NESDIS Snowfall Rate Product and Assessment in NWS Forecast Offices

July 18, 2018

Presented by:

Huan Meng[1], Kristopher White[2,3]

Team: Jun Dong[4], Cezar Kongoli[4], Ralph Ferraro[1]

[1]NOAA/NESDIS/Center for Satellite Applications and Research

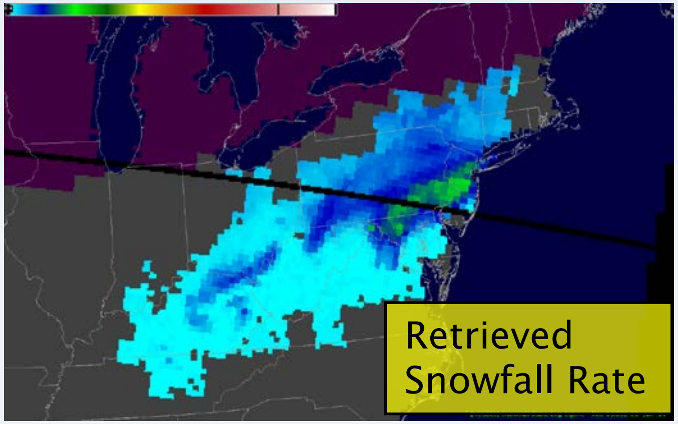
[2]NWS/Huntsville, AL Weather Forecast Office

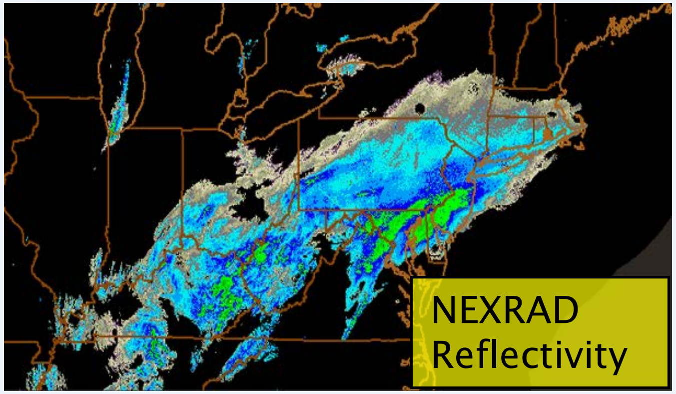
[3]NASA/MSFC/Short-term Prediction Research and Transition Center

[4]University of Maryland/ESSIC/Cooperative Institute for Climate and Satellites

Product Overview

- Water equivalent snowfall rate (SFR) estimate over global land
- SFR is generated from passive microwave sensors (ATMS, AMSU/MHS, SSMIS, GMI)
    - ✓ Conical or cross-track scanning radiometers
    - ✓ Frequencies used: 23 GHz – 183 GHz
- Nine satellites: S-NPP, NOAA-20, NOAA POES, EUMETSAT Metop, DMSP, NASA GPM
    - ✓ SFR in operation since 2012
    - ✓ S-NPP, POES and Metop SFR are operational
    - ✓ NOAA-20, DMSP and GPM will be transitioned to operation
- Eighteen snowfall rate estimates per day on average at mid-latitudes and more at high latitudes





Algorithm Overview

- SFR algorithm includes two main components
  - ✓ Snowfall detection (SD)
  - ✓ Snowfall rate estimation
- Snowfall Detection: Statistical algorithm (Kongoli et al., 2015, 2017)
- Snowfall Rate: Physically-based algorithm (Meng et al., 2017; Ferraro et al., 2018)

SD Algorithm

- Satellite-based module
- NWP model-based module
- Optimal combination of the two modules
- NWP model-based screening

SD – Satellite Module

- Coupled principal components and logistic regression model (Kongoli et al., 2015)

$$P = \frac{\exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ .... \ \beta_n X_n)}{1 + \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ .... \ \beta_n X_n))}$$

- Input data: High frequency channels above 88/89 GHz
- Three principal components for ATMS/MHS
- Model output is the probability of snowfall; preset thresholds for snowfall
- Training data sets are composed of matching satellite and ground snowfall observation data, Quality Controlled Local Climatology Data (QCLCD)

SD – Satellite Module

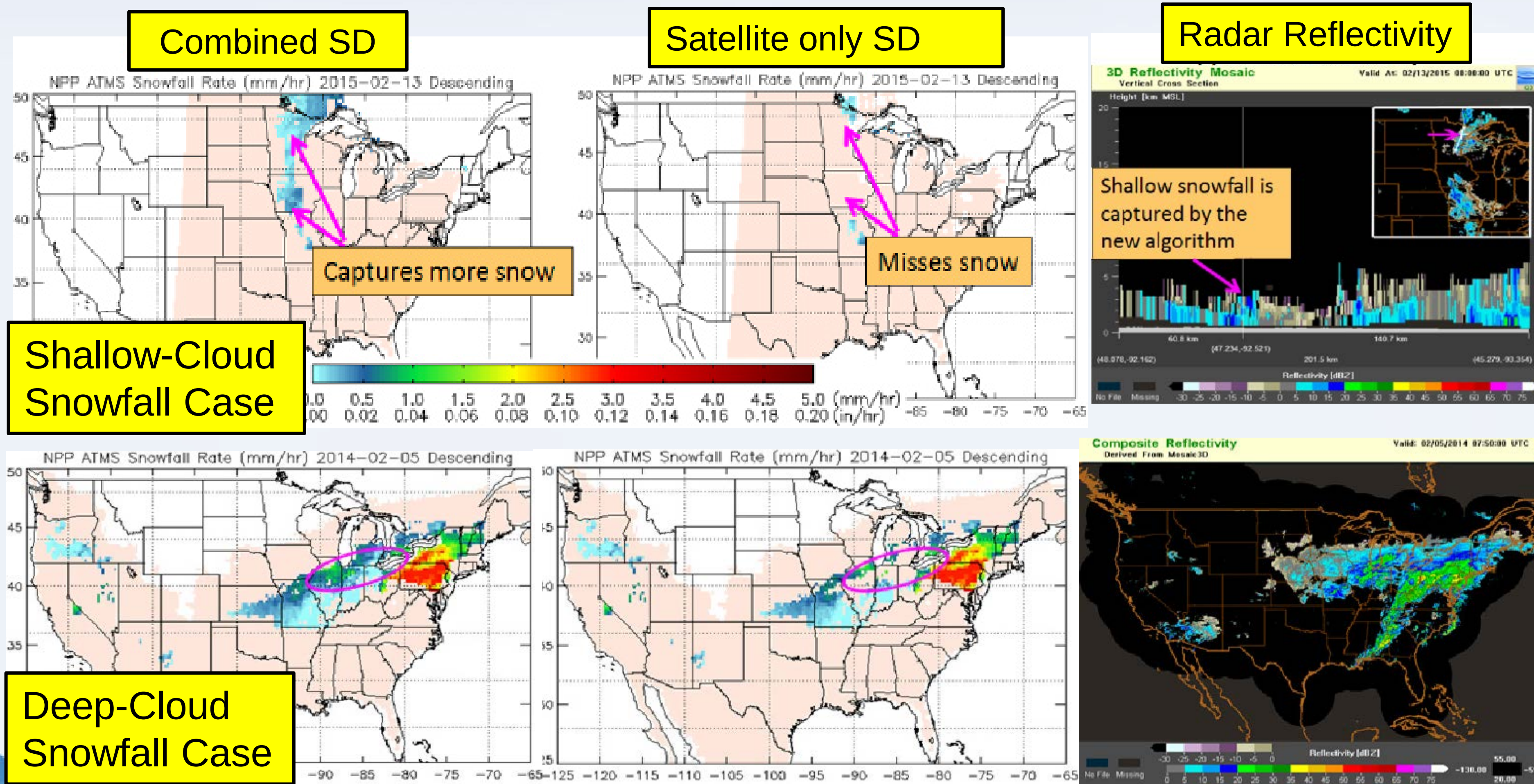
- Two temperature regimes: warm and cold
  - ✓ Defined with limb-corrected T_B53.6 GHz data
  - ✓ Satellite measurements exhibit different characteristics depending on atmospheric conditions: scattering signal dominates in relatively warm and moist atmosphere, emission signal dominates in cold and dry atmosphere or atmosphere with abundant supercooled cloud liquid droplets
  - ✓ No retrieval if limb corrected T_B53.6 GHz < 240 K; not enough water vapor to mask surface
- Two cloud thickness (CT) regimes
  - ✓ CT derived from NWP model data
  - ✓ Shallow (low and thin cloud layer) snowfall is much more challenging to detect than snowfall from thick clouds

Combined SD Algorithm

- Numerical Weather Prediction (NWP) model-based weather SD module
  - ✓ Logistic regression model
  - ✓ Input data: RH, T, V-Vel, CT
- The SD algorithm is an optimal combination of the satellite module and weather module (Kongoli et al., 2018)
- Screening
  - ✓ Relative humidity
  - ✓ Temperatures
  - ✓ CT

Combined SD Algorithm

- The combined SD algorithm improves detection of both shallow- and deep-cloud snowfalls



Snowfall Rate Algorithm

- Retrieve cloud properties with 1DVAR
- Derive ice water content (IWC)
- Compute ice particle fall velocity
- Derive SFR

SFR Algorithm

- 1D variational method
  - ✓ Forward simulation of T_B's with a radiative transfer model (RTM) (Yan *et al.*, 2008)

$$
\begin{vmatrix} \Delta I_w \\ \Delta D_e \\ \Delta \varepsilon_{23} \\ \Delta \varepsilon_{31} \\ \Delta \varepsilon_{88} \\ \Delta \varepsilon_{165} \\ \Delta \varepsilon_{176} \end{vmatrix} = \left| (A^T A + E)^{-1} A^T \right| \begin{vmatrix} \Delta T_{B23} \\ \Delta T_{B31} \\ \Delta T_{B88} \\ \Delta T_{B165} \\ \Delta T_{B176} \end{vmatrix}
$$

I_w: ice water path

D_e: ice particle effective diameter

ε_i: emissivity at 23, 31, 88/89, 165/157, and 183±7/190 GHz

T_{Bi}: brightness temperature at 23, 31, 88/89, 165/190, and 183±7 GHz

A: Jacobian matrix, derivatives of T_{Bi} *over* I_w, D_e, *and* ε_i

E: error matrix

  - ✓ Iteration scheme with ΔT_{Bi} thresholds
  - ✓ I_w and D_e are retrieved when iteration stops

SFR Algorithm

- Terminal velocity is a function of atmospheric conditions and ice particle properties, Heymsfield and Westbrook (2010):

$$v(D) = \frac{\eta R_e}{\rho_a D}$$

- Uncalibrated SFR (Meng et al., 2017):

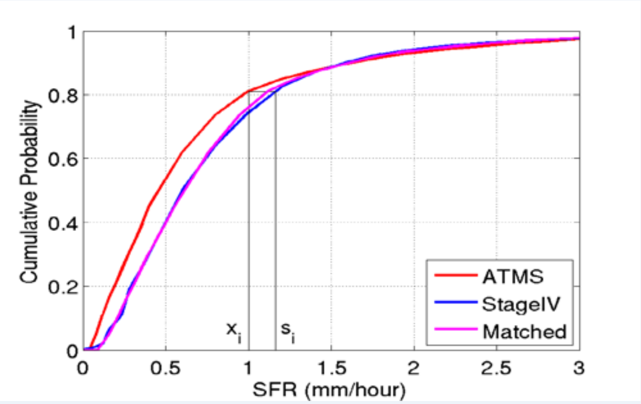
$$SFR_u = A \int_{D_{min}}^{D_{max}} D^2 e^{-D/D_e} \left[\left(1 + BD^{3/2}\right)^{1/2} - 1\right]^2 dD$$

$$A = \frac{I_c \delta_0^2 \eta}{24 \rho_w \rho_a D_e^4} \qquad B = \frac{8}{\delta_0^2 \eta} \sqrt{\frac{g \rho_a \rho_I}{3 C_0}}$$

- Equation solved numerically

SFR Calibration

- Calibration data is Stage IV precipitation analyses
  - ✓ Best snowfall rate data available: uses Multi-Radar Multi-Sensor (MRMS) precipitation data as input, incorporates gauge/model/satellite data, and applies human quality controls
  - ✓ Snowstorm data from two winter seasons (2015-2016)
  - ✓ CONUS coverage
- Histogram matching (Kidder and Jones, 2007):
  - ✓ CDF adjustment
  - ✓ Lease square method to achieve optimal overall agreement between SFR and StageIV CDFs



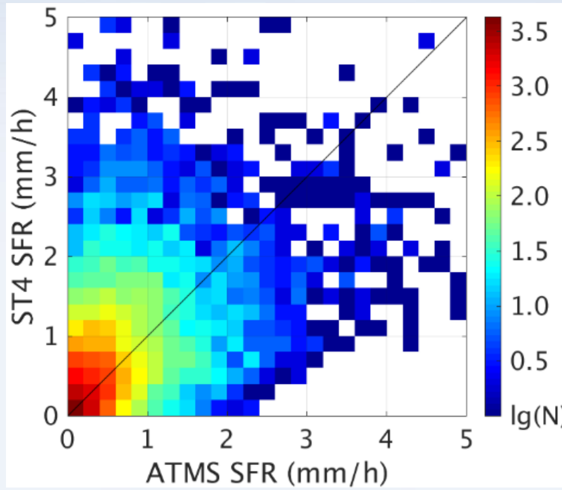
- SFR:

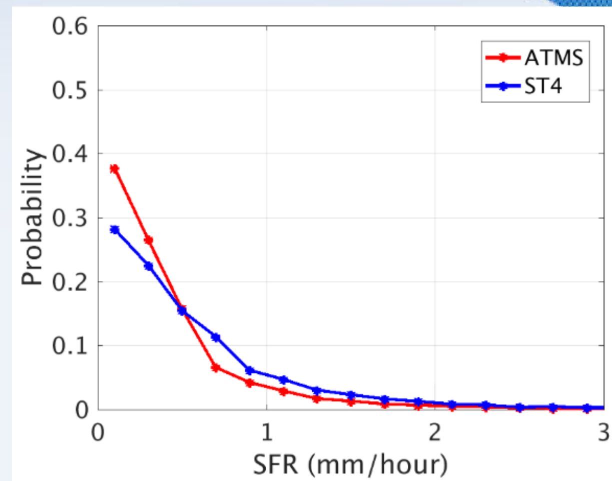
$$SFR = 1.5813\,SFR_u - 0.2236\,SFR_u^2 + 0.0216\,SFR_u^3$$

SFR Calibration

- **Before calibration**

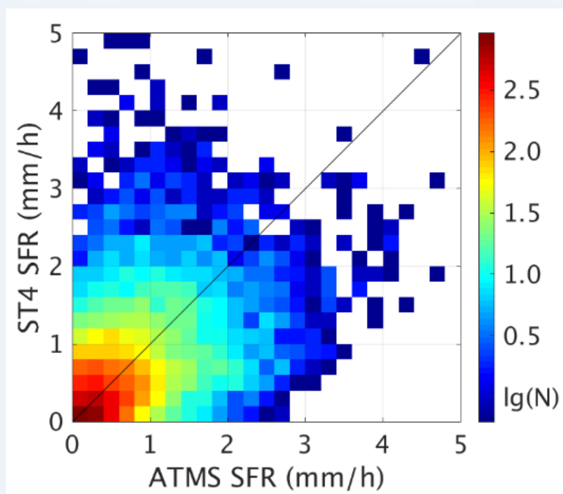
Corr. Coeff.	0.52
Accuracy (mm/hr)	-0.15
Precision (mm/hr)	0.63

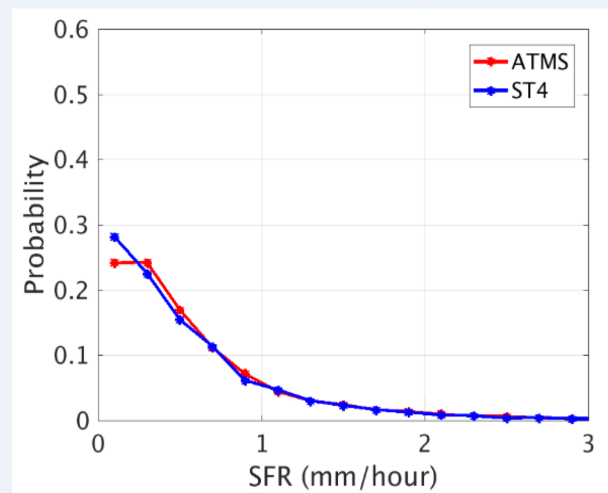




- **After calibration**

Corr. Coeff.	0.51
Accuracy (mm/hr)	-0.02
Precision (mm/hr)	0.64





SD Validation: Methodology

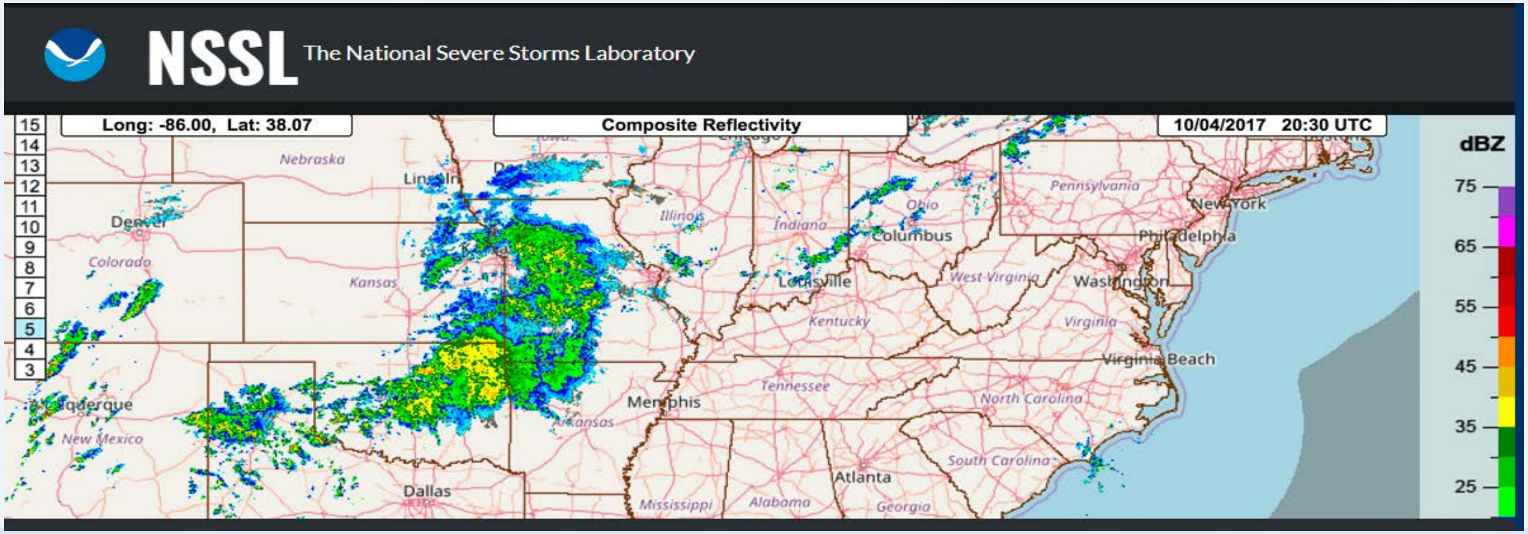
- Three-year validation dataset (2015-2017)
- Multi-Radar Multi-Sensor (MRMS) – ATMS Match-up
- In-situ – ATMS Match-up
- Over Continental US (MRMS and in-situ)
- Over Alaska (in-situ only)
- Validation Metrics

SD Validation Metrics

- Probability of Detection (POD) is the fraction of true snowfall retrieved
- False Alarm Rate (FAR) is the fraction of false snowfall retrieved
- Accuracy Rate is the fraction of correct snowfall and no-snowfall retrieved
- Heidke Skill Score (HSS) is the correct forecast relative to the chance forecast. A zero score indicates no skill. A negative score indicates forecast does worse than a chance forecast

MRMS – ATMS Match-up

- MRMS is a system with automated algorithms that quickly and intelligently integrate data streams from multiple radars, surface and upper air observations, lightning detection systems, and satellite and forecast models.
- MRMS pixels were collocated with ATMS FOVs. Calculated were fraction of precipitating ATMS FOV, fraction of snowing and raining FOV and an effective FOV snowfall rate (SFR). An ATMS FOV was classified as "snowing" for positive values of effective SFR and no-snowing for zero SFR values.



In-Situ – ATMS Match-up

- In-situ data: Quality Controlled Local Climatological Data (QCLCD)
  - ✓ Measurements include surface temperature, humidity, surface liquid precipitation and present weather
  - ✓ Present weather flag indicates if it is snowing, raining or no-precipitation
- Hourly weather observations were collocated with ATMS SFR/SD product
  - ✓ Nearest in-situ observation within 15 km to the ATMS FOV center and 30 minutes time off-set
  - ✓ An ATMS FOV was classified as snowing if the present weather was flagged as “snowfall” and not-snowing if the present weather was flagged as other than snowfall and accumulated gauge precipitation was equal to zero.

Results: vs MSMR (CONUS)

Year	Accuracy	POD (%)	FAR (%)	HSS
2015	0.92	53	4	0.47
2016	0.90	55	7	0.43
2017	0.88	51	8	0.40
Combined	**0.90**	**53**	**6**	**0.43**

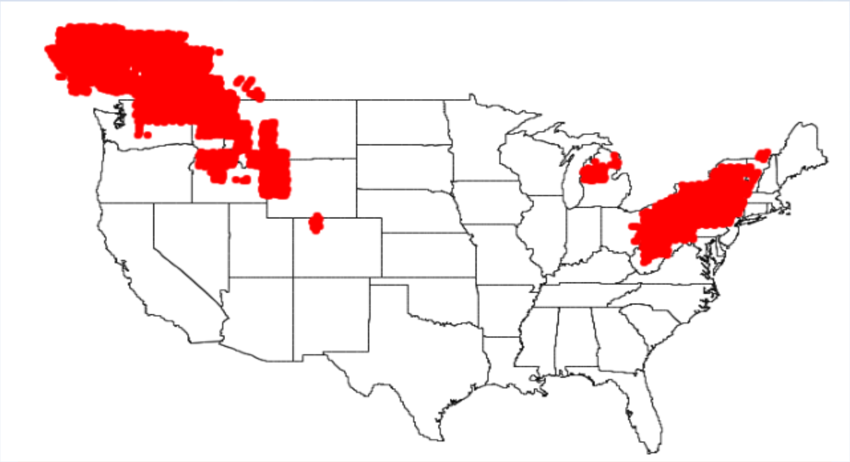
Results: vs in-situ (CONUS)

Year	Accuracy	POD (%)	FAR (%)	HSS
2015	0.90	50	7	0.42
2016	0.89	53	8	0.42
2017	0.88	50	8	0.40
Combined	**0.88**	**51**	**8**	**0.40**

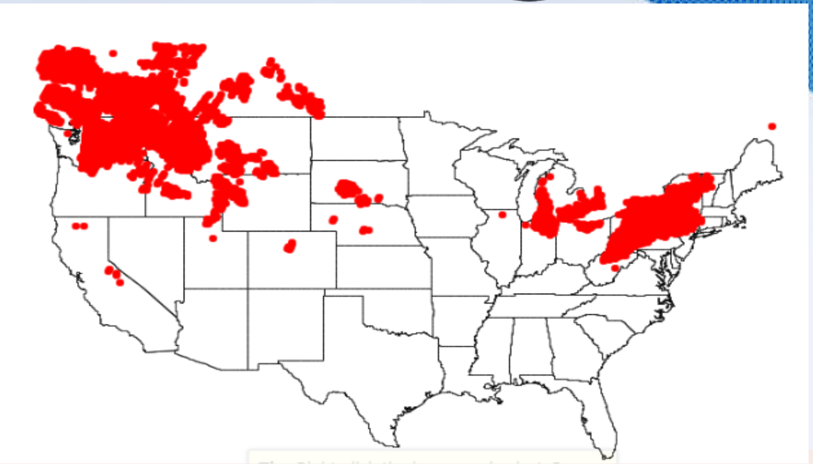
Results: vs in-situ (Alaska)

Year	Accuracy	POD (%)	FAR (%)	HSS
2015	0.85	45	9	0.39
2016	0.87	47	10	0.38
2017	0.85	47	11	0.35
Combined	**0.86**	**46**	**10**	**0.37**

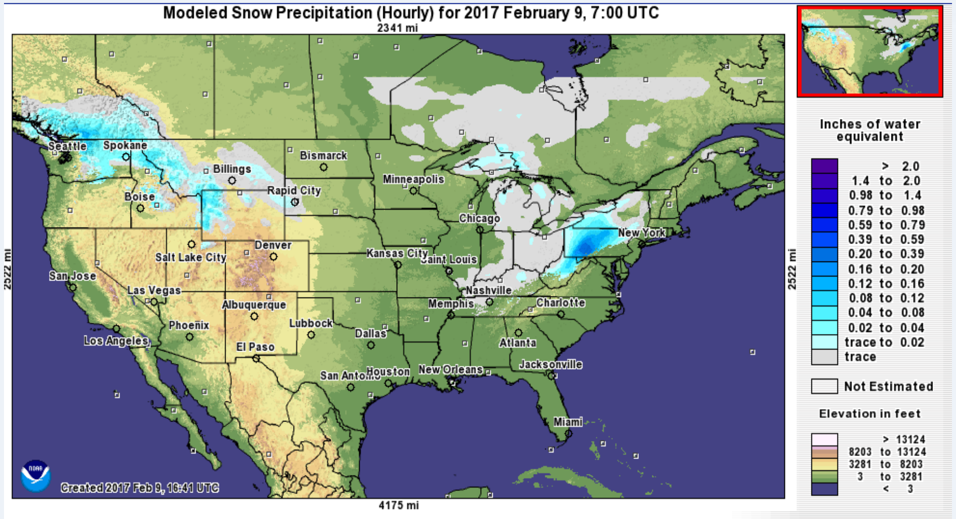
Comparisons with MRMS and NOHRSC



ATMS – 20170209: Descending



MRMS – 20170209: Descending



NOAA's NOHRSC Snow Analysis

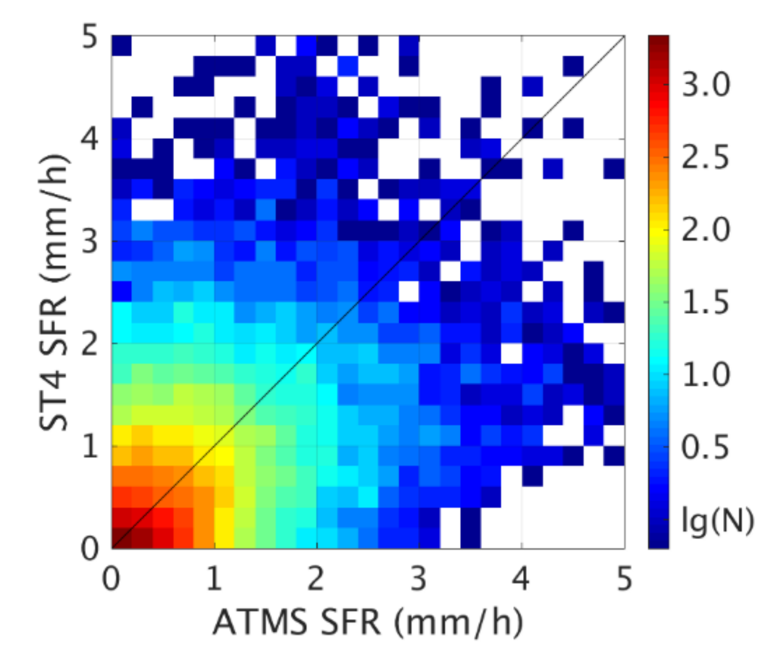
National Operational Hydrologic Remote Sensing Center (NOHRSC) Snowfall Analysis is a unified snowfall analysis from several high-resolution operational forecast model precipitation data sets

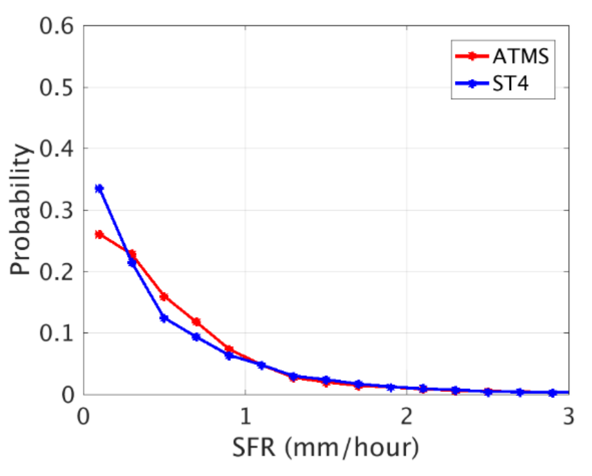
SFR Validation: Methodology

- **Validation data**
  - ✓ Stage IV (hourly, 4 km) data from winter 2016-2017, over 92K points, CONUS
  - ✓ MRMS (instantaneous, 0.01 degree) data from winter 2016-2017, over 160K points, CONUS
- **Validation method**
  - ✓ Statistics from collocated instantaneous SFR and validation data
  - ✓ Statistics from collocated seasonal-average SFR and validation data
- **Validation metrics**
  - ✓ Correlation coefficient
  - ✓ Bias
  - ✓ RMS
  - ✓ Histogram comparison
  - ✓ Scatter plot

SFR Validation: vs. Stage IV

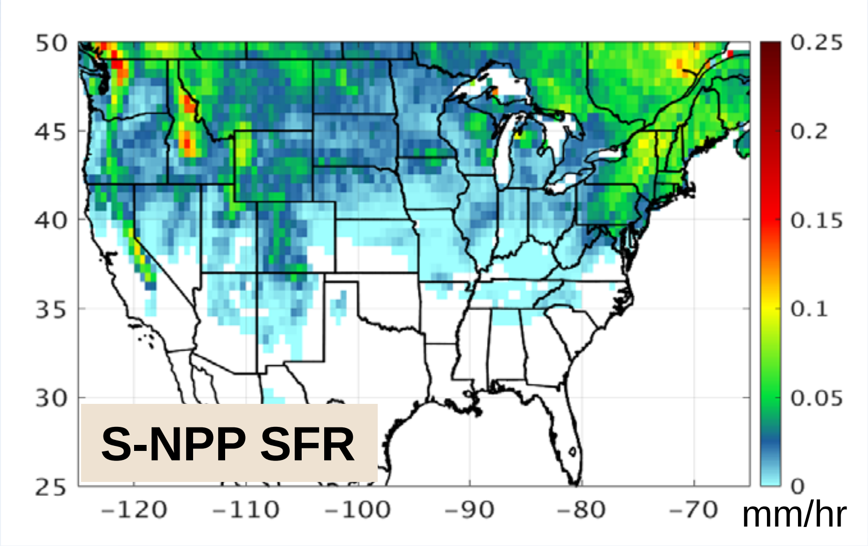
- Collocate Stage IV with S-NPP ATMS SFR through convolution to ATMS footprint

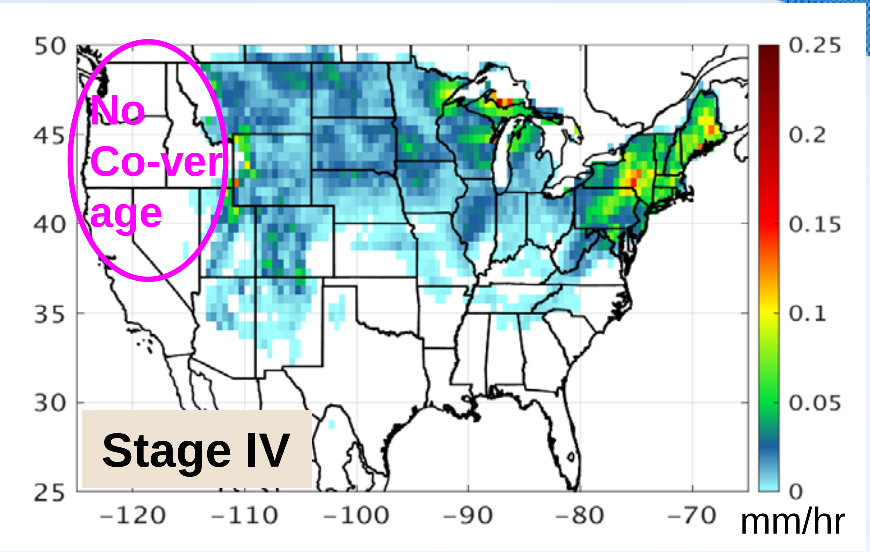


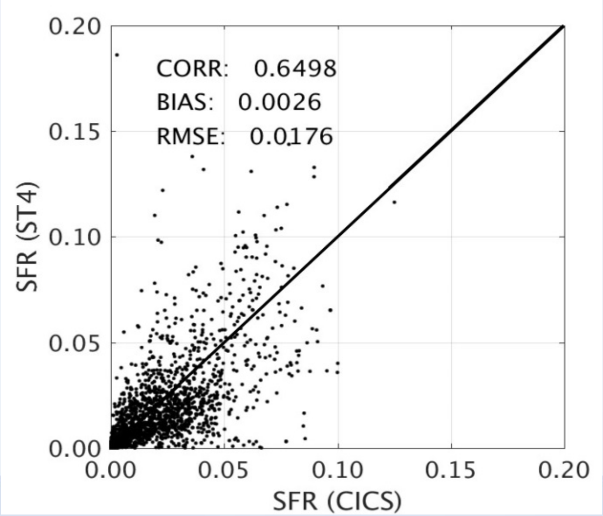


Corr. Coeff.	Bias (mm/hr)	RMS (mm/hr)
0.50	0.06	0.74

Seasonal Average (Jan – Mar, 2017)



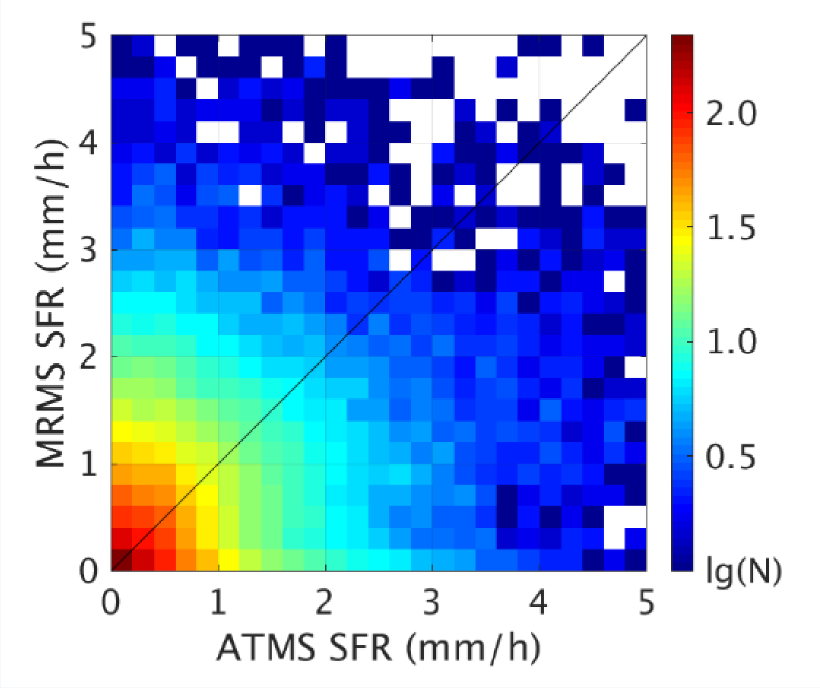


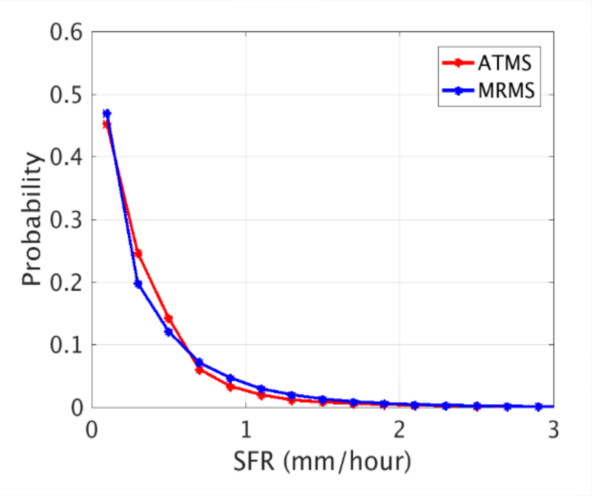


Corr. Coeff.	Bias (mm/hr)	RMS (mm/hr)
0.65	0.00	0.02

SFR Validation: vs. MRMS

- Collocate MRMS with S-NPP ATMS SFR through convolution to ATMS footprint

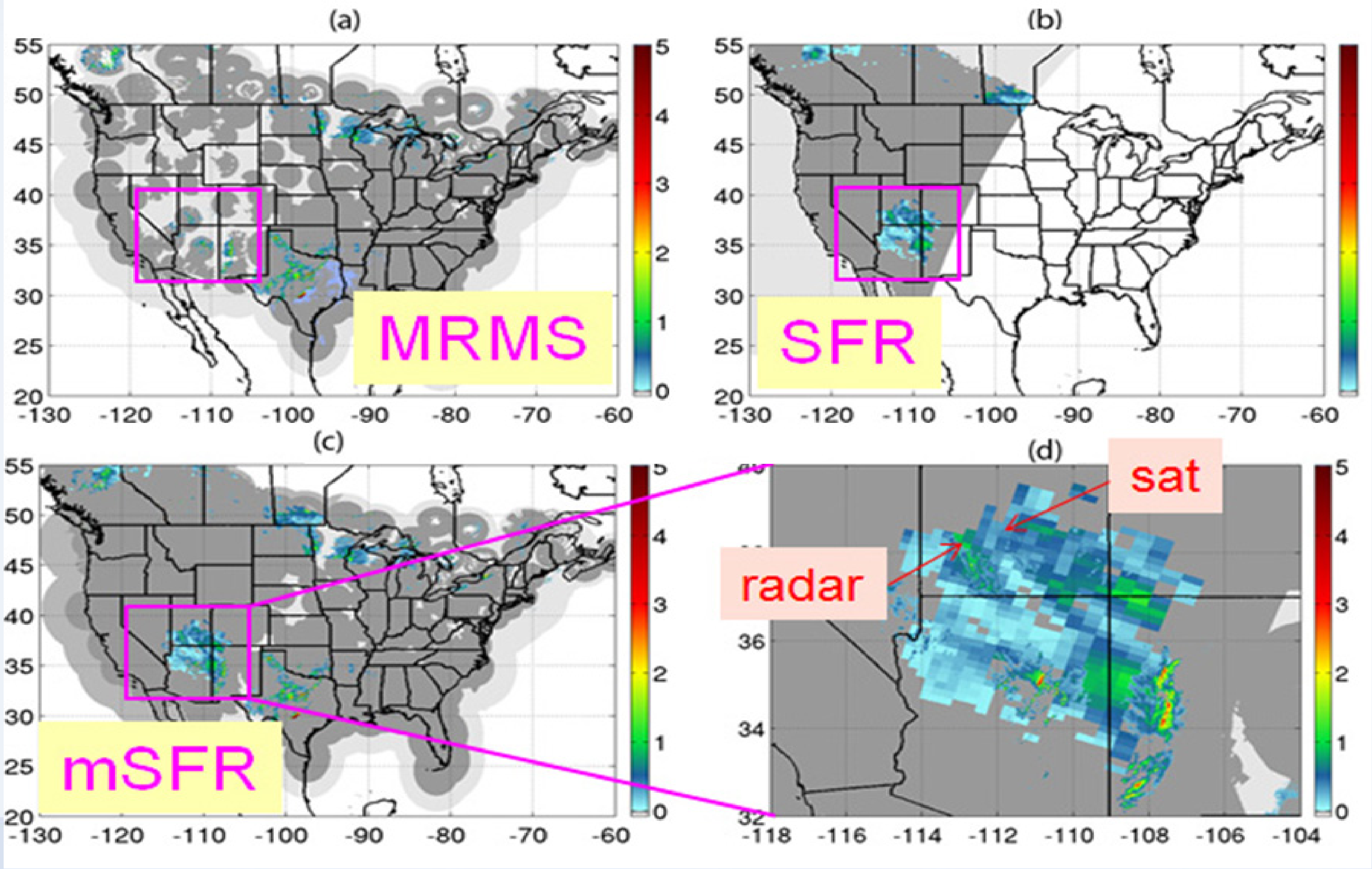




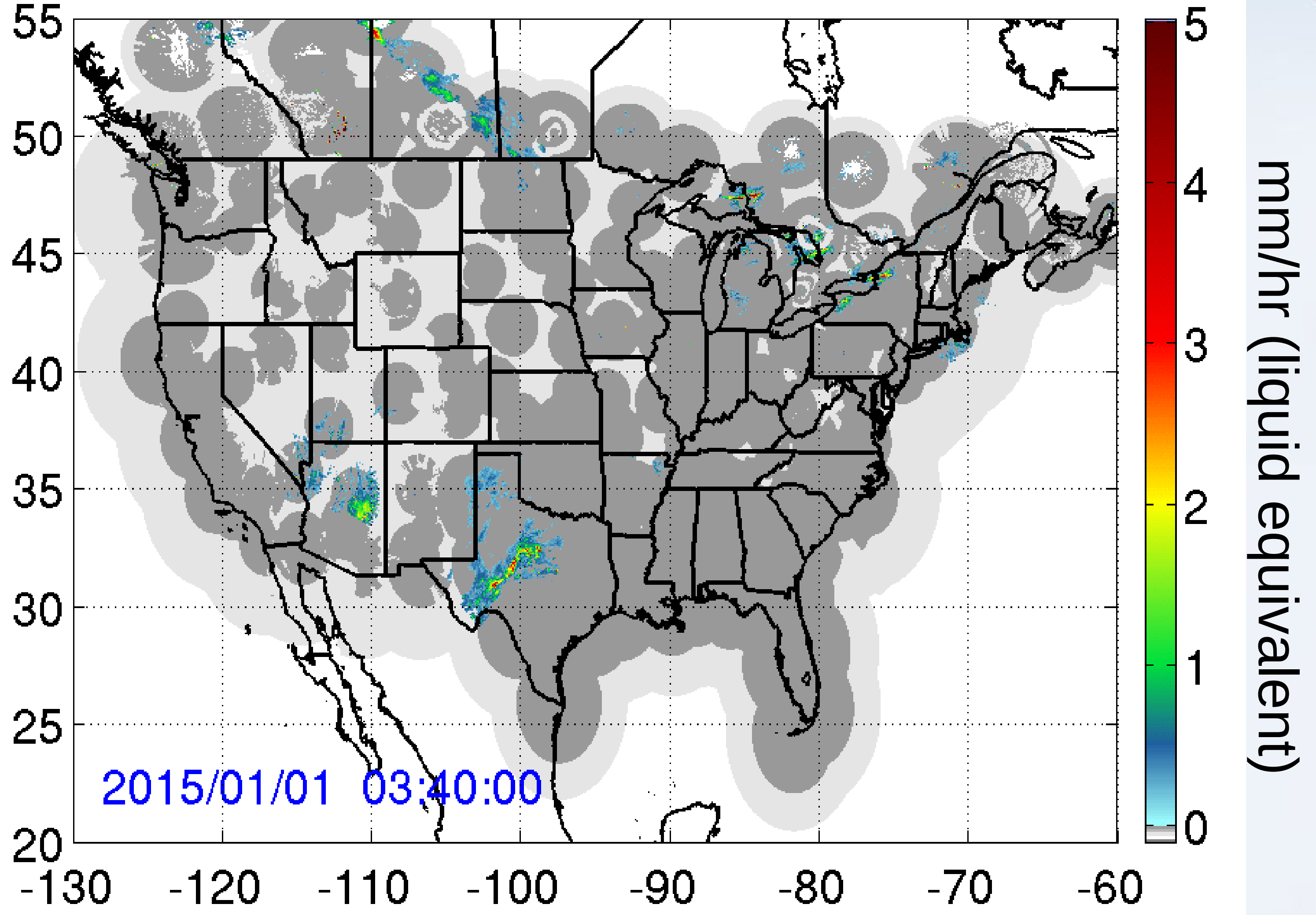
Corr. Coeff.	Bias (mm/hr)	RMS (mm/hr)
0.43	-0.01	0.55

Radar and Satellite Merged SFR (mSFR)

- Merging MRMS instantaneous snowfall product and SFR from 8 satellites provides better spatial and temporal (10-min) coverage and ability to loop the data (mSFR); fills radar gaps especially in western U.S.

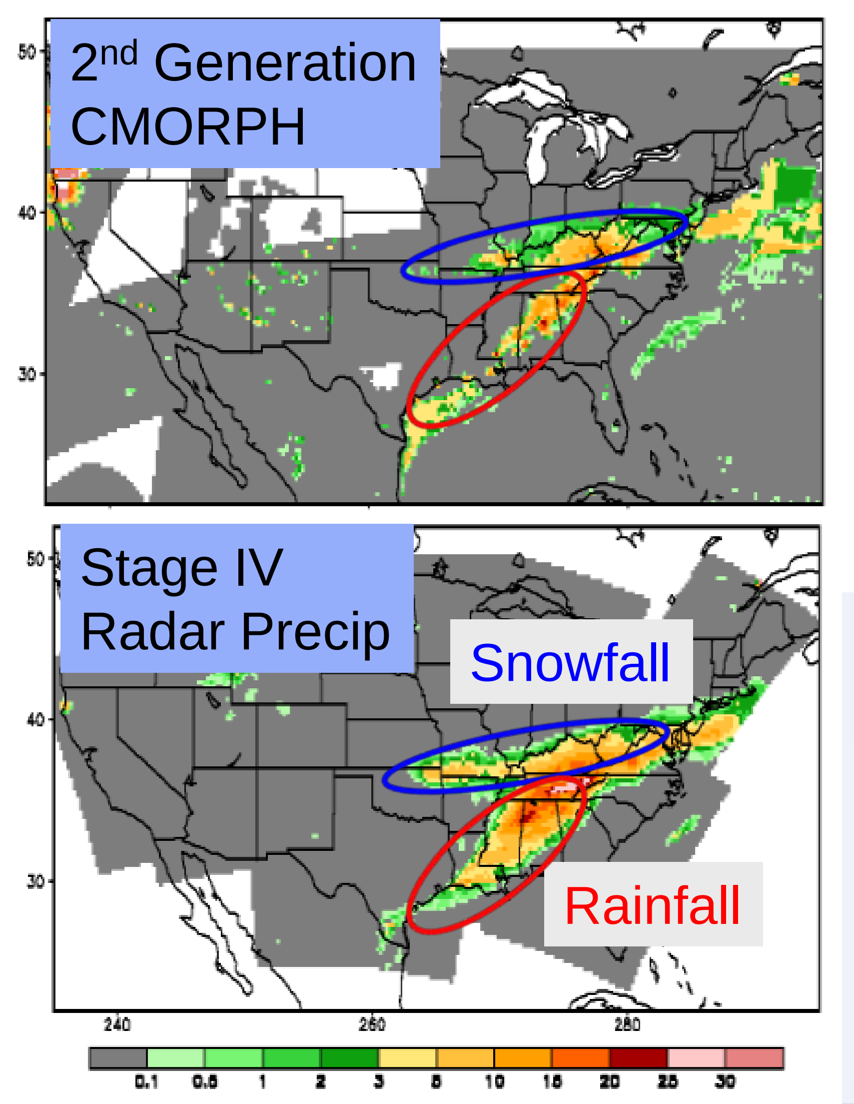


Radar and Satellite Merged SFR (mSFR)



SFR Applications

- Hydrology
  - ✓ Global blended precipitation analysis: Most blended satellite precipitation datasets do not include satellite snowfall rate product – use other data sources (model, ground observations, etc.)
  - ✓ SFR is used in CMORPH, a NOAA global blended precipitation analysis product with wide-ranging applications
- Weather Forecasting
  - ✓ Support situational awareness
  - ✓ Fill in radar gaps: mountainous area, e.g. western U.S., and remote regions
- Cryosphere
  - ✓ Snow cover
  - ✓ Snow depth



(Xie and Joyce, NOAA/NCEP/CPC)

Future Plans

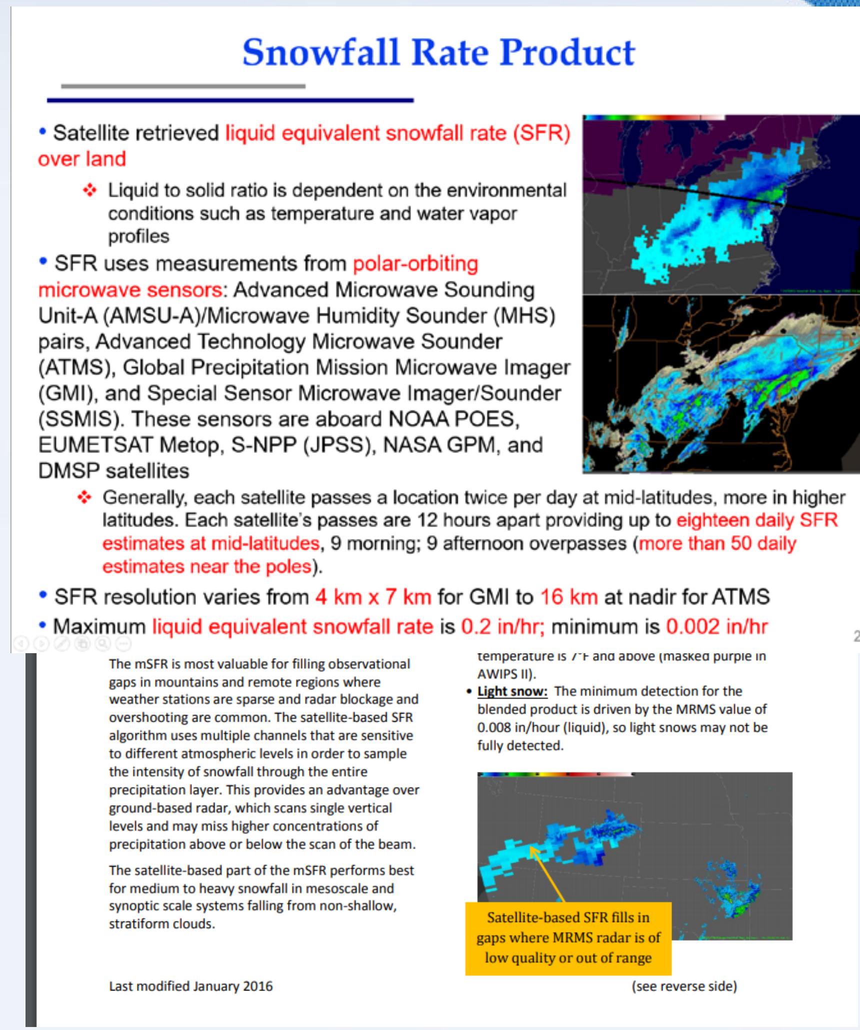
- SFR algorithms enhancement
- NOAA-20 SFR development, calibration and validation
- Transition NOAA-20 SFR to operation
- Transition GPM and DMSP SFR to operation
- Develop Metop-C SFR algorithm

NESDIS SFR 2018 Assessment

- **JPSS PGRR Project Milestone**
  - ✓ Leads: NASA SPoRT (POC: Kris White), NESDIS/STAR (POC: Huan Meng)
  - ✓ Support team: Algorithm developers from NESDIS/STAR and CICS-MD (J. Dong, C. Kongoli, and R. Ferraro)
  - ✓ Assessment period: January 2, 2018 – March 31, 2018
- **Product**
  - ✓ Existing sensors: ATMS and AMSU/MHS snowfall rate (SFR)
  - ✓ New sensors: SSMIS (DMSP: F16, F17) and GMI (NASA GPM)
    - – Available for CONUS (NWS ABQ) throughout, AK after March 12^{th}
  - ✓ SFR and merged SFR (utilizes MRMS derived precipitation)
  - ✓ Improved snowfall detection and snowfall rate algorithms
- **Goals:** Determine operational utility in the forecaster environment as it relates to:
  - ✓ Temporal and spatial resolution of data/imagery
  - ✓ Sufficient accuracy of snowfall detection and rates for operational purposes, especially with new measurements from SSMIS and GMI
  - ✓ Filling radar gaps
  - ✓ Tracking snowfall rate maxima
  - ✓ Determine areas where cloud seeding may be occurring ahead of falling precipitation
- **Active Participating NWS Offices:**
  - ✓ Albuquerque, NM
  - ✓ Juneau, AK
  - ✓ Anchorage, AK

Training

- Quick Guides
  - ✓ Available for both CONUS and Alaska
  - ✓ Separate QG to address the merged SFR product
- PowerPoint training file



Snowfall Rate Product

- Satellite retrieved liquid equivalent snowfall rate (SFR) over land
  - Liquid to solid ratio is dependent on the environmental conditions such as temperature and water vapor profiles
- SFR uses measurements from polar-orbiting microwave sensors: Advanced Microwave Sounding Unit-A (AMSU-A)/Microwave Humidity Sounder (MHS) pairs, Advanced Technology Microwave Sounder (ATMS), Global Precipitation Mission Microwave Imager (GMI), and Special Sensor Microwave Imager/Sounder (SSMIS). These sensors are aboard NOAA POES, EUMETSAT Metop, S-NPP (JPSS), NASA GPM, and DMSP satellites
  - Generally, each satellite passes a location twice per day at mid-latitudes, more in higher latitudes. Each satellite's passes are 12 hours apart providing up to eighteen daily SFR estimates at mid-latitudes, 9 morning; 9 afternoon overpasses (more than 50 daily estimates near the poles).
- SFR resolution varies from 4 km x 7 km for GMI to 16 km at nadir for ATMS
- Maximum liquid equivalent snowfall rate is 0.2 in/hr; minimum is 0.002 in/hr

2

The mSFR is most valuable for filling observational gaps in mountains and remote regions where weather stations are sparse and radar blockage and overshooting are common. The satellite-based SFR algorithm uses multiple channels that are sensitive to different atmospheric levels in order to sample the intensity of snowfall through the entire precipitation layer. This provides an advantage over ground-based radar, which scans single vertical levels and may miss higher concentrations of precipitation above or below the scan of the beam.

The satellite-based part of the mSFR performs best for medium to heavy snowfall in mesoscale and synoptic scale systems falling from non-shallow, stratiform clouds.

temperature is 7°F and above (masked purple in AWIPS II).

- **Light snow:** The minimum detection for the blended product is driven by the MRMS value of 0.008 in/hour (liquid), so light snows may not be fully detected.

Satellite-based SFR fills in gaps where MRMS radar is of low quality or out of range

Last modified January 2016

(see reverse side)

Getting Data into AWIPS

- Data need to be accessible via standard platforms (i.e., AWIPS)
- Ingest instructions for SFR data were created and provided to WFOs
- Data ingest via Local Data Manager

Title: Instructions for Ingesting the NESDIS Snowfall Rate product in AWIPS instructions included for DAM Addons configuration
Date: Dec 15, 2017
AWIPS II Ver.: 17.1.4
SPoRT Contacts: Kris White (kris.white@noaa.gov)
Matt Smith (matthew.r.smith@nasa.gov)

Please note: There are many other data sets which SPoRT transfers to users. Depending on the DAM ADDons installation, or if you're a current SPoRT products user, then you may already see other SPoRT data sets and products in your AWIPS, or you may potentially want other SPoRT data sets. However, these instructions are just meant to address the ingest of the NESDIS Snowfall Rate data/products. If you have any questions or issues during the ingest process, please contact me (kris.white@noaa.gov). Thanks!

######################
* EDEX CONFIG

Perform the following changes on your EDEX servers (dx3 and dx4).

NOTE: I may need to address #1 below for DAM Addons config. This is also there in Dam-Addons.

1.) Allow ingest of the data files by modifying the regionalSat distribution file (/awips2/edex/data/utility/common_static/site/<site ID>/distribution/regionalsat.xml). If this file doesn't exist, first copy it from base (/awips2/edex/data/utility/common_static/base/distribution/regionalsat.xml). See the included edex/regionalsat.xml.snippet file for example entries. Include these lines in the file. Note that these entries should be encapsulated by the <requestPatterns> tags. Note: For AK users, the mSFR product is not available for your area (this is the merged MRMS/SFR product).

If you have the DAM-Addons configuration, then go to step 2a below and then skip 2b. If you DO NOT have the DAM Addons config, then go to step 2b.

2a.) Since you DO have the DAM-Addons config, you'll need to add creatingEntities.xml and physicalElements.xml files to the following location:

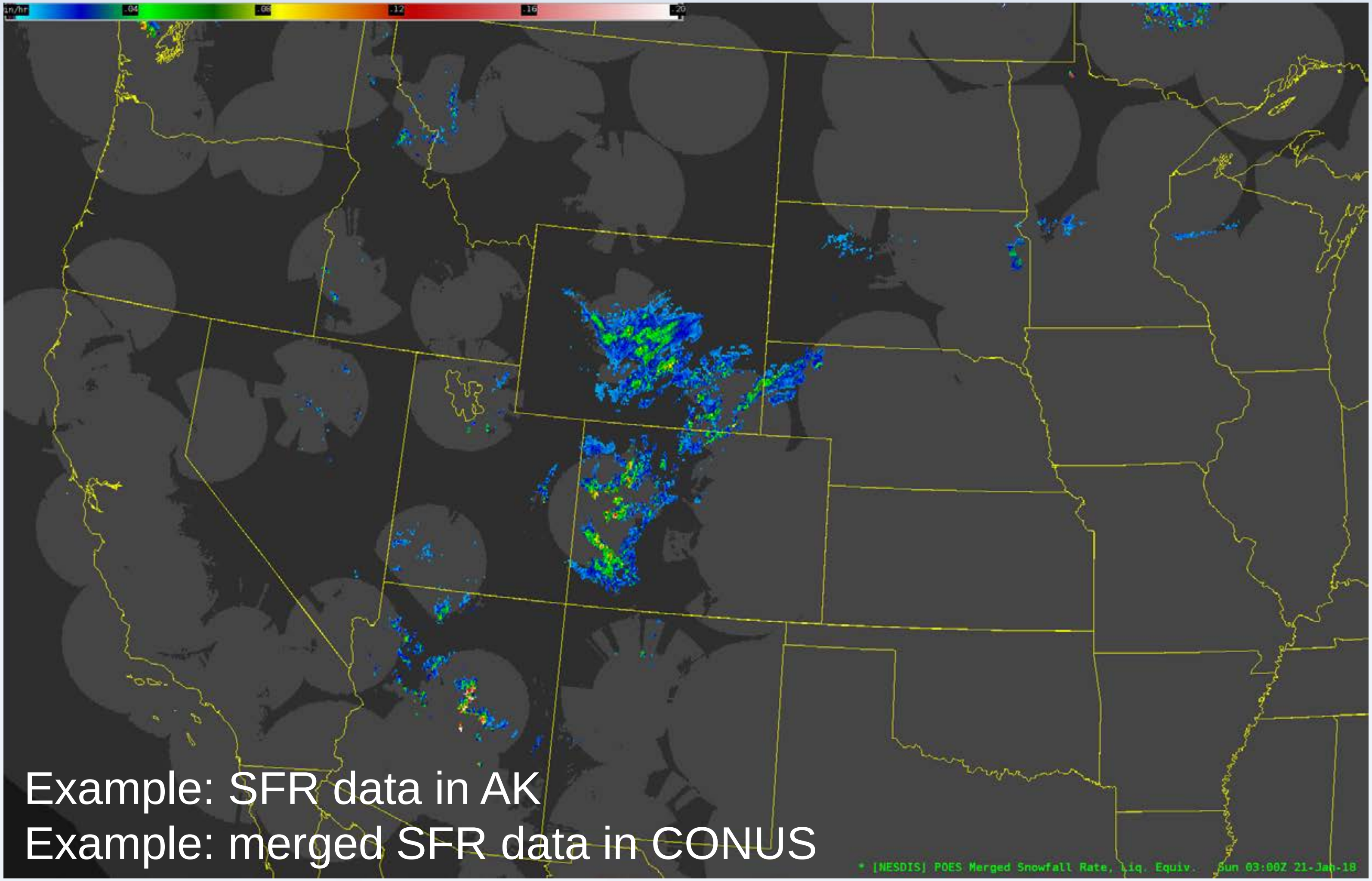
/localapps/runtime/DAM-Config/SITE/regsat/Common/edex_static/satellite/regionalsat

You may need to create the directory path if it does not exist. Only the necessary SFR entries are included in the included creatingEntities.xml.snippet and physicalElements.xml.snippet files. Note that the entries in both files should be encapsulated by the <map> tags.

At this time, rerun the install package DataAddonsManager.py

2b.) Since you DO NOT have the DAM-Addons config, you'll need to add the provided snippets in edex/physicalElements.xml.snippet and edex/creatingEntities.xml.snippet to the associated files. These files are found in… /awips2/edex/data/utility/edex_static/site/<site

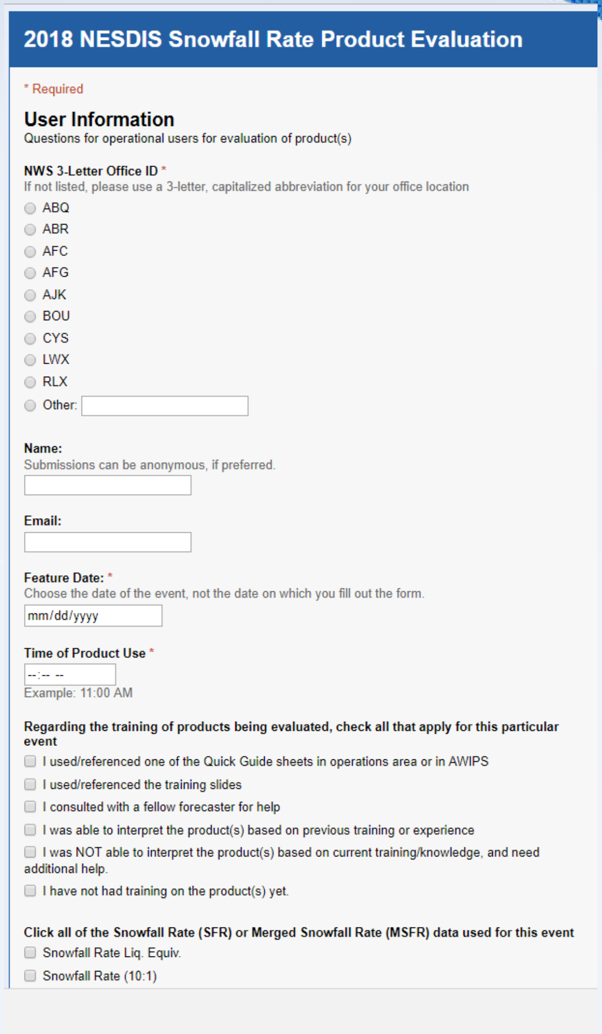
SFR Data in AWIPS



Example: SFR data in AK
Example: merged SFR data in CONUS

Feedback Methodology

- Feedback primarily obtained via survey
  - ✓ Office, name and contact, date/time of product use, training, product(s) used
  - ✓ Product impact and forecaster confidence
  - ✓ Overall product utility
  - ✓ Used for which operational challenges?
  - ✓ Product issues/problems
  - ✓ Comments
- Email
- Webinar



2018 NESDIS Snowfall Rate Product Evaluation

* Required

User Information

Questions for operational users for evaluation of product(s)

NWS 3-Letter Office ID *

If not listed, please use a 3-letter, capitalized abbreviation for your office location

- ○ ABQ
- ○ ABR
- ○ AFC
- ○ AFG
- ○ AJK
- ○ BOU
- ○ CYS
- ○ LWX
- ○ RLX
- ○ Other:

Name:

Submissions can be anonymous, if preferred.

Email:

Feature Date: *

Choose the date of the event, not the date on which you fill out the form.

mm/dd/yyyy

Time of Product Use *

--:-- --

Example: 11:00 AM

Regarding the training of products being evaluated, check all that apply for this particular event

- ☐ I used/referenced one of the Quick Guide sheets in operations area or in AWIPS
- ☐ I used/referenced the training slides
- ☐ I consulted with a fellow forecaster for help
- ☐ I was able to interpret the product(s) based on previous training or experience
- ☐ I was NOT able to interpret the product(s) based on current training/knowledge, and need additional help.
- ☐ I have not had training on the product(s) yet.

Click all of the Snowfall Rate (SFR) or Merged Snowfall Rate (MSFR) data used for this event

- ☐ Snowfall Rate Liq. Equiv.
- ☐ Snowfall Rate (10:1)

SFR Assessment Web Portal

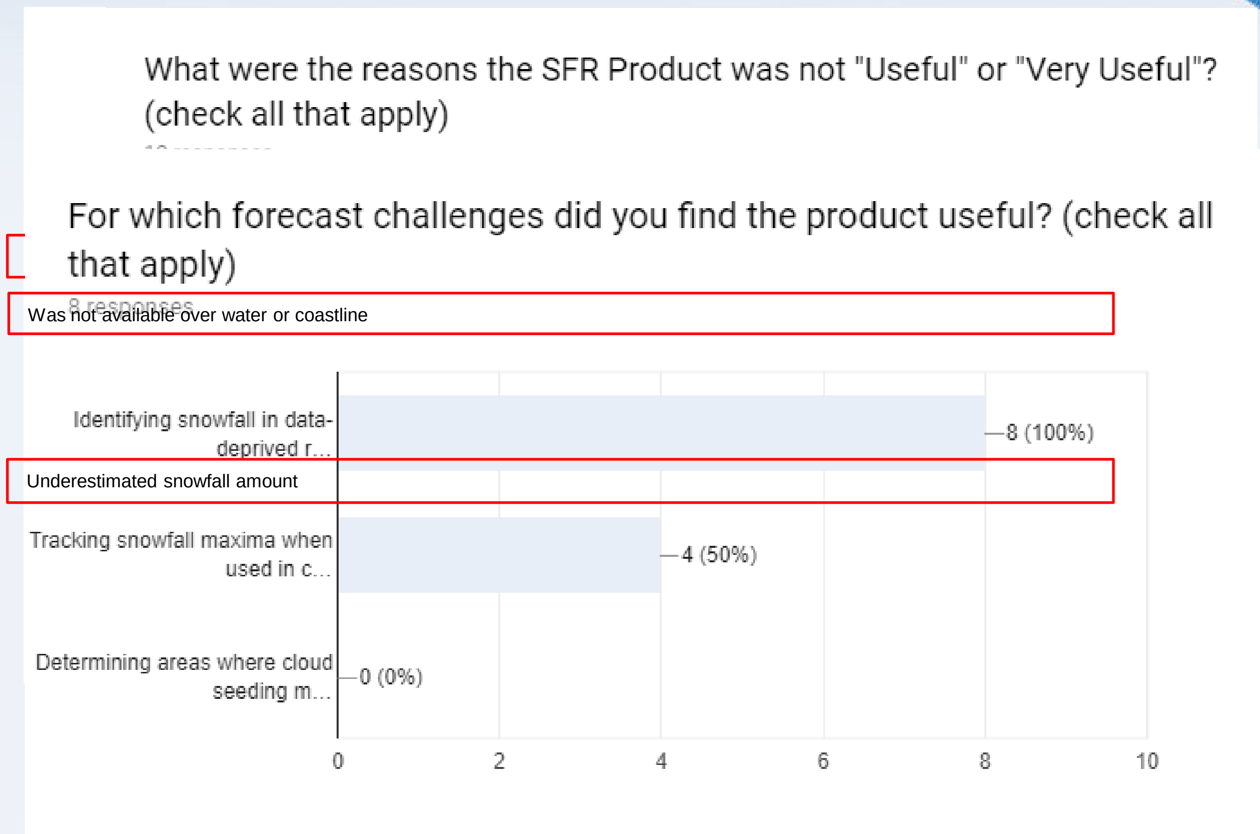
- Web portal
  - ✓ Survey access
  - ✓ Training
  - ✓ SPoRT social media
  - ✓ SPoRT NWS Chat Room

Assessment Results

- 15 survey responses received from the three different offices during the Jan-Mar period
- 8 email discussions
- 1 webinar
  - ✓ Hosted by NWS Albuquerque

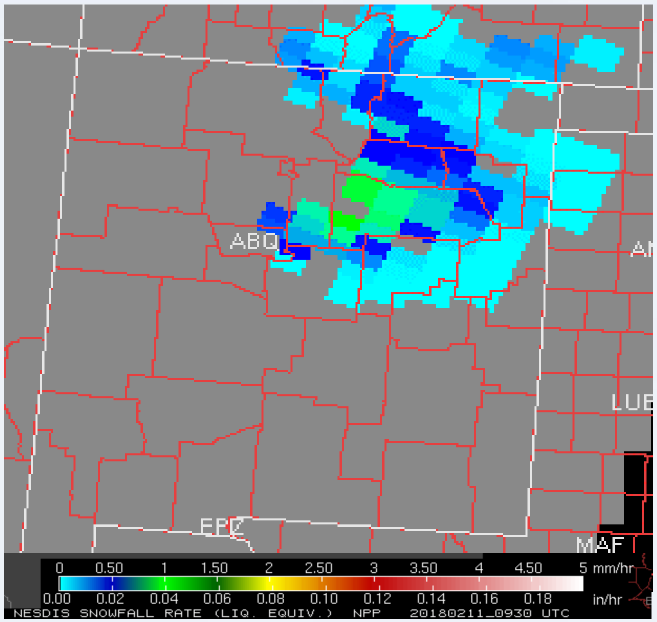
Assessment Results

- Training
- Product usage
- Goals
  - ✓ Data resolution
  - ✓ Data accuracy
  - ✓ Assessing utility

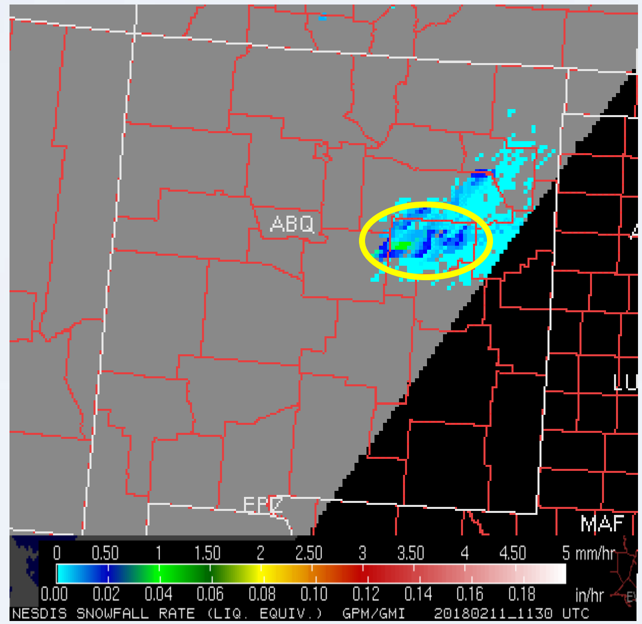


Resolution of Data/Imagery

Albuquerque, NM WFO: "… *The snowfall rate maximums in the higher resolution satellite passes were more accurate in location and intensity than the lower resolution imagery when compared to composite reflectivity values on radar. The additional number of satellite passes also made the product more useful and improved gaps in coverage compared to the assessment last year.*"



SFR Liquid Equivalent from Suomi-NPP, 0930 UTC 11 Feb 2018



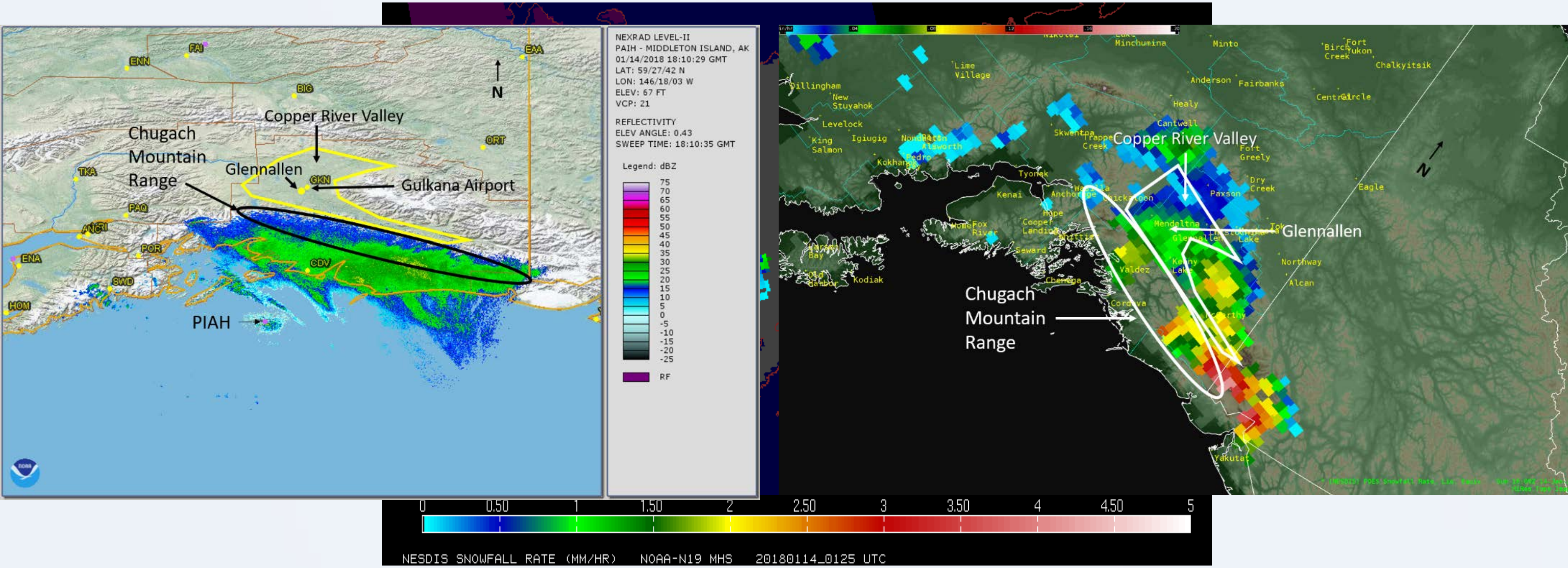
SFR Liquid Equivalent from GMI, 1130 UTC 11 Feb 2018

This information received from the Albuquerque, NM NWS office is the type of feedback that helps to address specific questions for product developers.

This band of snowfall had moved eastward and dissipated some during the 0930 to 1130 UTC period. During the assessment, the higher-resolution SFR data from GMI consistently indicated less snowfall coverage, but further testing and algorithm development is necessary. Nevertheless, the SFR data from GMI showed snowfall in Guadalupe County where radar indicated no snowfall (yellow circle).

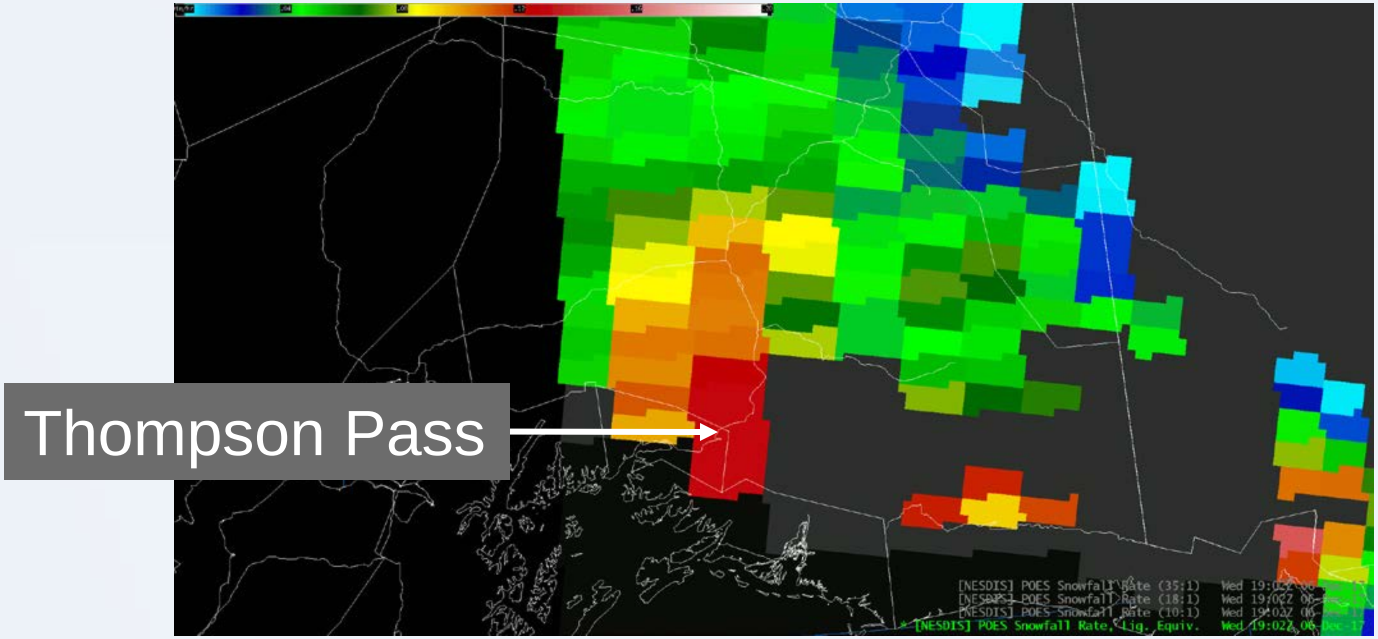
Filling Radar Gaps

Anchorage, AK WFO: *“This product has been especially useful in the Copper River Basin, an area where we have no radar imagery and very few surface observations (ASOS/Mesonet/Snotel). Not only does it give us an idea of where it is precipitating, but helps verify model performance in a location where they really struggle with qpf [quantitative precipitation forecasts] and where there can be wildly different model forecasts for precipitation. In this case, I was able to use the SFR product to help figure out which guidance was verifying the best and lean toward that solution for the new forecast.”*



Accuracy of Snowfall Detection/Rates

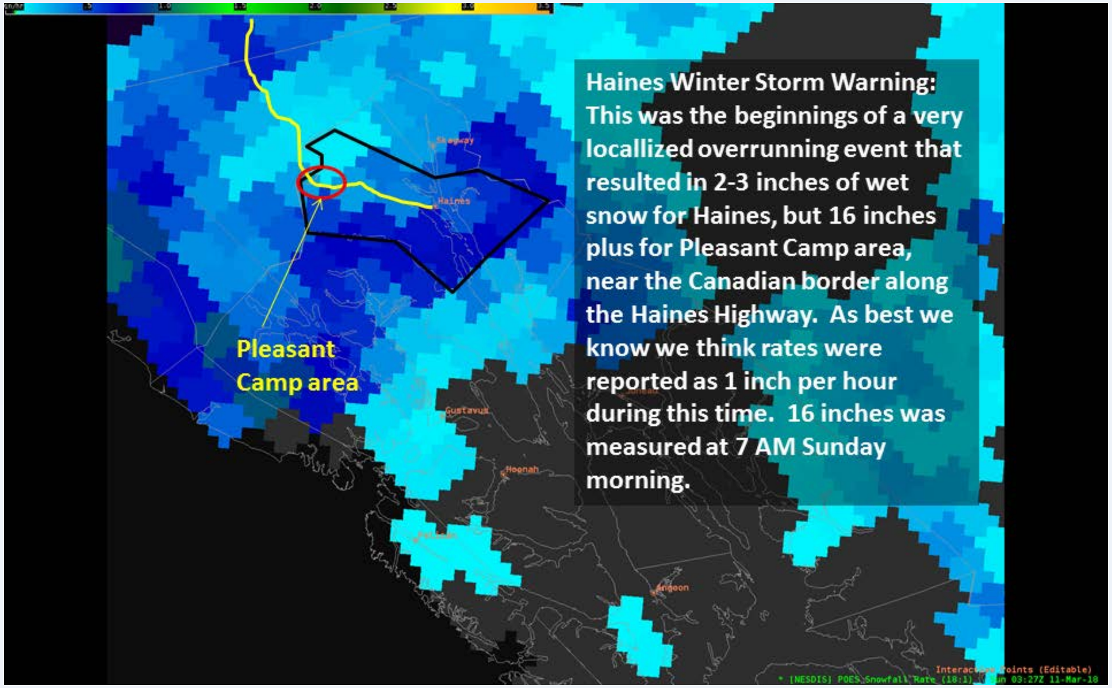
Anchorage, AK WFO: “*The SFR product did a great job of accurately depicting where the heaviest snow was falling in northeast Prince William Sound (Valdez/Thompson Pass) and across the Copper River Basin. Thompson Pass observed 15" of snow in a 90 minute period and 40" of snow in 12 hours. These products helped define the area over which the heaviest snow was falling. It was underdone on the snow rates, but did show a large area of 0.15"/hr liquid equiv.*”



Images provided by Shaun Baines, NWS Anchorage

Accuracy of Snowfall Detection/Rates

Juneau, AK WFO: "*We experienced another heavy snow event over local portions of Southeast Alaska from late Saturday afternoon through early Sunday afternoon. We still do not have a final total, but it appears that the "Pleasant Camp" area along the Haines Highway near the Canadian border received 16 plus inches of snow… Overall, I think the SFR could help us validate a winter storm warning we had in effect that was not supported by guidance. We suspect that the 0.3 - 0.7 inches per hour may have undercounted some of the snow rates. But we were pleased that it was indicated in the area. But it may be the more accurate rates were slightly displaced to the south.*"

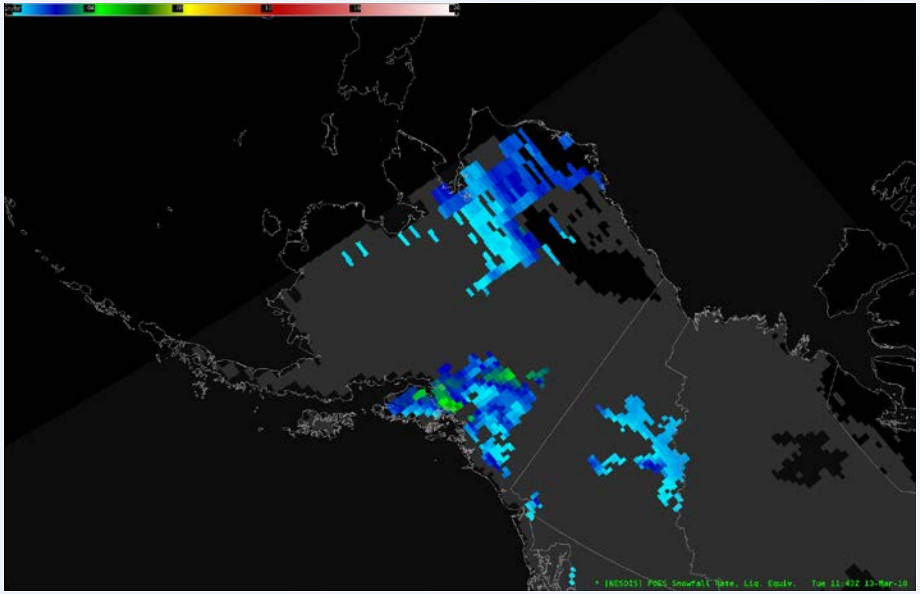


Graphic provided by Wes Adkins, NWS Juneau

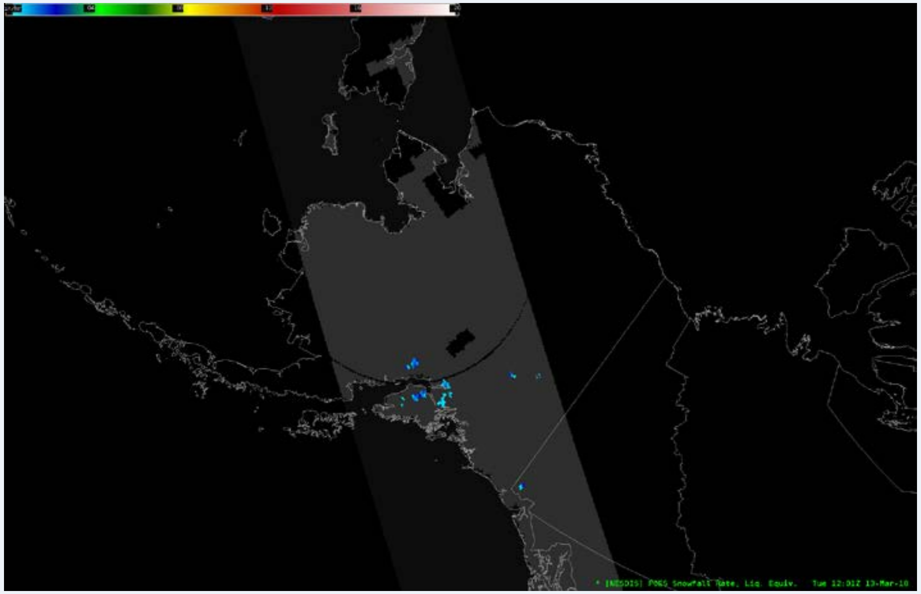
Advantages of Assessments…

New to the SFR product suite for this assessment was the inclusion of observations and data from the SSMIS and GMI instruments, which were not available until March in Alaska. Rather large discrepancies were noted in SFR values and coverage between these new data sets and the original, lower resolution ATMS and AMSU/MHS data, particularly over Alaska rather than the CONUS. This was communicated to the research/development team.

SFR from ATMS, 1143 UTC 13 Mar 2018



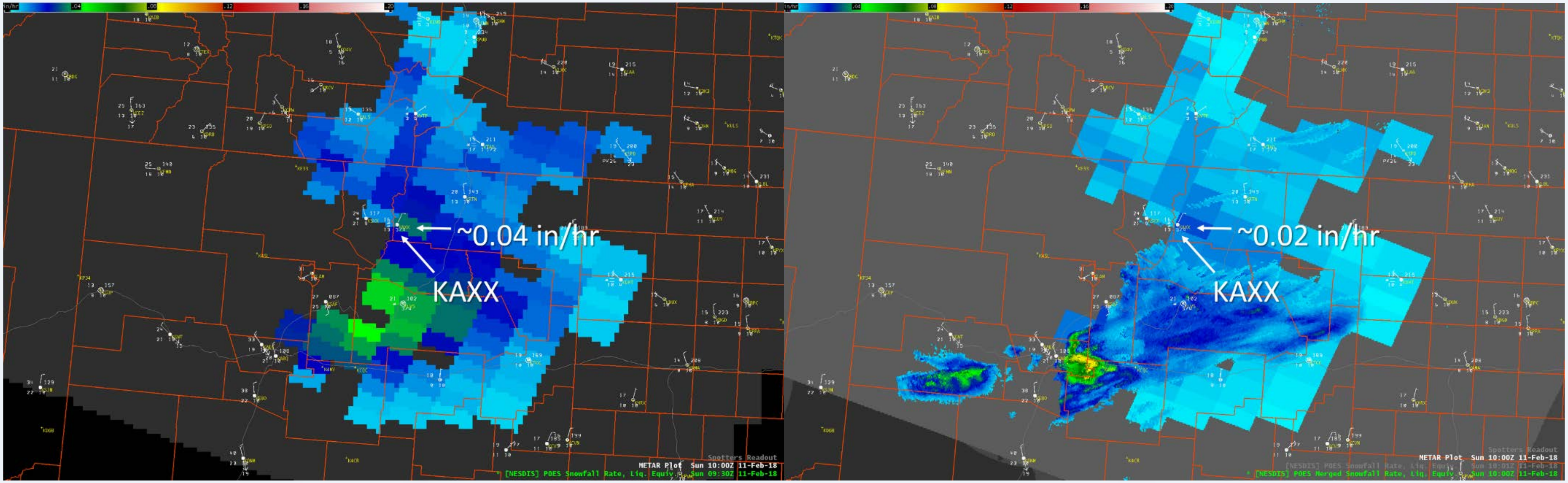
SFR from GMI, 1201 UTC 13 Mar 2018



Accuracy of Snowfall Detection/Rates

Albuquerque, NM WFO scheduled a webinar for the Snowfall Rate Assessment team following discrepancies observed between the SFR (polar-orbiting only data) and mSFR products. An example shown during the webinar is provided below. Snowfall rate values in the mSFR product were about half those in the standard SFR polar-orbiting swaths. This issue was tracked and subsequently fixed.

So, in this example, forecaster participants helped to identify and effectively communicate a problem, which lead to its quick resolution. Thus, these types of intensive assessment activities foster an environment of closer communication and collaboration between end-users and product developers, which can be advantageous for product development and refinement.



Conclusions…

- Consider future additional testing and evaluation at national testbeds or proving grounds, such as the WPC Hydrometeorology Testbed
- Need further evaluation and investigation of large discrepancies between ATMS and AMSU/MHS and SSMIS and GMI data sets, particularly over Alaska
- Continue research to extend product to include coastline areas
- Continue research to refine the algorithm for improvement with snowfall rates, especially with regard to the underestimation of rates that is typical in the Alaska region
- Add more direct broadcast data from the Alaska region if it is available.

Thanks for your time!

Questions or suggestions?

Huan Meng: huan.meng@noaa.gov

Kris White: kris.white@noaa.gov

Special thanks to our NWS participants!

- Wes Adkins, WFO Juneau
- Shaun Baines, WFO Anchorage
- Brian Guyer, WFO Albuquerque
- Aaron Jacobs, WFO Juneau
- Michael Lawson, WFO Anchorage
- Edward Liske, WFO Juneau
- Samuel Shea, WFO Anchorage

Also, Thanks to Kevin McGrath and Frank LaFontaine of NASA SPoRT for their support