Total Ozone Analysis from Stratospheric and Tropospheric (TOAST) Satellite Sources

Presented by L. Flynn

with contributions from J. Niu and the rest of the TOAST Team

Date: 2018/08/30

Outline

- Team Members and Affiliations
- Blended Product Development
  - Inputs needed for the Blended Product Algorithm
  - Technical Approach
  - Product Examples/Outputs
  - Product Evaluation/Validation/Tools
- Identified Issues/Risks/Mitigations
- Future Algorithm Improvements
- Documentation/website links

TOAST Blended Product Team

Algorithm Team Members

Role	Name	Organization	Task
Lead	Lawrence Flynn	NOAA/NESDIS/STAR	Manage development resources
PAL	Vaishali Kapoor	NOAA/NESDIS/OSPO	Manage implementation resources
Developer	Jianguo Niu	STAR/IMSG	Algorithm development and validation
Implementer	Venkata Rao Anne	OSPO/PSGS	Operational processing and monitoring
Support	Eric Beach	STAR/IMSG	Data management

Input Needs for the TOAST Algorithm

Required Satellite Data Products

	Data Product Name (Inputs)	Input Data Type (Satellite/Model Forecasts/*In-situ*)	Temporal/ Spatial Resolution, Format	Source(s)
1	V8Pro or V2Limb	NOAA-19 SBUV/2 PMF S-NPP/NOAA-20 OMPS EDRs S-NPP OMPS EDRs	Daily PMF Daily NetCDF Daily NetCDF	OSPO NDE NDE
2	NUCAPS Ozone	S-NPP/NOAA-20 CrIS EDRs MetOP-A,-B,-C IASI EDRs	Daily NetCDF Daily NetCDF	NDE NDE
3	TOVS Ozone	Metop-A HIRS EDRs	Daily	NDE

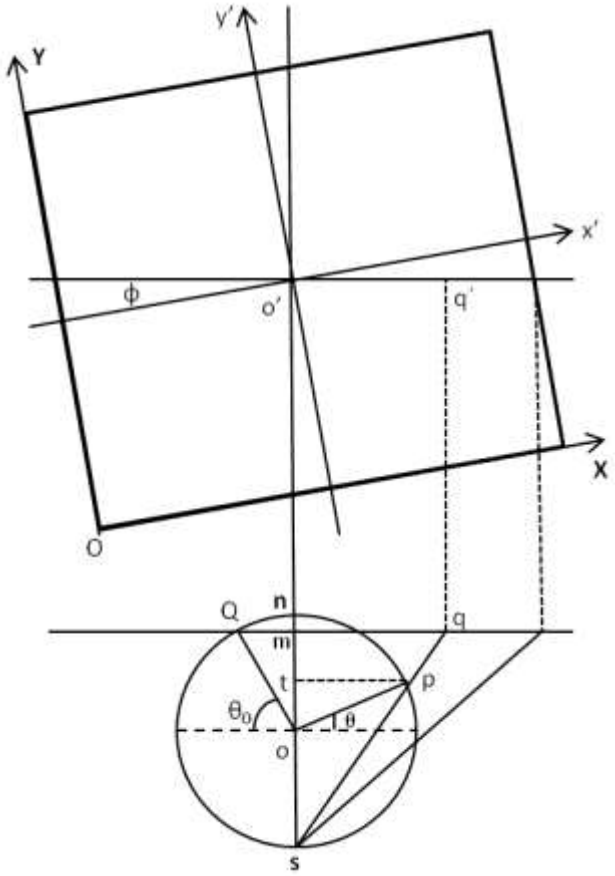
NDE products are in granules with approximately 1100 per day for OMPS

{Product Name} Technical Approach

1. Blended Product Algorithm Description
2. Technical Approach
   - Methods of Bracketing – daily data from 180 E to 180 W
   - Quality Control Methods – need for improvements
   - Calibration – single input for each piece
   - Geo-location Tests – from input product Geolocation
   - Gap Handling – persistence with distance weighting
   - Handling Duplicates – infrequent, duplicates are double weighted

TOAST objective analysis

- **Basic consideration:**
  1. IR obs. possess higher sensitivity to tropospheric ozone.
  2. UV obs. possess higher sensitivity to stratospheric ozone
  3. Combining the IR and UV retrieved O_3 may increase the total column O_3 accuracy.
  4. Use analysis to fill in the UV observation gaps.
- **Basic procedures:**
  1. Convert IR and UV O_3 pressure scale into same pressure scales.
  2. Transform coordinate from geographic into stereographic.
  3. Objective analysis.
  4. Analyzed global ozone data are transformed back to the geographic coordinate with 1˚× 1˚ resolution.



$$X = \cos\theta \cdot \cos\phi \cdot \frac{\sin\theta_0 + 1}{\sin\theta + 1} \cdot \frac{\mathrm{Re}}{mesh} + \frac{N-1}{2} \qquad (1)$$

$$Y = \cos\theta \cdot \sin\phi \cdot \frac{\sin\theta_0 + 1}{\sin\theta + 1} \cdot \frac{\mathrm{Re}}{mesh} + \frac{N-1}{2} \qquad (2)$$

mesh=24,384/(N-1) km, θ_0=60˚; N is mesh grid number;
For CrIS N=245; for OMPS N=65

Fig 1. Coordinate transformation from geographic to Stereographic.

$$C = WE \qquad (3)$$

$$W = \frac{R^2 - d^2}{R^2 + d^2} \qquad (4)$$

Any initial value on the grid within radius R of a measurement point A will be corrected by a weighted sum, where E is the difference between the observation and the initial value and W is the weighting factor.

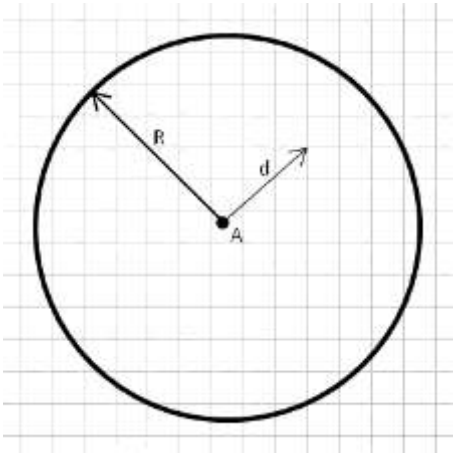
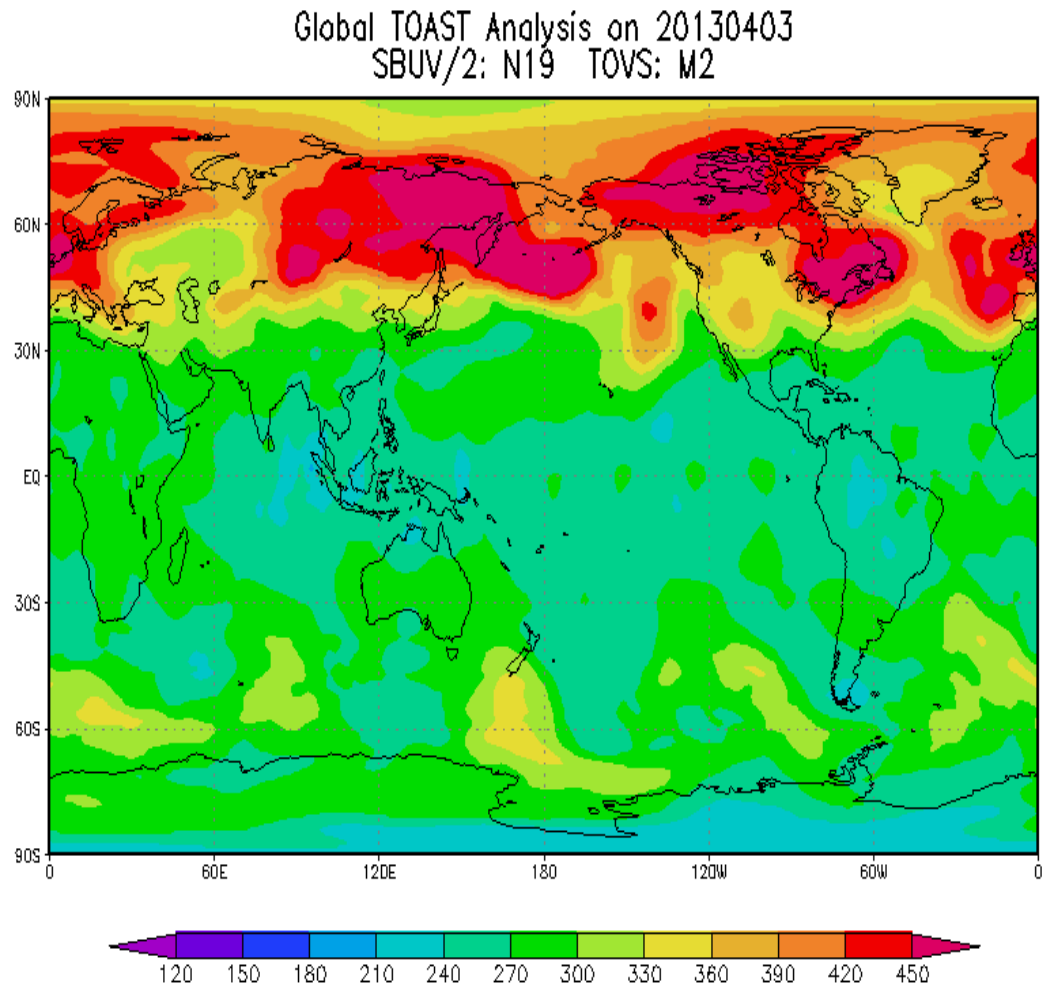


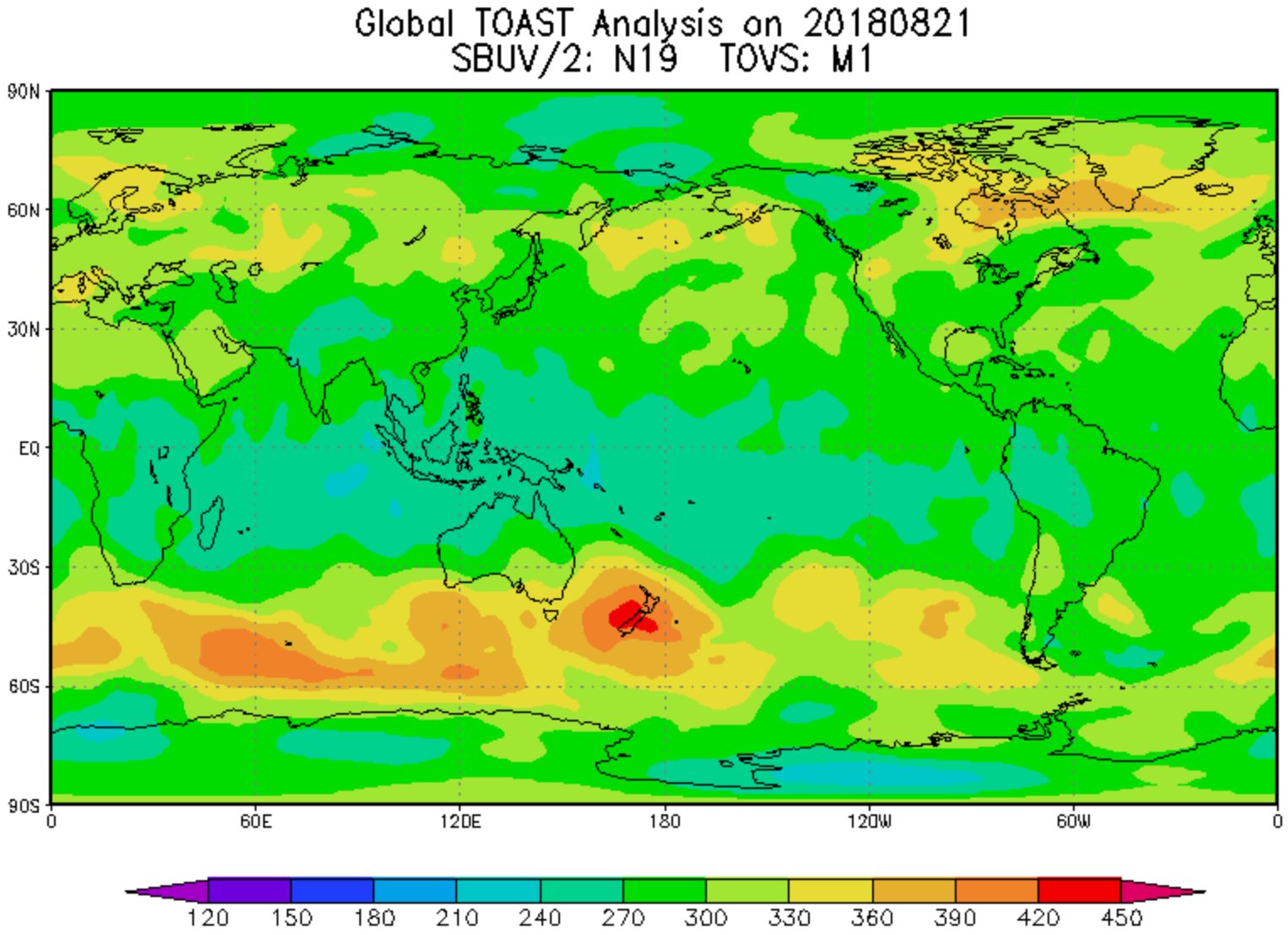
Fig 2. scheme of objective analysis

TOAST Description

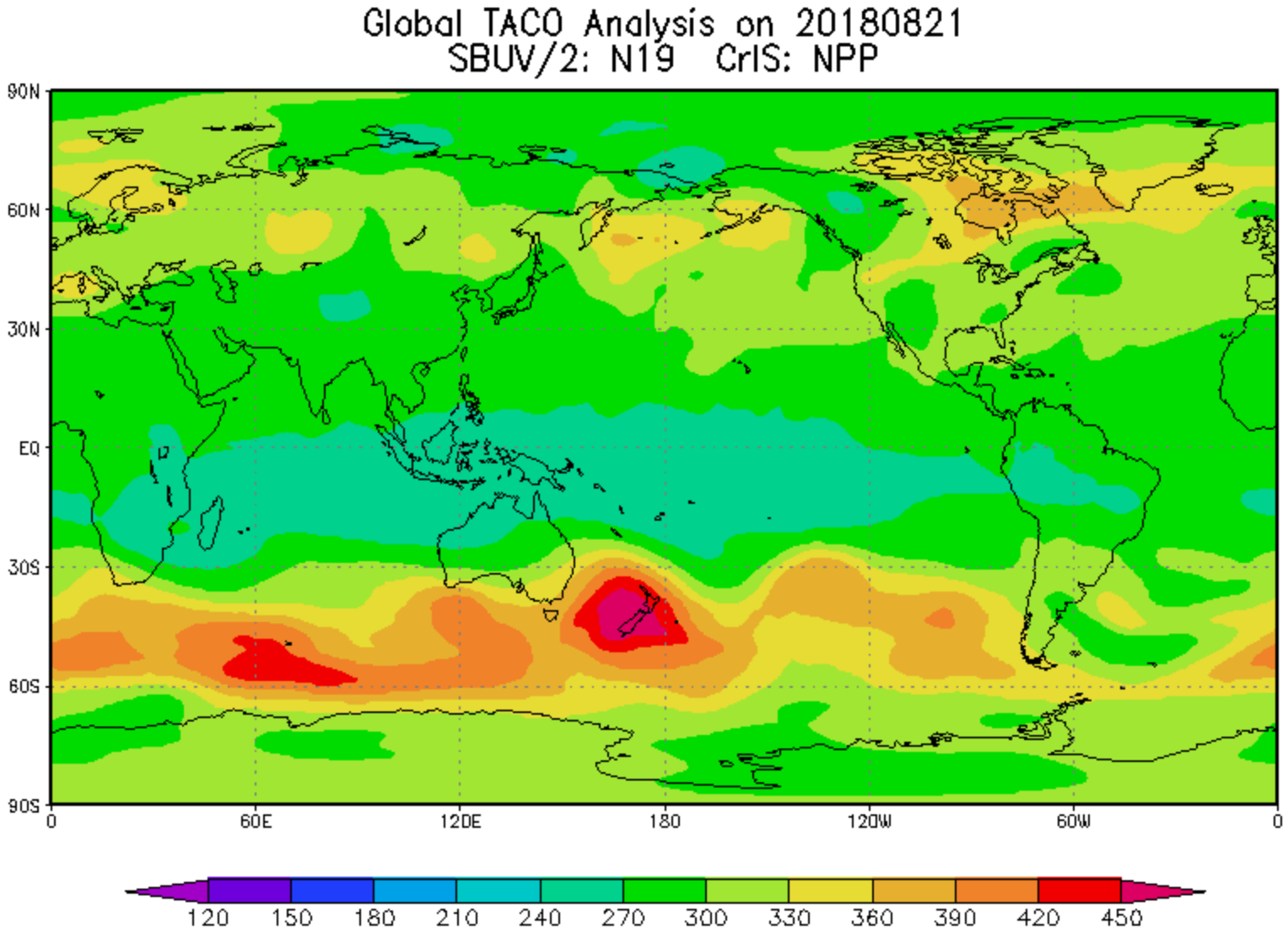


The original TOAST is a total column ozone map generated by combining TOVS tropospheric and lower stratospheric (4 to 23 km) ozone retrievals with SBUV/2 spatially smoothed mid-to-upper stratospheric (24 to 54 km) layer ozone retrievals. In essence, we are replacing TOVS climatology with real-time SBUV/2 measurements in the mid-to-upper stratosphere.

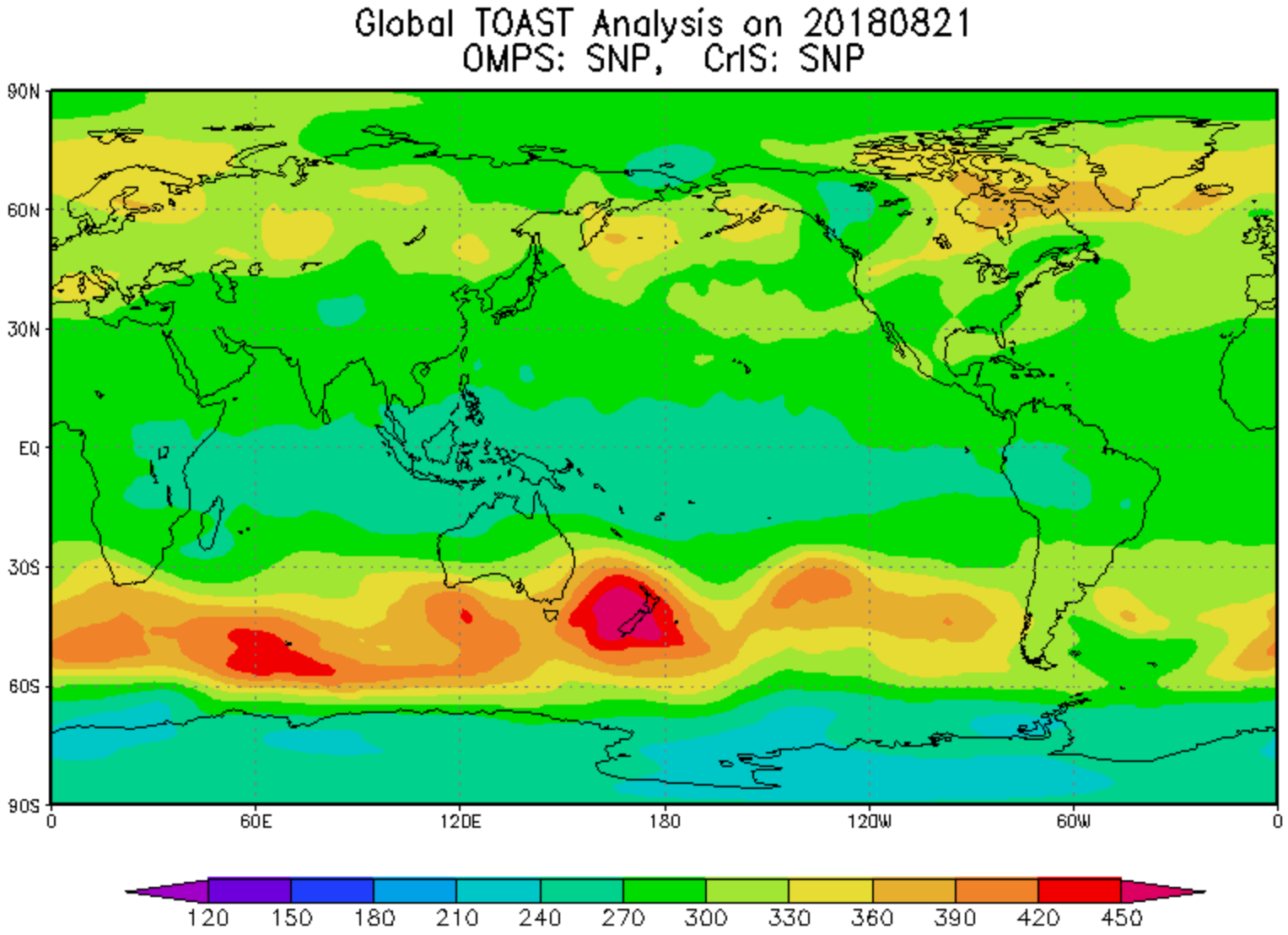
TOAST (SBUV/2 + HIRS)



eTOAST (SBUV/2 + CrIS)



nTOAST (OMPS NP + CrIS)

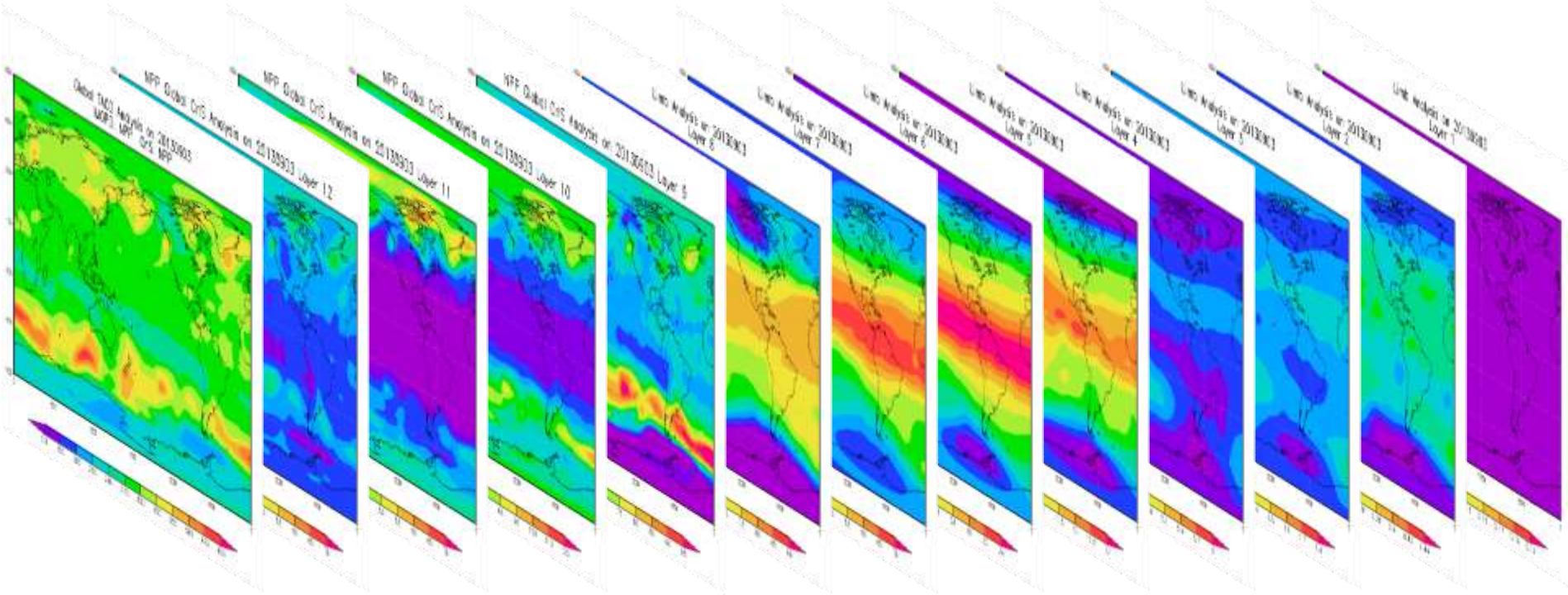


Product(s) Examples/Outputs

Output Data Products

	TOAST (Outputs)	Output Data Type Daily maps of Total Ozone and Ozone Profiles	Spatial, Temporal Resolution, Format
1	TOAST	Total ozone and NOAA-19 SBUV/2 and HIRS layers	1° x 1° Grib, Binary and png
2	eTOAST	Total ozone and NOAA-19 SBUV/2 and NUCAPS	1° x 1° etc.
3	nTOAST	Total ozone and S-NPP/NOAA-20 OMPS-NP and NUCAPS	1° x 1° etc.
4	lTOAST	Total ozone and S-NPP OMPS-LP and NUCAPS	1° x 1° etc.

TOAST using CrIS and OMPS LP (09-03-2013)

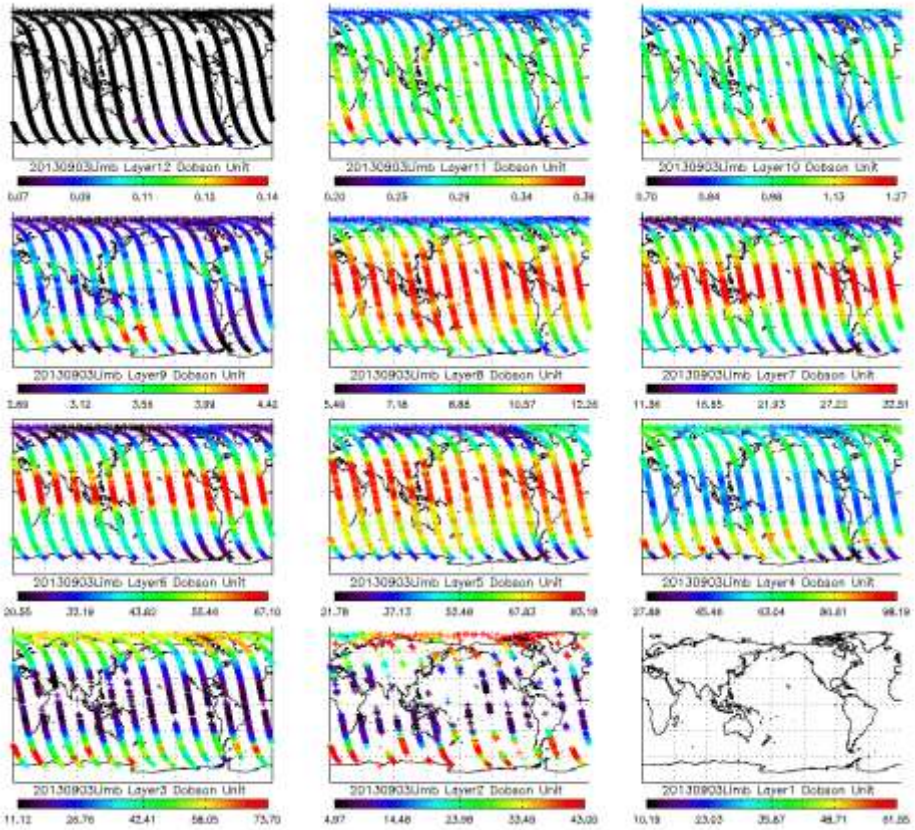


TACO total amount 1013 253 127 63.3 31.7 15.8 7.93 3.96 1.98 0.99 0.5 0.25 mb

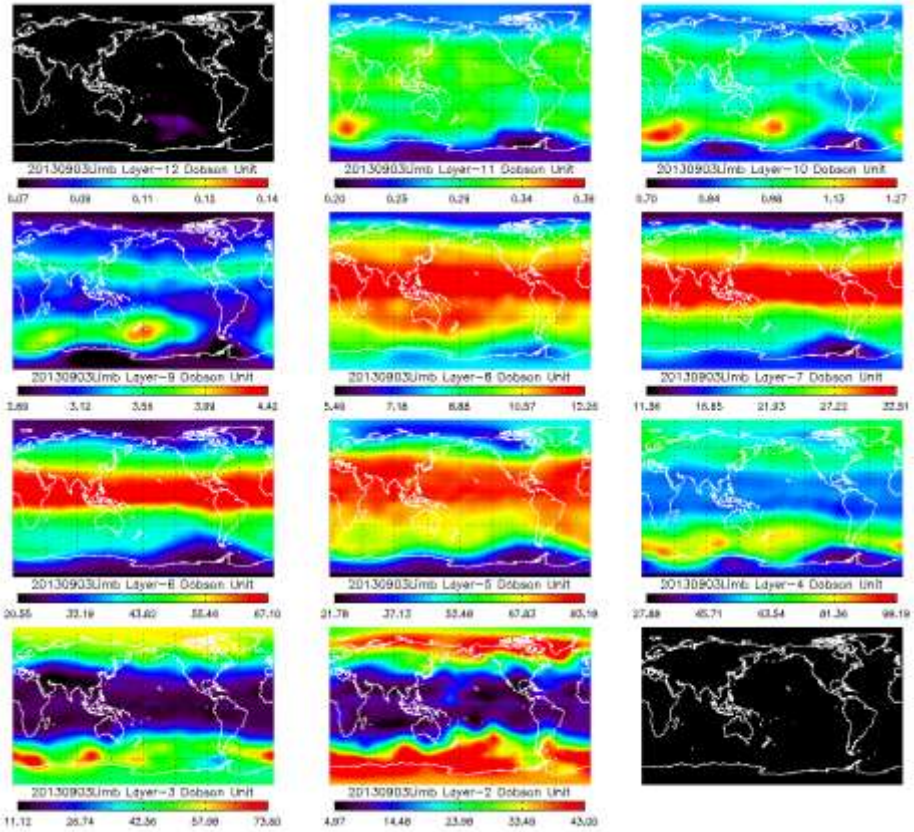
TOAST= ***CrIS*** **+** ***OMPS /Limb***

Limb Layer reformed vs. analyzed 09-03-2013

- Layer reformed Limb input

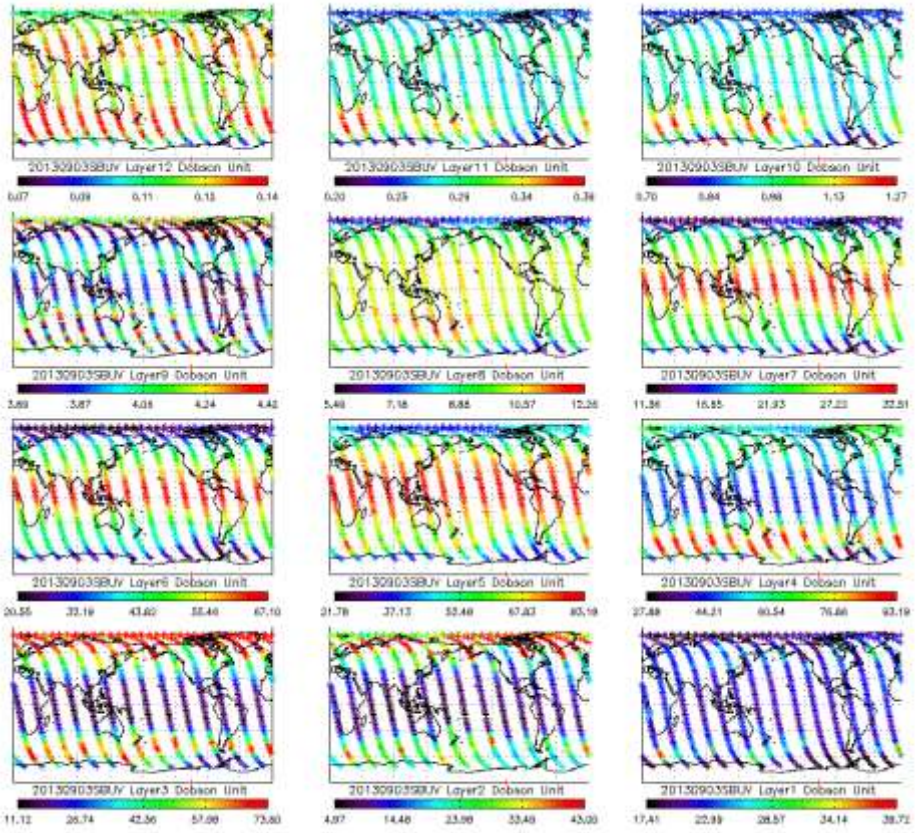


- Limb TOAST analyzed

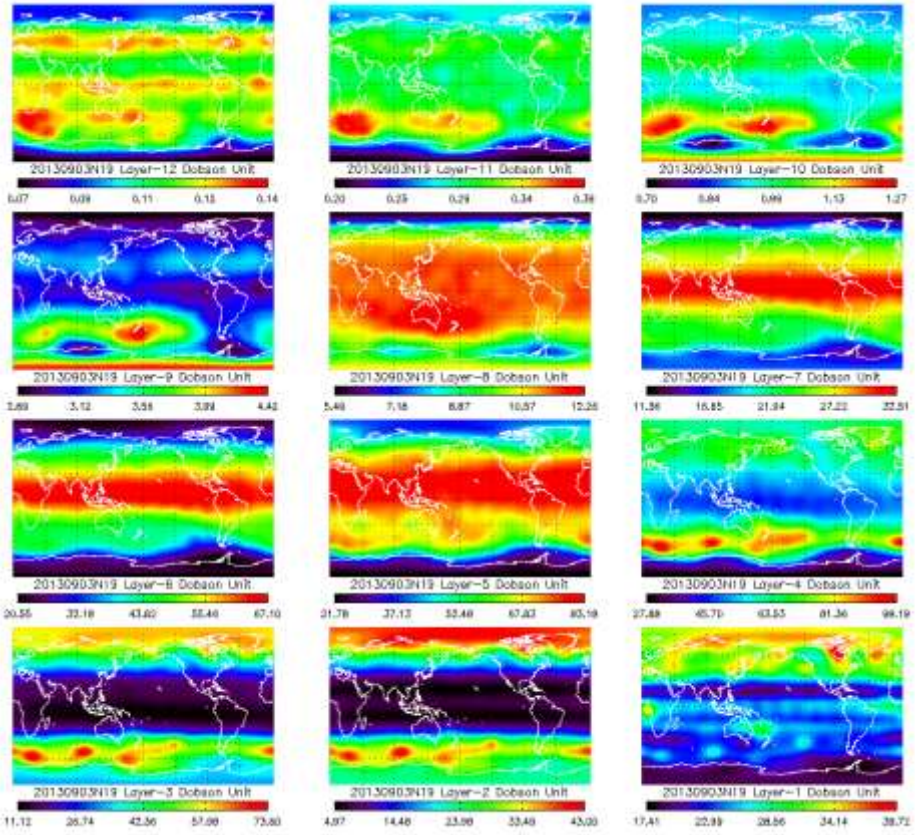


SBUV 12-layer vs. analyzed 09-03-2013

- SBUV-2 input

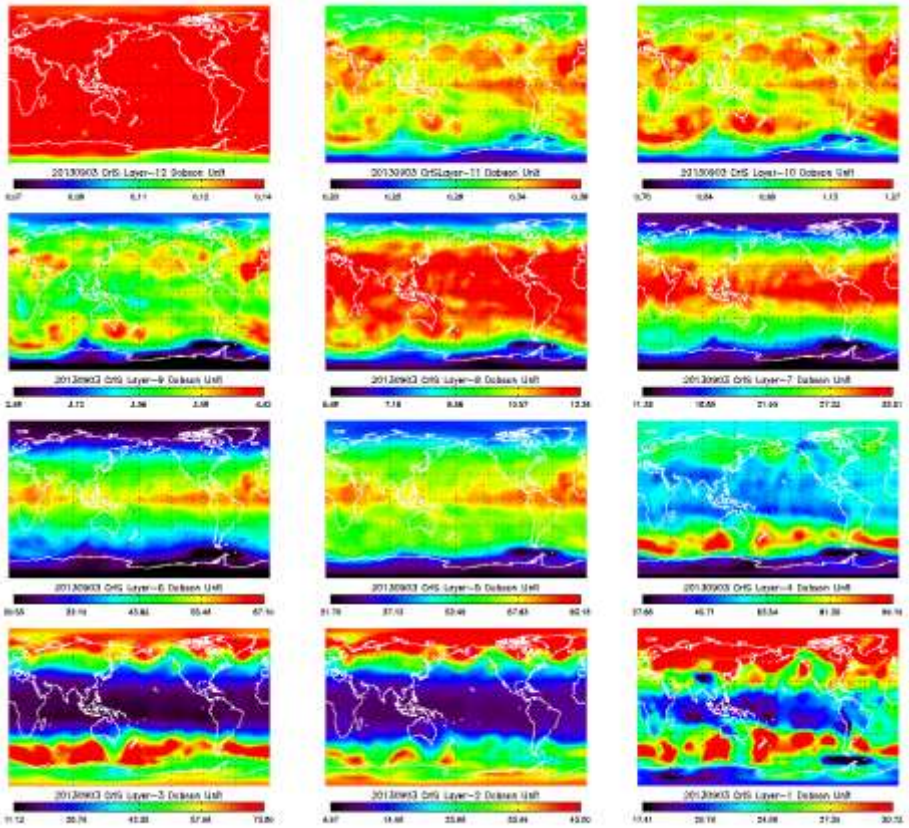


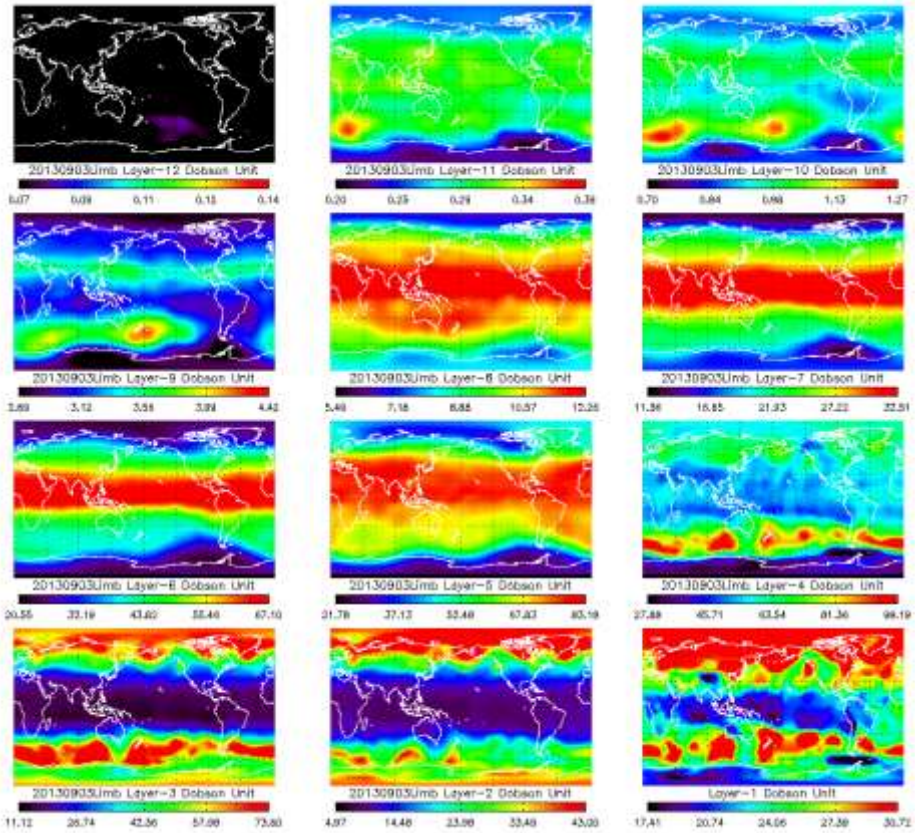
- TOAST SBUV-2 analyzed



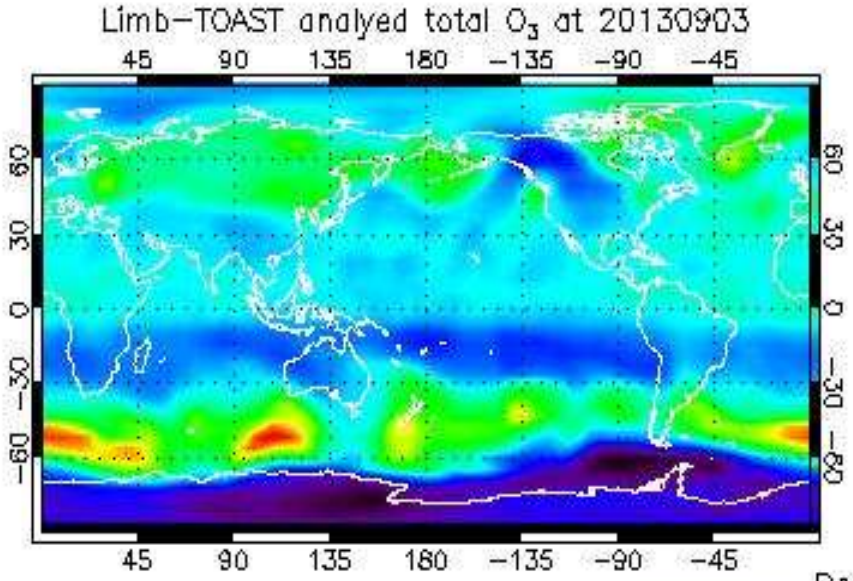
Analyzed 12 Umkehr O_3 layers 09-03-2013

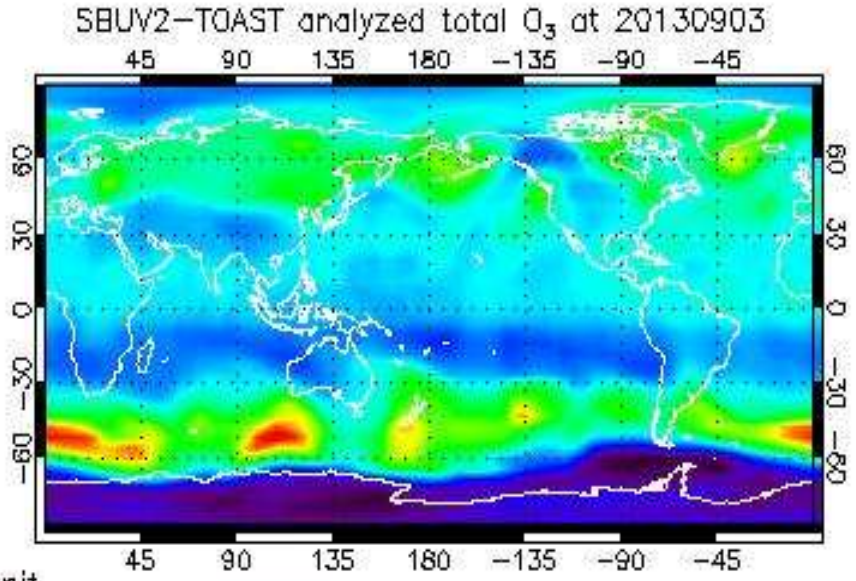
- CrIS
- CrIS + Limb

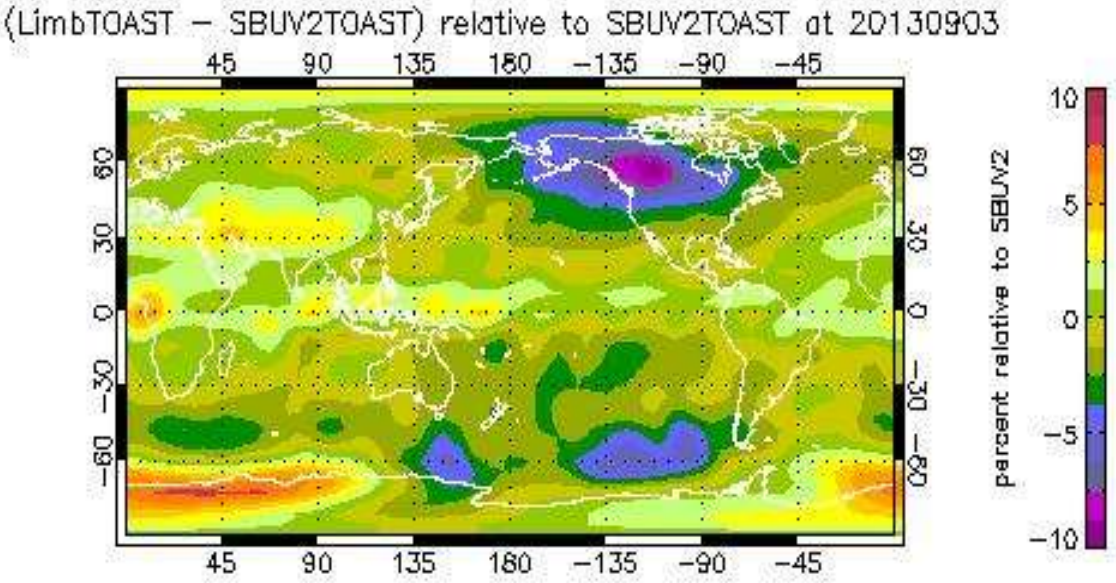




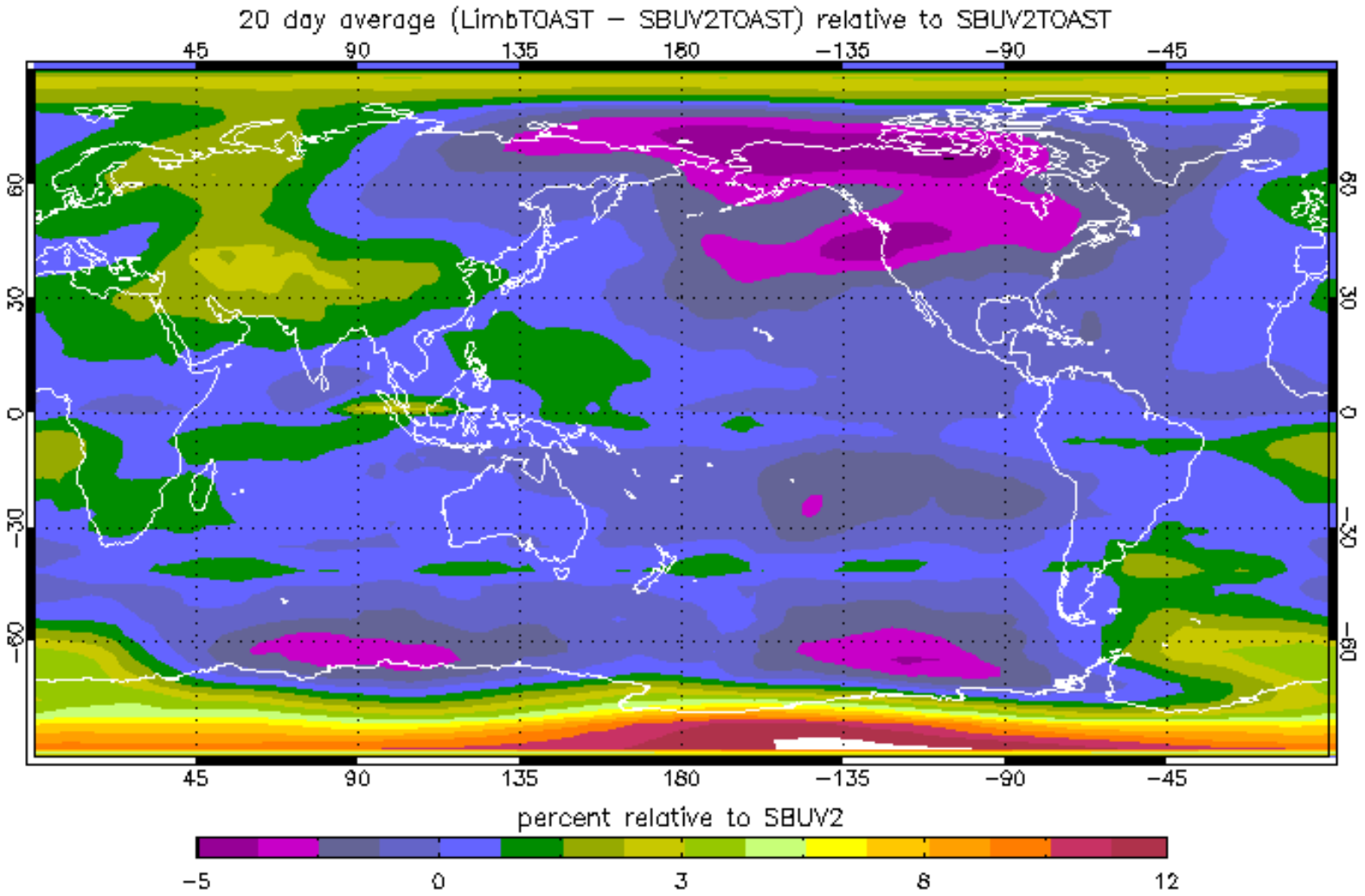
Comparison of Limb and SBUV/2







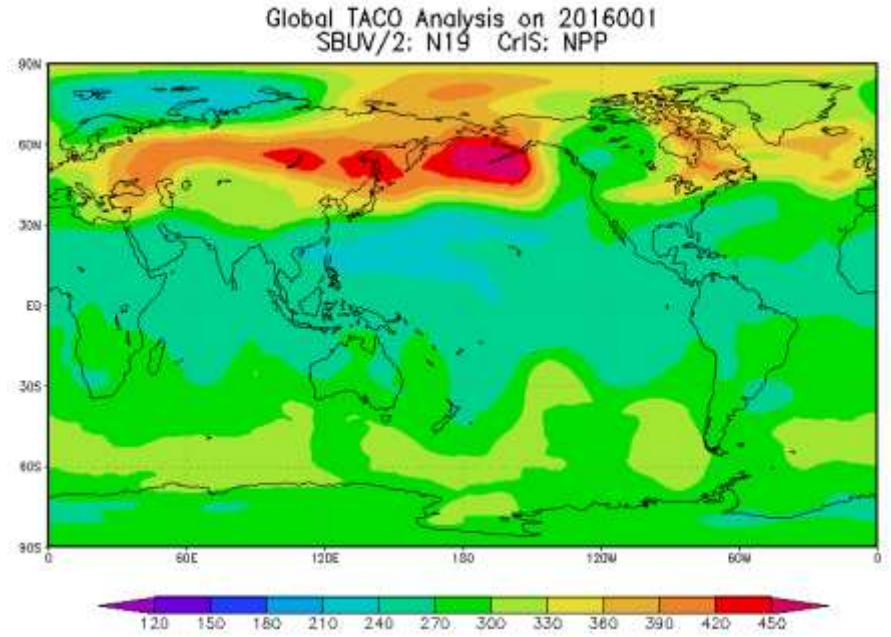
20-day average of the relative differences to current version from 09-03-2013 to 09-22-2013

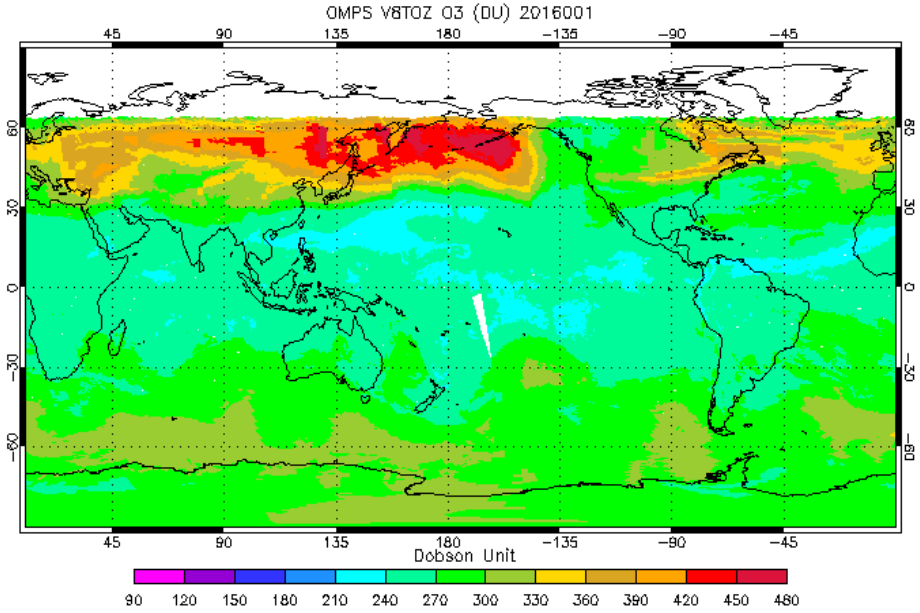


Product Evaluation/Validation/Tools

- Product Evaluation/Validation
  - Compared to individual components and their validation.
  - Compared to sunlit Earth from Daily UV Mappers.
- Defined Quality Flags
  - Need to determine how to show where data was updated.

eTOAST versus S-NPP OMPS V8TOz for January 1, 2016





Identified Issues/Risks/Mitigations

- Provide a list of identified risks/issues/mitigations and any examples identifying artifacts.

Identified Risk/Issues	Action/Mitigation
NOAA-19's Drifting orbit limits SH coverage for TOAST and eTOAST.	Switch to lTOAST and nTOAST using S-NPP and NOAA-20 OMPS products.
Final products do not have flags to show where recent data was available for analysis.	Consider creating maps showing where components were updated.
Product screening for OMPS products does not use error flag information.	Modify code to screen input to only use error flag values of 0, 1, and 10, 11.

Recent and Future Algorithm Improvements

- Provided code with better handling of Equatorial “boundary”.
- Deliver code with better error flag handling for OMPS.
- Deliver code to read in NetCDF version of Limb Profile products.
- Future Validation Plans for lTOAST
  - Comparisons to MLS and SAGE III
  - Comparisons to OMPS NM and TropoMI
  - Provide code with better error flag handling.
- Use stratospheric ozone analysis fields as A Priori to NUCAPS

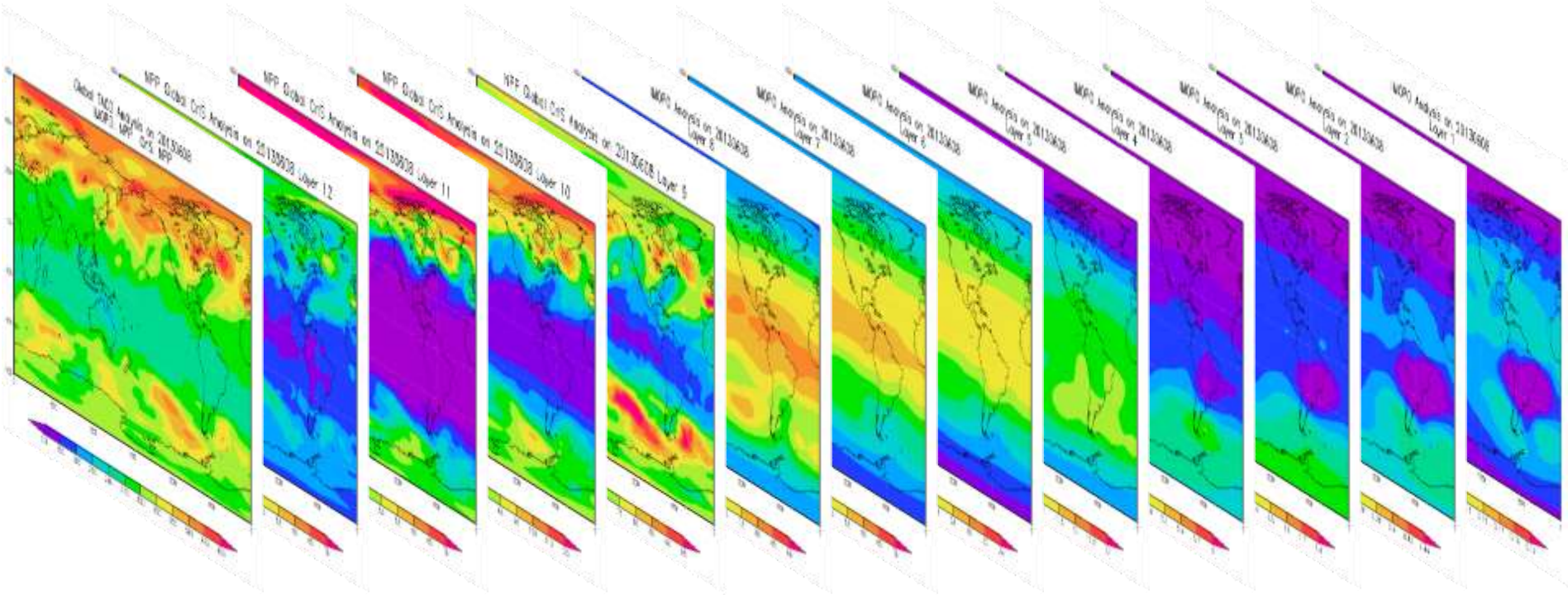
Documentation/website links

Toast products can be accessed at the following pages

- https://www.ospo.noaa.gov/Products/atmosphere/toast/index.html
- https://www.ospo.noaa.gov/Products/atmosphere/etoast/index.html
  https://www.ospo.noaa.gov/Products/atmosphere/ntoast/index.html
- https://www.ospo.noaa.gov/Products/atmosphere/ltoast/index.html

Backup Slides

Current operational eTOAST using CrIS and SBUV-2 for June 8, 2013



1013 253 127 63.3 31.7 15.8 7.93 3.96 1.98 0.99 0.5 0.25 mb

TOAST = ***CrIS*** **+** ***SBUV***

Implementation Status

- eTOAST is operational
- nTOAST will be soon
- lTOAST is awaiting a new delivery and the start of operational processing at NDE.

Input Product(s) Requirements

Identify satellite and ancillary data Inputs

(use additional slides as needed)

Input Data	Resolution	Source
e.g. GFS – T(p), q(p)	0.5 x 0.5 deg; 31 levels	NCEP
e.g. Annual Surface Type	1 km Global	JPSS-VIIRS
e.g. SST	5 km Global	ACSPO

Output Product(s) Specifications

- Blended Product Name: **{SST}**
- Output Data Type(s): {S-NPP/NOAA-20/GOES-16}
- If your blended product algorithm produces more than one output product, use additional slides as required.

Output Product(s) Attributes	Threshold	Observed/validated
Latency		
Geographic coverage		
Vertical Coverage		
Vertical Cell Size		
Horizontal Cell Size		
Mapping Uncertainty		
Measurement Range		
Measurement Accuracy		
Measurement Precision		
Measurement Uncertainty		

Quality Flags

- Defined Quality Flag(s)
  - Variable, description, value, verification

Quality Flag	Description	Value

Implementation Status

- Discuss current status of implementation including the availability in AWIPS or alternatives.
- Algorithm version/LUTs
- Processing environment and resources required for implementation or porting.
- Future plans on implementations including AWIPS or alternatives

Importance/Benefits/Users

- Product Importance/Benefits/Users
- PGRR/PGI Activities

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations

Documentation/website links

- Provide website links for documentation, down-load instructions, etc.

TOAST TOTAL OZONE MAPS USING CRIS AND OMPS LP PROFILES

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System Research Group@NOAA/NESDIS/STAR

Larry Flynn,
NOAA/NESDIS/STAR

STAR JPSS Annual Science Team Meeting
August 9, 2016

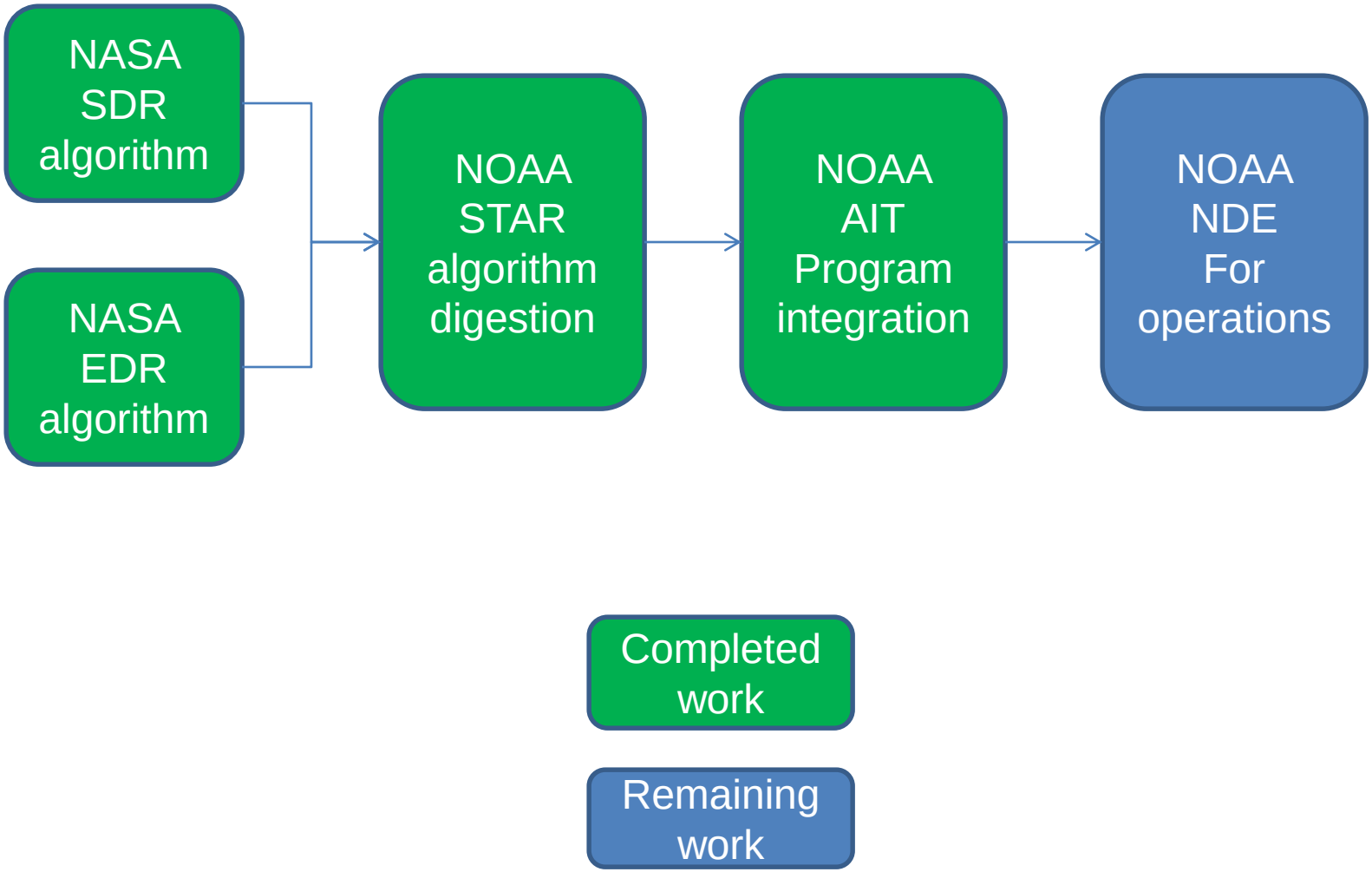
S-NPP provides following ozone sensors

- CrIS IR full global day and night profiles
- OMPS NP nadir view vertical profiler
- OMPS NM full daily total ozone for sunlit Earth
- OMPS LP limb view vertical profiles

The current TOAST was developed in 2014

- **T**otal **O**zone from **A**nalysis of CrIS and SBUV2 in **S**tratosphere and **T**roposphere
- ***TOAST*** will use CrIS + OMPS NP when OMPS NP is at NDE.
- ***TOAST*** will use CrIS + OMPS LP when OMPS LP is at NDE.

Limb processing algorithm status



What have we achieved?

- OMPS Limb TOAST and SBUV/2 TOAST show similar global patterns and values in the upper layers (comparison need to introduce retrieval averaging kernels).
- Limb analysis algorithm functions well from the comparison of the EDR input and analyzed figures.
- 20 days of total column Ozone analysis have been tested.
- The averaged relative differences show Limb TOAST total analysis has ±5% differences relative to the current operational version (SBUV/2 TOAST).

The upcoming TOAST (CrIS + OMPS/Limb)

Baseline products:

- 12 layers global 1˚ × 1˚ layer VCD O_3 maps
- Eight layers of Limb global 1˚ × 1˚ layer VCD maps at pressure level of 31.7, 15.8, 7.93, 3.96, 1.98, 0.99, 0.50, 0.25 mb
- Four layers of CrIS global 1˚ × 1˚ layer VCD maps at pressure level of 1013, 253, 127, 63.3 mb.

Based on operational request we could:

- Provide 21 layer (V8 layers ~3km) the same analyzed maps
- Provide 61 Limb layers of analyzed maps

Summary

- The TOAST algorithm for CrIS + Limb has been developed and tested using NUCAPS and NASA Limb Profiler daily data products.
- The OMSP Limb Profiler SDR and EDR processing algorithms have been successfully transferred from NASA to NOAA, and have completed code and security review, they are ready for implementation the next builds at NDE.