ASSISTT – Accelerating the Transition of Science to Operations; and MSN updates

Presented by:

Walter Wolf

Tom King

IMSG, Inc.

Shanna Sampson

GAMA-1

ASSISTT – Algorithm Scientific Software Integration and System Transition Team

Overview

- Algorithms are currently being delivered to operations
- Implementing plans to decrease the time to deliver these products to operations
- Mission Science Network – is there any effect on the scientific algorithm transition to operations process

Status

- The STAR Algorithm Scientific Software Integration and System Transition Team (ASSISTT) works with the science teams to deliver their algorithm updates to operations for both S-NPP and NOAA20.

- ASSISTT currently delivers:
  - Sensor Data Record (SDR) algorithms for transition to operations in the Interface Data Processing Segment (IDPS)
  - Environmental Data Record (EDR) enterprise algorithms to operations in NOAA Data Exploitation (NDE)

- All the Level 2 enterprise algorithms for S-NPP have been delivered to NDE for operational implementation.

SDR Algorithms

- The SDR algorithm change process is well established:
  - ASSISTT works with science teams to implement their algorithm updates in the Algorithm Development Library (ADL)
  - ASSISTT tests the algorithms, science teams verifies the updates, and then ASSISTT delivers an algorithm package to the Data Product Engineering (DPE) team
  - DPE tests the updated algorithm on the GRAVITE system and delivers the updated algorithm to Raytheon (after science team verification) for implementation into the Interface Data Processing Segment (IDPS)

EDR Algorithms

- The EDR algorithm change process is well established:
  - Science teams deliver their algorithm updates to ASSISTT
  - ASSISTT tests the algorithm, science team verifies the updates, and then ASSISTT delivers an algorithm package to the NDE team
  - NDE tests the updated algorithm on the NDE system and after science team verification, they implement the algorithm in operations
  - All the enterprise algorithms for S-NPP have been delivered to NDE and only a few land products are currently not in operations
  - Most of the N20 algorithms have been delivered to NDE recently and are currently in the testing process before transition to operations (pending provisional reviews)

Speeding up the Transition to Operations Process

- The ASSISTT team has been looking to streamline the algorithm update and testing processes to reduce the transition to operations (TTO) time for each algorithm

- The SDR process is well streamlined, so we will focus on the EDR process

Speeding up the Transition to Operations Process

- Reduce the amount of algorithm testing done before the delivery of algorithms

- Improved communications with NDE after algorithm deliveries

Reducing Test Data Sets

- Each year, ASSISTT has two planned deliveries for most EDR products to NDE
- Part of the TTO process includes testing the algorithms on 2.5 months of data
- This end to end TTO process for algorithm updates, algorithm testing and science team validation take approximately 6 months to complete (due to algorithm dependencies). Two months of this work is testing and validation.
- ASSISTT has been working with the science teams to reduce the amount of test data used for algorithm updates to about 7-10 days worth of data
- The reduced data set can be run within 10 days and the testing time can be reduced from 6 weeks down to a maximum of three weeks
- Smaller testing dataset will also enable a quicker turn around on any interim algorithm fixes

Improve Communications with NDE

- Working with the Algorithm Management Project (AMP) to improve communications with NDE
  - AMP tracks status of algorithms
  - https://docs.google.com/spreadsheets/d/131J_UBrisKPTYmRBlwYRbliHxxyd6RVLbau31BtRwD4/edit?usp=sharing

- AMP has worked with NDE on short term schedules on when algorithms are being delivered and the dates when they will be implemented

- Need to work with the PALs more closely on tracking the NDE transition to operations schedule

- Note that there is the "ESPDS Product Generation IPT" meeting every other Tuesday at 11 am ET

Breakout Sessions

- Two ASSISTT breakout session are schedule to discuss these issues with the science teams:
  - ASSISTT Framework Algorithms Breakout in the Conference Center at 11 am on Wednesday
  - ASSISTT Stand Alone Algorithm Breakout in the Conference Center at 2 pm on Wednesday

Mission Science Network (MSN)

Mission Science Network

- The Mission Science Network (MSN) is an IT platform that will provide enterprise services to:
  - Deliver cost-effective, secure, cloud capable infrastructure to support research to operations
  - Enable research and development of scientific data and applications
  - Support operational availability for product generation
  - Manage data through its full lifecycle from creation to preservation
  - Provide access to NOAA’s data, information and services

MSN Phases

- MSN is being implemented in two phases
  - Phase 1: Put the STAR and NCEI infrastructure within one security boundary
  - Phase 2: Develop agile, scalable and secure architecture for future science mission(s)

MSN Phase 1

- Phase 1: Put the STAR and NCEI infrastructure within one security boundary
  - Stand-up nascent Mission Science Network (MSN)
    - Connect existing systems between STAR and NCEI
    - Exploit existing N-Wave connectivity
  - Consolidate systems in order to obtain efficiencies of scale and long-term cost savings
    - Migrate data and applications, and shutdown systems in NCEI-MD and NCEI-MS
    - Consolidate existing systems into Condor Server/Storage Cluster at STAR
  - Deploy IT services that support entire science enterprise
    - Determine best-of-breed capabilities between NCEI and STAR
    - Leverage open source applications wherever possible
- Phase 1 will be complete by October 2019

MSN Phase 2

- Phase 2: Develop agile, scalable and secure architecture for future science mission(s)
  - Architecture for the MSN will be updated
  - Infrastructure will be common for both NCEI and STAR
  - Migration plans will be put in place for the transition of the current capabilities to use the new infrastructure
- Phase two will be completed in the Fall of 2021

Effect on TTO

- ASSISTT is currently running the algorithms in the HTCondor cluster within STAR for testing

- ASSISTT is implementing a kubernetes cluster where the algorithms will be run on the cluster using Docker containers

- The kubernetes cluster will be an offline representation of a cloud based infrastructure

Effect on Algorithms

- ASSISTT is currently testing the implementation of some algorithms on the new cluster

- Expect full implementation into the kubernetes cluster before MSN Phase II is complete

Effect on Algorithms

- Migration plans to the new infrastructure will be put in place before the end of Phase 2
- ASSISTT will work with the MSN team to minimize the effect of the new infrastructure on the science algorithm development

Summary

- To improve the transition to operations process, ASSISTT will:
  - Reduce the amount of test data used for algorithm testing before delivery of the algorithms
  - Improve communications with NDE after algorithm deliveries
- MSN will be implemented in two phases
  - ASSISTT will be working with the algorithms and science teams to be ready for Phase 2 completion
  - Migration plans will be put in place for the transition of the current capabilities to use the new infrastructure

Reprocessing of Suomi-NPP/JPSS Sensor Data Records: On-Going Efforts, Plans and Preparations

Ninghai Sun[1,2], Murty Divakala[1,3], Lin Lin[1,4], Bin Zhang[1,2], Yuanzheng Yao[1,4], Lihang Zhou[1], Mitch Goldberg[5]

[1] NOAA/NESDIS/STAR, [2] ERT, Inc. , [3] IMSG, Inc. , [4] UMD/ESSIC, [5] NOAA/NESDIS/NJO

With contribution from Changyong Cao (VIIRS SDR), Hu Yang/Quanhua Liu (ATMS SDR), Trevor Beck/Ding Liang (OMPS SDR), Yong Chen/Flavio Iturbide (CrIS SDR)

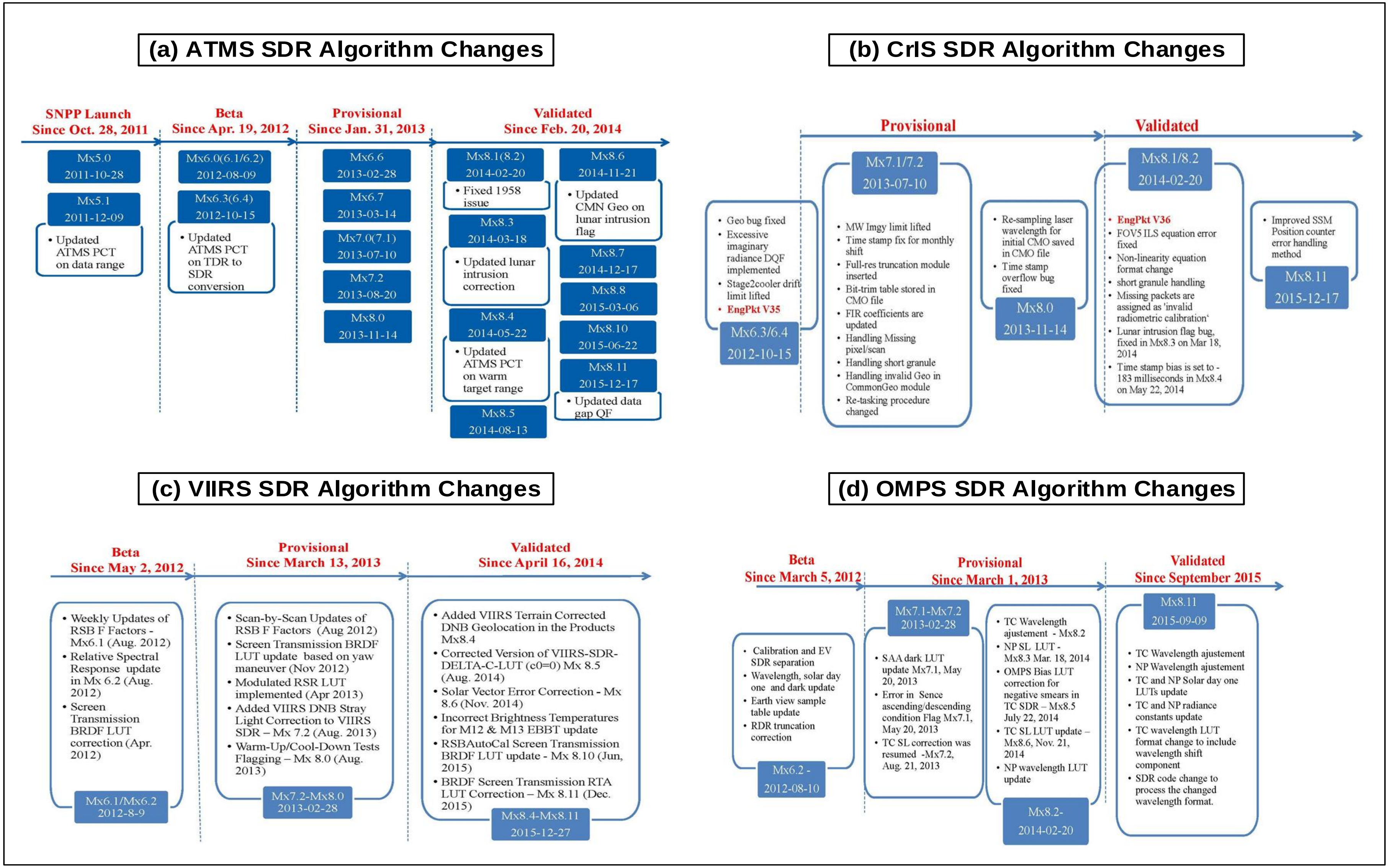
Outline

- Objectives of Suomi-NPP/JPSS Lifecycle Sensor Data Record (SDR) Reprocessing
- Suomi-NPP SDR Reprocessing Status
  - Overview on SDR Reprocessing
  - ATMS/VIIRS/CrIS/OMPS SDR Reprocessing Improvements
  - SDR Reprocessing Status and Data Access
- Summary
- Path Forward
- SDR Reprocessing Future Plan

Objectives

- 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 societal impacts of JPSS datasets

Chronology of S-NPP SDR Algorithm Changes



Each maturity stage represents an improvement in science quality

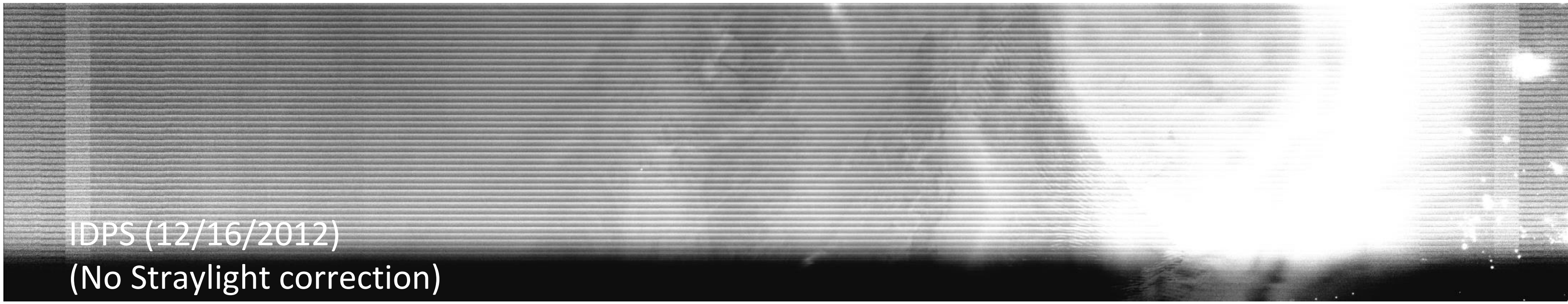
S-NPP VIIRS SDR Reprocessing Improvements

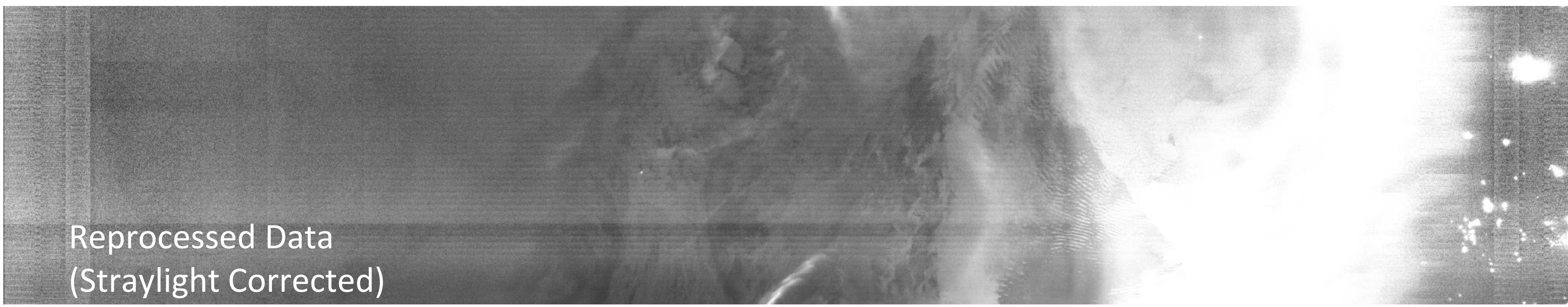
Updates	Reprocessing System	Improvements
Cal/Val Algorithm Updates	Using latest calibration parameters and algorithms	Consistent IDPS baseline calibration
RSBs	• Baseline SDRs calibrated using consistent RSBAUTOCAL F-factors • A "radiometric bias correction" term was introduced	Addressed issues related to: • OC hybrid calibration correction and constant bias correction for M5/M7
TEBs:	• Improved BT limits, less saturation in M13 • WUCD bias correction for M15/M16	• Improvements for fire EDR. • Mitigated spikes in SST time series.
DNB:	• Consistent Low Gain Stage (LGS) gain • Improved offset and gain ratio; • Stray light correction for the entire data records.	More consistent data records for change studies; significant improvements in early data. Less negative radiance.
Geolocation:	• Removed short-term anomalies before August 2013; • DNB geolocation are terrain corrected for the entire data record.	Consistent terrain corrected geolocation

Slide Courtesy: VIIRS SDR Team

S-NPP VIIRS Reprocessing SDR Assessment

VIIRS DNB Straylight Correction Improvements





- Reprocessing implements straylight correction for all DNB SDR
- Significant improvements in all DNB data before August 2014

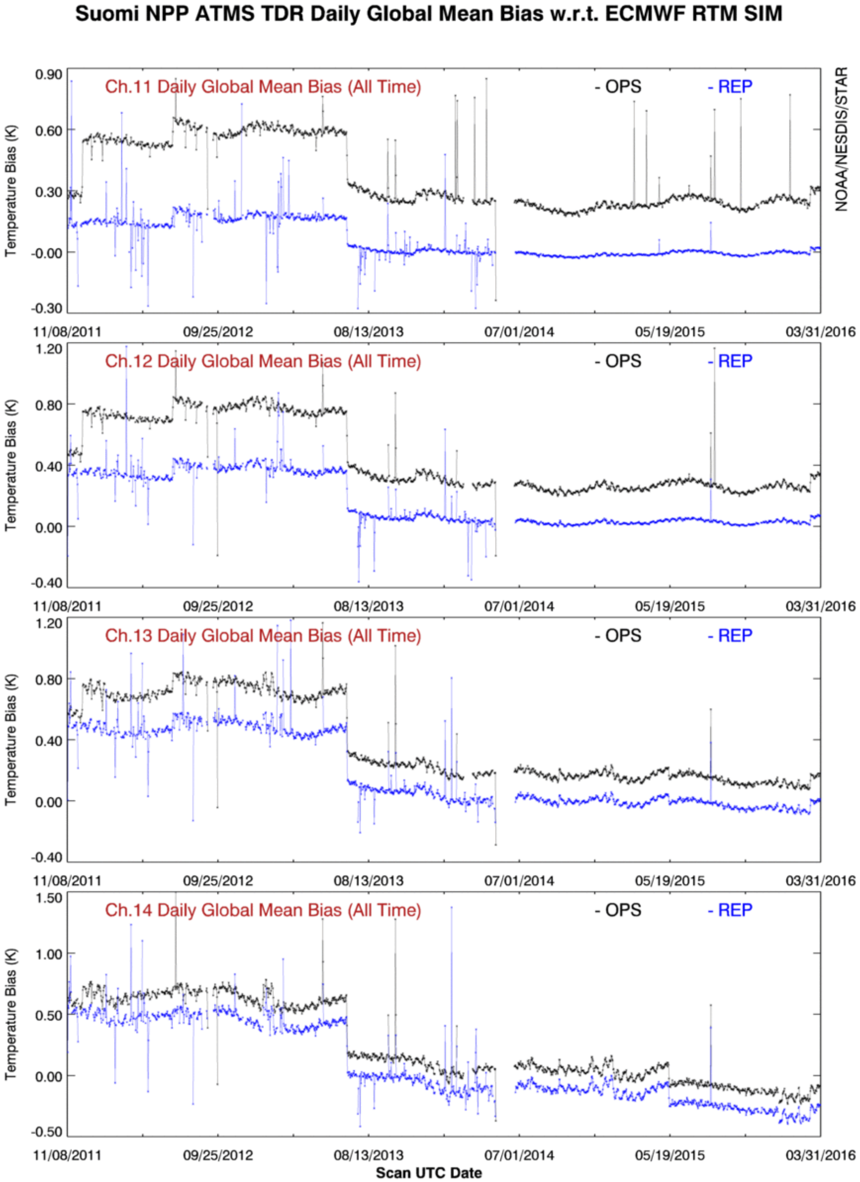
Courtesy: STAR VIIRS SDR Team

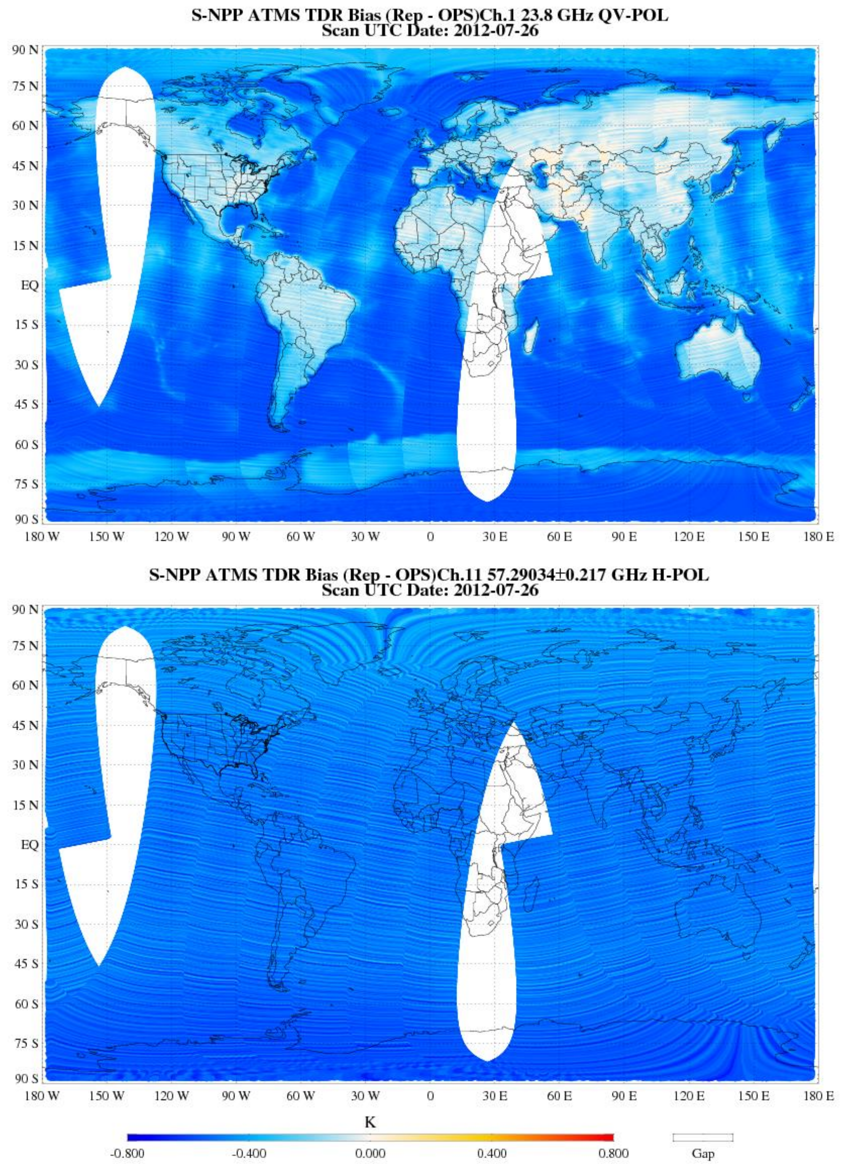
S-NPP ATMS SDR Reprocessing Improvements

Error Source	Reprocessing System	Improvements
Calibration Method	Calibration in radiance space	Improve accuracy over cold region in high frequency channels
Non-linearity	Physical model based antenna emission correction (μ- parameters)	Correct error in coefficients and keep algorithm consistency to heritage microwave sensors
Lunar Contamination	Maximum threshold lunar intrusion correction algorithm	Improve the lunar intrusion prediction accuracy
Noise Filtering	Boxcar	Reduce the striping effect
Calibration Target Quality Check	Adjust raw data quality check threshold	Improve SDR data accuracy

Slide Courtesy: STAR ATMS SDR Team

S-NPP ATMS Reprocessing SDR Assessment



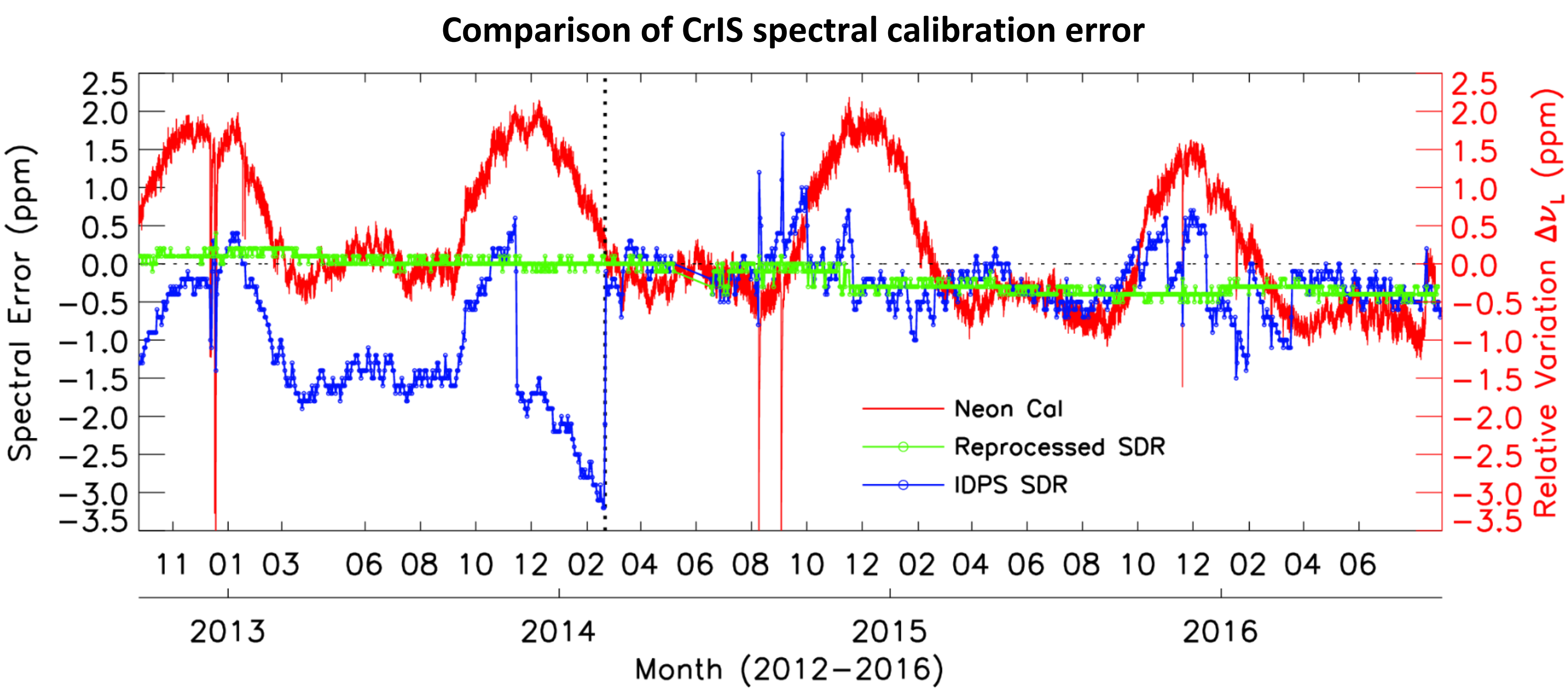


S-NPP CrIS SDR Reprocessing Improvements

Updates	Reprocessing System	Improvements
Calibration Algorithm	A4 type of calibration, first spectral, then radiometric	Reduced the ringing at the band edges and improved the calibration accuracy
Non-linearity coefficients	New MW FOV7 a2 coefficient, and keep other FOVs a2 as the same in the latest EngPkt v37	Improved the FOV-2-FOV radiometric consistency
ILS parameters	Keep the ILS the same as the latest EngPkt v37	Improved the spectral accuracy from +/- 3.0 ppm to within 1 ppm
Geolocation Mapping Angels	Keep the mapping angels the same as the latest EngPkt v37	Improved the geolocation accuracy from 1.2 km to less than 0.3 km using VIIRS as reference

Slide Courtesy: STAR CrIS SDR Team

S-NPP CrIS Reprocessing SDR Assessment



- Comparison of the Neon subsystem spectral calibration versus calibration using the upwelling radiances for IDPS and reprocessed SDRs from September 22, 2012 to August 31, 2016.
- The upwelling calibration has been offset by -0.6 ppm.
- The Neon zero shift time is determined by the Correction Matrix Operator (CMO) update on December 19, 2012. The several sharp spikes in the December 19, 2012, August 9, 2014, and September 2, 2014 are due to NPP spacecraft issues, not CrIS malfunctions.
- The upwelling calibration is for the daily average of FOV5 at nadir (FOR 15 or 16), descending orbit over clear tropical ocean scenes.

Courtesy: STAR CrIS SDR Team

S-NPP OMPS SDR Reprocessing Improvements

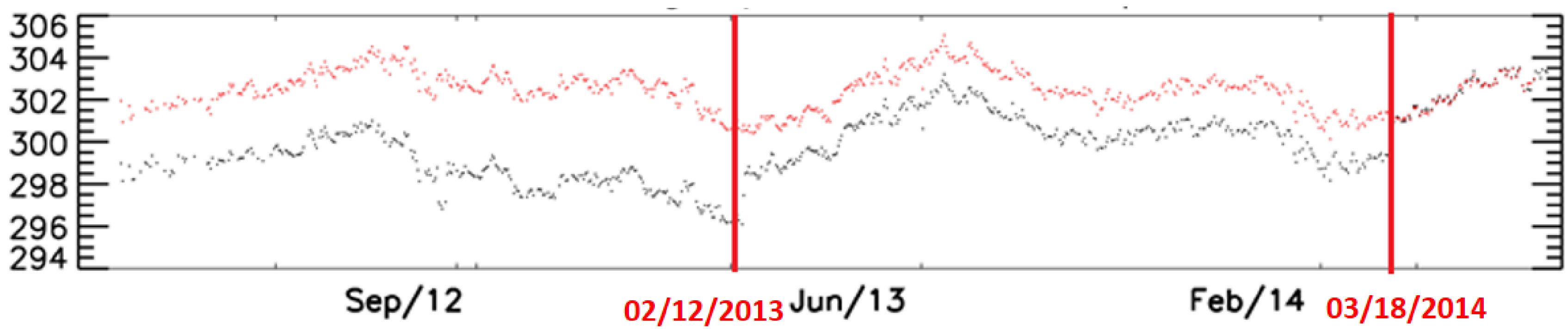
Error Sources	Reprocessing System	Impact/Improvements
Wavelength registration	Coefficients update based on on-orbit solar irradiance measurements	Improve NP/NM SDR quality and ozone total column and profile retrieval accuracy
Straylight	Coefficients adjustment based on EDR performance	Consistent NP and NM SDR stray light correction algorithm. Ozone total column and profile retrieval accuracy
Albedo	Coefficients update based on on-orbit observations	NP/NM SDR accuracy between 300 and 310 nm channels
Irradiance	Calibration coefficients for solar irradiance measurements	NP/NM SDR accuracy for all channels

Courtesy: STAR OMPS SDR Team

S-NPP OMPS Reprocessing SDR Assessment

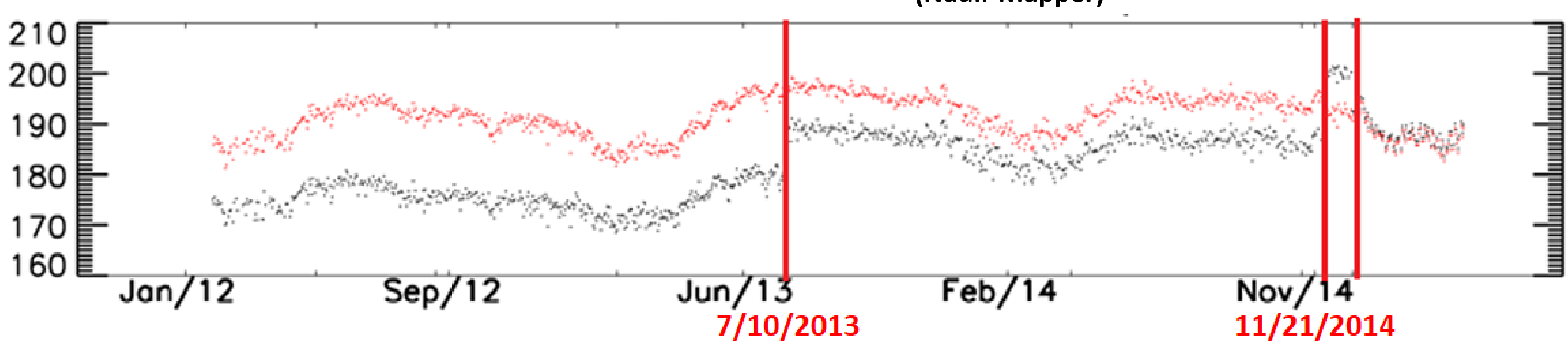
OMPS daily nadir view N-value (stability) over tropical Pacific region (20S-20N,90W-180W)

252nm N-value (Nadir Profiler)



- **02/12/2013: Start of weekly updates to NP dark LUT**
- **03/18/2014: NP Stray Light correction**

302nm N-value (Nadir Mapper)



- **7/10/2013: TC Stray Light temporary table update**
- **11/21/2014: TC Stray Light LUT update**
- **12/18/2014: TC Stray Light LUT update**

Courtesy: STAR OMPS SDR Team

S-NPP SDR Reprocessing Data Status

- Build a cost effective High Performance Computing (HPC) cluster for JPSS reprocessing and temporary archiving at http://jlrdata.umd.edu/opendap/thredds
- Utilize the latest version with new, fully tested, and validated science algorithms
- Integrate the latest version of PCT, LUT, and engineering packages into a baseline system for reprocessing
- Recover the missing RDR granules from every possible medium (e.g. CLASS, GRAVITE)
- Produce mission-long S-NPP Reprocessed SDRs in the same format as what provided in CLASS, and work is underway to transfer datasets to NCEI/CLASS

Sensor	Data Types	Daily Volume	Date Period	Total Days	Total Volume
ATMS	TDR+SDR+GEO	1241 MB	2011/11/08~2017/03/08	1948	2.42 TB
CrIS	NSR SDR+GEO	44.3 GB	2012/03/01~2017/03/08	1834	81.25 TB
CrIS	FSR SDR	74 GB	2014/12/04~2017/03/08	826	61.12 TB
VIIRS	SDR+GEO	415 GB	2012/02/20~2017/03/08	1845	765.68 TB
OMPS NP	SDR+GEO	261 MB	2012/01/26~2017/03/08	1869	487.81 GB
OMPS TC	SDR+GEO	3 GB	2012/01/26~2017/03/08	1869	5.61 TB
Total					**916.57 TB**

Access of S-NPP Reprocessing SDR Data

http://jlrdata.umd.edu/opendap/thredds/catalog.html

JPSS Life-Cycle Reprocessing

ninghai.sun

OPeNDAP THREDDS Catalogs

JPSS Life-Cycle Reprocessing Data Service Catalog : S-NPP ATMS Data S-NPP CrIS Data S-NPP VIIRS Data S-NPP OMPS Data

Catalog Services

Service Name	Service Type	Service Base
Hyrax	OPeNDAP	/opendap/hyrax/

Dataset	Size	Last Modified
S-NPP ATMS Data/	--	--
ATMS TDR /	--	--
ATMS SDR /	--	--
ATMS GEO /	--	--
S-NPP CrIS Data/	--	--
CrIS SDR /	--	--
CrIS FSR SDR /	--	--
CrIS GEO /	--	--
S-NPP VIIRS Data/	--	--
VIIRS I-Band SDR /	--	--
VIIRS I-Band Terrain Corrected GEO /	--	--
VIIRS M-Band SDR /	--	--
VIIRS M-Band Terrain Corrected GEO /	--	--
VIIRS DNB SDR /	--	--
VIIRS DNB GEO /	--	--
S-NPP OMPS Data/	--	--
OMPS NP SDR /	--	--
OMPS NP GEO /	--	--
OMPS TC SDR /	--	--
OMPS TC GEO /	--	--

THREDDS Catalog XML

Hyrax development sponsored by NSF , NASA , and NOAA

OPeNDAP Hyrax (1.13.4)

Documentation

Summary

- Reprocessing SDR data has been treated as one of the JPSS data products and will go through scientific data product quality review before public release
- 1st JPSS reprocessing workshop held in 2016: https://www.star.nesdis.noaa.gov/jpss/meetings2016.php
- Suomi-NPP SDR version 1 (cut-off by March 8, 2017) reprocessing has been done for evaluation
- Preliminary analysis shows that the quality of S-NPP SDR data is significantly improved after reprocessing
- Reprocessing SDR data has been sent to users, such as NWS, for further evaluation
- S-NPP reprocessing SDR is available from OPeNDAP/THREDDS for research evaluation purpose at http://jlrdata.umd.edu/opendap/thredds
- Working with NCEI/CLASS on the fast access and dissemination of the reprocessed data for worldwide users
- EDR teams have demonstrated EDR reprocessing and associated improvements. Enterprise algorithms implemented for Suomi-NPP EDR products are either operational or close to operations with algorithm maturity acceptable for reprocessing.

Path Forward

- Work with JPSS SDR and EDR users to understand their requirement so as to better serve the data users worldwide
- Work closely with NCEI/CLASS teams to define a repeatable process for archiving current and future reprocessed data.
  - NCEI Request To Archive (R2A) has been submitted and discussed
  - CLASS/NCEI Engineering Assessment process has been started
  - Interface Control Documents development is on-going
- Integrate the accumulated SDR calibration algorithm updates after the first reprocessing in the new reprocessing system and prepare for the version 2 reprocessing

ATMS/CrIS/OMPS SDR Reprocessing Plan

- **ATMS SDR Reprocessing Plan**
  - Antenna emission correction on calibration target and earth view scenes
  - Hybrid antenna pattern correction algorithm to improve SDR data quality
  - Model based lunar intrusion detection and correction on cold calibration targets
  - S-NPP ATMS SDR reprocessing (version 2) is planned in middle 2019
  - NOAA-20 ATMS SDR post-validated reprocessing is on-going
- **CrIS SDR Reprocessing Plan**
  - S-NPP CrIS FSR/NSR SDR reprocessing (version 2) is optional
  - NOAA-20 CrIS SDR post-validated reprocessing will be planned after validated review
- **OMPS SDR Reprocessing Plan**
  - OMPS-TC stray light correction update
  - S-NPP OMPS SDR reprocessing (version 2) is planned in early 2019
  - NOAA-20 OMPS SDR post-validated reprocessing will be planned after validated review

VIIRS SDR Reprocessing Plan

Updates	Ongoing V2 Reprocessing With Further Improvements
Cal/Val Algorithm Updates	All M&I bands: Corrected an IDPS coding error in the VIIRS DELTA-C LUT relating to CFPA temperature.
RSBs	VIIRS SDR final Baseline product, based on re-analyzed of SD/SDSM screen and BRDF LUTs → Annual oscillation removed and further smoothed; future changes will not require fundamental reprocessing (only need bias correction). Support two VIIRS SDR version products through Radiometric Bias Correction terms: 1) New OC Hybrid calibration (extended up to 03/2017). 2) STAR VIIRS SDR team's Kalman filter model F-factors, based on reconciled Lunar, DCC, SNO calibrations.
TEBs:	1) Improved WUCD bias correction for all bands.
DNB:	1) Improved calibration offsets with striping correction.

Reprocessing On-Demand

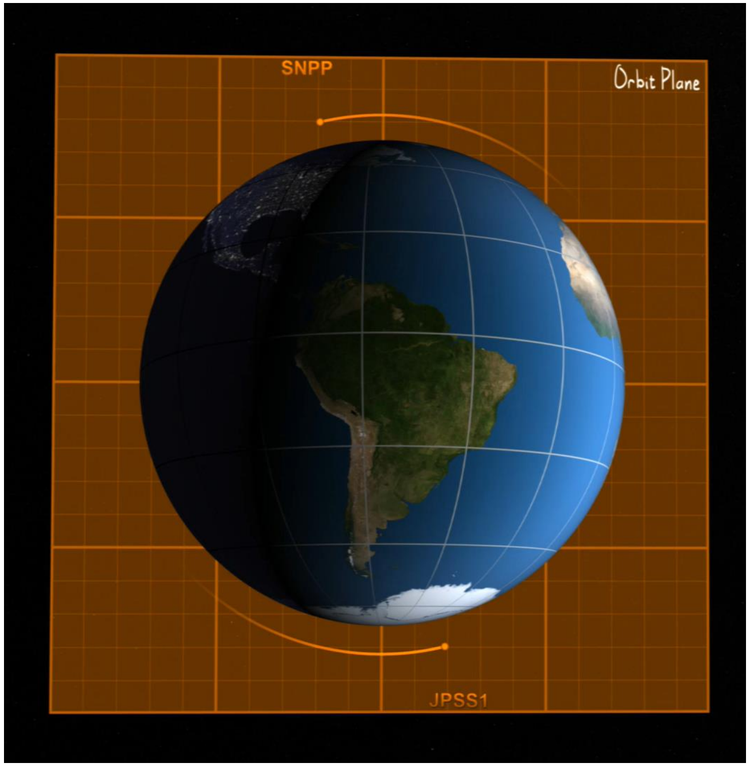
Why?

- VIIRS data volume is large (~1 PB/7 years) There is not enough storage space
- SDR volume is 10x of RDR
- Generating SDR files on the fly is faster than transmitting over the network
- Most users don't need all the data (few have the storage capacity)

How?

- Work with specific users to define needs
- Generate the required SDRs only when needed
- User can define spatial and temporal criteria
- SDR can be either generated at STAR or user site
- Tested with NOAA-20 VIIRS DNB reprocessing
- Will provide fully reprocessed SDR to NCEI when they are ready to accept.

Slide Courtesy: Changyong Cao, VIIRS SDR Lead

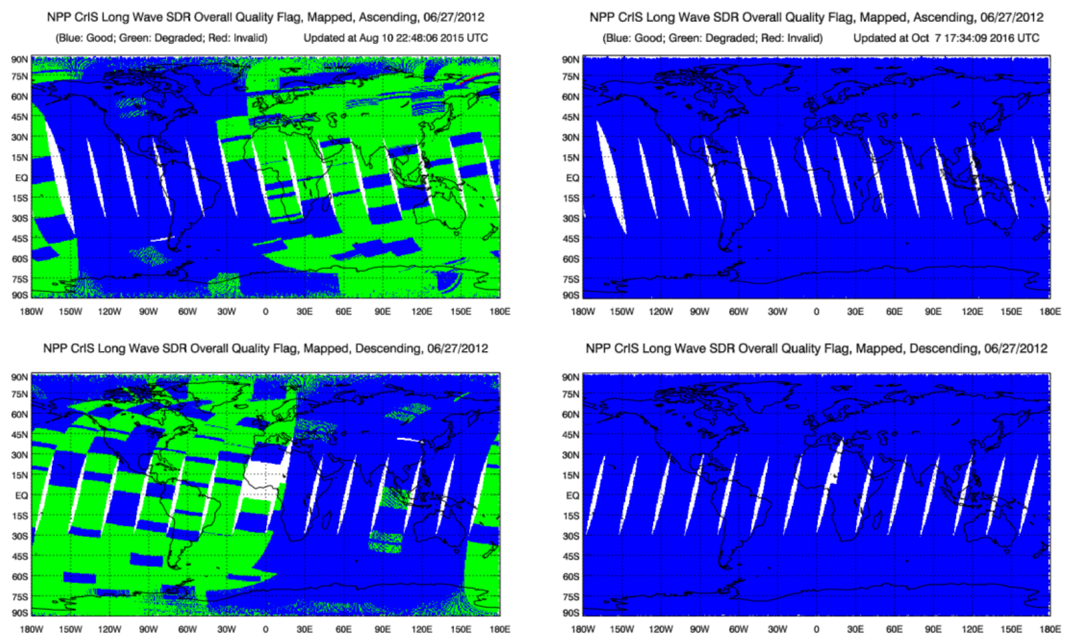


Thank you!

Backup Slides

STAR CrIS Data Reprocessing (1/3)

- Engineering packet version 37 and new MW FOV7 NL a2 coefficient
- ADL Block 2.0 with A4 calibration algorithm and improved geolocation algorithm
- TSR SDR for the whole history
- FSR SDR since December 4, 2014
- Latest RDR version
- CrIS TSR data reprocessing from February 20, 2012 to August 31 2016 completed



06/27/2012

IDPS SDR

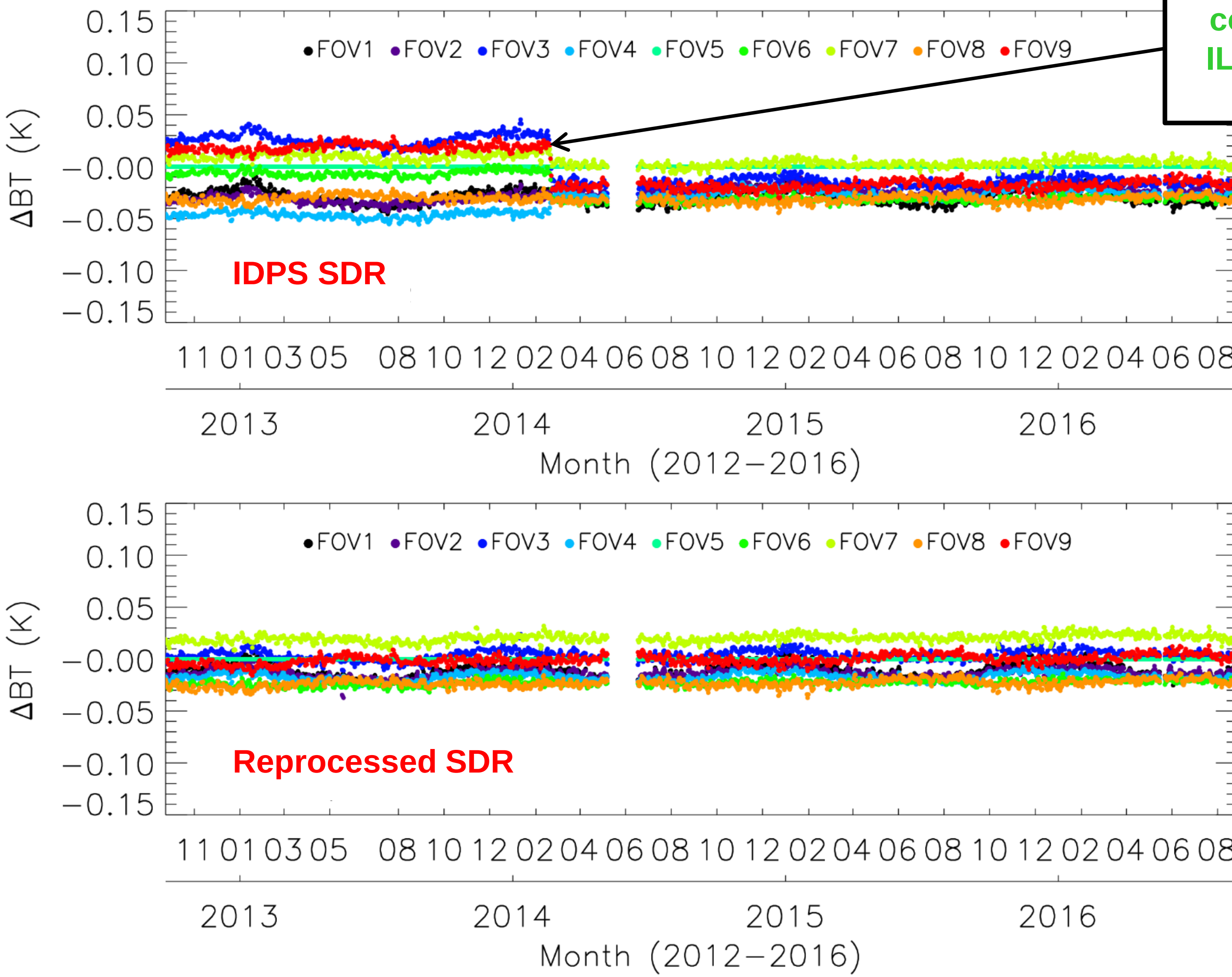
Reprocessed SDR

STAR CrIS Data Reprocessing (2/3)

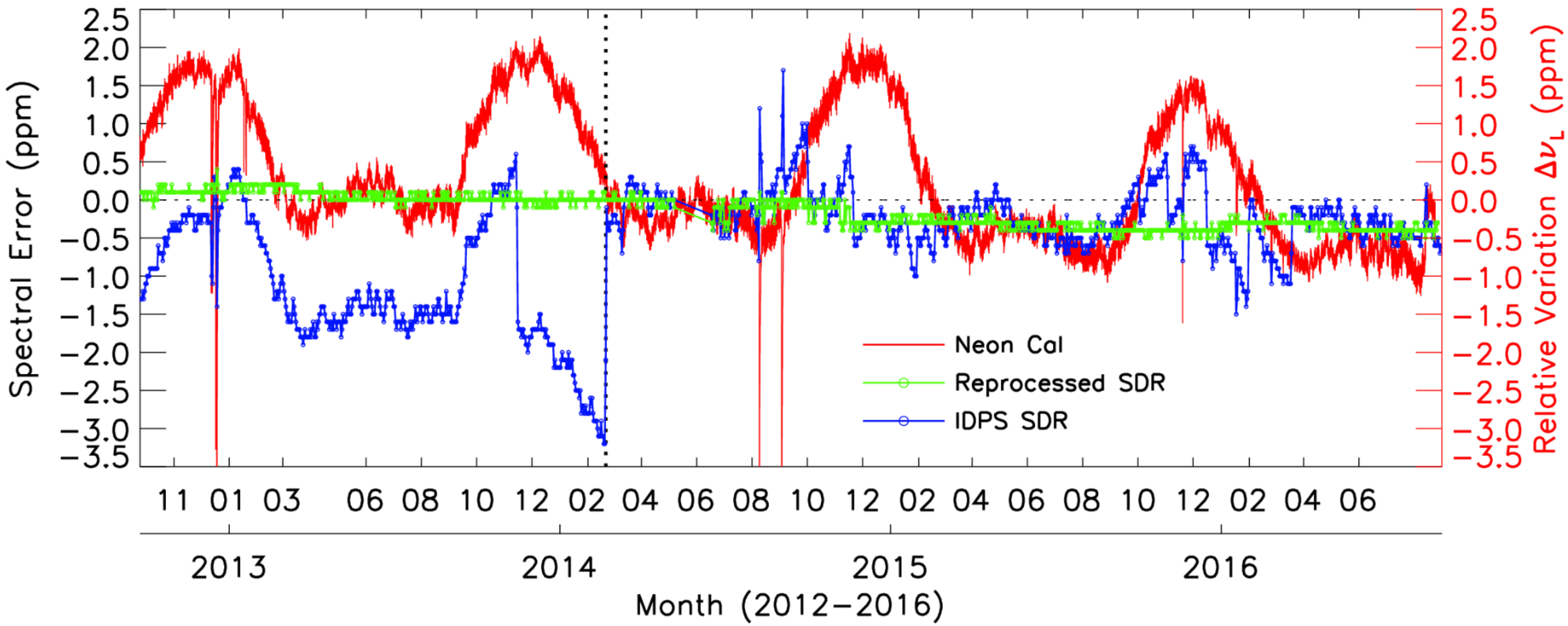
CrIS Radiometric Stability:
Daily Mean FOV-2-FOV Difference wrt FOV5

LW, 672-682 cm^{-1}

02/20/2014
CrIS non-linearity coefficient and ILS parameters update

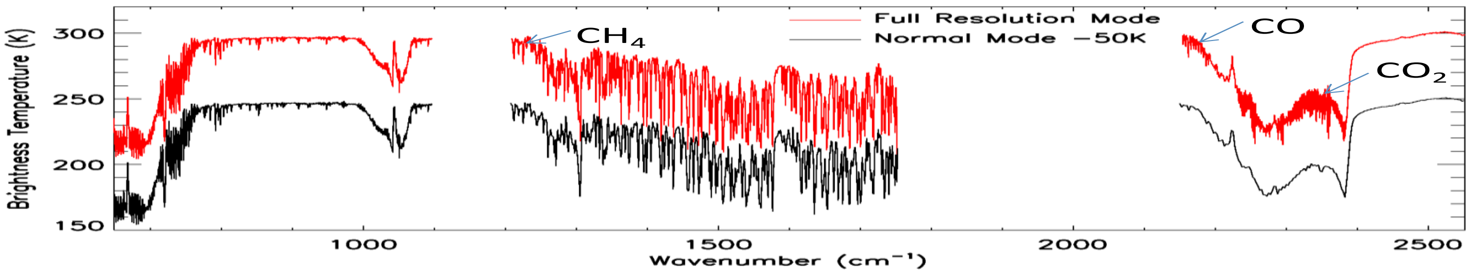


STAR CrIS Data Reprocessing (3/3)

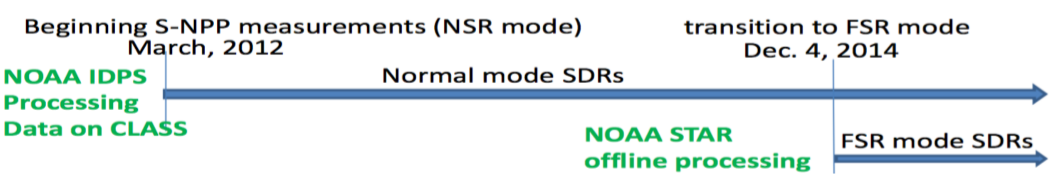


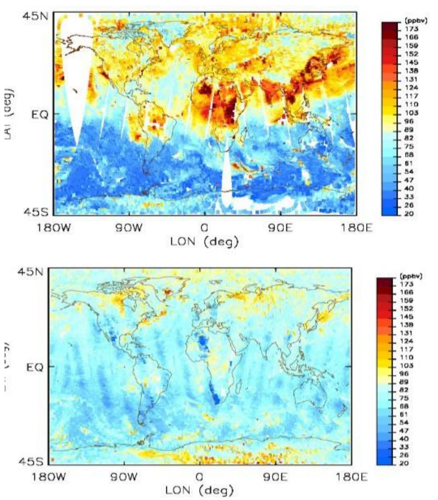
- Comparison of the Neon subsystem spectral calibration versus calibration using the upwelling radiances for IDPS and reprocessed SDRs from September 22, 2012 to August 31, 2016.
- The upwelling calibration has been offset by -0.6 ppm.
- The Neon zero shift time is determined by the Correction Matrix Operator (CMO) update on December 19, 2012. The several sharp spikes in the December 19, 2012, August 9, 2014, and September 2, 2014 are due to NPP spacecraft issues, not CrIS malfunctions.
- The upwelling calibration is for the daily average of FOV5 at nadir (FOR 15 or 16), descending orbit over clear tropical ocean scenes.

S-NPP/JPSS-1 CrIS Full Spectral Resolution (FSR)



Frequency Band	Spectral Range (cm^{-1})	Number of Channel	Spectral Resolution (cm^{-1})
LWIR	650 to 1095	713 (713)	0.625 (0.625)
MWIR	1210 to 1750	865 (433)	0.625 (1.25)
SWIR	2155 to 2550	633 (159)	0.625 (2.5)





2/17/2015 NUCAPS CO FSR (top), NSR (bottom)

NWP Centers worldwide routinely access CrIS FSR SDRs from STAR FTP servers.

Benefits of full spectral resolution

- **Carbon monoxide retrieval becomes viable**
  - **Useful for air quality application**
- **Resolve weak water vapor spectral lines to improve upper troposphere water soundings**
- **Better calibration of 4.3 um band improves lower tropospheric temperature**

Need for SDR/EDR Reprocessing

- ✓ Meet mission requirements with the state-of-the art retrieval algorithms for consistent mission-long data products
- ✓ SDR/EDR product maturity from beta, provisional, to validated is achieved over the time, and each maturity stage represents an improvement in science quality.
  - Without reprocessing, data products in the archive would have varying accuracy due to periodic updates of algorithms (to fix shortfalls) used for real-time product generation
- ✓ Reprocessing using the most matured (validated) algorithm now part of the cal/val program to validate algorithm corrections/improvements over a large and wide range of representative conditions, with comprehensive documentation of product performance –consistent with the "FULL" (Validated) product performance level.

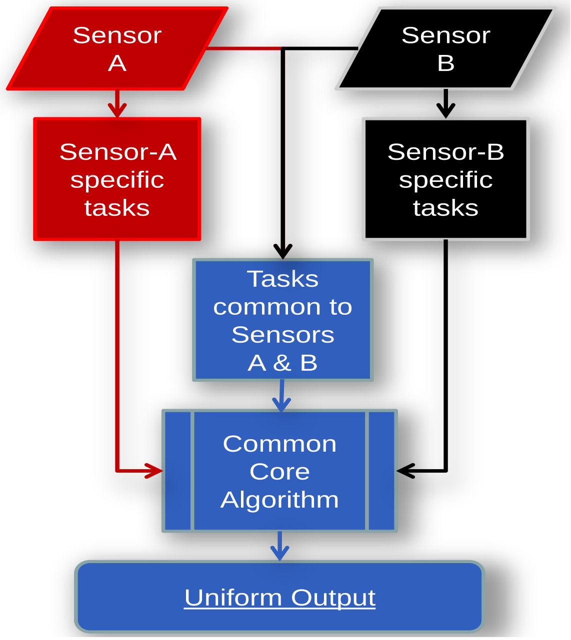
- Science Benefits, Addressing User Needs
  - ✓ Enable users to utilize high-quality products retroactively to evaluate impacts on user applications.
  - ✓ NWP users requested reprocessed SDRs for their next reanalysis plan

Consistent long-term product quality metrics can only be achieved through reprocessing with algorithms that has reached validated maturity.

Reprocessing workshop: https://www.star.nesdis.noaa.gov/jpss/meetings2016.php

EDR Enterprise Algorithms and Reprocessing

- JPSS STAR science teams have implemented many of the S-NPP priority 3 and 4 EDRs using enterprise algorithms.
- Evaluation of JPSS Enterprise algorithms/EDR products show enhanced performance/APUs



- Same method (physics and assumptions) and its realization (software) are applied to retrieve regardless of source of satellite input
- Optimizes processes and use of resources
- Instrument specific tasks are built around a common core

Benefits

- Brings continuity of NOAA products between current and future NOAA operational satellites
- Supports NWS's strategy of multi-sensor algorithms and products
- Cost-effective processing for NOAA products
- Maintenance of fewer algorithms and systems within operations

Examples of Enterprise Algorithms operating in NDE

- ✓ VIIRS Enterprise Cloud Mask (ECM), Aerosol Optical Thickness and Detection products (AOT, ADP)
- ✓ NOAA Unique Combined Atmospheric Processing System (NUCAPS) products using hyper-spectral CrIS and ATMS
- ✓ Microwave Integrated Retrieval System (MIRS) products from ATMS.
- ✓ Ozone EDR product suite (V8TOz and V8Pro)

S-NPP Enterprise Data Products (EDRs Only)

Note: Does not include VIIRS Imagery EDRs because they will be processed in IDPS

Completion of S-NPP algorithm transition to **Enterprise Algorithms:** Summer of 2018

Enterprise Algorithm Status

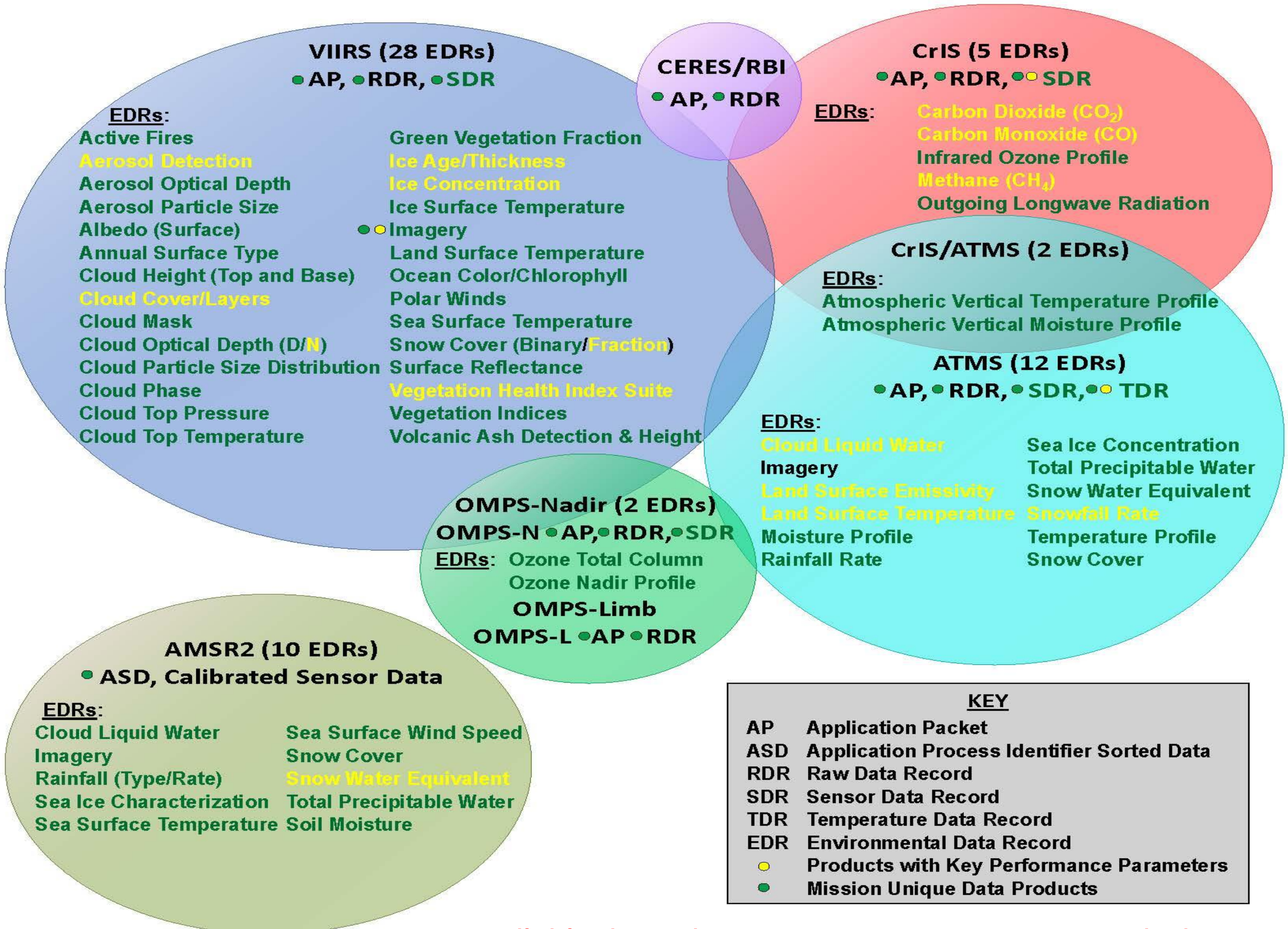
Aerosol Detection (VIIRS)	Global Annual Surface Type (VIIRS)*	Rainfall Rate (ATMS)
Active Fires (VIIRS)	Green Vegetation Fraction (VIIRS)	Sea Ice Characterization (AMSR-2)
Aerosol Optical Depth(VIIRS)	Ice Age/Thickness (VIIRS)	Sea Surface Temperature (AMSR-2)
Aerosol Particle Size (VIIRS)	Ice Concentration (VIIRS)	Sea Surface Temperature (VIIRS)
Albedo (Surface) (VIIRS) 2018*	Ice Concentration (ATMS)	Sea Surface Wind Speed (AMSR-2)
AMSR Calibrated Sensor Data (AMSR-2)	Ice Surface Temperature (VIIRS)	Snow Cover/Depth (AMSR-2)
Atmospheric Vertical Moisture Profile (CrIS/ATMS)	Imagery (AMSR-2)	Snow Cover (ATMS)
Atmospheric Vertical Temperature Profile (CrIS/ATMS)	Imagery (ATMS)	Snow Cover (VIIRS)
Carbon Dioxide (CO) (CrIS)	Infrared Ozone Profile (CrIS)	Snow Water Equivalent (ATMS)
Carbon Monoxide (CO2) (CrIS)	Land Surface Emissivity (ATMS)	Snow Water Equivalent (AMSR-2)
Cloud Cover/Layers (VIIRS)	*Land Surface Temperature (VIIRS) 2018*	Soil Moisture (AMSR-2)
Cloud Height (Top and Base) (VIIRS)	Land Surface Temperature (ATMS)	Surface Reflectance (VIIRS)
Cloud Liquid Water (AMSR-2)	Methane (CH4) (CrIS)**	Surface Type (AMSR-2)
Cloud Liquid Water (ATMS)	Moisture Profile (ATMS)	Temperature Profile (ATMS)
Cloud Mask (VIIRS)	Ocean Color/Chlorophyll (VIIRS)	Total Precipitable Water (AMSR-2)
Cloud Optical Depth (VIIRS)	Outgoing Longwave Radiation (CrIS)	Total Precipitable Water (ATMS)
Cloud Particle Size Distribution (VIIRS)	Ozone Nadir Profile (OMPS-N)	Vegetation Indices (VIIRS) 2018
Cloud Phase (VIIRS)	Ozone Total Column (OMPS-N)	Vegetation Health Index Suite (VIIRS)
Cloud Top Pressure (VIIRS)	Polar Winds (VIIRS)	Volcanic Ash Detection And Height (VIIRS)
Cloud Top Temperature (VIIRS)	Precipitation (Type/Rate)(AMSR-2)	

Generated in ESPDS, Products available through PDA, CLASS	DAP delivered, Operational implementation in 2018

*Global (annual) Surface Type is generated by STAR

S-NPP/N-20 Instruments and Products

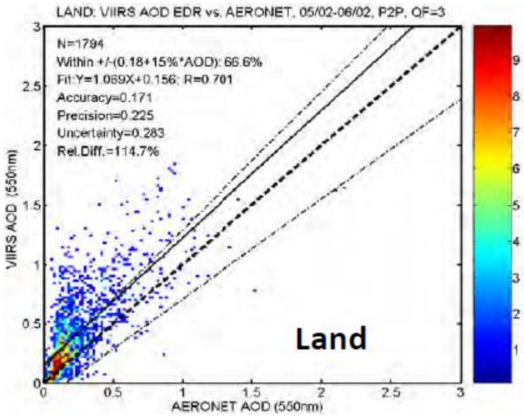
JPSS Program Data Products

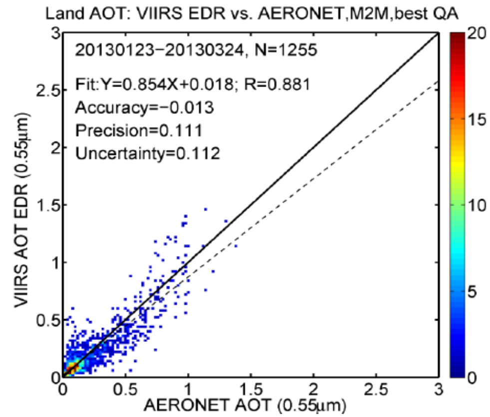


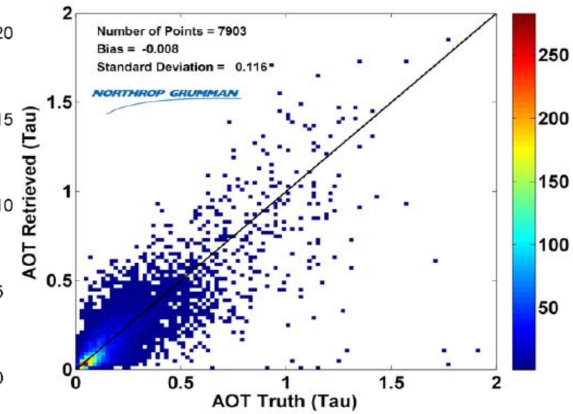
Data available through PDA , CLASS, GRAVITE, and Direct Readout

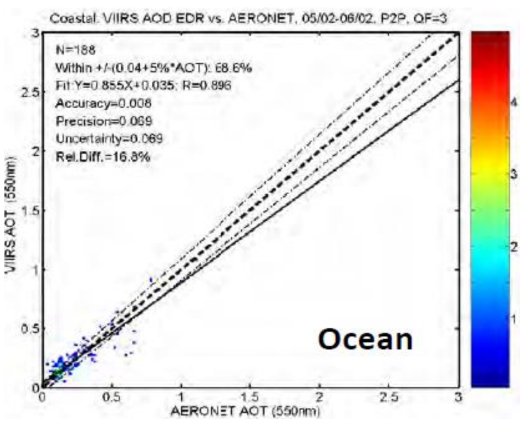
Example: Aerosol: VIIRS AOT EDR vs. AERONET AOT

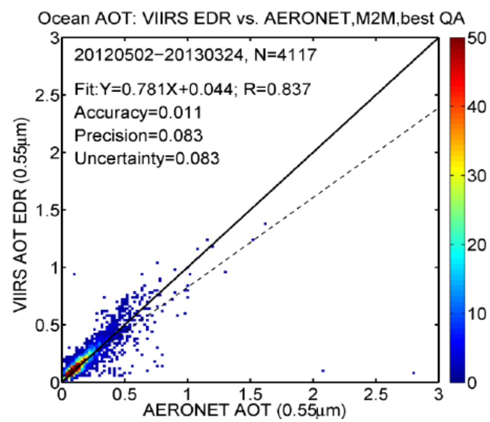
APU: Beta - -> Provisional - Validated

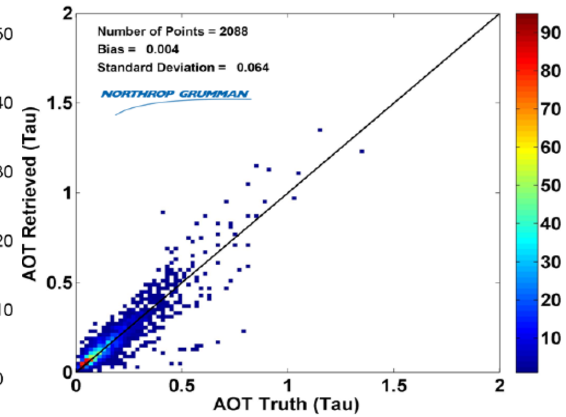












VIIRS AOT EDR vs. AERONET AOT		Beta (# of samples)	Provisional (# of samples)	Validated (# of samples)
Accuracy	Land	0.171 (1794)	-0.013 (1255)	-0.008 (7903)
	Ocean	0.008 (188)	0.011 (4117)	0.004 (2088)
Precision	Land	0.225 (1794)	0.111 (1255)	0.116 (7903)
	Ocean	0.069 (188)	0.083 (4117)	0.064 (2088)

S-NPP SDR/EDR Product Maturity Status:

S-NPP Products Reached Validated Maturity and are in Long Term Monitoring Phase

Sensor	Algorithm	Beta	Provisional	Validated
ATMS	ATMS SDR	Jan-2012	Oct-2012	Dec-2013
CrIS	CrIS SDR	Apr-2012	Oct-2012	Dec-2013
VIIRS	VIIRS SDR	Apr-2012	Oct-2012	Dec-2013
OMPS	OMPS SDR: NTC & NP	Feb-2012	Oct-2012	Aug-2015
VIIRS	Imagery (Not Near-Constant Contrast)	May-2012	Jan-2013	Jan-2014
VIIRS	NCC Imagery	Oct-2012	Aug-2013	Jan-2014
VIIRS	Cloud Mask	Jun-2012	Jan-2013	Jan-2014
VIIRS	Cloud Property Algorithms	Jun-2013	Jan-2014	Sep-2014*
VIIRS	Aerosol Optical Thickness and Particle Size	Sep-2012	Apr-2013	Aug-2014
VIIRS	Aerosols Detection Product	Jun-2013	Dec-2015	**
VIIRS	Ice Surface Temperature	May-2013	Aug-2013	Jan-2014
VIIRS	Sea Ice Concentration and Ice Thickness	May-2013	Nov-2013	**
VIIRS	Binary Snow Cover	May-2013	Nov-2013	Jan-2014
VIIRS	Fraction Snow Cover	May-2013	Nov-2013	**
VIIRS	Active Fires	Oct-2012	Aug-2013	Sep-2014
VIIRS	Land Surface Temperature	Dec-2012	Apr-2013	Dec-2014
VIIRS	Land Surface Albedo	Jun-2013	Apr-2014	Dec-2014
VIIRS	Surface Type	Feb-2013	Jan-2014	Dec-2014
VIIRS	Land Surface Reflectance	Feb-2013	Aug-2013	Sep-2014
VIIRS	Vegetation Index	Feb-2013	Aug-2013	Sep-2014
VIIRS	Ocean Color	Jan-2013	Jan-2014	Mar-2015
VIIRS	Sea Surface Temperature	Feb-2013	Jan-2014	Sep-2014
CrIS	Soundings	Aug-2012	Jan-2013	Sep-2014
OMPS	Total Column Ozone EDR	Jul-2012	Jan-2013	Aug-2015
OMPS	Nadir Profiler Ozone EDR	Aug-2012	Jan-2013	Aug-2015

More Details: https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php

***** Use Enterprise Products for Product Maturity***

Each maturity stage represents an improvement in science quality

Summary

- S-NPP EDRs Reprocessing
  - Enterprise algorithms/products implemented for Suomi-NPP are either operational or close to operations with algorithm maturity acceptable for reprocessing.
  - EDR Reprocessing efforts are on the way to create consistent record of S-NPP data products by removing the artifacts, biases, error processing; to maximize impacts on NWP forecasting and climate applications
  - VIIRS SST, Ocean Color, OMPS: Ozone, CrIS: Soundings and other product science teams have reprocessed data products.
  - Evaluation of the enterprise algorithms implemented in various systems, e.g. GOES-R and JPSS, to optimize the enterprise algorithm.
  - Working to identify computational resources, product dependencies to setup reprocessing chains for implementation either as individual systems or through framework integration.
- Working with the users in identifying the user needs for reprocessed products
  - How do we reprocess systems that have had channels go bad or have lost instruments entirely in case if the EDR product uses multi-instrument SDRs?

Need for SDR/EDR Reprocessing

- Consistent Mission Long S-NPP/NOAA-20 SDR/EDR Products
  - ✓ Meet mission requirements with the state-of-the art retrieval algorithms for consistent mission-long data products
  - ✓ EDR products get impacted both by upstream SDR product changes (due to uncovered deficiencies and improved sensor characterizations in SDR algorithms) as well as EDR algorithm changes
    - Without reprocessing, data products in the archive would have varying accuracy due to periodic updates of algorithms (to fix shortfalls) used for real-time product generation
- Science Benefits, Addressing User Needs
  - ✓ Enable users to utilize high-quality products retroactively to evaluate impacts on user applications.
  - ✓ NWP users requested reprocessed SDRs for their next reanalysis plan

JPSS Instruments/Data

- **Raw Data Records**
  Raw data generated by sensors on the satellites.
- **Sensor Data Records (SDRs)**
  Science algorithms that perform calibration and geo-location are applied on the RDRs to produce SDRs and Temperature Data Records (TDRs, for MW instruments).
- **Environmental Data Records (EDRs)**
  Geophysical parameters that are derived by applying retrieval algorithms on the SDRs.
  - VIIRS Imagery Products
  - Atmospheric Products
  - Land Products
  - Ocean Products
  - Cryosphere Products
- **Blended Products**
  Fusion of baseline products derived from a multitude of satellite sensors such as ATMS, AMSR-2, etc.

Reprocessing workshop: https://www.star.nesdis.noaa.gov/jpss/meetings2016.php

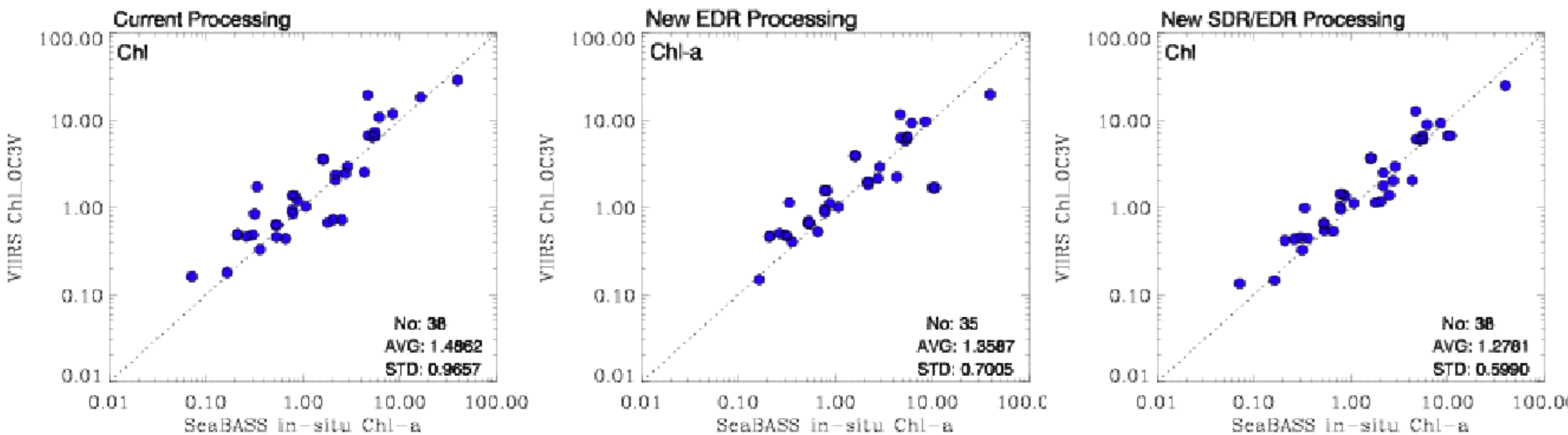
Reprocessing for Consistent Mission Long S-NPP EDR Products

- EDR products get impacted both by upstream SDR product changes (due to uncovered deficiencies and improved sensor characterizations in SDR algorithms) as well as EDR algorithm changes through beta, provisional, and validated maturity stages, and upstream EDR algorithm changes.
- Without reprocessing, data products in the archive would have varying accuracy due to periodic updates of algorithms (to fix shortfalls) used for real-time product generation.
- Enable users to utilize high-quality products retroactively to evaluate impacts on user applications.
  - Setup a baseline for further advancement of observational data records

Consistent long-term product quality metrics can only be achieved through reprocessing with algorithms that has reached validated maturity.

Reprocessing workshop: https://www.star.nesdis.noaa.gov/jpss/meetings2016.php

Ocean Color Reprocessing for Satellite Based Ocean Observations.



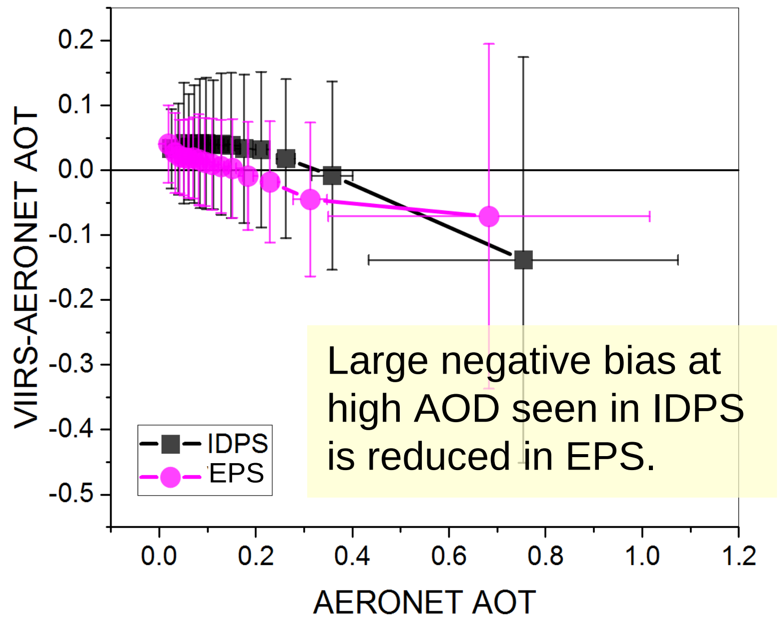
	Ratio of OC3V/Chl			OC3V vs Chl			log(OC3V) vs log(Chl)			No
	AVG	MED	STD	Slope	Intcpt	R^2	Slope	Intcpt	R^2	
Current Data Processing	1.4862	1.2273	0.966	0.812	1.225	0.78	0.866	0.112	0.81	38
New EDR Processing (2015-03-19)	1.3587	1.2210	0.701	0.487	1.391	0.66	0.743	0.102	0.77	35
New SDR/EDR Processing (2015-02-26)	1.2781	1.1933	0.599	0.652	1.099	0.83	0.857	0.085	0.89	38

The MSL12 Ocean Color Processing system produces NRT products (meeting latency requirements) for many real-time applications. Science quality OC products are produced at the expense of latency for applications requiring better accuracy and for incorporation into longer time series needs, such as the integrated ecosystem approach for fisheries management applications (**Ocean Color Lead: Menghua Wang)**

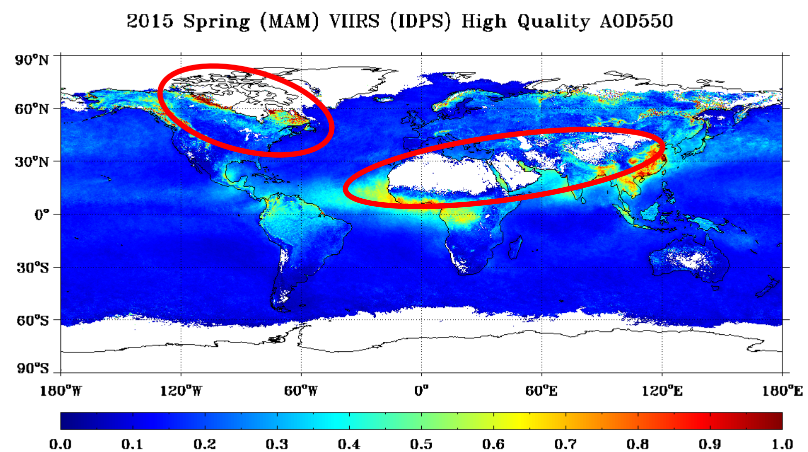
Ocean Color Data Sets: https://www.star.nesdis.noaa.gov/socd/mecb/color/

Enterprise Algorithms and Reprocessing

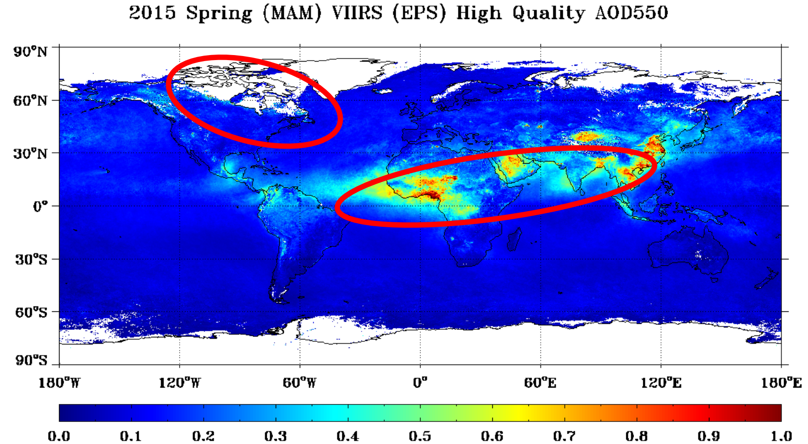
Aerosol Optical Depth

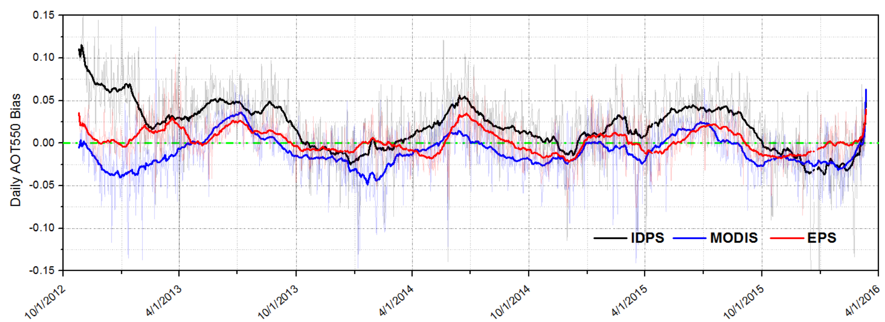


IDPS



EPS



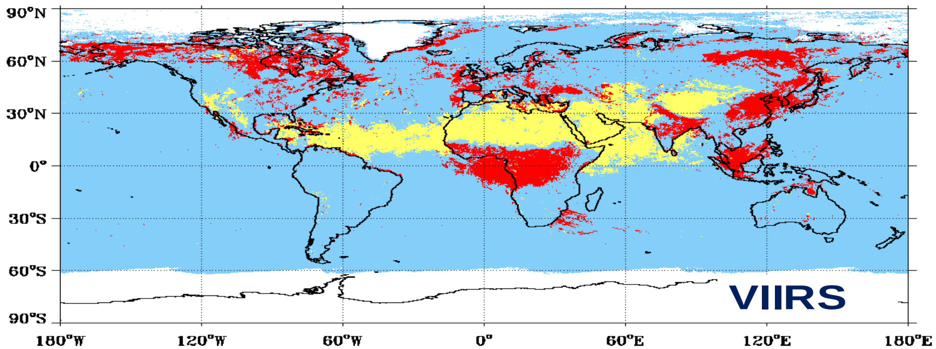


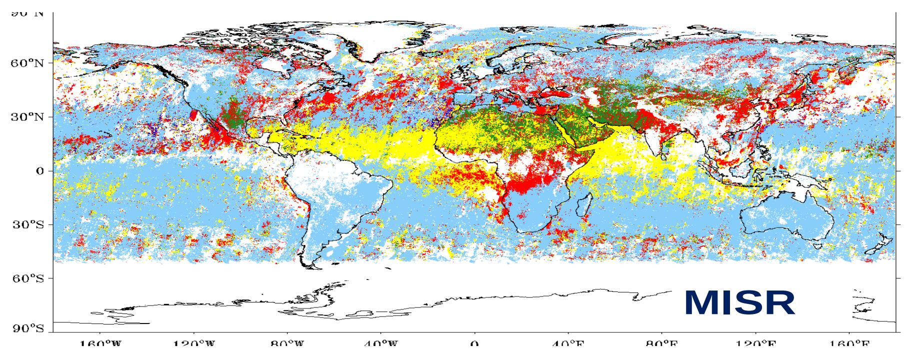
IDPS: Interface Data Processing Segment (current operational system)
EPS: Enterprise Processing System for NOAA Data Exploitation (NDE) operational system

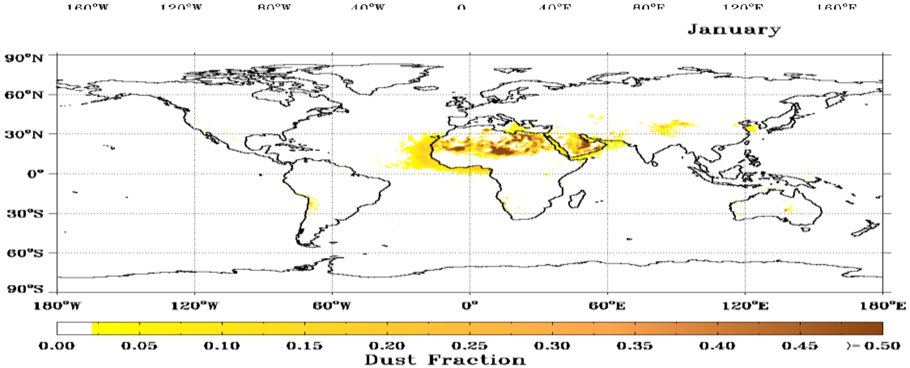
Aerosol Leads: **Istvan Laszlo/Shobha Kondragunta**

Enterprise Algorithms

Aerosol EDRs: Aerosol Detection







SNPP VIIRS Dust Climatology 2013 - 2015

- VIIRS Aerosol Detection Product is in good agreement with MISR with respect to location of dust and smoke.
- Both dust and smoke products meet requirements

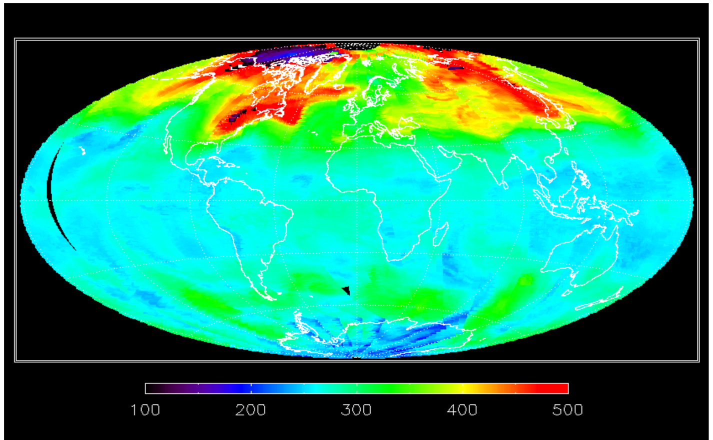
- **Enterprise ADP Algorithm Status:**
  - Algorithm is ready
  - Operational since July 5, 2017
- **Reprocessing:**
  - with EPS algorithm
  - 2015 completed; other years ongoing

NOAA-eidea website
https://www.star.nesdis.noaa.gov/smcd/spb/aq/eidea/

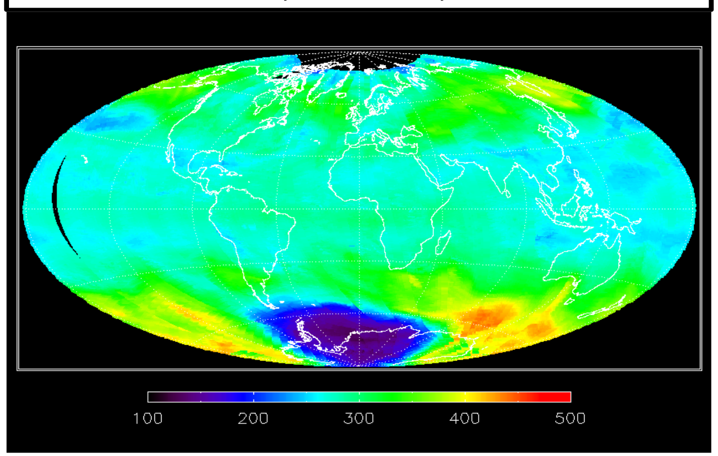
Aerosol Leads:
Shobha Kondragunta/Istvan Laszlo

OMPS Ozone Products

V8TOz Daily Total Ozone Products



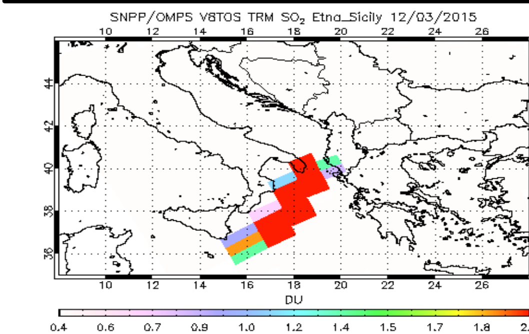
March 14, 2017 NH, Maxima



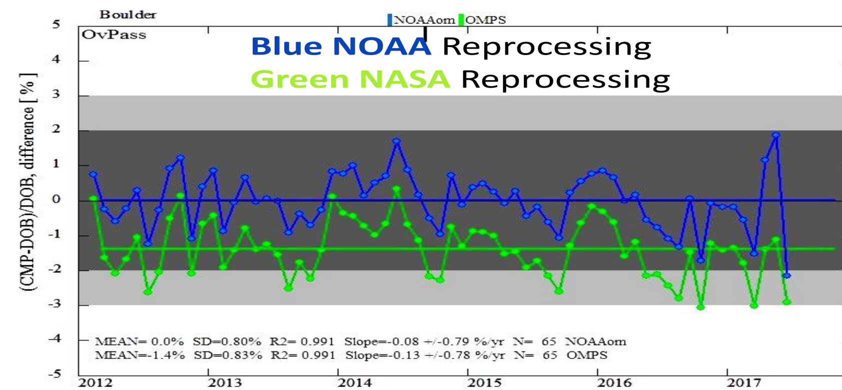
2016 SH Ozone Hole

OMPS EDR Products

- Total Ozone, using the version 8 algorithm
- Ozone profile, using version 8 algorithm
- SO2, Linear Fit SO2 method (LFSO2)



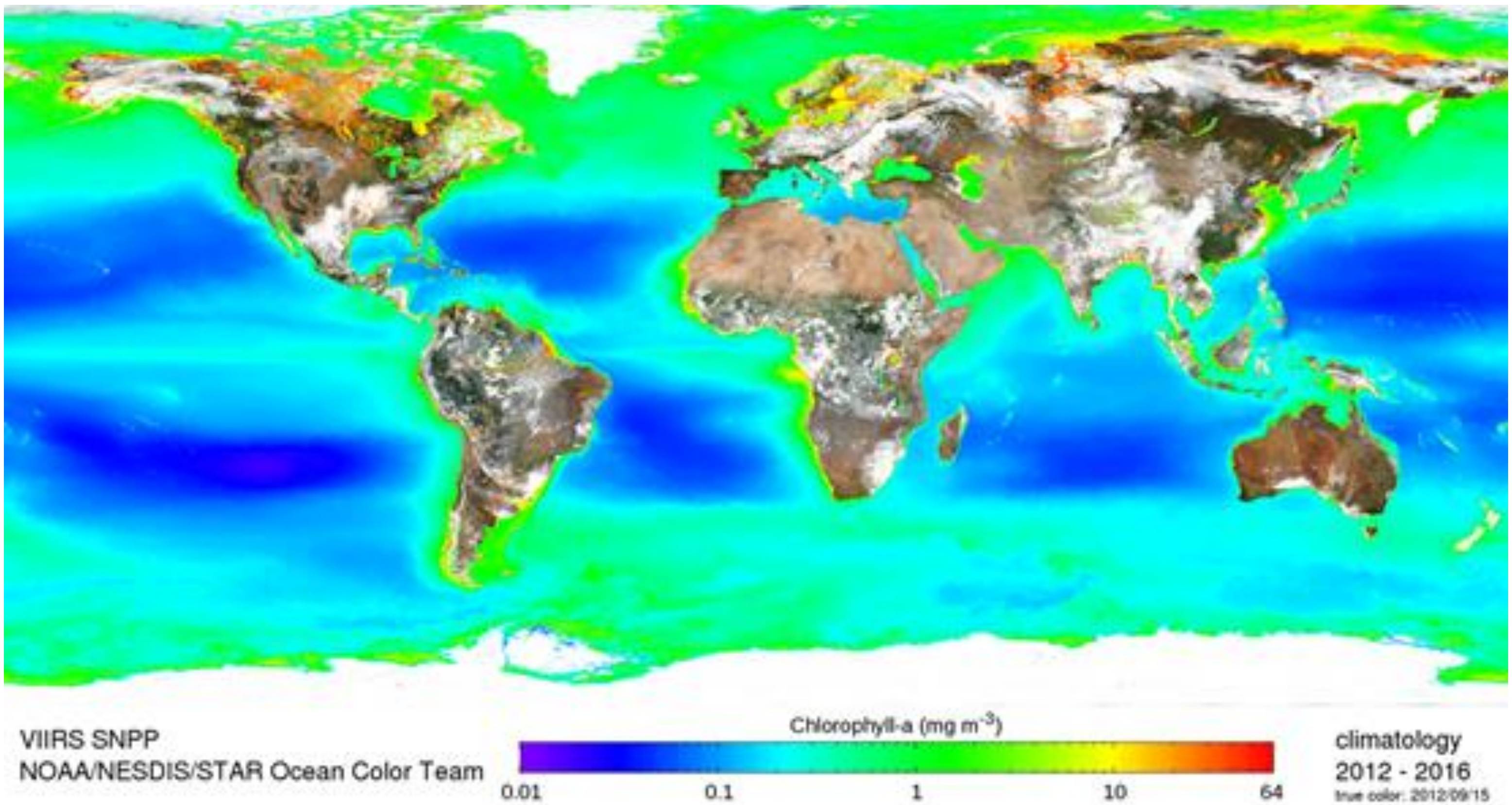
Estimated SO2 over active volcanos



Monthly average percent differences for OMPS total ozone estimates for overpass data compared to NOAA Dobson Station in Boulder CO

OMPS Lead(s): Larry Flynn (EDRs), Trevor Beck (SDRs)

S-NPP VIIRS Ocean Products

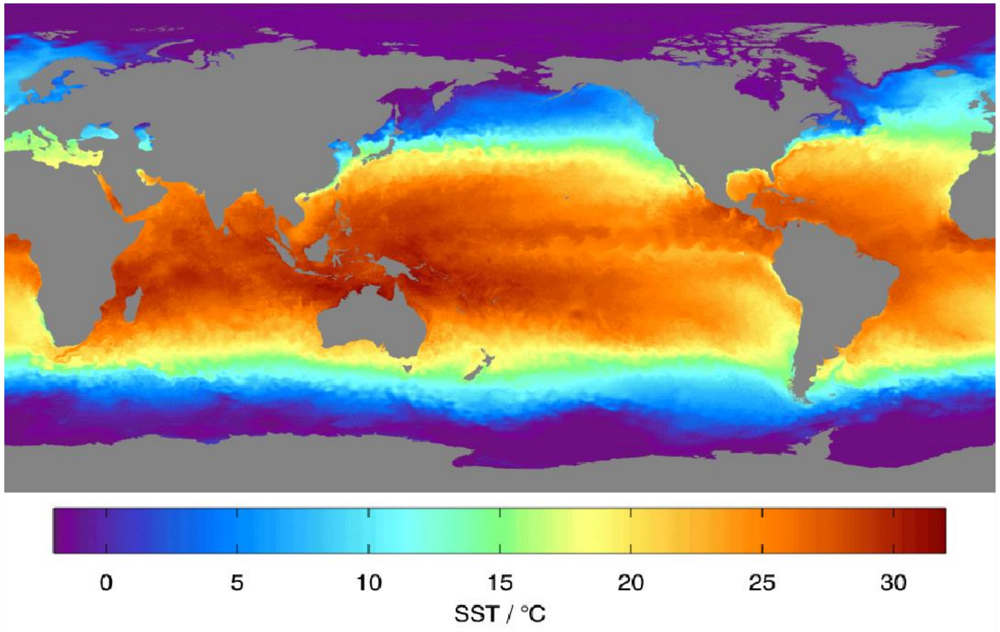


S-NPP Ocean Color Product Climatology generated through VIIRS mission-long reprocessed data Ocean Color Lead: Menghua Wang.
https://www.star.nesdis.noaa.gov/socd/mecb/color/

ACSPO VIIRS Sea Surface Temperature

These 5-km blended SST analyses are produced daily from 24 hours of polar and geostationary sea surface temperature satellite retrievals:

- S-NPP/NOAA-20
- Metop-B,
- GOES-E/W
- Meteosat-10
- MTSAT-2 (willbe replaced by Himawari-8 in late 2015.)
- **SST Lead: Sasha Ignatov**



PHASE I 2004 to present
September 2015

PHASE II 1994 to 2004
September 2016

Coral Reef Watch will use the latest 5 km global blended SST to generate a new climatology for their bleaching alert and monitoring products for the coral reefs around the globe.

SST website: https://www.star.nesdis.noaa.gov/jpss/SST.php

https://www.star.nesdis.noaa.gov/sod/sst/arms/

Enterprise Algorithms

STAR Microwave Integrated Retrieval System (MiRS)

https://www.star.nesdis.noaa.gov/jpss/mirs.php;

Satellite Microwave (TB) Measurements (INPUTS)

~ 20 channels (multispectral)

- TB (Channel 1)
- TB (Channel 2)
- TB (Channel 3)
- TB (Channel Ntot)
- Sensor Noise

MiRS Components

Forward RT Model (CRTM):
(1) TB= F(Geophysical State Vector)
(2) Jacobians (dTB/dX)

A Priori Background:
Mean and Covariance of Geophysical State

Basis Functions for State Vector:
Reduce degrees of freedom in geophysical profile (~20 EOFs)

Uncertainty of satellite radiances:
Instrument noise estimates

MiRS 1D Variational Retrieval

V11.1

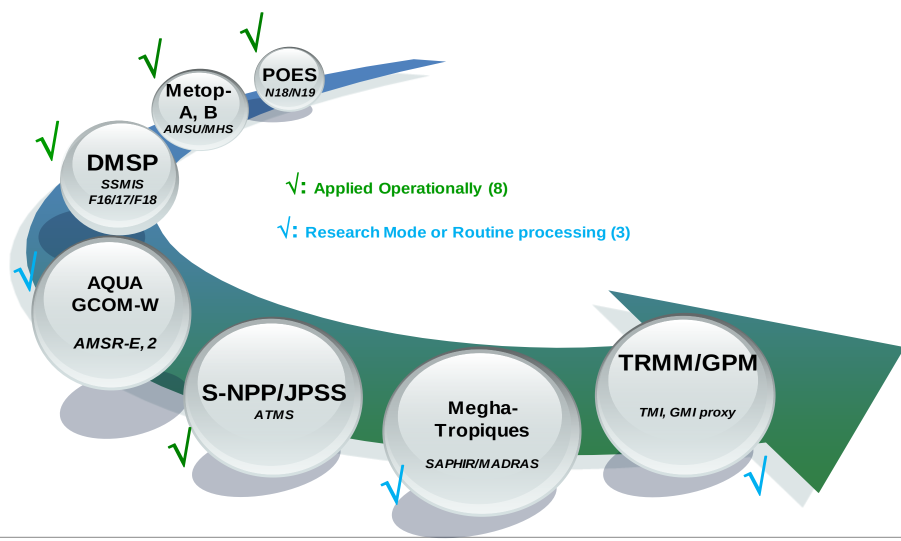
Geophysical State Vector (OUTPUTS)

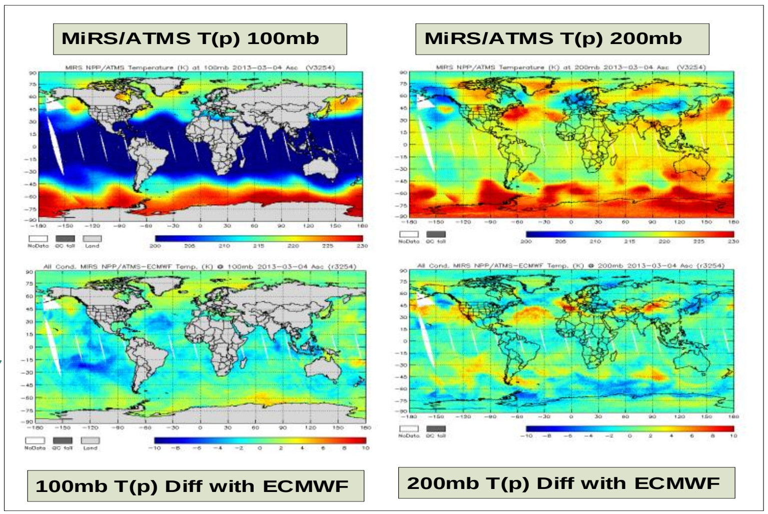
- Temp. Profile (100 layers)
- Water Vapor Profile (100)
- Cloud Water Profile (100)
- Graupel Water Profile (100)
- Rain Water Profile (100)
- Emissivity Spectrum (~ 20 channels)
- Skin Temperature (1)

MiRS Postprocessing

Derived Products (OUTPUTS)

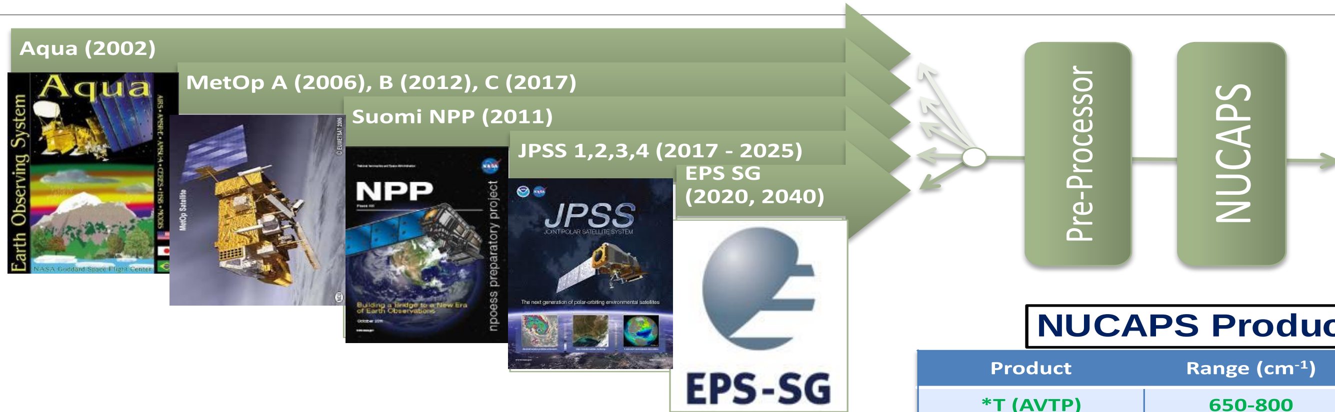
- TPW
- CLW
- RWP
- GWP
- RR
- SFR
- SIC/SIA
- SWE/GS

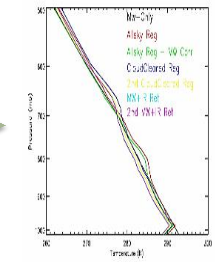




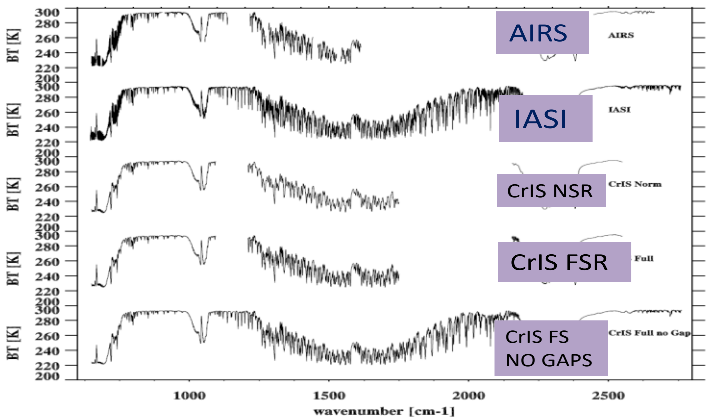
MiRS: An All-Weather 1DVAR Satellite Data Assimilation & Retrieval System, , S.-A. Boukabara, et al., IEEE Trans. Geosci. Remote Sens., 10.1109/TGRS.2011.2158438

Enterprise Algorithms
NOAA Unique Combined Atmospheric Processing System (NUCAPS)





- Enterprise Algorithm: Same Science Code applied to multiple sensors (CrIS/ATMS; AIRS/AMSU; IASI/AMSU/MHS)
- Atmospheric Vertical Temperature and Moisture Profiles (AVTP, AVMP), Trace gas profile (O3, Co, CO2, CH4)



NUCAPS Products

Product	Range (cm^{-1})	Precision
*T (AVTP)	650-800 2375-2395	1K/km
*H_2O (AVMP)	1200-1600	15%
*O_3 (p)	1025-1050	10%
*Cloud P, T, fraction	700-900	25 mb 1.5K, 5%
CO	2080-2200	15%
CH_4	1250-1370	1.5%
CO_2	680-795 2375-2395	0.5%
+ Volcanic SO_2	1340-1380	50% ??
+HNO_3	860-920 1320-1330	50% ??
+N_2O	1250-1315 2180-2250	5% ??
&$CFCl_3$ (F11)	830-860	20%
&CF_2Cl (F12)	900-940	20%
&CCl_4	790-805	50%

*Products available in AWIPS for WFOs
&Potential additions
+Products generated by NUCAPS but not part of requirements

NUCAPS EDR Leads: Lihang Zhou, Antonia Gambacorta

Applications of Suomi NPP Reprocessed Data in Climate Research

- NWP reanalysis using Suomi NPP reprocessed data (e.g. NASA GMAO)
- Climate data record (40 years) of microwave sounder radiances and products from MSU/AMSU/ATMS, temperature, moisture, precip., etc
- Climate data record (40 years) of infrared sounder radiances and products from SSU/HIRS/CrIS; and hyperspectral sounders (AIRS, IASI, CrIS), atmospheric temperature, moisture, trace gases. etc
- Climate data record (40 years) of global data products from polar satellite imagers (AVHRR, MODIS, VIIRS), such as Clouds, Aerosols, Ice and Snow, SST, LST, Albedo, Surface Type, Vegetation, Ocean Color, etc
- Climate data records of global trace gases (Ozone, CO, CO_2, CH_4, etc)

Exploring Using Artificial Intelligence (AI) to Exploit Big Satellite Data for NowCasting and NWP

- Focus on JPSS-related Applications/Sensors-

S. Boukabara*, E. Maddy+, N. Shahroudi +, R. Hoffman~, C. Sprague#, J. Conran +, S. Upton^, T. Connor^ , K. Ide and A. Karpovich&

***NOAA/NESDIS Center for Satellite Applications and Research (STAR) , College park, MD**

+ Riverside Technology Inc. (RTI) @ NOAA/STAR, College park, MD

~ University of Miami, Miami, FL, USA

#Aerospace Co, Arlington, VA

^ Atmospheric and Environmental research (AER Inc.)

& University of Maryland, College Park, MD

JPSS Meeting, College Park, MD, August 27-30th 2018

Agenda

1 **Why Artificial Intelligence (AI) ? Background and Motivations**

2 **What are we exploring using AI for?**

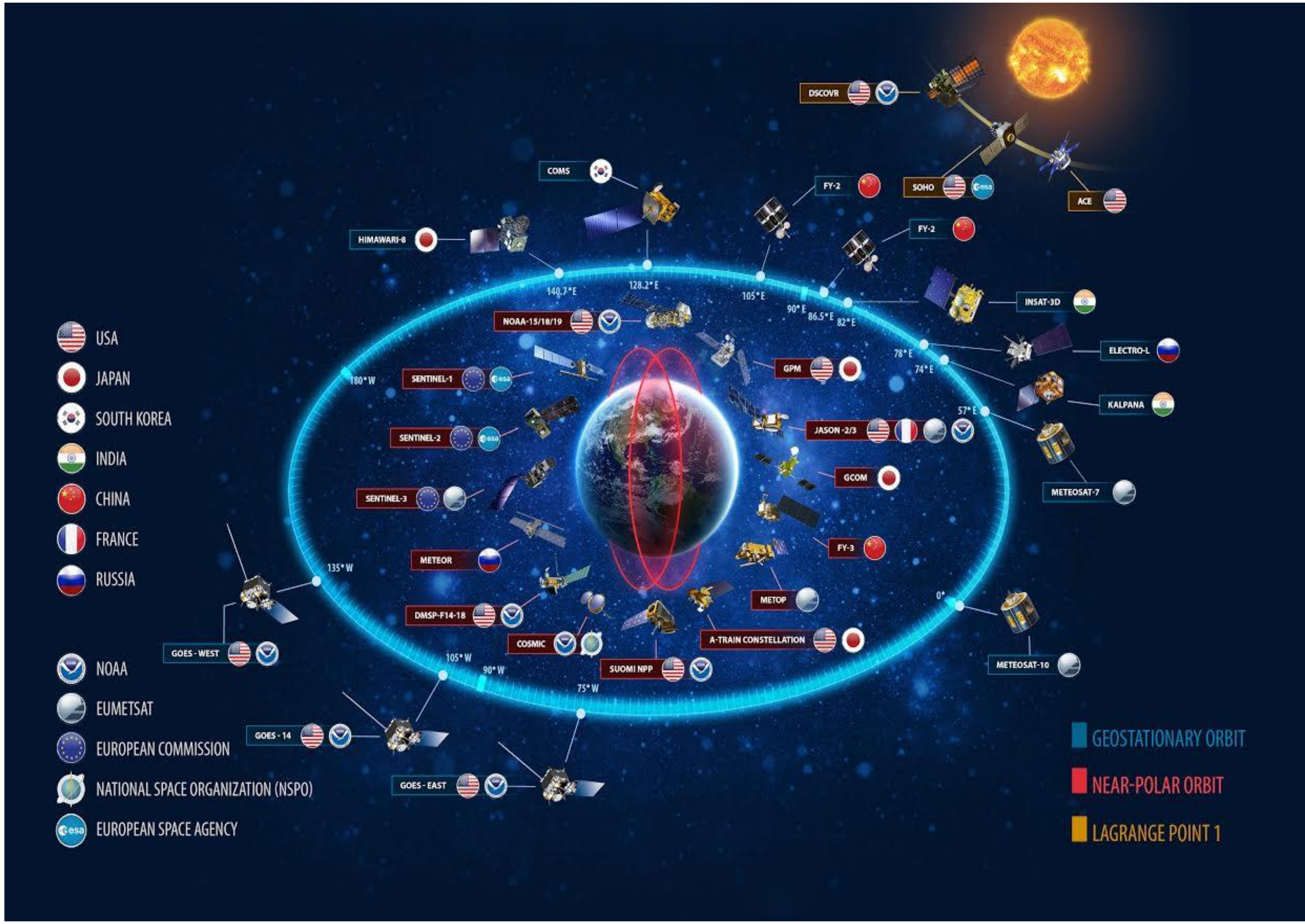
3 **JPSS-related Examples of AI Applications:**

- Remote Sensing Algorithms (next-Gen Algorithms)
- Radiative Transfer
- Data Fusion / Nowcasting & Data Assimilation
- Exploiting Satellite data for Supporting Prediction
- Morphing

4 **Conclusions**

Trends in Global Earth Observation Systems

- **GOS Trends:**
  - New Players in GOS (international, commercial, etc)
  - New Sensors (higher resolutions, etc)
  - New technologies (small sats, etc)
  - Emergence of New GOS (IoT, etc)
  - **Significant Increase in volume and diversity of data**

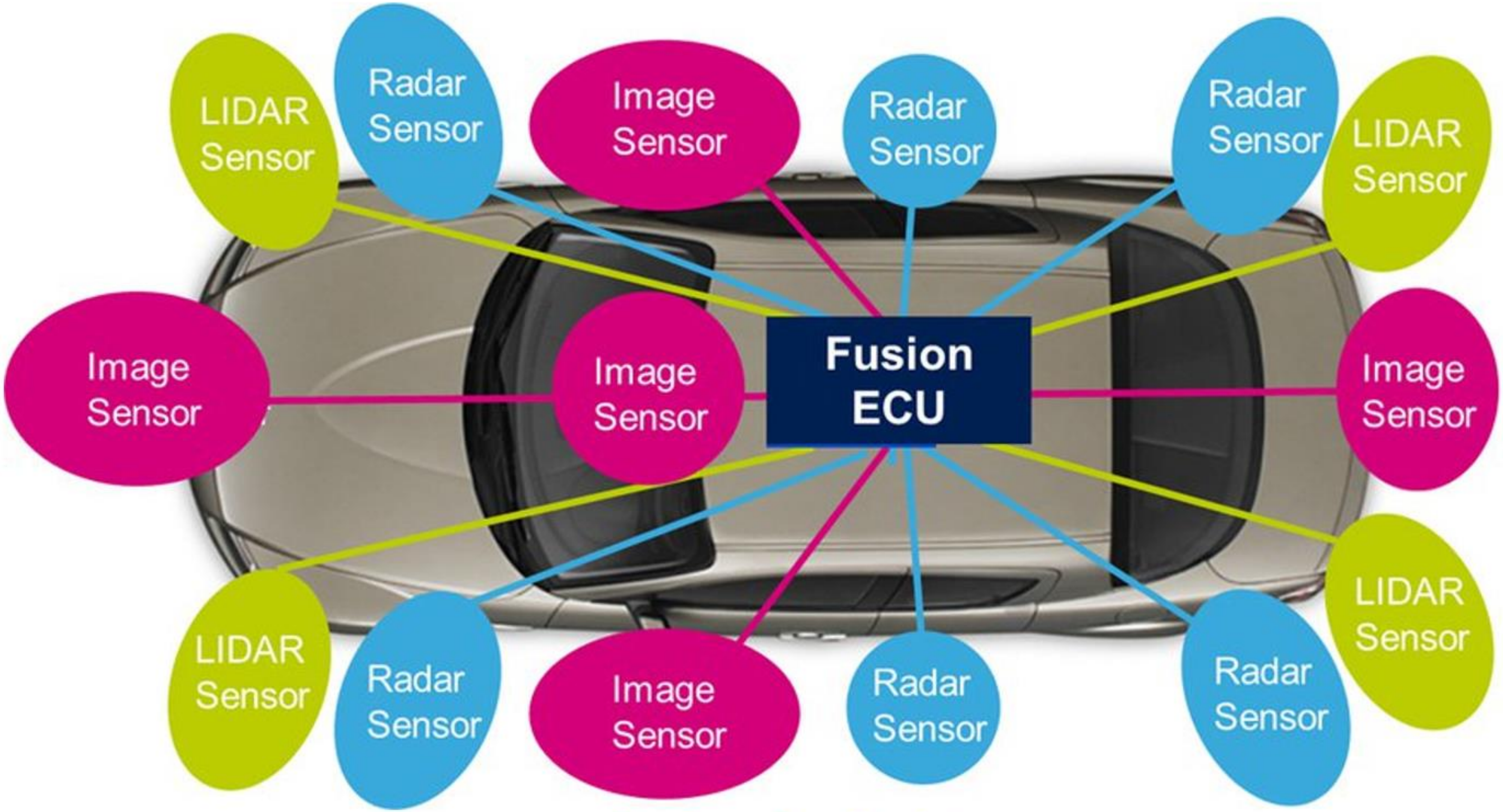


- **Parallel Trends**
  - Budget, HPC Constraints
  - Higher societal impact and expectations
  - Higher users expectations
  - Demand for Increase in quantity of data assimilated (5% currently assimilated)

Why Consider AI to address these Challenges?

Example of Autonomous Vehicles Using AI

(Similarities to Satellite Data Use in Earth Observation and Nowcasting/NWP)



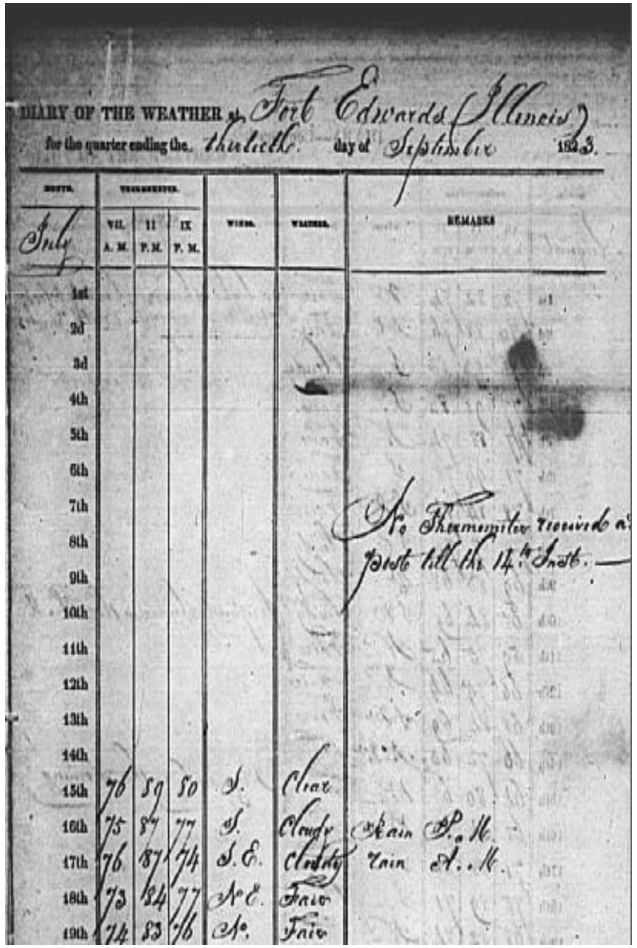
Reference: Sensors Magazine published ST article "[Three Sensor Types Drive Autonomous Vehicles]" by Gert Rudolph and Uwe Voelzke:

- AI … & NW… be…
  - …
  - …
  - …
  - … onal
  - …
- Ba… n (re… via…
- Th… po…

Evolution of Environmental Data Exploitation

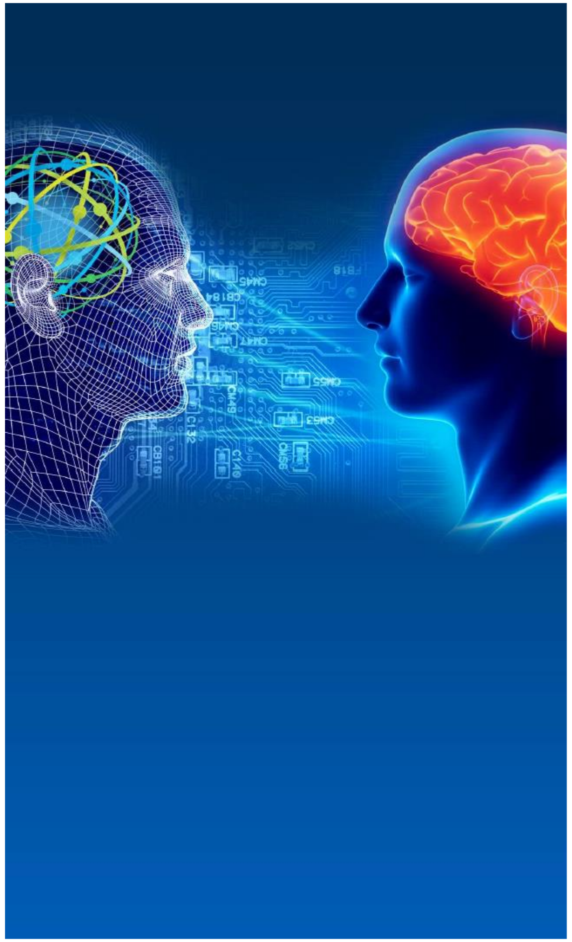
This evolution applies to all areas of computing.

It has led several major companies to adapt their business models to take advantage of AI



Tabulating Systems Era
(1800-1940s)
Manual Measurement and analysis

Programmable Intelligence Era
(1950-Now)
Transformational efficiency in Applying Human Intelligence



Cognitive Computing –AI Era
(2011- Foreseeable Future)
Enhancement/Augmentation of Human Intelligence

Credit: Materials adapted for Environmental Observations specifically, inspired from an IBM presentation by Dr John Kelly, senior vice president, cognitive solutions, to the NOAA Science Advisory Board (SAB) on November 2016

Agenda

1 **Why Artificial Intelligence (AI) ? Background and Motivations**

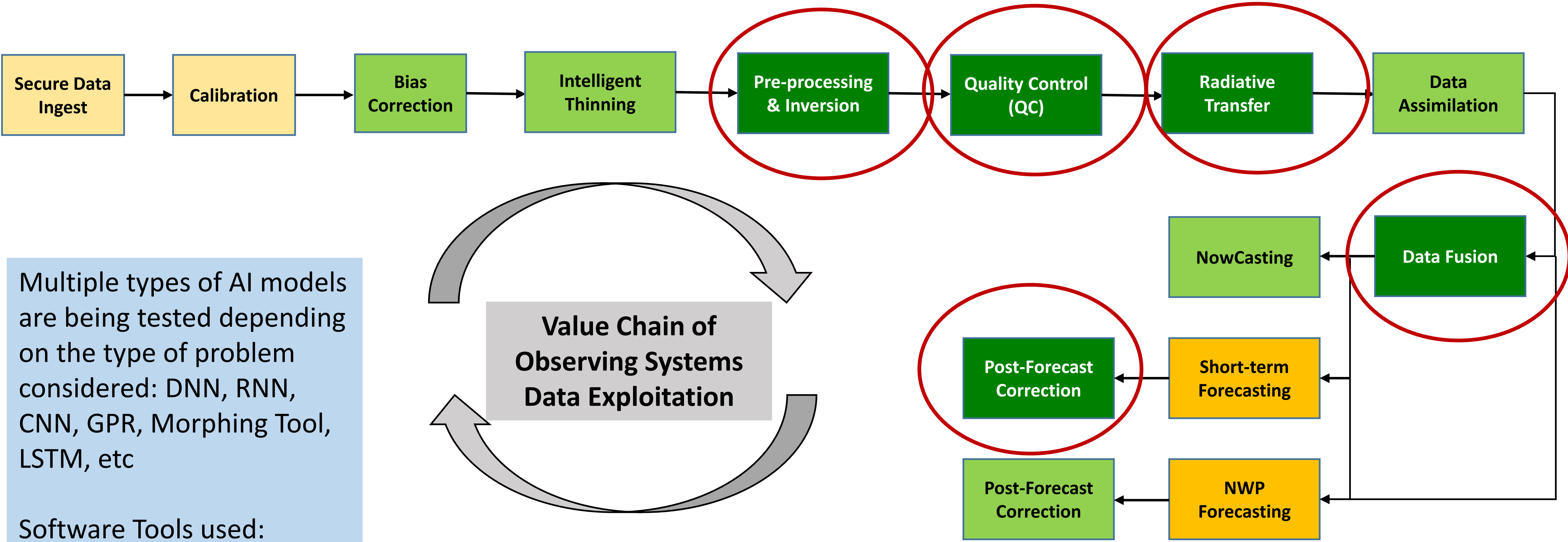
2 **What are we exploring using AI for?**

3 **JPSS-related Examples of AI Applications:**

- Remote Sensing Algorithms (next-Gen Algorithms)
- Radiative Transfer
- Data Fusion / Nowcasting & Data Assimilation
- Exploiting Satellite data for Supporting Prediction
- Morphing

4 **Conclusions**

Exploring AI for Remote Sensing, NWP & Nowcasting/Situational Awareness (SA). Status



Multiple types of AI models are being tested depending on the type of problem considered: DNN, RNN, CNN, GPR, Morphing Tool, LSTM, etc

Software Tools used: TensorFlow and KERAS

Not Tested. Unknown level of confidence	Not tested. Reasonable level of confidence	Tested or not: Moderate level of confidence	Tested. High level of confidence

Agenda

1 **Why Artificial Intelligence (AI) ? Background and Motivations**

2 **What are we exploring using AI for?**

3 **JPSS-related Examples of AI Applications:**

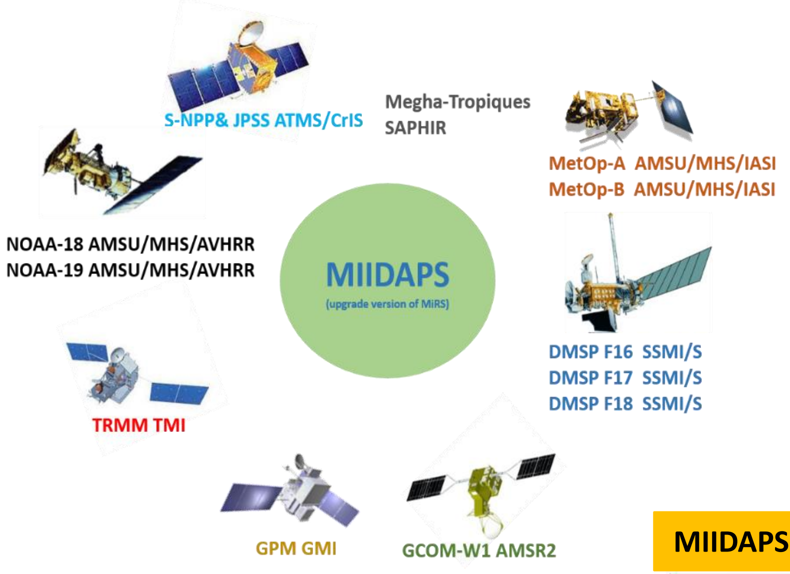
- Remote Sensing Algorithms (next-Gen Algorithms)
- Radiative Transfer
- Data Fusion / Nowcasting & Data Assimilation
- Exploiting Satellite data for Supporting Prediction
- Morphing

4 **Conclusions**

Pilot Project: MIIDAPS-AI:

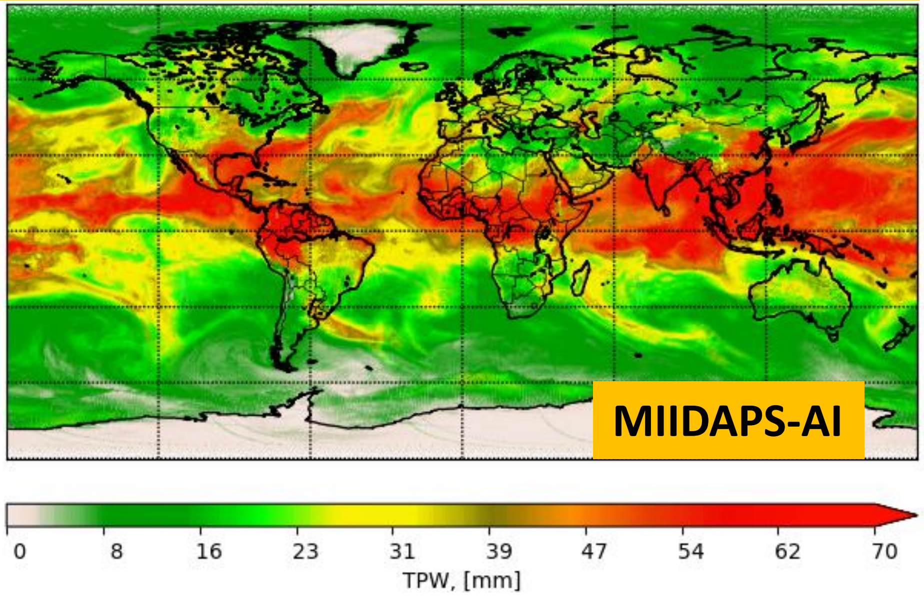
Multi-Instrument Inversion and Data Assimilation Preprocessing System

Use of Deep Neural Network (DNN) for Geophysical Retrieval and Quality Control Purposes

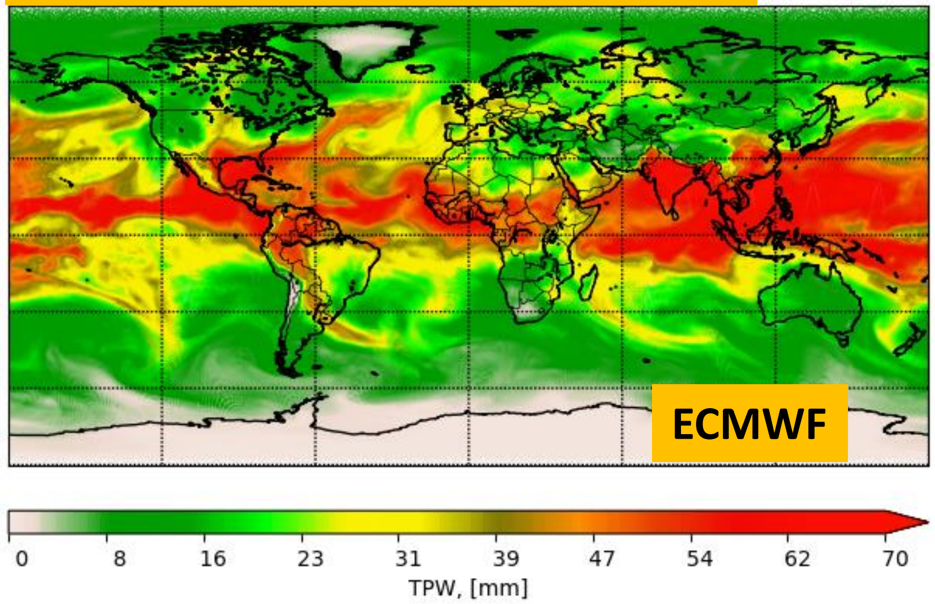


Google TensorFlow Tool used for MIIDAPS-AI

MIIDAPS-AI outputs (TPW) Using SNPP/ATMS Real Data



Reference source of TPW: ECMWF Analysis

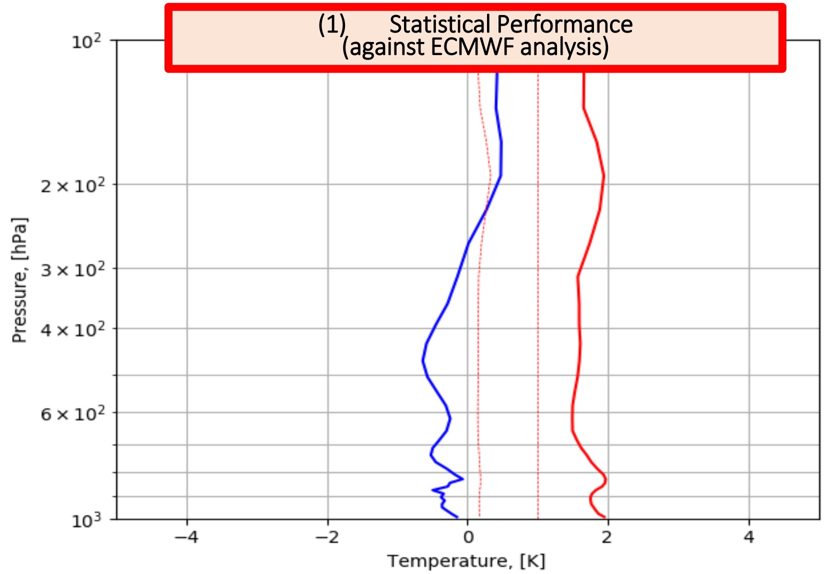


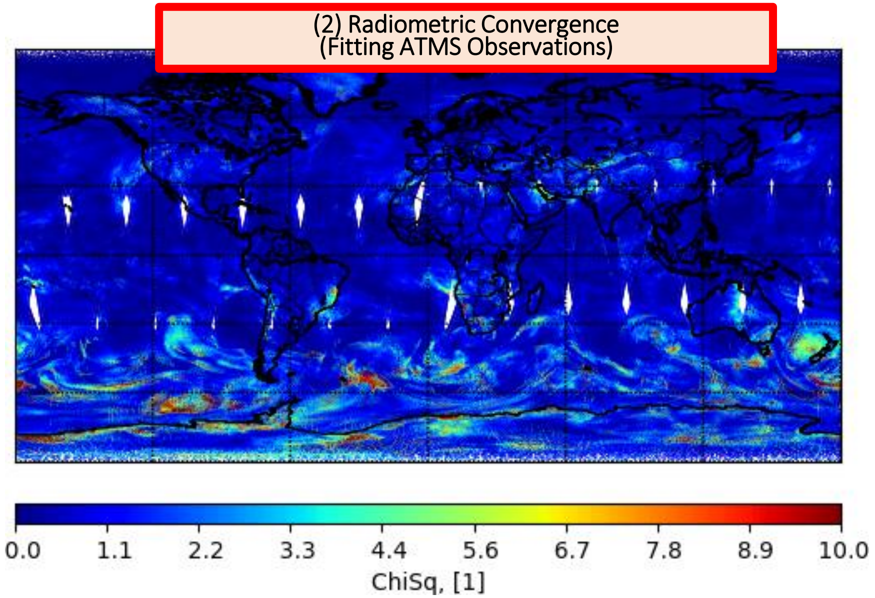
How to assess that AI-based output (Satellite Analysis) is valid?

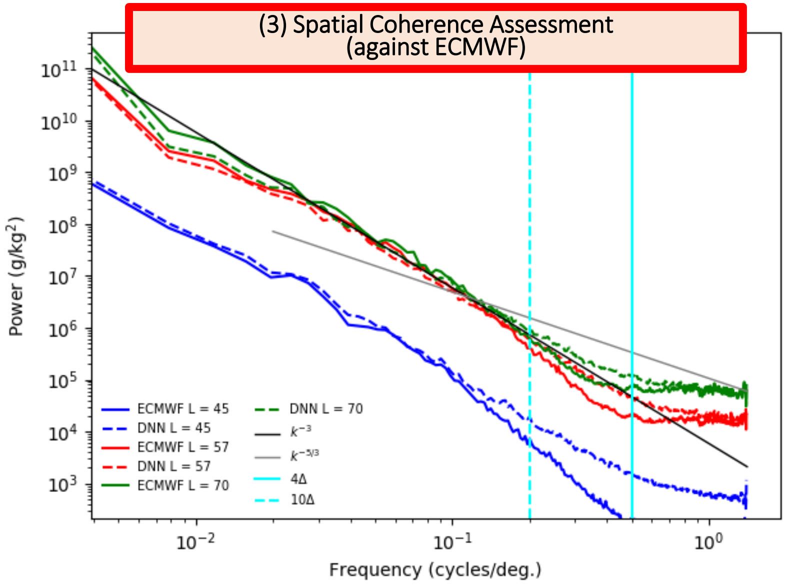
(1) Assessing quality by comparing against independent analyses
(2) Assessing Radiometric Fitting of Analysis
(3) Assessing analysis spatial coherence
(4) Assessing inter-parameters correlations

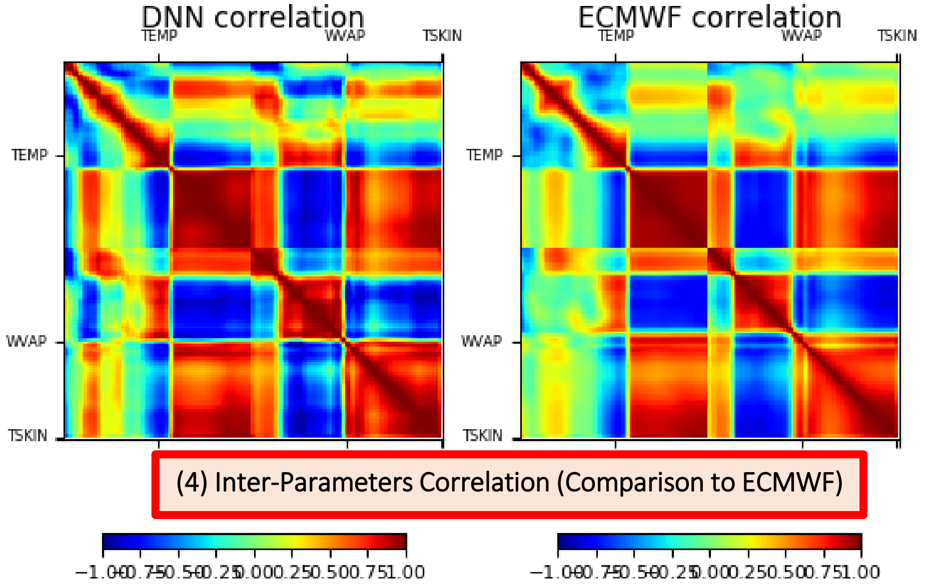
	MIIDAPS-AI	MIIDAPS
Processing Time for a full day data. A single sensor (ATMS). Excluding I/O	**~5 seconds**	**~ 2 hours**

How do we know if this AI-based satellite-analysis is scientifically valid?



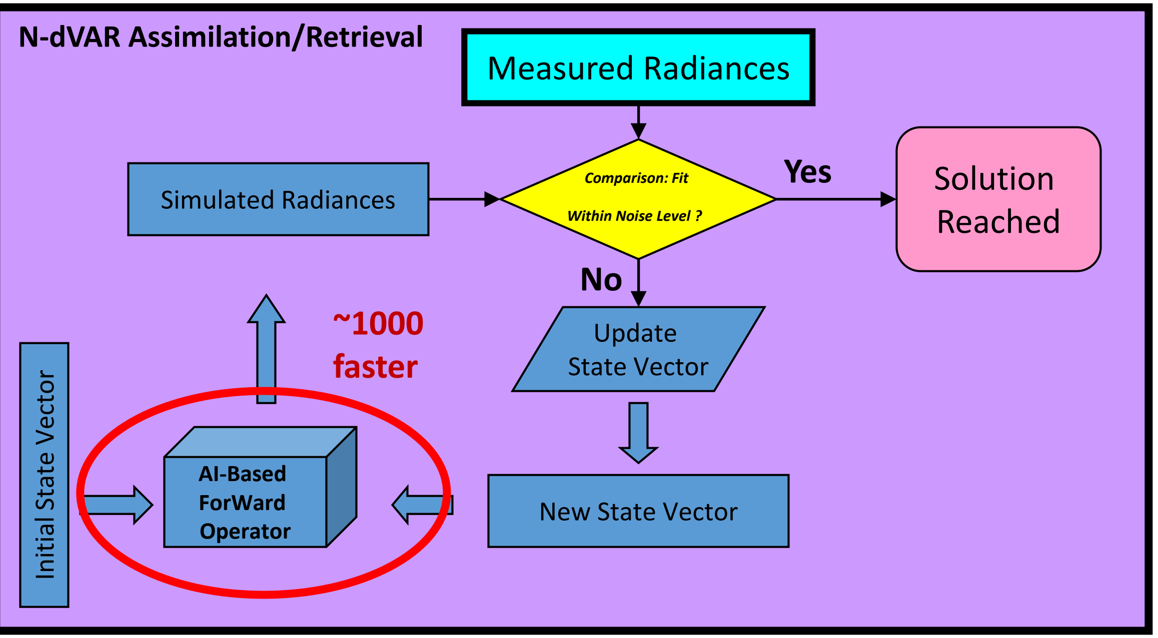


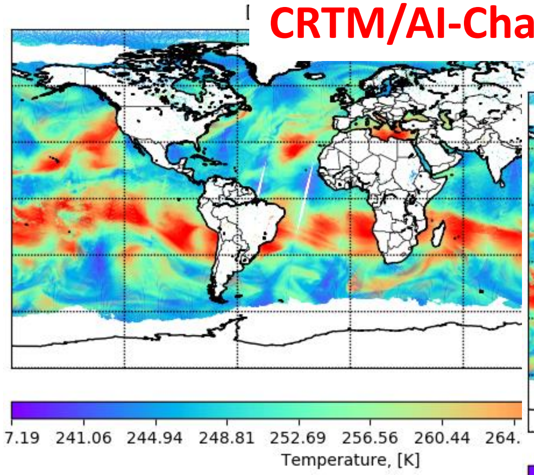


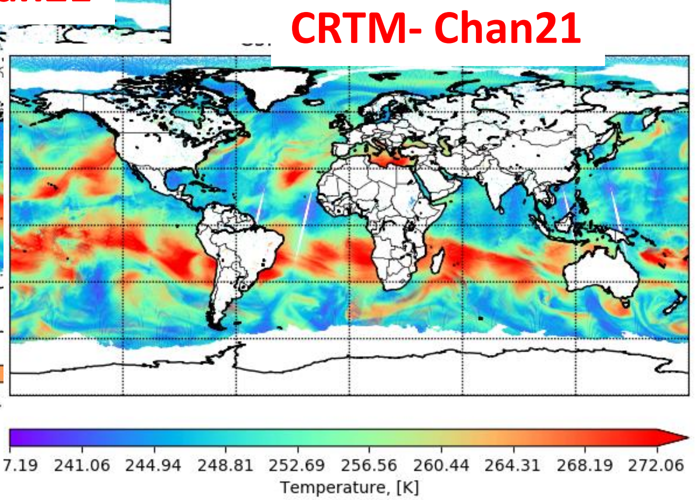


Can AI Be Used as Forward Operator?

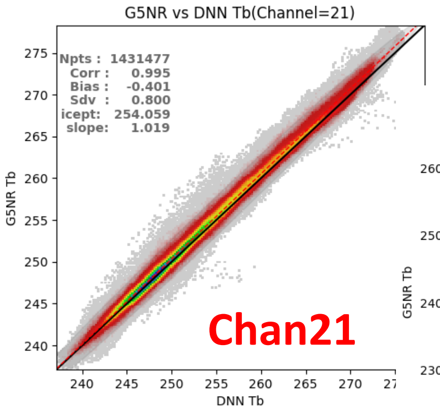
Use of Deep Neural Network (DNN) for Radiative Transfer Modeling Purposes

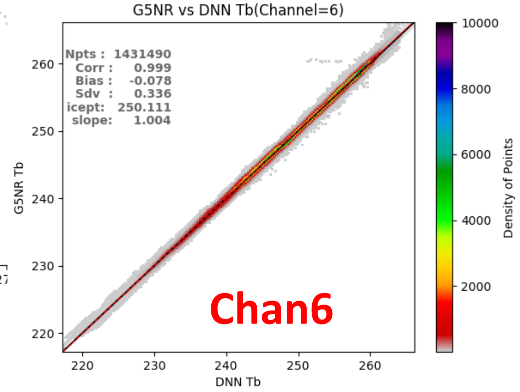






AI vs CRTM

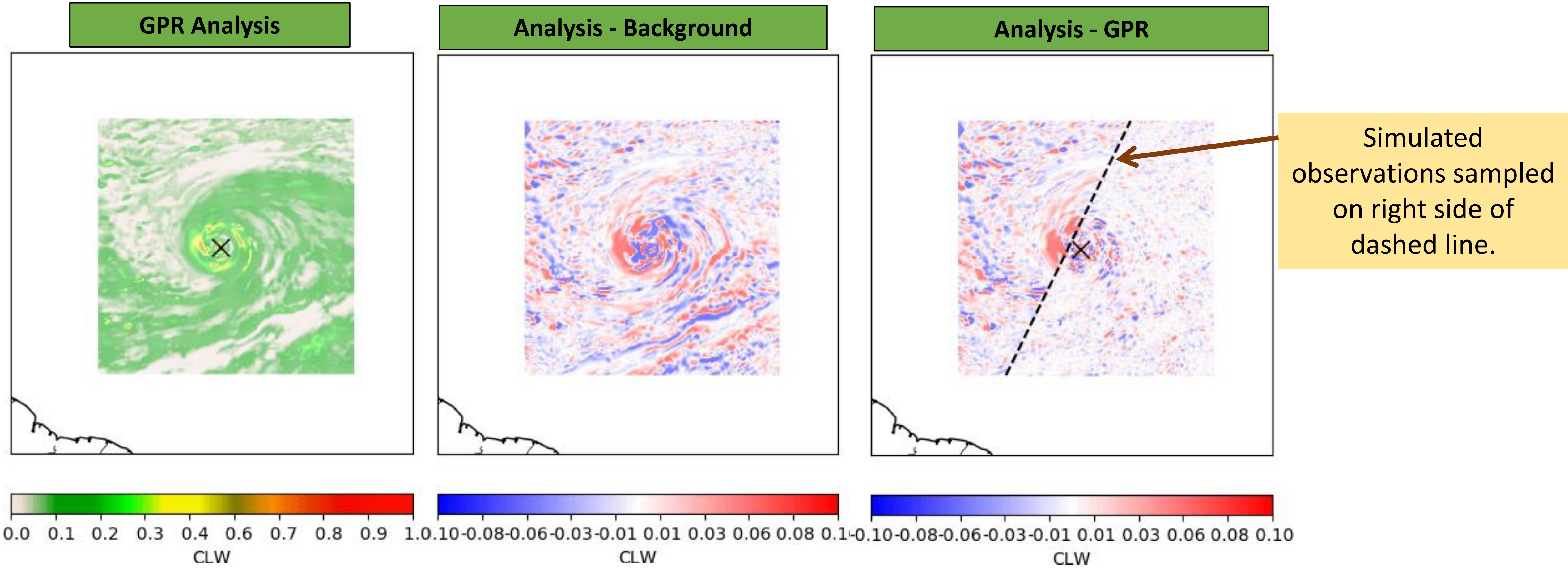




	CRTM-AI	CRTM
Processing Time for a full day data. A single sensor channel(ATMS). Excluding I/O	<1 second	~ 1.3 hours

Can AI Tools Be Used for Data Fusion & Data Assimilation?

Use of GPR (Gaussian Process Regression) AI Model for Data Fusion/Assimilation (Case of Hydrometeors/Clouds)

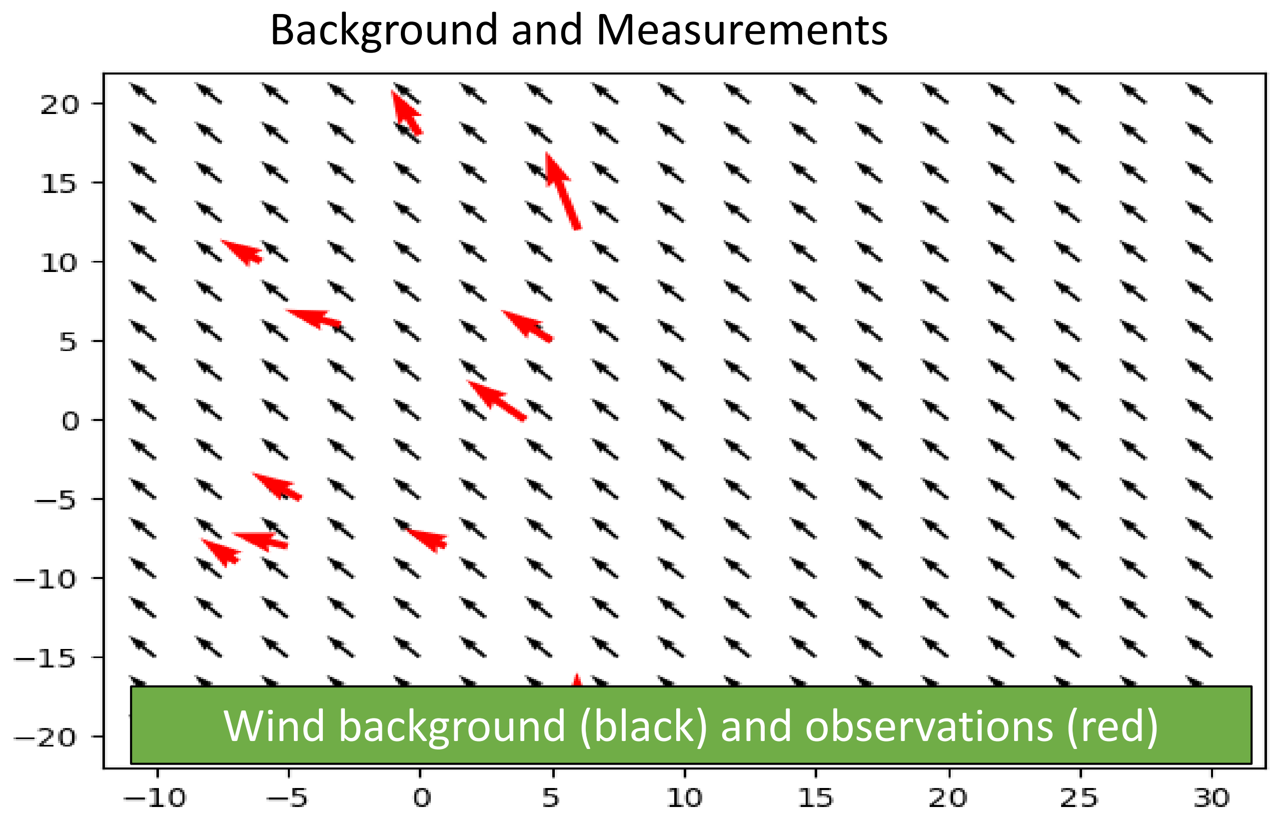


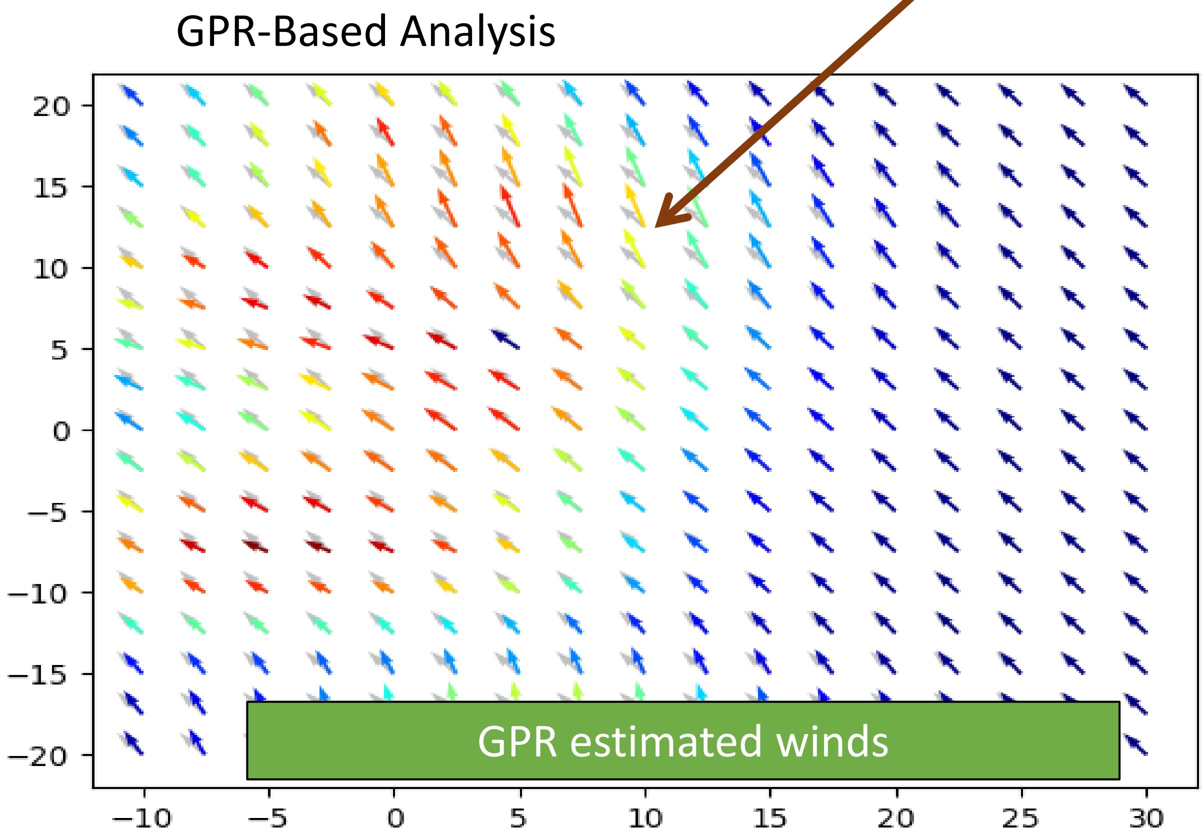
- Fused GPR analysis of total cloud water matches analysis where observations are dense and relaxes to the background field where they are sparse.
- Some distortion near the center of the hurricane is evident in the GPR fields and is due to the sampling.

Can AI Tools Be Used for Data Fusion & Data Assimilation?

Use of GPR (Gaussian Process Regression) AI Model for Data Fusion/Assimilation (Case of AMV)

Color confidence/error estimates





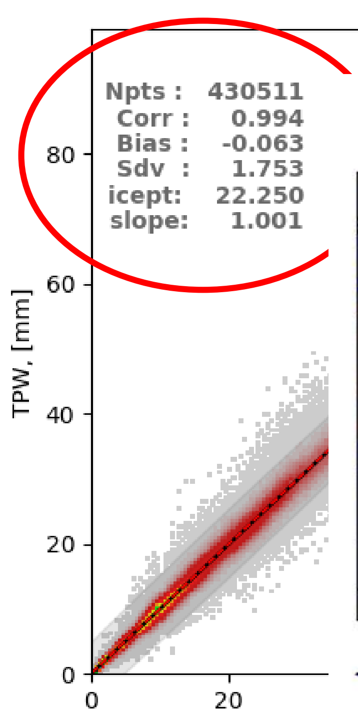
- Synthetic wind observations (red) are injected onto background (black) fields and GPR used to “fuse” the two.
- Color code corresponds GPR confidence – warmer colors reflect high confidence, while colder colors reflect low confidence estimates – and are consistent with observation locations.

Correcting TPW Forecasting with AI?

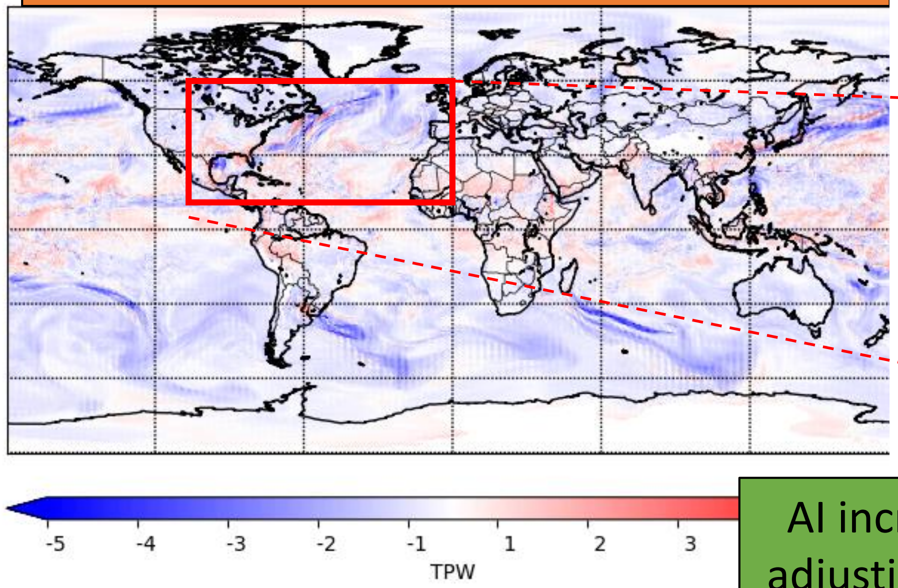
ECMWF vs AI-corrected 6h fcst valid @ECMWF analysis time

ECMWF vs 6 hr frcst valid @ECMWF analysis time.

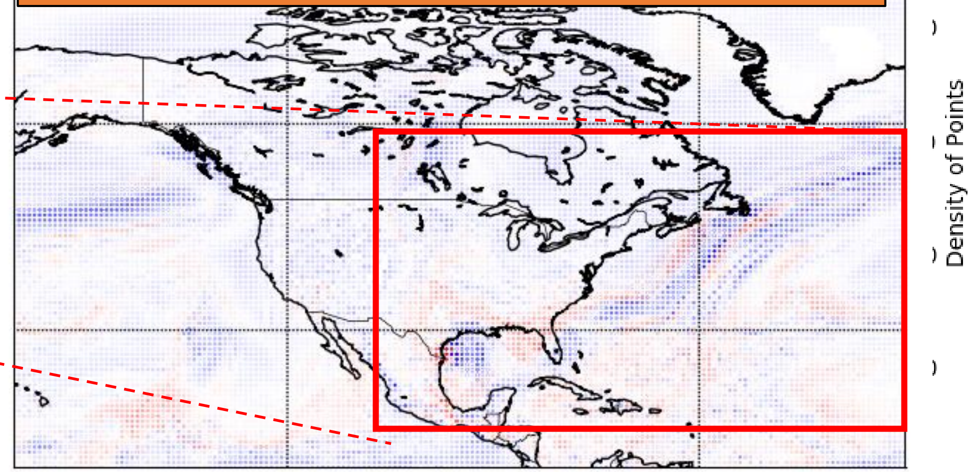
One day - all 4 cycles concatenated together.



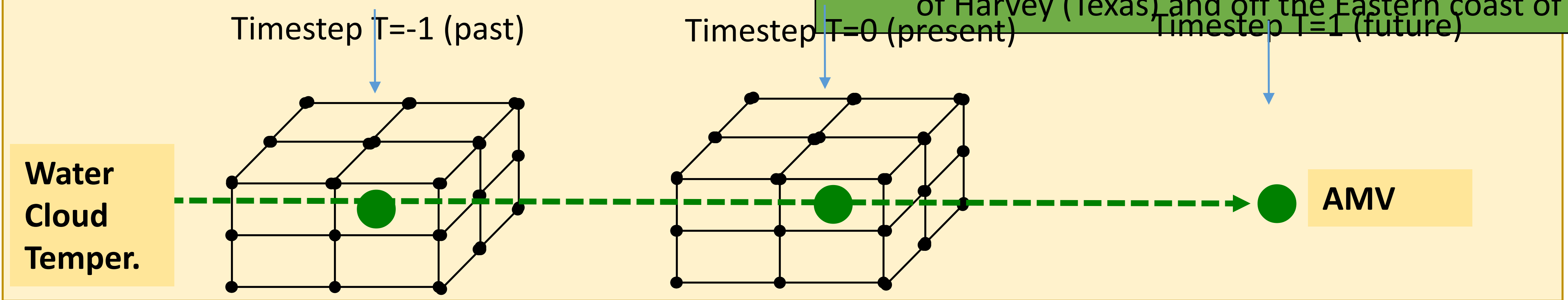
AI Increment



AI Increment – N. America

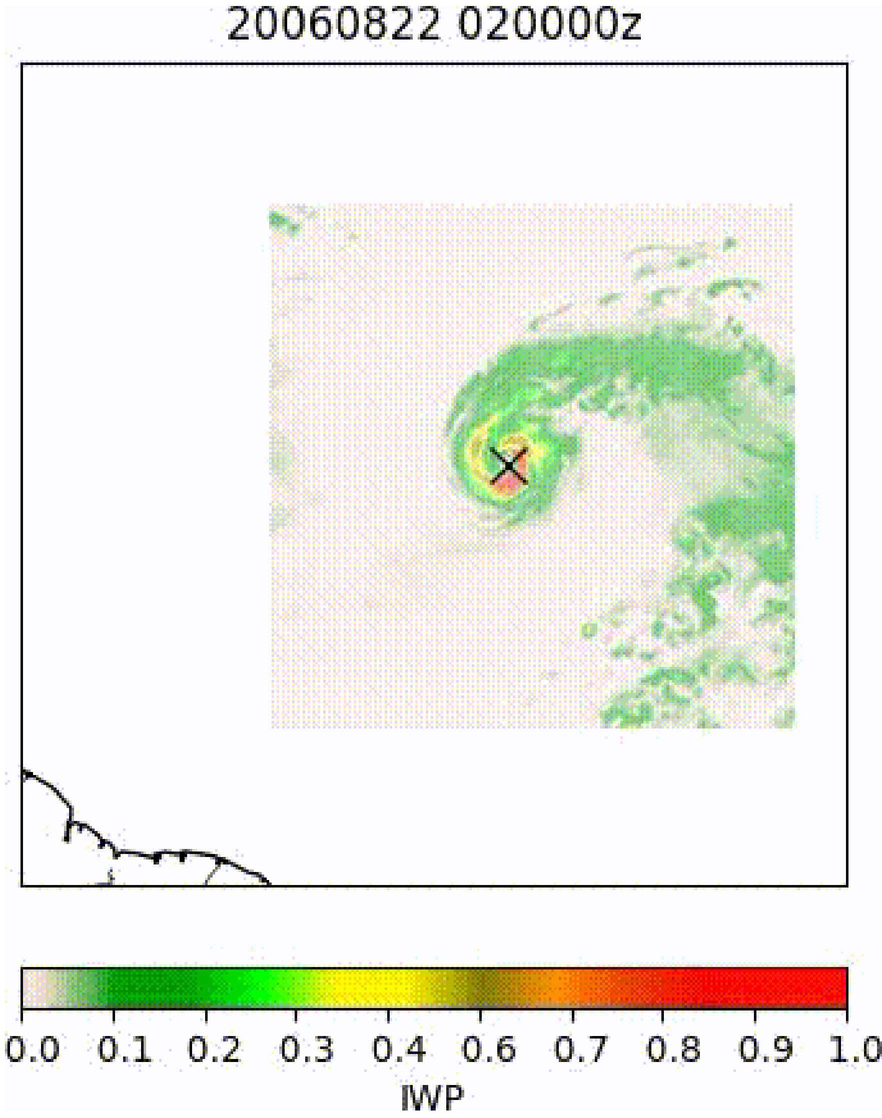


AI increment shows some dipoles indicating that the correction is adjusting the position of some features – Most notably the position of Harvey (Texas) and off the Eastern coast of N.America



Use of “morphing” AI Tool (“dogs” video morphing software) for Cloud/Precip morphing

Note the potential for morphing both the shape and color (i.e. equivalent of track and intensity)



- Used total integrated cloud ice from NASA GEOS-5 Nature Run (G5NR) “AL01” tropical cyclone at two time-steps (0200z and 0600z).
- Morphing software applied as a black box with some hand tuning of transformations between the two images.
    - Image at right sampled using 20 transformations between images

<u>Credit: Example output and software from:</u>
http://andrew.gibiansky.com/blog/image-processing/image-morphing/

Conclusions

- ❖Big Data Challenge already here

- ❖AI/ML approach is a natural evolution of how to exploit data

(think evolution of Programming languages: Assembler, Basic, Pascal, F66, C++, F00, Java, Python, …to TensorFlow, Keras, ….)

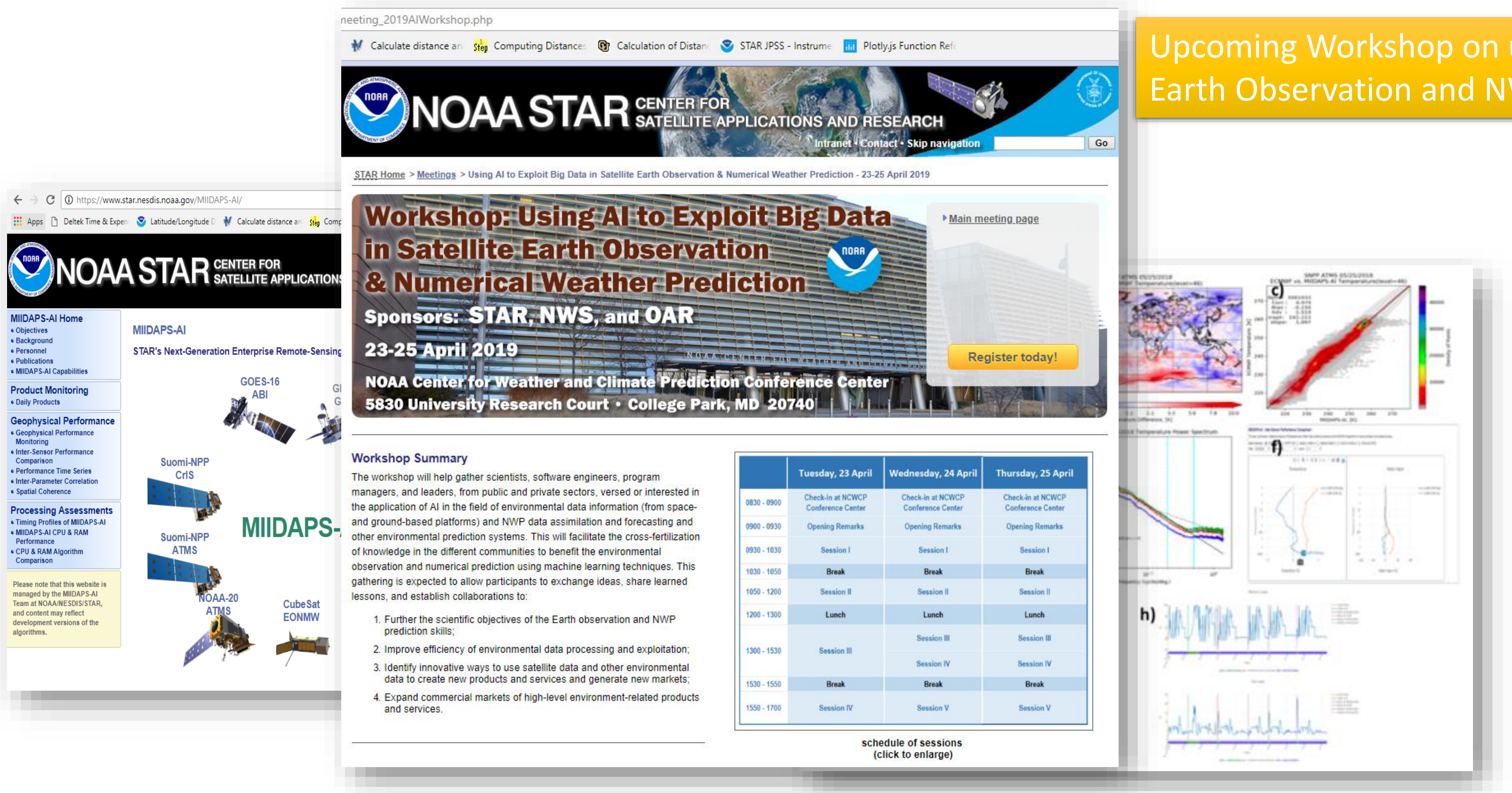
- ❖Goal of this study is not to show AI/ML approach can do better, but that it can provide at least similar quality, much faster, therefore it can process more data.

- ❖Significant potential to leverage AI tools and models developed in other fields, to our field: for remote sensing, radiative transfer, data fusion, morphing, etc.

- ❖AI has the potential to be a transformational new approach in our exploitation of Big Environmental data

For More Information....

Upcoming Workshop on use of AI in Earth Observation and NWP



Toward Improved Climate Data Records with Stable SNPP/JPSS Observations

Cheng-Zhi Zou[1], Mitch Goldberg[2], and Lihang Zhou[1]

[1]NOAA/NESDIS/Center for Satellite Applications and Research

[2]NOAA/NESDIS/Joint Polar Satellite system

STAR JPSS 2018 Annual Conference, College Park, MD, August 27-30, 2018

Requirements on Climate Data Records (CDRs)

- **CDR Definition: Time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change (US national Research Council)**

- **Essential Climate Variables (ECVs) as identified by the Global Climate Observing System (GCOS) (Red colors are currently available at NESDIS/NCEI: https://www.ncdc.noaa.gov/cdr)**

- **Atmosphere:** Temperature, Wind speed and direction, Water vapor, precipitation, Cloud properties, Earth radiation budget, Carbon dioxide, Methane, and other long-lived greenhouse gases, Ozone and Aerosol;

- **Ocean:** Sea-surface temperature, Ocean heat content, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton, Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers;

- **Terrestrial:** River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture, vegetation index;

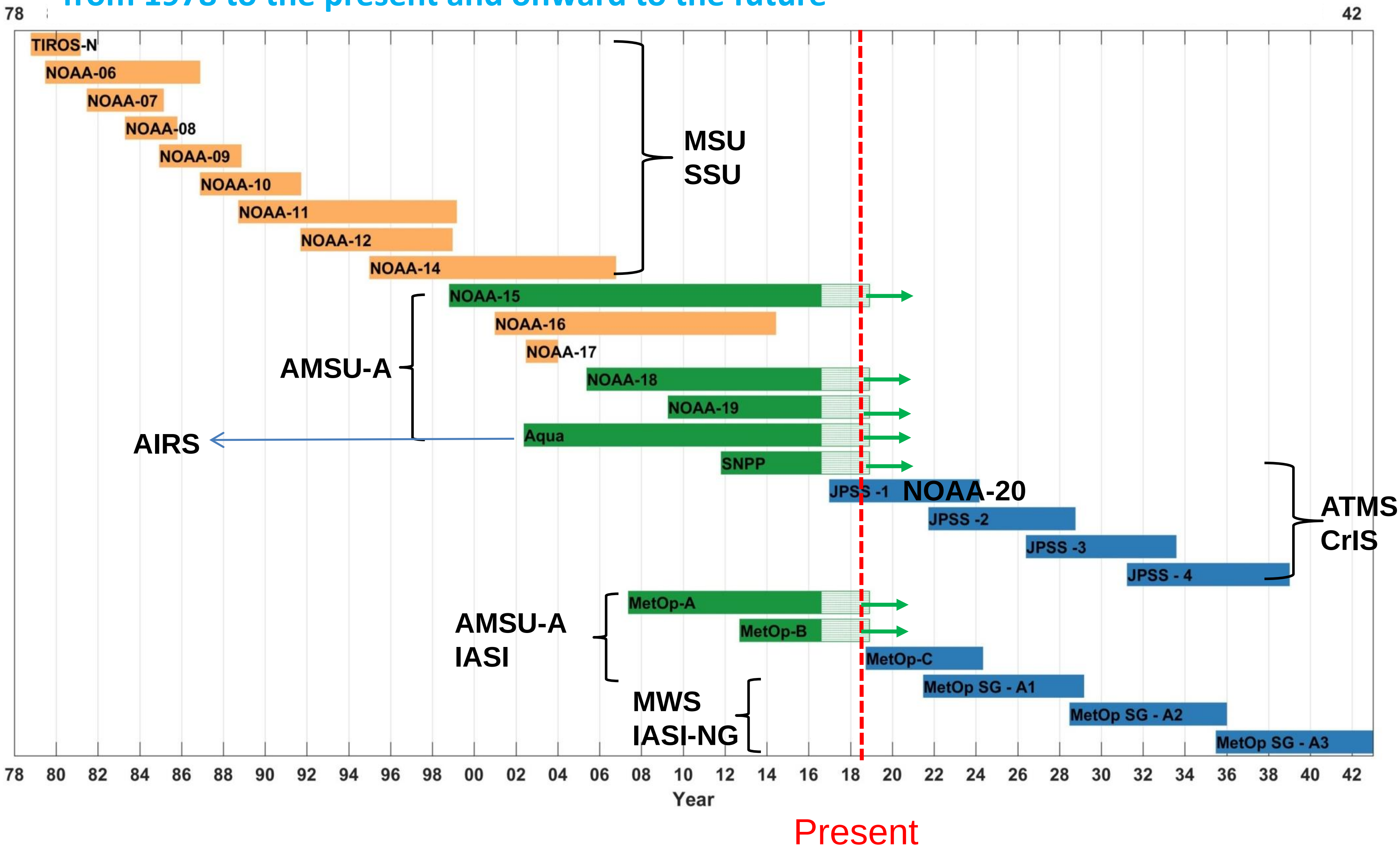
- **Fundamental:** sensor data; calibrated radiances and brightness temperatures that have been improved and quality controlled over time: MSU/AMSU-A deep layer temperatures, MSU/AMSU-A brightness temperatures, AVHRR radiances and reflectance, AVHRR polar pathfinder, AMSU-B/MHS brightness temperatures, HIRS ch12 brightness temperatures, SSMI(S) brightness temperatures.

Issues Involved in CDR Development

- **CDRs are used to**
  - Investigate long-term climate trends and variability
  - Monitor climate change
  - Validate and verify climate model simulations of climate change

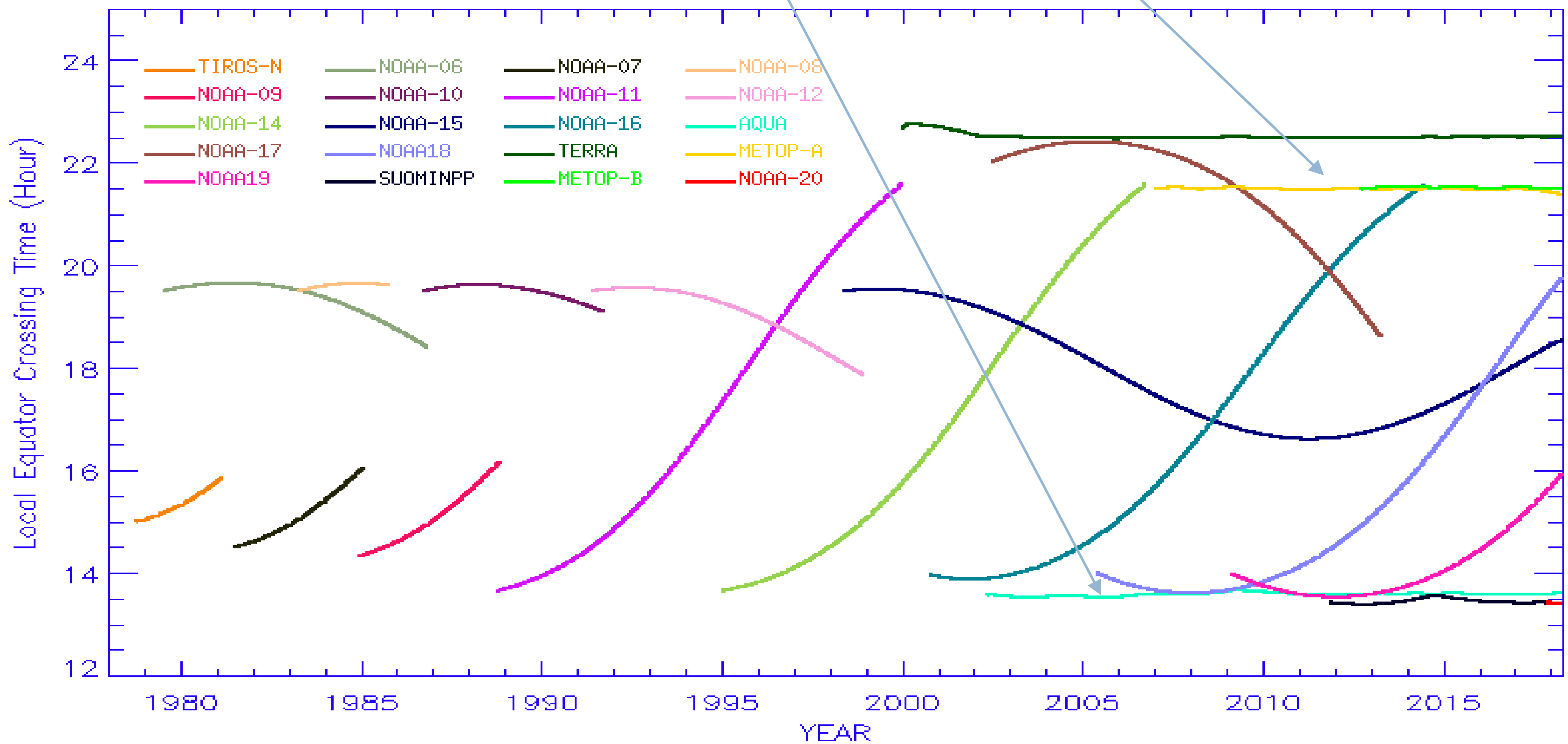
- **CDR development addresses**
  - time series consistency
  - stability of time series
  - inter-sensor calibration/recalibration
  - inter-satellite bias removal
  - continuity in instrument design and channel frequency
  - gap filling between satellites
  - ….

Example of Atmospheric Temperature CDR Development: Involving Microwave/Infrared Sounders on NOAA/NASA/MetOp Satellite Series from 1978 to the present and onward to the future



Challenges in Developing Climate Data Records —Satellite Orbital Drifts

- MetOp-A, -B, and future –C have close to the same 9:30am stable morning orbits
- Aqua, SNPP, NOAA-20, and future JPSS have close to the same 13:30pm stable afternoon orbits
- Terra has a stable 10:30am morning orbit
- All other satellite's orbits drifted with time



Satellite local equator crossing time (LECT) for ascending orbits

(Plot is provided by STAR calibration team)

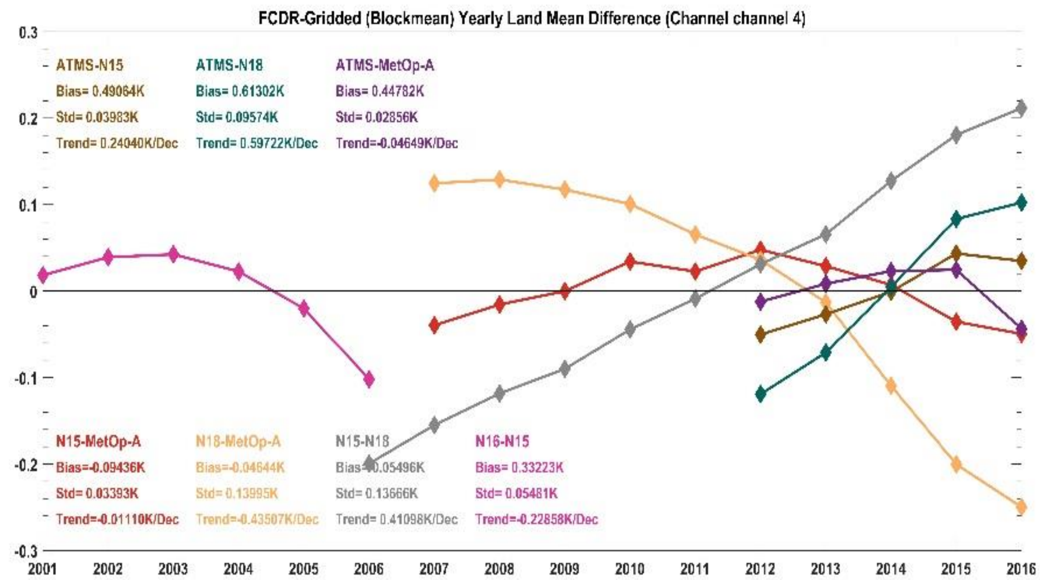
Challenges in Developing Climate Data Records —Satellite Orbital Drifts Induce Bias Drifts

- **Satellite Orbital Drifts Cause**

➢ Changes with time in diurnal Sampling

➢ Changes in biases with time

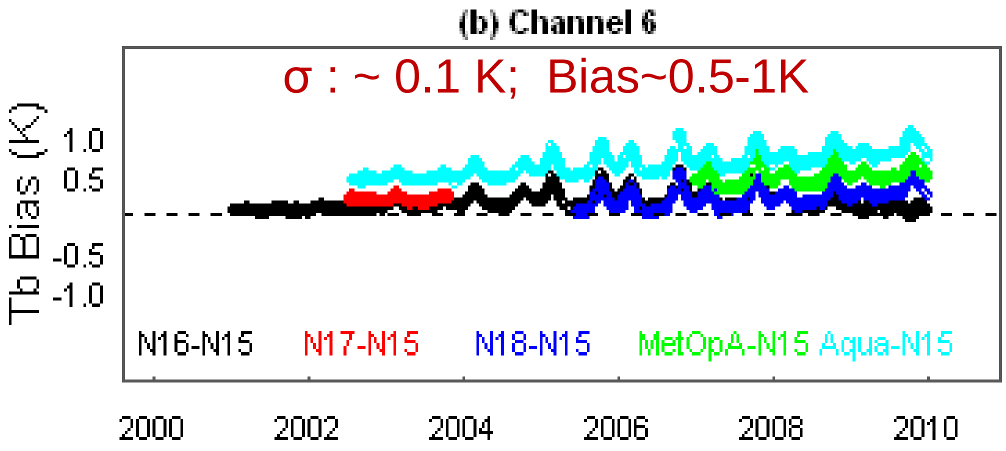
➢ Need complicated bias correction algorithms to remove these time-varying biases



Inter-satellite difference time series for AMSU-A satellite pairs.

Challenges in Developing Climate Data Records —Calibration Drifts

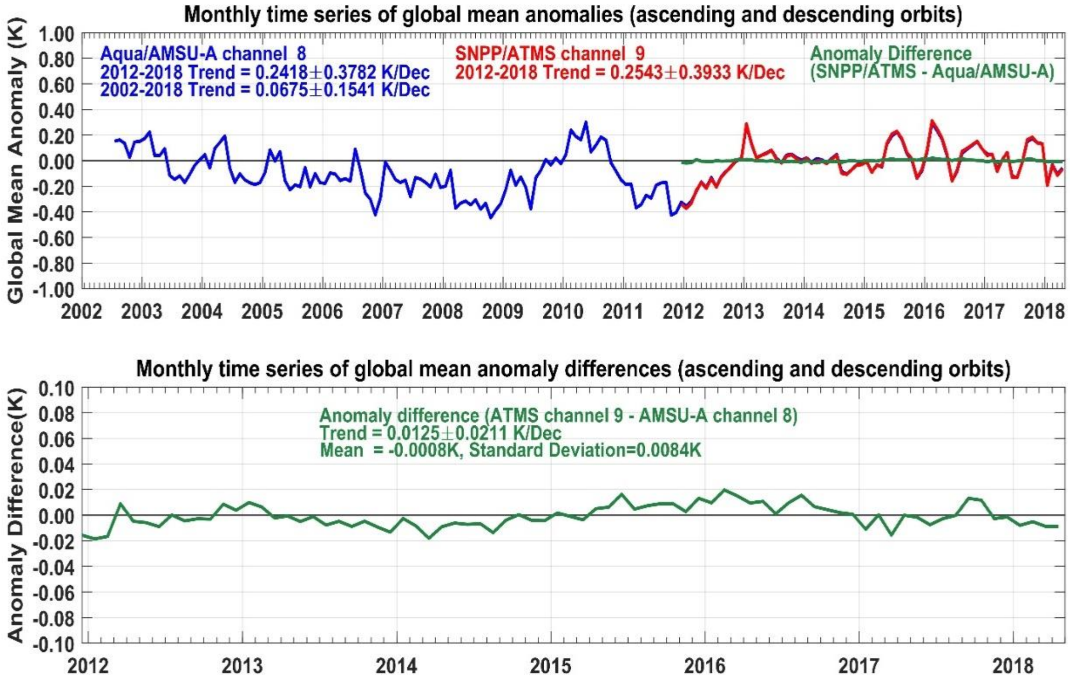
- Inaccurate instrument calibration could result in time-varying biases between satellite pairs
- Need complicated inter-calibration/recalibration algorithms to remove these time-varying biases



Inter-satellite difference time series for AMSU-A satellite pairs showing calibration drifting errors (plot from Zou and Wang 2011)

Stable SNPP and JPSS Orbits Make A Difference

- Diurnal sampling difference is absent – diurnal sampling biases are naturally removed by satellites with stable orbits of the same overpass time
- Time series from different satellites match with each other nearly perfectly without applying any diurnal drift corrections
- Calibration drifts could be estimated quite accurately
- Small trend differences suggest absolute stability on either instruments
- Radiometric stability within 0.04K/Decade for SNPP/ATMS and Aqua/AMSU-A for all analyzed channels



Monthly global mean anomaly time series of brightness temperatures for AMSU-A channel 8 onboard Aqua (blue, top panel) versus ATMS channel 9 onboard SNPP (red, top panel) and their difference time series (green, top and lower panels). The AMSU-A and ATMS data are respectively from June 2002 and December 2011 to April 2018. The AMSU-A anomaly time series are overlaid by ATMS during their overlapping period with their differences shown as nearly a constant zero line in the same temperature scale. Amplified scale of temperature is used in the bottom panel to show detailed features in the anomaly difference time series. Both ATMS and AMSU-A data are from limb-adjusted views and averaged over ascending and descending orbits (plot from Zou et al. 2018).

Perspective

- **Radiometric stability assessment for other SNPP/Aqua instruments:**

- Aqua instruments: AMSR-E, AMSU-A, HSB, AIRS, MODIS, CERES
- SNPP/JPSS instruments: ATMS, CrIS, VIIRS, OMPS, CERES

Similar comparisons could be made for

CrIS—AIRS
ATMS—AMSU-A (Done for 8 out of 15 channels)
ATMS—HSB
VIIRS—MODIS
CERES—CERES

Perspective

- **Radiometric stability assessment for MetOp instruments:**

- MetOp instruments: AMSU-A, ASCAT, AVHRR, GOME-2, GRAS, HIRS, IASI, MHS,SARP, SARR, SEM
- Comparisons for the same instruments could be made for MetOp-A (launched on 10/19/2006) and Metop-B (launched on 09/17/2012), which has 6 years of overlap now

Perspective

- **Improving CDRs:**

- Stable observations from SNPP and Aqua and MetOp could be used as references

- SNPP/JPSS satellites could be merged together without conducting diurnal drift correction

- Adjusting satellites with orbital drifts to the references using their overlaps. Developing CDRs from the stable satellites backward to the earlier satellites

- Improved diurnal correction algorithms—need reference for best effect

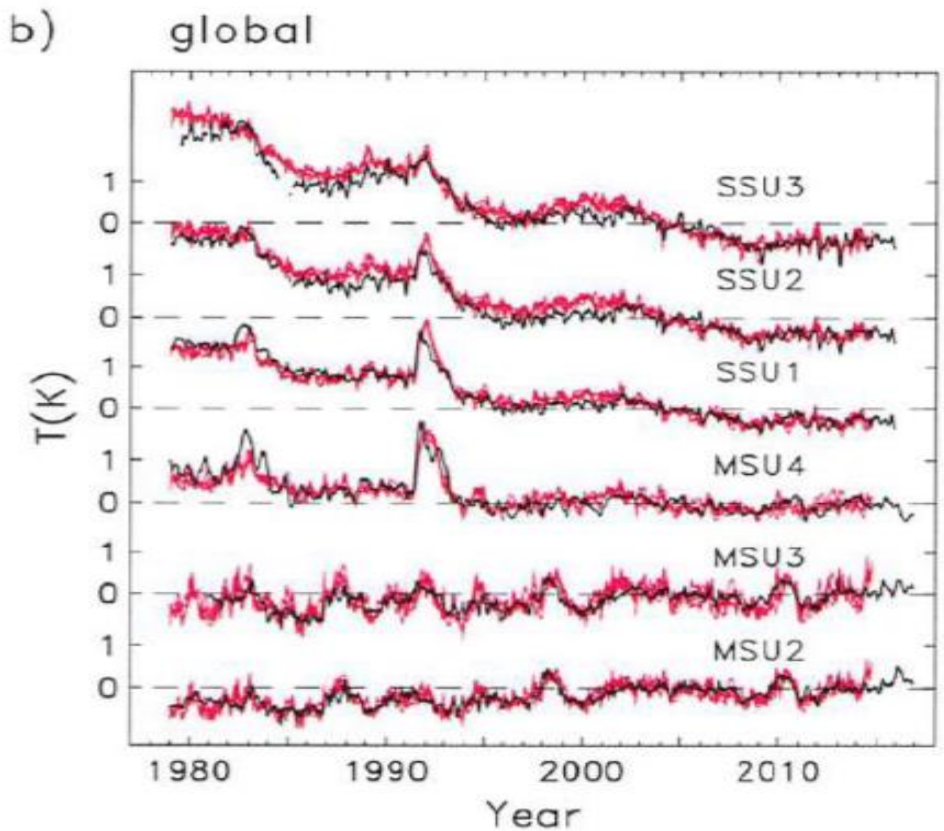
- Improved accuracy in trend determination from CDRs are expected

An example for CDRs to verify climate model simulation of the past climate changes

Black Curve: Satellite observations of layer mean temperatures

Red Curve: NCAR WACCM Simulations (SST control runs)

Upper Atmosphere (cooling)



Lower atmosphere (warming)

Plot from Randel et al. (2017)

Conclusion and Path Forward

- The stable SNPP and Aqua orbits with the same overpassing time naturally remove diurnal sampling differences, allowing accurate assessment of instrument calibration drifts
- Preliminary evaluation of SNPP and Aqua microwave sounders suggest they achieve an absolute stability within 0.04K/Decade. Such an accuracy meets requirements for instruments to reliably detect climate trends
- Such evaluations could be extended to many other instruments on SNPP/Aqua/MetOp satellites to determine their radiometric stability
- Stability information is critical for use of these instruments as references in developing climate data records for a variety of essential climate variables
- Improved CDRs are expected in terms of accurate trend determination with the help of stable SNPP/JPSS satellite observations