# JPSS Atmospheric Products and Their Reprocessing for Advancing Weather and Climate Applications

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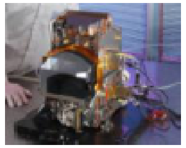
# Suomi NPP Instruments and Their Applications

| 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

# NWP User Recommendations on ATMS/CrIS SDR Reprocessing from the 2016 NOAA Workshop

- 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)

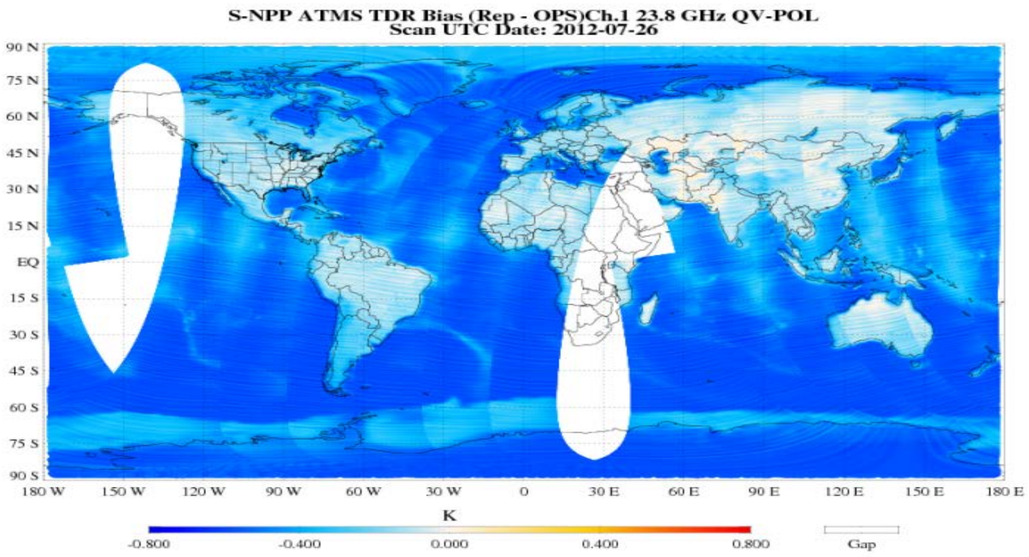
# Suomi NPP SDR Reprocessing Status

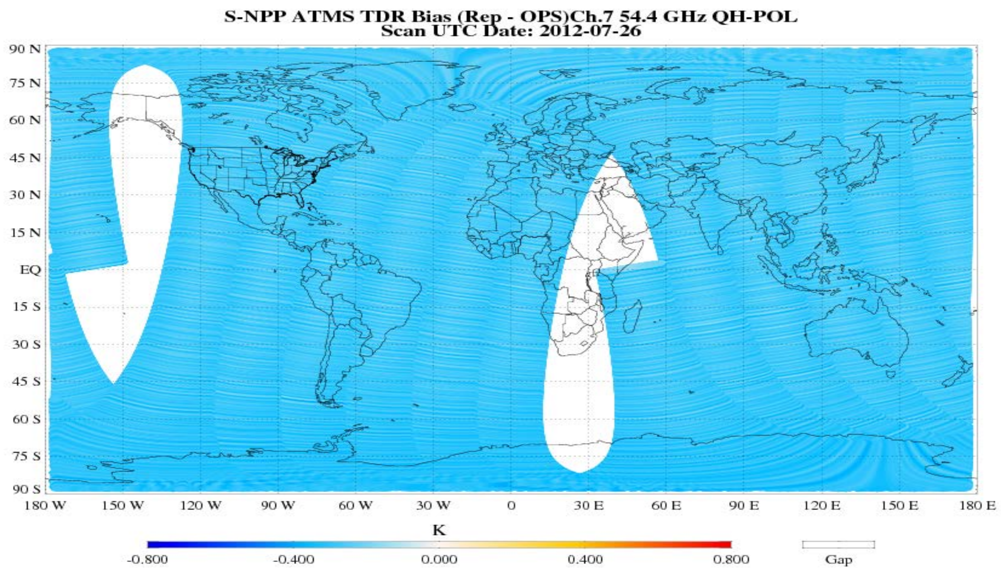
| Instrument | Data Length | Data Volume | Processing Speed | SW Version |
|---|---|---|---|---|
| ATMS | 2011-11-08 ~ 2016-08-31 | 500 GB/year | 5 hours/year | ADL 4.2_Mx8.11 with updates |
| CrIS | 2012-02-20 ~ 2016-08-31 | 16 TB/year | 1 day/year | ADL 5.3.1 |
| VIIRS | 2012-05-20~2012-05-28<br>2012-12-15~2012-12-21<br>2015-07-06~2015-07-12<br>2015-10-18~2015-10-24 | 200 TB/year | 10 days/year | ADL 4.2_Mx8.11 with updates |
| OMPS (NP) | 2012-01-26 ~ 2015-09-09 | 86 GB/year | 2.8 hours/year | ADL 5.3.1 |
| OMPS (TC) | 2012-01-26 ~ 2015-09-09 | 1 TB/year | 1 day/year | ADL 5.3.1 |

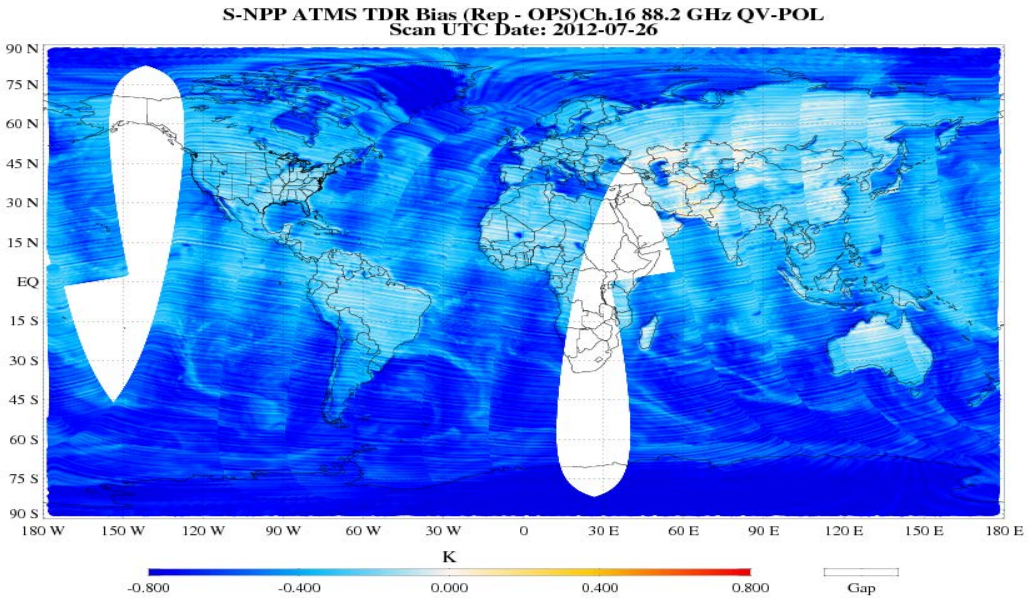
# Suomi NPP SDR Reprocessing Status

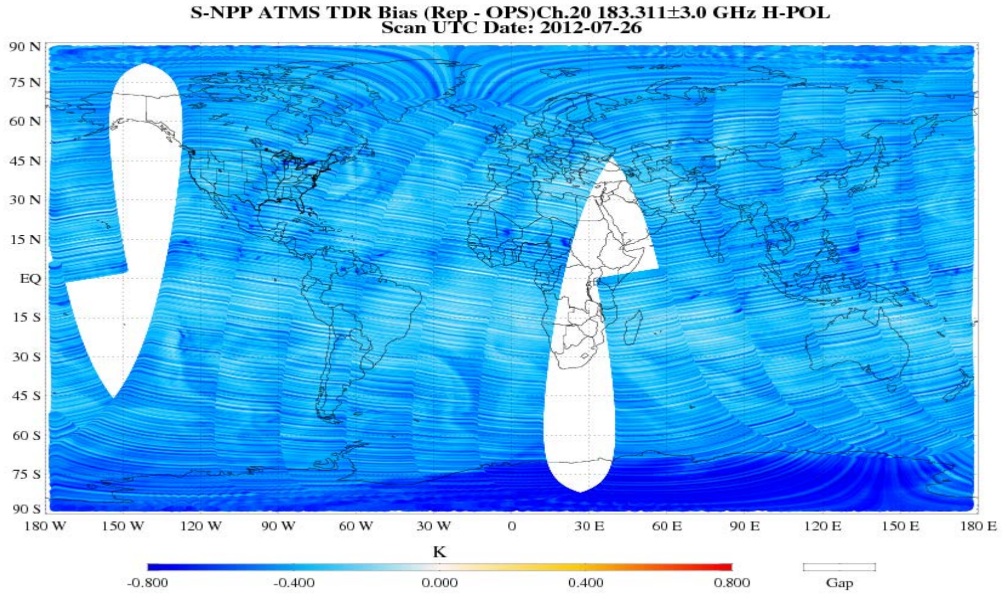
| Instrument | Data Availability at STAR | Note |
|---|---|---|
| ATMS | Reprocessed TDR/SDR/GEO<br>/data/data246/wchen/ATMS-REP-V0<br><br>2.2 degree FOV size resampled TDR from reprocessed TDR<br>/data/data246/gregk/Remap_Reprocess_TATMS/output_remap | Data quality verification performed |
| CrIS | Normal spectral resolution data | Data quality verification performed |
| VIIRS | Reprocessed SDR/GEO/Terrain Corrected GEO<br>/data/data263/gregk/VIIRS_SDR | No extended data quality verification performed |
| OMPS (NP) | Reprocessed SDR/GEO<br>/data/data245/gregk | Data migration ongoing<br>Data quality verification performed |
| OMPS(NM) | Reprocessed SDR/GEO<br>/data/data245/gregk | Data migration ongoing<br>Data quality verification performed |

# ATMS TDR Difference between Reprocessing and Operation

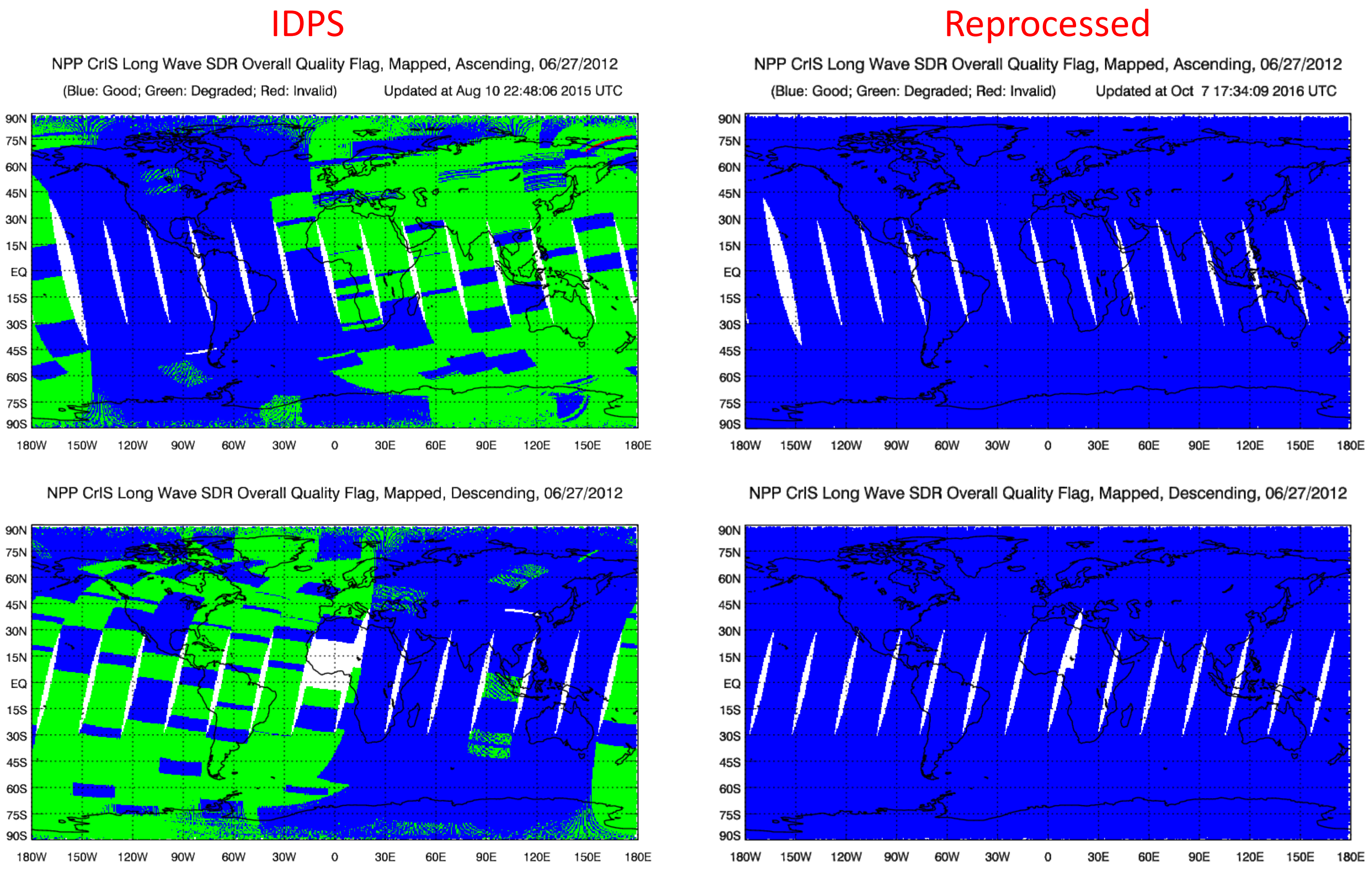


# Impacts of CrIS SDR Reprocessing on Data Quality



# Satellite Data Assimilation for Improving Forecasts of Hurricanes and Precipitation: Participants and Partnership

1. NOAA Center for Satellite Applications and Research
2. NWS/NCEP Environmental Modeling Center
3. Joint Center for Satellite Data Assimilation
3. University of Maryland
4. NOAA Atlantic Ocean and Marine Laboratory
5. NOAA Joint Polar Satellite Program Office
6. NOAA GOES-R Program Office
7. OAR/ESRL/GSD

# Radiance Assimilation in Hurricane WRF Model

- Refine the NCEP Gridpoint Statistical Interpolation (GSI) system (e.g. quality control, bias correction, background covariance) for regional NWP applications

- Increase the HWRF model top to 0.5 hPa for assimilating more upper-air sounding channels from polar-orbiting satellites

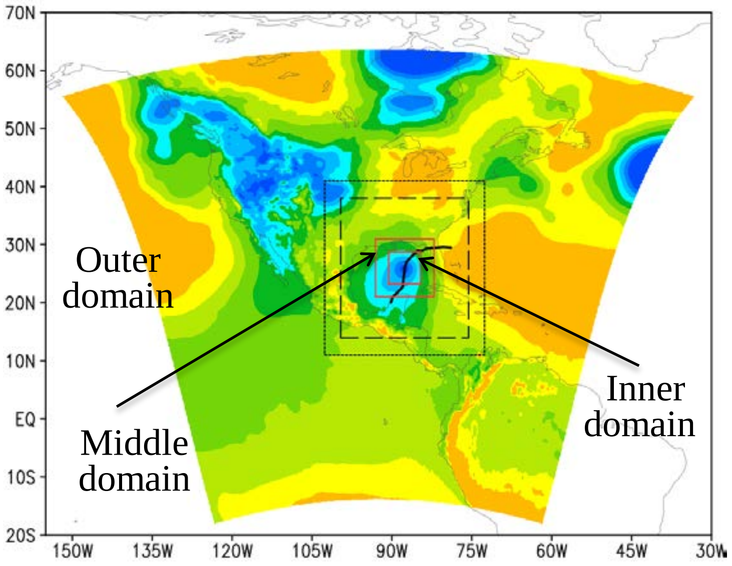
- Warm-start running the HWRF with its six hour forecast as the background field

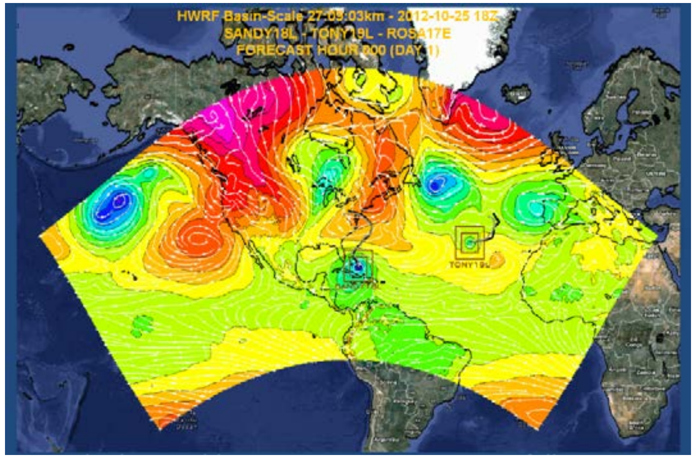
- Perform more experiments on assimilation of surface sensitive channels and cloudy and rain-affected radiances in NWP models

# HWRF Model and Data Assimilation System

- HWRF version 934 (3 nested domains) and Basin Scale HWRF (in testing)
- HWRF/DA
  - Higher model top (0.5 hPa, 61 levels)
  - Warm start (HWRF 6-h forecasts as background)
  - Asymmetric vortex initialization (VI)
  - Incremental analysis updates
- Advanced POES and GOES DA
  - POES sounding instruments: AMSU, ATMS, CrIS, IASI, AIRS
  - New Ice Cloud QC for MHS, Double CO2 Cloud QC for CRIS
  - ABI and AHI imager radiance
  - Microwave imagers: AMSR2 and GMI
  - Two-scale microwave FastEM including polarimetric components

Model Domains



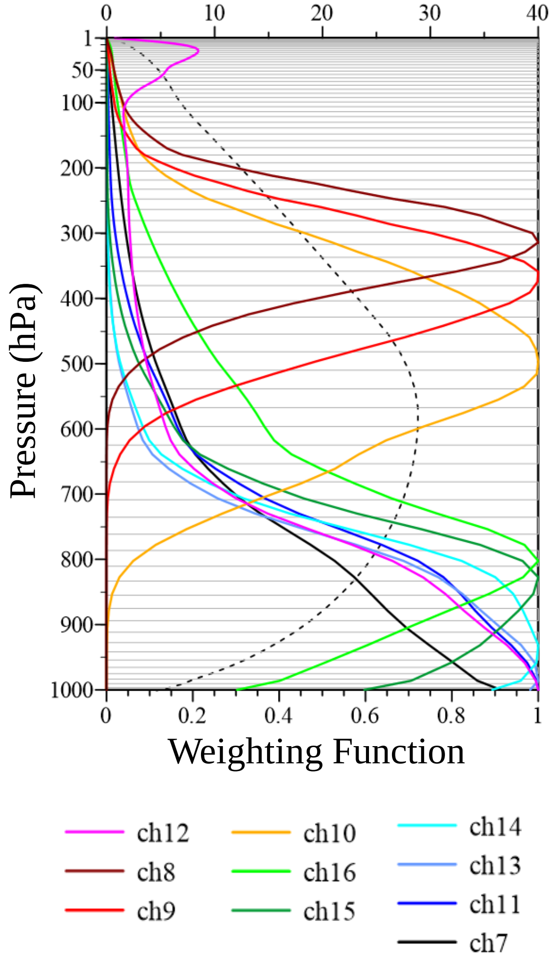




Three telescoping model domains:
Outer domain: 27 km (fixed, ASDA)
Middle domain: 9 km (movable, ASDA)
Inner domain: 3 km (movable)

# AHI Spectral Bands

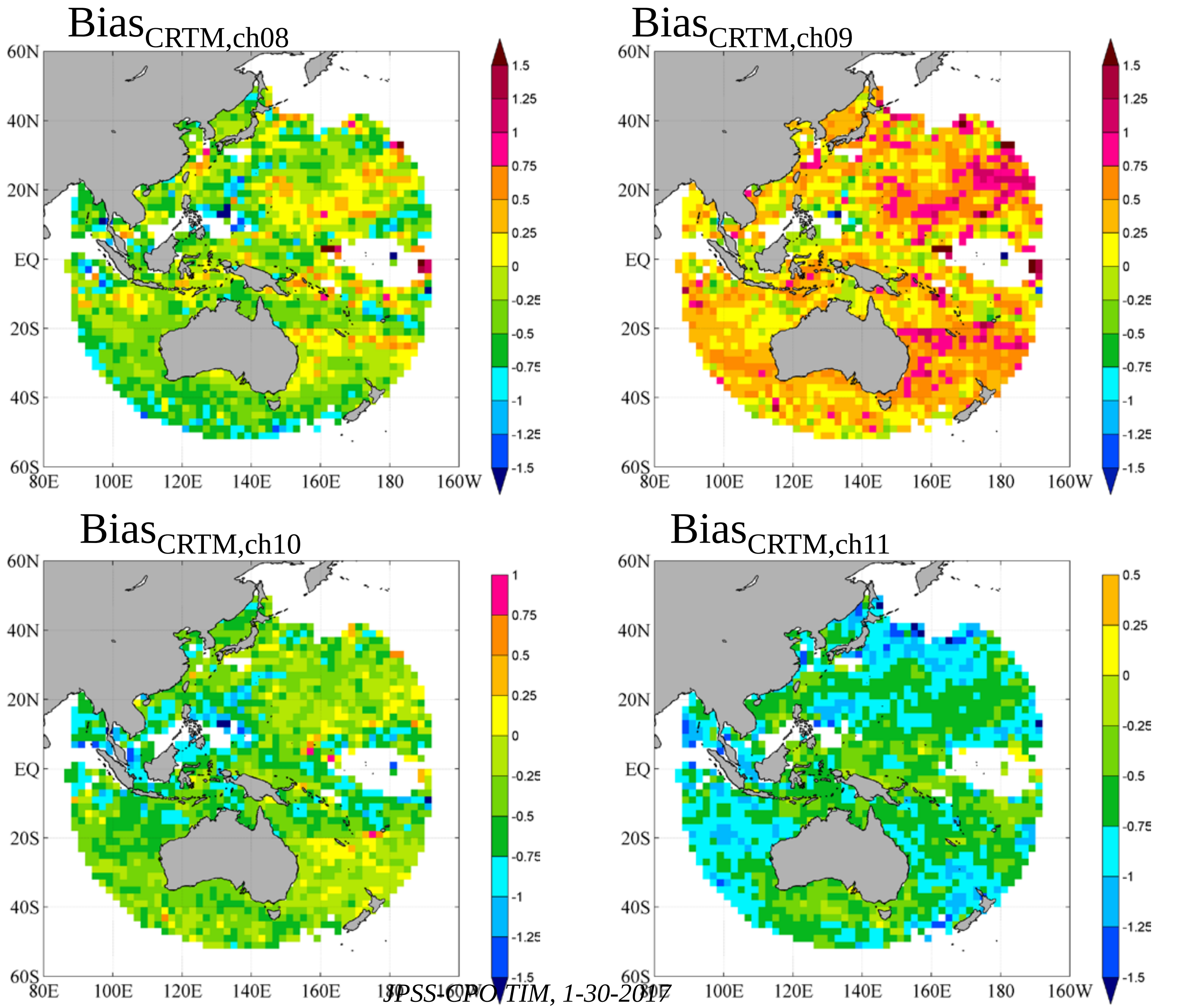
## Himawari-8/9 Imager (AHI)

| Band | | Spatial Resolution | Central Wavelength | Physical Properties |
|---|---|---|---|---|
| 1 | Visible | 1 km | 0.47 µm | vegetation, aerosol |
| 2 | | | 0.51 µm | vegetation, aerosol |
| 3 | | 0.5 km | 0.64 µm | Vegetation, low cloud, fog |
| 4 | Near Infrared | 1 km | 0.86 µm | vegetation, aerosol |
| 5 | | 2 km | 1.6 µm | cloud phase |
| 6 | | | 2.3 µm | particle size |
| 7 | Infrared | 2 km | 3.9 µm | low cloud, fog, forest fire |
| 8 | | | 6.2 µm | mid- and upper-level moisture |
| 9 | | | 6.9 µm | mid-level moisture |
| 10 | | | 7.3 µm | mid- and lower-level moisture |
| 11 | | | 8.6 µm | cloud phase, $SO_2$ |
| 12 | | | 9.6 µm | Ozone content |
| 13 | | | 10.4 µm | cloud imagery, information of cloud top |
| 14 | | | 11.2 µm | cloud imagery, sea surface temperature |
| 15 | | | 12.4 µm | cloud imagery, sea surface temperature |
| 16 | | | 13.3 µm | cloud top height |



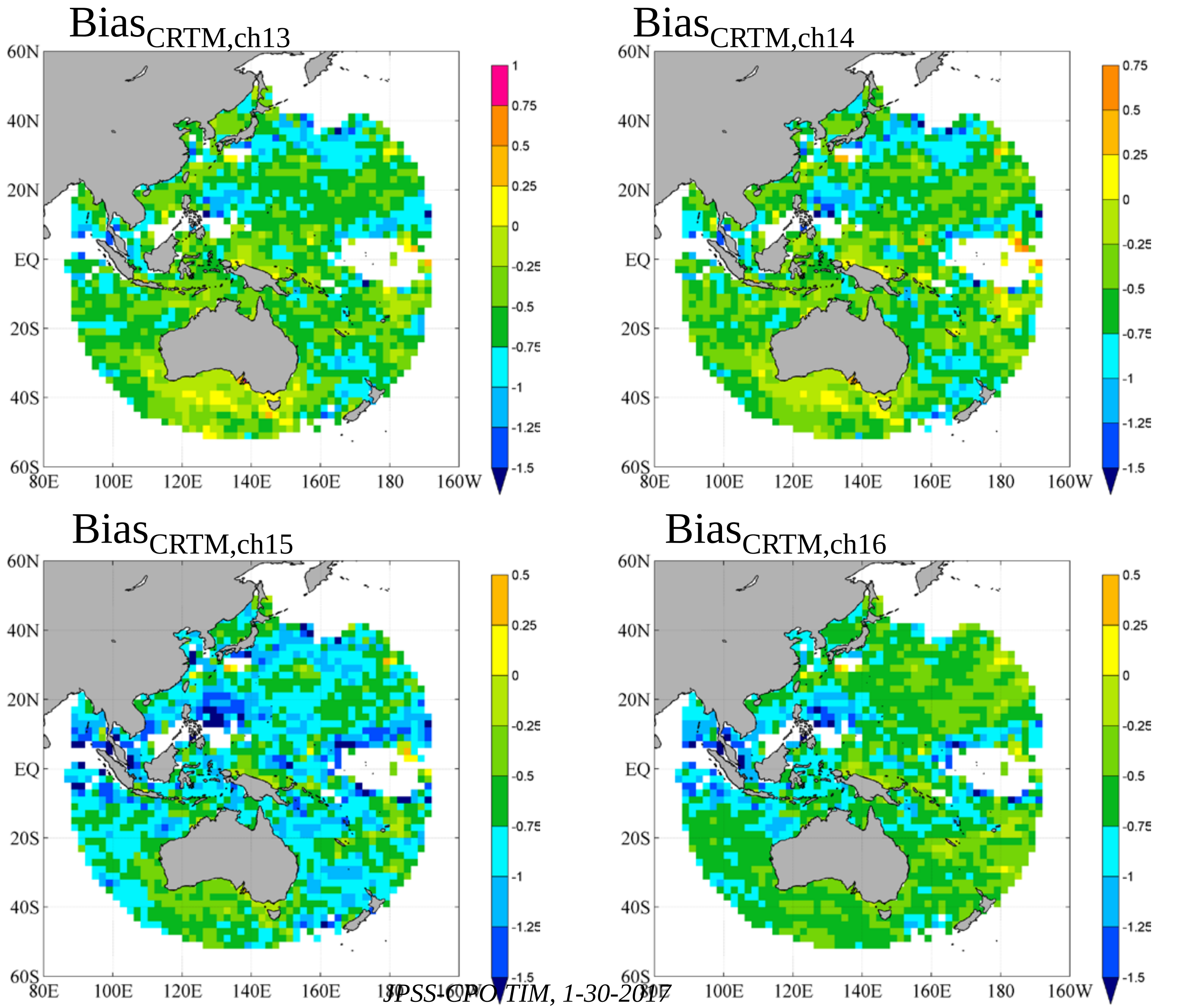
# Spatial Distribution of AHI O-B Bias (Ocean only)

**AHI Channels 8-11**

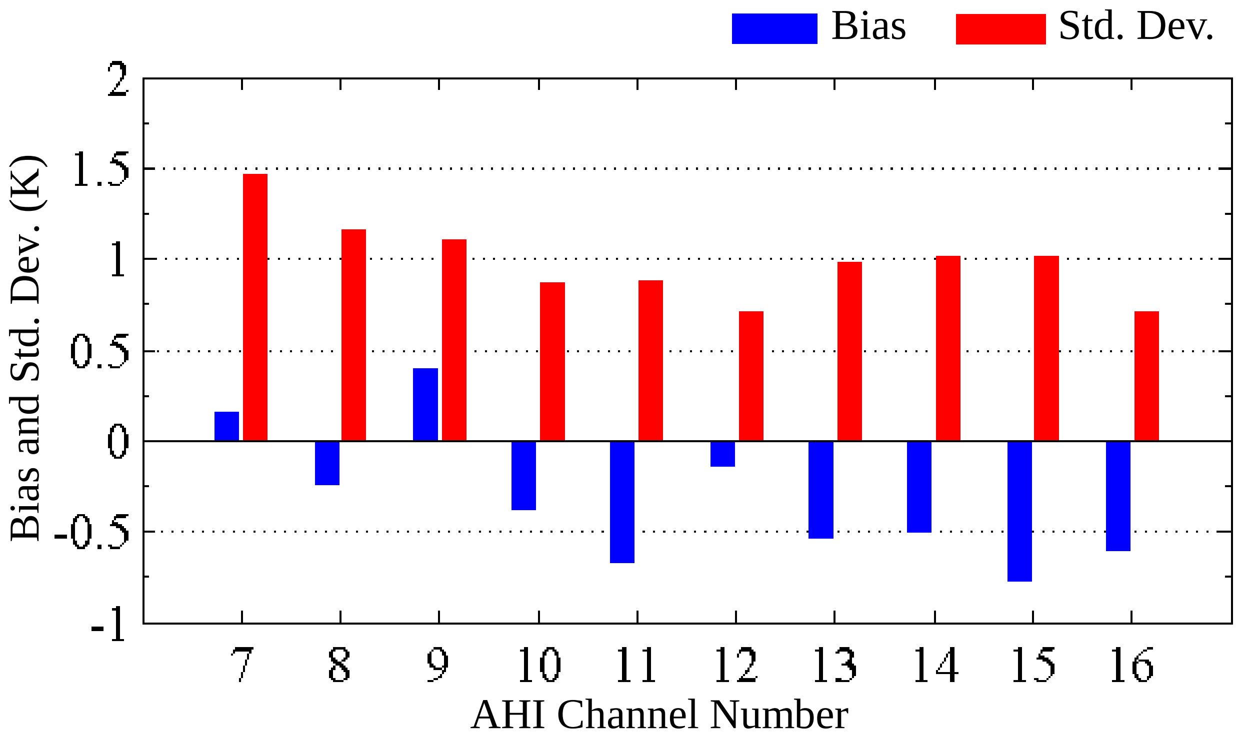


# Spatial Distribution of AHI O-B Bias (Ocean only)

**AHI Channels 13-16**



# Bias and Standard Deviation between AHI Observations and CRTM/ECMWF Simulations (Ocean Only)




| Channel | Bias (K) | Std. (K) |
|---|---|---|
| 7 | 0.16 | 1.46 |
| 8 | -0.25 | 1.16 |
| 9 | 0.40 | 1.11 |
| 10 | -0.38 | 0.87 |
| 11 | -0.68 | 0.88 |
| 12 | -0.15 | 0.71 |
| 13 | -0.54 | 0.98 |
| 14 | -0.51 | 1.01 |
| 15 | -0.78 | 1.01 |
| 16 | -0.61 | 0.71 |

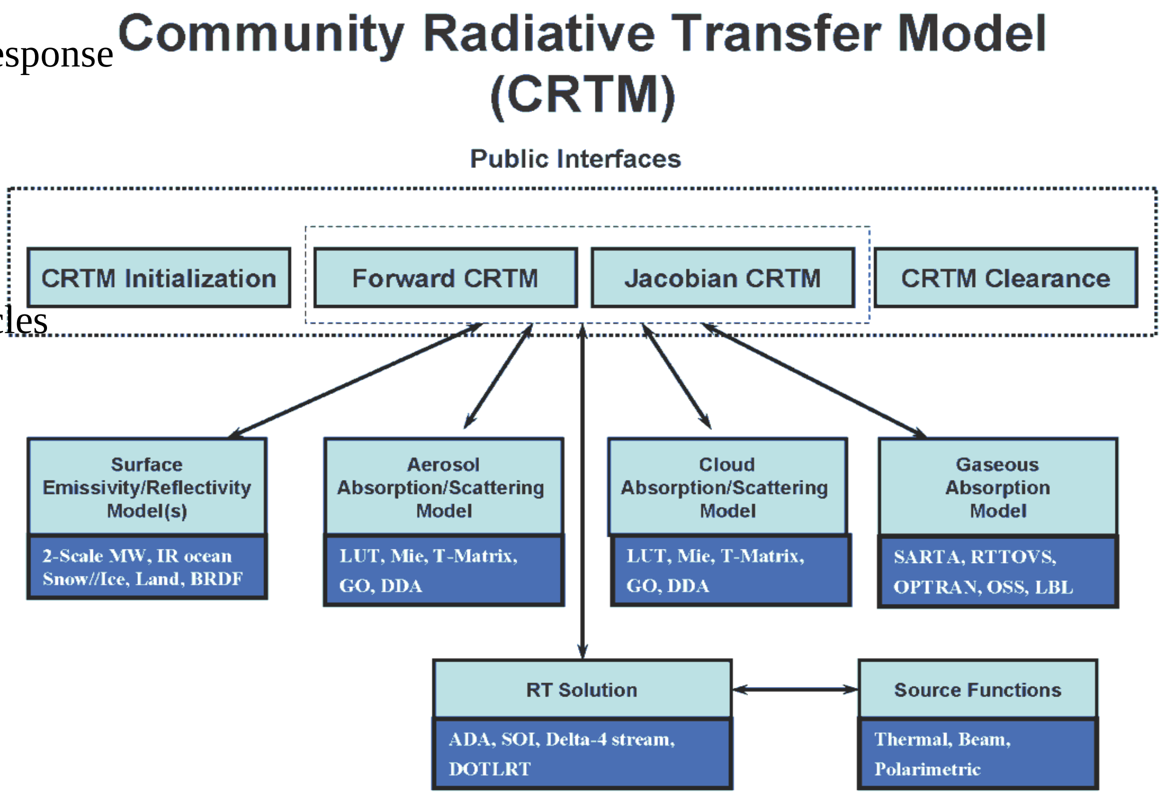
All clear-sky data with satellite zenith angle being less than 60$^{o}$ are included.

# Advanced Radiative Transfer Sciences for Satellite Data Assimilation

- Generate the new LUT for CRTM using discrete dipole approximation (DDA) to advance the cloudy and rain-affected 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

# CRTM Software Architecture, Sciences and Physical Processes

- Atmospheric gaseous absorption
  - ✓ Band absorption coeff trained by LBL spectroscopy data with sensor response functions
  - ✓ Variable gases ( H2O, CO2, O3 etc) .
  - ✓ Zeeman splitting effects near 60 GHz
- Cloud/precipitation scattering and emission
  - ✓ Fast LUT optical models at all phases including non-spherical ice particles
  - ✓ Gamma size distributions
- Aerosol scattering and emission
  - ✓ GOCART 5 species (dust, sea salt, organic/black carbon, )
  - ✓ Lognormal distributions with 35 bins
- Surface emissivity/reflectivity
  - ✓ Two-scale microwave ocean emissivity
  - ✓ Large scale wave IR ocean emissivity
  - ✓ Land mw emissivity including vegetation and snow
  - ✓ Land IR emissivity data base
- Radiative transfer scheme
  - ✓ Tangent linear and adjoints
  - ✓ Inputs and outputs at pressure level coordinate
  - ✓ Advanced double and adding scheme
  - ✓ Other transfer schemes such as SOI, Delta Eddington

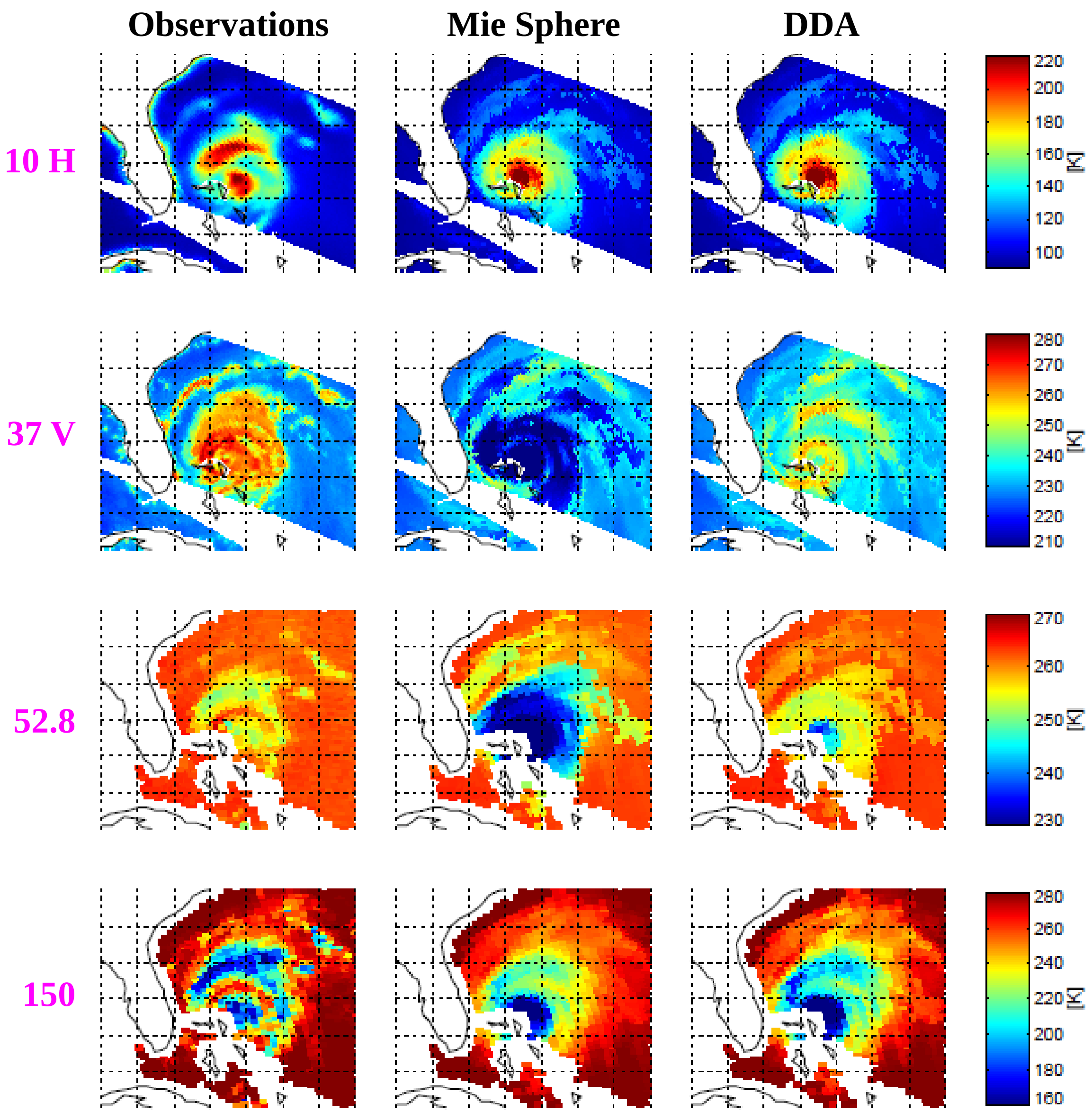



***"Technology transfer made possible by CRTM is a shining example for collaboration among the JCSDA Partners and other organizations, and has been instrumental in the JCSDA success in accelerating uses of new satellite data in operations" – Dr. Louis Uccellini, Director of National Weather Service***

# Comparison of Mie Sphere and DDA for Hurricane Irene

- Liu (2008) produced scattering database that contains pre-computed optical properties of non-spherical ice particles, and made it practical to incorporate discrete dipole approximation (DDA) results into fast radiative transfer models for microwave data assimilation.
- Geer and Baordo (2014) implemented Liu's scattering database in RTTOV-SCATT.

*Geer A. J., and F. Baordo, 2014: "Improved scattering radiative transfer for frozen hydrometeors at microwave frequencies", Atmos. Meas. Tech. Discuss., 7, 1749-1805, 2014. DOI:10.519/AMTD-7-1749-2014*




**Hurricane Irene on Aug. 25, 2011**

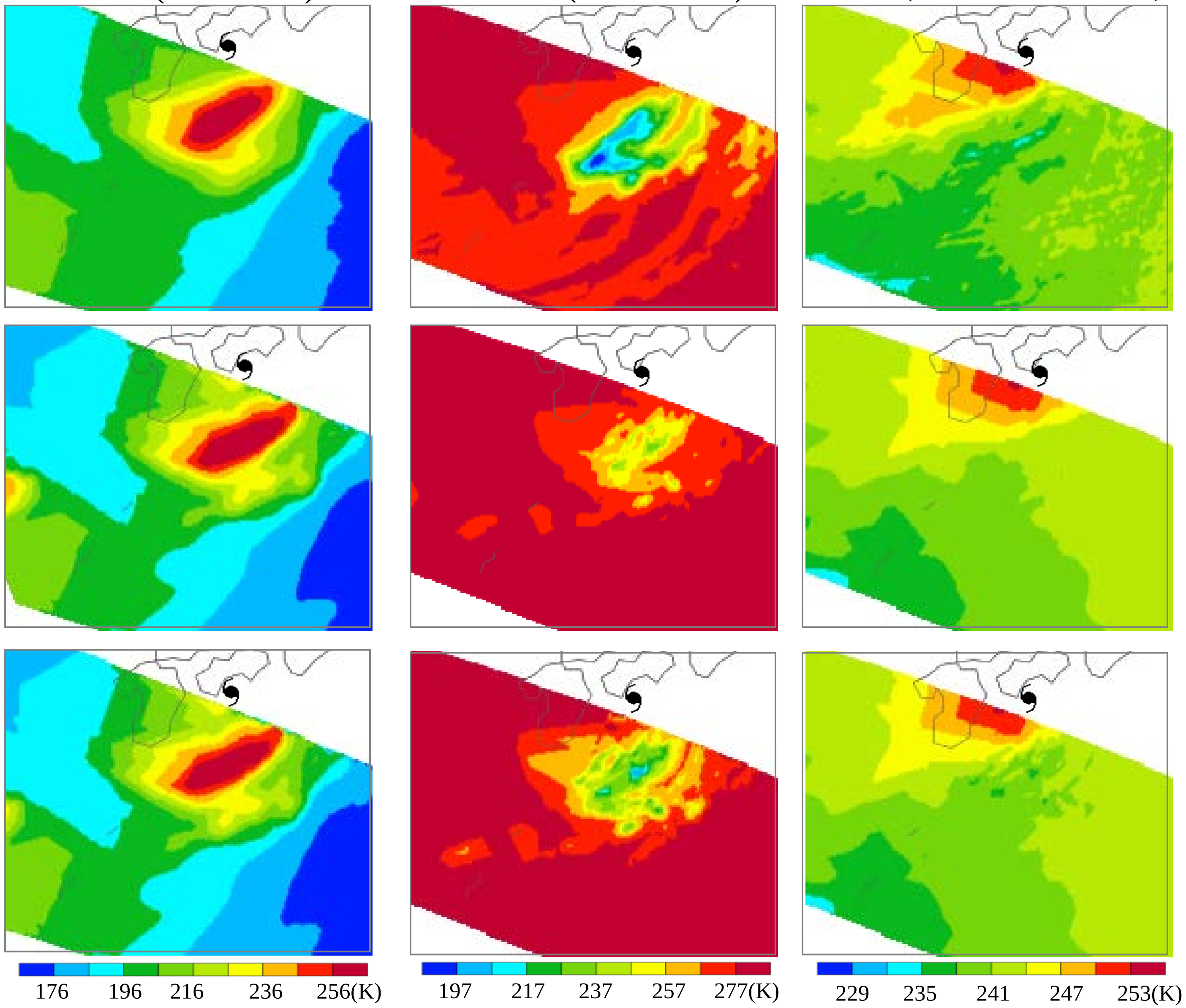
# ATMS Observed and Simulated Tb from Mie and DDA

Ch 2 (31.4 GHz) | Ch 17 (165.5 GHz) | Ch 22 (183.31±1.0 GHz)

Observations

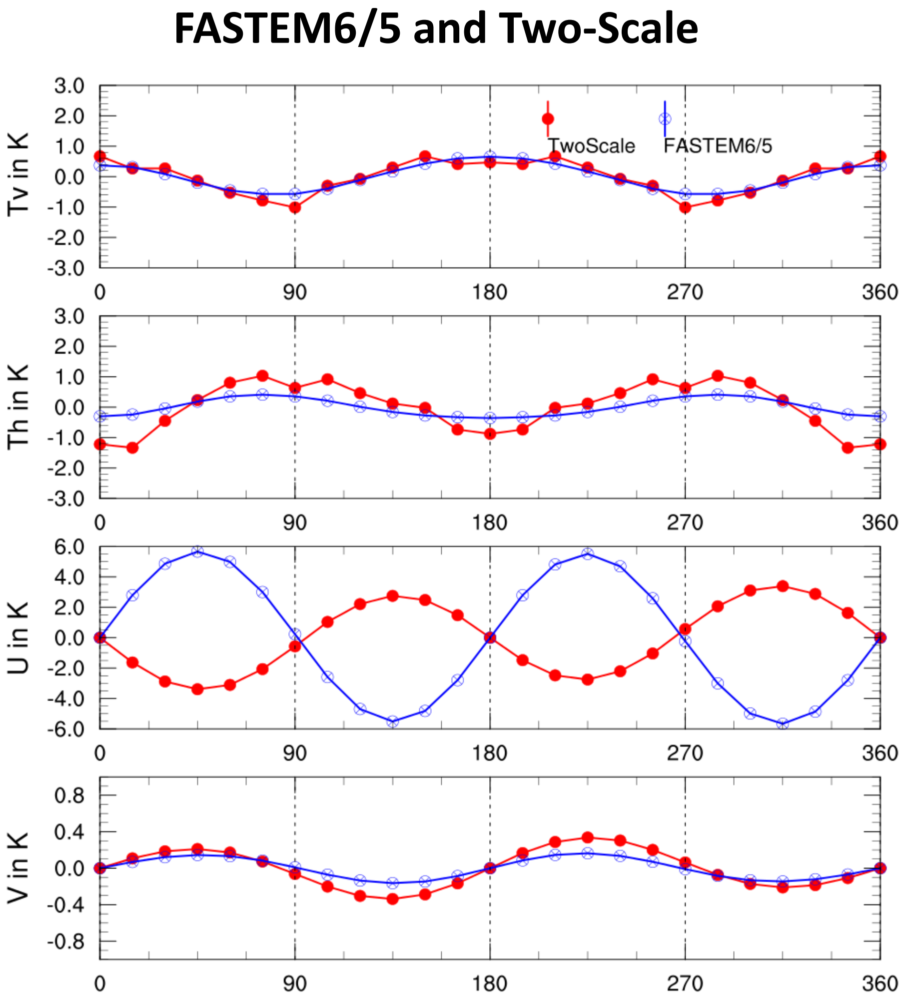
Simulations using Mie Sphere

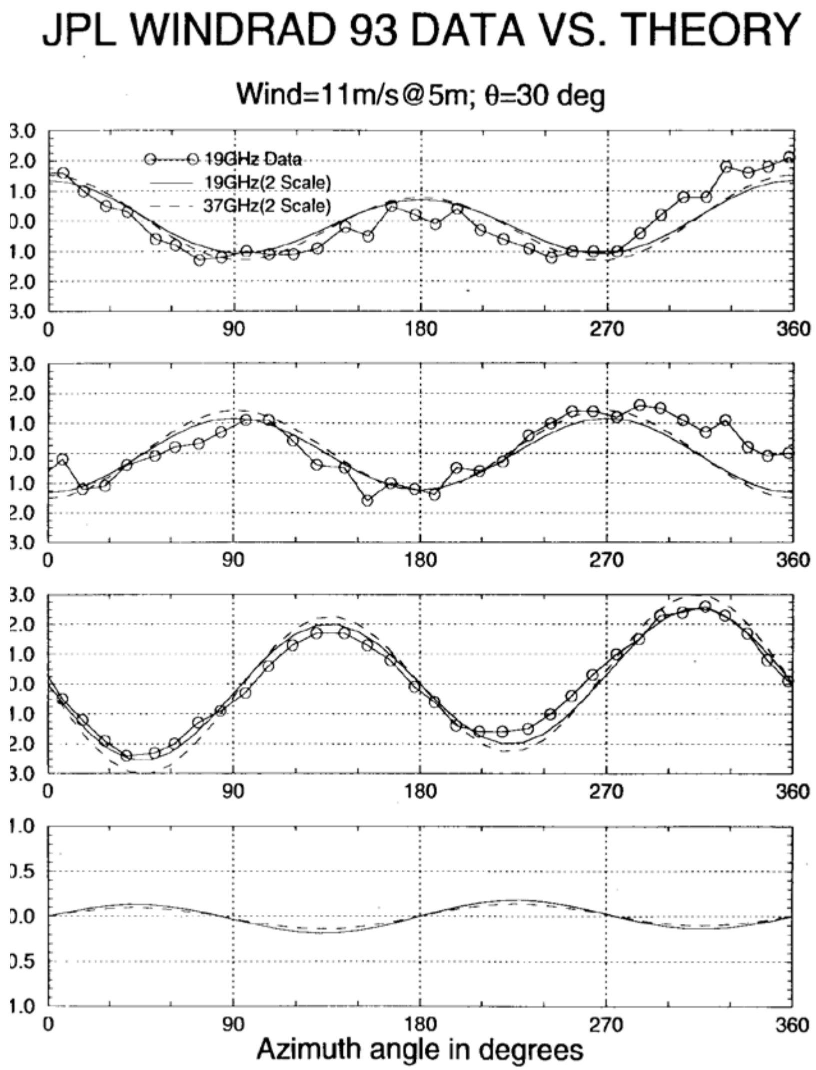
Simulations using DDA




- 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

# Comparison of Model Simulations with JPL WINDRAD Observations (theta=30º)




*(Yueh 1997)*

# Summary and Conclusions

- JPSS real-time data are assimilated in NCEP NWP models. Societal benefits from satellite data assimilation are enormous. The large success is made through direct radiance assimilation in global NWP models
- JPSS lfe-cycle data reprocessing s important for NWP reanalysis, fixed real-time bugs in instrument calibration and SDR and improved the SDR algorithms for real-time applications
- The approach of using the global DA system for regional NWP applications is challenging. In particular, the regional NWP have different focuses (e.g. storm track, coastal precipitation). The evaluation of the data impacts on forecasts should be based on the forecasting variables. Also, more fine tunes are required for the quality control, bias corrections
- Satellite data streams from legacy missions were not optimally produced earlier. The lesson learned from SNPP ATMS – O2/H2O sounding channel data in a single data stream resulted in the highest impact on forecasts. Thus, an approach is proposed for combining AMSU-A and MHS data into one data stream for NWP community
- Assimilation of GOES IR imager radiances results in better QPF due to their high spatial/temporal resolutions, and low noises
- Cirrus clouds can cause a large uncertainty in simulating CrIS spectral radiances. The CrIS double CO2 bands can detect vertical distribution of non-opaque clouds, which will further improve the quality control for CrIS data assimilation
- There remain large uncertainties in CRTM for simulating rain-affected radiances and the surface emissivity over land.