JPSS Sensor Data Record (SDR) Overview

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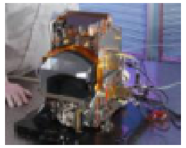
Outline

- Suomi NPP SDR Status and Reprocessing
- Applications of Suomi NPP SDR Data in NWP
- J1 SDR Algorithm Status and Schedule
- Summary and Conclusions

Suomi NPP Instruments and Their Applications

NPP/JPSS Instrument		NOAA Mission Benefits
	**Advanced Technology Microwave Sounder (ATMS)**	ATMS and CrIS together provide high vertical resolution **temperature** and **water vapor information needed to maintain and improve forecast skill** out to 5 to 7 days in advance for extreme weather events, including hurricanes and severe weather outbreaks
	**Cross-track Infrared Sounde (CrIS)**	
	**Visible Infrared Imaging Radiometer Suite (VIIRS)**	VIIRS provides many **critical imagery products** including snow/ice cover, clouds, fog, aerosols, fire, smoke plumes, vegetation health, phytoplankton abundance/chlorophyll. All are required for environmental hazard monitoring and are useful for crucial economic sectors (transportation, fishing, energy, agriculture), all of which impact human health
	**Ozone Mapping and Profiler Suite (OMPS)**	Total ozone for **monitoring ozone** hole and recovery of stratospheric ozone and for UV index forecasts
	**Clouds and the Earth's Radiant Energy System (CERES)**	Provide **climate quality measurements** of the Earth's outgoing radiation budget- longwave infrared, reflected solar flux, and incoming solar radiation, all of which are vital to climate monitoring

Suomi NPP TDR/SDR Algorithm Schedule

Sensor	Beta	Provisional	Validated
CrIS	February 10, 2012	February 6, 2013	March 17, 2014
ATMS	May 2, 2012	February 12, 2013	March 17, 2014
OMPS	March 7, 2012	March 12, 2013	September 17, 2015
VIIRS	May 2, 2012	March 13,, 2013	April 17, 2014

Beta

- Early release product.
- Initial calibration applied
- Minimally validated and may still contain significant errors (rapid changes can be expected. Version changes will not be identified as errors are corrected as on-orbit baseline is not established)
- Available to allow users to gain familiarity with data formats and parameters
- Product is not appropriate as the basis for quantitative scientific publications studies and applications

Provisional

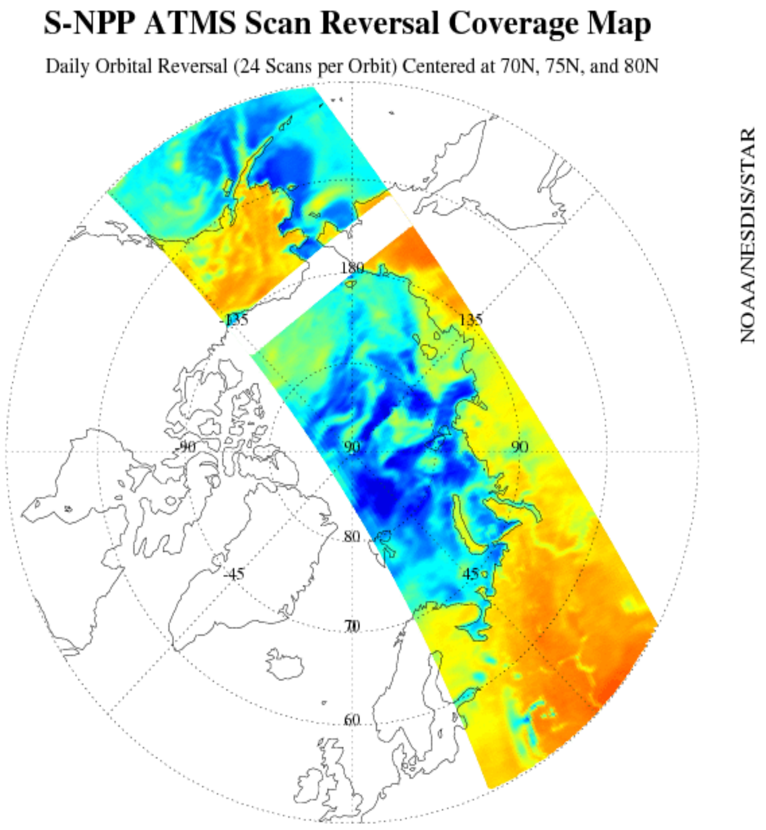
- Product quality may not be optimal
- Incremental product improvements are still occurring as calibration parameters are adjusted with sensor on-orbit characterization (versions will be tracked)
- General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
- Users are urged to consult the SDR product status document prior to use of the data in publications
- Ready for operational evaluation

Validated

- On-orbit sensor performance characterized and calibration parameters adjusted accordingly
- Ready for use in applications and scientific publications
- There may be later improved versions
- There will be strong versioning with documentation

JPSS SDR 2016 Major Accomplishments

- CrIS full spectral resolution (FSR) SDR data are routinely produced at STAR processing system and the FSR data have been made available to the user community for various applications and research
- ATMS SDR team have completed the two-round J1 ATMS TVAC analysis, is timely supporting the anomaly investigations, and the team is prepared for the third round performance analysis after the ATMS channel 17 anomaly is fixed.
- VIIRS SDR team delivered J1 codes that accommodate 13 waivers (e.g. DNB aggregation). RSBautocal has been transitioned into IDPS operation. VIIRS SDR team, STAR OC team and NASA VCST are further working on uses of lunar observations to improve the RSB calibration
- J1 OMPS SDR algorithm was delivered with calibration tables and LUTs, after its end-to-end tests. The core dump issue in the OMPS 43 data sets was found and associated with the FSW compressor
- STAR Integrated CalVal System (ICVS) is monitoring the ATMS scan motor current excursion and the ICVS team has been supporting the NASA/NOAA decision makers for defining the Suomi NPP ATMS scan reversal scheme
- Suomi NPP SDR reprocessing project is initiated and a high quality of SDR data sets from ATMS and CrIS have been reprocessed and can be applied for climate applications



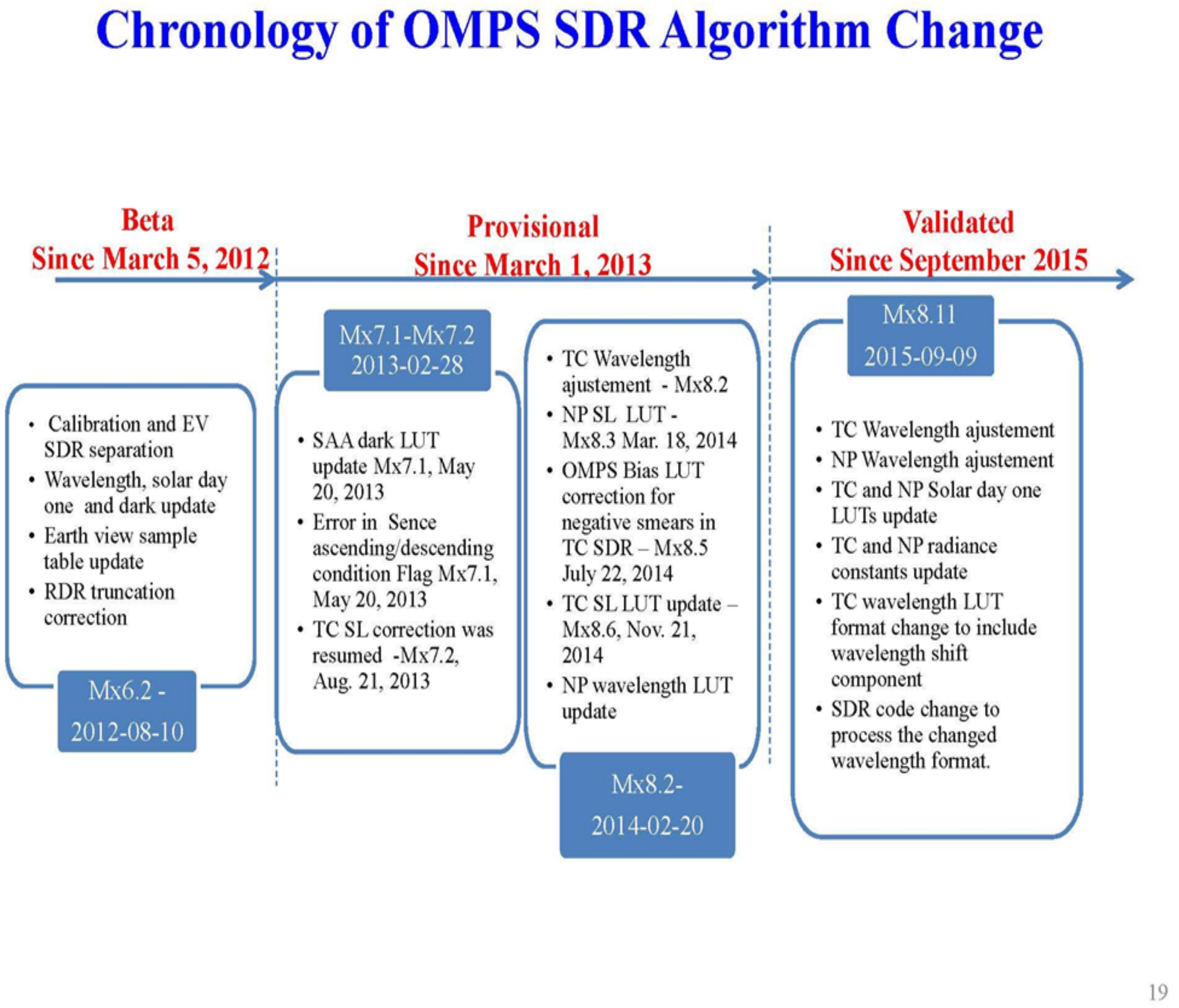
Objectives of JPSS Life-Cycle Data Reprocessing

- Optimize the algorithms and processing systems to achieve the lowest JPSS data uncertainties

- Implement the mission-life consistent sciences to achieve a long-term stability of JPSS data accuracy

- Reduce the processing anomalies to the lowest level for preserving the highest integrity of the JPSS data stream

- Incorporate the user-oriented algorithm sciences into reprocessing to further augment the society impacts of JPSS datasets

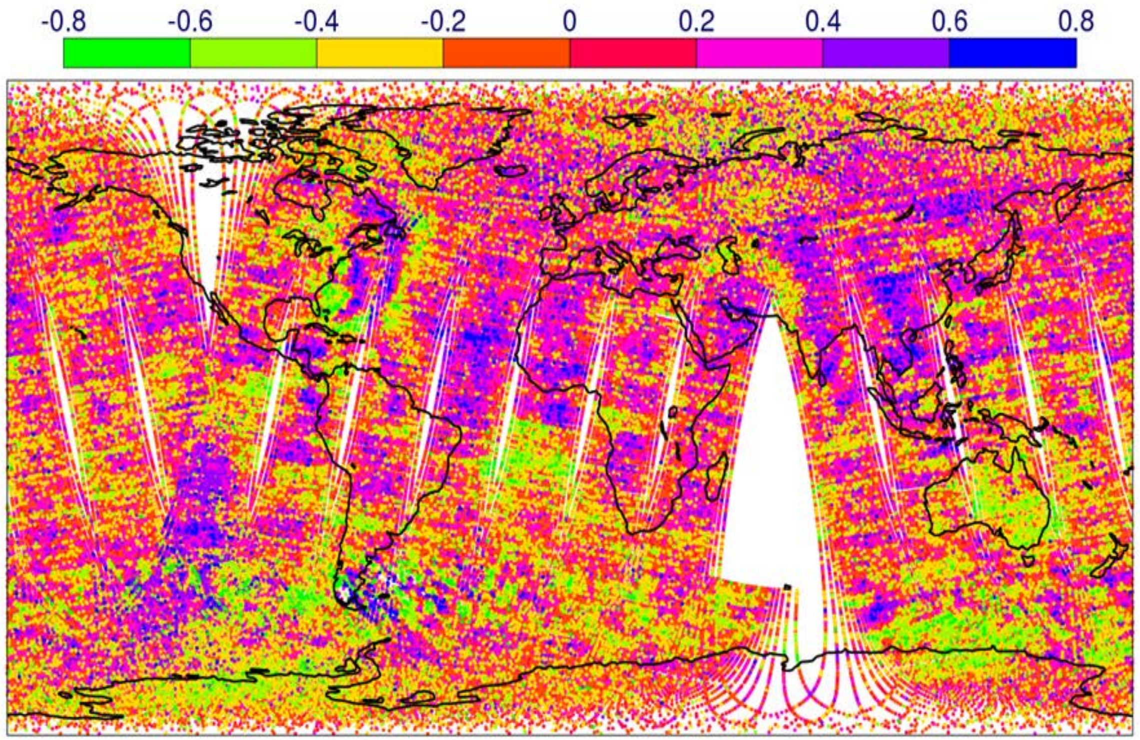


Technical Approaches for JPSS Data Reprocessing

- Integrate the recommendations from user's community into the JPSS life-cycle data reprocessing plan
- Build a cost and effective HPC infrastructure for JPSS data reprocessing and accessing
- Utilize the latest version of algorithms with new sciences fully vetted by the calval teams
- Recover the missing/repaired granules from every possible archival and medium
- Update all the processing coefficient tables, look up tables and engineering package in reprocessing

ATMS NRT data:

Striping: ATMS ch12 O – B (K)



Heather Laurence, ECMWF reported at 2016 NOAA JPSS Reprocessing Workshop

Example of NWP User Recommendations for ATMS/CrIS Reprocessing

- Lunar intrusions in cold calibration should be flagged for whole ATMS time series (ECMWF)
- Lunar intrusion correction should be applied for whole ATMS time series (ECMWF)
- ATMS striping correction algorithms need to be applied for reprocessed data (ECWMF)
- ATMS data stream at temperature sounding channels need to be remapped to AMSUA-like channels (NCEP)
- ATMS channel correlations should be well quantified through reprocessed data (NRL)
- CrIS data can be collocated with VIIRS imager data to assist in cloud-detection (ECMWF)
- CrIS data stream should be generated at both normal and full spectral resolution (NCEP)

Examples of VIIRS User Recommendations

- A “hybrid methodology” by combining SD and lunar calibrations is necessary for VIIRS calibration due to the RTA uniformity degradation (OC team)
- SD/SDSM calibration provide stable and clean calibration coefficients but each component must be robustly characterized – VF, BRF, H-factor, F-factor, Hybrid coefficients (OC team)
- VIIRS RSB channels requires the calibration stability of 0.1 – 0.2% level for the ocean color products (OC team)
- Warm up and cool down (WUCD) in thermal calibration results in spikes in VIIRS derived SST. Thermal channel calibrations should be compared w/o (WUCD) in VIIRS SDR reprocessing and be assessed on SST impacts (SST Team)
- VIIRS EDR repressing should be implemented with the enterprise algorithms (Land Team)
- VIIRS EDR reprocessing should be based on a holistic approach and should estimate impact of SDR and upstream product changes on downstream product such AOT (Aerosol Team)

OMPS User Recommendations

- 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

SMCD/CICS Cluster for JPSS Reprocessing

- Cluster: 36 nodes with each node having 24 cores
- Hard disk/node: 236 GB
- Memory/core: 64 GB
- Total distributed cluster storage: 1 Petabytes
- Operating system: 64-bit Linux (Red Hat)
- Aggregated network speed (storage to compute): 56 gigabits / second
- Job management: PBS Torque and MAUI
- Optimized ways of job submission for different sensors

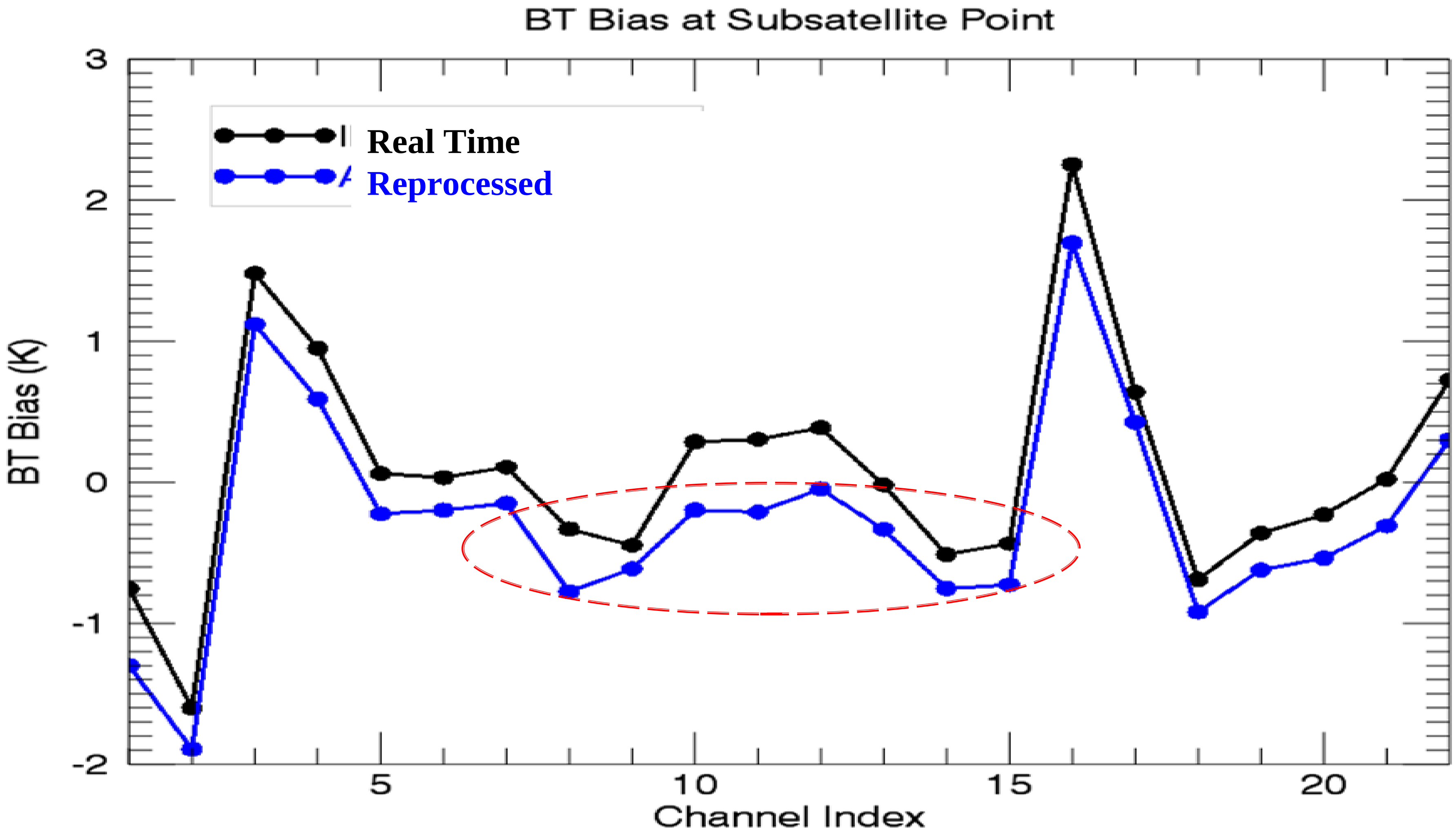
Suomi SNPP SDR Reprocessing Benchmark Tests

Instrument	Process Time Needed for One-Year SDR Data
ATMS	5 hours
CrIS	1 day
OMPS NP	2.8 hours
OMPS TC	18 hours
VIIRS	8.5 days
S-NPP Total	10 days

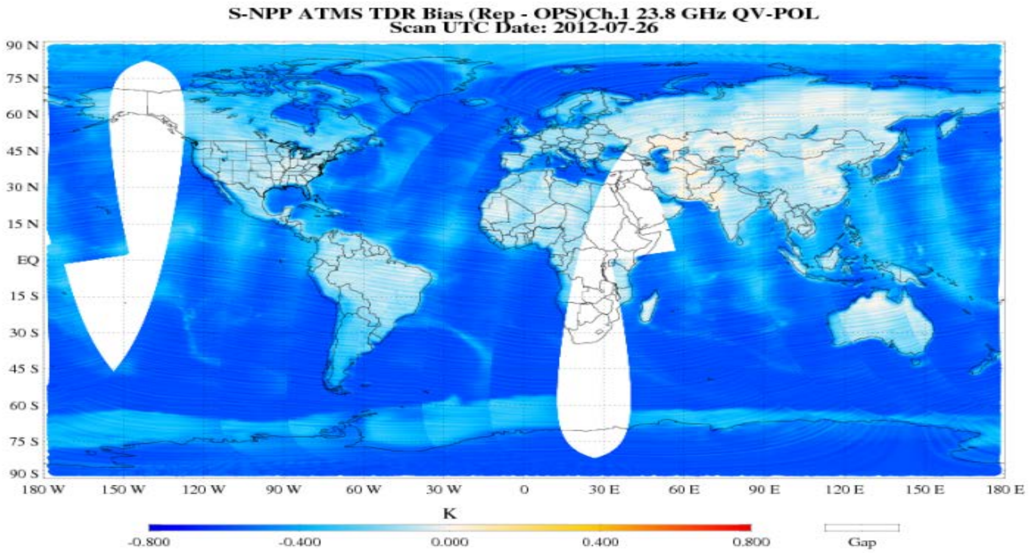
Suomi NPP Yearly SDR Data Volume

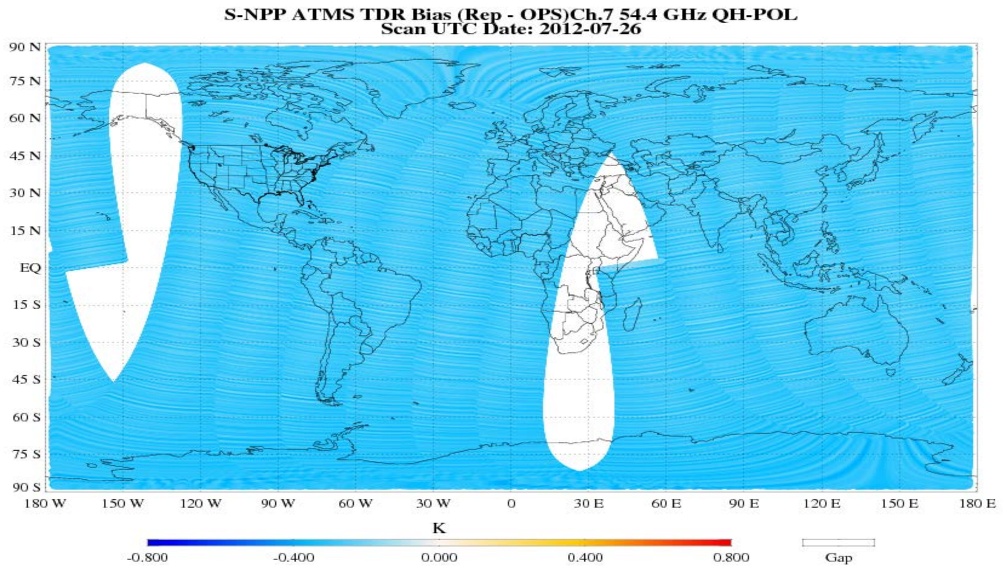
Instrument	Input Data	Output Data
ATMS	185 GB	400 GB
CrIS	6.57 TB	17.2 TB
OMPS NP	30 GB	86 GB
OMPS TC	138 GB	1.1 TB
VIIRS	20 TB	230 TB
S-NPP Total	27 TB	275 TB

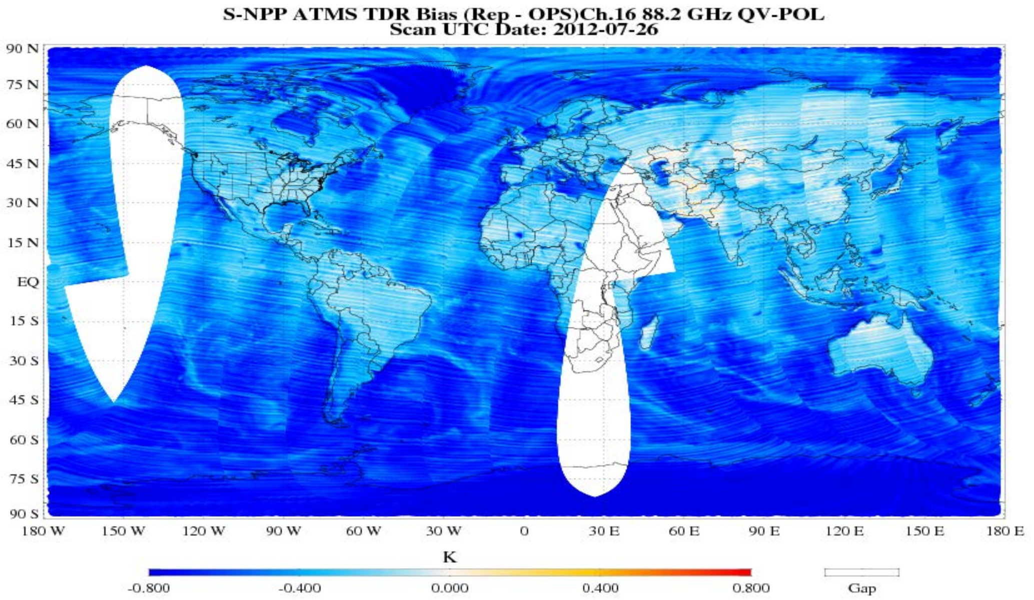
ATMS TDR Mean Bias after Reprocessing

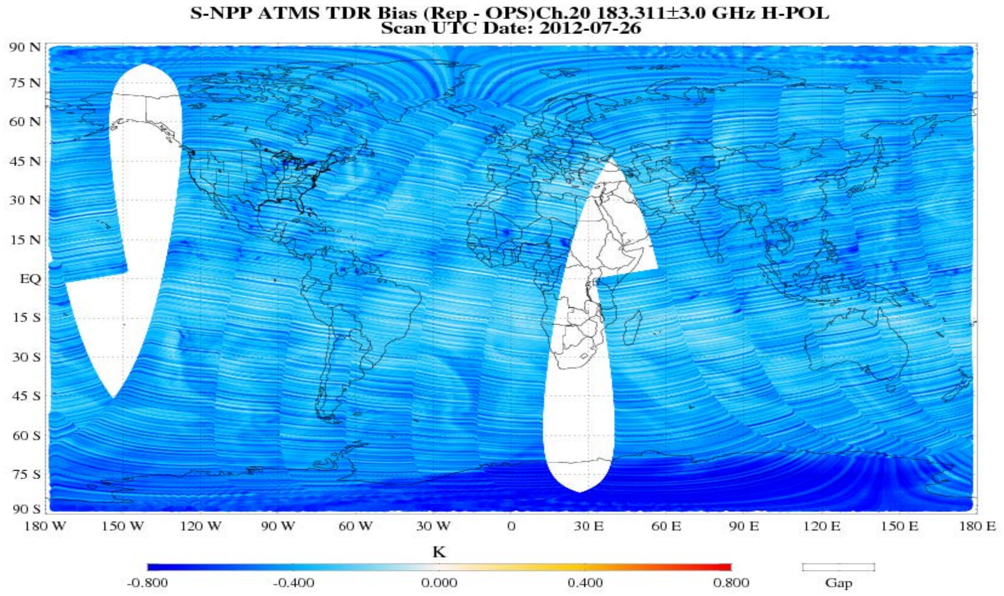


ATMS TDR Difference between Reprocessing and Operation







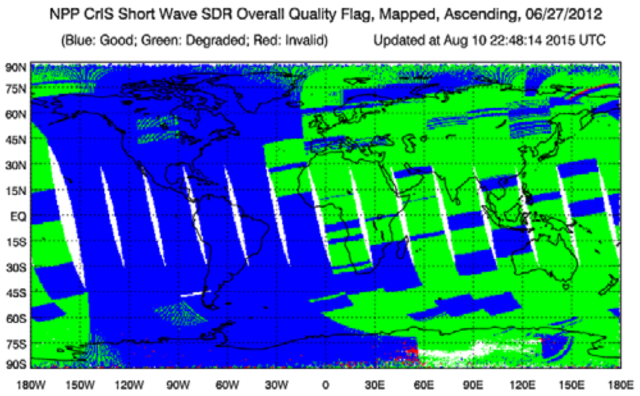


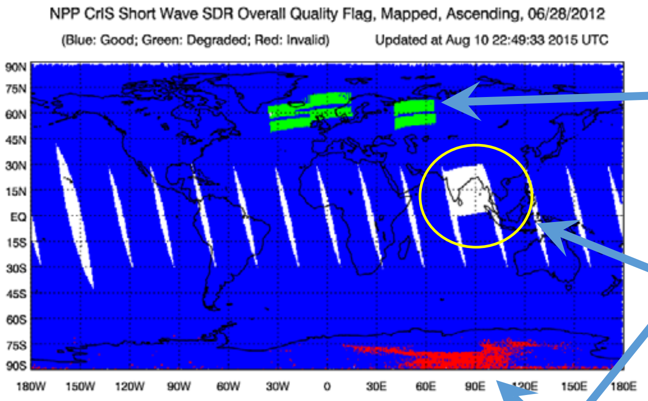
Impacts of CrIS SDR Algorithm Update on Data Quality

Internal thermal drift thresholds in engineering packet were updated around 14:00 on June 27, 2012

The next day after this update

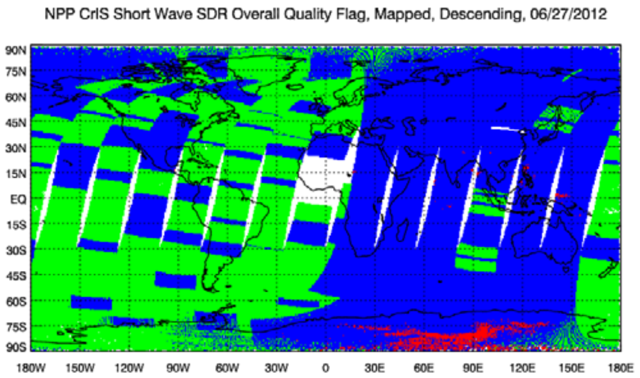
Remaining issues will be fixed after reprocessing

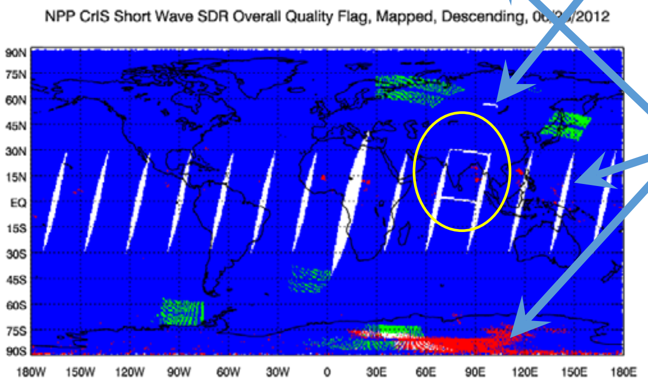




Cooler stage thermal drift limit is still too tight

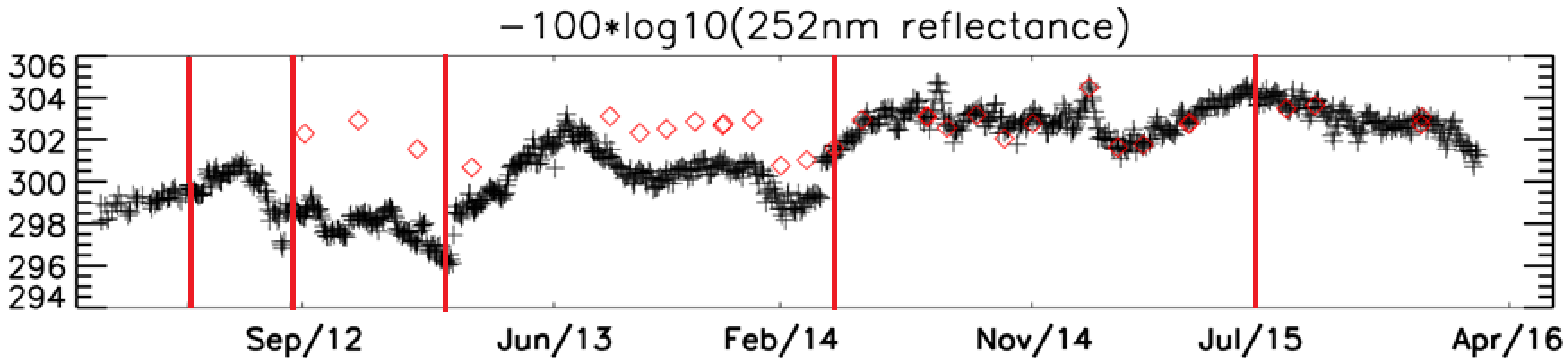
Blank granules with pre-defined filled values, i.e. the ‘1958’ granules





False alarm: Negative values as thresholds for Short-wave radiance invalidity over very cold scenes, i.e. Antarctic, Tropical cloud tops

Impacts of OMPS SDR Algorithm LUT Update on Data Quality



STRAYLIGHT-LUT

CF-EARTH-GND-PI

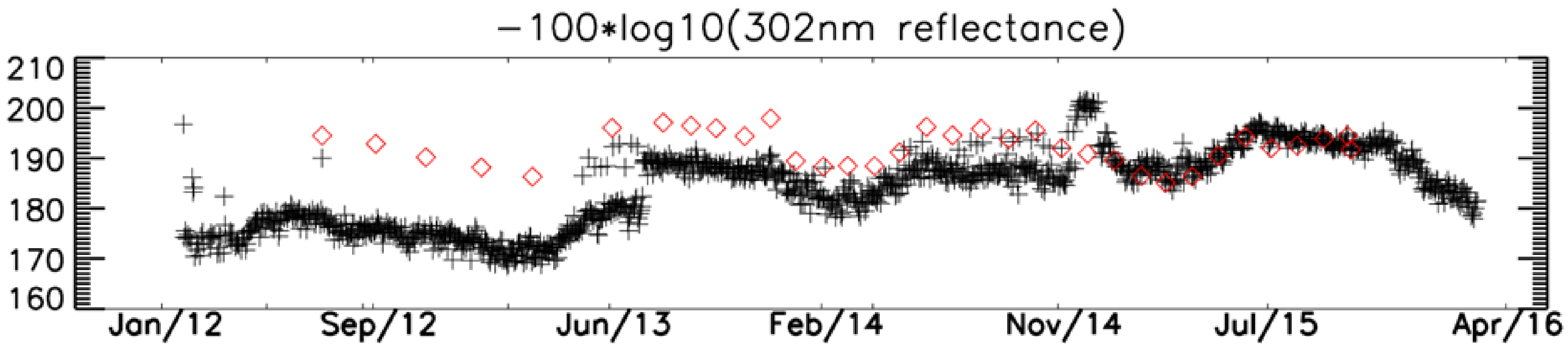
SDR-CC

BIAS-GND-PI

OSOL-LUT

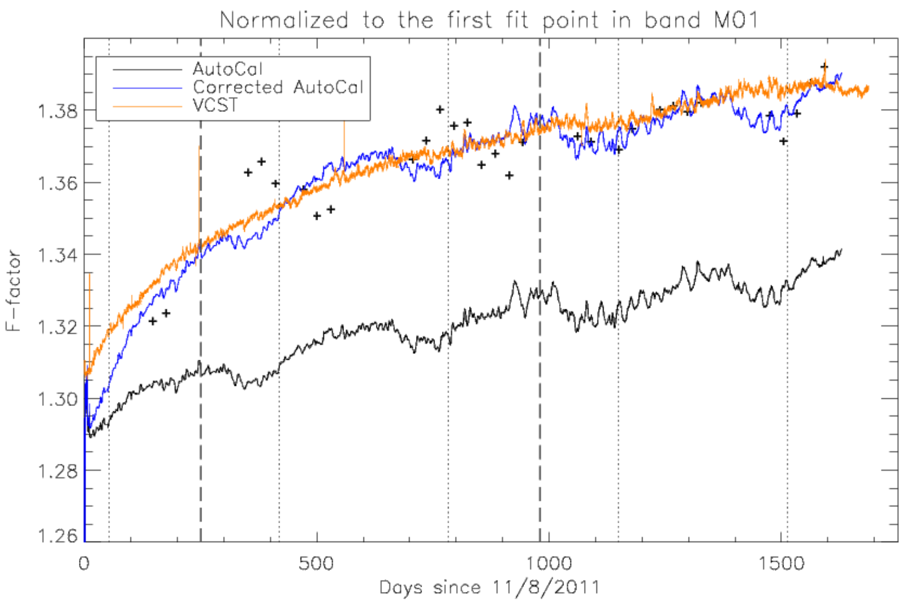
CALCONST-LUT

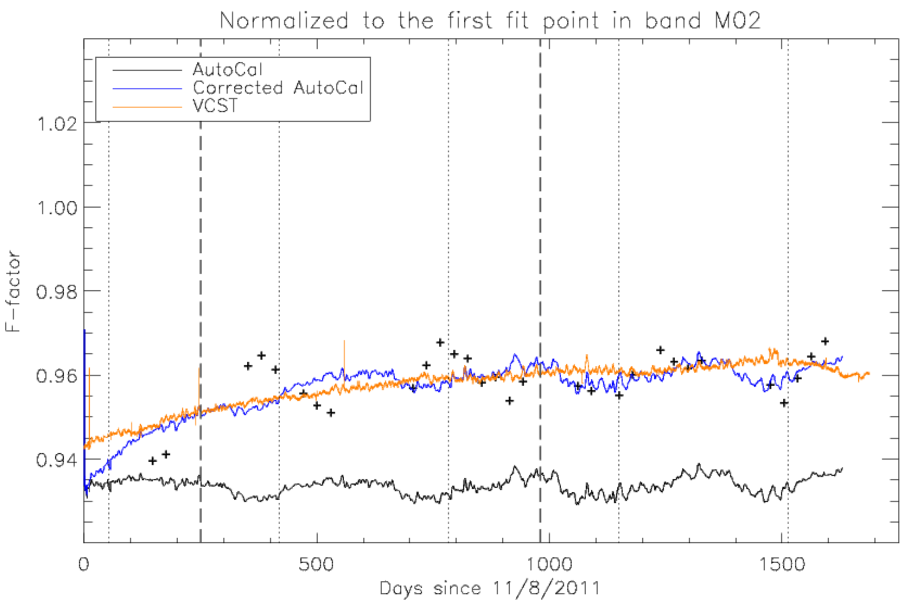
WAVELENGTH-GND-PI

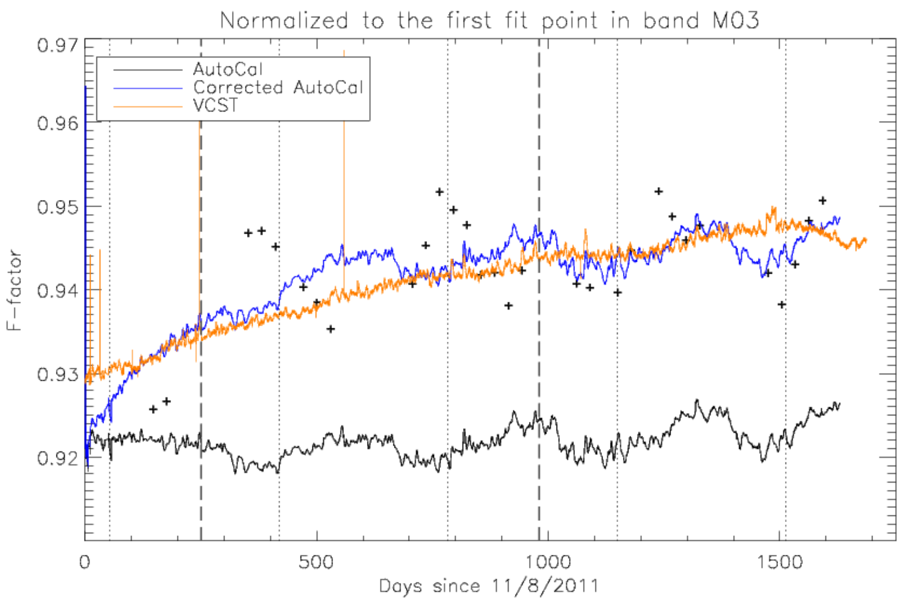


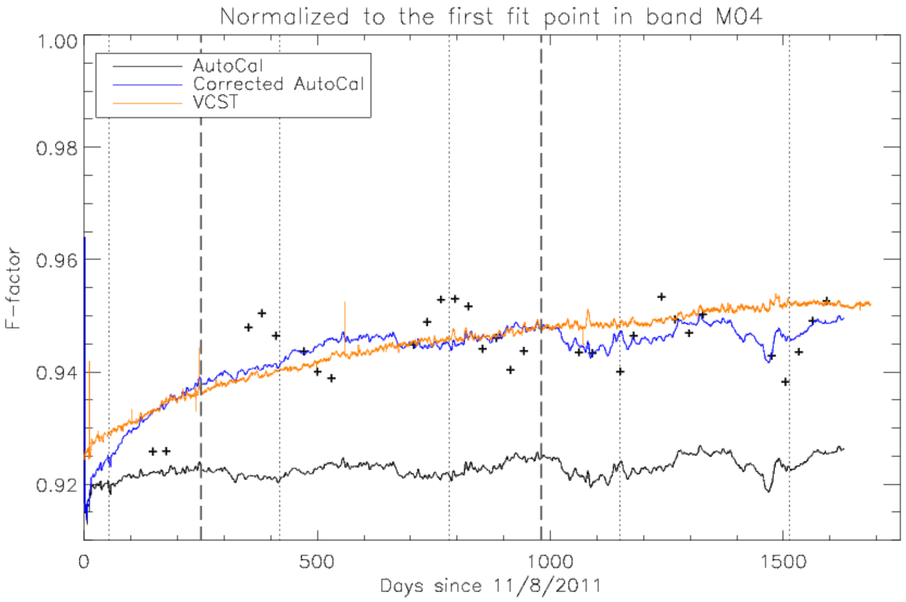
OMPS daily nadir view reflectance trending produced by ADL4.2 with up-to date table

VIIRS SDR F-Factor from Lunar-Corrected RSBAutocal



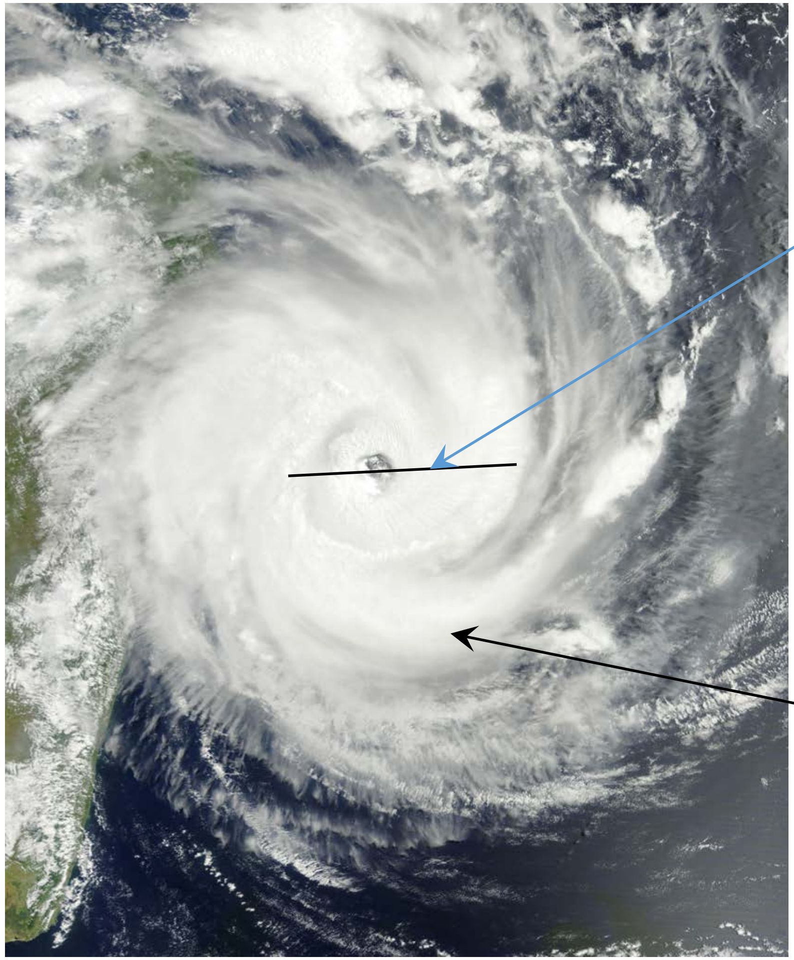


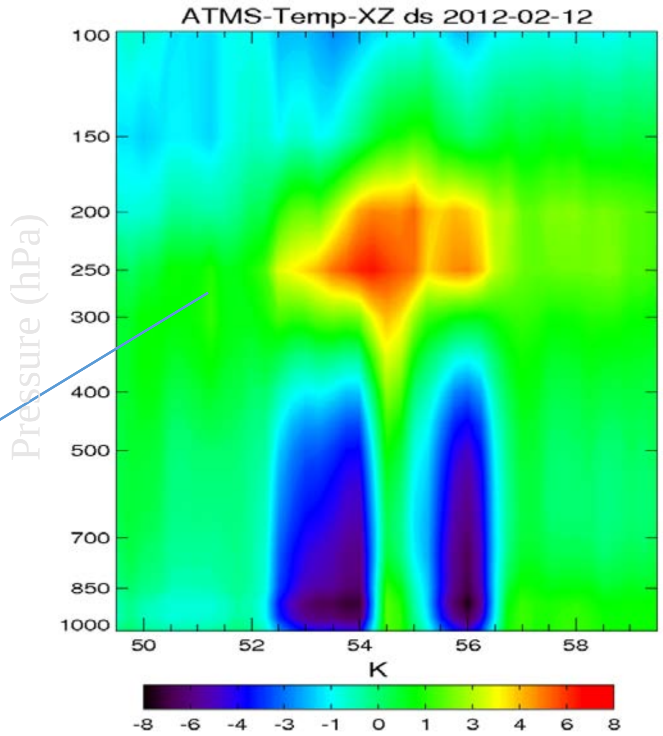




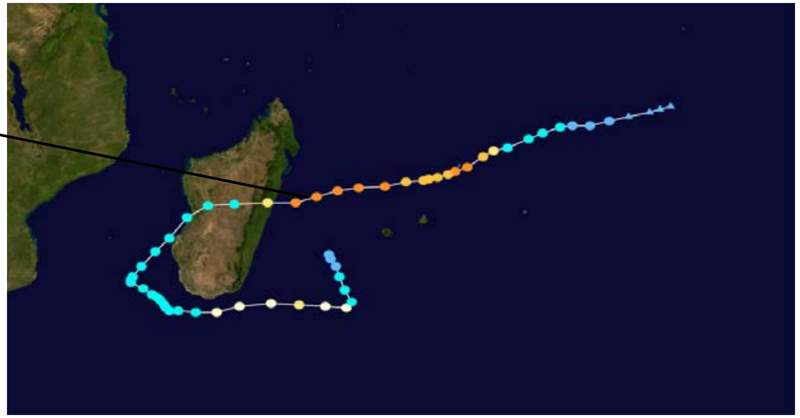
ATMS Monitors Well the Development of Tropical Cyclone Giovanna

Giovanna at Feb 13 2012 0630Z
MODIS Visible Channel

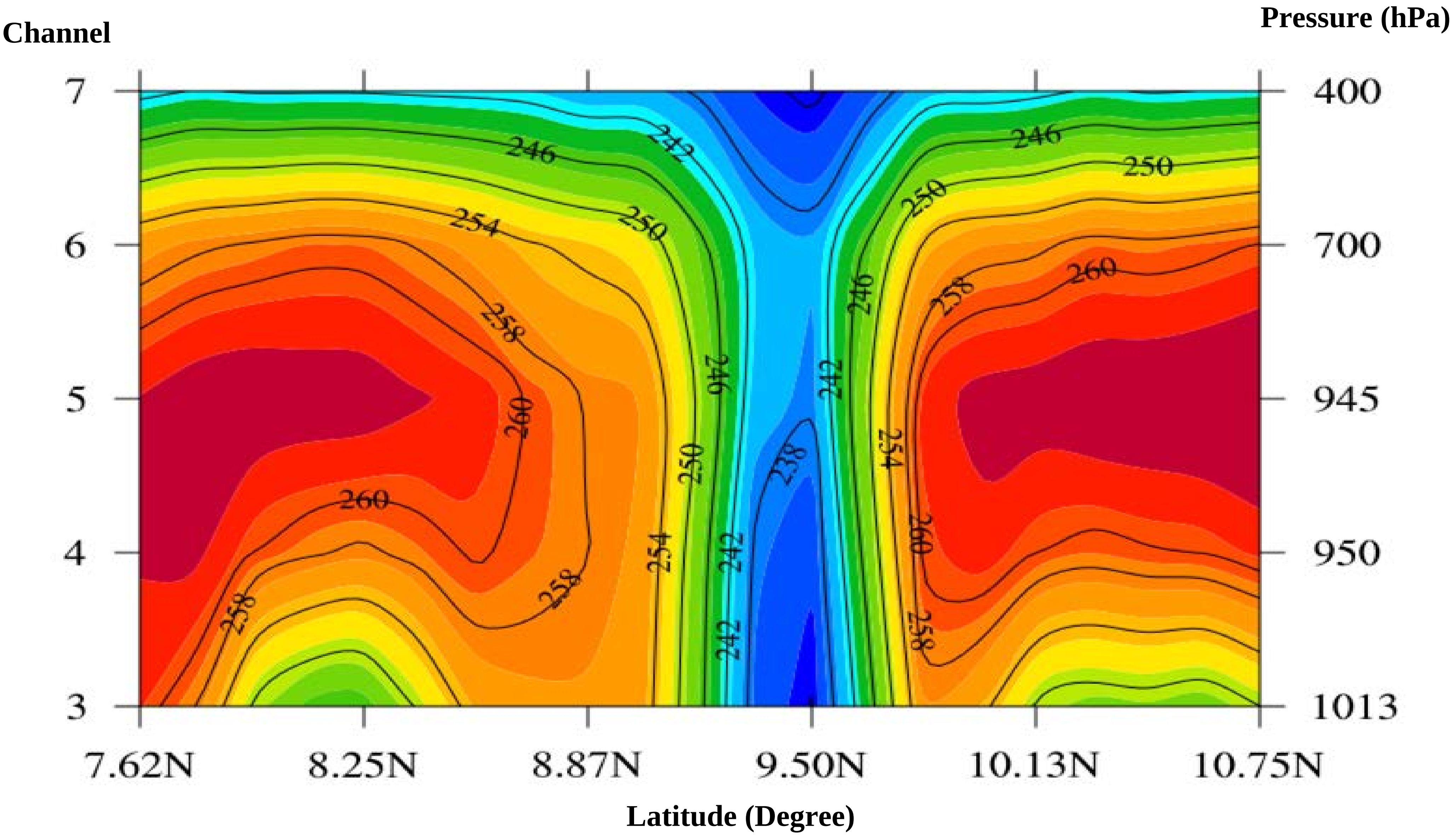




A warm core of 8K ore more at 250 hPa from ATMS indicated a category 4 to 5 hurricane intensity

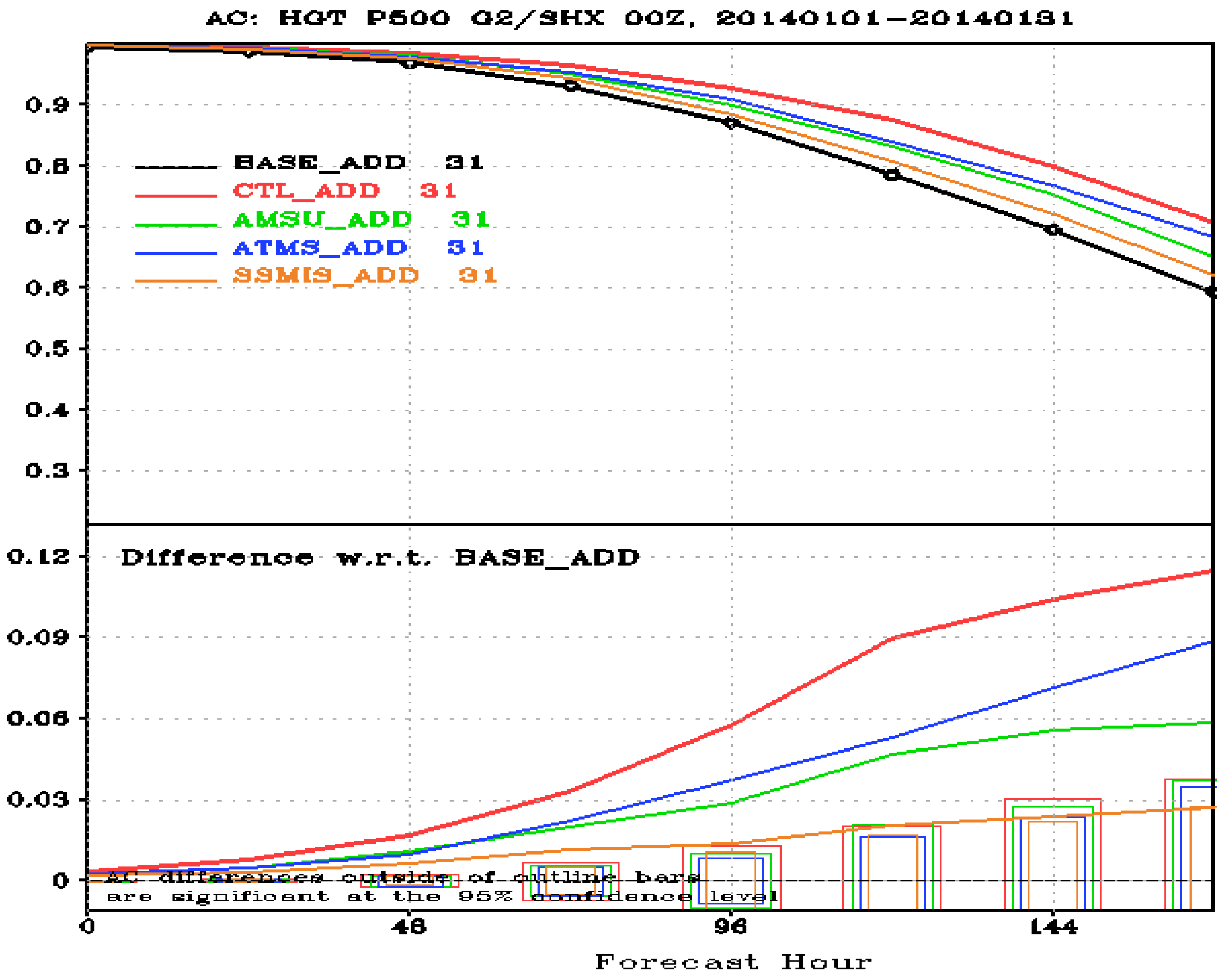


New ATMS Channel Composite Reveals Hurricane Structures



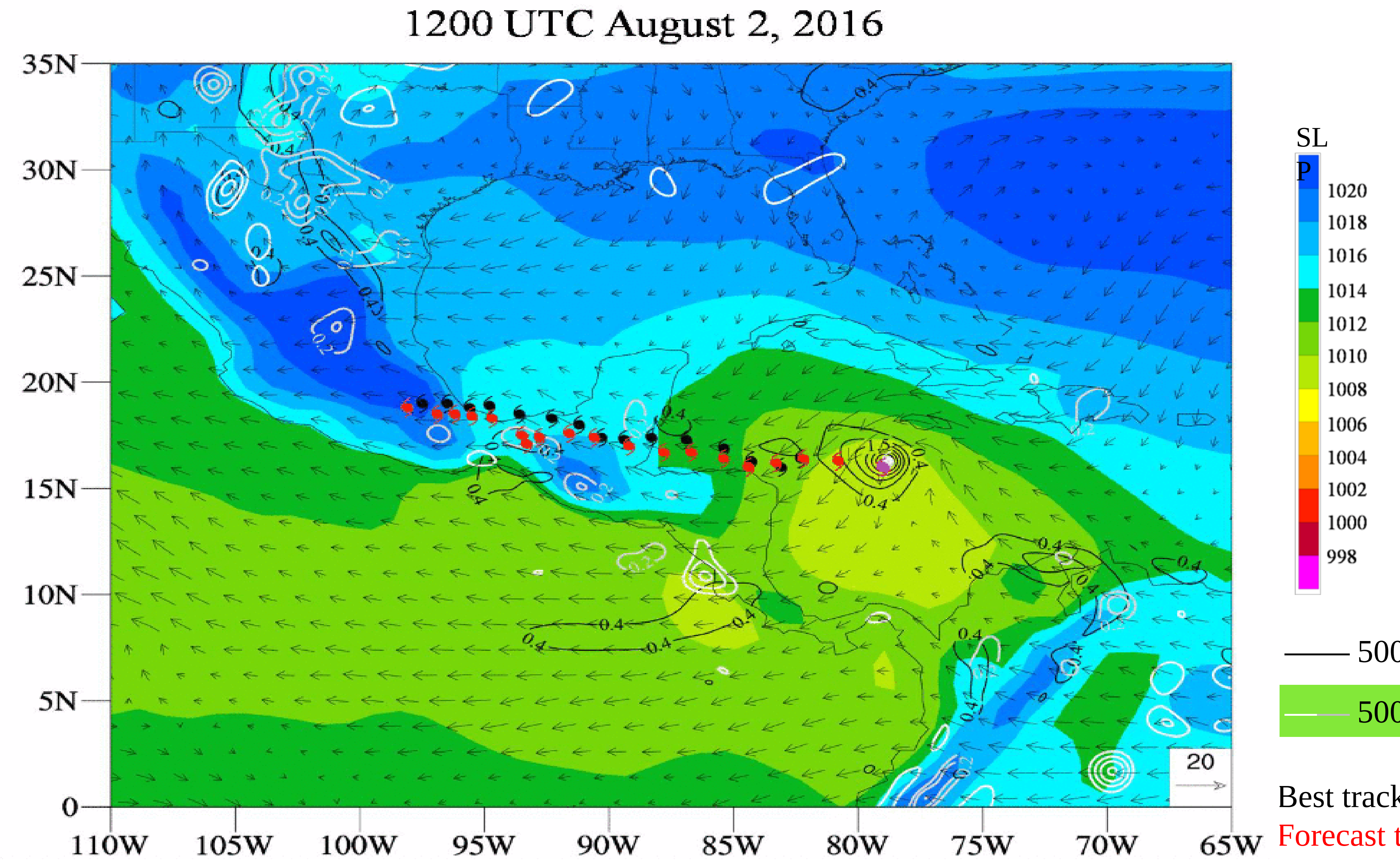
Impacts of Microwave Sounders in NCEP GFS

500 hPa Southern Hemisphere AC scores for 20140101 – 20140131 00Z



Assimilation of ATMS radiances in NCEP GFS produces a largest impact on global medium-range forecast, especially in southern hemisphere. The baseline experiment includes the conventional and GPSRO data and the control experiment includes all the satellite instruments and conversional data.

2016 Hurricane Earl Predicted by HWRF



500 hPa vorticity

500 hPa divergence

Best track in white/black

Forecast track in pink/red

ATMS DA Research Highlighted in Nature

METEOROLOGY

Satellite improves storm forecasts

Data from a US Earth-observing satellite could help improve the accuracy of prediction of hurricane track and strength.

When generating hurricane forecasts the US National Weather Services does not use real-time information from weather satellites. But Xiaolei Zou at Florida State University in Tallahassee and her colleagues looked at the effect of including data from the Suomi NPP satellite, launched in 2011, on hurricane forecasts.

The satellite's microwave instrument measures air temperature and humidity.

Incorporating Suomi data into the government's hurricane model for four 2012 storms, including Sandy(pictured), made for more accurate forecasts of track and intensity. The work suggests a way to improve the notoriously difficult predictions of storm strength. J. *Geophys. Res. Atm.*, 118, 11558-11576(2013)

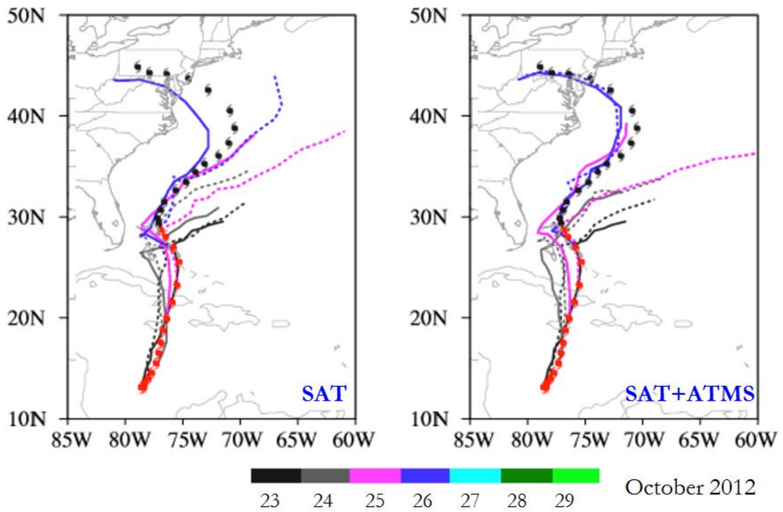
ROBERT SIMMON/NASA/NOAA GOES

Suomi NPP launch date: October 28, 2011
ATMS into NCEP operational system: May 25, 2012
Impact test completed: Spring 2013
Results published: Fall 2013

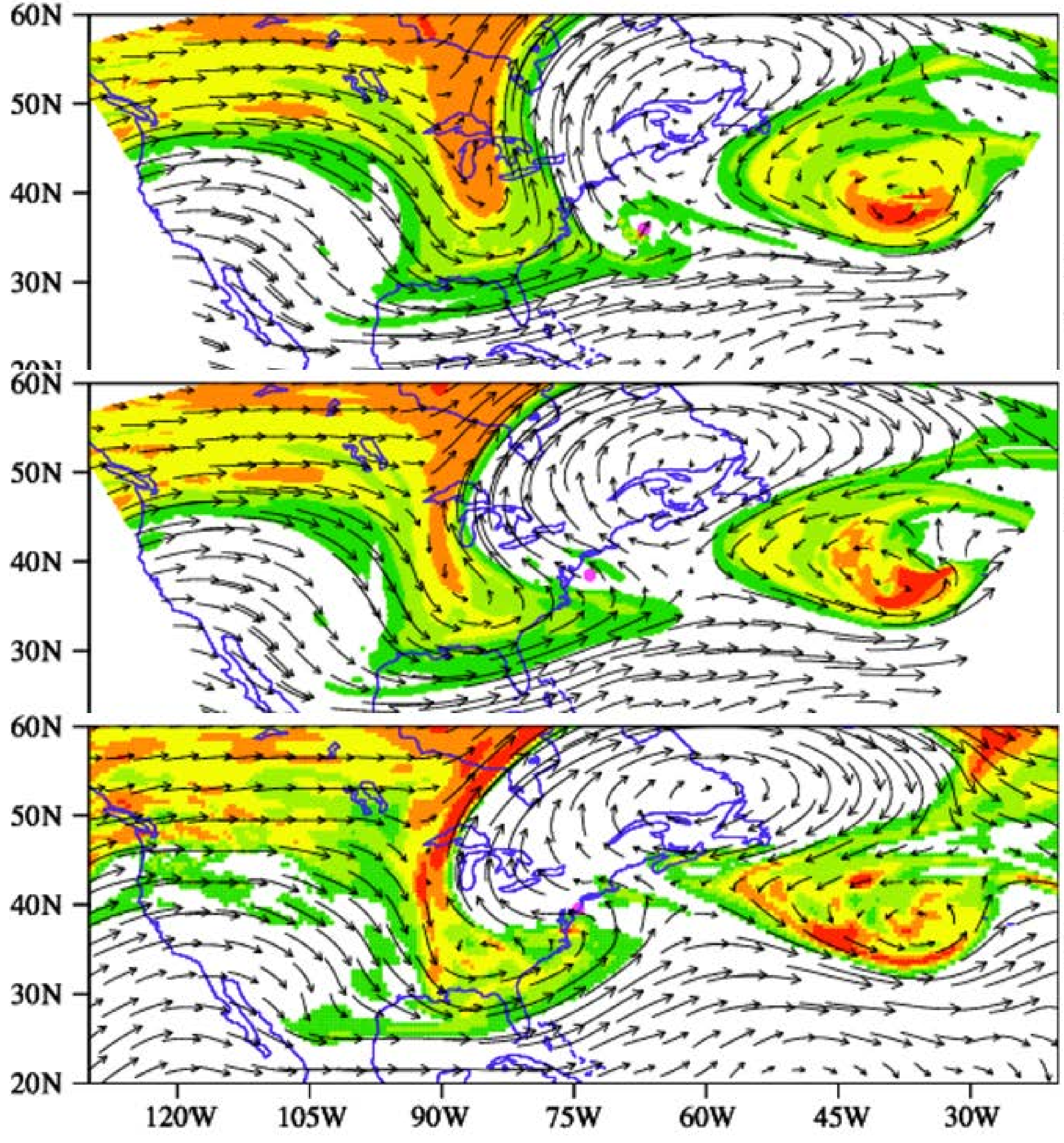
12 DECEMBER 2013 VOL 504 NATURE [19]

ATMS data assimilation in GSI/HWRF results in a consistent positive impact on the track and intensity forecasts of the four landfall hurricanes in 2012.

Impacts of ATMS Data Assimilation on Track Forecast of Hurricane Sandy



Hurricane Sandy (PV at 200 hPa)



84-h Forecast without ATMS

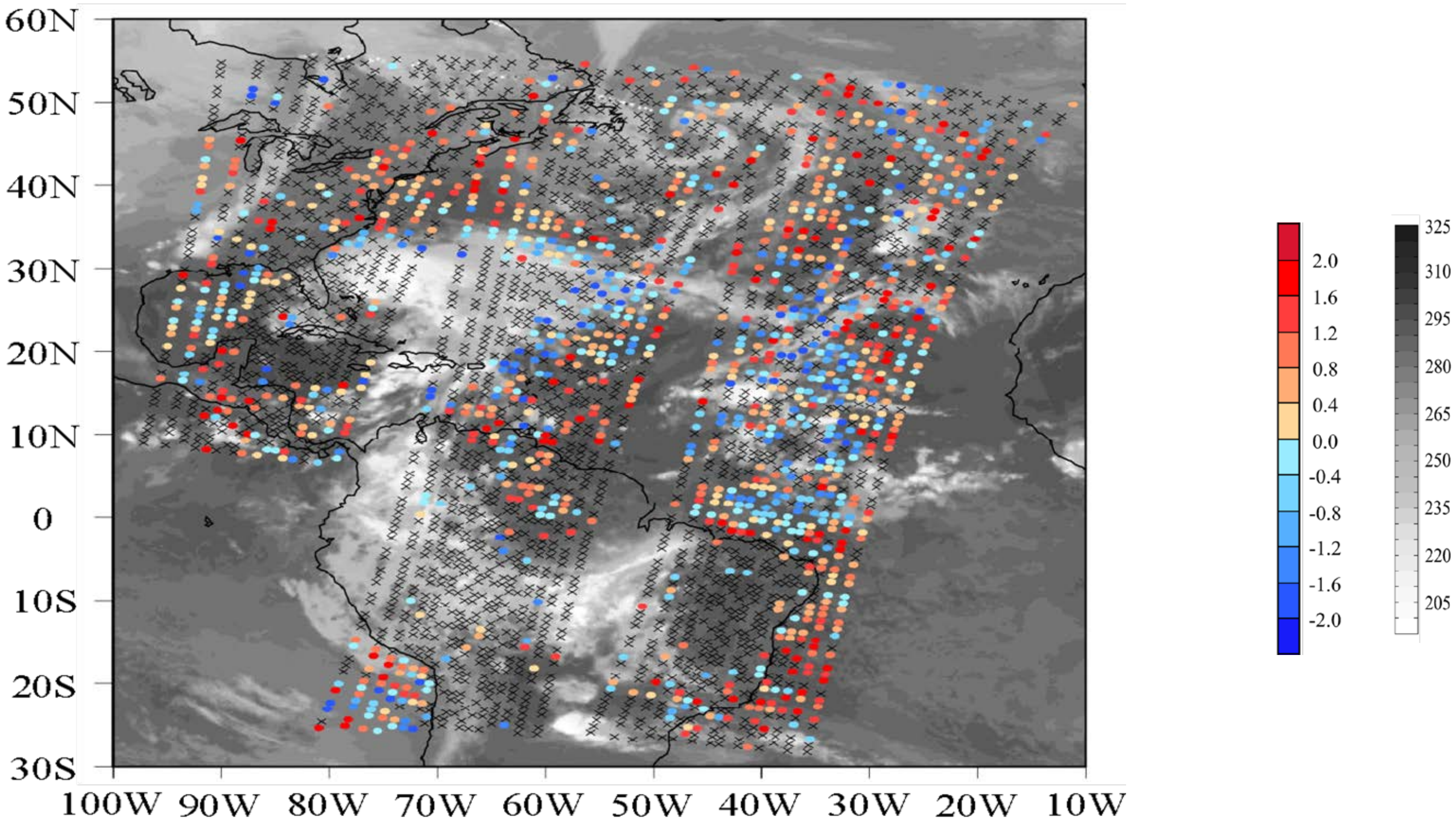
84-h Forecast with ATMS

NCEP GFS analysis

0000UTC October 30

ATMS Quality Control in HWRF/GSI

O-B
ATMS
Ch19



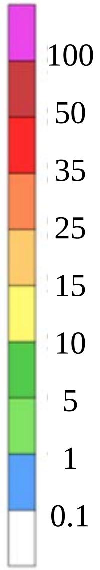
GSI QC performs well for ATMS water vapor sounding channels due to the use of more window channels (1, 2, 16, 17) for cloud detection

0600-0900 UTC

1200-1500 UTC

AMSU-A and MHS data assimilation improves forecasts of Hurricane ISAAC's rainbands

Observed
3-h rainfall



CTRL

AMSU-A, MHS assimilation as two data streams

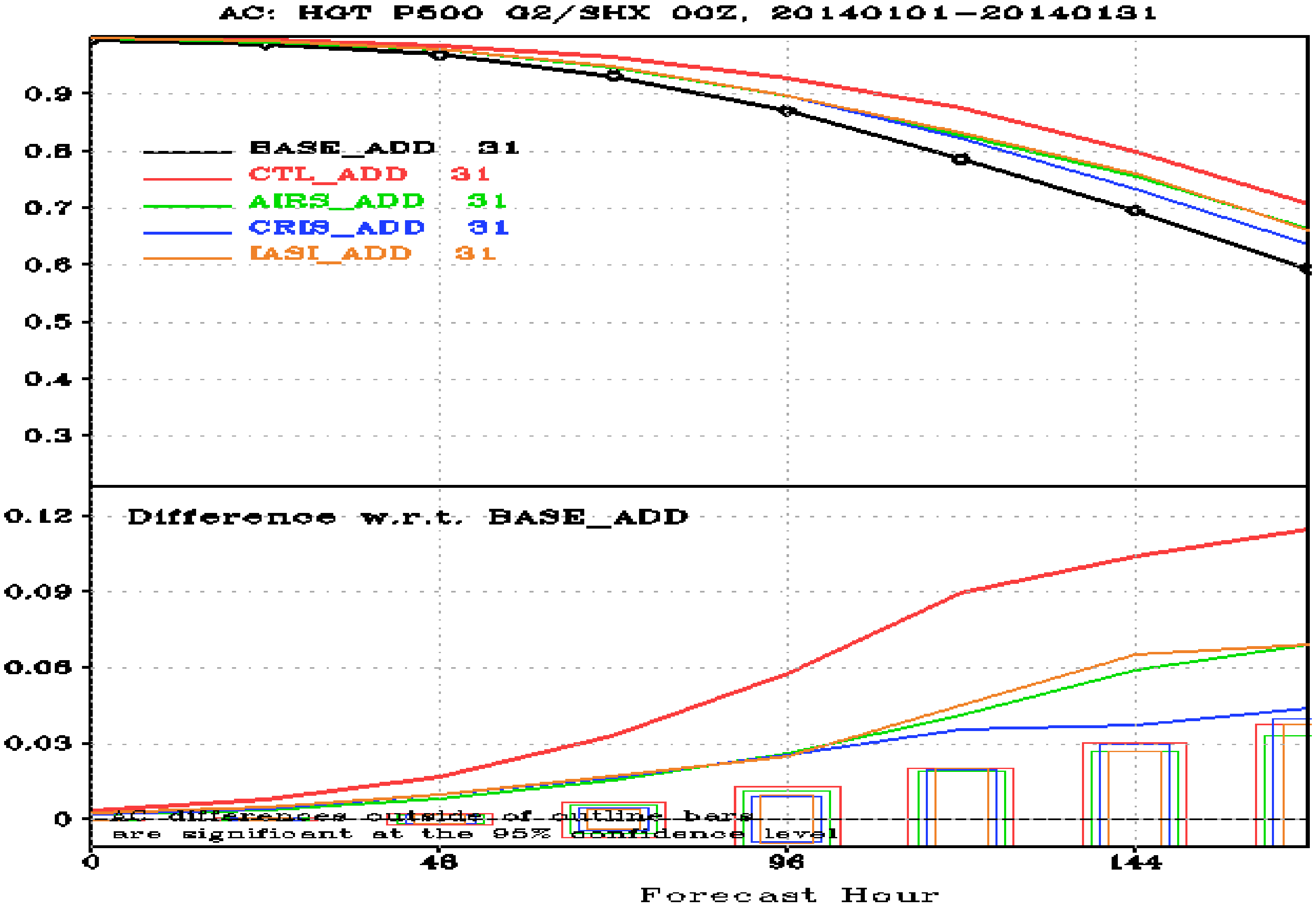
ODS

AMSU-A, MHS assimilation as one data stream

August 30, 2012

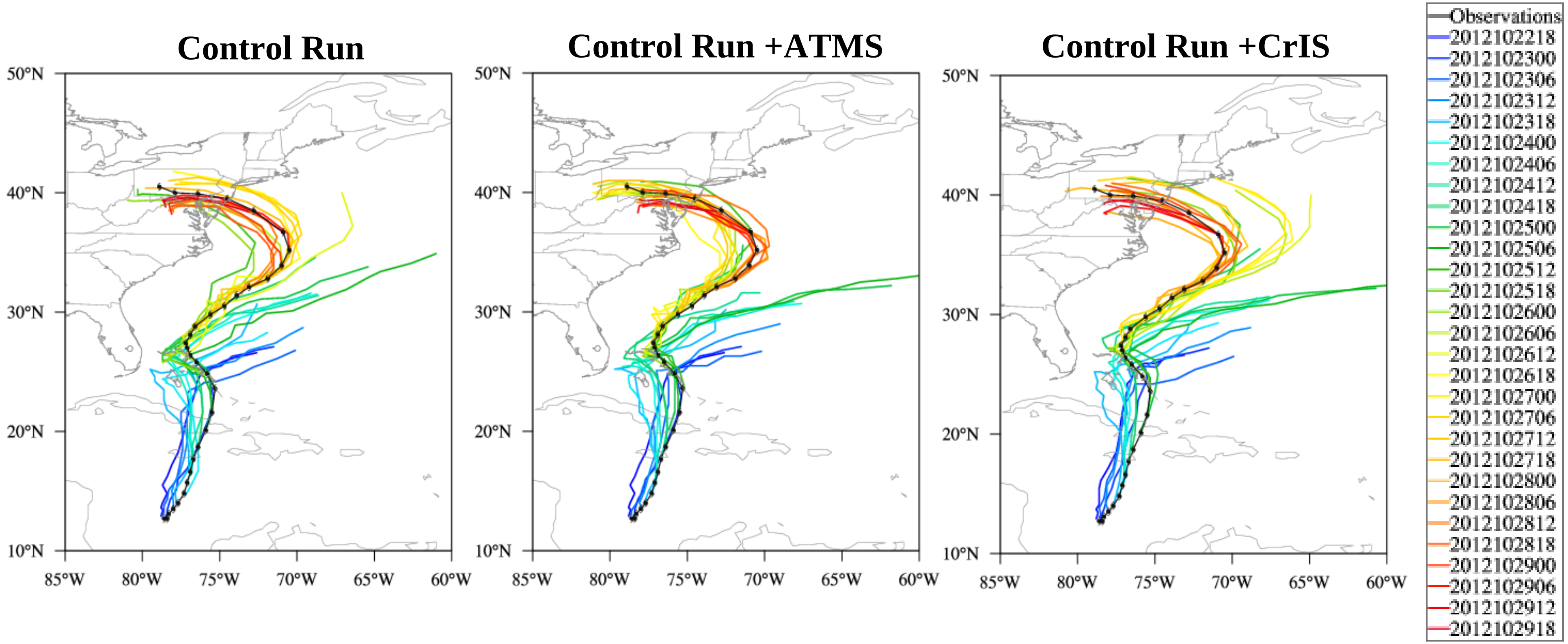
Impacts of Infrared Sounder in NCEP GFS

500 hPa Southern Hemisphere AC scores for 20140101 – 20140131 00Z



The impact from assimilation of CrIS radiances in NCEP GFS is smaller, compared to that from AIRS and IASI.
The baseline experiment includes the conventional and GPSRO data and the control experiment includes all the satellite instruments and conversional data.
The new quality control is required for ….

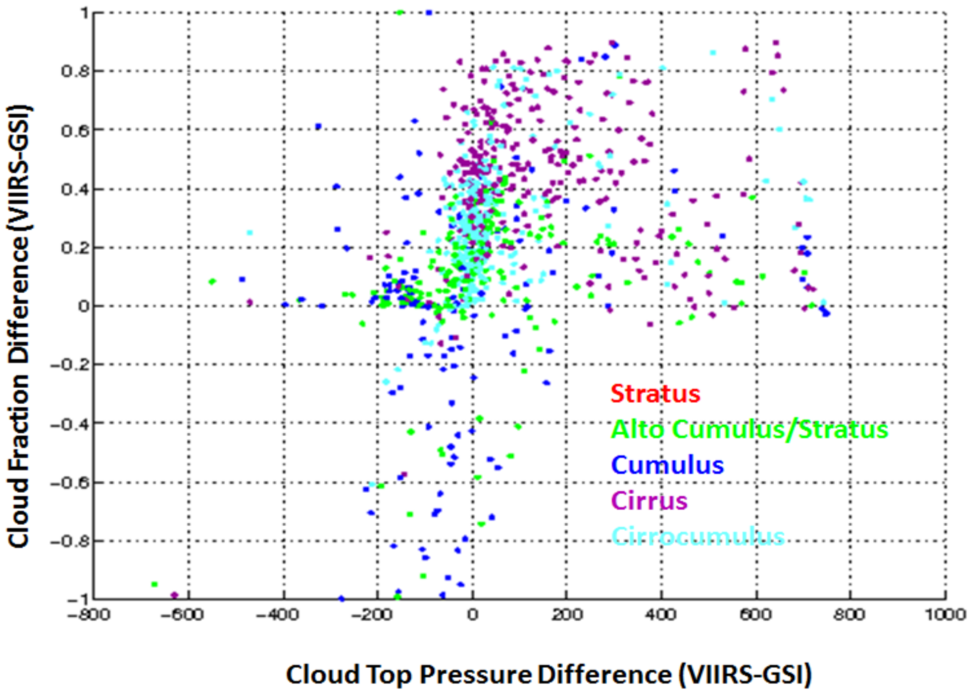
Impacts of CrIS and ATMS DA on Hurricane Forecasts

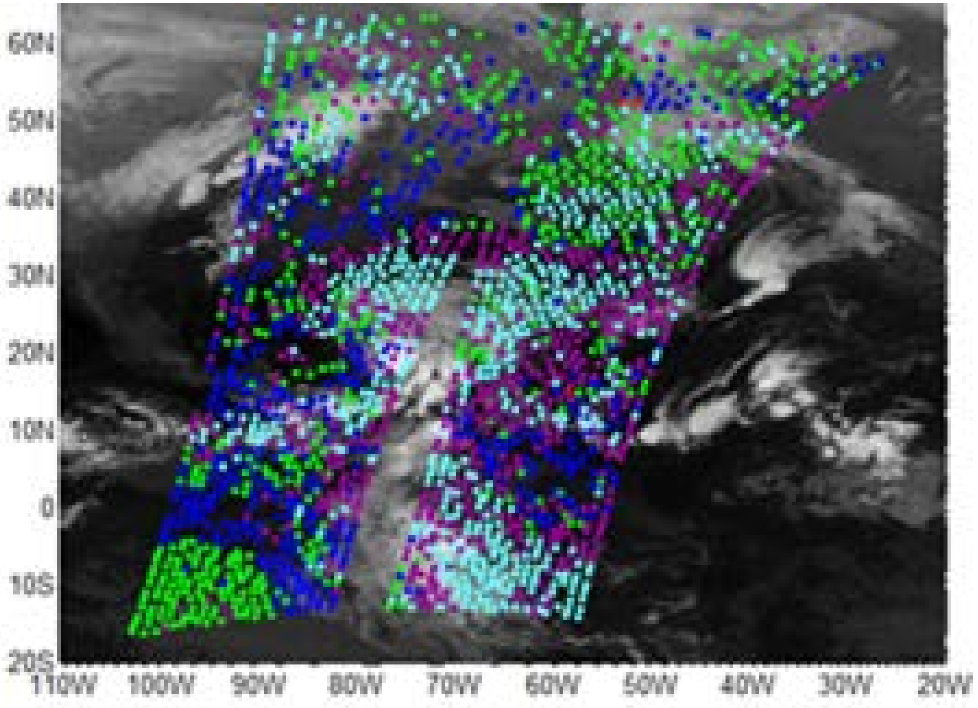


Unlike ATMS data, assimilation of CrIS radiance observations in HWRF degraded the forecasts of Superstorm Sandy tracks.。 Some fundamental issues related to QC of CrIS data are yet to be resolved!

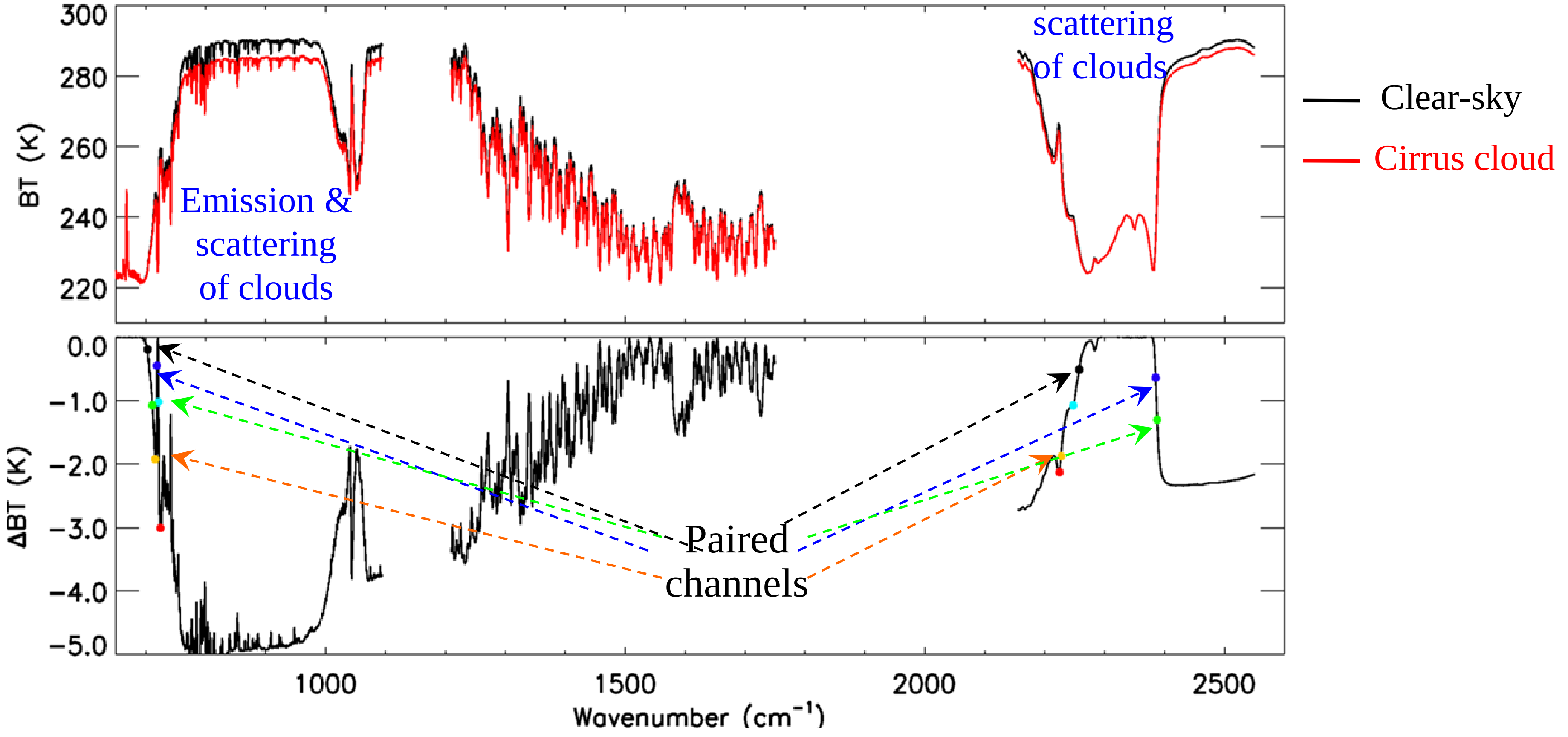
Issues with the Current GSI Cloud Detection

- The IR semi-transparent thin cirrus clouds are poorly detected by the current GSI QC scheme and thus the cloud-affected CrIS radiances could be treated as clear-sky radiances and assimilated wrongly into GSI.
- Compared with VIIRS cloud products, both CrIS cloud fraction and cloud top pressure derived in the current GSI are significantly biased.
- A new cloud detection algorithm needs to be developed for better discrimination of the optically thin cirrus clouds within CrIS FOVs.





Physical Basis for CrIS Double CO_2 Cloud Detection Algorithm



- The CrIS BTs at both LW (e.g., 670-750 cm^{-1}) and SW (e.g., 2200-2400 cm^{-1}) CO_2 channels display different responses to the changes of cloud vertical structures.
- A new cloud detection algorithm will be developed using the two CrIS CO_2 bands.

A New Cloud Index for CrIS DA QC Using CrIS Double CO2 Bands

A linear regression is established between the paired CrIS SWIR and LWIR channels.

$$T_{b,SWIR}^{regression} = \alpha T_{b,LWIR}^{obs} + \beta$$

where the regression coefficients α and β are obtained by minimizing the following cost function

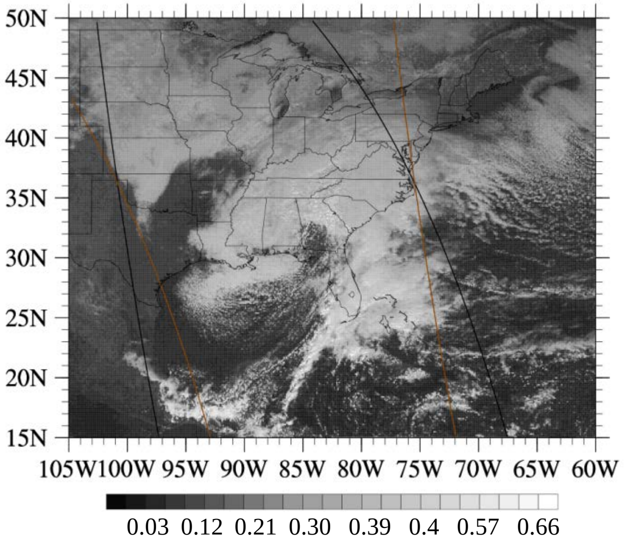
$$\min J(\alpha_i, \beta_i) = \sum_{j=1}^{JJ} \left(T_{b,SWIR}^{regression}(i,j) - T_{b,SWIR}^{CRTM}(i,j) \right)^2 \quad \text{(Clear pixels)}$$

An empirical cloud emission and scattering index (CESI) is defined for cloud detection at various altitudes

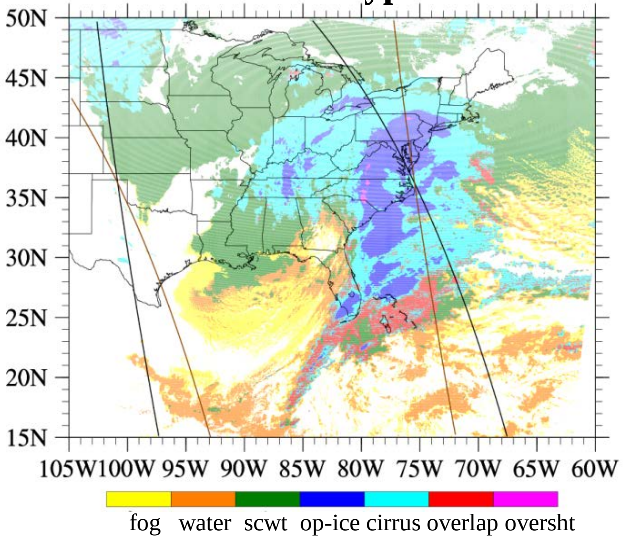
$$\boxed{CESI = T_{b,SWIR}^{regression} - T_{b,SWIR}^{obs}}$$

Validation of CESI by GOES Cloud Products

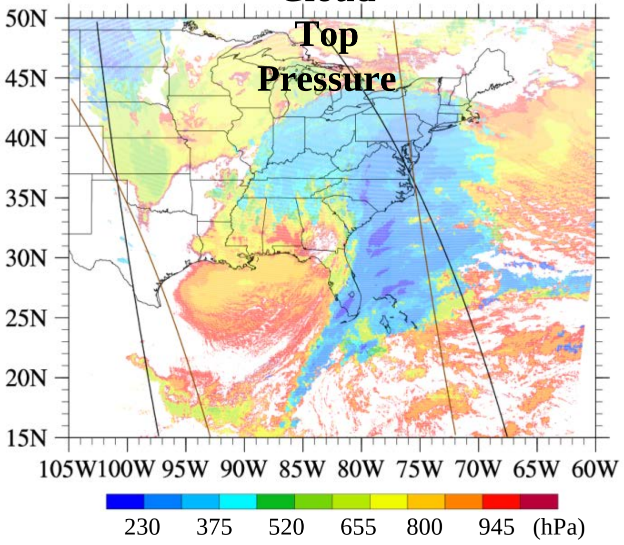
Reflectance of VIS Channel



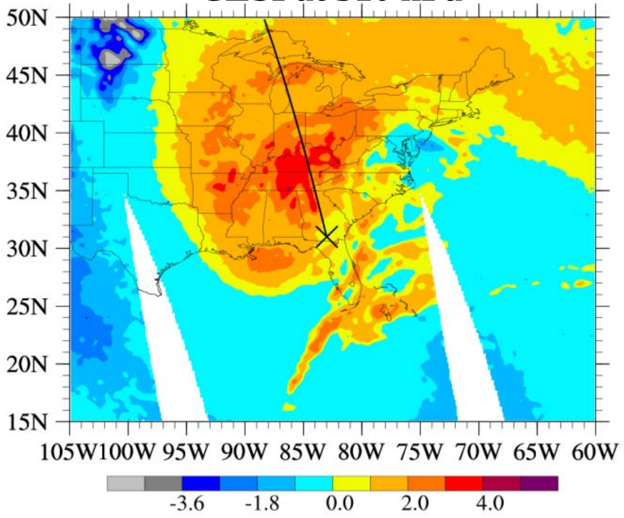
Cloud Types



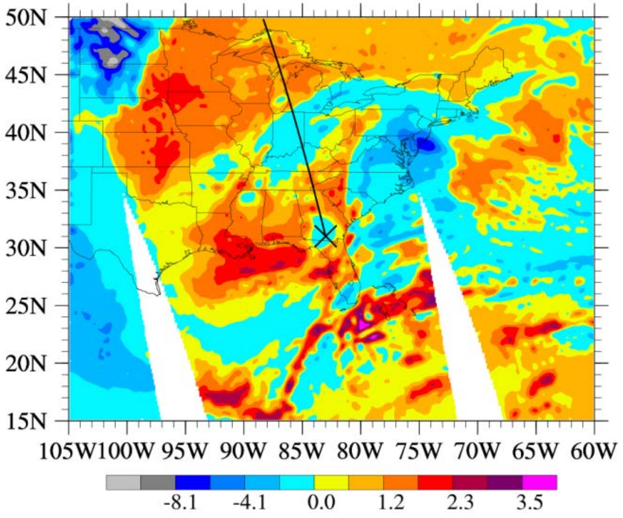
Cloud Top Pressure



CESI at 310 hPa



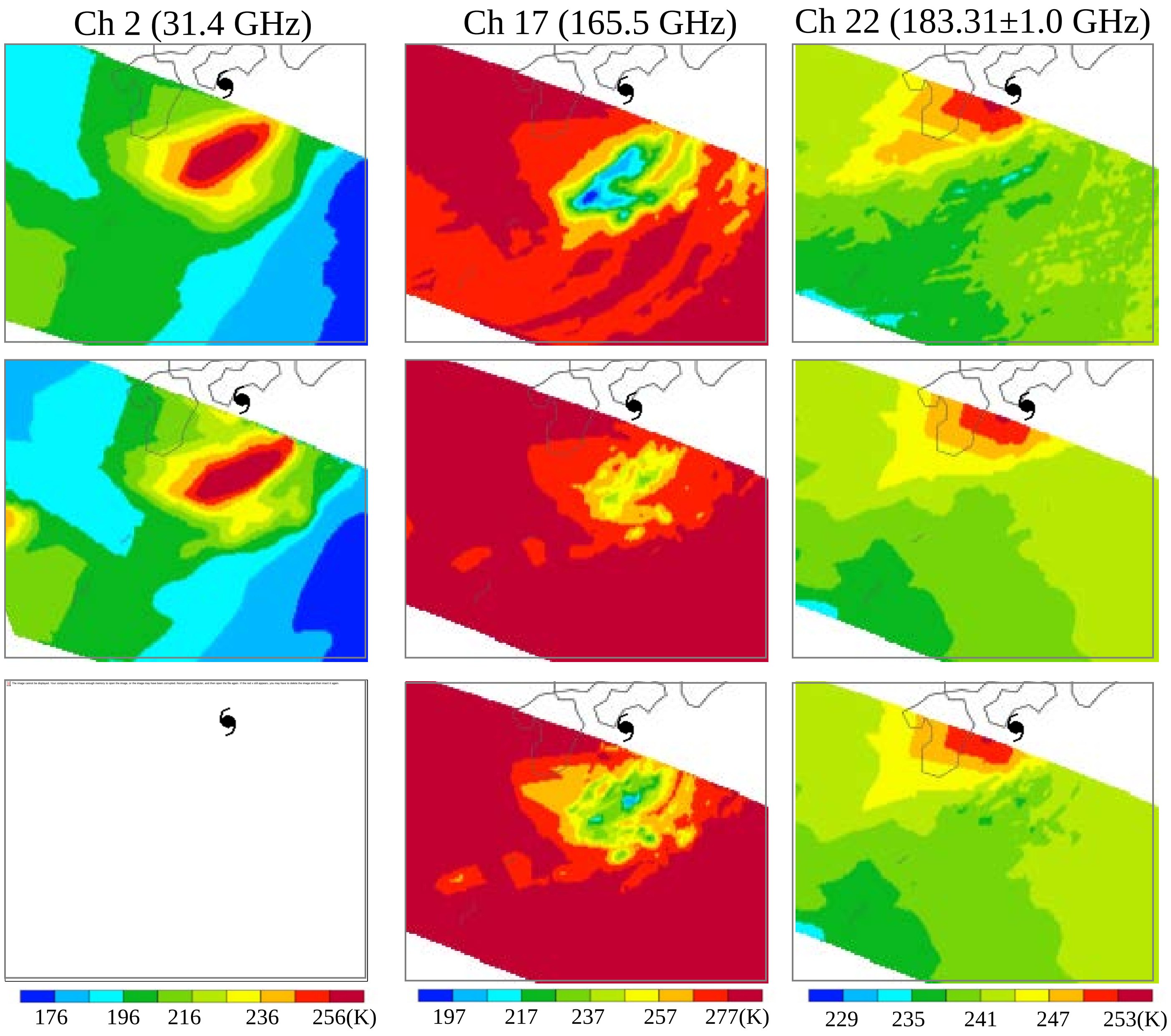
CESI at 469 hPa



Advanced Satellite Data Assimilation Activities

- Generate the new LUT for CRTM using discrete dipole approximation (DDA) to advance the cloudy radiance assimilation
- Develop a new interface for CRTM to incorporate the polarization capability
- Prepare CRTM readiness for uses of CrIS unapodized radiance data
- Evaluate cloud scattering and absorption table at infrared wavelengths
- Implement NLTE and solar reflection modules in CRTM
- Improve CRTM microwave surface emissivity model

Updates on ATMS Cloudy Radiance (O-B) from CRTM (Mie vs. DDA)



- The DDA can correct the over-estimation of scattering by Mie theory at 165 GHz
- The lower frequency channels are mainly affected by water phase clouds, thus the difference between DDA and Mie is not significant
- Scattering effect is not significant for upper-air temperature channels

J1 SDR Algorithm Readiness and Deliverables

- ATMS SDR:
  - Delivery of Pre-Launch Characterization Package: Feb-16
  - Delivery of PCT updates (ADR8199, CCR-2955): Jun-16
  - J-1 PCT with mounting Coefficients (ADR 8224, CCR-2981): Jul-16
- CrIS SDR:
  - FCE updates: updated delivery (with ADL5.3_PSAT16; ADR 4481, CCR-2898): Apr-16
  - J-1 updates (DQI, A4, and Geo) (ADR 4481, 8057, 7968, and 7487, CCR-2979): Jun-16
  - J-1 PCT with mounting Coefficients (for TS & FS) (ADR 8210, CCR-2978): Jun-16
- VIIRS SDR:
  - Delivery of algorithm updates based on TVAC (ADR8036, CCR-2590): updated delivery: Nov-15
  - Delivery of LUTs updates based on TVAC (ADR7996,CCR-2589): updated delivery: Dec-15
  - J-1 Geo code update (ADR8160, CCR-2890): Apr-16
  - J-1 Launch Ready LUTs with mounting Coefficients (ADR 8161, CCR-2859): Jul-16
- OMPS SDR:
  - LUTs for S-NPP Block 2.0 (TC: ADR8088, CCR-2764; NP: ADR8139, CCR-2765):
    - ❖ Delivery: Mar-16; updated delivery (with ADL5.3_PSAT16): Apr-16
  - JPSS-1 Launch Ready LUTs (Initial delivery. TC: ADR8158, CCR-2848; NP: ADR8159, CCR-2849):
    - ❖ Delivery: Mar-16; updated delivery (with ADL5.3_PSAT16): Apr-16
  - JPSS-1 Launch Ready LUTs (final delivery) with mounting Coefficients
    - ❖ TC: ADR 8211, CCR-2962; NP: ADR 8212, CCR-2963
    - ❖ Delivery: Jul-16

J1 TDR/SDR Algorithm Schedule

Beta

- CrIS L+68D
- ATMS L+20D
- VIIRS L+70D
- OMPS NM L+68D, NP: L+68D

Provisional

- CrIS L+90D
- ATMS L+36D
- VIIRS L+90D
- OMPS NM L+90D, NP L+90D

Validated

- CrIS L+9M
- ATMS L+6M
- VIIRS L+9M
- OMPS NM: L+9M, NP: L+9M

Summary and Conclusions

- Suomi NPP instruments are well calibrated and their performance in orbit meet the specification
- Many of ATMS instrument calibration and SDR science advances have been published through peer-reviewed process (2013 JGR special issue, 2016 Remote Sensing special issues, etc)
- JPSS IDPS processing system is enhanced with new SDR sciences (e.g. CrIS FSR, ATMS antenna reflector emission, VIIRS RSB autocal-Lunar corrected)
- STAR ICVS is transitioned into operation and monitoring all the instrument performance in orbit
- SNPP SDR data are successfully assimilated into NWS global and regional forecast models and produced the largest positive impacts.