibration relative to internal and external validation measures.

4.2.5.3 OMPS Hardware

The OMPS instruments (NM, NP, and Limb Profiler) are designed to take a set of measurements to allow analysts to maintain the instrument characterization and calibration. For each of the instruments, this task can be broken into two components, tracking the performance of the CCD array detectors and electronics, and tracking the performance of the optical components (i.e., telescopes and spectrometers). The instruments make measurements on the night side of orbits with the apertures closed. One set is made without any sources and is used to track CCD array dark currents. Another set is made with illumination by an LED and is used to track CCD non-linearity and pixel-to-pixel non-uniformity response. The instruments also make solar measurements using pairs of diffusers. Judicious operation of working and reference diffusers allows analysts to track the diffuser degradation. The solar measurements also provide checks on the wavelength scale and bandpass. The instruments have completed multiple passes through their internal dark and nonlinearity calibration sequences and have been making regular solar measurements once every two weeks. The hardware is shown in **Figure 4.31**.

Nadir Profiler (NP)

- Grating spectrometer, 2-D CCD; Nadir view, 250 km cross track; 250 nm to 310 nm spectral; 1.1nm FWHM bandpass

Nadir Mapper (NM)

- Grating spectrometer, 2-D CCD; 110 degrees cross track; 300 nm to 380 nm spectral; 1.1nm FWHM bandpass

Limb Profiler (LP)

- Prism spectrometer, 2-D CCD; three vertical slits, -20 to 80 km; 290 nm to 1000 nm

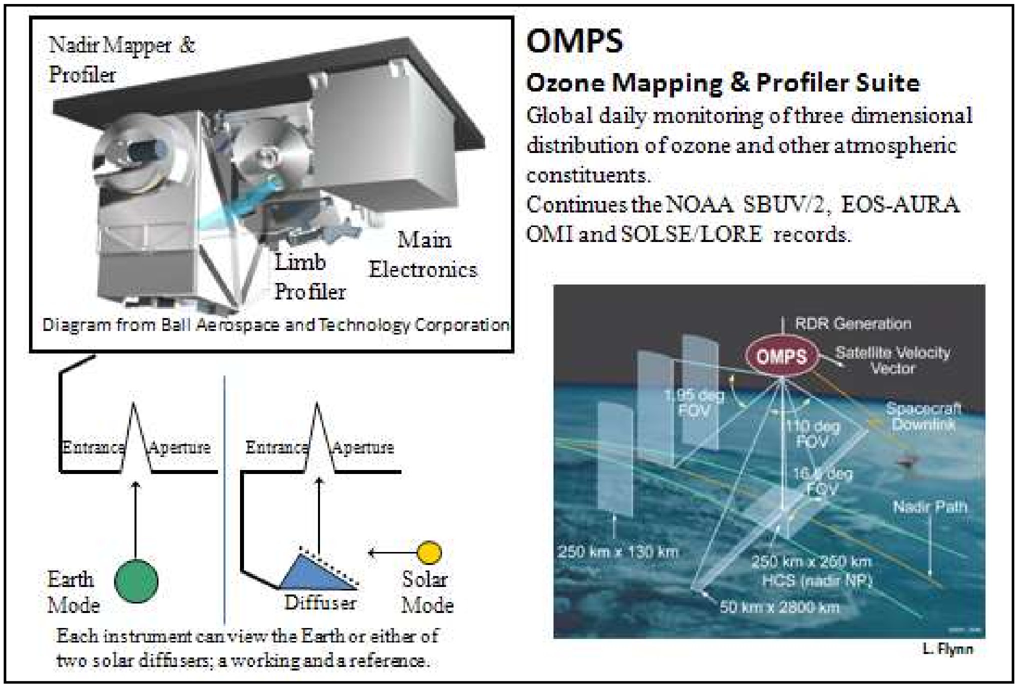


Figure 4.31: OMPS instrumentation schematic description.

The calibration systems use pairs of working and reference solar diffusers.

Performance

1. The CCD and electronics performance is shown in **Figure 4.32**. The analysis shown is from NASA PEATE and NOAA STAR monitoring. The weekly updating of the darks is now working, which was not the case during the first year. The updates now available will be used in reprocessing, filling in the gap for the first year.
2. The dual diffuser systems with a reference diffuser are used twice a year at the same viewing angles and a working diffuser is used every other week to provide good information on the instrument and diffuser degradation. There is not much degradation to correct for NM diffuser, whereas the NP diffuser degradation reached 0.8% over the four and half years and it is worth correcting in reprocessing.
3. The calibration difference between NP and NM over the dichroic overlap region of 300 nm to 310 nm discussed by Glen Jaross in Section 4.2.4 was addressed and fixed at NOAA IDPS processing a year ago. Radiance/irradiance coefficients are modified to account for ground to orbit wavelength shifts, as well as normalized radiance consistency between NP and NM. The Day-one solar LUT accounts are updated for irradiance calibration coefficients. The updated radiance coefficient LUTs improve normalized radiance consistency up to ~10% between NP and NM in 300-310 nm. This will be addressed in reprocessing to have a consistent ozone product from the beginning of SNPP OMPS.
4. The solar wavelength shift pattern and solar activity pattern are shown in **Figure 4.33**. The effect is approximately ±1% in the channels for NP retrieval. The Magnesium II index values for Earth view are regularly monitored and the relating temporal information with the spectral pattern gives the solar activity information. Therefore, the effects in the solar spectral pattern and their temporal coefficients can be corrected. These two corrections can be input into the solar data that goes along with no calibration change for OMPS SDR.

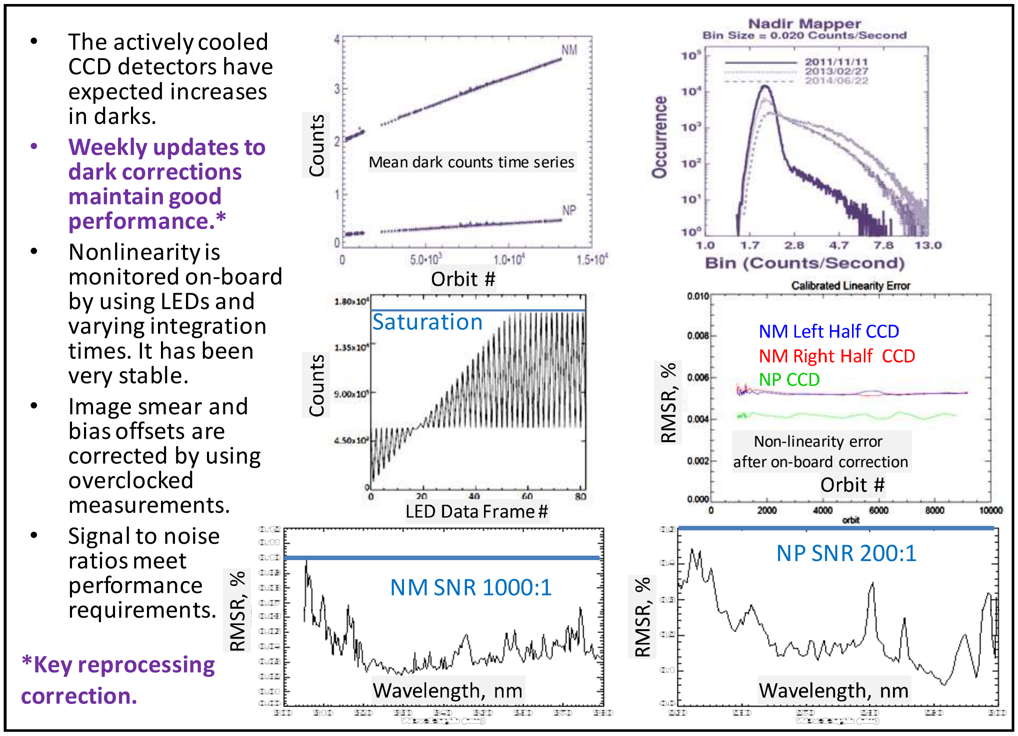


Figure 4.32: OMPS CCD and electronics performance.

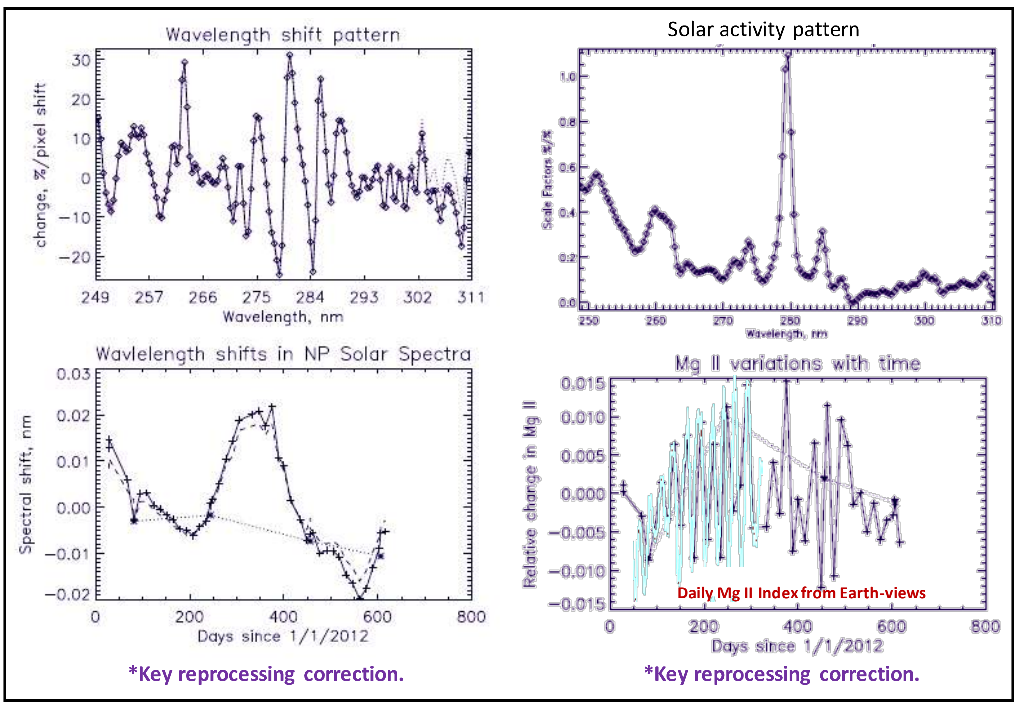


Figure 4.33: Wavelength shifts and solar activity are key corrections for reprocessing.

5. The full spectral measurements provide information on the stability of the wavelength scales. The wavelength shifts have thermal relationship, as Glen Jaross pointed out in Section 4.2.4. The NM has an intra-orbit wavelength scale variation correlated with the orbital cycle of the instrument temperature gradient. The NP has an annual wavelength scale variation correlated with the annual cycle of the

instrument temperature. Therefore, as the temperatures are known, the wavelength variations can be estimated accurately for reprocessing.

4.2.5.4 NP Performance Error Impacts on Precision and Accuracy

The sensitivity of the ozone retrievals to radiance to irradiance ratio errors is approximately 1.6%.

- Wavelength scale errors produce radiance variations of ±1% (Key reprocessing correction); i.e., 1.6% x 1% = 1.6% ozone effects
- Wavelength scale errors produce Ozone cross-section variations, alpha, of ±0.4%; i.e., 0.02 nm x 100%/5 nm x 1%/1% = 0.4% ozone effects
- Solar activity produces irradiance variations of ±1% (Key reprocessing correction); i.e., 1.6% x 1% = 1.6% ozone effects
- Instrument degradation is -0.5%/(3 years) at 253 nm (Key reprocessing correction) i.e., 1 year x 1.6% x 0.5%/(3 years) = 0.3% ozone effects (Assuming annual updates to Calibration Factor Earth tables)
- Stray light errors are now approximately 1/3 of the original errors with radiance variations of ±1% (Key reprocessing correction) i.e., 1.6% x 1% = 1.6% Ozone effects

4.2.5.5 Soft Calibration Adjustments

1. Product statistics and cross-track variations are monitored in an uneventful region of the globe extending from 20°S to 20°N and 100°W to 180°W. Highly repetitive patterns are produced by cross-track channel biases. These will be removed when reprocessing by soft calibration adjustments using the Calibration Factor Earth tables or in the EDR processing by the channel adjustment tables.
2. Comparisons to other current ozone instruments on orbit will help to match OMPS measurements by soft calibration and eliminate variations seen in reflectivity and UV absorbing aerosol index retrieval values. Comparisons with 23 Dobson station measurements provide validation of OMPS measurements at the ozne product level for consistency.

4.2.5.6 Summary

- The OMPS Nadir Instruments are performing as designed and the reference solar diffuser measurements show stable throughput for most wavelengths.
- Non-geophysical measurement variations and biases that affect ozone retrievals have been identified and can be modeled and corrected in SDR reprocessing or by soft calibration at the EDR stage.
  – Improved characterization of darks, radiance, and irradiance calibration constants, non-linearity, stray light, and intra-orbit NM wavelength scales provide good SDR adjustments and have improved product accuracy.
  – The OMPS NM SDRs show a small cross-track bias in their calibration.
  – The OMPS NP has experienced a small amount of throughput degradation for the shortest wavelengths but its time dependence is accurately determined.
  – The OMPS NP has an annual cycle in its wavelength registration, and the 27-day and 11-year solar activity produces corresponding radiance variations.
  – The OMPS NP SDRs show small, wavelength-dependent biases in their calibration versus NOAA-19 SBUV/2.

- The V8 retrieval algorithms are well-suited for the measurements and compliment soft calibration adjustment strategies.
- The ozone products are validated by comparisons to those from ground-based and other space-based systems.
- A full OMPS reprocessing from the RDRs through to the V8TOz and V8Pro will provide high quality components to extend the long-term atmospheric ozone monitoring records.

4.2.6 NUCAPS and MIRS Product Assessments

Presenter

Dr. Mark Liu

NESDIS/STAR

Dr. Mark Liu of NOAA/NESDIS/STAR gave an assessment of the NOAA Unique CrIS/ATMS Processing System (NUCAPS) and the Microwave Integrated Retrieval System (MIRS) in light of JPSS life cycle data reprocessing. The following is a summary of the presentation.

4.2.6.1 NUCAPS

The NUCAPS system utilizes CrIS and ATMS sounding data to generate products for the operational and research users. The operational users are NWP centers with the next generation Advanced Weather Interactive Processing System (AWIPS II). The retrieved products made available through CLASS have users such as NOAA/CPC, NOAA/Air Resources Laboratory, and others. The seven mandatory EDRs are temperature (*T*), water vapor (H_2O), ozone (O_3), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), outgoing longwave radiation (OLR). Seven other products, called supplemental, are not required by the JPSS program. The variational method used for retrieval assures the EDRs are consistent within uncertainty of measurements and forward model of NWP.

Assessment

The current NUCAPS operational algorithm is version 1.5. Version 1.7 was an experimental version in offline use at STAR (at the time of the presentation, May 2016), which utilizes the CrIS full spectral resolution data now available. The temperature, water vapor, and ozone vertical atmospheric column profiles generated by NUCAPS Version 1.7.2, in comparison to ECMWF, are shown in **Figure 4.34** as three charts. The lines represent the standard deviation (SDV) between the NUCAPS retrieval and the model prediction of ECMWF. *(For more about ECMWF, see Heather Lawrence's presentation in Section 4.1).* The blue line represents the retrieval using CrIS (IR) plus ATMS (microwave) data, the red line is a first guess for the model, and the green line is using only the microwave data. The improvements in the SDRs resulted in improved EDRs. As a further illustration, **Figure 4.35** shows the NUCAPS Version 1.5 (*New IR regression/emissivity coefficients*). The problems in the microwave data showing convergence in the non-precipitation region is shown in red. Arrows point to the quality flag images of ascending and descending orbits. **Figure 4.36**, however, shows the improvement in the analysis of the same data using the NUCAPS version 1.7.2. The identified problems in the microwave convergence shown previously in Figure 4.35 has now been eliminated. The overall area of microwave-only retrievals, shown in green, has been reduced, indicating an improvement in IR+MW convergence = Global reference/dedicated radiosonde collocations used for formal validation efforts within the STAR Validation Archive (VALAR) of offline NUCAPS versions undergoing development are facilitated by the NOAA Products Validation System (NPROVS). The

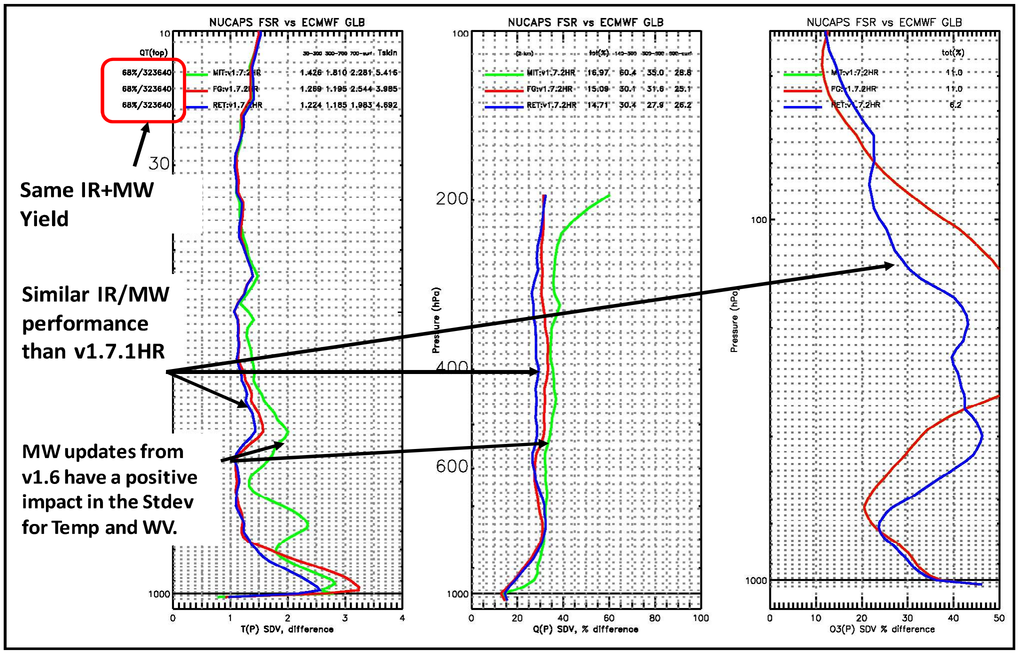


Figure 4.34: NUCAPS CrIS full spectral resolution version 1.7.2 versus ECMWF (SDV).

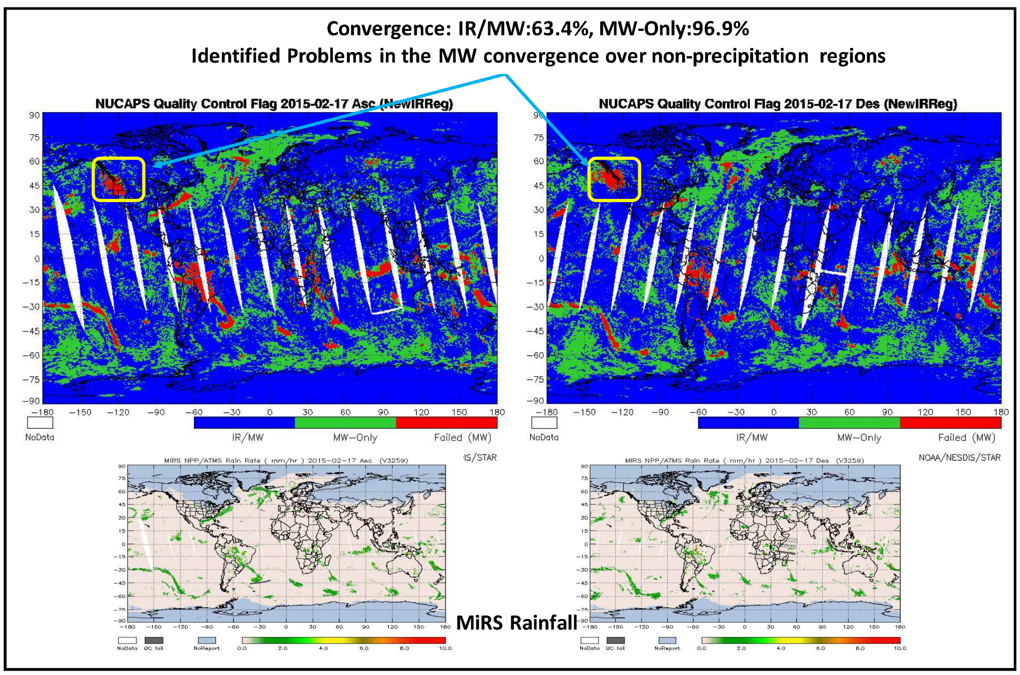


Figure 4.35: NUCAPS version 1.5 identified problems in the microwave convergence, shown in red.

NUCAPS Version 1.7.2 has also generated the methane product and CO_2 product satisfactorily. The OLR product generation has also been successful, with the climate requirement being met based on satellite intercomparisons. Great progress has been made in the SDRs, which is one of the major reasons for reprocessing.

4.2.6.2 MIRS

MIRS produces EDRs, utilizing the ATMS sounding data. It uses a variational method to ensure the final EDRs are consistent within uncertainty of measurements and for-

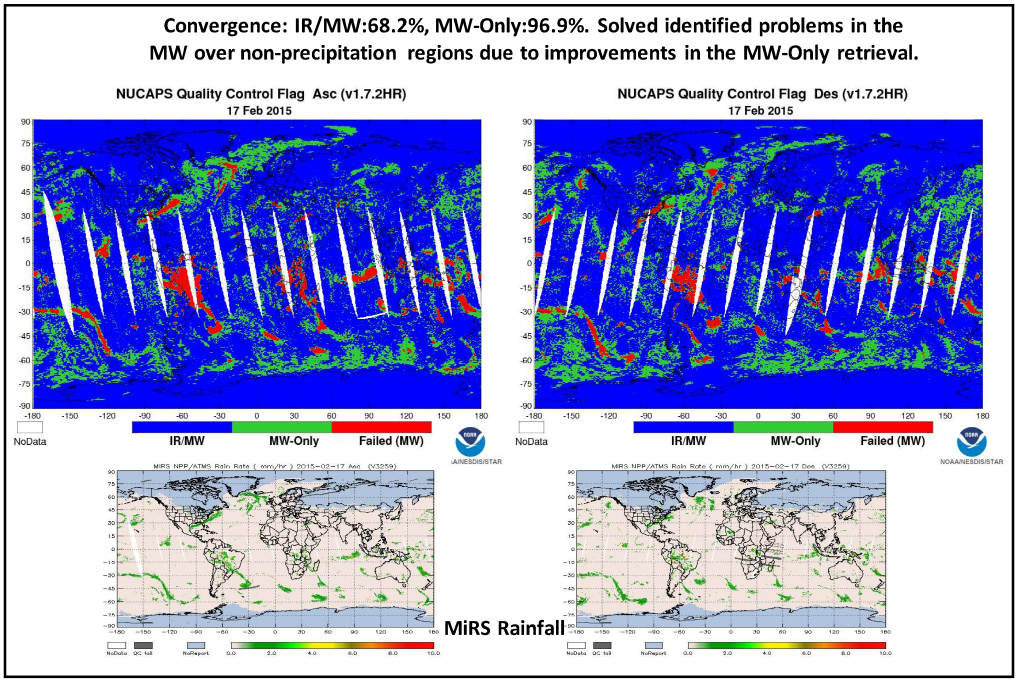


Figure 4.36: NUCAPS version 1.7.2 solved problems identified in the microwave convergence over non-precipitation regions.

ward model of NWP The mandatory MIRS EDRs are land surface temperature, cloud liquid water, rainfall rate, sea ice concentration, snow cover, snow water equivalent, total precipitable water, land surface emissivity, moisture profile, and temperature profile. The supplementary EDRs are snowfall rate, sea ice age, snow grain size, and graupel water profile. The users of the MIRS EDRs range from direct broadcast users of the Community Satellite Processing Package (CSPP) to users of NOAA/Cooperative Institute for Research in the Atmosphere (CIRA) for hurricane intensity forecasts to users of the CLASS archives.

Assessment

1. Together, MIRS and ECMWF are able to generate Global Temperature Product (GTP). The MIRS GTP captures all the features of the ECMWF, as shown in **Figure 4.37**. The global water vapor pattern produced by MIRS and ECMWF showed good agreement and the sea-ice extent and snow cover extent compared very well with the national Ice Center product. The MIRS had several versions in development. Version 11.1 took into account the significant need for reprocessing and was, as a result, a great improvement over Version 9.2.
2. A typical hurricane is studied at Colorado State University (CSU)/(CIRA) using the ATMS MIRS data as input. **Figure 4.38** is provided by Mark Demaria at CSU/CIRA. The cyclone rapid intensification index is compared with both Global Forecast System (GFS) and MIRS input. It shows three percent improvement in Brier skill and ten percent improvement for the position. The MIRS product used was without the heavy rain EDR. There is a request from UCA/CIRA for MIRS to be generated with the heavy rain EDR.
3. The operational MIRS product is only available from April 8, 2014. There have been many requests for MIRS data to study Hurricane Sandy of 2012. This request can only be served after reprocessing.

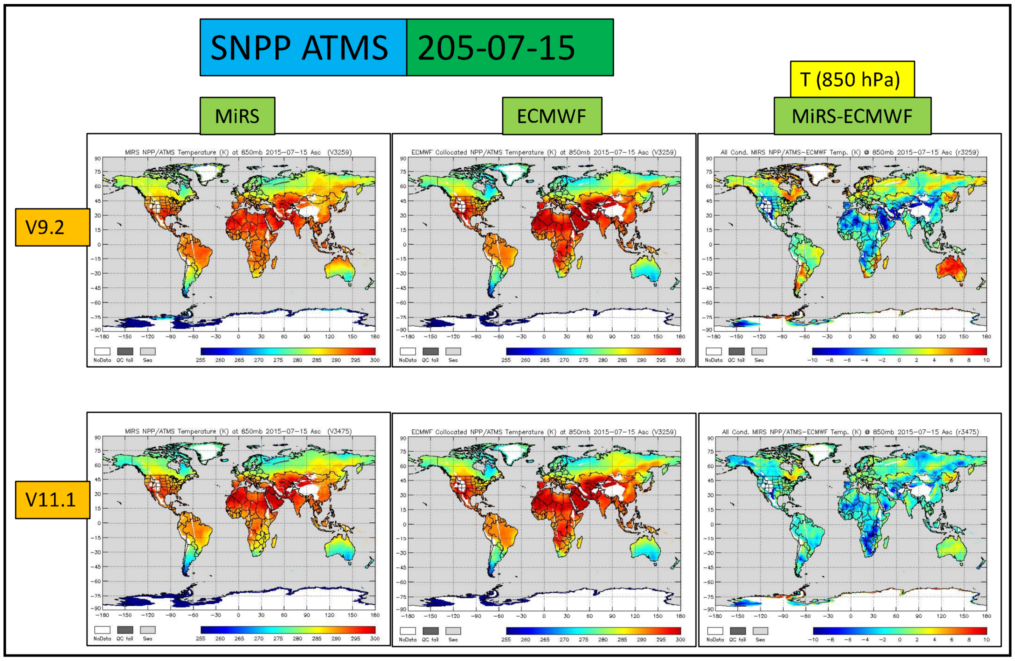


Figure 4.37: MIRS and ECMWF comparison of global temperature distribution. Also shown are MIRS V9.2 and MIRS V11.1.

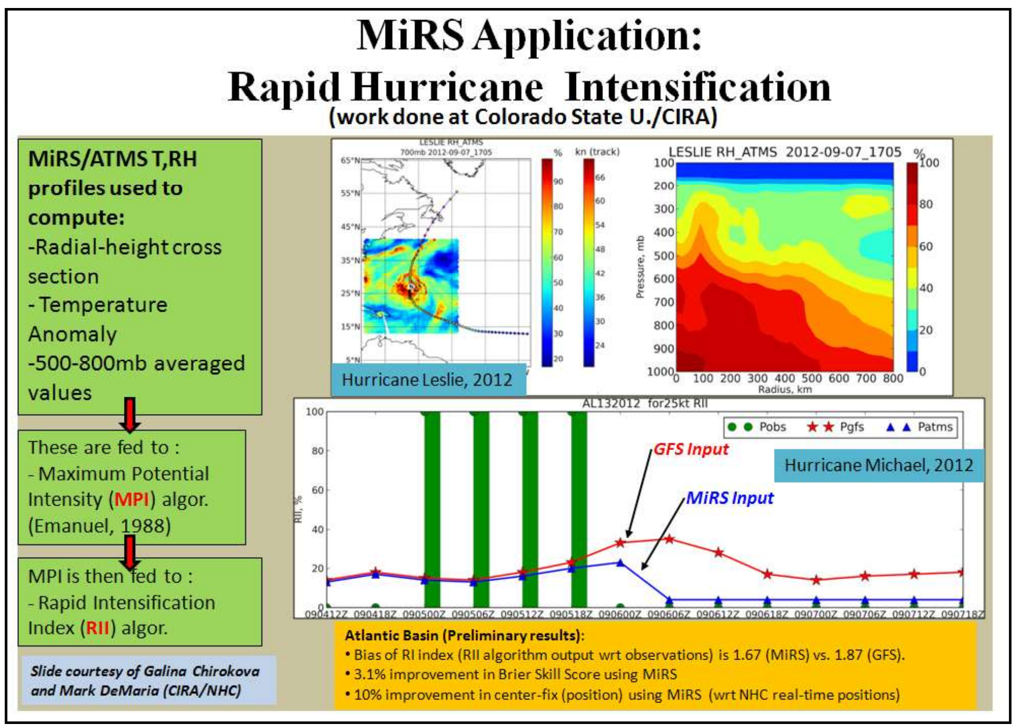


Figure 4.38: MIRS application: Rapid (Hurricane) Intensification index.

4.2.6.3 Summary

The SDRs of CrIS and ATMS have been improved and are ready for reprocessing. Both NUCAPS and MIRS algorithms have been improved and reprocessing will generate complete and consistent EDRs with better quality.

Demonstrating the Improved and Advanced Calibration and Validation Algorithms for Reprocessing Applications

5

Dr. Tom Atkins

Chair

Dr. Tom Atkins chaired the session, which included five speakers from NOAA/NESDIS/STAR: Dr. Yong Han, Dr. Hu (Tiger) Yang, Dr. Changyong Cao, Dr. Chunhui Pan, and Dr. Menghua Wang. Their presentations are summarized in the sections below.

5.1 Latest Improvements of CrIS SDR Sciences and Algorithms for Reprocessing

Presenter

Dr. Yong Han

NESDIS/STAR

Dr. Yong Han spoke about the major updates to the current IDPS CrIS SDR algorithm[31] in the new STAR offline code called the baseline code: ADL 5.3.1 (PSAT-16, Block 2.0)[32]. The code is capable of processing both truncated (normal) and full spectral resolution (FSR) SDRs. The updates in this code are listed below and discussed one by one separately.

5.1.1 Updates in ADL/PSAT-16

- Correction Matrix Operator (CMO) handling update.
- Calibration order change and post-filter update.
- Self-apodization (SA) correction noise effect Geolocation algorithm change update.

CMO Handling Update

- *Current Status:* The CMO matrix is a combination of three components: an SA correction matrix, a resampling matrix, and a post-filter update. In order to avoid frequent updating of the CMO, as the 27 SA correction matrices are expensive to compute, the current IDPS algorithm updates the CMO only when the laser sampling wavelength changes more than 2 ppm. Therefore, the variation is generally more than 2 ppm.
- *Update:* The new improved ADL has a CMO handling algorithm that separates the SA correction matrix update from the resampling matrix update. The resampling wavelength in the matrix is dynamically updated once per orbit to address the sampling laser wavelength variation. The new algorithm allows parallel computing.
- *Impact:* The impact on the spectral frequency error over the four and half years of IDPS SDR can be seen in **Figure 5.1**. The new algorithm will retrospectively reduce the error to 1 ppm in reprocessing, as shown in the red curve.

Calibration Order Change and Post-filter Update

- *Current Status:* The CrIS on-orbit signal processing and the current SNPP Level 1b algorithm processing is shown in **Figure 5.2**. The radiometric calibration is per-

31 For the IDPS CrIS SDR modules improvements: See May 18 -19 workshop presentations at http://www.star.nesdis.noaa.gov/star/meeting_JPSS2016_LDRW.php.

32 CrIS Algorithm Development Library (ADL).

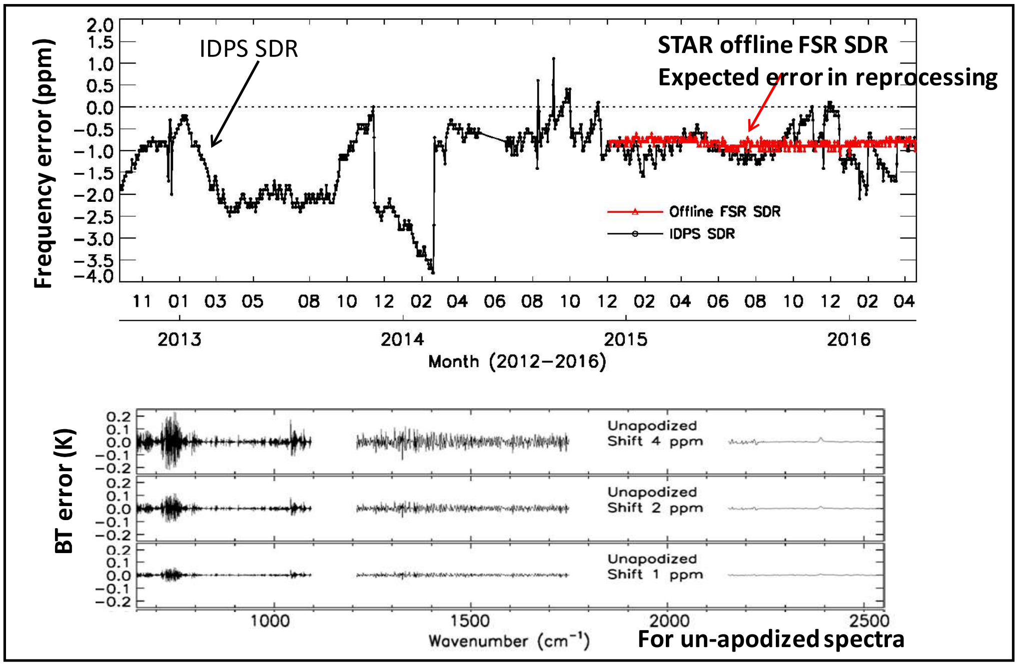


Figure 5.1: Spectral frequency uncertainty; IDPS SDR vs after reprocessing the FSR SDR.

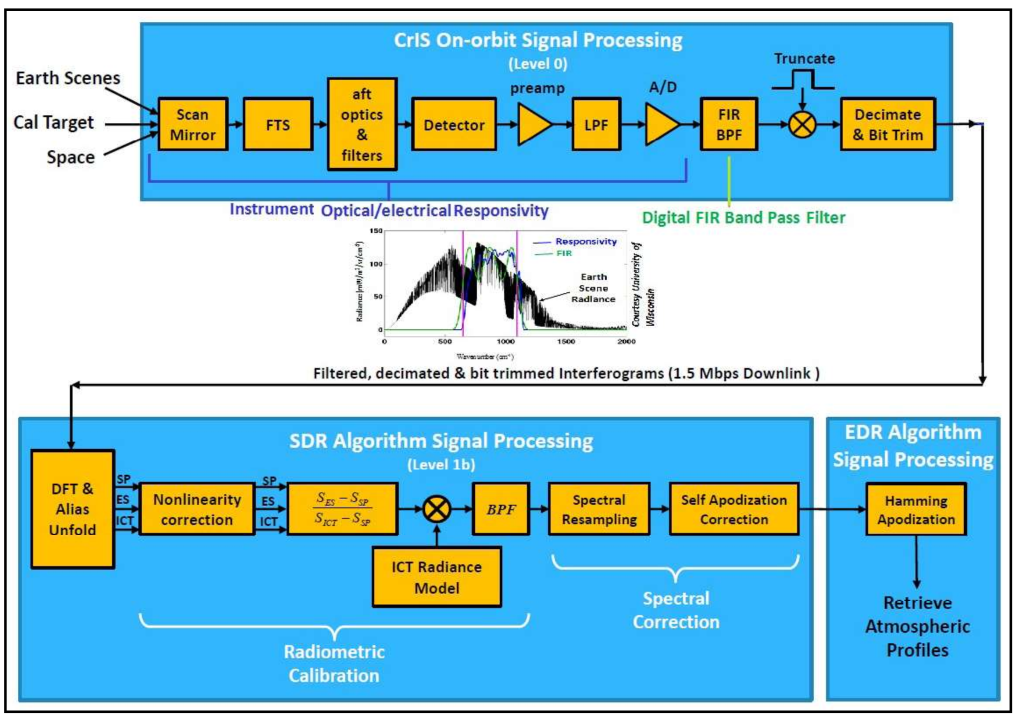


Figure 5.2: Current SNPP CrIS on-orbit signal processing and Level 1b algorithm processing.

formed prior to the spectral calibration. Predina[33] et al, in their analysis of the current algorithm, suggested changing the calibration order whereby the spectral calibration would precede the radiometric calibration that is implemented in the update.

33 OSA Hyperspectral Imaging & Sounding of the Environment (HISE) Conference., January 2015; DOI:10.1364/FTS.2015.JM1A.1.

- *Update:* The responsivity effect in on-orbit processing is taken into account in the SA correction and resampling algorithms that are based on an un-decimated interferogram, as shown in **Figure 5.3**. While the current IDPS algorithm, based on decimated interferogram, distorts the spectrum, as can be seen in the Figure 5.3.b, the spectrum is restored and the noise in the short wave and long wave is removed in the updated algorithm, allowing a wider post-filter, as shown Figure 5.3.a. The updated calibration equation is also shown. The new calibration order allowed a wider post-filter to include information from out of band, improving calibration.
- *Impact:* As an illustration of the impact of the update is shown as the brightness temperature difference compared to the radiative transfer model simulation in **Figure 5.4** using the real data on a clear uniform scene. The black line represents the current IDPS algorithm while the red line represents the updated algorithm.

New calibration equation:

$$S_{Cal} = B_{ICT} \cdot \frac{F \cdot SA^{-1} \cdot f \cdot \{\frac{\Delta S_1}{\Delta S_2}|\Delta S_2|\}}{F \cdot SA^{-1} \cdot f \cdot |\Delta S_2|}$$

Current calibration equation:

$$S_{Cal} = SA^{-1} \cdot F \cdot f \cdot \{\frac{\Delta S_1}{\Delta S_2}(SA \cdot B_{ICT})\}$$

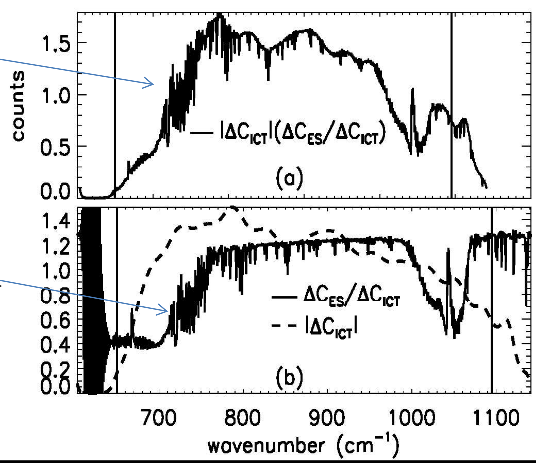


Figure 5.3: Resampling (F) and SA correction (SA-1) in the new calibration account for the responsivity effect in the on-orbit processing; (a) current algorithm, (b) new algorithm.

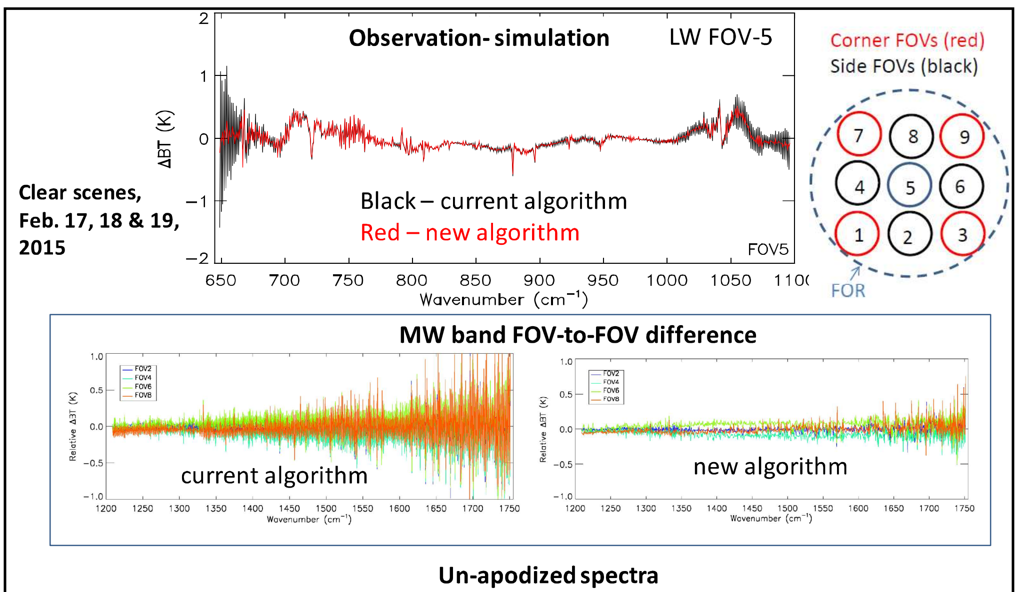


Figure 5.4: The algorithm update significantly improves noise reduction.

The reduced noise using the new algorithm in the mid-wave band Fields of View (FOV) is shown in the bottom part of the figure.

SA Correction and NEdN in the Update

The SA correction is included in the NEdN calculation in the update because it gives the user the correct picture, which significantly increases the spread in the noise, in the MW and SW bands for un-apodized spectra.

Geo-location Algorithm Change Update

The geo-location error is caused by the FOVs being reversed in the current algorithm, i.e, [FOV1, FOV3], [FOV4, FOV6], and [FOV7, FOV9] are reversed. This cannot be corrected by assuming the pairs of FOVs are symmetrical around the nadir track, because this is not always the case. Since the origin of the problem in the FOV projections was recognized, simple changes in the algorithm have improved the geo-location performance. The error is now only within 200 meters. The geo-location update of the algorithm is validated by the significant improvement shown in the comparison of the VIIRS and CrIS images.

5.1.2 Suggested Software/Algorithm Configuration for Reprocessing

- Engineering packet version 36 (the most recent) with geo-location mapping parameter updates and a new MW FOV7 NL a2 coefficient.
- ADL 5.3.1.
- Truncation spectral resolution (TSR) mode SDR (entire history).
- FSR mode SDR (December, 4 2014).
- Raw Data Record (RDR) version (most recent).

5.2 Latest Improvements of the ATMS TDR SDR Sciences and Algorithms for Reprocessing

Presenter

Dr. Tiger Yang

NESDIS/STAR

Dr. Tiger Yang of NESDIS/STAR gave an update on the ATMS algorithms for reprocessing, as summarized below.

5.2.1 The Status of the Current Calibration Algorithm in IDPS

- The radiance to brightness temperature relationship is based on Raleigh-Jeans approximation two-point calibration with blackbody and cold space as the two points.
- The nonlinearity correction is based on a polynomial regression algorithm but is applied incorrectly within the IDPS software.
- The lunar contamination correction in IDPS is based on a maximum-threshold experience correction algorithm and has only been applied since 2013.
- There are uncorrected error sources in the SDR algorithm revealed by the non-negligible bias in the calibration results during pitch maneuver observations of deep space.
- The instrument performance is shown as stable and the channel noise is kept to a low level.

5.2.2 Algorithm Improvements

Table 5.1 shows the improvements in the ADL Full Radiance Calibration (FRC) and future plans.

Table 5.1: Improvements ATMS TDR Science Algorithm and Future Plans.

Error Source	Current IDPS	Improvements in ADL (FRC)	Future Improvements
Calibration Method	Calibration in temperature space	Calibration in radiance space	NA
Nonlinearity	Polynomial function, no antenna emission correction	Physical model-based antenna emission correction[33] (μ - parameter)	NA
Calibration Target Bias	Side-lobe correction, R J approximation	No R-J approximation needed	Antenna emission correction for cold and warm target radiance[34]
Lunar Contamination	Maximum threshold lunar correction algorithm	Maximum threshold lunar correction algorithm	Lunar intrusion identification and correction algorithm[35]
Antenna Emission	No	No	Antenna emission correction (reference same as footnote 5)
Noise Filtering	Triangle, Rectangle	Triangle, Rectangle	Sync function

The flow chart of the improved ADL FRC algorithm is shown in **Figure 5.5**.

The ATMS radiance calibration equations[34] and the calibration error model[35] were discussed during the presentation and the main points are summarized below.

The error budget has four parts: (1) warm target radiance determination error, (2) cold target radiance determination error, (3) maximum nonlinearity error, and (4) system noise and gain drift errors. The warm target error has static and dynamic parts. The static error is in the warm target emissivity and the coupling loss. The dynamic error is in the temperature drift, temperature gradients, and measurement accuracy. The cold target error is due to earth contamination, spacecraft contamination, and the cosmic background temperature estimation. The total uncertainty of all of the error sources has been estimated based on the prelaunch data and modeling. To verify the calibration results, the pitch maneuver data at the center location observing deep space microwave

34 Weng, F., X. Zou, N. Sun, H. Yang, M. Tian, W. J. Blackwell, X. Wang, L. Lin, and K. Anderson, 2013: Calibration of Suomi national polar-orbiting partnership advanced technology microwave sounder. J. of Geophys. Res. 118, 187–200.

35 Weng, F., and H. Yang, 2016: Validation of ATMS Calibration Accuracy Using Suomi NPP Pitch Maneuver Observations. Remote Sensing Journal. 8, 332-345.

36 Weng, F., H. Yang, and X. Zou, 2013: On Convertibility from Antenna to Sensor Brightness Temperature for ATMS. IEEE Geosci. and Remote Sens. Lett. 10, 771-775.

37 Yang, H., F. Weng, and K. Anderson, 2016: Estimation of ATMS Antenna Emission from Cold Space Observations. IEEE Transactions on Geosci. and Remote Sens. 54, 4479-4487.

38 Yang, H., and F. Weng, 2015: Corrections for On-Orbit ATMS Lunar Contamination. IEEE Transactions on Geosci. and Remote Sens. 54, 1989-1924.

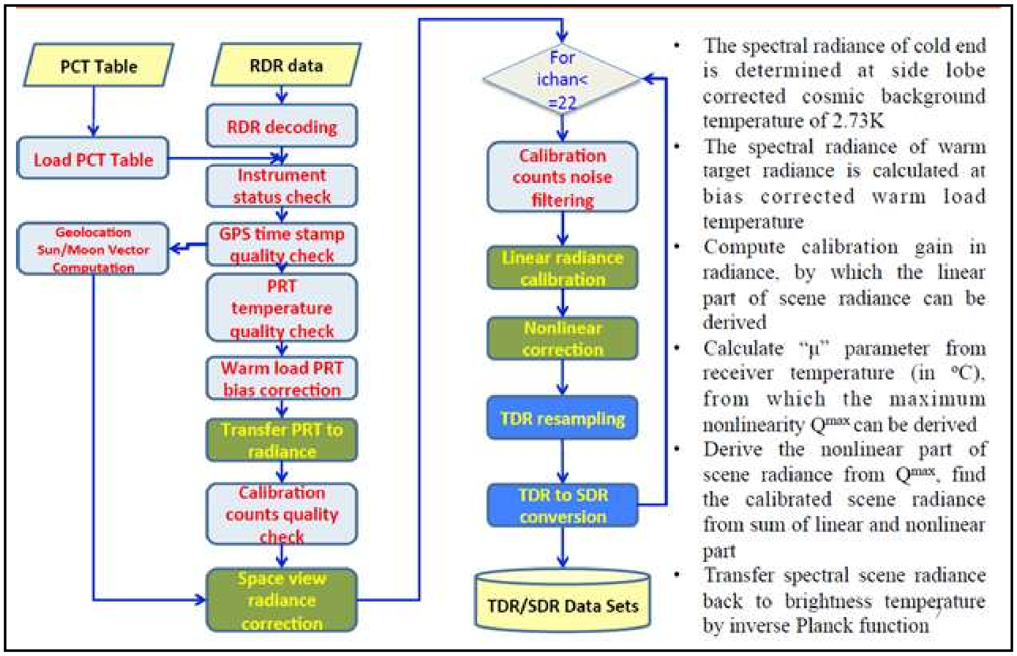


Figure 5.5: ADL FRC flow chart.

radiation was compared with the truth (2.728 K). The comparison of the calibration accuracy modeling results at the cold scene with the deep space observations is shown in **Figure 5.6**.

The larger bias in cold space calibration results indicates that there is an additional angle-dependent error source not being corrected in the calibration process. Also, the negative bias for the vertical polarization (QV) channels and the positive bias for horizontal polarization (QH) channels shows that a polarization-dependent error source needs to be examined. Another way to verify the calibration accuracy is through radiative transfer model (RTM) simulations. The Community Radiative Transfer Model (CRTM)version 2.1.3, with Fastem-1 as the surface emissivity model, is used with ADL 4.2 with IDPS Mx8.8. The global mean TDR RTM brightness temperature (BT) bias (ADL-FRC vs IDPS) is calculated by taking the average at the center part of the FOV for each channel. The result is shown in **Figure 5.7**.

Channel	Scene Temperature (K)	
	PFM at 80K	On-orbit at 2.728K
1	0.265	-0.607
2	0.194	-0.343
3	0.184	0.431
4	0.231	0.498
5	0.224	0.427
6	0.149	0.441
7	0.135	0.553
8	0.225	0.564
9	0.116	0.544
10	0.179	0.653
11	0.240	0.649
12	0.206	0.679
13	0.188	0.723
14	0.132	0.786
15	0.207	0.753
16	0.353	-1.342
17	0.327	1.064
18	0.256	1.342
19	0.291	1.383
20	0.295	1.477
21	0.270	1.429
22	0.289	1.543

Figure 5.6: Calibration accuracy verification through deep space observations – Pre Flight Model (PFM).

The ATMS FRC TDR RTM is performed including three corrections: (1) Planck function radiance replacing the brightness temperatures (R-J approximation);

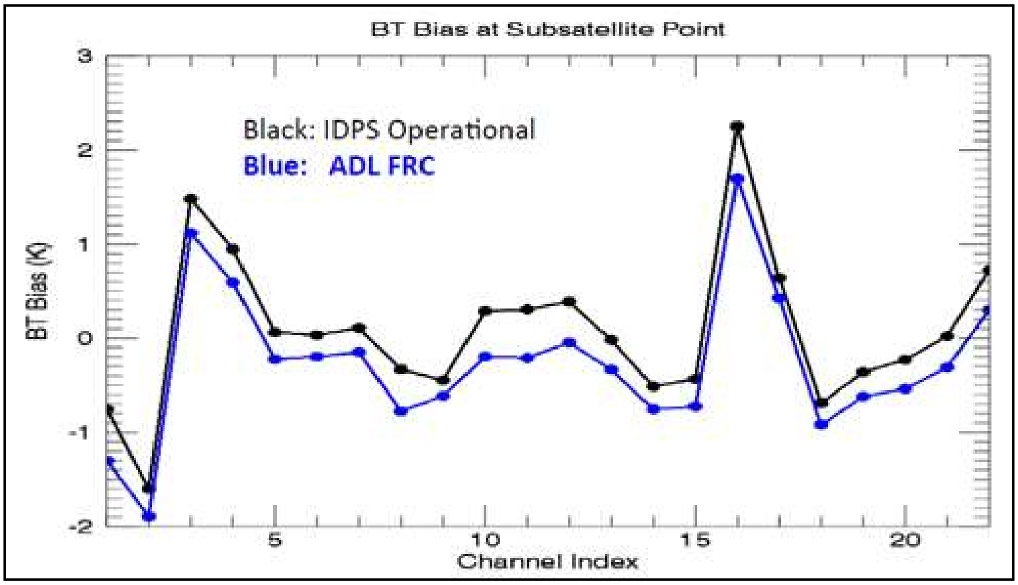


Figure 5.7: ATMS TDR RTM BT bias using ADL FRC (blue) and IDPS (black).

(2) physical model-based nonlinearity correction; and (3) lunar intrusion (LI) correction. The BT bias in FRC TDR is smaller than those in IDPS TDRs. Many of the channels are affected by the nonlinearity correction terms. Similar analysis on the angle-dependent bias showed a consistent angle dependence feature with a deep space view. The geo-location accuracy is improved by reconstructing the ATMS instrument mounting matrix.

5.2.3 Conclusion and Future Improvements

- The radiance calibration algorithm with physical model-based nonlinearity correction has been implemented in ADL and tested, showing improvement in the algorithm.
- Future improvements:
  - Implementing antenna emission correction to reduce scene dependent calibration error.
  - Developing polarized RTM to eliminate angle-dependent bias in TDR.
  - Updating the on-orbit beam alignment/instrument mounting matrix to improve geo-location accuracy.

5.3 VIIRS SDR Science and Algorithms for Reprocessing

Presenter

Dr. Changyong Cao

NESDIS/STAR

Dr. Changyong Cao presented the status of the VIIRS SDR science and algorithm improvements for reprocessing as summarized below.

5.3.1 IDPS VIIRS SDR Algorithm and Input Parameter Major Changes

- Relective Solar Band (RSB): the implementation of AutoCal in IDPS (2015) and the Relative Spectral Response (RSR) changes due to rotating Telescope Assembly (RTA) mirror degradation.
- Day Night Band (DNB): the stray light correction, RSR changes due to RTA mirror degradation, terrain correction, and geo-location error correction.
- TEB: the blackbody temperature (EBBT) look-up table (LUT) change and the warm-up cool-down bias.

The VIIRS event log database[39] at the NOAA National Calibration Center URL is set up in a SQL database to provide access to information about events in the time series for reprocessing. The information can be searched in different ways. An example of the information page is shown in **Figure 5.8**.

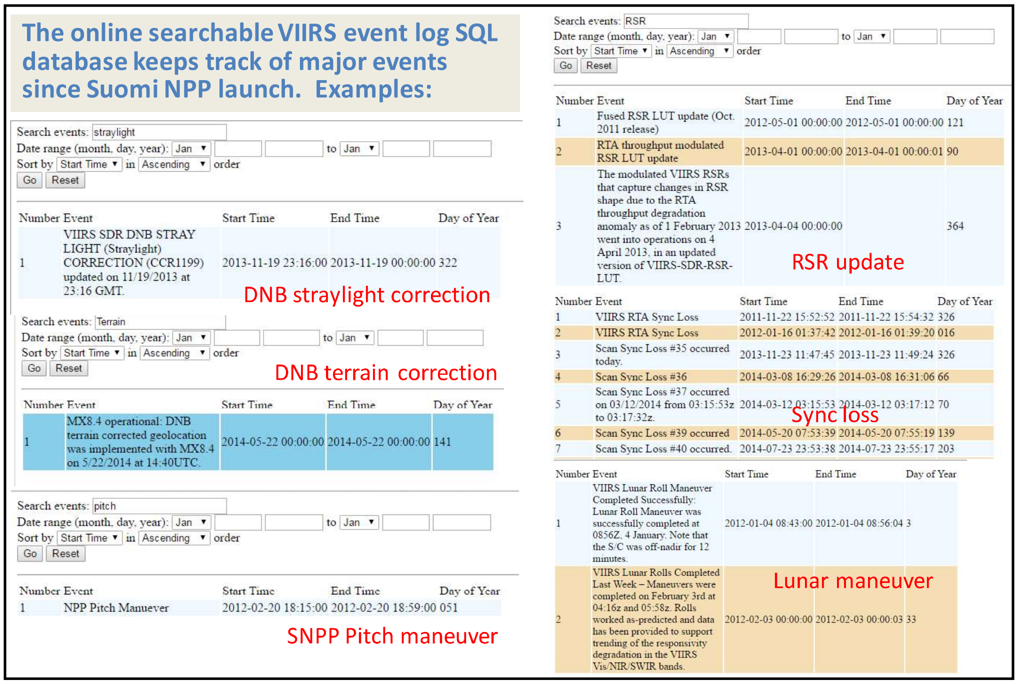


Figure 5.8: The online and searchable VIIRS event log database.

5.3.2 RSB

RSB Algorithm Improvements

- Automated calibration of the reflective solar bands[40] (RSB AutoCal) has been implemented.
- Re-calibrated LUTs have been generated using RSB AutoCal[41].
- Re-calibrated LUTs are being used for reprocessing by customers such as the Advanced Satellite Products Branch in Wisconsin.
- All major VIIRS calibration algorithms have been peer reviewed to identify strengths and weaknesses[42].

RSB AutoCal Compared to Prior IDPS

- Early orbits in 2012 showed large differences between operational and RSB AutoCal of up to 1.5%. The difference has been getting smaller as the RTA mirror degradation levels off.

39 For details see the VIIRS calibration knowledge base and event log at http://ncc.nesdis.noaa.gov/VIIRS/index.php.
40 Rausch, K., S. Houchin, J. Cardema, G. Moy, E. Haas, and F. J. De Luccia, 2013: Automated Calibration of the Suomi National Polar Orbiting Partnership (S-NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Reflective Solar Bands. J. of Geophys. Res.—Atmos., 118, 13434–13442.
41 Blonski, S., and C. Cao, 2016: Suomi NPP VIIRS reflective solar bands operational calibration reprocessing. Remote Sens. 7, 16131-16149.
42 Datla, R., X. Shao, C. Cao, and X. Wu, 2016: Comparison of the Calibration Algorithms and SI Traceability of MODIS, VIIRS, GOES, and GOES-R ABI Sensors. Remote Sens. 8, 126-152.

- RSB AutoCal improved solar diffuser[43] calibration with optimized filtering.
- Major benefits of AutoCal are automation, accuracy, reduced opportunity for human error, more frequently updated calibration (per orbit), resolved inconsistencies due to manual update and “predict ahead”, “more accurate”, and cost savings.

RSB AutoCal Limitations and Future Work

- RSB AutoCal relies on the Robust Holt Winters (RHW) filter, which simplifies the models and works well for operational processing due to its fast speed and long-term captured trends. However, its mimicking of short-term averaging has shortcomings, with artifacts on the order of 0.1%.
- Any alternative algorithms to further improve fidelity would likely be at the expense of speed.
- Future work will incorporate lunar calibration[44,45], which is not part of RSB AutoCal.

5.3.3 DNB

DNB Algorithm Improvements

- The VIIRS DNB observations were affected by stray light until the stray light correction was implemented in August of 2013. The images appeared as haze on the night side of the terminator. The stray light affected regions as far south as 30º latitude in the Northern Hemisphere during summer, as shown in **Figure 5.9**.
- The geo-location for DNB was off up to ten kilometers at high altitudes until the terrain correction was implemented in 2014.
- VIIRS DNB monitored with the DCC time series revealed inconsistencies due to an RSR change in early orbits as a result of RTA mirror degradation. The DNB became stable after the RSR update in mid-2014.

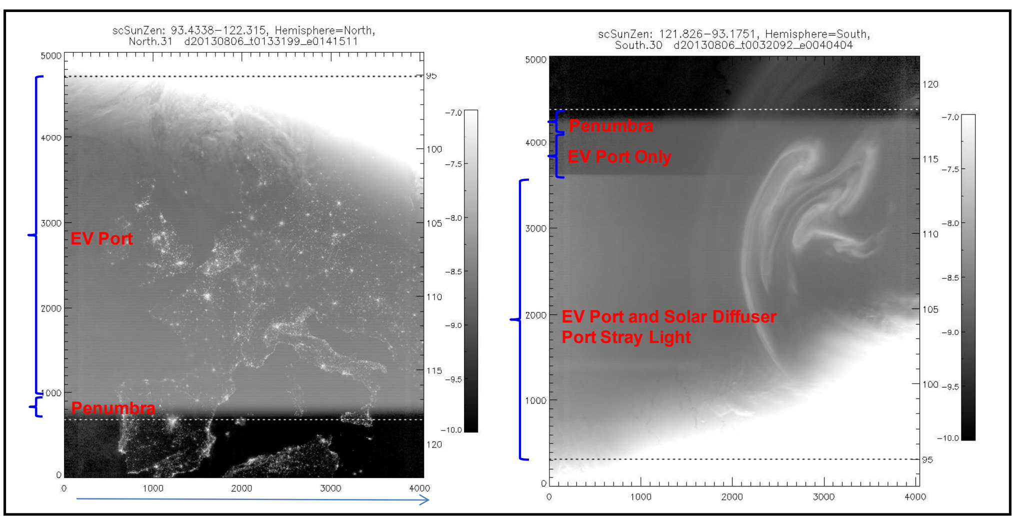


Figure 5.9: The DNB observations were affected by the stray light until a correction was implemented in August 2013.

43 Shao. X., C. Cao, T. C. Liu, 2016: Spectral dependent degradation of thye solar diffuser on Suomi-NPP VIIRS due to surface roughness-induced Rayleigh Scattering, Remote Sens., 8, 254 -265.

44 Sun, J., and M. Wang, 2015: Radiometric calibration of the visible infrared imaging radiometer suite reflective solar bands with robust characterizations and hybrid calibration coefficients. Appl. Opt., 54, 9331 – 9342.

45 Choi, T., X. Shao, C. Cao, and F. Weng, 2016: Radiometric Stability Monitoring of the Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS) Reflective Solar Bands Using the Moon. Remote Sens. 8, 1-16.

DNB Algorithm Limitations and Future Work

- The stray light correction is empirical and should be further improved.
- The southern hemisphere and tropical stray light is not currently corrected.
- The root cause of stray light has yet to be found.
- The dark offset uncertainties require further improvements.
- The on-board vs. vicarious calibration tradeoff is to be explored.
- The VIIRS DNB dark offset is difficult to determine. Even the darkest part of the ocean during the new moon is not dark enough for DNB offset. Alternatives include using Blackbody. The increased complexity is due to aggregation zones. Future work should include finding an active light source for improved accuracy.

5.3.4 TEB

VIIRS TEB Algorithm

- The early versions (prior to IDPS MX8.10) of the EBBT table had problems. The latest LUT version is available on VIIRS web site[46].
- WUCD bias observed in the Sea Surface Temperature (SST) is a remaining issue. The solution proposed by colleagues at the Aerospace Corporation has pros and cons and STAR is investigating alternative algorithms.
- Future work includes investigating detector-based RSR processing to improve striping and to use MICROS for validation.

5.3.5 Validating Reprocessed VIIRS SDR

- Simultaneous Nadir Observation: The major calibration updates in 2012 and mid-2014 had the largest impact with RSB M1, indicating a change as large as 4% when compared with MODIS. The stability of band M4 has been concerning since 2014. The bands M5 and M7 are generally stable.
- Validation at 30 vicarious sites.
- Validation at the reprocessing test beds.
  1. 2012 and 2014 VIIRS Geo/SDR over major metropolitan areas were reprocessed using:
     - ADL4.2_Mx8.11;
     - RSBAUTOCAL F-factors and other latest RSB calibration parameters;
     - Latest GEO LUTs;
     - Reprocessed GITCO, I1-I3, I5 data validated using a monthly percent cloud cover time series for before and after the reprocessing; and
     - VIIRS I-bands cloud mask algorithm[47].
  2. Larger cloud climatology differences were observed in 2012 compared to 2014
     - Consistent with the expected calibration improvements in the reprocessed data;
     - Larger geo. and radiometric calibration improvements for early 2012 IDPS data; and
     - Small improvement for 2014 data by using more consistent F-factors.
  3. DNB test bed for Ocean observations (e.g., Bearing Sea fishing boats)
     - Good location for checking stray light correction;
     - Frequent orbit coverage; and
     - Potential use for boat tracking improvements with reprocessing.

46 http://ncc.nesdis.noaa.gov/VIIRS.

47 Piper, M., and T. Bahr, 2015: A rapid cloud mask algorithm for Suomi NPP VIIRS imagery EDRs. ISPRS – Int. Archives of the Photogramm. Remote Sens. and Spatial Infor. Science, XL-7/W3, 237-242.

5.3.6 Summary

- VIIRS algorithms have evolved since the Suomi NPP launch, with major changes in RSB AutoCal, DNB stray light, and terrain correction, and RSR changes.
- VIIRS reprocessing LUTs are available on the VIIRS home page[48]. The VIIRS SDR team will further improve the algorithms and LUTs.
- Test beds are being developed to verify and showcase the benefits of reprocessed data.
- The SDR team will work closely with the EDR teams to address all reprocessing issues.

5.4 OMPS Life-Cycle SDR Reprocessing

Presenter

Dr. Chunhui Pan

NESDIS/STAR

Dr. Chunhui Pan of NESDIS/STAR presented the OMPS SDR algorithm improvements and readiness for reprocessing. The presentation is summarized below.

5.4.1 OMPS SDR Algorithm Improvements

The Earth View (EV) SDR improvement time line is shown below:

- Beta Status: The SNPP launch was held on October 28, 2011 and the first SDR was generated in January 2012. The IDPS SDR reached Beta status on March 13, 2012.
- Provisional Status: The following updates were implemented to bring the algorithm to provisional status on March 1, 2013.
  - Implemented weekly dark current calibration updates of the detector arrays (CCDs).
  - Resolved negative smear and bias correction in the RDR.
  - Applied an initial stray light correction for Nadir Mapper (NM)[49].
- Validation: The following improvements were implemented to bring the algorithm to validated status on September 9, 2015.
  - Improved NM (TC) stray light by adding Out of Band correction.
  - Reduced radiometric calibration errors and minimized cross-track effects in NM.
  - Improved data consistency between NM and NP in 300-310 nm the spectral overlap region.

The improvements listed above were chronologically achieved based on research and reprocessing was necessary for the EV SDR to be consistent from the beginning of the mission. The following are the major corrections implemented in the algorithm to reach the validated status.

Stray Light Correction

The stray light is modeled and corrected for NM. The relative difference of corrected stray light count to measured signal (%) is plotted as a function of the EV frame spectral index and is shown for a Macro pixel cell 10 on the top right of **Figure 5.10**. The blue curve represents the first initial correction of only 40% on July 10, 2013. The red curve represents the most recently updated LUT correction (December 18, 2014). This second update captured 100% of the stray light. The correction result was evaluated via SDR EV radiance is between the two corrections and is shown in green. The lower diagram in Figure 5.10 shows the consistency between the two sensors, NM and NP. at the overlap region.

48 http://ncc.nesdis.noaa.gov/VIIRS/index.php

49 NM is also referred as TC to signify that it measures the total column ozone.

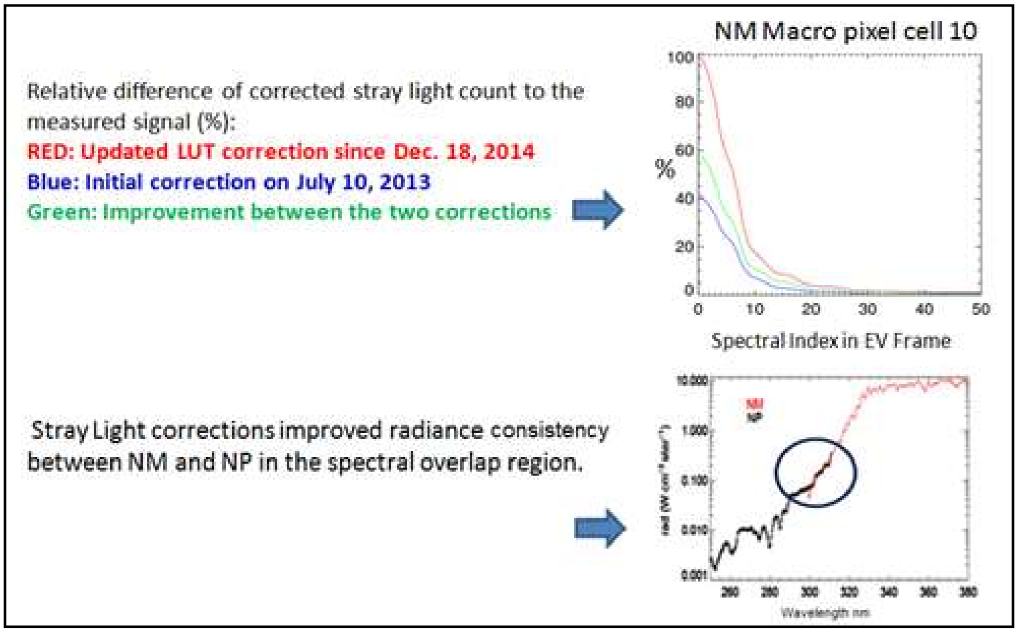


Figure 5.10: Stray light correction by instrument modeling.

Sensor Dichroic Shift Correction

The solar irradiance discrepancy between NM and NP in the overlap region is shown in the top of **Figure 5.11**. One of the root causes was dichroic shift when sensor was transitioned from ground to orbit. Wavelength calibration were made for both the NM and NP to correct the dichroic shift via the EV SDR algorithm LUT updates on November 13, 2014, that completely removed the discrepancy.

Cross-Track radiometric Error Correction

The irradiance errors for three different cross-track positions relative to the nadir position are shown in **Figure 5.12**. The updated wavelength and solar flux LUTs implemented on September 9, 2015 eliminated the cross-track error as shown in the bottom in Figure 5.12. The normalized radiance error is computed between OMPS and the EOS-Aura MLS using the TOMRAD radiative transfer model. The errors are less than 2% for most channels, except for several channels at the far end of the CCD as shown in left side of the **Figure 5.13** under the title "Before September 9". This residual error is eliminated by implementing soft calibration at the EDR level and the result is shown on the right side of Figure 5.13 under the title "After September 9".

Radiometric Consistency Improvement Between NM and NP

The radiance/irradiance coefficients were modified to account for ground-to-orbit wavelength shifts. The updated LUTs improved albedo by up to ~ 10% in the 300 -310 nm wavelength region, as shown in **Figure 5.14**.

Expected Results of Reprocessing

- No long-term time-dependent change relative to SBUV/2 of the current NOAA-19 polar satellite.
- OMPS Nadir Mapper (TC) bias of near zero and a profiler bias of approximately 0.5% (for V8 EDR ozone products).
- Consistent SDRs that meet the top level products requirement. The EV SDR will have the following improvements implemented.

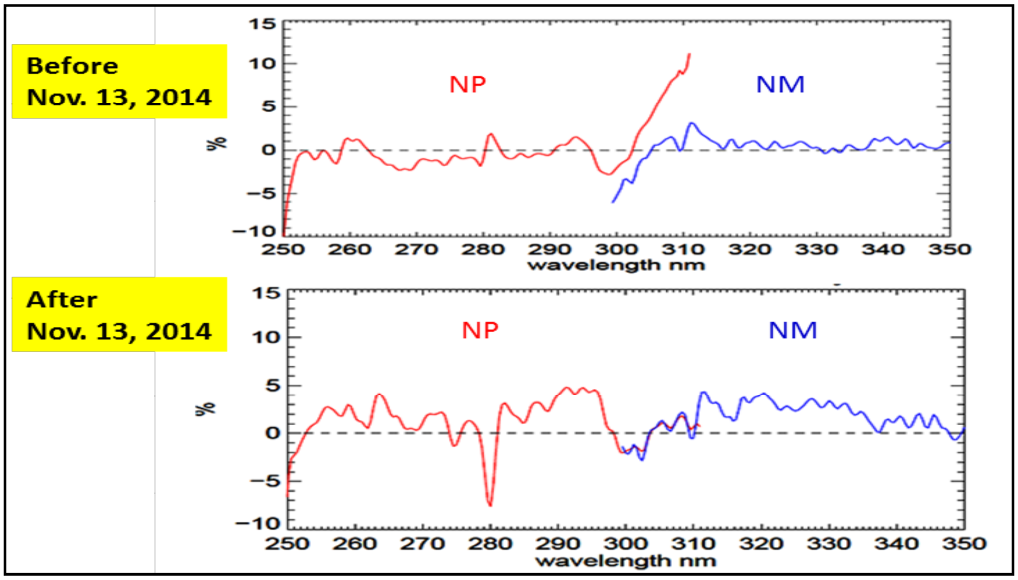


Figure 5.11: Solar irradiance correction implemented November 13, 2014.

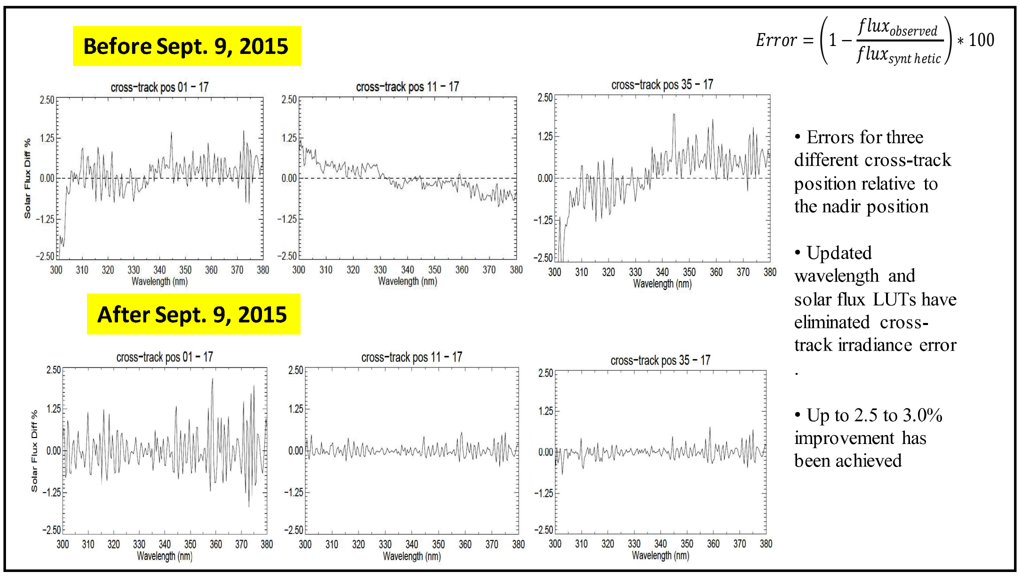


Figure 5.12: Cross-track irradiance error correction for solar data.

- Minimized cross-track IFOV radiometric error < 2.0% for nearly all the channel and pixels.
- Consistent data records between NP and NM in 300-310nm.
- Negligible stray light contamination.
- Adjusted NM wavelength registration by considering the EV sensitivity.
- Corrected wavelength thermal sensitivity caused temperature gradient.

5.3.2 Summary

- OMPS EV SDRs meet the top level of SDR and EDR products requirements for nearly all OMPS channels.
- Sensor orbital performance is stable and meets expectations.
  - However, the wavelength registration is sensitive to the sensor thermal loading change. The performance requirement of <0.02 nm wavelength variation was

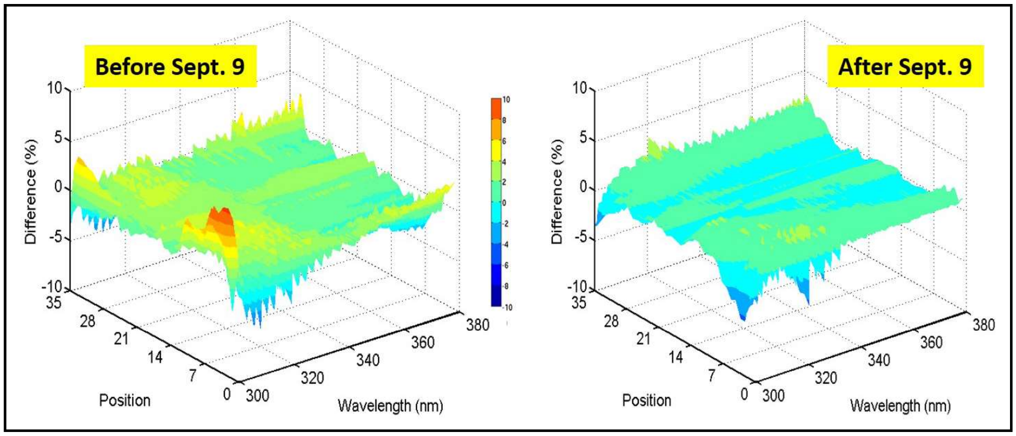


Figure 5.13: Cross-track radiance error correction for Earth view data.

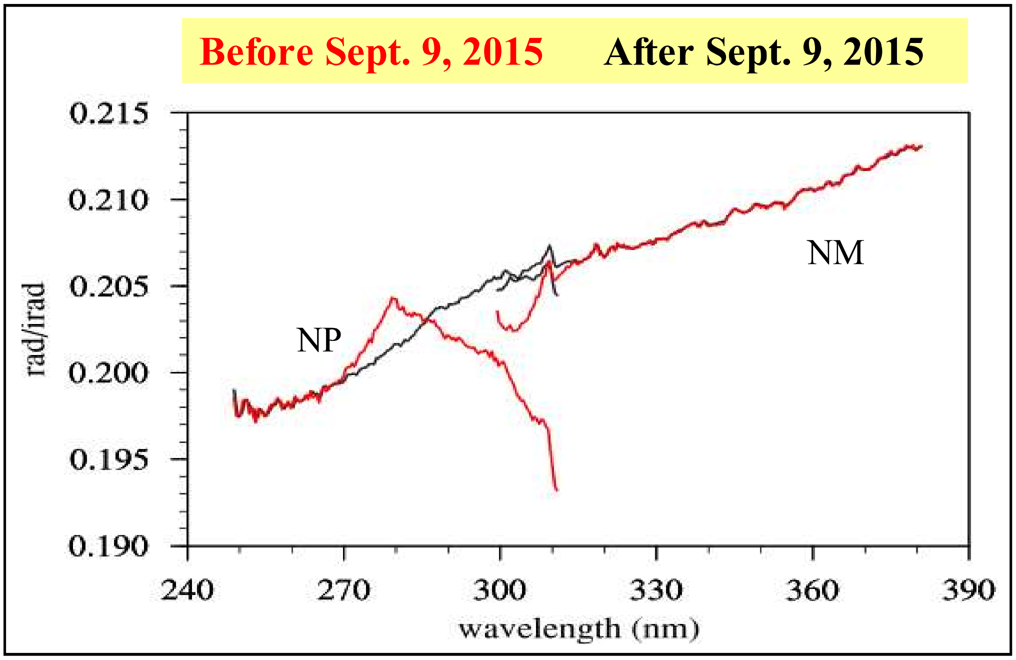


Figure 5.14: Radiometric improvement after the EV SDR update on September 9, 2015.

waivered and this thermal sensitivity correction will be made on SDR algorithm level.

- OMPS NM and NP EV SDR will have life cycle data reprocessing to produce stable and attainable quality products by implementing the following:
  - Maintain the stability of the sensor operation activities in the operation stage.
  - Refine NP wavelength calibration table in collaboration with NASA SOC team and OMPS EDR team to compensate for sensor thermal sensitivity.

5.5 VIIRS Mission-long Ocean Color Data Reprocessing

Presenter

Dr. Menghua Wang

NESDIS/STAR

Dr. Menghua Wang of NOAA VIIRS Ocean Color team presented the overview and status of ocean color products and the SDR and EDR algorithm improvements for reprocessing. The presentation is summarized below.

5.5.1 Ocean Color EDR Products

The ocean color products (EDRs) are extremely sensitive to the input SDR data quality. The SDR time series requirement is ~0.1% stability in band-to-band and individual band radiances.

VIIRS Input Data

1. VIIRS SDR data of VIS/NIR bands M1-M7 and SWIR bands M8, M10, and M11.
2. Terrain-corrected geo-location file.
3. Ancillary meteorological and ozone data.

5.5.1.1 Operational (Standard) Ocean Color Products

1. Normalized water-leaving radiance (nLw) at VIIRS visible bands M1 – M5.
2. Chlorophyll-a (Ch1-a) concentration.
3. Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, Kd(490) (New).
4. Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), Kd(PAR) (New).
5. Level-2 quality flags.

5.5.1.2 Experimental Products

1. Inherent optical properties (IOP-a, IOP-aph, IOP-adg , IOP-bb, IOP-bbp) at VIIRS M2 or other visible bands (M1-M5) from the quasi-analytical algorithm (QAA)[50].
2. Photosynthetically available radiation (PAR)[51] .
3. Ch1-a from the ocean color index (OCI) method[52,53].
4. Others from user requests.

5.5.2 End-to-End Ocean Color Data Processing

The NOAA ocean color (OC) team has been developing/building the capability for the end-to-end satellite ocean color data processing, which includes Level-0 (RDR) to Level-1B (SDR); Level-1B (SDR) to ocean color Level-2 (EDR); and Level-2 to global Level-3. The data analysis capability has also been developed to perform validation of ocean color products.

VIIRS Mission-Long OC Data Reprocessing

1. The VIIRS global OC products are being produced routinely in two data streams, near-real-time (NRT) and science quality. The NRT processing turnaround is within 12 to 24 hours operational latency. The science quality processing is being done with a one- to two-week delay. The VIIRS NRT data stream began in the summer of 2015 and the science quality data stream began in May of 2016.
2. The VIIRS mission-long SDR has been reprocessed for the science quality data stream with significantly improved on-orbit calibration using both solar and lunar

50 Lee, Z. P., K. L. Carder, and R. A. Arnone, 2002: Deriving inherent optical properties from water color: a multiband quasi-analytical algorithm for optically deep waters. Appl. Opt. 41, 5755-5772.

51 Frouin, R., and R. T. Pinker, 1995: Estimating Photosynthetically Active Radiation (PAR) at the earth's surface from satellite observations. Remote Sens. of Env.51, 98-107.

52 Hu, C., Z. Lee, and B. Franz, 2012: Chlorophyll aalgorithms for oligotrophic oceans: A novel approach based on three-band reflectance difference. J. of Geophy. Res., 117, 1-25.

53 Wang, M., and S.H. Son, 2016: VIIRS-derived chlorophyll-a using the ocean color index method. Remote Sens. of Env., 182, 141-149.

approaches. The reprocessed data showed the importance of the lunar calibration, particularly in recent years and forwarding to account for the future solar diffuser degradation. The results show improved VIIRS OC data over global high altitude lakes, which is significant progress for remote sensing inland water quality. The improvements can also be seen in the VIIRS Chlorophyll-a (Chl-a) and Kd(490) from global oligotrophic waters that are shown for the NRT data stream and science quality data stream in **Figure 5.15** and **Figure 5.16**, respectively. The SDRs are processed from the same RDR. Both SDR data are processed using the same L1B to L2 algorithm, i.e., NOAA-MSL12[54] . The NOAA OC team processed SDR shows significantly improved consistent time series compared to the IDPS processed SDR. **Figure 5.17** also shows the quantitative comparisons of VIIRS OC products from the NRT data stream with IDPS SDR and the science quality data stream with the OC SDR with in situ MOBY measurements. Again, the science quality OC data quality (with OC SDR) is validated by the good agreement shown in the ratio and standard deviation (SD) columns for OC products.

5.5.3 Conclusions

1. The OC team has successfully reprocessed VIIRS mission-long ocean color data products for the near-real-time data stream in summer 2015 and the science quality data stream in May 2016. Both data streams have been going forward routinely.
2. For the science quality data stream, VIIRS mission-long SDR has been reprocessed from RDR using significantly improved on-orbit calibration using both solar and lunar approaches. It is necessary now to use also lunar data for VIIRS calibration.
3. The reprocessed VIIRS mission-long science quality ocean color data have been significantly improved by the NOAA OC team providing accurate and consistent OC data for science research and applications.
4. The NOAA OC team is working with the NOAA CoastWatch and NCEI teams and the science quality data stream to be distributed through NCEI. (A noted added on

Figure 5.15: VIIRS OC data of global oligotrophic waters – Chlorophyll-a.

54 The NOAA Multi-sensor Level 1 to Level 2 (MSL12) is based on NASA SeaWiFS Data Analysis System (SEADAS) version 4.6 with significant improvements made by the OC group. For details see http://www.star.nesdis.noaa.gov/star/meeting_JPSS2016_LDRW.php.

October 2016 that both VIIRS NRT and science quality OC data (all mission-long and forwarding data) are now being distributed in NOAA CoastWatch).

5. The VIIRS mission-long data reprocessing will be carried out about every three years or so, when there are significant improvements for algorithms and SDR calibrations.

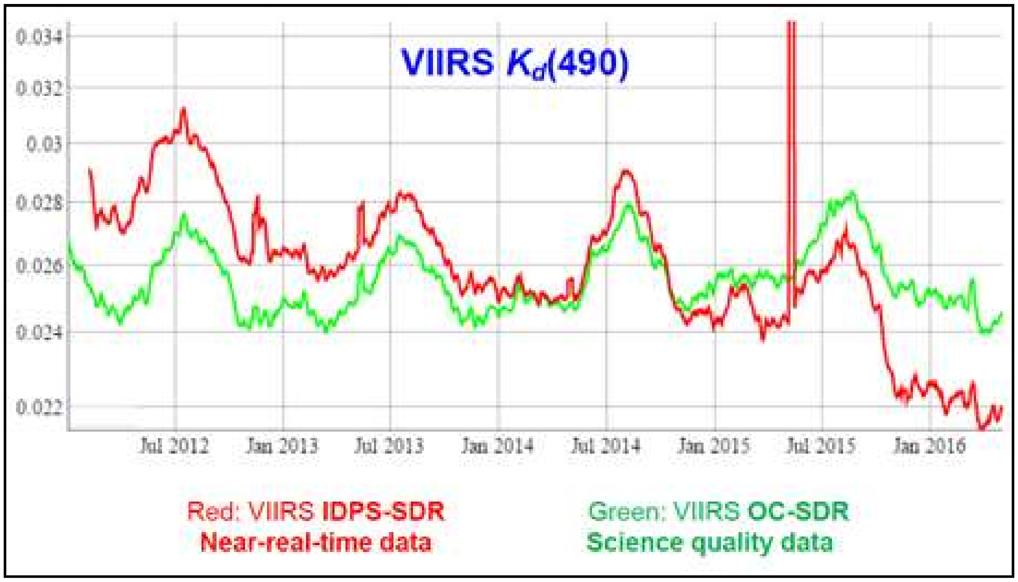


Figure 5.16: VIIRS OC data of global oligotrophic waters - Kd (490).

VIIRS Data vs. In Situ (MOBY)

(2012-01-01 ~ 2016-04-27)

	IDPS-SDR MSL12 (ver. 1.10) (Near-Real-Time Data)				OC-SDR MSL12 (ver. 1.10) (Science Quality Data)			
	AVG	MED	STD	No	AVG	MED	STD	No
$nL_w(410)$	**1.0083**	1.0065	0.0961	463	**1.0164**	1.0157	0.0956	509
$nL_w(443)$	**1.0191**	1.0005	0.1733	475	**1.0083**	1.0062	0.0899	509
$nL_w(486)$	**1.0258**	0.9991	0.1861	475	**1.0110**	1.0103	0.0846	509
$nL_w(551)$	**1.0604**	0.9809	0.4910	475	**1.0148**	1.0004	0.1338	509
$nL_w(671)$	**1.3366**	1.0059	2.1345	487	**1.1762**	1.1053	0.5393	505
Chl-a	**1.0508**	0.9764	0.4254	468	**1.0141**	1.0041	0.1647	509
$K_d(490)$	**1.0135**	0.9826	0.2437	471	**0.9842**	0.9760	0.1007	505

Figure 5.17: The MOBY in situ and VIIRS OC products comparison statistics.

Understanding the Potential Impacts of the Reprocessed SNPP Data

6

Dr. Fuzhong Weng

Chair

Dr. Fuzhong Weng of NOAA NESDIS chaired the session, which included five speakers: Dr. Xiaolei Zou of the Earth System Science Interdisciplinary Center (ESSIC)/UMD; Dr. Likun Wang of the Cooperative Institute for Climate Studies (CICS)/ESSIC/UMD; Dr. Sasha Ignatov, Chief, Satellite Ocean Sensors Branch of NESDIS STAR; Dr. Shobha Kondragunta of NESDIS STAR; and Dr. Liam Gumley of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin (UW) Space Science and Engineering Center (SSEC).

6.1 Lessons Learned from GSI ATMS Quality Control (QC) for Improving AMSU-A and MHS Data Assimilation

Presenter

Dr. Xiaolei Zou

ESSIC/UMD

Dr. Xiaolei Zou presented the experience gained in assimilating ATMS and the application of the lessons learned in order to improve the AMSU-A and MHS data assimilation. The presentation is summarized below.

Satellite Data Assimilation: AMSU-A, MHS, and ATMS Instrument Data and GOES Radiances

Data assimilation (DA) is the process of incorporating all available observations into weather forecast models in order to produce the *best* description of the atmospheric state at a desired resolution. Satellite DA success requires that the satellite data and the Numerical Weather Prediction (NWP) model be effectively integrated together into a DA system from which the results can be analyzed and interpreted. An evaluation of the added benefits of assimilating the GOES imager radiance data with the conventional satellite data streams from six other satellite instruments for coastal quantitative precipitation forecast (QPF) near the northern Gulf of Mexico produced an interesting result[55], as shown in **Figure 6.1**. The threat score became much lower upon the addition of the Microwave Humidity Sounder (HMS) to the rest of the instruments assimilated together. Further study revealed that the assimilation of the SNPP ATMS consistently showed positive improvements to Hurricane forecast

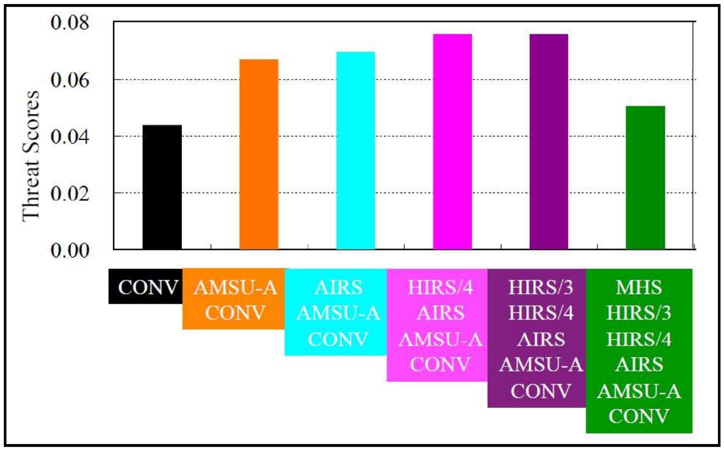


Figure 6.1: The negative impact of MHS DA on the Quantitative Precipitation Forecast (QPF). CONV (Conventional); AMSU-A, AIRS, HIRS/4, HIRS/3, and MHS are instruments on Polar satellites.

55 Qin, Z., X. Zou and F. Weng, 2013: Evaluating added benefits of assimilating GOES imager radiance data in GSI for coastal QPFs., MWR, 141, 75-92.

skill[56], as shown in **Figure 6.2**, whereas the assimilation of MHS data did not. The Gridpoint Statistical Interpolation (GSI)[57] assimilation system is examined for the data streams in these cases through simulations, paying close attention to the quality control impact of humidity channels on the QPF forecast. The ATMS temperature channels and the humidity channels are in the same Binary Universal Form for the Representation (BUFR) of meteorological data input to the GSI whereas the AMSU-A and MHS channels are put into two separate BUFR files for GSI. A simulation experiment buffing the AMSU-A and the MHS into one data BUFR mimicking what has been the case for ATMS showed improvement in the QPF forecast. The following is the summary and conclusion of these simulation experiments.

Summary and Conclusion

1. The single data stream distribution for the ATMS SDR is very convenient for users who want to develop QC for all channels with liquid and ice water information.
2. A combined AMSU-A and MHS dataset was developed for the GSI assimilation and analysis and the QC of MHS data is improved for those conditions having cloud liquid water at low levels without strong ice scattering aloft.
3. The one-data stream AMSU-A and MHS radiance assimilation more significantly improves the analysis of relative humidity in the middle and low troposphere than do the two data streams for these sensors.
4. Assimilation of AMSU-A and MHS data as one-data stream in GSI/ARW[58] resulted in more significant positive impacts on QPFs during a 10-day period during which Hurricane Isaac (2012) made landfall.

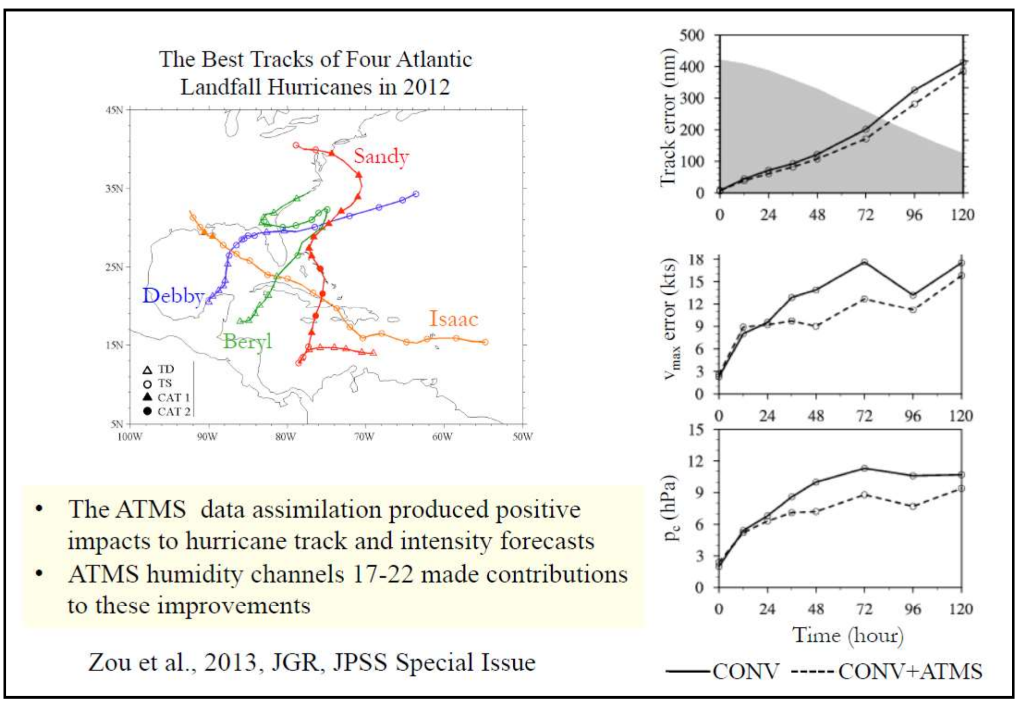


Figure 6.2: Positive impact of ATMS DA on hurricane forecasts.

56 Zou, X., F. Weng, B. Zhang, L.Lin, Z. Qin and V. Tallapragada, 2013: Impact of ATMS radiance data assimilation on hurricane track and intensity forecasts using HWRF., J. Geophys. Res., 118, 11558 – 11576.
57 http://www.dtcenter.org/com-GSI/users/.
58 Advanced Research WRF (ARW); Weather Research and Forecasting (WRF).

6.2 Using Reprocessed CrIS SDR as a GSICS Reference

Presenter

Dr. Likun Wang

ESSIC/UMD

Dr. Likun Wang presented the status and impact of potentially using the reprocessed CrIS SDR as a GSICS infrared radiometric reference for inter-calibration of satellite sensors. The presentation is summarized below.

GSICS Framework and On-orbit IR References – AIRS, CrIS, and IASI

The simultaneous nadir observations (SNO) or simultaneous observations of an Earth scene in general provide the opportunity to inter-compare the results of the two satellite observations. This is the basis of the Global Satellite Inter Calibration System (GSICS). The GSICS process allows the inter-comparison of the satellite calibrations with respect to one reference that is considered to have a high accuracy calibration. The comparison of currently available IR sensors on orbit to serve as GSICS references is shown below.

- AIRS
  - 10% of 2,378 channels degraded or dead
  - No follow-on sensor since Aqua/AIRS in 2002
  - Spectral gaps
  - Reprocessing capabilities
- IASI
  - MetOp-A → -MetOp B → MetOp C → EPS NG
  - No reprocessing capabilities
  - Fully spectral coverage
- CrIS
  - SNPP → J1 →J2 → J2 beyond
  - Spectral gaps
  - Reprocessing capabilities

The Atmospheric Infrared Sounder (AIRS) is on the AQUA satellite of the NASA's Earth Observing System (EOS). The AIRS has been in operation since 2002 and 10% of its 2,378 channels are degraded or dead till now. The high resolution spectral dispersion is provided by a grating spectrometer configuration and there are spectral gaps in the IR observations. There is no follow-on AIRS planned. The AIRS data have been be reprocessed for several times and last-released version of AIRS level 1B data is version 5.

The Infrared Atmospheric Sounding Interferometer (IASI) has been utilized as part of the MetOp–A, MetOp–B, MetOp-C meteorological missions of the European Space Agency (ESA) since 2006 and is slated to be continued on future missions. Though the instrument has full coverage of the IR spectrum of interest for sounding the atmosphere, the data is not slated for reprocessing because several calibration procedures (e.g., non-linearity correction) are performed on-orbit and some key information cannot be fully covered from the ground system.

The Cross-track Infrared Sounder (CrIS) is the NASA/NOAA instrument on the SNPP currently on orbit and will be followed by instrument updates in the JPSS satellite long-term time series. The CrIS instrument is a hyper spectral interferometer with three spectral ranges—LWIR, MWIR, and SWIR—and has spectral gaps between the ranges. The data is slated for reprocessing.

Status of CrIS to Serve as a GSICS Reference

The CrIS instrument has gone through an intensive calibration and validation (ICV) process since its launch on SNPP in 2011, as shown in **Figure 6.4**. The on-orbit instrument performance has been thoroughly characterized using the pre-launch calibration as a baseline. The calibration algorithm and coefficient updates were implemented in the operational IDPS Mx8.1 version in February 2014. The instrument has been in operation in full spectral resolution mode since October 2014.

CrIS SDR Improvements – ICV Process

- The radiometric ICV process developed and validated nonlinear coefficients for the detectors in the long-wave and mid-wave spectral ranges as a function of the field of view. The updated coefficients showed good agreement with IASI on MetOp-A and MetOp-B in the GSICS inter comparison.
- The spectral shift has been characterized by applying the cross-correlation method to a pair of fine grid spectra to get the maximum correlation and minimum standard deviation by shifting one of the spectra in a given shift factor[59 60 61].
- The geolocation calibration has been improved by comparing CrIS location to the best collocation position of VIIRS. At the conclusion of the scan, misalignment is noticed in CrIS showing a systematic error. While at the beginning of the scan, the error was less than one kilometer, by the end of the scan the error had increased to a full kilometer. To correct the error, the parameters in the geolocation algorithm were adjusted, reducing the error to less than 200 meters at the end of scan.

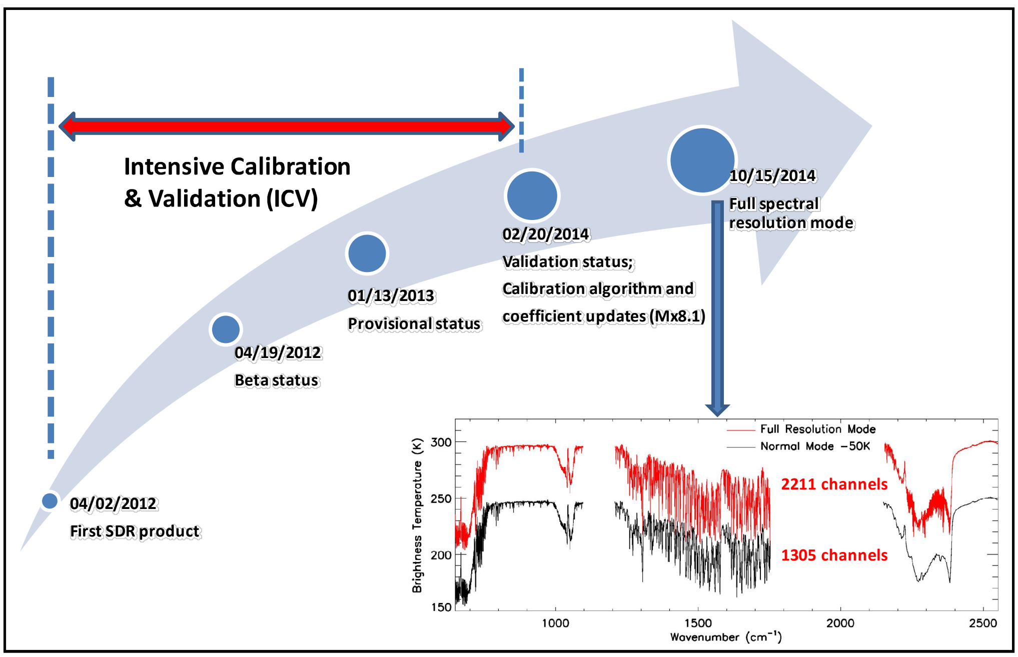


Figure 6.4: CrIS SDR calibration/validation milestones.

59 Strow, L. L., H. Motteler, D. Tobin, H. Revercomb, S. Hannon, H. Buijs, J. Predina, L. Suwinski, and R. Glumb, 2013: Spectral calibration and validation of the Cross-track Infrared Sounder (CrIS) on the Suomi NPP satellite. J. Geophys. Res. Atmos., 118, 12486-12496.

60 Chen, Y., Y. Han, and F. Weng, 2013: Detection of Earth-rotation Doppler shift from Suomi National Polar-Orbiting Partnership Cross-Track Infrared Sounder, Appl. Opt., 52, 6250-6257.

61 Chen, Y., F.Weng, and Y. Han, 2015: SI traceable algorithm for characterizing hyperspectral infrared sounder CrIS noise. Appl. Opt., **54,** 7889-7894

Summary
The reprocessed CrIS SDR will provide much improved radiometric, spectral, and geometric calibration accuracy to better benefit the GSICS inter-calibration capabilities. The instrument performance will be consistent based on the same software and calibration parameters.

Recommendations

- The reprocessed CrIS SDR should be linked to the future J1 CrIS, making long-term CrIS SDR consistent. A thorough inter-calibration effort between CrIS/SNPP and CrIS/J1 has to be undertaken to achieve this goal.
- The spectral coverage for future CrIS on J2 or J2 beyond in the series should be improved.

6.3 SNPP VIIRS SST Reanalysis v1 (RAN1)

Presenter

Dr. Sasha Ignatov

NESDIS/STAR

Dr. Sasha Ignatov presented the current status of the Sea Surface Temperature (SST) products and lessons learned. The presentation is summarized below.

NOAA Enterprise SST System
The system comprises two subsystems. One is for retrieval, called the Advanced Clear-Sky Processor for Ocean (ACSPO), and the other for monitoring, which comprises several elements[62]. The ACSPO SST products are in real-time (RT) and in reanalysis version 1 (RAN1). The timeline of the SNPP VIIRS SST product development is shown below. Currently, the ACSPO SST records are incomplete and non-uniform and need to be reprocessed and archived as a full record.

- 28 Oct 2011: SNPP launched
- 18 Jan 2012: VIIRS cryoradiator doors opened
- 20 Jan 2012: IDPS (operational) and ACSPO (experimental, STAR) SST products generated and monitored by the SST Quality Monitor (SQUAM)[63]
- Jan 2014: Based on cross-evaluation and users' feedback, JPSS SST requirements reallocated from IDPS to ACSPO
- Mar 2014: ACSPO v2.30 L2 product operational in NDE
- May 2014: ACSPO v2.30 L2 archived with PO.DAAC and NCEI (data before May 2014 not available in archives)
- May 2015: ACSPO transitioned to v2.40. L3U product added and archived with PO.DAAC and NCEI (L3U data before May 2015 are not archived)

The URLs to access the current real-time SST products and the algorithm status are shown in **Figure 6.5**. The initial reprocessing of March 2012 to December 2015 data with ACSPO 2.40 was done at the University of Wisconsin/CIMSS by Gumley et al.

The flow-chart of the RAN1 process is shown below. The generation of the uniform SDR from RDR is initiated at the University of Wisconsin using the Mx7.2 ADL code and continues at STAR as follows.

62 Details on the ACSPO and monitoring system elements can be found at: https://www.star.nesdis.noaa.gov/jpss/SST.php (Ignatov)
63 Monitors global L2 & L3 SSTs w.r.t. L4 fields and in situ data. Intercompares and validates various global L4 *SST products*

RT Product URLs

ACSPO VIIRS L2P real-time product

- podaac.jpl.nasa.gov/dataset/VIIRS_NPP-OSPO-L2P-v2.4
- data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:GHRSST-VIIRS_NPP-OSPO-L2P

ACSPO VIIRS L3U real-time product

- podaac.jpl.nasa.gov/dataset/VIIRS_NPP-OSPO-L3U-v2.4
- data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:GHRSST-VIIRS_NPP-OSPO-L3U

Status

- Currently operational: ACSPO v2.40 (May 2015)
  - Redesigned Single Scanner Error Statistics (uncertainty estimates in each pixel)
  - Destriped imagery (important for pattern recognition and ocean dynamics analyses)
  - New ACSPO L3U product generated
- ACSPO enhancements underway: geo-capable (Himawari-8, GOES-R) (2.41); Improved imagery (2.50); Pattern analyses (2.60); Explore new bands in SST retrievals; Improve/Add L3 products

Figure 6.5: RT product URls and ACSPO algorithm status.

1. (STAR) Preprocessor
   a. Aggregator: Aggregate 86sec SDR granules into 10min granules
   b. Destriping: Each individual SST band destriped
2. (STAR) L2 and L3 code
   a. L2: Core ACSPO code (clear-sky mask, QC)
   b. L3U (uncollated): Grids L2 swath data into 0.02º equal-grid
3. (STAR) Generate L2/L3U Match-Ups
   a. With QC'ed *in situ* SSTs from *i*Quam
   b. With three L4 fields (Reynolds, CMC, OSTIA)
4. (STAR) SST Quality Monitor (SQUAM)
   a. Generate global statistics of match-ups; Produce daily graphs for web display
5. (STAR) Monitoring IR Clear-sky Radiances over Ocean for SST (MICROS)
   a. Generate global statistics of BTs-CRTM; Produce daily graphs for web display

JPSS SST Requirements

The JPSS SST requirements that started with SNPP VIIRS are shown in **Figure 6.6**.

Global Match-ups with iQUAM in Situ Data

The number of daytime and nighttime match-ups with *i*QUAM *in situ* data for SNPP VIIRS were typically one to three thousand per day. The operational matchups in real time were assessed as one *in situ* SST compared with only one VIIRS SST closest in space within 20 km and within 2 hours. The RAN1 number of match-ups increased by a factor of two as the match-up criteria was changed to one *in situ* SST to all VIIRS SSTs within 2km and within a 2-hour space time window. The validation bias of VIIRS vs *i*Quam SST in real time is shown in **Figure 6.7** and in RAN1 in **Figure 6.8**. In real time, the archived data beginning in May 2014 shows improved biases as SST coefficients were recalculated and the ACSPO algorithm matured. The product meets JPSS specifications and user's expectations during both day- and night-time match-ups. Ev-

	Threshold	Objective
a. Horizontal Cell Size (Res)	1.6km[1]	0.25km
b. Mapping Uncertainty, 3σ	2km1	0.1km
c. Measurement Range	271 K to 313 K	271 K to 318 K
d. Measurement Accuracy[2]	0.2K	0.05K
e. Measurement Precision[2]	0.6K	0.2K (<55° VZA)
f. Refresh Rate	Attribute	3 hrs
g. Latency	90 min	15 min
h. Geographic coverage	Global cloud and ice-free ocean; excluding lakes and rivers	Global cloud and ice-free ocean, plus large lakes and wide rivers

[1] *Worst case scenario (corresponding to swath edge); both numbers are ~1km at nadir*

[2] *Represent global mean bias and standard deviation validation statistics against quality-controlled drifting buoys (for day and night, in full VIIRS swath, in full range of atmospheric conditions). Uncertainty is defined as square root of accuracy squared plus precision squared. Better performance is expected against ship radiometers.*

Figure 6.6: JPSS SST requirements.

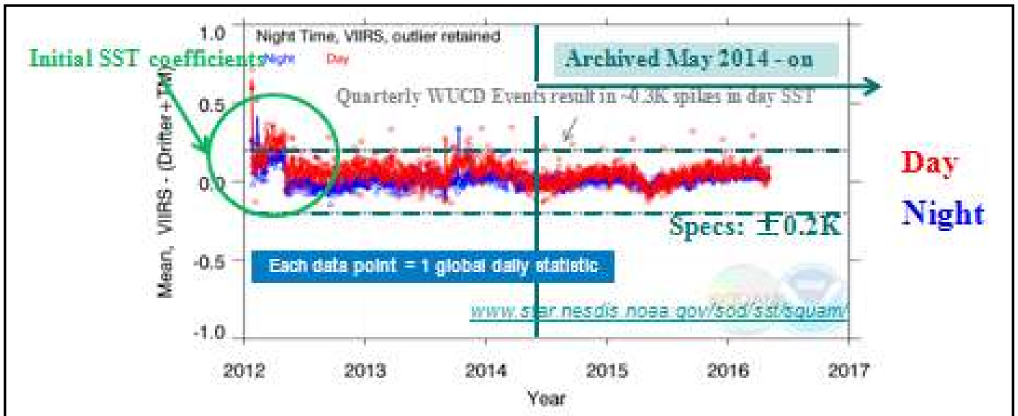


Figure 6.7: Global validation of bias VIIRS vs *i*Quam *in situ* SSTs (real time).

ery three months, 0.3K spikes are seen in daytime SSTs due to the blackbody warm-up/cool-down anomaly. In RAN1, shown in Figure 6.8, the time series is shorter as the data from January, 20 through March 1, 2012 (forty days) as well as the data after June 25, 2015 was not reprocessed. The RAN1 SST is more stable with the exception of a few new outliers. The quarterly spikes due to a WUCD anomaly are seen more clearly. The standard deviations of the bias analysis show all are within specifications.

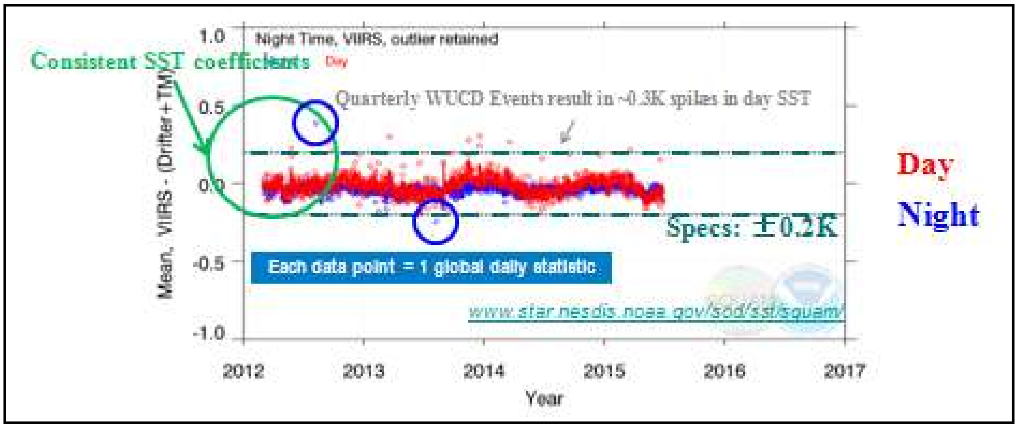


Figure 6.8: Global validation of bias VIIRS vs *i*Quam *in situ* SSTs (RAN1).

Status of RAN1

University of Wisconsin

- The good
  - RAN1 codes/scripts were set-up and tested end-to-end at the University of Wisconsin. Bottlenecks were identified and some have been minimized.
- The not-so-good
  - RAN1 is incomplete (40 days at the beginning of 2012 missing, some data are missing and/or degraded, matchups are unfinished), and it's unclear how to resolve this. Smaller-scale problems may come to the forefront once the "biggies" are fixed.
- The bad
  - The VIIRS SST RAN infrastructure is not set up in STAR (for AVHRR Global Area Coverage (GAC), data from five NOAA satellites and two MetOp satellites that provided AVHRR data from 2002–present have been reprocessed three times in-house)
  - There is no access to the full RDR record in STAR
  - There is no RDR2SDR converter code/LUTs for the full period
  - RAN1 was started two years ago and is behind schedule

Path Forward

- Wrap up RAN1
  - The most obvious problems in RAN1 data should be fixed (still unsure how) and should be archived with NCEI/PO.DAAC
- RAN2 will be performed in STAR (expected within a year, with ACSPO v2.60)
  - The SST cluster environment continues to improve. Some elements of the processing chain require, however, optimization. The plan is to collaborate with CoastWatch to leverage computer resources and labor.
- Resolve Archival Mechanism with NCEI
  - The Group for High Resolution Sea Surface Temperature (GHRSST) Model is changing (PO.DAAC may not archive NOAA products any more). Therefore, discussions have been initiated with NCEI/Silver Spring to direct-archive with them. NCEI/Silver Spring is far superior to CLASS in terms of data access.

Help Needed

- Access to complete reprocessed SDRs
  - The SDRs should be periodically reprocessed and made available online or via SCDR.
  - Ideally, the EDR RAN-x should be produced off SDR RAN-x. If impossible, full RDR should be online or on SCDR + RDR2SDR code.
- We should learn from NASA
  - The reprocessed L1b should be online (similarly to MODIS on ladsweb.nascom.nasa.gov).
  - The SDR reprocessing should be linked to/trigger the EDR reprocessing.
- Master file of non-existing/partial/degraded SDRs needed
  - The file should be updated and made available to EDR teams.
  - Real time and reprocessed file versions should be retained.
  - The file should be versioned and periodically reprocessed.

Reprocessed VIIRS SST Users and Climate Applications

- The Geo-Polar (blended L4), the Canadian Met Center (CMC L4), and the UK MO (OSTIA L4) will be users of the VIIRS SST reprocessed data.
- It is highly desirable to reprocess with hi-res SST data (from VIIRS and MetOp, AVHRR FRAC 1-km) where available.
- It is desirable to run reprocessing with diurnal adjustment to improve estimates of foundation temperature as it is relevant for coral depths and also for heat storage in the oceanic mixed layer.

6.4 SNPP VIIRS Reprocessed Aerosol Products: Current and Future Activities

Presenter

Dr. Shobha Kondragunta

NESDIS/STAR

Dr. Shobha Kondragunta presented the improved algorithm for aerosol products for reprocessing and examples of validation of the reprocessed products. The presentation is summarized below.

Reprocessing Need for Aerosol Retrieval

The short-term and long-term needs have been addressed. In the short term, the need arises due to processing errors. The time series of aerosol optical thickness (AOT) over ocean is shown as an example where there was high bias for couple of months due to a processing error. The operational algorithm did not get the cloud information. As there were clouds, the retrieved aerosol during that period showed high. The product exists in the archive and can be fixed in reprocessing with an updated algorithm and the necessary data as input. The long term need arises to produce a consistent time series when the science is improved and the algorithm gets updated. As an example, the images of bright surfaces were shown retrieved by the current operational IDPS algorithm and the new improved version. The surface was left blank in the current algorithm retrieval whereas the new algorithm improved to handle bright surfaces showed the aerosol retrieval. The new algorithm is a science improvement and even MODIS retrieval did not have this improvement. The new algorithm should therefore be used to reprocess the entire time series to have consistent data.

The Updated Algorithm Features

- Aerosol Optical Thickness (AOT)
  - A new Enterprise AOT algorithm that provides retrievals over both dark and bright surfaces
    - New science (*Zhang et al., JGR-Atmospheres, submitted, in review*)
    - New pixel screening procedures
    - Improved performance for high AOTs
    - *Chief improvements:* extended spatial coverage (deserts and arid regions) and extended measurement range (-0.05 to 5.0)
- Suspended matter (SM), also known as "Aerosol Detection Product"
  - A new Enterprise aerosol detection algorithm
    - New science (Ciren and Kondragunta, JGR-Atmospheres, 2014)
    - New pixel screening procedures
    - *Chief improvements:* improved accuracy

Validation of the New Enterprise Algorithms

1. The new algorithm-derived AOT is compared with the IDPS algorithm and the AERONET data with the bias, as shown in **Figure 6.9**. The comparison is based on four years of data to have enough validation statistics. The IDPS results, shown as the black curve, deviated from MODIS and EPS at the beginning of the land time series and improved as the IDPS algorithm was improved and updated. The bias is substantially reduced in the new algorithm, shown in red. The blue curve shows

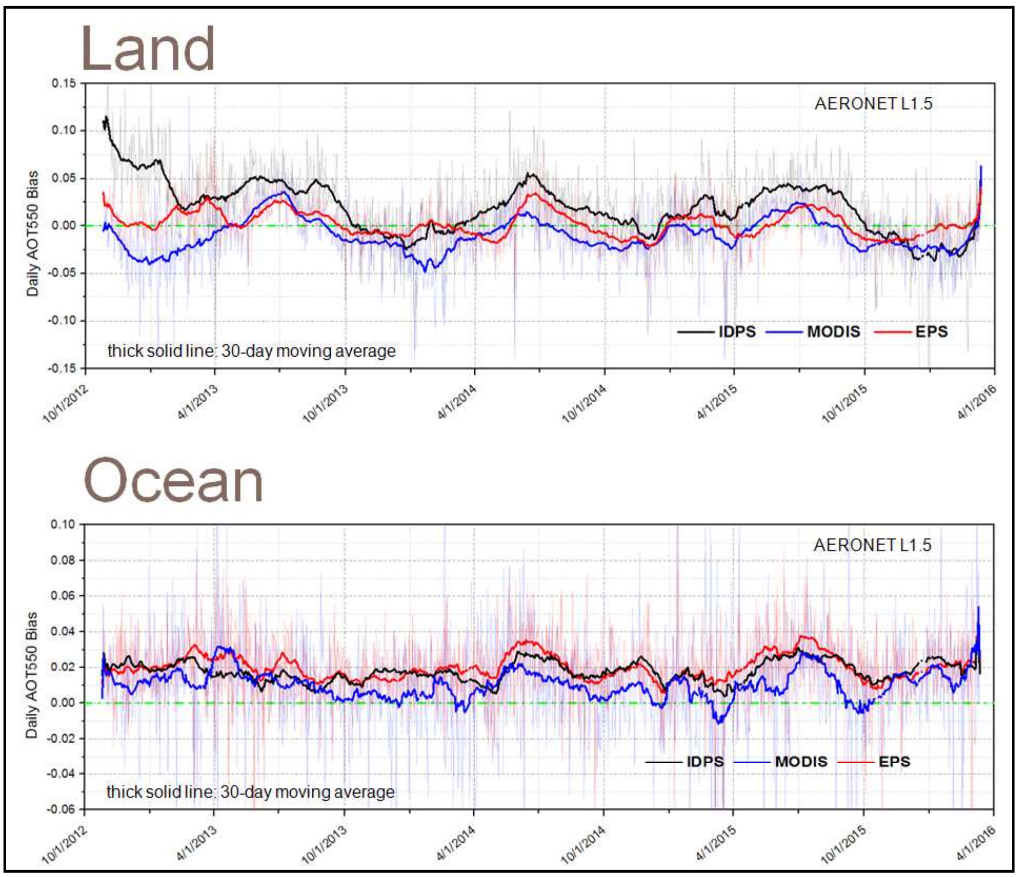


Figure 6.9: Validation of reprocessed VIIRS AOT (red) vs AERONET (Land and Ocean), MODIS (Blue) and the current operational IDPS algorithm (Black)

the MODIS data for comparison. The comparison over ocean shows minimal difference between IDPS and the new algorithm.

2. The performance metrics of accuracy and precision at various levels of AOT show that the new Enterprise algorithm is slightly better compared to the current IDPS and is same for Oceans. However, the new Enterprise algorithm brings out AOT features over bright surfaces, which the current IDPS does not have the science to do, as shown **Figure 6.10**.
3. The performance metrics for the detection of particulates (SM) i.e., aerosol detection product of smoke and dust, is shown in **Figure 6.11** in comparison with op-

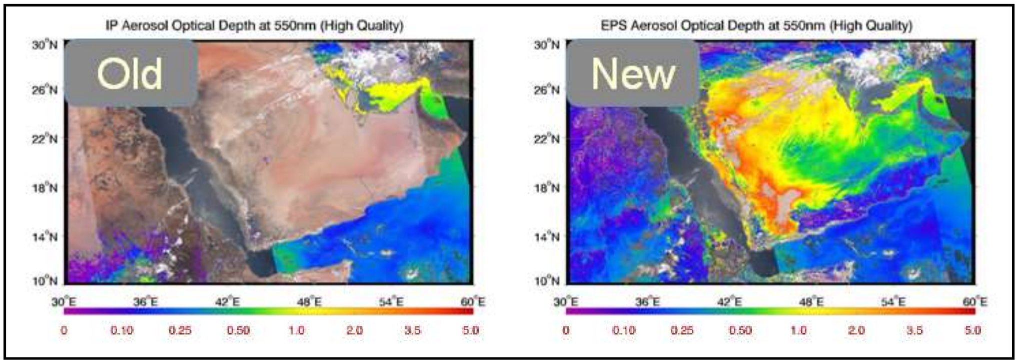
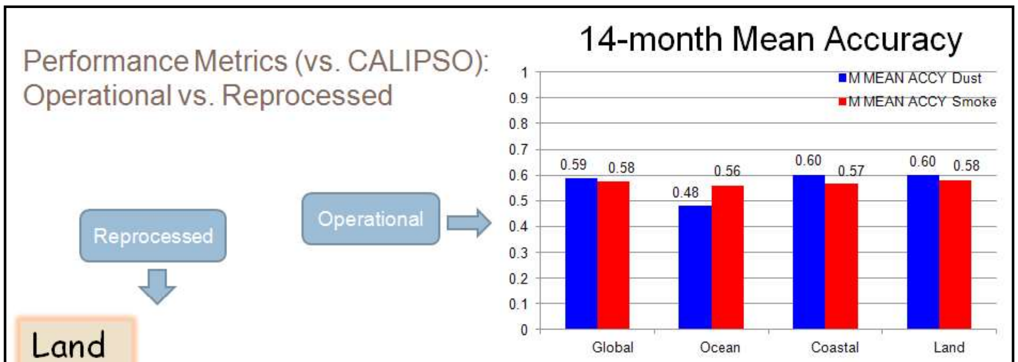


Figure 6.10: The left-hand image of the Aerosol product was developed using the IDPS algorithm (old). The right-hand imageis the reprocessed image by the new algorithm using the same SDR data.



Land

Type	True positive	False positive	True negative	False Negative	Accuracy (%)	POCD (%)	POFD (%)
Dust	2202	69	2397	375	91.1	85.3	3.1
Smoke	117	98	4214	1	95.4	99.2	45.5

Water

Type	True positive	False positive	True negative	False negative	Accuracy (%)	POCD (%)	POFD (%)
Dust	297	11	139	10	95.4	96.4	3.3
Smoke	107	85	2309	3	92.7	97.2	44.2

Figure 6.11: Comparison of performance metrics between the operational algorithm and the new Enterprise algorithm in detecting smoke and dust. The comparisons are made using CALIPSO data as the basis.

erational current IDPS using the CALIPSO[64] data as the common basis. The new algorithm has close to a 90% success rate in detecting smoke meeting the 80% requirement compared to ~60% with the current IDPS. Similar comparisons using the AERONET data as the basis show that the new algorithm performance metric is above 90%.

4. The NWS downloads the VIIRS aerosol product for display on their aerosol monitoring page. The product is the NOAA global aerosol component (NGAC). The NWS found the new Enterprise algorithm to show a positive impact compared to the IDPS, as the former was associated with the retrieval over bright surface.

Current Activities Agenda

- Complete the reprocessing of the full 4-year record for AOT and aerosol detection
- Validate reprocessed datasets
- Work with users: 1. NWS for historic case study analyses and preparation for routine use, 2. NRL for assimilation activities for select past case studies, 3. EPA on air quality monitoring, and 4. Academia for aerosol research
- Develop training packages

Resources Needed

- Storage and processing capabilities for the anticipated several iterations of reprocessing, due to changes in SDR, changes in cloud mass, etc.
- Storage to archive locally and work with users until CLASS is ready.
- One FTE dedicated to reprocessing and analyzing the data; and one FTE to function as a user representative to develop training packets, receive requests, process information, and maintain the web page with up-to-date information.

Open Questions

- Should reprocessing of VIIRS SDR and upstream products (cloud, snow/ice, fire masks, cloud adjacency) trigger reprocessing of AOT? A way to estimate the impact of SDR and upstream product changes on AOT is to be addressed. A quantitative summary (statistics) of reprocessed data relative to the previous version could help.
- Should "better" ancillary data (water vapor, ozone, wind speed) be considered in reprocessing? Would this impact consistency with upstream products?

6.5 SNPP NUCAPS and ACSPO Reprocessing at CIMSS/SSEC/UW

Presenter

Dr. Liam Gumley

CIMSS/UW

Dr. Liam Gumley posed the question, "What would it take to reprocess the entire SNPP mission record (in a demonstration mode) to generate a consistent set of NUCAPS and ACSPO products?" The presentation answered the question and is summarized below.

The CIMSS/SSE at the University of Wisconsin, with the help from the NUCAPS and ACSO teams of STAR, volunteered to answer the question above. The NUCAPS and the ACSPO are the NOAA enterprise algorithms for retrieving the SNPP atmospheric profiles and SST respectively. The goal is to have consistent SDR calibration, retrieval algorithms, and science products for the entire mission. The key is to start with RDRs and create the VIIRS SDRs.

64 CALIPSO is the NASA satellite mission launched to space in 2006 to study the role that clouds and aerosols play in regulating Earth's weather, climate, and air quality.

CIMSS Key Ingredients

- Complete archive of VIIRS, CrIS, and ATMS RDRs since the start of SNPP mission.
- CSPP SDR processing software (to convert RDR to SDR) based on ADL, with LUTs for entire mission provided by NASA VCST (Vincent Chiang).
- Excellent collaboration with NUCAPS and ACSPO enterprise algorithm development teams at STAR to prepare CSPP release packages.
- Cluster compute, storage, and processing expertise funded by NASA as part of Atmosphere PEATE (now SIPS).
  – More than 1,200 compute cores (64-bit CentOS Linux) with 4 GB to 8 GB of memory per core.
  – More than 2 petabytes of distributed cluster storage.
  – Network delivers data from storage servers to compute server speeds of up to 30 gigabits/second (aggregated).

Job Management Capability at CIMSS

- The PostgreSQL database is used to keep track of more than 50 million files from multiple satellites (Suomi-NPP, Aqua, Terra, Metop-A/B, Caliop,…).
- HTCondor is used as the workload management system that provides dynamic scheduling based on job requirements (e.g., memory, disk space).
- Custom workflow manager (FLO) is used to scan the database for files to process, construct work orders, and then submit the jobs to HTCondor.

Data Volumes Capability

- Input RDR volumes
  – VIIRS RDR = 74 TB; CrIS and ATMS RDR = 18 TB
- Intermediate SDR volumes
  – VIIRS SDR (GMTCO + 6 M-bands required by ACSPO) = 70 TB
  – CrIS and ATMS SDR = 54 TB
- Level 2 product volumes
  – NUCAPS L2 = 11 TB
  – ACSPO L2, L2/L3 SQUAM, MICROS, L3U = 145 TB

NUCAPS

Reprocessing Overview

- Time Period Processed
  – May 1, 2012 through July 31, 2015
- Some Data Missed Due to:
  – CSPP SDR not able to produce ATMS before May 1, 2012
  – Missing/failed CrIS/ATMS processing
  – Missing GFS AVN ancillary data
- Job Granularity
  – Used 8 minute aggregated CrIS and ATMS granules
  – 1,184 Days * 180 granules/day = ~66K jobs
- Inputs (per 8 minutes)
  – CrIS RDR
  – ATMS RDR
  – GFS AVN
- Outputs (32 second granules)
  – NUCAPS EDR

- NUCAPS CCR
- Statistics file for analysis

• Science Software
  - CSPP SDR v2.0.1 (= IDPS Mx8.4)
  - CSPP NUCAPS v1.0.2

Results

• ATMS SDR Processing
  - ~3 hours/year

• CrIS SDR Processing
  - ~9 hours/year

• NUCAPS Processing
  - 1,184 days * 180 granules/day = 66K jobs
  - 45 outputs per job = 3M outputs
  - 32 minutes/job * 1,184 cores = 30 hours/year

• Total Processing
  - 42 hours/year for ATMS/CrIS SDR + NUCAPS (Speedup: 208X)
  - ~97% product yield

• 1 week to reprocess entire mission

Lessons Learned in NUCAPS Reprocessing

• Yield can be improved
  - Need to investigate CrIS/ATMS SDR processing failure cases to improve yield (this includes ATMS SDR pre May 1, 2012).
  - It appears NUCAPS does not handle CrIS granules with less than 4 scan lines (known issue).

• Helpful improvements for cluster environment
  - Specify all required inputs on command line.
  - Assume software tree is read-only.
  - Assume the network is not available, i.e., can't download ancillary data (the workflow manager will provide it).

ACSPO

Reprocessing Overview

• Time Period Processed
  - May 1, 2012 through July 31, 2015. Some data was missed due to the CSPP SDR's inability to produce VIIRS SDRs prior to March 1, 2012.

• Job Highlights
  - 1,210 Days =1.4 million jobs. Saving intermediate products from various stages produced 500TB of data.
  - Network sustained 30 gigabits/second when delivering large dataset to compute nodes.

• Inputs
  - VIIRS RDR (86-second)
  - Ancillary: CMC, OSTIA, daily
  - Reynolds, i*QUAM*

• Outputs
  - png/json files for web
  - L2/L3 product files

• Science Software

- CSPP VIIRS SDR v2.0.1 (=IDPS Mx 8.4) with VCST LUTS
- ACSPO v2.40

Results

- VIIRS Processing (granularity = 86 seconds)
  - ~52 hours/year
- Aggregate/Destripe (granularity = 10 minutes)
  - ~6 hours/year
- ACSPO Processing (granularity = 1 day)
  - ACSPO: ~35 hours/year
  - ACSPO MICROS: ~30 hours/year
  - ACSPO L2 SQUAM: ~33 hours/year
  - ACSPO L3 SQUAM: ~10 hours/year
- Total Processing
  - 165 hours to reprocess one year of all ACSPO steps (speedup: 53X)
- 3.5 weeks to reprocess the entire record

Lessons Learned

- Yield can be improved
  - Need to investigate VIIRS SDR processing failures for March 2012 and get a working set of LUTS, allowing us to get back to Jan 2012.
- Helpful improvements for cluster environment
  - The biggest challenge was IDL integration. A way to run IDL jobs in IDLRT cluster mode had to be found. The ACSPO team and CIMSS worked together to solve this problem. Numerous jobs had long run times (~10 hours), which makes the feedback loop for debugging purposes difficult. Jobs that have smaller runtimes are highly preferred not only for debugging purposes but also it will parallelize better over the cluster.
- Examination of the ACSPO products revealed some anomalies in retrieved SSTs.
- The cause of some anomalies was erratic behavior in a netCDF I/O library. Software was patched and tested at STAR.
- CIMSS/SSEC ran the entire record again in early 2016, extending the dataset through the end of 2015.
- CSPP SDR v2.1 was used in the second reprocessing (= IDPS Mx 8.6) with LUTs from VCST.

NUCAPS and ACSPO Reprocessing Summary

- NUCAPS and ACSPO software packages need to be adapted to cluster environments, for example:
  - Hard coded paths need to be removed
  - Dynamic ancillary should be selected prior to job submission
  - The granularity should be kept small (~1 hour) to aid in both debugging and optimal use of the cluster hardware.
- The science software workflow needs be understood so that jobs can be scheduled based on resources needed (cpu, memory, disk), which is critical to reprocessing as fast as possible.
- There is much attention to detail needed to achieve 99% data coverage over the life of the mission.

Conclusion

The lessons learned will be helpful in planning future reprocessing efforts.

Acknowledgements: NOAA/NESDIS/STAR NUCAPS and ACSPO teams provided close collaboration on this demonstration project. The CIMSS team (Steve Dutcher, Bruce Flynn, Jim Davies) put in many hours on this demonstration project.

Developing Baseline Approaches, Schedules, and Plans for SDR and EDR Reprocessing: Issues, Challenges, and Next Steps

7

Ms. Lihang Zhou

Chair

Ms. Lihang Zhou chaired the session, which included eight speakers from NESDIS/STAR: Drs. Fuzhong Weng, Paul DiGiacomo, Ivan Csiszar, Ralph Ferraro, Walter Wolf, and Nancy Ritchey; and Ms. Lihang Zhou. Their presentations are summarized in the sections below.

7.1 JPSS SDR Reprocessing Plan

Presenter

Dr. Fuzhong Weng

NESDIS/STAR

Dr. Fuzhong Weng recalled the objectives of the workshop, listed below, and laid out the strategies to achieve them.

7.1.1 Objectives of the Workshop

1. Understand SNPP instrument and sensor data anomalies and prepare for JPSS-1 launch and post-launch activities.
2. Develop baseline approaches, schedules, and plans for SDR and EDR reprocessing.
3. Demonstrate the improved and advanced cal-val algorithms for reprocessing applications.
4. Understand the potential impacts of the reprocessed SNPP data on operations.

7.1.2 Strategies

In order to achieve the objectives of the workshop, it is necessary to fully understand user's requirements for SDR product improvements and reprocessing, including the needs of the broader community. Achievement of the requirements is to be approached using a single, consensus-based, unified solution. Dr. Menghua Wang's request for 0.1% stability of calibration in SDR for the VIIRS ocean color product was used as an example of a desired outcome. Also, as consensus was one of the reasons for holding the workshop, it is intended that input received during the workshop will be integrated into SDR reprocessing.

The High Performance Computing (HPC) infrastructure being built for reprocessing must be a cost-effective common ground system. The resources for both the STAR HPC Center (HPCC) and long term archiving must be sustained. The close coordination must be maintained between STAR and the National Center for Environmental Information (NCEI) for archiving of reprocessed SDR (RSDR) datasets[65].

7.1.3 Reprocessing Team

The current STAR JPSS SDR reprocessing team is shown in **Figure 7.1**. A majority of the team members wear two hats. For example, the ICVS team performs the sen-

65 See 7.6 presentation of Nancy Ritchey from NCEI.

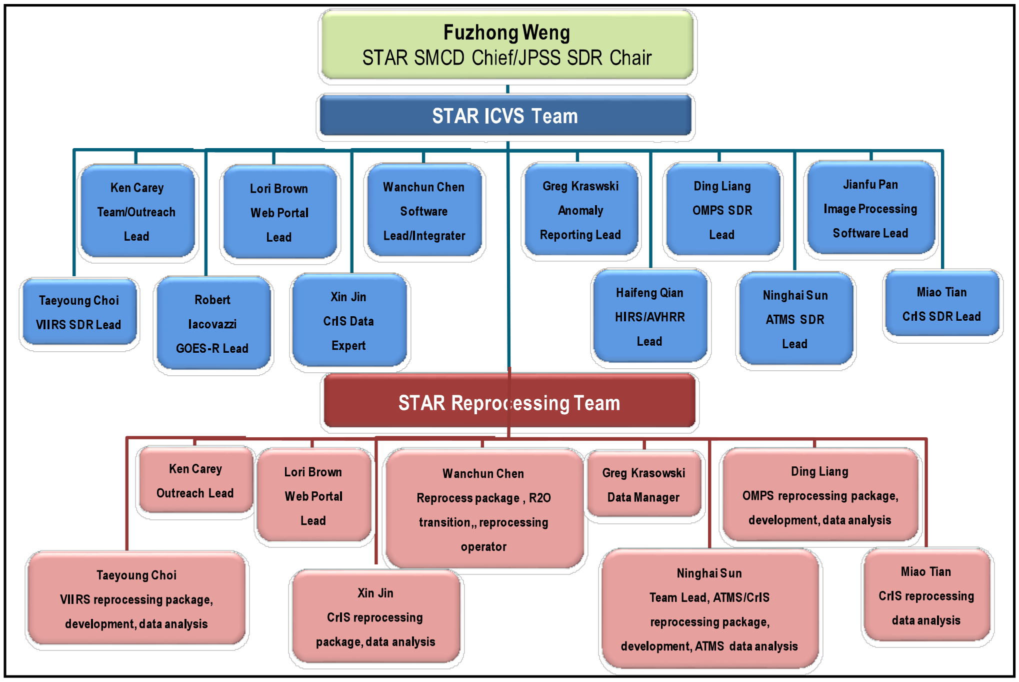


Figure 7.1: JPSS SDR Reprocessing Team.

sor monitoring as well as partially covers the reprocessing by leveraging the former. Therefore, the existing cal/val resources can be leveraged for reprocessing.

7.1.4 Reprocessing Guidelines for SDR Teams

7.1.4.1 Error Budget

Each team should have a full understanding of the error budget of the reprocessed data. Error budget refers to not only precision and accuracy, but also to stability—the time dependence of calibration accuracy. The focus then, with regard to the error budget, needs to be on all three indices, as shown in **Figure 7.2**. The data quality flag is to be set according to the uncertainty requirement. Figure 3.3 in Section 3.0, ATMS, was shown as an example of the impact of the quality flag.

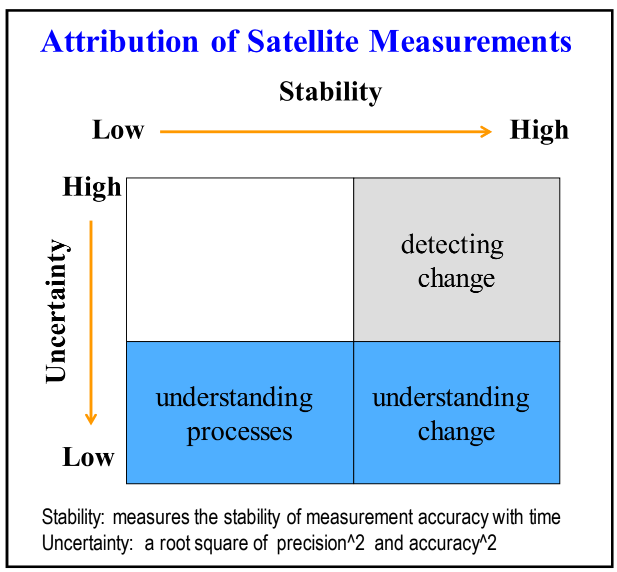


Figure 7.2: The three indices of measurement: precision, accuracy, and stability.

7.1.4.2 RDR to SDR Processing Diagram

SDR teams currently work to a variety of reprocessing procedures. To streamline the reprocessing effort, it is necessary to refine the versions down to a single workflow version. As an example, the ATMS diagram is shown as a template in **Figure 7.3**. The focus on the radiometric calibration in the diagram is extended to the spectrum and even to the geo-location. The reason for this is that the Numerical Weather Prediction (NWP) community and the international communities have more requirements bearing on the geo-location. The CrIS workflow, shown in **Figure 7.4**, is considered to be a good process representation, as it shows all three components—radiometric, spectral, and geo-location—to be equally important, and the research done is shown in each box. The diagram for VIIRS, shown in **Figure 7.5**, needs to be improved, as it shows a simplified layout without much explanation. The diagram could be significantly improved by including more content detail at each step of the procedure. For example, as RSBAutoCal is a major implementation, more of its details should be presented within the graphic. The lunar correction should also be included with RSB calibration. The OMPS diagram, presented in **Figure 7.6**, is adequate.

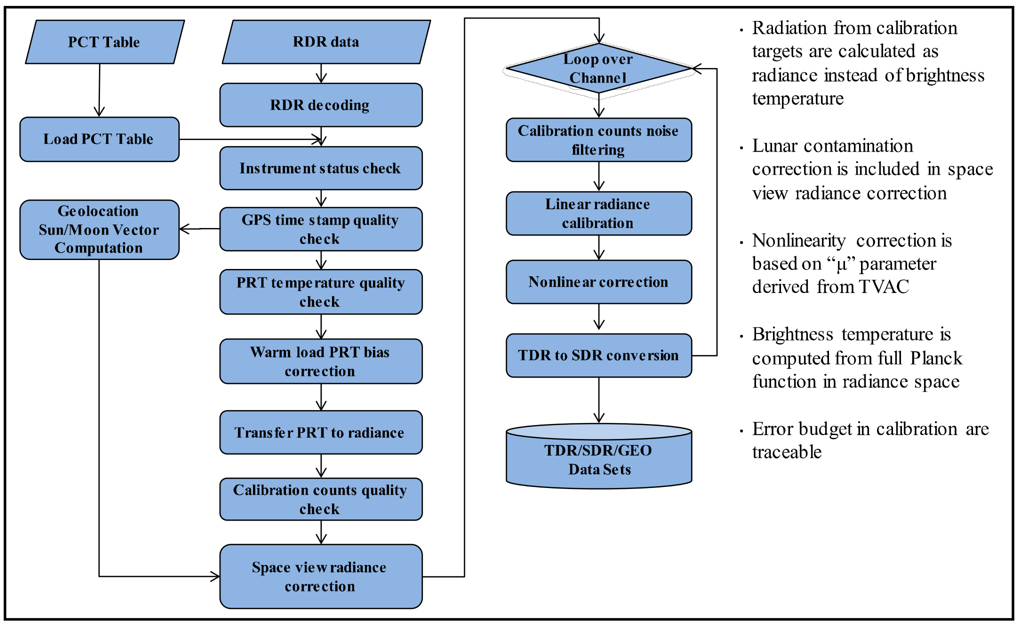


Figure 7.3: Suomi NPP ATMS RDR to SDR processing diagram.

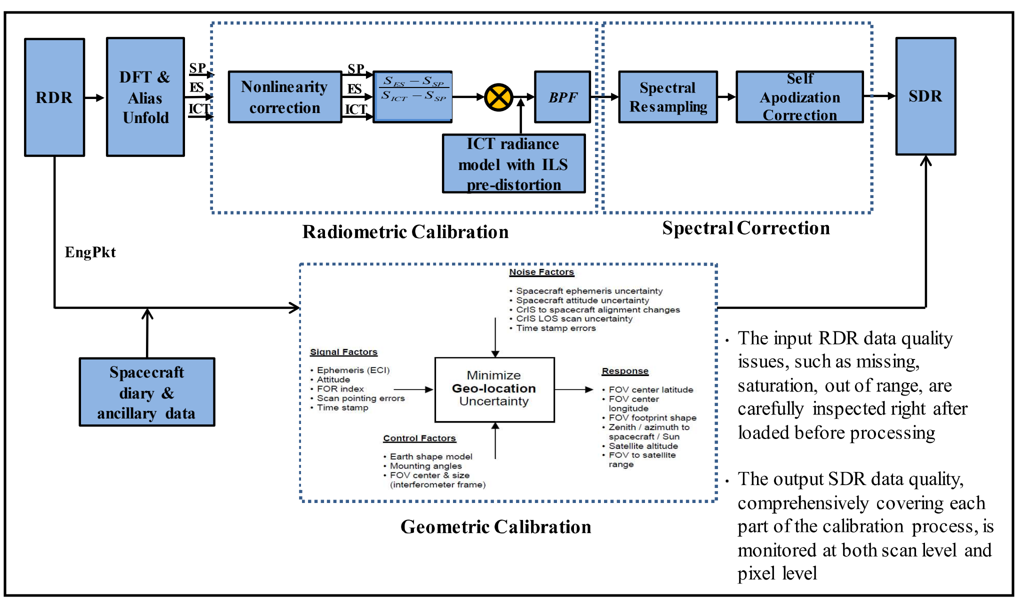


Figure 7.4: CrIS RDR to SDR processing diagram.

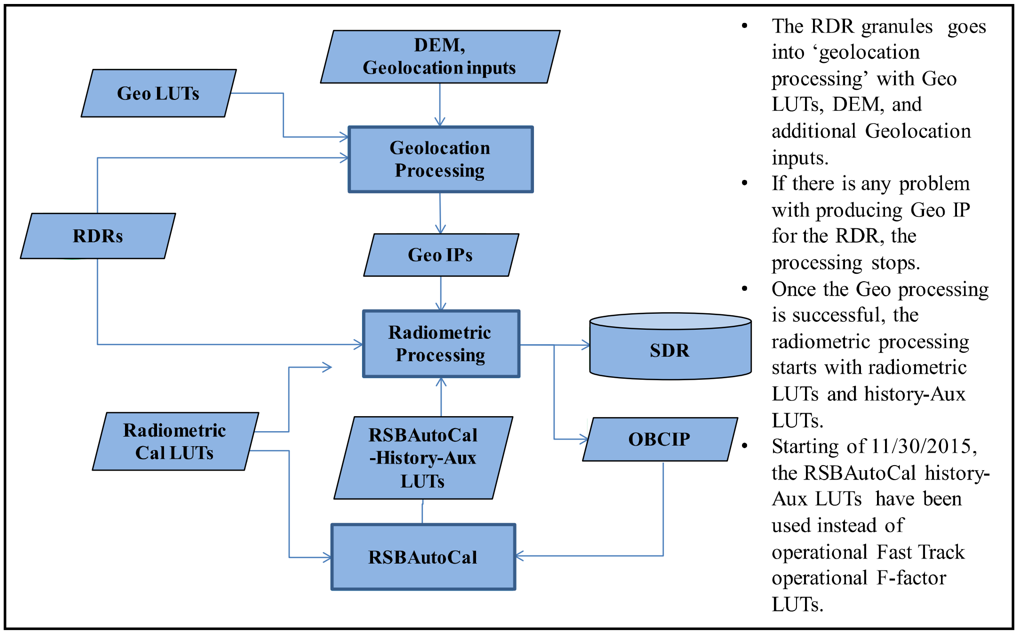


Figure 7.5: VIIRS RDR to SDR processing diagram.

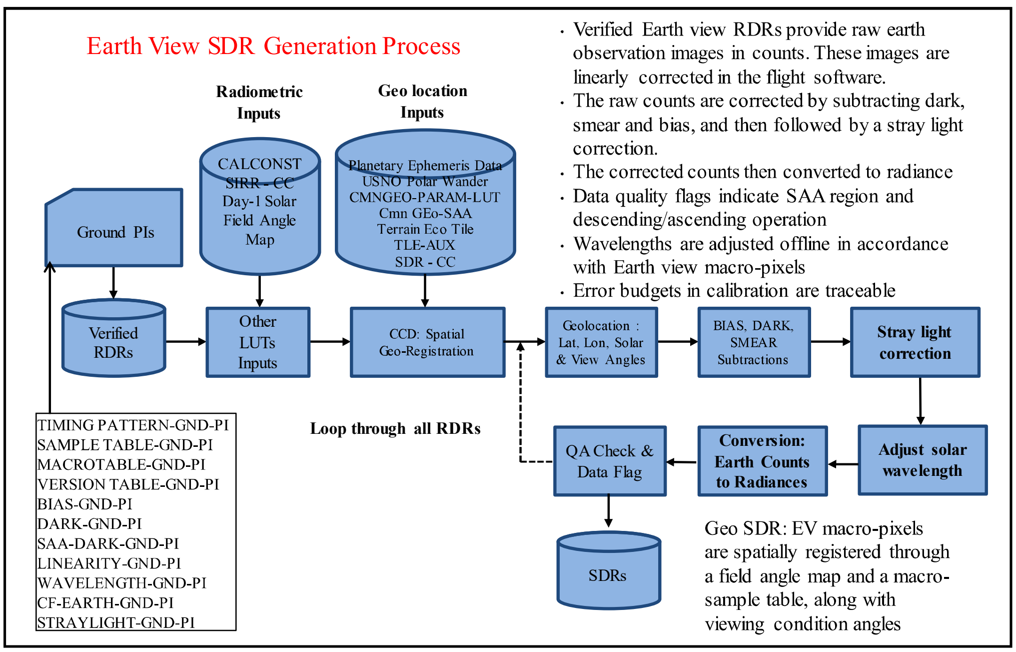


Figure 7.6: OMPS RDR to SDR processing diagram.

7.1.4.3 Data Quality

1. The ICVS is to be regularly monitored for anomalies. It is considered to be a satisfactory system for monitoring SDR data quality. The community uses ICVS and provides welcome feedback. As an example, a week before the workshop, the ICVS team received a message from a user stating that the ATMS instrument was out of scale. The ICVS team appreciated the input and was able to correct the problem.
2. The use of commercial satellites and small satellite missions to enhance data quality is to be encouraged. The example given was of the use of COSMIC data by the STAR staff to remove ATMS spikes via cross-calibration.

3. Proven data is to be provided for weather forecasting. The ATMS data will be provided through the ICVS to Heather Lawrence of ECMWF, who expressed such a need.

The data quality of the SNPP instruments is summarized below.

ATMS

- ATMS performances in orbit are very stable and the instrument noise values at all the channels are much lower than specification.
- The ATMS biases with respect to NWP/Global Positioning System Radio Occultation (GPSRO) simulations are characterized and trended from STAR ICVS. They are very stable with respect to GPSRO simulated brightness temperatures.
- While the pointing angle of ATMS displayed some irregularity during the motor current spikes, the brightness temperatures deduced from IDPS processing remained good quality.
- The calibration algorithm in radiance space has been delivered and will further improve the ATMS SDR data quality.

Further Comments: The full radiance calibration system is in place for ATMS.

CrIS

- SNPP CrIS SDR data quality has stabilized since the implementation of ADL version Mx8.2, which includes an improved engineering packet (v36) and other code fixes.
- For most channels, the radiometric uncertainty is four times less than the corresponding requirements.
- The spectral calibration accuracy is 3 ppm with respect to CRTM and is well within the requirement of 10 ppm.
- Using VIIRS as a reference, the geometric uncertainty at nadir FOV is less than 0.3 km, compared to the required 1.5 km.
- All NEdNs are well below their corresponding requirements with the exception of MW FOV7 (channels 1240 cm^{-1}, 1375 cm^{-1}, 1580 cm^{-1}, and 1710 cm^{-1} as monitored by ICVS).

Further Comments: Many of the mission goals have been achieved using the NIST traceable algorithm, Allan Variance for noise. After reprocessing, the data quality is 99 percent accurate.

VIIRS

- Suomi NPP VIIRS has been performing very well in orbit since its launch and all the major calibration parameters are within specifications.
  – Intercomparison of reflective solar bands (RSB) with AQUA MODIS using SNOs and vicarious calibration sites suggests consistency to within 2% ± 1%.
  – TEB bands suggest trends of <5 to 20 mK/year, with the exception of M12 (~30 mK/year), over the course of nearly four years of MetOp-A IASI comparisons (similar for 2+ years of MetOp-B comparisons).
- The radiometric calibration parameters, such as F- and H-factors, have been monitored to ensure the quality of the data.
- The F-factor stability is within 1% based on lunar calibration in all RSB bands.
- Since 11/30/2015, the RSBAutoCal has been applied to improve the RSB and Day Night Band (DNB) calibration performance.

Further Comments: The lunar correction is to be included with RSB calibration. RSB-AutoCal is to be combined with the Menghua approach to achieve the stability needed for ocean color teams. While the VIIRS data is considered to be fairly accurate, the major jump in F-factors upon switching to RSBAutoCal that reduced differences with operational F-factors, as shown in **Figure 7.7**, needs to be researched.

OMPS

- SNPP OMPS SDR data quality has stabilized since the implementation of ADL Mx8.11, which included a major stray light OOR correction in Nov. 2014 and a major radiometric improvement on September 9, 2015.
- For most channels, the wavelength independent albedo uncertainty is <2%, using MSL as a reference.
- The requirement of 0.02nm for the inter-orbital thermal wavelength shift was waived at the instrument level but will be corrected on the SDR products level.
- Using MODIS as a reference, the geometric uncertainty at nadir is much less than the requirement of 5.0 km.
- All channels meet signal to noise ratio (SNR) requirements from both Earth view and solar observation measurements.

Further Comments: The validated version of the OMPS algorithm reached maturity in September 2015 and is ready for reprocessing. The wavelength scales required substantial corrections within the SDR processing, which took time to resolve. New capability was built to evaluate the cross-track (CT) bias. The NASA team will provide the final model calculation. However, the co-located OMPS data, the MLS microwave limb data, and the radiative transfer model (TOMRAD)-based data are being used successfully to evaluate the two-dimensional CT bias, as shown in **Figure 7.8**.

7.1.4.4 Chronology of Algorithm Updates

The chronology of algorithm updates from different SDR teams should be synchronized. The chronology, which should start at satellite launch, should show beta, provisional, and validated versions of the algorithms with major changes that have happened highlighted. The chronology chart for ATMS is shown as an example in **Figure 7.9**.

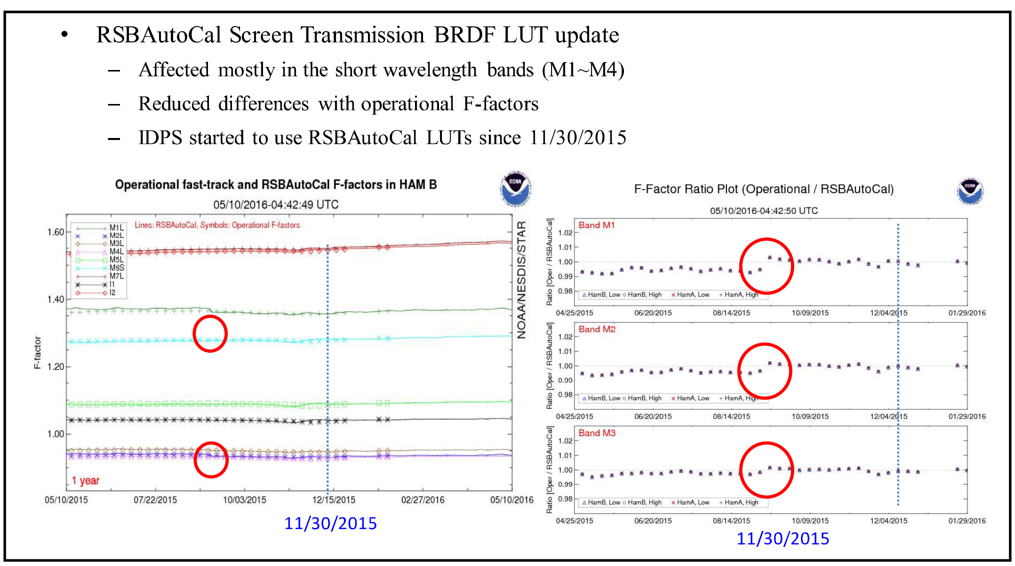


Figure 7.7: Example of impacts of VIIRS SDR algorithm update on data quality.

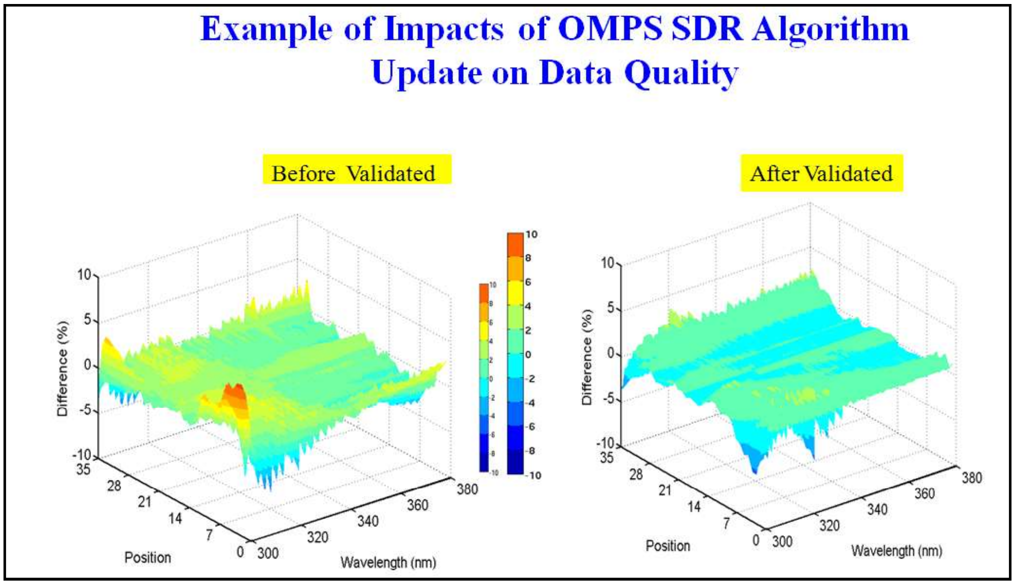


Figure 7.8: Normalized radiance error is computed between OMPS and MLS via TOMRAD. (The margin of error is <2% for most of the channels with the exception of a few channels at the two- edge CT positions. Soft calibration is being implemented to eliminate this residual error.)

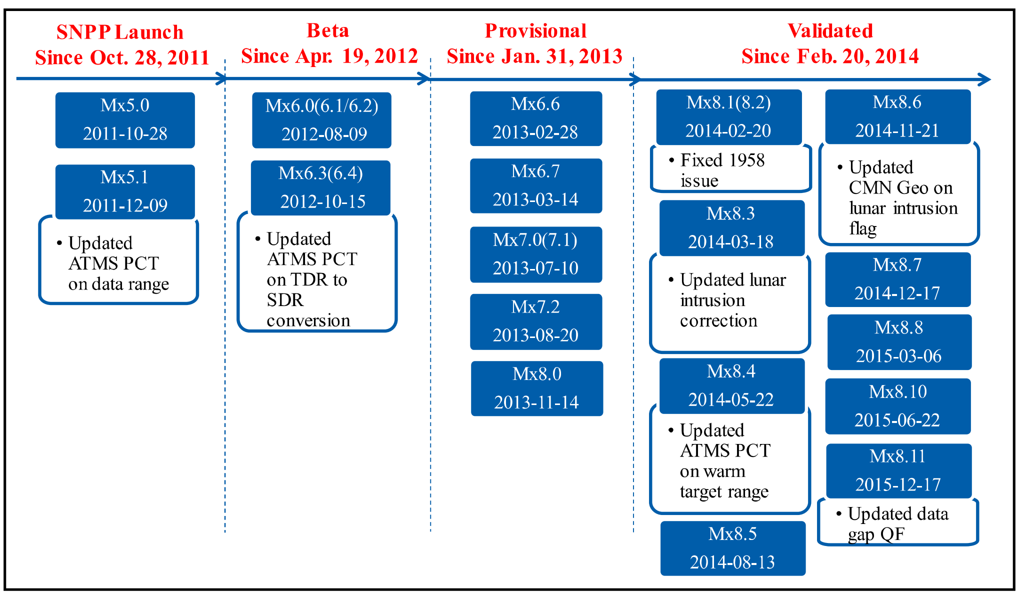


Figure 7.9: Chronology of ATMS SDR algorithm changes.

The algorithm update Mx8.6 has a geo-location update and lunar intrusion flags. The NWP needs such flags set up correctly. The final update of the ATMS algorithm shows a 99 percent accuracy rate. The chronology charts of CrIS, VIIRS, and OMPS, shown in **Figures 7.10**, **7.11**, and **7.12**, respectively, are to be updated as needed.

7.1.5 JPSS Reprocessing Requirements

- 72 nodes with each node having 24 CPUs; 1,728 CPUs in total
- 64GBs of memory per node
- Local hard disk space of 236GBs for each node

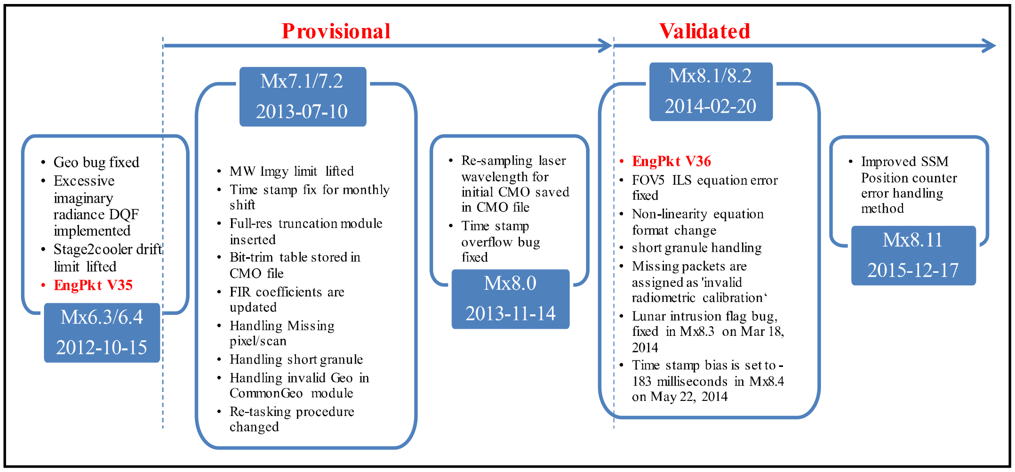


Figure 7.10: Chronology of CrIS SDR algorithm changes.

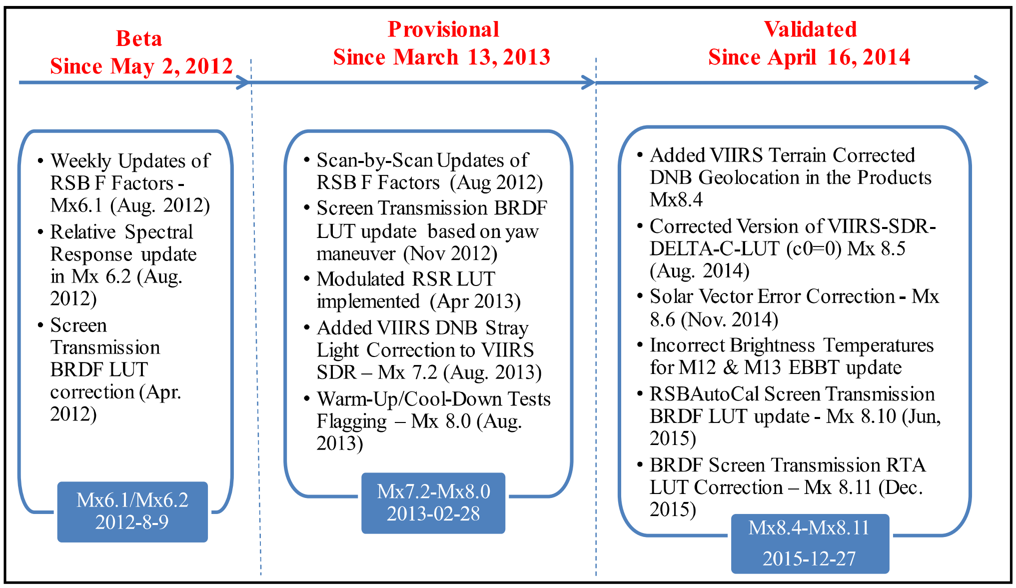


Figure 7.11: Chronology of VIIRS SDR algorithm changes.

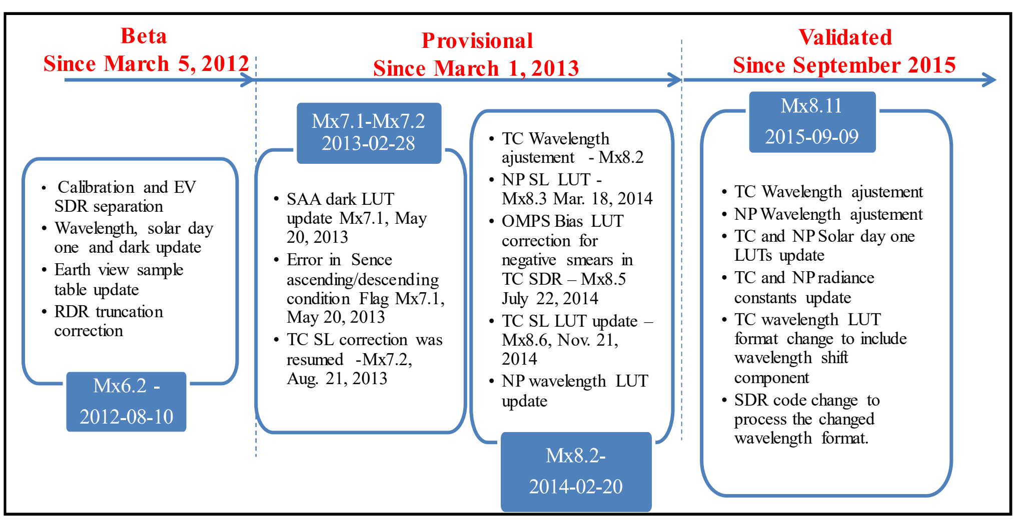


Figure 7.12: Chronology of OMPS SDR algorithm changes.

- Total storage of 3,000TB
- Operating system: 64-bit Linux (Red Hat)
- Aggregated network speed: 56GB/second
- Job management: PBS Torque and MAUI
- Optimized methods of job submission for different sensors

STAR will have a system of 72 nodes, similar to Wisconsin's Liam Grumley approach, with each node having 24 CPUs. The overall STAR distributed cluster and the STAR CICS cluster in the ESSIC building are shown in **Figure 7.13**. The server, named Bamboo, is currently being used to do bench tests, the results of which are as follows: the SDR reprocessing time for one year of ATMS data is 5 hours, CrIS is roughly one day, OMPS Nadir Profiler (NP) and Total Column Mapper (TC) data are 2.8 hours and 18 hours respectively, and VIIRS data is 8.5 days. The total time required to process one year of SNPP data is currently approximately 11 days. Dr. Weng projected that once the full capacity is built, the required time will be cut to 2 days. The goal is to accomplish complete reprocessing of one year of ATMS/CrIS/VIIRS/OMPS data by November 2016 or January 2017. The milestones are shown below.

7.1.6 Milestones

2016	May	Complete the benchmark tests for reprocessing SDR datasets.
	June	Complete the reprocessing of 5 years ATMS SDR data (done).
	August	Complete reprocessing of 5 years of CrIS SDR data (done).
	October	Complete the reprocessing of 1 year of OMPS SDR data.
	November	Complete the reprocessing of 1 year of VIIRS SDR data.
2017	January	Complete the analysis of reprocessed ATMS/CrIS/OMPS SDR data.
	March	Publish articles on quality improvements of Suomi NPP reprocessed SDR (R-SDR) data in AMS journals.

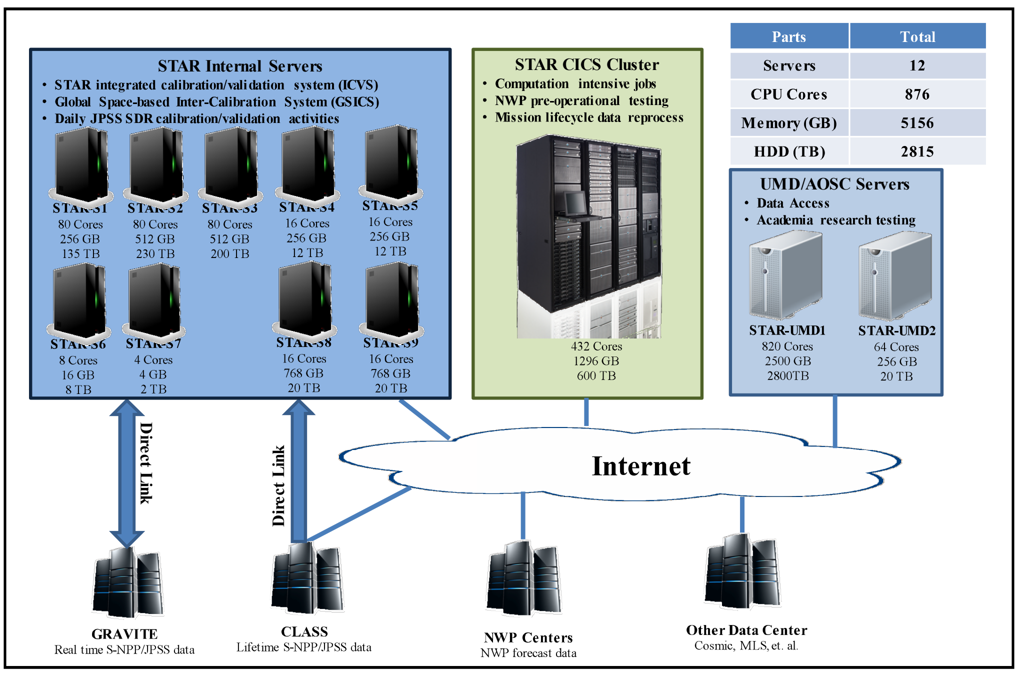


Figure 7.13: STAR/CICS HPC for JPSS processing (Phase I).

7.2 Ocean Reprocessing – Back to the Future

Presenter

Dr. Paul DiGiacomo

NESDIS/STAR

Dr. Paul DiGiacomo presented the Oceans perspective of reprocessing as an essential requirement (summarized in Section 2.0). He further elaborated on the importance of reprocessing and advocated for a change in the NOAA paradigm for handling of satellite data.

7.2.1 Two Data Streams – Near-Real-Time and Non-Real-Time

In his presentation (summarized in Section 5.0), Dr. Menghua Wang discussed the concept of two data streams. One data stream—the near-real-time stream—is intended for low latency users. For example, a spill from a ship would result in water quality being the most immediate issue. In such a case, timeliness is what drives the requirement and data quality, by necessity, takes on a secondary role, being achieved on a best effort basis. Taking a week or two to perform quality data reprocessing may not help to deal with a spill from a ship. On the other hand, non-real-time data stream users, such as fisheries, require the most accurate and consistent seasonal trends and annual variability data. Dr. Wang showed two examples, one of which is shown in **Figure 7.14**. In this figure, the time series illustrated in red represents the VIIRS IDPS SDR acquired real time from operations. It derives the radiometric calibration from look-up tables. A downward trend in the time series is clearly seen. It is an anomaly when compared with in situ Moby data. The green line illustrates the time series processed by the same EDR algorithm, but using the reprocessed science quality SDR derived carefully evaluating radiometric calibration of the VIIRS channel. It is consistent with Moby observations and removes the anomaly. Another example is the sea surface temperature (SST) product results presented by Dr. Ignatov (summarized in Section 6.0), shown here in **Figures 7.15** and **7.16**. The real-time SDR derived SST shows outliers

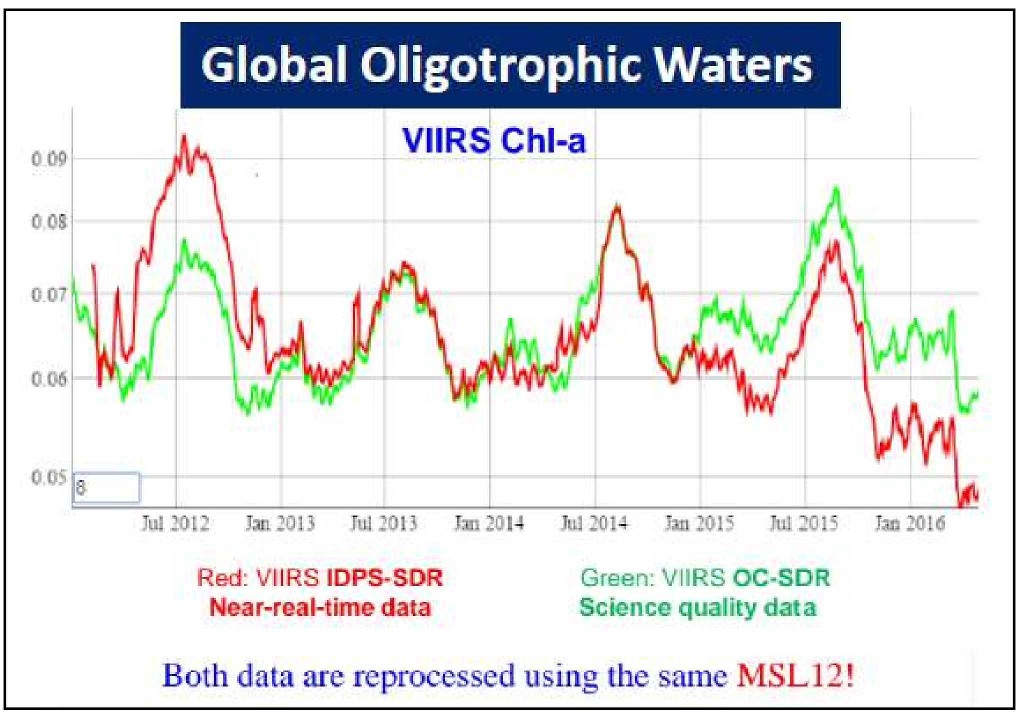


Figure 7.14: Ocean color product processed using the same EDR algorithm with different SDR inputs.

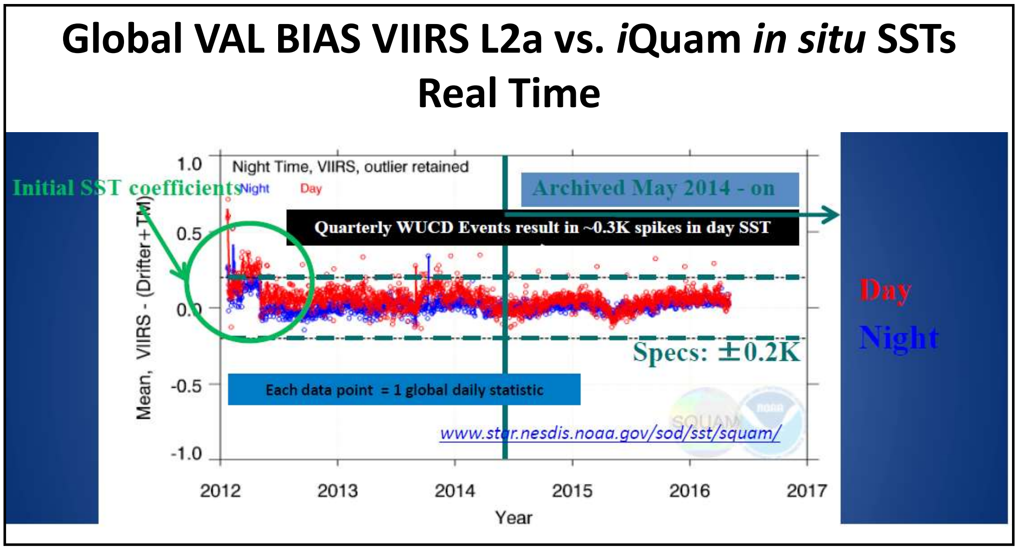


Figure 7.15: SST product derived from VIIRS real-time SDR.

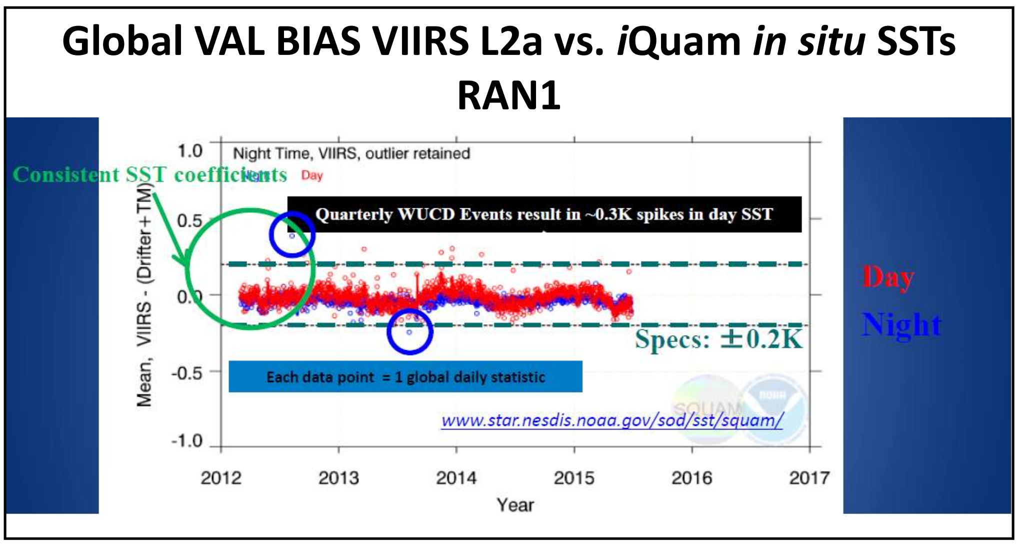


Figure 7.16: SST product derived from reprocessed SDR.

although it did meet specifications. The reprocessed SDR shows the SST product even more in line with specifications, though the 0.3 K anomaly at the warm and cool down time of the blackbody still persists and is being investigated. This evidence points toward reprocessing as giving the users better data and products in support of their information needs.

7.2.2 Looking for a Different Paradigm in Handling Satellite Data at NOAA

The following programmatic and cultural issues were discussed in reference to a different paradigm in handling satellite data within NOAA NESDIS.

1. Operational

The word ‘operational’ is weather service paradigm meaning ‘near-real-time.’ Currently, old data is dropped. However, we feel old data should be sustained ‘fit for purpose’ to support user needs such as the example given earlier (Section 7.2.1) of fisheries' needs for long-term time data.

2. Science

At NESDIS, 'science' is seen as research using the data at hand. However, science is also a process requiring infrastructure, communication with peers, and trial and error. Science goes well beyond the beginning algorithm development. Algorithms must be constantly updated based on new science, quality assurance (QA), and quality control (QC). In our case, science supports the research, applications, and services that lead to the generation of high-quality data throughout the life cycle of the satellite mission.

3. Requirements

There is a notion that the satellite mission requirements came down the mountain, written on stone tablets, and that one should not change or add to them. This notion is naïve and unrealistic. Requirements must evolve over time as data providers and users interact and new understandings develop, as new capabilities are identified and new products and tools are developed. NESDIS does not currently have a process to capture that evolution, that dynamic nature of requirements. For many years, people tried, unsuccessfully, to incorporate reprocessing into Level 1 requirements. Those efforts failed as they did not fit the 'operational' concept. Here, the scope needs to be broadened to ensure user needs—consistent, high-quality time series generated by reprocessing—are met. Of course, resource and capability limitations must be considered and requirements prioritized.

4. Measurement-based Approach

NESDIS has a mission-centric approach. The term JPSS is the de facto polar program but it doesn't truly span all the polar needs. The same is true of the geo program, GOES/GOES-R. That introduces constraints and limits on the scope of what can be done in those programs. This approach is not in the best interest of users both within and external to NOAA, U.S. public users, or international partners. A better approach for users would be the mission-agnostic measurement-based approach shown in **Figure 7.17**. Observations from other than NOAA missions can also be brought in to augment and serve users' needs. For example, some of the geostationary users want aerosol data over the Indian Ocean. For this, NOAA can leverage the data from other international satellite observations. Likewise, Sentinel-3A, a mid-morning polar orbiter launched earlier this year, can provide ocean color and SST data to complement mid-afternoon observations of SNPP, allowing for multiple looks daily and helping to fill in data gaps that ensue from cloud cover and other drop outs. Therefore, the most effective approach to data usage for science research is to leverage all possible data sources, and process all data in a consistent, 'fit for purpose' manner.

5. Integration

For the different paradigm, integration is having the capability to process non-NOAA observations. While this workshop fully addresses essential JPSS reprocessing requirements, the scope of reprocessing must be broadened to integrate other observations and to ensure their consistency with NOAA's JPSS enterprise algorithms. STAR staff collectively strives to provide the best value for NOAA's users as well as from the international suite of satellite observations.

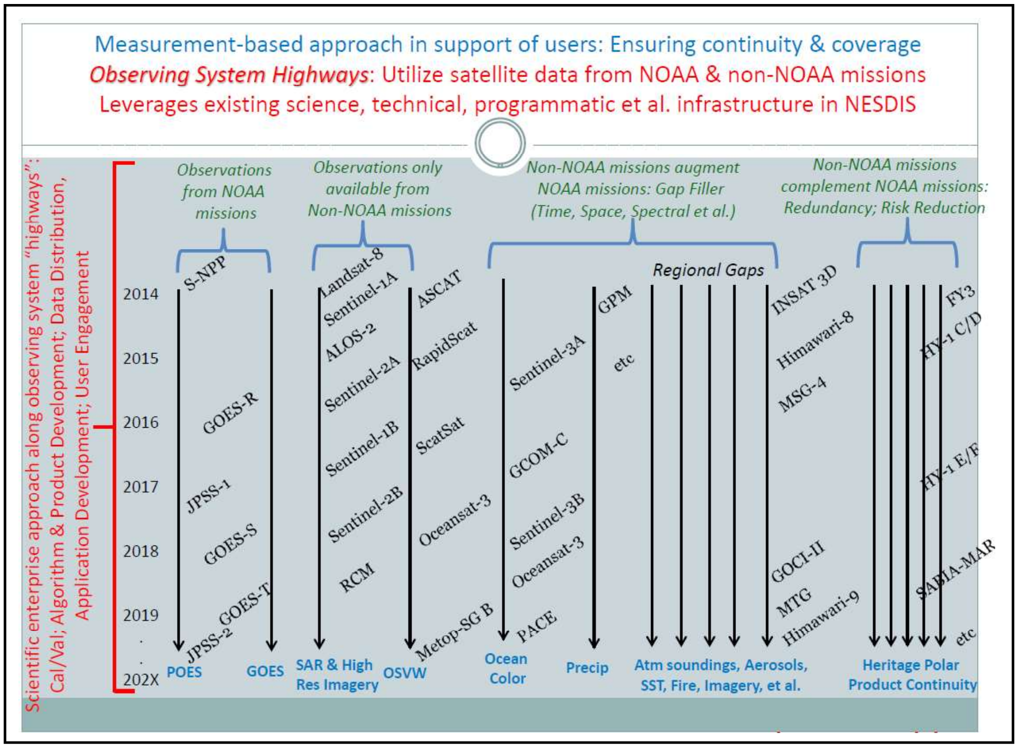


Figure 7.17: Measurement-based approach.

7.3 Land Reprocessing

Presenter

Dr. Ivan Csiszar

NESDIS/STAR

Dr. Ivan Csiszar focused his presentation on transitioning the current land product algorithms to the Enterprise solutions. There is high dependency on the upstream products, especially the SDR. By the end of this year, the reprocessed one-year data will be available (referring to Dr. Fuzhong Weng's earlier presentation, see Section 7.1). There is a real need to have coordinated effort for the production of other upstream products, including optical thickness, cloud mask, and surface reflectance. In the very near future, a schedule for the acquisition of these other products will be drafted by STAR. There is a need for validation datasets to ensure the correct algorithms are selected for reprocessing using accurate, high quality code.

7.3.1 Accelerated Product Maturity

There is a real opportunity for accelerated product maturity. Through reprocessing and the enterprise redesign of the products, better integration into more generic multi-sensor, multi-mission systems such as the Land Product Characterization System (LPCS) is possible. Once the enterprise products are available, they will be evaluated and likely integrated into the LPCS. Once in the LPCS, the products will be directly comparable to other similar data and products—currently MODIS and Landsat. The schematic view of the proposed Land Enterprise System is shown in **Figure 7.18**. Pixel-level i.e. granule-based surface reflectance is generated first within the enterprise system. Other granule-based products, such as land surface temperature (LST), land surface albedo (LSA), and active fire, are shown in the figure. Following reprocessing, the global gridded products are to be generated. This might be considered as a two-phased approach with the granule-based products being generated first followed by gridding. As an example of a granule-based product, **Figure 7.19** presents the current NOAA

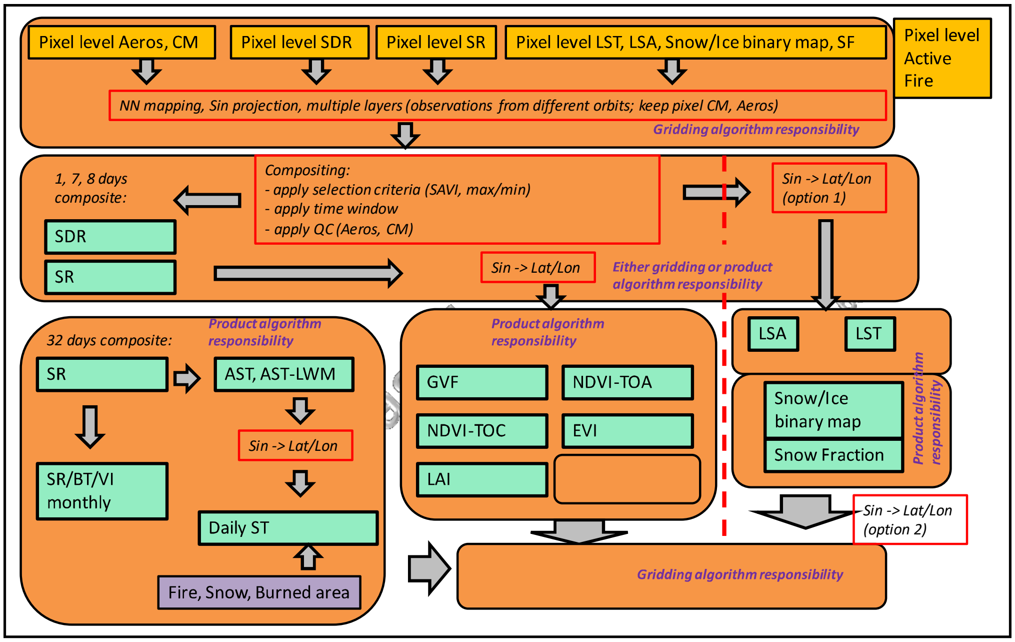


Figure 7.18: Proposed Land Enterprise System.

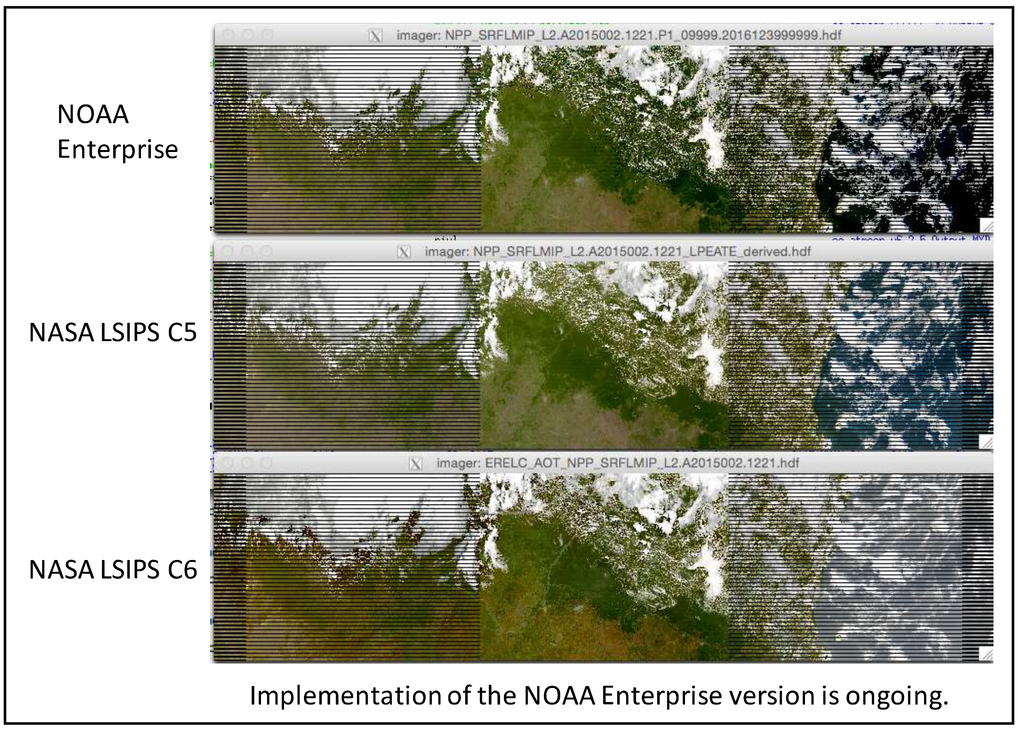


Figure 7.19: VIIRS surface reflectance.

enterprise version of the surface reflectance product. The NASA version, also shown in the figure, compares well to the NOAA version. This will be the first product from the new enterprise package that will be given operational status.

Moving on, the vegetation index product suite is shown in **Figure 7.20**. At the conclusion of the processing chain, it will be integrated into the current green vegetation fraction product. The new version of the Normalized Difference Vegetation Index (NDVI)

REPROCESSING THE SNPP VIIRS VEGETATION INDEX PRODUCTS

- The VI Team wants to generate (reprocess) all the VIIRS Vegetation products since the beginning of the SNPP mission, using the Enterprise Algorithm for Vegetation Products (EAVP) that will run operationally at NDE in the near future
- The new Vegetation products (Phase-1:EVI, EVI2*, NDVI, GVF) will be global gridded at 1* km resolution
- For generating these new vegetation products, the EAVP will ingest the reprocessed versions (enterprise versions) of the VIIRS SDR, CM, SR, and AOT datasets
- These new Vegetation products generated with the EAVP will incorporate all the refinements in sensor calibration (VIIRS SDR), improvements to the input datasets (CM, SR, and AOT), as well as changes/improvements to the VI-EDR algorithm (additional quality flags, new TOC NDVI dataset, improved quality definition, etc)

*there is no JPSS requirement yet

Figure 7.20: VIIRS vegetation index products.

will be produced on a global one-kilometer resolution grid. For the LST, again the reprocessed SDR is needed. The current status is summarized in **Figure 7.21**. Again at the end, a roughly one-kilometer resolution global map will be generated for LST. Consistency between products generated in different ways is critical. The consistency in LST inter-comparison between satellite and ground data is shown in **Figure 7.22**. For the albedo, again the dependency is on upstream products. The approach is two-phased, beginning with a granule-based product followed by a daily and multi-day grid.

- Based on the reprocessing of upstream data: SDR, cloud mask, surface type and AOT if possible
- Reprocessing LST production will rely on an enterprise algorithm that applies emissivity data explicitly
- The input/output data structure as well as the QC flags are determined for enterprise LST algorithm
- The software code for the enterprise LST calculation is ready in local environment
- Possible risk is the availability of corresponding water vapor information
- Limited retrospective reference data and validation tools are available.

Figure 7.21: Enterprise LST reprocessing.

7.3.2 Active Fire Product Reprocessing

There is strong sensitivity on the SDR performance for the fire product. The calibration and gain setting have to be accurate. The current status of the active fire product is summarized in **Figure 7.23**. The NDE VIIRS product was developed by the STAR-led

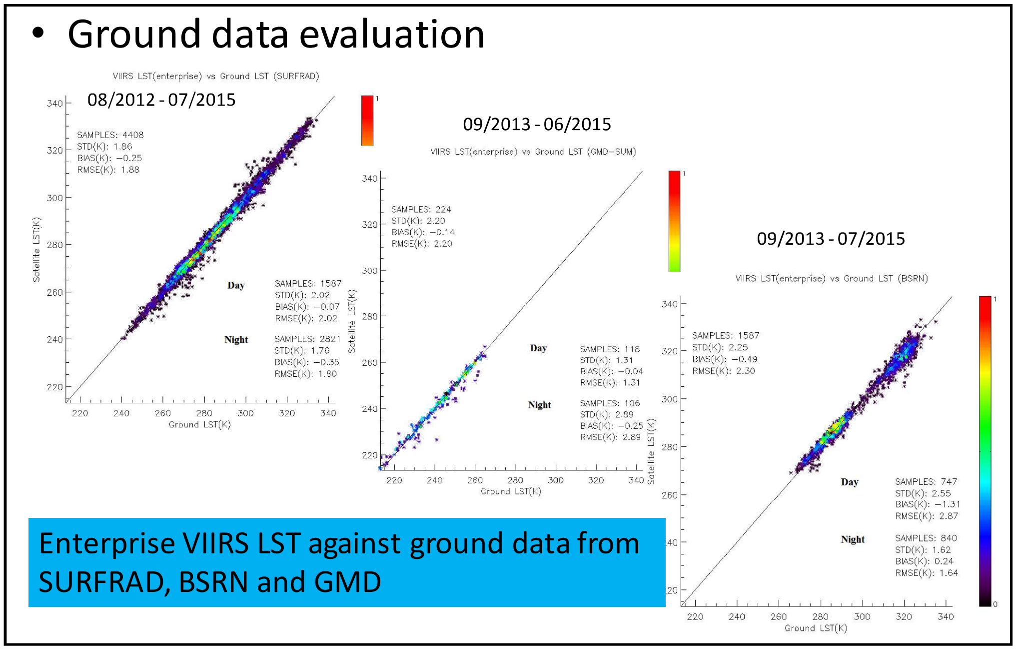


Figure 7.22: VIIRS LST testing and validation.

ACTIVE FIRE PRODUCT REPROCESSING ISSUES

- Strong sensitivity to SDR performance
  - Dual-gain calibration
    Replace (i.e. not just flag) "bad" scanlines
  - Saturation handling
    Reported radiometric value and flagging
  - etc.
- NDE VIIRS product is ready
  - Possible additional screening of bad input SDR (i.e. flight software update)
- Additional candidate NOAA operational products are emerging
  - i.e. I-band and merged products
  - ideally, SDR reprocessing should accommodate needs of a potential future I-band reprocessing effort
    - Saturation handling
    - SAA noise
    - Etc.

Figure 7.23: Active fire product issues.

Science Team. This is an M-band-based product that is very consistent with the heritage MODIS product. There is currently a discussion taking place regarding how to implement a product using VIIRS Ibands. One of the complications with this approach is that Iband is high resolution but the saturation in radiance is an issue. There is also interest in an I-band- and M-band-merged product. Therefore, the SDR reprocessing should accommodate the need for a potential I-band reprocessing effort for fires.

7.3.3 Annual Surface Type

The annual surface type (AST) is a fairly mature product and it is ready to be reprocessed. However, the real need is the input of the gridded surface reflectance product.

The AST reprocessing issues are summarized in **Figure 7.24**. By February 2017, the surface reflectance should be ready for reprocessing.

7.3.4 Summary

VI, LST, and LSA will be ready for reprocessing by August 2017. For those products, the approach is two phased: first, to produce granule-based products and, subsequently, global gridded composites. For land products, there is a need for cross-fertilization between NOAA and NASA reprocessing efforts. Currently they work closely together for validation through the Committee on Observing Satellites (CEOS), but there is also a need for the two agencies to work closely on the SDR science content and understand any differences.

AST REPROCESSING ISSUES

- The product is based on classification metrics computed from at least one year of gridded and composited Surface Reflectance
  - Using the same classification algorithm and training database, the AST product based on VIIRS SR data can be significantly different from similar AVHRR or MODIS AST product
- Reprocessed SR data may result in different classification metrics which in turn may make a difference in the final AST product
  - as long as the seasonal trajectories in the SR data are kept the resulting AST may not be significantly changed
- Impact of reprocessing can be estimated from the differences between current and reprocessed VIIRS, and AVHRR/MODIS data
- An AST validation data set obtained so far could be directly used to validate reprocessed product

Figure 7.24: VIIRS annual surface type (AST) reprocessing issues.

7.4 Precipitation/Hydrology Reprocessing

Presenter

Dr. Ralph Ferraro

NESDIS/STAR

Mr. Ralph Ferraro focused his presentation on precipitation and hydrology. In his definition, Hydrology EDRs are all products derived from microwave observations. They can be put together as products: composite layered as sea ice, snow, precipital water, cloud water, ice water path, and precipitation. The importance of consistency is reiterated. The products derived from various microwave sensors of the past are to be extended seamlessly with products being derived from current and future sensors. The solid lines in **Figure 7.25** are all of the Defense Meteorological Satellite Program's (DMSP) microwave imagers, which date back all the way to 1987. The dashed lines are sounders on the NOAA and MetOp missions, as well as SNPP. Additionally, the AMSR sensors are noted. Satellites that are not sun-synchronous (e.g., TRMM, M-T and GPM) are simply denoted by the grey shade and black arrows on top. These are just times of the equatorial crossings, of which some show drift and some don't. Sometimes drift is good to have for intersatellite calibration as more intersections with other satellites occurs.

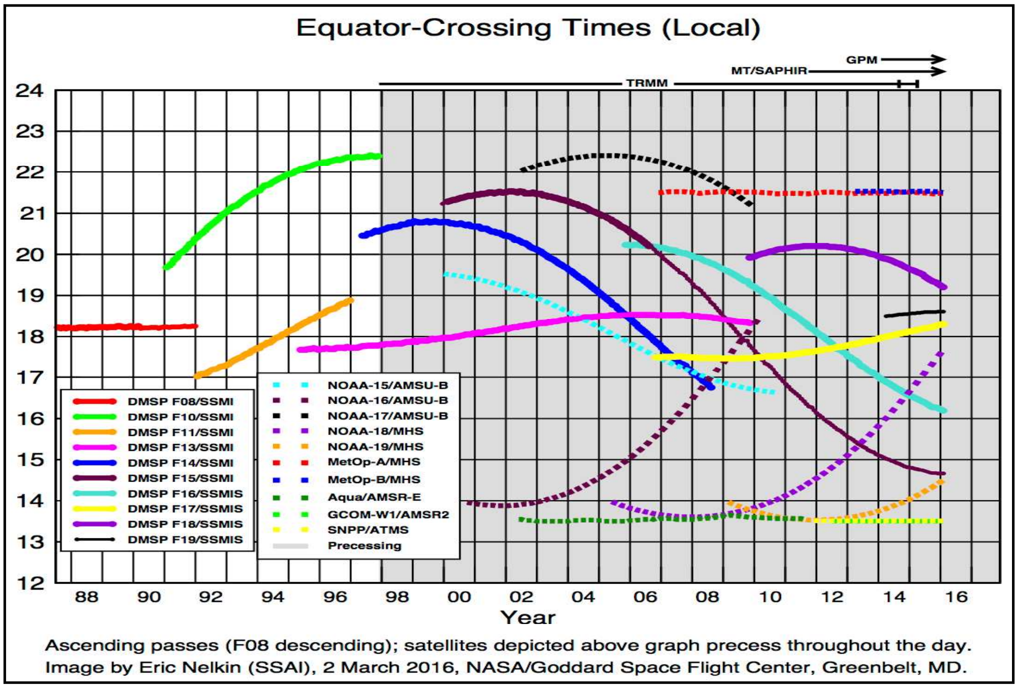


Figure 7.25: The passive microwave "Constellation."

7.4.1 Importance of Reprocessing

The need for a continuous, consistent time series from the primary NOAA satellites as interim records is shown in **Figure 7.26** and Mr. Ferraro's presentation in this aspect about primary users is summarized in Section 2.0. The secondary users—downstream users generating Level 3 products—are by no means less important; JPSS has these blended precipitation/precipitation products. The NWS has CMORPH, a method that produces global precipitation from passive microwave and infrared data at high spatial and temporal resolution. It is very important to have consistency with all these products. Beyond this, NOAA's domestic and international obligations require consistent data sets.

7.4.1.1 Continuity

Continuity among all similar classes of satellite sensors is important. Reprocessing is not a new concept for creating a consistent time series. For example, in terms of microwave data, in the early 90s, NASA and NOAA jointly spun up the Pathfinder Program and developed an SSM/I Pathfinder time series dataset. There is a legacy of reprocessing at STAR and NCEI, shown in **Figure 7.27**.

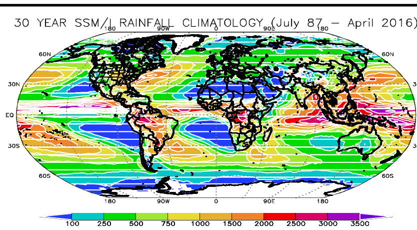
7.4.2 Summary of the Microwave Side of SDR

The microwave SDR has to take into account geo-location, sensor drifts, cross-scan biases, etc. Any biases during the orbit due to the sun are challenging due to contamination. There are three different classes of channels—oxygen bands, water vapor bands, and window channels—which must be considered when SDR corrections are to be made. On the EDR side, the improvements made are science improvements. On occasion, changes can be forced due to a channel going bad that must be remedied, as was the case with AMSU. There should be a synergy between SDRs and EDRs in order to

- Need a continuous, consistent time series for our primary satellites – **“Interim records”**
  - First tier users (NWSFO’s, NCEP centers, etc.)
    - ➢ Need consistency for using products to support real-time operations/comparison with forecast “analogs”
    - ➢ Consistency for testbed activities
    - ➢ Emerging needs for NWS/National Water Center - National Water Model!
  - Secondary users
    - ➢ “L3” products/downstream users (blended products, CMORPH, etc.)
      - Consistent record vital – NWP reanalysis, climate assessments, etc.
    - ➢ Fulfills NOAA’s domestic and international obligations
      - Partnerships with NASA and NRL/AFWA, ...
      - WMO/CGMS, SCOPE-CM; GEO/CEOSS, etc.
      - And well it makes sense – EUMETSAT, etc.
- Need to ensure long-term continuity amongst all “similar” classes of sensors – **“Climate records”**
  - AMSU/MHS/ATMS
  - SSMI/SSMIS (and SSMT/2?)
  - AMSR-E/AMSR-2
- Enterprise Precipitation!
  - JPSS/GOES/+others

Figure 7.26: Why is reprocessing important?

- NASA-NOAA “Pathfinder” projects
  - Precursors to EOS program goals
  - Included an SSM/I pathfinder
- NOAA’s Climate Program Office
  - Supported NOAA’s contribution to GPCP
    - ➢ GPCP – most popular merged global precip. product, 1979 to present
  - Evolved to NCDC lead Scientific Data Stewardship (SDS) & Applied Research Center (ARC) programs
  - **NOT** derived from reprocessed SDR data
- NESDIS AMSU MSPPS
  - We did an in-house reprocessing ~2008 when our Day-2 algorithms were frozen
  - **NOT** derived from reprocessed SDR data
- AMSU Hydrology CDR project (see backup slides)
  - By end of 2016, we will have 15+ year AMSU/MSPPS CDR’s
  - **DERIVED** from reprocessed SDR data



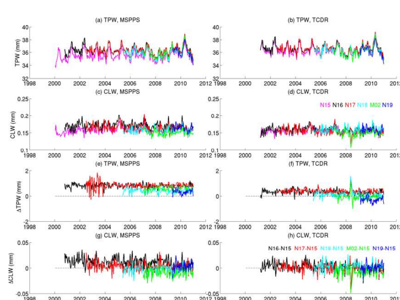


Figure 7.27: “Reprocessing” legacy at STAR and NCEI.

test whether reprocessing has been performed correctly. If, in a five channel algorithm, one algorithm did not retrieve correctly at the SDR level, the EDR will not be valid. Working from both ends, therefore, is required. A listing of the SDR reprocessing requirements and suggestions for JPSS is shown in **Figure 7.28**.

- JPSS
  - S-NPP/ATMS
    - MiRS – hoping PGRR project can get jump started soon…likely need to adjust based on synergy with ATMS SDR, funding, computer capacity, etc.
    - Snowfall rates – stand-alone, but now part of MiRS "package"
  - GCOM/AMSR-2
    - Might be able to do within GAASP project with additional resources?
- POES – covered by CDR program (partially)
    - Legacy/MSPPS
    - MiRS – likely out of scope due to computing restrictions, etc.
- DMSP – covered by CDR (partially)
  - SDR's but not EDR's
- The (million or less $$) question…how often?
  - ***NO MORE THAN once/year, probably every 2 years***

Figure 7.28: Requirements/suggestions for JPSS.

7.5 Enterprise Algorithms for Reprocessing

Presenter

Dr. Walter Wolf

NESDIS/STAR

Dr. Walter Wolf talked about the Enterprise algorithms and their transition to operations. An Enterprise algorithm is an algorithm that uses the same scientific methodology and software base to create the same classification of products from differing input data. An Enterprise algorithm does not have to be satellite-based. It can be an in situ or ancillary algorithm. The key is maintaining the same software base for the algorithm across multiple instruments. The primary advantage of this is that it provides continuity of products between current and future NOAA operational satellites. It is cost-effective processing. It is easier to re-run and there will be fewer algorithms and systems to maintain within operations. Currently, there are multiple versions of algorithms with similar products across instruments, all running on different hardware within OSPO. The goal is to move to Enterprise by consolidating these systems into one eventual GEARS ground system, where all the products are run. The team working on this is ASSISTT – the Algorithm Scientific Software Integration and System Transition Team (formerly known as Algorithm Integration Team (AIT).) The team will support the science teams' change process for the SDR to EDR algorithms, algorithm updates, and fixing bugs. The look up table updates and extended data processing will be done as needed. Another goal of ASSISTT is to be ready to process J1 data using SDR and EDR algorithms when the J1 data is available, and to run these algorithms in near-real-time for validation purposes, and to eventually reprocess the EDR algorithms.

7.5.1 ASSISTT, MIRS, and NUCAPS

ASSISTT has a number of products that are already handling Enterprise algorithms, including cloud mask, cloud phase, cloud height, cloud type, cloud top temperature, cloud top pressure, cloud optical properties, cloud microphysical properties, derived motion winds, ozone products, microwave products, hyper spectral soundings, and ocean color. The MIRS system handles microwave products and NOAA Unique CrIS/ATMS Processing System (NUCAPS) handles hyper spectral soundings. The Enterprise algorithms across VIIRS and ABI are as follows:

- Aerosol Optical Depth
- Aerosol Particle Size
- Smoke and Dust Detection
- Sea/Lake Ice Cover and Concentration
- Sea and Lake Ice Temperature
- Sea and Lake Ice Age/Thickness
- Volcanic Ash Mass Loading and Height

The process to transition to operations by the end of year is currently ongoing. The algorithms under development are as follows:

- Low Cloud and Fog (Geo only)
- SST (Currently Polar, migrating to ABI and AHI)
- LST (VIIRS and ABI)
- NDVI (Polar only)
- Snow Cover (VIIRS and GOES)
- Radiation Budget Products (Geo only)
- Surface Albedo (VIIRS and ABI)
- Surface Reflectance (VIIRS and ABI)

7.5.2 Steps Involved for Algorithm Change

When the science teams update their algorithms, they are input into an offline system resembling the Operational system where they are unit tested before being tested on extended data. Currently, the testing can last anywhere between six weeks and three months. A new step is being added to test the algorithms in near-real-time prior to delivery to operations. To accommodate this additional test, the plan is to extend the algorithm testing period to between six months and one year following the transition to operations. The HTCondor cluster was implemented within STAR to support the algorithm change process and algorithm testing. Currently the cluster has 13 machines with 156 cores which will be expanded to 288 cores by the summer of 2016, 72 of which are for S-NPP/J1 processing. Two other machines are being used to test upgrades and other software packages before deploying to the rest of the cluster. The scheduler CRON that is currently in use is not very efficient and better schedulers are under evaluation. More cores will be added in FY 17 to support near-real-time J1 processing before transitioning to operations. Regarding reprocessing, large scale operation is not currently attainable due to the lack of storage: a total of one petabyte of storage is needed. Other limiting factors are power and floor space limitations within NCWCP.

7.6 Enterprise Archive for Reprocessed Data

Presenter

Dr. Nancy Ritchey

NESDIS/STAR

Dr. Nancy Ritchey took the opportunity to speak about data archiving and access to NCEI, NOAA's national data center. Her presentation was a follow-up to NCEI's Dr. Jeffrey Privette's presentation, which we summarized in Section 2.0. One year ago, the data centers, which had been located all across the United States, were merged into a single organization—NCEI. NCEI's strategic vision is to be the nation's trusted authority on environmental data and information. One of its goal is to provide consistent data management capability for all of NOAA and to preserve the data for future generations. Currently, more than 26 petabytes of data is being managed by NCEI. Another goal is to provide access through multiple interfaces, including CLASS, as described in Section 2.2.2. Procedures for archiving data are being made more transparent. The data stewardship and modernization of IT infrastructure to support archiving data is being improved. The next generation of data access is under development, with three main projects: the first being to build a user friendly interface—called One Stop—to access all of NOAA's data. Advanced capabilities, including visualization and the ability to rank data based on maturity, will be added to One Stop. The goal of the second project—called the Big Data Project—will provide cloud partners with access to NCEI data. The third project is to improve NOAA data for easier access for which NCEI submitted proposals to the Big Earth Data Initiative (BEDI). The general spectrum of NCEI data users is shown in **Figure 7.29**. Users new to STAR are welcome partners when it comes to reprocessed data.

7.6.1 NCEI Services

The services of NCEI are shown in a tiered structure in **Figure 7.30**. Tier 1 provides basic access and preservation; it is where the metadata is created. How long the products will be stored will be determined based on retention schedules. Digital object identifiers will be generated for both original and reprocessed products. Tier 2 provides enhanced access, an example of which is the accessibility of available SNPP data via the Internet or SNPP products at the Online store.

7.6.2 Partnering with NCEI

With regard to partnering with NCEI, the first step is to develop a data management plan. It is a requirement from NOAA's Environmental Data Management Committee documented in the NOAA Data Management Planning Procedural Directive. NCEI can help in writing this plan. Some of the ways to partner with NCEI relate to data

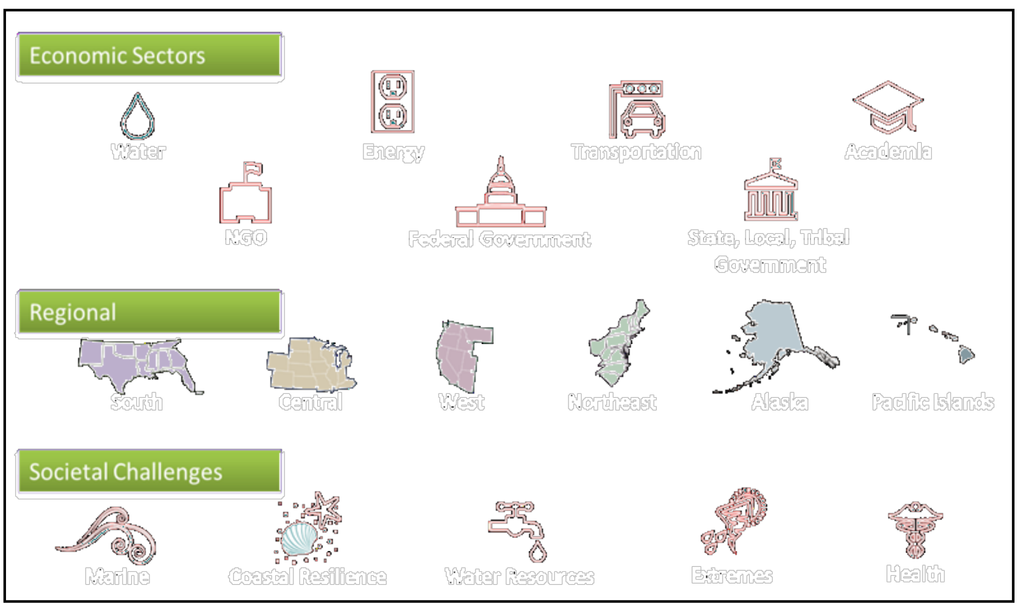


Figure 7.29: NCEI is responding to a broad spectrum of users.

Figure 7.30: NCEI tiers of stewardship.

formats, metadata, and documentation. For example, NCEI is currently working on a product for STAR that generates 8,000 files per day. While users can easily access the data in such a structure, downloading that many files can be very cumbersome for a single user. NCEI would like to work with STAR to better aggregate the data to alleviate the difficulties in such cases. One goal is to change the configuration of the netCDF format at STAR so that it works more compatible with the access system at NCEI. By working together to change the formatting of the STAR-generated products on netCDF, the products can more easily be integrated into the NCEI system. In this way, NCEI tools will give users easier access to STAR products. Another goal is establishing formal contacts for archiving and updating documentation, such as look up tables and anomalies. Currently, NCEI is working on SNPP data products, trying to update the metadata to make it compatible with the OneStop project. A lack of contacts at STAR, however, is hindering progress. As part of a partnership, contacts can be formally established, facilitating communication.

Information on how to access data from CLASS and the levels of access service available is given below.

7.6.3 How Data is Accessed from CLASS

Step 1: Register for a user id account at www.class.noaa.gov (minimal information: name, e-mail address, and password);
Step 2: Select a dataset from the drop-down product menu;
Step 3: On the Search page, make your selections (geographic region, start/end dates and times, and data types); and
Step 4: Determine if you need greater access or a subscription.

Levels of Access Services in CLASS
CLASS provides daily TAR files containing publicly available SNPP products for easy anonymous FTP download at: ftp://ftp-npp.class.ngdc.noaa.gov/.

Characteristics of the Data are as Follows:

- Most recent 85 days
- 80 data types (including Geolocation files)
  - Newly added NDE_L2 NUCAPS and MIRS and NDE_Daily Polar Winds
- Data are compressed and "tar"-ed by data type
- Sorted by date (YYYYMMDD)/data family/data type
- Includes manifest files (xml format)
- No log-in required for access

CLASS Order Types

1. Ad hoc orders – Completion time: Usually within 12 to 24 hours;
   File Limit: up to 500 files (Use Search button to obtain inventory) -
   Contact the Help Desk: No
2. Large orders – Completion time: Usually within 24 to 48 hours;
   File Limit: up to 1,000 files (Use Quick Search button to skip inventory) -
   Contact the Help Desk: No
3. Block orders – Completion time: > 48 hours;
   File Limit: up to 3,000 files (Use Quick Search button) -
   Contact the Help Desk: Yes
4. Subscription (Standing orders) – Completion time: <6-7 hours;
   No File Limit - Contact the Help Desk: Yes

7.7 Discussions and Q&A

Presenter

Ms. Lihang Zhou

NESDIS/STAR

Ms. Lihang Zhou led the Discussion and Questions and Answers (Q&A) portion of Session 7. The following are the action items from the Enterprise Workshop[66] that were discussed.

1. Action Item 1: SST uses 10 minute granules, aggregating at the start of processing. This is more useful to the Users. Do other users need 10 minutes? What should be done for consistency? What do users want?

   The discussion led to the following ancillary questions from participants:

   a. How do we aggregate in SDR reprocessing? We know NASA is doing six minutes and our SST is doing 10 minutes. For our SDR processing/reprocessing, do we want to propose consistent data aggregation strategy?
   b. Does this question also relate to real-time processing?
   c. Are we talking about putting into NDE all the granule based products and granule attributes instead of the 86 sec granule?
   d. Do we want to have an Enterprise algorithm for both real-time processing and reprocessing? Is the Enterprise algorithm affected by the granule size to have compatibility?

   Response/Comments

   – There is no easy answer. In general, six minutes for ARIES and five minutes for MODIS were chosen by NASA because of a clean break in the measurements from those instruments. We have to put more thought into whether or not we want to do some sort of aggregation. We have to look into real time

66 Workshop organized by NOAA/NESDIS/STAR in March 30-31, 2016. Title: STAR JPSS Enterprise Algorithm Workshop – NDE Implementation of J1 Products.

processing and our latencies, etc. (Response by Dr. Wolf of STAR, who is overseeing the Enterprise algorithms development)

- Aggregation is different from creating a granule. Aggregation is simply combining several granules. Basically, you are throwing scans, called "granules," into a bucket. They can be full scan granules or partial scan granules. The number of scans per granule is decided at the project level. For example, NPOESS decided that in the case of ATMS and CrIS, the requirement was one scan per granule. (Response by Dr. Wael Ibrahim of Raytheon)
- If the aggregation goes forward, there should be software tools available to them to revert back to the 86 sec scan level (Ocean color perspective). The CrIS data analysts stated that their perspective was also same. (CrIS perspective)
- User input is needed in deciding the granule size. The preference will be based on the User's end product size. The users generally request data at the one- or two-granule size. However, software packages such as CLASS prefer to have aggregated data. (Audience)

Ms. Zhou summed up the discussion on Action Item 1, stating that it is an important issue and requires consensus. She requested that Dr. Changyong Cao gather input from all participants and interested STAR staff to make a group decision.

2. Action Item 2: There is a requirement for pixel-level products but users are requesting aggregated products. As an example, the Aerosol Optical Depth (AOD) team was approached by NWS for an aggregated product.

   Response/Comments
   This action item was quickly addressed by Ms.Zhou as it essentially relates to the same discussion of Action Item 1.

3. Action Item 3: NDE resources may be insufficient to process all EDRs and there is a lack of redundancy (e.g., catch-up of data outages). A "master list" of L1b outages does not exist and the data required to build one is missing or incomplete. NDE Quality Control (QC)/monitoring of L2 data is sub-optimal. (Users pointed out that files are broken/incomplete). There is no requirement to process fixed granules, and S-NPP has a high rate of missing data. What is causing these data gaps?

   Response/Comments
   - A process is needed to integrate Changyong Cao's and Cole Rossiter's databases of anomalies and origin. The ICVS or some other monitoring system could likely accomplish that. Cole's page should be able to provide all the sensors. (Ms. Zhou)
   - An on-line searchable database will be very helpful in showing what occurred and when. The goal is to have it in real-time for long-term monitoring. (Audience)
   - It was asked, "Will we accept the anomalies in SDRs and imagery only? If so, what happens to EDRs and RDRs?" (Audience)
   - One should be cautious about the repaired RDR. The problem is CLASS vs gridded data. CLASS has a six-hour delay and may only have the repaired data, as if nothing happened. One has to manage both systems by double-checking all files. (Dr. Wael Ibrahim of Raytheon)

- Analysis showed only two percent of the data gets repaired. The question was whether or not it is worth fixing. Perhaps it is only necessary to know where the repair was done. (Audience)
- Repair information is in the IDPS system and is available as daily spreadsheets in the NCEI reports. (Audience)

Closing Remarks

8

Presenter

Dr. Fuzhong Weng

NESDIS/STAR

Dr. Fuzhong Weng gave the final closing remarks. The recommendations from all areas of STAR that relate to reprocessing are included in the report, a few of which were reviewed in the closing remarks. The participants were encouraged to continue to send any new recommendations. Dr. Weng's general approach for JPSS reprocessing is shown in **Table 8.1.**

Table 8.1: General Approach for JPSS Data Reprocessing.
• Incorporate the user feedbacks and recommendations from this workshop
• Utilize the latest ADL version or a version with new and fully tested science algorithms
• Recover the missing RDR granules from every possible medium (e.g., GRAVITE, CLASS)
• Integrate the latest version of PCT, LUT, and engineering packages into reprocessing
• Work with NCEI on the fast access and dissemination of the reprocessed data

The main focus is SDR reprocessing. An integrated approach needs to be established. Product team leaders will be consulted for any EDR reprocessing. The researchers themselves should perform the analysis and compare the results of before and after reprocessing. STAR does not have staffing resources dedicated to help in the analysis. The reprocessing program may not be able to handle user-oriented reprocessing as there is a limitation on data storage. While it is often convenient to request a reprocessed dataset to test an issue, the resources to generate and store different versions of reprocessed data are not available. Any SDR level improvements can be made as part of pre-processing, which should be discussed in the future.

General Comments

The general approach is to use the latest ADL version, which teams have already begun testing. Recovering an RDR missing granule from every possible medium is another way to restore data integrity and is very important. Obviously, the latest version of the PCT, LUT, and engineering packages are to be used in the reprocessing. Regarding fast access, STAR needs to work with NCEI. STAR has many files but the current file name-based search is not appropriate. Currently VIIRS spends most of its processing time in searching. A search engine-type database approach, such as are used by Amazon and Google Docs, is preferable, as the search engines have good number of attributes and work quickly.

Regarding computer resources, the Bamboo server cluster is a small but powerful machine. The funding for this common ground system came from not only JPSS and the National Weather Service, but also from OSGS. The NWS also wants STAR to perform the radiant forecast model testing. Once we have a new dataset, NWS wants to measure the improvement in hurricane intensity forecasting. Therefore, the Bamboo server cluster will be a laboratory resource and a great asset.

End of the Workshop

Following the workshop, participants were invited to visit the cluster room located in the ESSIC building.

Below are the tables of recommendations and other input from users (Dr. Weng's comments are added in the end row where available)

Table 8.2: User Recommendations for ATMS SDR Reprocessing

- Heather et al. (ECMWF)
  - Lunar intrusions flagged for whole time series
  - Lunar intrusion correction applied for whole time series
  - Further investigation of striping correction algorithm
- Andrew et al. (NCEP)
  - Data stream with channels remapped to similar FOV of AMSUA-like channels
  - Early acquisition of the data and access to the best information characterizing the instruments
- Bill et al. (NRL)
  - Correlated error derived from reprocessed ATMS will be tested and implemented in near future
- Zou et al. (ESSIC)
  - Compared to two stream data, the combined one data stream of AMSU-A and MHS benefits the QPF for Hurricane Isaac

Table 8.3: User Recommendations for CrIS Reprocessing

- ECMWF (Heather et al.)
  - Collocated imager data could assist cloud-detection, as with IASI (CrIS and VIIRS collocated data stream is generated)
- Andrew et al. (NCEP)
  - Data stream of both normal spectral resolution (NSR) and full spectral resolution (FSR) mode
  - Early acquisition of the data and access to the best information characterizing the instruments
- Bill et al. (NRL)
  - Correlated error derived from reprocessed CrIS will be tested and implemented in near future
- Wang et al. (ESSIC)
  - Reprocessed CrIS SDR should be linked to future J1 CrIS, making long-term CrIS SDR consistent
  - Spectral coverage for future CrIS on J2 and beyond should be improved

Dr. Weng: CrIS vs VIIRS: Two data streams for cloud detection are being used which will be helpful. Early access of data is critical for users. CrIS is a better instrument for GSICS. Expanding its spectral coverage will be good and may possibly happen on J2.

Table 8.4: Data Anomalies in CGS IDPS
• Wael and Michelle (Raytheon): – SNPP data anomalies occurred upstream of IDPS • Identified RT/NRT; communicated to IDPS (through OSPO Operators, CGS MST); IDPS handles gracefully • Identified RT/NRT; communicated to IDPS (through OSPO Operators, CGS MST); initially IDPS could not handle gracefully and required IDPS updates (code changes, SOP changes, etc.) • Could not be identified; IDPS could not handle gracefully and required IDPS updates (code changes, CFG changes, etc.) • Could not be identified; functionally, IDPS was not affected, however, quality of generated IDPS product was compromised/incorrect – SNPP data anomalies occurred within IDPS • Inherent known issues per agreed-upon IDPS architecture/design • Leap "repeated" second insertion on 6/30/2012 23:59:59 • Table (LUT, PCT, GND-PI, AUX HIST, etc.) insertion into IDPS DMS with wrong effectivity.
Dr. Weng: The IDPS (common ground system) could identify anomalies that occurred upstream to IDPS. Some can be recovered. Some can't. These inputs were put in reprocessing system.

Table 8.5: User Recommendations for EDR Reprocessing
Liu et al. (STAR) NUCAPS and MIRS Reprocessing **NUCAPS** • ATMS/CrIS SDR data have been improved, • NUCAPS algorithm has been improved, • Incomplete EDRs, OLR available from 11/30/2015 • New valuable EDRs CO, CH4, and CO2 • Reanalysis of Radiation Budget at the Top of the Atmosphere • Outcome of the reprocessing complete and consistent NUCAPS EDRs with better quality **MIRS** • ATMS TDR/SDR/GEO data have been improved, • MIRS v11 performs much better versions before v11, • Bug fixed for missing scan lines • New Product (snowfall rate) • Improved temperature under rainy condition, • Operational MIRS ATMS EDRs started from April 8, 2014 • Outcome of the reprocessing complete and consistent MIRS EDRs with better quality **Further improvement is needed for capture of severe winter storm (e.g., Blizzard 2016)**
Dr. Weng: NUCAPS is already being tested at Wisconsin. Probably our teams should continue to work with Wisconsin teams of Leon Gramley?

Table 8.6: Status and User Recommendations for OMPS SDR Reprocessing
Flynn and Long (STAR): OMPS SDR Product summary • Non-geophysical measurement variations and biases that affect ozone retrievals have been identified and can be modeled and corrected in SDR reprocessing or by soft calibration at the EDR stage. – Improved characterization of darks, radiance and irradiance calibration constants, non-linearity, stray light and intra-orbit NM wavelength scales provide good SDR adjustments and have improved product accuracy. – The OMPS NM SDRs show a small cross-track bias in their calibration. – The OMPS NP has experienced a small amount of throughput degradation for the shortest wavelengths but its time dependence is accurately determined. – The OMPS NP has an annual cycle in its wavelength registration, and the 27-day and 11-year solar activity produces corresponding radiance variations. – The OMPS NP SDRs show a small, wavelength-dependent bias in their calibration versus NOAA-19 SBUV/2. • The V8 retrieval algorithms are well-suited for the measurements and compliment soft calibration adjustment strategies. • A full OMPS reprocessing from the RDRs through to the V8TOz and V8Pro will provide high quality components to extend the long-term atmospheric ozone monitoring records.
Dr. Weng: Larry's idea is to make OMPS derived EDR, for climate application.

Table 8.7: User Recommendations for VIIRS EDR Reprocessing
Ivan et al. (STAR): Key Issues for VIIRS Land EDR Reprocessing • Impact of the performance of upstream products throughout the Suomi NPP data record – accuracy of the delivered variable (e.g. SDR calibration, cloud mask accuracy etc.) – performance of the quality flags and any other deficiencies – traceability, data anomalies, data gaps etc. • Experience with current operational product – accuracy, content, traceability, user-friendliness etc. • Reprocessing in the context of implementing Enterprise algorithms – impact of the change in upstream products – Enterprise product readiness and adequacy for reprocessing – realistic schedule to reprocessing – test datasets needed for proper evaluation before full reprocessing • Validation of the reprocessed data – reprocessing is also an opportunity to accelerate the confirmation of validation and maturity stages of the new Enterprise products – retrospective reference data available – long-term monitoring to ensure the sustainment of product quality – reprocessing validation plans to your J1 cal/val plan where it makes sense
Dr. Weng: Ivan highlighted above good points for Land EDR reprocessing.

Table 8.8: User Recommendations for VIIRS EDR Reprocessing
Sun and Wang (STAR): Improvement of VIIRS SDR for Ocean Color EDR Science Quality Reprocessing • SD/SDSM calibration provide stable and clean calibration coefficients but each component must be robustly characterized – VF, BRF, H-factor, F-factor, Hybrid coefficients, etc. This has been done. • Lunar-based calibration is necessary for VIIRS calibration to fix a vital gap caused by the "degradation uniformity condition" proven untrue for the calibration calculation. A "hybrid methodology" is built by combining SD and lunar calibrations to correct this issue. • With all components robustly characterized and procedure correctly restored, effects such as the non-uniformity issue and long-term bias, anomalous noises and seasonal variation artifacts are removed. • The 4.5 years results shows that the RSB are performing very well, with results stable at 0.1 – 0.2% level in the SDR, and with significant improvement in EDR to meet the requirement of the ocean color products. • Ocean color products have reached maturing status in March 2015 using the improved LUTs. Products have already been reprocessed several times. • Currently, the LUTs from Dec. 2015 for final EDR reprocessing and for forward science quality ocean color products. • VIIRS is well-designed but more challenges will emerge with age.
Dr. Weng: I think we need to utilize the hybrid approach to derive the gain as part of reprocessing.

Table 8.9: User Recommendations for VIIRS EDR Reprocessing
Wang (STAR): Mission-long Ocean Color Data Reprocessing • We have successfully reprocessed VIIRS mission-long ocean color data products for the Near-Real-Time data stream in summer 2015 and the Science Quality data stream in May 2016. Both data streams have been going forward routinely. • For the Science Quality data stream, VIIRS mission-long SDR has been reprocessed from RDR using significantly improved on-orbit calibration (both solar and lunar approaches). It is necessary to use also lunar data for VIIRS calibration now. • The reprocessed VIIRS mission-long Science Quality ocean color data have been significantly improved, providing accurate and consistent ocean color data for science research and applications. • We have been working with the NOAA CoastWatch and NCEI teams. The Science Quality data stream is planned to be distributed in the NCEI in summer 2016. • VIIRS mission-long data reprocessing will be carried out about every three years or so, when there are significant improvements for algorithms and SDR calibrations. • Until the next mission-long data reprocessing!

Table 8.10: User Recommendations for VIIRS EDR Reprocessing
• Sasha et al. (STAR) VIIRS SST Reprocessing – Access to complete reprocessed SDRs • SDRs should be periodically reprocessed and made available online or via SCDR • Ideally, EDR RAN-x be produced off SDR RAN-x • If impossible, full RDR should be online or on SCDR + RDR2SDR code – Lessons learned from NASA • Reprocessed L1b should be online (similarly to MODIS on ladsweb.nascom.nasa.gov) • SDR Reprocessing should be linked to/trigger the EDR Reprocessing – Master file of Non-existing/Partial/Degraded SDRs needed • The file should be updated and made available to EDR teams • In real time and for reprocessing • Should be versioned and periodically reprocessed • Shobha et al. (STAR) VIIRS Aerosol Reprocessing – Complete reprocessing of the full 4-yr record for AOT and Aerosol Detection – Validate reprocessed datasets – Work with users (NWS, NRL, EPA and academia) – Develop training packages • Liam et al. (CIMSS) NUCAPS and ACSPO – Investigate NUCAPS CrIS/ATMS SDR processing failure cases to improve yield – NUCAPS doesn't handle CrIS granules with less than 4 scan lines – Investigate ACSPO VIIRS SDR processing failures for March 2012 and get a working set of LUTs allowing to go back to January 2012
Dr. Weng: Sasha's SST team should get the latest version. Particularly VIIRS has some new corrections in AutoCal system plus some lunar correction algorithm. Also the getting rid of the spikes in SST for VIIRS blackbody Wamup and Cool down anomaly should be addressed. Regarding Aerosals, Shobha's system is small and powerful. Users are starting to access her datasets.

Table 8.11: SDR Team Recommendations for ATMS Reprocessing Improvements on ATMS TDR Science.

Yang (STAR)

Error Source	Corrections in Current IDPS	Corrections in ADL FRC	Future improvements
Calibration method	Calibration in Temperature Space	Calibration in Radiance Space	
Nonlinearity	Polynomial function, no antenna emission correction	"μ" parameter based physical model, antenna emission correction included	
Calibration target bias	Side lobe correction, R-J approximation correction	Side lobe correction No R-J correction is needed	Antenna emission correction for cold and warm target radiance
Lunar contamination	Maximum-thresh-hold lunar correction algorithm	Maximum-thresh-hold lunar correction algorithm	Physical based LI identification and correction algorithm
Antenna Emission	No	No	Physical based antenna emission correction for warm and cold targets
Noise filtering	Triangle, rectangle	Triangle, rectangle	Sinc function

Table 8.12: SDR Team Recommendations for VIIRS Reprocessing.

Cao (STAR)

RSB Autocal

- RSB autocal relies on the RHW filter, which simplifies the models and works well for operational processing due to fast speed;
- Longterm trend captured well but mimicking short term averaging has short-comings with artifacts on the order of 0.1%;
- Future work can evaluate alternative algorithms to further improve fidelity at the expense of speed.
- Lunar calibration is not part of RSB autocal; separate efforts for lunar cal: hybrid calibration by ocean color team and lunar band ratio.

DNB Algorithm

- Straylight correction is empirical and should be further improved;
- Southern hemisphere and tropical straylight currently not corrected;
- Root cause of straylight yet to be found;
- Dark offset uncertainties require further improvements;
- Onboard vs. vicarious calibration tradeoff; · Active light source for improved accuracy.

VIIRS TEB Algorithm

- EBBT table: early versions had problems(<MX8.10);
- Latest LUT version available on the VIIRS website.
- WUCD: bias observed in SST
- Future work: Striping and detector RSR processing.
- Using MICROS for validation.

Table 8.13: User Requirements for VIIRS SDR Reprocessing.

VIIRS SDR Improvements

Xiong et al. (NASA)

- SDSM screen transmission (τ_{SDSM})
- SD screen transmission and $\tau_{SD}BRDF_{SD}$(SDSM_View) } yaw data + regular data
- SD screen transmission and $\tau_{SD}BRDF_{SD}$(RTA_View) ⇨ yaw data
- SD degradation (H)
  - Revised extrapolation of H to the mission very beginning
  - H dependence on the solar azimuth angle
  - Model H to cover SWIR wavelength
  - Fit H at RTA view to lunar trending
- Correction for the solar vector error
- DNB offsets and stray light correction (forward processing)
  - DNB offsets derived from BB observations
  - Stray light correction LUT derived from LUTs in previous years (weighted average of the "same" day LUTs from previous years)

Table 8.14: User Recommendations for OMPS EDR Reprocessing.

OMPS SDR Product summary

Jaross et al. (NASA)

- Improvements in reprocessed products
  - -Wavelength registration: NP & NM (300 – 310 nm)
  - -Stray light correction: NM (300 – 310 nm)
  - -Albedo calibration: NP & NM (300 – 310 nm)
- Remaining data issues
  - -Albedo calibration errors within 1%: NM nadir
  - -Albedo calibration within 2%: NM cross-track dependence
  - -Albedo calibration within 2%: NP
  - -5 year albedo cal. change of 1% at 250 nm
  - -Stray light: NM, < 5% at 302 nm
  - -Stray light: NP, < 3% at 250 nm
  - -Cross-track wavelength registration: NM, < 0.03 nm
  - -Along-track wavelength registration: NM, < 0.01 nm

Table 8.15: SDR Team Recommendations for OMPS Reprocessing

Expected Results from Data Reprocessing

Pan (STAR)

- No long term time dependency change relative to NOAA-19
- Mapper bias near zero and profiler bias about 0.5% (V8 EDR)
- Produce consistent SDRs that meet the top level products requirement
  - Minimized cross-track IFOV radiometric error
  - Achieve consistent data records between NP and NM in 300-310 nm
  - Minimized stray light contamination
  - Adjusted wavelength registration to best of our knowledge
  - Will improve wavelength registration in dichroic region by consider sensor EV sensitivity
  - Will correct wavelength thermal sensitivity caused temperature gradient

Evaluated by comparison w/ MLS on SDR level and NOAA 19 SBUV/2 on EDR level

List of Acronyms and Abbreviations

A

AAPT	American Association of Physics Teachers
ABI	Advanced Baseline Imager
AC	Anomaly Correlation
ACSPO	Advanced Clear-Sky Processor for Oceans
ADL	Algorithm Development Library
AERONET	Aerosol Robotic Network
AHI	Advanced Himawari Imager
AIRS	Atmospheric Infrared Sounder
AIT	Algorithm Integration Team
AMP	Algorithm Management Project
AMS	American Meteorological Society
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
AMSU-A	Advanced Microwave Sounding Unit -A
AOD	Aerosol Optical Depth
AOT	Aerosol Optical Thickness
APU	Accuracy, Precision, and Uncertainty
AQUA	Aqua Earth-observing satellite mission
ARW	Advanced Research WRF
ASSISTT	Algorithm Scientific Software Integration and System Transition Team
AST	Annual Surface Type
ATMS	Advanced Technology Microwave Sounder
ATT	Attitude
AVHRR	Advanced Very High Resolution Radiometer
AWIPS	Advanced Weather Interactive Processing System

B

BB	Black Body (also Blackbody)
BBR	Black Body Radiation (also Blackbody Radiation)
BEDI	Big Earth Data Initiative
BRDF	Bidirectional Reflectance Distribution Function
BRF	Bi-directional Reflectance Factor
BT	Brightness Temperature
BUFR	Binary Universal Form for the Representation
BUV	Backscatter Ultraviolet
BVP	BRF VF Product

C

CAL	Calibration
CALIPSO	Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observation
CCD	Charge-Coupled Device
CCR	Code Change Request
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CFG	Configuration

CGS	Common Ground Segment
CICS	Cooperative Institute for Climate and Satellites
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CLASS	Comprehensive Large Array-data Stewardship System
CMC	Canadian Met Center
CMO	Correction Matrix Operator
CMORPH	A method that produces global precipitation from passive microwave and infrared data at high spatial and temporal resolution
CNTRL	Control
CO	Carbon Monoxide
CONV	Conventional
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate
COTS	Commercial Of The Shelf
CPC	Climate Prediction Center
CRTM	Community Radiative Transfer Model
CSPP	Community Satellite Processing Package
CSU	Colorado State University
CT	Cross-Track

D

DA	Data assimilation
DAAC	Distributed Active Archive Center
DCC	Deep Convection Cloud
DMS	Data Management System
DMSP	Defense Meteorological Satellite Program
DNB	Day/Night Band
DPH	Data Product History

E

EBBT	Blackbody Temperature
ECMWF	European Center for Medium-range Weather Forecasting
EDR	Environmental Data Record
EMC	Environmental Modelling Center
EOS	Earth Observing System
EPA	Environmental Protection Agency
EPH	Ephemeris
EPS	EUMETSAT Polar Satellite System
ERT	Earth Resources Technology
ESA	European Space Agency
ESDR	Earth System Data Records
ESPC	Environmental Satellite Processing Center
ESSIC	Earth System Science Interdisciplinary Center
EV	Earth View

F

FFT	Fast Fourier Transform
FG	First-Guess
FILL	Acronym for Filled values
FLO	Custom workflow manager
FOV	Field-Of-View

FRAC	Full Resolution Area Coverage
FRC	Full Radiance Calibration
FSR	Full Spectral Resolution
FTE	Full Time Employee
FTP	File Transfer Protocol
FWHM	Full Width Half Maximum
FY	Fiscal Year

G

GAC	Global Area Coverage
GB	Gigabyte
GCAS	NOAA Global Forecast System
GDAS	NOAA Global Data Assimilation System
GEARS	Ground Enterprise Architectures Services
GEO	Geolocation Evaluation
GFS	Global Forecast System
GFS AVN	GFS Aviation Model
GHRSST	Group for High Resolution Sea Surface Temperature
GITCO	Terrain Corrected Geolocation
GMT	Greenwich Mean Time
GMTCO	Terrain Corrected Geolocation file
GOES	Geostationary Operational Environmental Satellite
GOS	Global Observing System
GPM	Global Precipitation Measurement
GPSRO	GPS Radio Occultation
GRAVITE	Government Resource for Algorithm Verification, Independent Testing, and Evaluation
GRUAN	GCOS Reference Upper-Air Network
GSFC	Goddard Space Flight Center
GSI	Grid point Statistical Interpolation
GSICS	Global Space-based Inter-Calibration System
GSRD	Ground System Requirements Document
GTP	GRAVITE Transfer Protocol
GVF	Green Vegetation Fraction

H

HAM	Half-Angle Mirror
HIRS	High-Resolution Infrared Radiation Sounder
HMS	Microwave Humidity Sounder
HPC	High Performance Computing
HPCC	HPC Center

I

IASI	Infrared Atmospheric Sounding Interferometer
ICV	Integrated Calibration/Validation
ICVS	Integrated Calibration/Validation System
IDL	Interface Data Language
IDPS	Interface Data Processing Segment
IFOV	Instantaneous Field of View
IOP	Inherent Optical Properties
IR	Infrared
IT	Information Technology

J

JCSDA	Joint Center for Satellite Data Assimilation
JGR	Journal of Geophysical Research
JPSS	Joint Polar Satellite System

L

LAN	Local Area Network
LED	Light Emitting Diode
LI	Lunar Intrusion
LITE	Local thermodynamic equilibrium
LP	Limb Profiler
LPCS	Land Product Characterization System
LSA	land surface albedo
LST	Land Surface Temperature
LUT	Look-Up Table
LWIR	Long Wavelength Infrared

M

MAUI	Job Scheduler by Cluster Resources, Inc
METOP	Meteorological Operational Satellite Programme of EUMETSAT
MHS	Microwave Humidity Sounder
MICROS	Monitoring Clear-sky Radiances for SST
MIRS	Microwave Integrated Retrieval System
MLS	Microwave Limb Sounder
MO	Metoffice in UK
MOBY	Marine Optical Buoy
MODIS	Moderate Resolution Imaging Spectro radiometer
MOST	Mission Operations Support Team
MSL	NOAA Multi-sensor Level
MW	Micro Wave?
MWIR	Medium Wave Infrared
MWR	Monthly Weather Review

N

NASA	National Aeronautics and Space Administration
NAVDAS	NRL Atmospheric Variational Data Assimilation
NAVDAS–AR	NRL Atmospheric Variational Data Assimilation – Accelerated Representer
NAVGEM	Navy Global Environmental Model
NCC	National Calibration Center
NCC	Near-Constant Contrast
NCDC	National Climate Data Center
NCEI	National Centers for Environmental Information
NCEP	National Centers for Environmental Prediction
NCWCP	NOAA Center for Weather and Climate Prediction
ND	Nadir profiler
NDE	NPP Data Exploitation
NDVI	Normalized Difference Vegetation Index
NESDIS	National Environmental Satellite, Data, and Information Service
NGAC	NOAA global aerosol component
NIR	Near Infrared

NIST	National Institute for Standards and Technology
NJO	NOAA JPSS Office
NM	Nadir Mapper
NOAA	National Oceanic and Atmospheric Adminstration
NP	Nadir Profiler
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	National Polar-orbiting Partnership
NPROVS	NOAA Products Validation System
NRL	Naval Research Laboratory
NRT	Near Real-Time
NSR	Normal Spectral Resolution
NUCAPS	NOAA Unique CrIS/ATMS Processing System
NWP	Numerical Weather Prediction
NWS	National Weather Service

O

OC	Ocean Color
OCI	Ocean Color Index
OLR	Outgoing Longwave Radiation
OMI	Ozone Monitoring Instruement
OMPS	Ozone Mapping and Profiler Suite
OPS	Operations
OSGS	Office of Satellite Ground services
OSPO	NESDIS' Office of Satellite and Product Operations
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis

P

PAR	Photosynthetically Available Radiation
PCT	Processing Coefficients Table
PEATE	Product Evaluation and Analysis Tools Element
PFM	Pre Flight Model
PL	Post-Launch

Q

QA	Quality Assurance
QAA	Quasi-Analytical Algorithm
QC	Quality Control
QF	Quality Flag
QH	Quasi-Horizontal
QPF	Quantitative Precipitation Forecast
QV	Quasi-Vertical

R

RAN	Re-Analysis
RDR	Raw Data Record
RHW	Robust Holt Winters Filter
RMSE	Root Mean Square Error
RSB	Reflective Solar Bands
RSDR	Reprocessed SDR
RSR	Relative Spectral Response
RT	Radiative Transfer

RT	Real Time
RTA	Totating Telescope Assembly
RTM	Radiative Transfer Model
RVS	Response Versus Scan Angle

S

S/C ATT&EPH	Spacecraft Attitude/Ephemeris
SBUV	Solar Backscatter Ultraviolet
SCDR	STAR Central Data Repository
SD	Snow Depth
SD	Solar Diffuser
SDR	Sensor Data Record
SDSM	Solar diffuser Stability Monitor
SDV	Standard Deviation
SI	International System of Units
SIP	Science Investigator-led Processing
SIPS	Science Investigator- led Processing System
SM	System Monitor?
SMCD	Satellite Meteorology and Climatology Division
SNO	Simultaneous Nadir Overpass
SNPP	Suomi National Polar-orbiting Partnership
SNR	signal-to-noise ratio
SOC	Satellite Operations Center
SOP	Standard Operating Procedures
SQL	Structured Query Language
SQUAM	SST Quality Monitor
SSEC	Space Science and Engineering Center
SSM	Scene Selection Module
SST	Sea Surface Temperature
STAR	Center for Satellite Applications and Research
SV	Space View
SW	Software
SWIR	Shortwave Infrared

T

TTC	terrain correction
TC	Total Column
TC	Tropical Cyclone
TDR	Temperature Data Record
TEB	Thermal Emissive Bands
TOC	Top-Of-Canopy
TOMRAD	Radiative Transfer Model
TOMS	Total Ozone Mapping Spectrometer
TRMM	Tropical Rainfall Measuring Mission
TSR	Truncation spectral resolution

U

UK	United Kingdom
UMD	University of Maryland
URL	Uniform Resource Locator
UTC	Universal Coordinated Time

UV	Ultraviolet
UW	University of Wisconsin

V

VALAR	Validation Archive
VCST	VIIRS Calibration Support Team
VF	Vertical Feature
VF	Vignetting Function
VI	Vegetation Index
VIIRS	Visible Infrared Imager/Radiometer Suite
VIS	Visible
VZA	Viewing Zenith Angle

W

WRF	Weather Research and Forecasting
WRS	Weather Reconnaissance Squadron
WUCD	Warm-up/Cool-down