



#### Impacts of Suomi NPP Data Reprocessing on Weather and Climate Applications

Dr. Fuzhong Weng Satellite Meteorology and Climatology Division (SMCD) NOAA/NESDIS/Center for Satellite Applications and Research (STAR)



#### **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	
	Cross-track Infrared Sounder (CrIS)	advance for extreme weather events, including hurricanes and severe weather outbreaks	
	Visible Infrared Imaging Radiometer Suite (VIIRS)	VIIRS provides many <b>critical imagery products</b> 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	
	<b>Ozone Mapping and Profiler Suite (OMPS)</b>	Total ozone for <b>monitoring ozone</b> hole and recovery of stratospheric ozone and for UV index forecasts	
	Clouds and the Earth's Radiant Energy System (CERES)	Provide <b>climate quality measurements</b> of the Earth's outgoing radiation budget- longwave infrared, reflected solar flux, and incoming solar radiation, all of which are vital to climate monitoring	

## **CrIS Noise Computed from Standard and Allan Deviations**





Using Allan deviation (upper) vs standard deviation (lower panel) algorithm for characterizing hyperspectral infrared sounder CrIS noise (Chen and Weng, 2015, AO)

DATMOSPA

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## **ATMS NEDT Computed from Standard and Allan Deviation**





Use of Allan deviation (red) and Standard deviation (blue) for Characterizing Satellite Microwave Sounders Noise Equivalent brightness temperature (Tian and Weng, 2015, GRSL)



# 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	<b>September 17, 2015</b>
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





#### **Chronology of OMPS SDR Algorithm Change**





# **Objectives of JPSS Life-Cycle Data Reprocessing**



- Implement the mission-life consistent sciences to achieve a long-term stability of JPSS data accuracy
- Optimize the algorithms and processing systems to achieve the lowest JPSS data uncertainties
- 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



# 2016 NOAA Workshop on Suomi NPP Reprocessing NWP User Recommendations



- 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)



### 2016 NOAA Workshop on Suomi NPP Reprocessing 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)
- 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)



# 2016 NOAA Workshop on Suomi NPP Reprocessing 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



# **Technical Approaches for JPSS Data Reprocessing**



#### ATMS NRT data

- 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 Cal/Val 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



Heather Laurence, ECMWF reported at 2016 NOAA JPSS Reprocessing Workshop



# **UMD/ESSIC Linux 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 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





# **Suomi NPP Reprocessed SDR Products**

- ATMS Antenna Temperature Record (TDR) @original FOV (ADL Version 5.3)
- ATMS Antenna Temperature Record (TDR) resampled to a 2.2 degree FOV (ARTS Version 1.0)
- CrIS Sensor Data Record (SDR) @normal spectral resolution (1305 channels) (ADL Version 5.3)
- CrIS Sensor Data Record (SDR) @full spectral resolution (2211 channels) (ADL Version 5.3)
- VIIRS Sensor Data Record (SDR) with auto-cal RSB channels (ADL Version 4.2)
- VIIRS Sensor Data Record (SDR) with ocean-color team RSB calibration (ADL Version 4.2)
- OMPS Sensor Data Record (SDR) with NASA calibration look up tables (ADL Version 5.3)



#### **ATMS TDR Mean Bias after Reprocessing**







#### **ATMS TDR Difference between Reprocessed and Operational Data**



S-NPP ATMS TDR Bias (Rep - OPS)Ch.1 23.8 GHz QV-POL Scan UTC Date: 2012-07-26



S-NPP ATMS TDR Bias (Rep - OPS)Ch.16 88.2 GHz QV-POL Scan UTC Date: 2012-07-26



S-NPP ATMS TDR Bias (Rep - OPS)Ch.7 54.4 GHz QH-POL Scan UTC Date: 2012-07-26



S-NPP ATMS TDR Bias (Rep - OPS)Ch.20 183.311±3.0 GHz H-POL Scan UTC Date: 2012-07-26





#### **Impacts of CrIS SDR Reprocessing on Data Quality**





NPP CrIS Long Wave SDR Overall Quality Flag, Mapped, Descending, 06/27/2012



NPP CrlS Long Wave SDR Overall Quality Flag, Mapped, Ascending, 06/27/2012 (Blue: Good; Green: Degraded; Red: Invalid) Updated at Oct 7 17:34:09 2016 UTC



NPP CrIS Long Wave SDR Overall Quality Flag, Mapped, Descending, 06/27/2012





Overall quality flag has no degraded values after Temperature Drift Limits Updated in Eng Pkt V34



# **Impacts of Microwave Sounders in NCEP GFS**

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





Forecast Hour

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.

Acknowledgement: NCEP

# ATMS Quality Control NCEP Data Assimilation System (GSI)







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#### **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 conventional data. New quality control is required for better assimilation of CrIS radiance.

**CICS Science Conference** 



# Issues with the Current GSI Cloud Detection

- Compared with VIIRS cloud products, both CrIS cloud fraction and cloud top pressure derived in the current GSI are significantly biased
- The IR semi-transparent thin cirrus clouds are poorly detected by the current GSI QC scheme and thus the cloudaffected CrIS radiances could be treated as clear-sky radiances and assimilated wrongly into GSI
- A new cloud detection algorithm has been developed using CrIS double CO2 bands for better discrimination of the optically thin cirrus clouds within CrIS FOVs





Acknowledgement: Drs. Xiaolei Zou and Xin Li



#### Uses ATMS Derived Temperature to Monitor Hurricane Warm Core Evolution and Intensification Process





Observations from POES microwave sounders have proved to be invaluable to NWP, but four observations/day do not resolve the fast-evolving weather events. Visible and infrared observations from GOES imagers and sounders offer higher temporal resolution but cannot resolve the hurricane warm core structure and therefore are of limited applications.



#### **ATMS Limb-Adjusted Imaging of Typhoon Meranti**







#### **ATMS Limb-Adjusted Imaging of Typhoon Meranti**









#### Applications of Suomi NPP Reprocessed SDR Data in Climate Research

- NWP reanalysis using Suomi NPP reprocessed data (e.g. NASA GMAO)
- Climate data record (40 years) of microwave sounder radiances from MSU/AMSU/ATMS
- Climate data record (40 years) of infrared sounder radiances from SSU/HIRS/CrIS
- Tropical cyclone genesis analysis using regional data assimilation



# **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 peerreviewed process (2013 JGR special issue, 2016 Remote Sensing special issues, etc)
- SNPP SDR data are successfully assimilated into NWS global and regional forecast models and produced the largest positive impacts
- New capabilities (limb-adjusted ATMS imager and warm core time series) are developed for monitoring the severe storms
- JPSS IDPS processing system is enhanced with new SDR sciences (e.g. CrIS FSR, ATMS antenna reflector emission, VIIRS RSB autocal-lunar corrected)
- Suomi NPP mission life-time SDR data from ATMS, CrIS and OMPS are reprocessed and the datasets are available from NESDIS/STAR and will be soon available from NOAA CLASS archival