Impacts of Suomi NPP Data Reprocessing on Weather and Climate Applications

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## Suomi NPP Instruments and Their Applications

<table>
<thead>
<tr>
<th>NPP/JPSS Instrument</th>
<th>NOAA Mission Benefits</th>
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<tbody>
<tr>
<td>Advanced Technology Microwave Sounder (ATMS)</td>
<td>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</td>
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<tr>
<td>Cross-track Infrared Sounder (CrIS)</td>
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<tr>
<td>Visible Infrared Imaging Radiometer Suite (VIIRS)</td>
<td>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</td>
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<tr>
<td>Ozone Mapping and Profiler Suite (OMPS)</td>
<td>Total ozone for monitoring ozone hole and recovery of stratospheric ozone and for UV index forecasts</td>
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<tr>
<td>Clouds and the Earth's Radiant Energy System (CERES)</td>
<td>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</td>
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11/30/2016
CICS Science Conference
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)
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

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Beta</th>
<th>Provisional</th>
<th>Validated</th>
</tr>
</thead>
<tbody>
<tr>
<td>CrIS</td>
<td>February 10, 2012</td>
<td>February 6, 2013</td>
<td>March 17, 2014</td>
</tr>
<tr>
<td>ATMS</td>
<td>May 2, 2012</td>
<td>February 12, 2013</td>
<td>March 17, 2014</td>
</tr>
<tr>
<td>OMPS</td>
<td>March 7, 2012</td>
<td>March 12, 2013</td>
<td>September 17, 2015</td>
</tr>
<tr>
<td>VIIRS</td>
<td>May 2, 2012</td>
<td>March 13,, 2013</td>
<td>April 17, 2014</td>
</tr>
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</table>

**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

**Beta**
Since March 5, 2012

- Calibration and EV SDR separation
- Wavelength, solar day one and dark update
- Earth view sample table update
- RDR truncation correction

**Provisional**
Since March 1, 2013

- SAA dark LUT update Mx7.1, May 20, 2013
- Error in Sense ascending-descending condition Flag Mx7.1, May 20, 2013
- TC SL correction was resumed -Mx7.2, Aug. 21, 2013

**Validated**
Since September 2015

- TC Wavelength adjustment - Mx8.2
- NP SL LUT - Mx8.3 Mar. 18, 2014
- OMPS Bias LUT correction for negative smears in TC SDR – Mx8.5 July 22, 2014
- TC SL LUT update – Mx8.6, Nov. 21, 2014
- NP wavelength LUT update

- TC Wavelength adjustment
- NP Wavelength adjustment
- TC and NP Solar day one LUTs update
- TC and NP radiance constants update
- TC wavelength LUT format change to include wavelength shift component
- SDR code change to process the changed wavelength format.
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
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)
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).
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

- 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

ATMS NRT data

Striping: ATMS ch12 O – B (K)

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

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Input Data</th>
<th>Output Data</th>
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<tbody>
<tr>
<td>ATMS</td>
<td>185 GB</td>
<td>400 GB</td>
</tr>
<tr>
<td>CrIS</td>
<td>6.57 TB</td>
<td>17.2 TB</td>
</tr>
<tr>
<td>OMPS NP</td>
<td>30 GB</td>
<td>86 GB</td>
</tr>
<tr>
<td>OMPS TC</td>
<td>138 GB</td>
<td>1.1 TB</td>
</tr>
<tr>
<td>VIIRS</td>
<td>20 TB</td>
<td>230 TB</td>
</tr>
<tr>
<td>S-NPP Total</td>
<td>27 TB</td>
<td>275 TB</td>
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</tbody>
</table>
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
Impacts of CrIS SDR Reprocessing on Data Quality

Operational

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

Reprocessed
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
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.
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.

Acknowledgement: NCEP
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 cloud-affected 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

Isaac’s warm core characterized by 2 K anomalous temperature (3D isosurface in red)

500 hPa temperature

GOES imager radiance

Vertical temperature

Hurricane symbols represent the best track at 12-h interval from 0600 UTC 21 August to 1800 UTC 30 August 2012.

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

Typhoon Meranti, 2016-09-13

Cross section of Atmospheric Temperature (K) at 150hPa

Channel Number Index

Peak Volumetric Function Pressure (mb)

AHI Radiance (0.1 [W m^-2 sr^-1 m^{-1}] at 10.85 microns)
ATMS Limb-Adjusted Imaging of Typhoon Meranti

Typhoon Meranti, 2016–09–13
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 peer-reviewed 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