NUCAPS and ABI - Stronger together using AI

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JPSS/GOES-R Proving Ground / Risk Reduction Summit

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Outline

- Motivation
- NUCAPS questions to be addressed
- Methodologies and technical approaches
- Preliminary results and case demonstration
- Summary and future Work

1. Motivation

NUCAPS sounding(left) and observed RAOB(right), HWT report, 2017

NUCAPS (left) and Experimental NUCAPS(right), HWT report, 2017

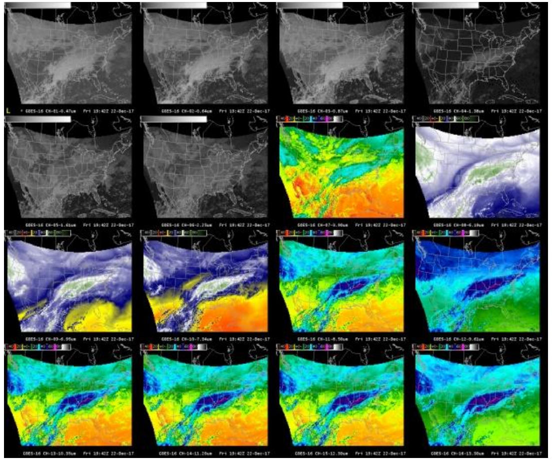
- **The NOAA Unique Combined Atmospheric Processing System(NUCAPS) is an algorithm designed for deriving environmental data records (EDRs) from the JPSS LEO satellites, providing retrieved estimates of atmospheric vertical temperature and moisture profiles.**

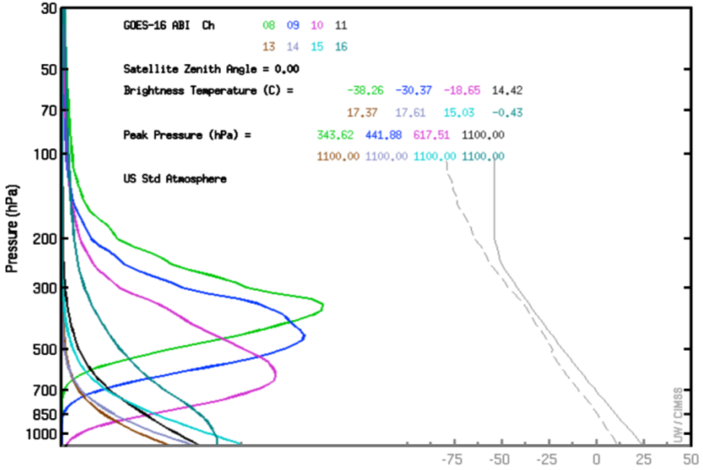
- **NUCAPS has shown reduced accuracy in the lower atmosphere near the surface, like many satellite based sounding retrievals. This has limited the applications of NUCAPS soundings in severe storm forecasting and nowcasting.**

- **The team of NUCAPS developed a automated correction scheme based on the assumption of well-mixed BL. But has limitations when BL is not well-mixed and for levels beyond BL.**

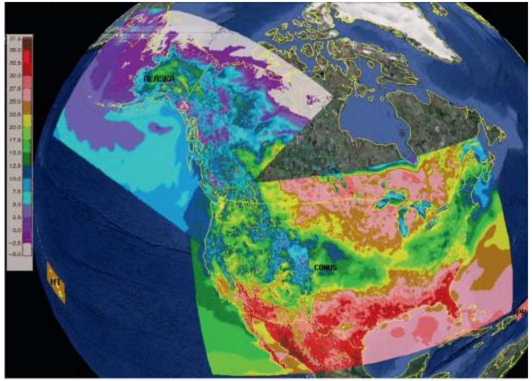
ABI

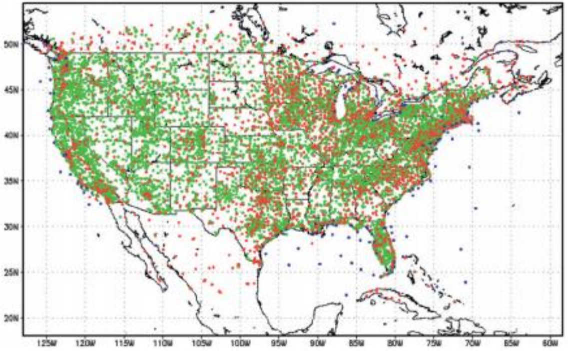
COMPARISON GOES-R SERIES ABI VS CURRENT GOES		
ATTRIBUTE :	ABI	CURRENT GOES IMAGER
Spectral Coverage	16 bands	5 bands
Spatial Resolution		
0.64 µm Visible	0.5 km	~ 1 km
Other visible/near-IR	1.0 km	n/a
Bands (>2 µm)	2 km	~ 4 km
Spatial Coverage		
Full Disk	4 per hour	Scheduled (3 hrly)
CONUS	12 per hour	~4 per hour
Mesoscale	30 or 60 sec	n/a
Visible (reflective bands)		
On-orbit calibration	Yes	No





RTMA





A representative map of the temperature stations used at a given analysis time. The example is from the 1500 UTC 20 Nov 2009 analysis. Green dots represent Mesonets, red dots show land synoptic and METAR stations, and blue dots show marine stations. The total number of stations is 14 299.

ABI :

- **Fine spatial resolution(2km for IR) and fast scan rate (5 minutes for CONUS)**
- **Bands (11/13/14/15/16) sensitive to lower atmosphere, together with three H_2O bands (8/9/10), containing important information for profiles in the lower atmosphere.**

RTMA :

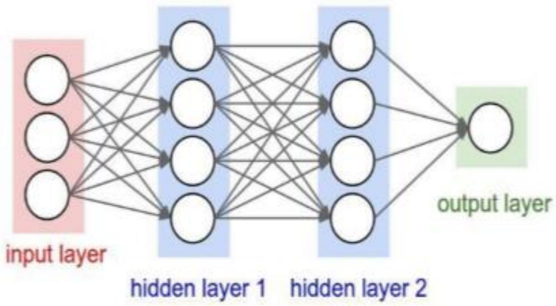
- **Hourly, high spatial resolution (2.5 km) of gridded fields of 2-m temperature/specific humidity/dewpoint, 10-m U/V components, and surface pressure.**
- **Conventional and satellite-derived observations assimilated.**

2. NUCAPS questions to be addressed:

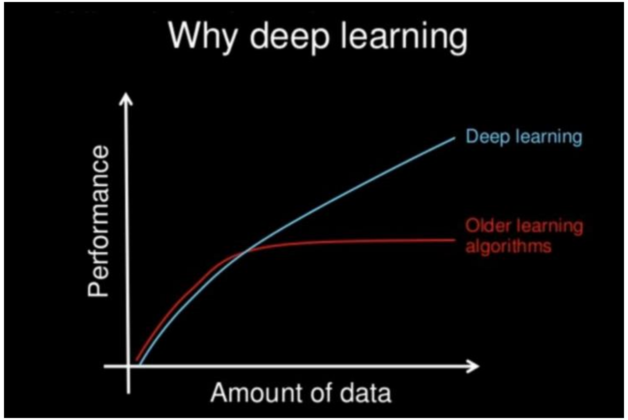
(1) How to improve the NUCAPS lower level (LL) soundings through effective data fusion of multiple data sources, especially the high temporal and spatial resolution ABI?

(2) What is the relative impact of high resolution ABI and surface RTMA on improving the NUCAPS LL soundings, respectively?

Deep Neuron Network:



- Has ability to execute feature engineering by itself.
- Maximum utilization of unstructured data
- Ability to deliver high-quality results.

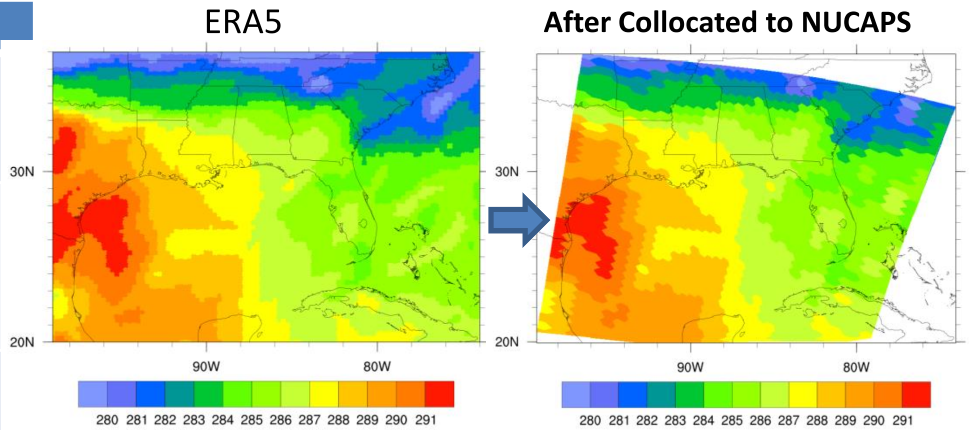


(Andrew Ng, 2013)

3. Datasets and Methodologies

Data Inputs

Data Source	Predictors	unit
NUCAPS	Temperature H2O_MR Surface Pressure	K $g \cdot kg^{-1}$ hPa
ABI BT Sub-FOR ABI homogeneity Angle	6.2, 6.9 ,7.3, 10.3, 11.2, 12.3 and 13.3 µm STD of ABI BT within FOR: 6.2, 6.9 ,7.3, 10.3, 11.2, 12.3 and 13.3 µm CosΘ	K K
RTMA	surface temperature Surface dewpoint	K K



850 hPa T (0730 UTC 01 April 2018)

Data as True Value:

Data Source	Variable	unit
ERA5 (hourly, 0.25º X 0.25º)	Temperature Water_vapor_mixing_ratio	K $g \cdot kg^{-1}$

Data Period: April to June 2018,   Region: CONUS

Quality Control:

- The most strict quality flag applied to all datasets.
- Cloud mask dataset used to remove the ABI pixels in cloud areas. Only clear FORs used.
- **80% for training, 20% for independent validation**

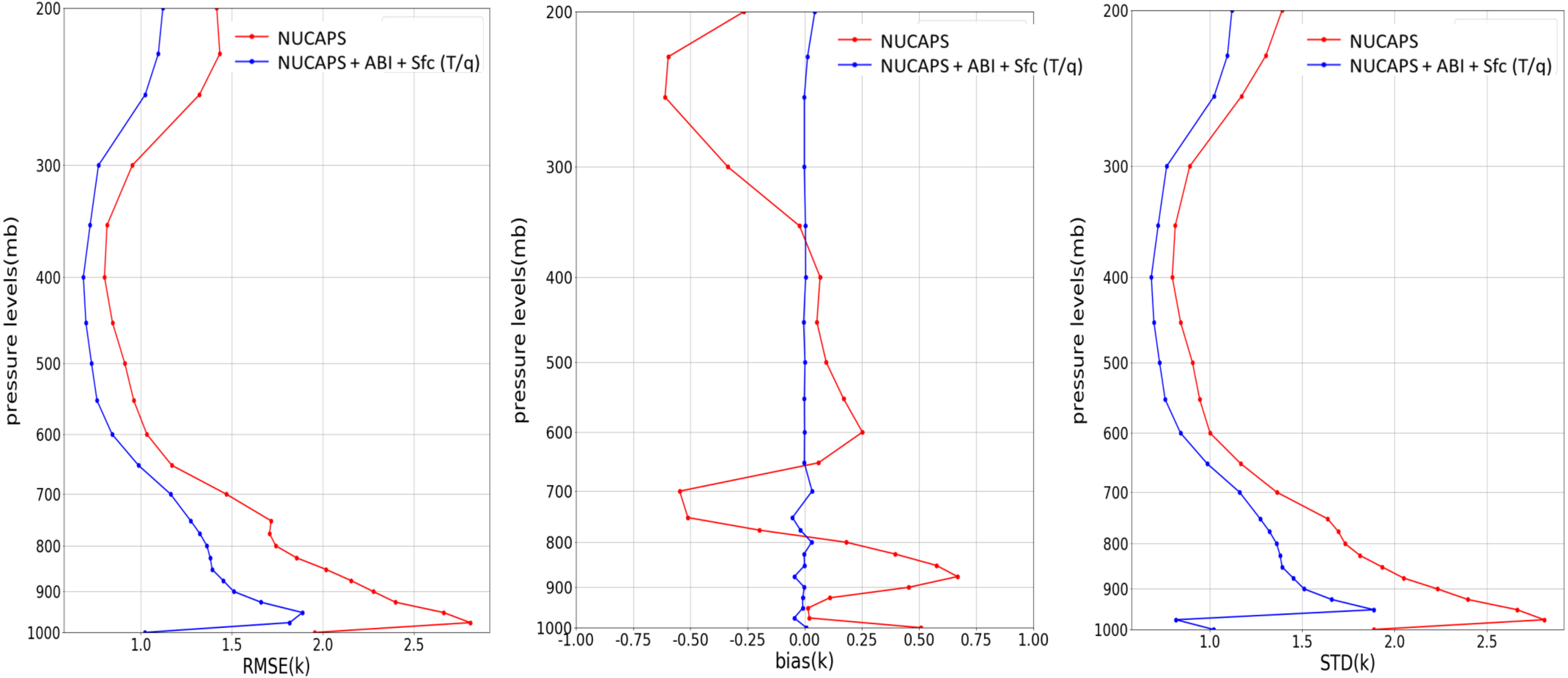
Preprocessing:

- **All datasets other than NUCAPS are spatially and temporally collocated to the FORs of NUCAPS observations.**
- **Averaging the ABI pixels within each NUCAPS FOR.**
- **Features normalized based on training set.**

4. Preliminary results

Temperature RMSE reduction:

- ✓ 850 mb and below: 34.465%
- ✓ 500 ~ 850 mb: 21.360%
- ✓ 500 mb and above: 18.552%



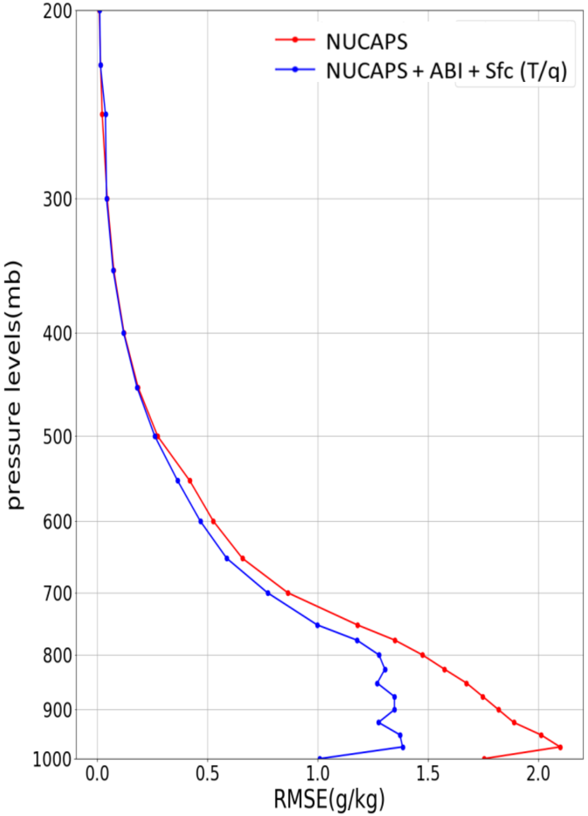
Temperature RMSE

Temperature Bias

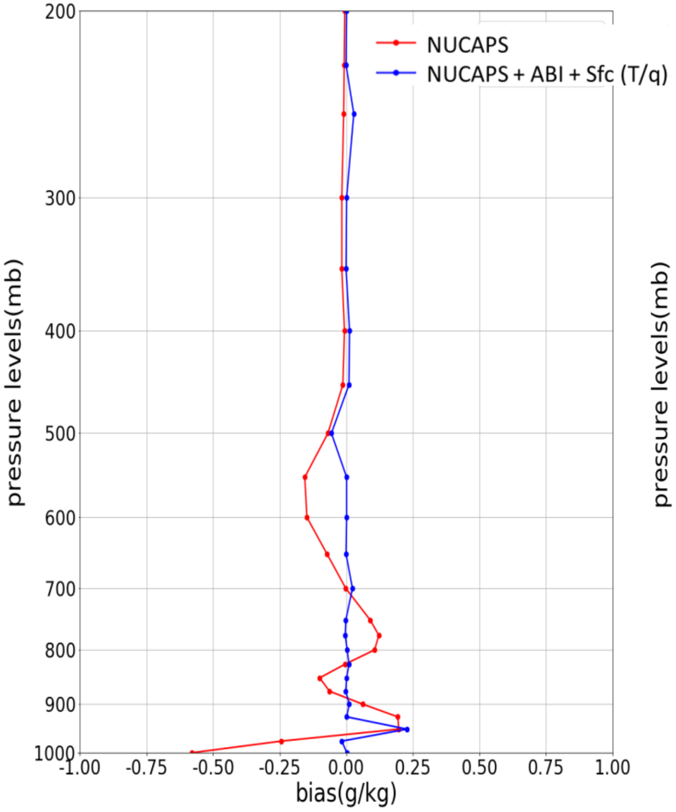
Temperature STD

Moisture RMSE reduction:

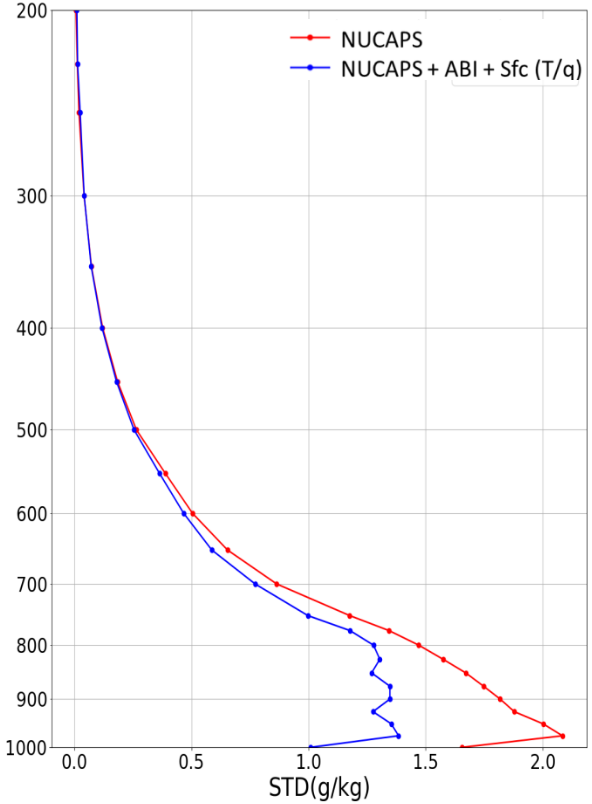
- ✓ 850 mb and below: 30.899%
- ✓ 500 ~ 850 mb: 12.374%
- ✓ 500 mb and above: N/A



Moisture RMSE

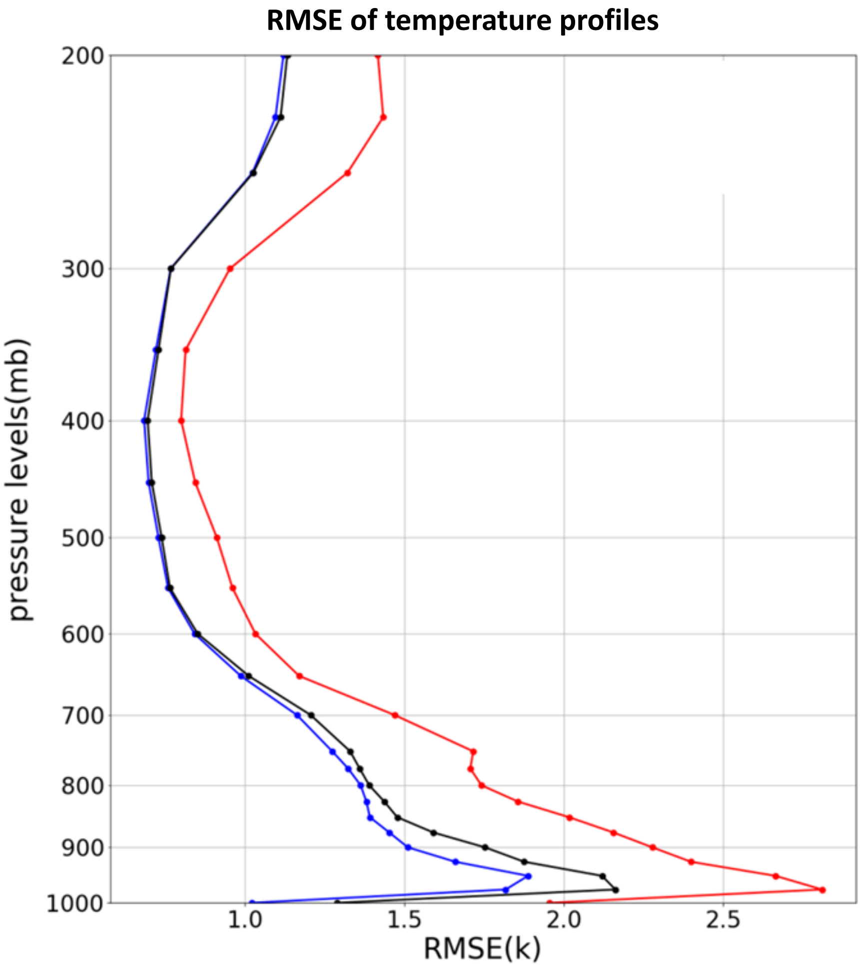


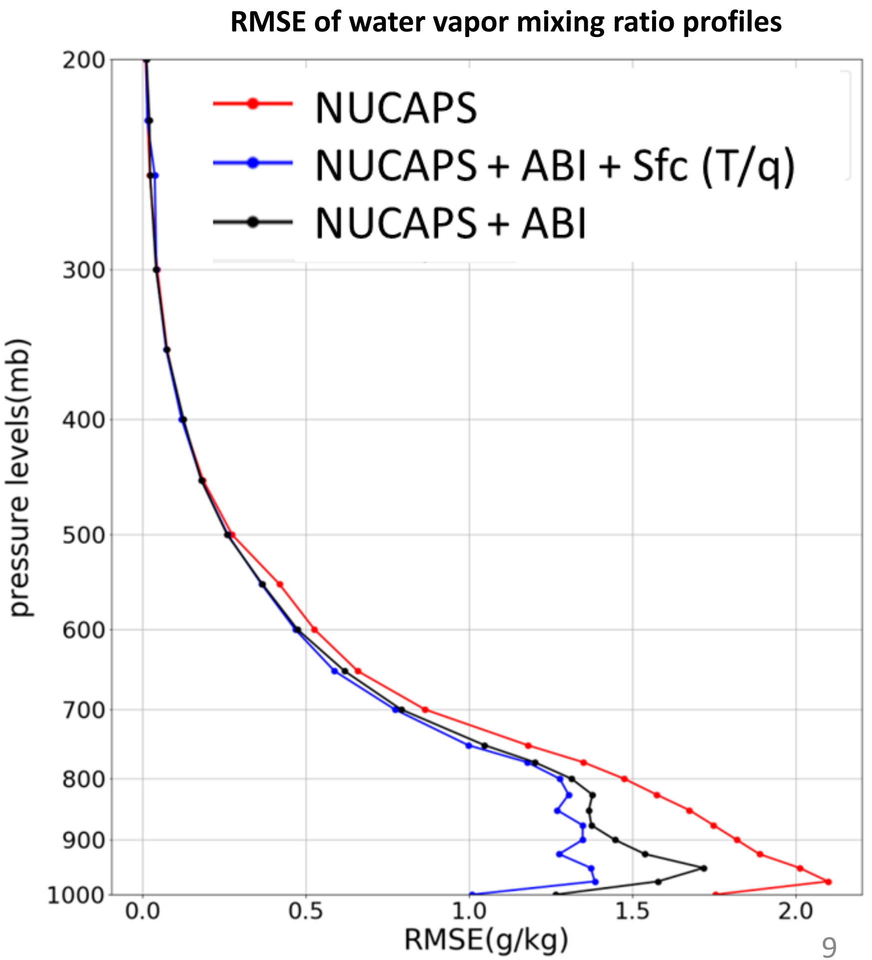
Moisture Bias



Moisture STD

Relative impact of ABI radiances on improving NUCAPS soundings

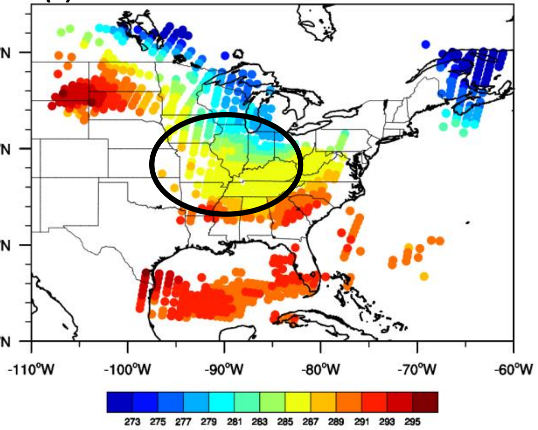




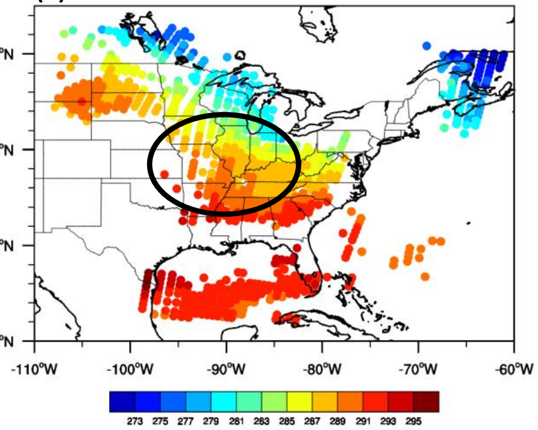
Case I: significant impact on T

850 hPa Temperature 00 - 12 UTC 4 June 2018

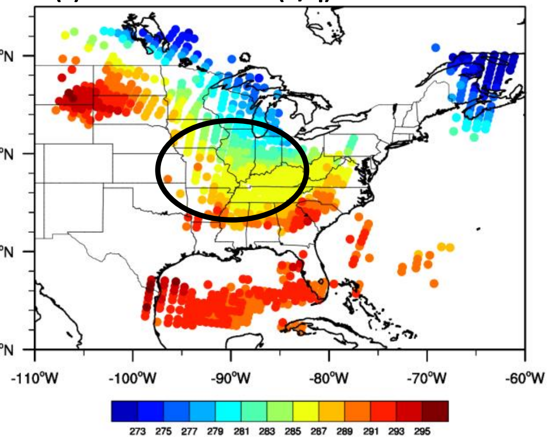
(a) ERA5



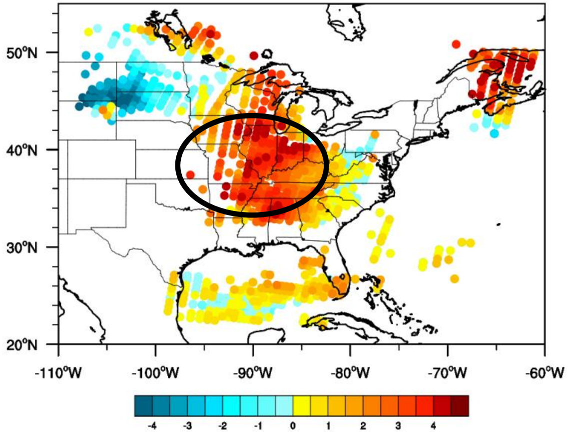
(b) NUCAPS



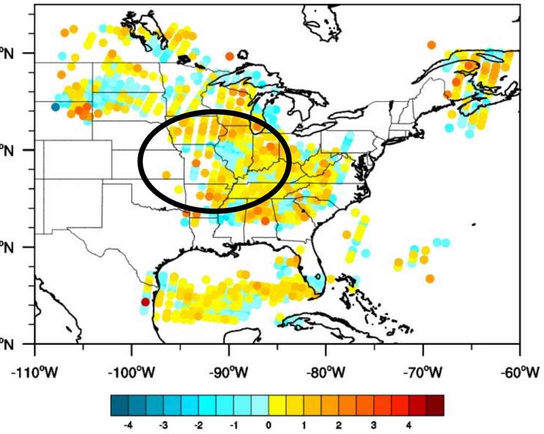
(c) NUCAPS+ABI+Sfc(T/q)



(d) NUCAPS - ERA5



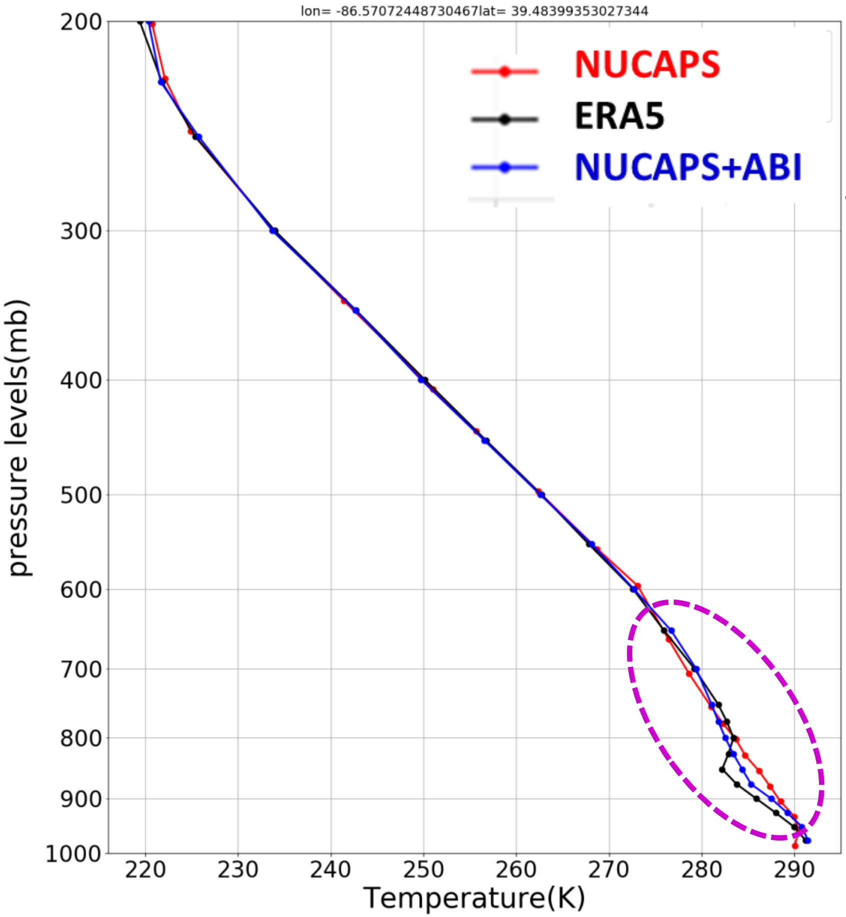
(e) (NUCAPS+ABI+Sfc) - ERA5



Temperature at 850 hPa from FORs which meet the pre-processing conditions,

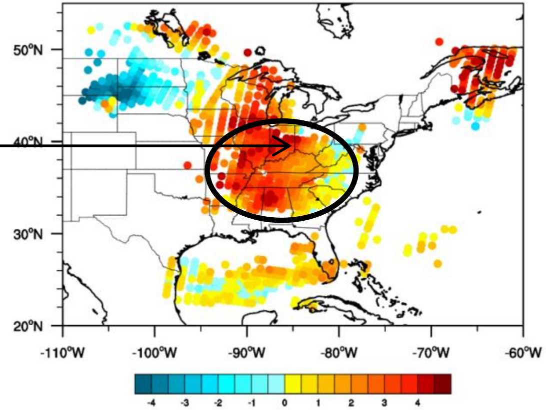
(a) ERA5 (K),
(b) NUCAPS (K),
(c) NUCAPS+ABI+Sfc(T/q) (K)
(d) NUCAPS minus ERA5 (K),
(e) NUCAPS+ABI+Sfc minus ERA5 (K)

Example of Temperature Profile: 04 June 2018

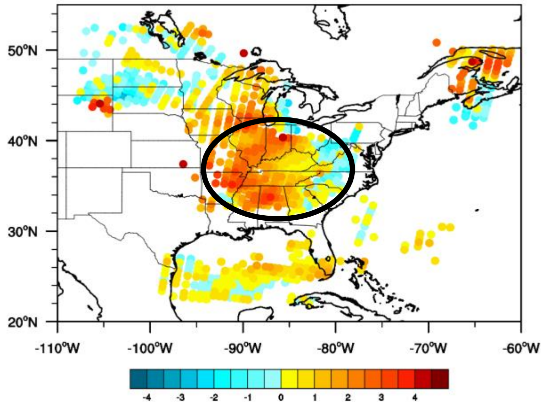


(-86.571°W, 39.484°N)

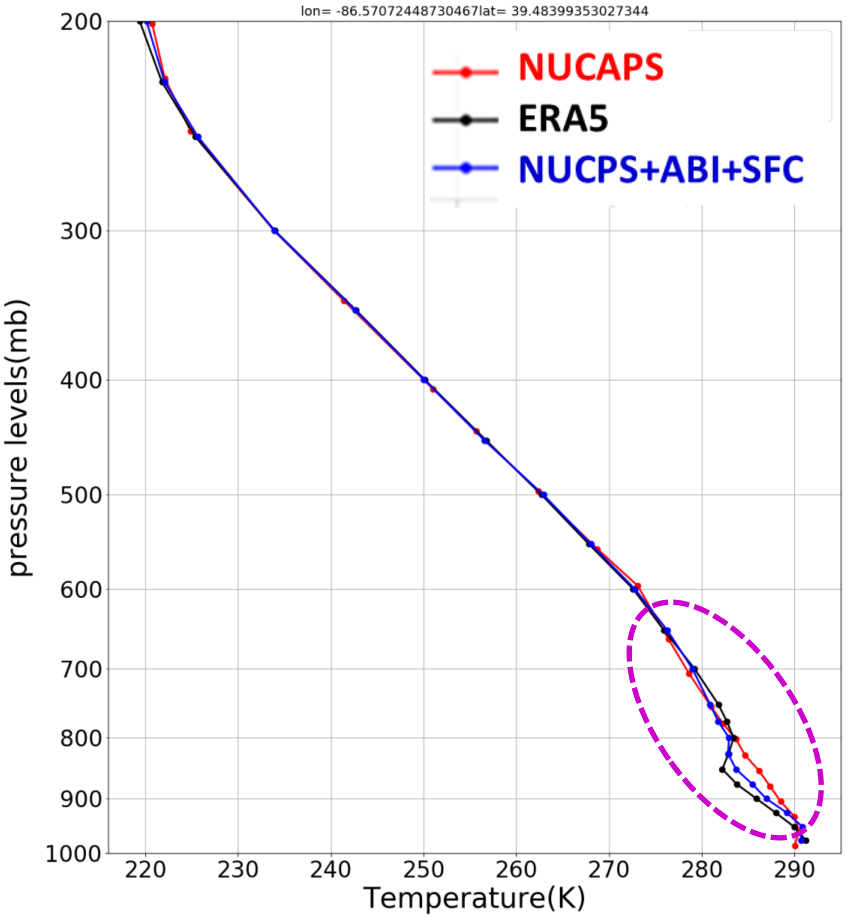
(a) 850 hPa T (K): NUCAPS – ERA5



(b) 850 hPa T (K): NUCAPS+ABI) –ERA5



Example of Temperature Profile: 04 June 2018



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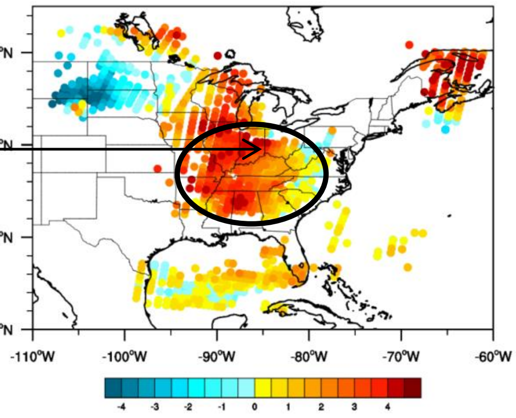
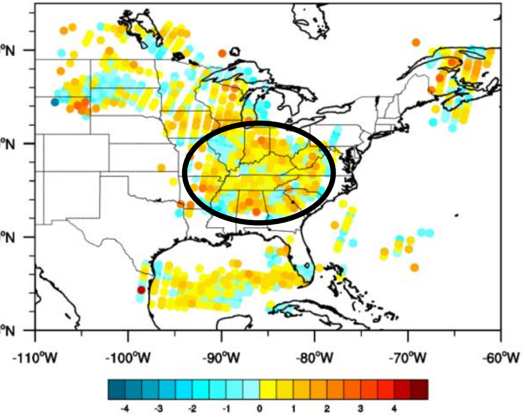
(a) 850 hPa T (K): NUCAPS – ERA5



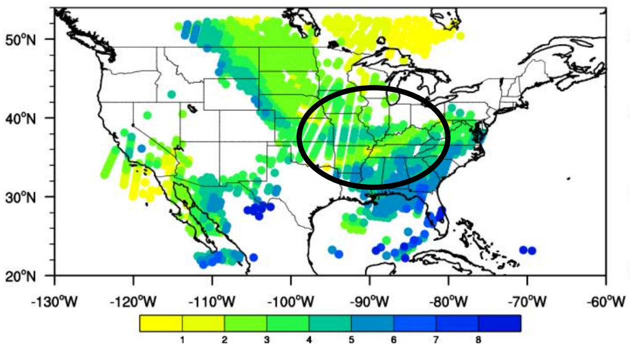
(b) 850 hPa T (K): NUCAPS+ABI+Sfc) –ERA5



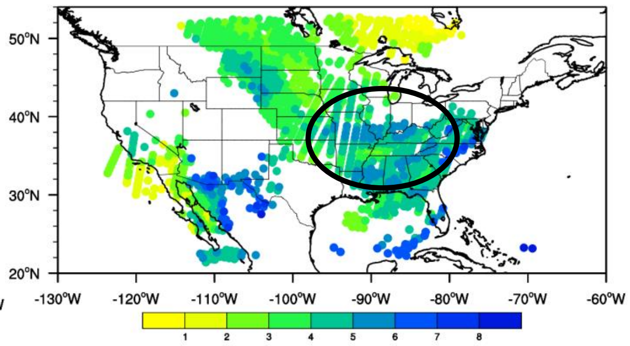
Case 2: significant impact on q

850 hPa Moisture 00 - 12 UTC 28 April 2018

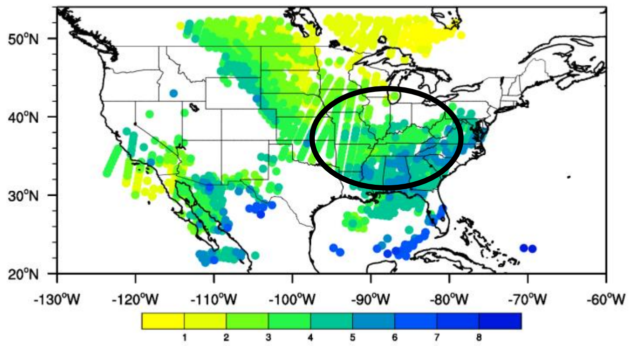
(a) ERA5



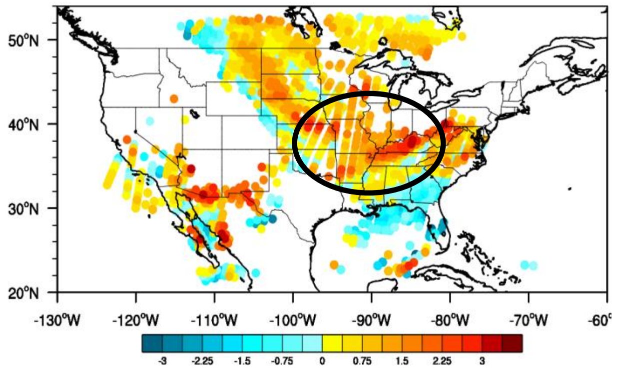
(b) NUCAPS



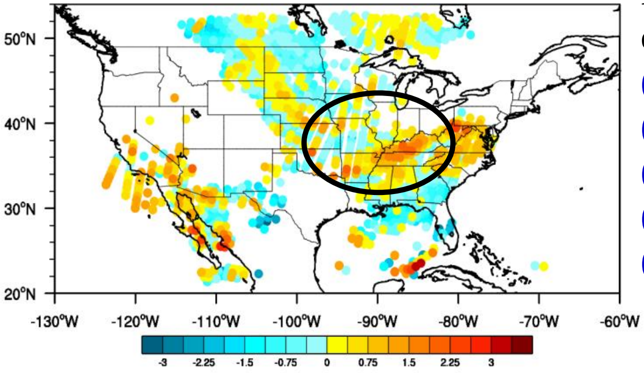
(c) NUCAPS+ABI+Sfc(T/q)



(d) NUCAPS - ERA5



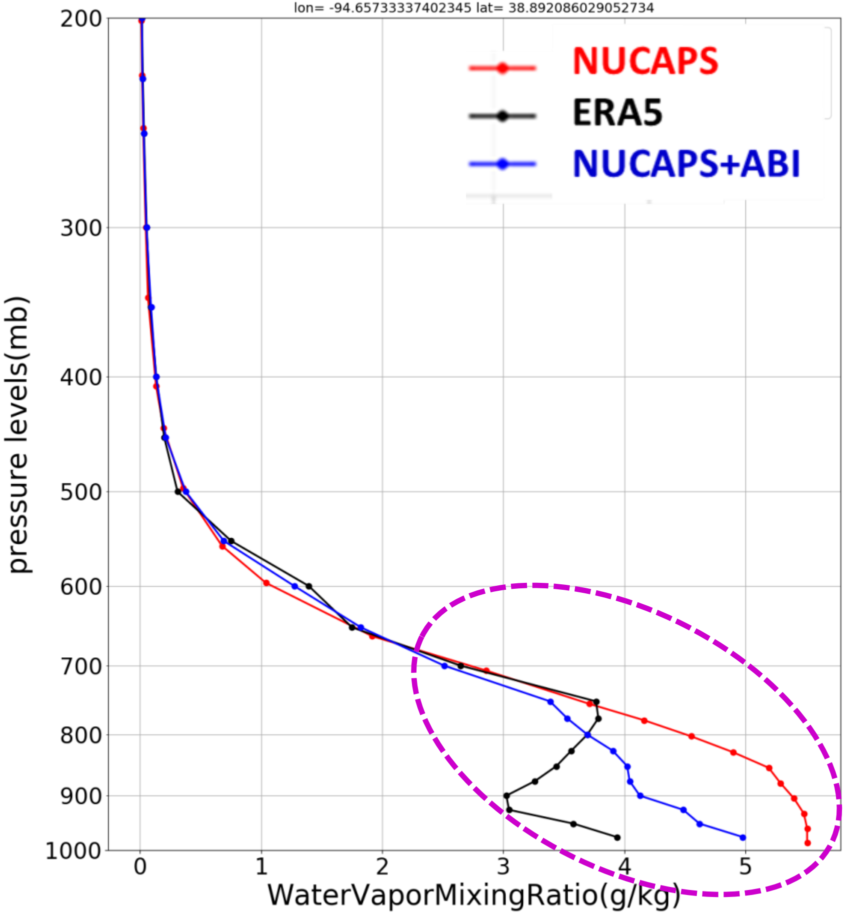
(e) (NUCAPS+ABI+Sfc) – ERA5



Water vapor mixing ratio at 850 hPa from FORs which meet the pre-processing conditions,

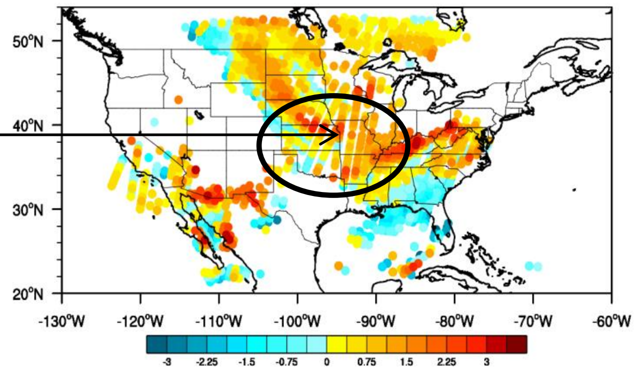
(a) ERA5 (g/kg),
(b) NUCAPS (g/kg),
(c) NUCAPS+ABI+Sfc(T/q) (g/kg),
(d) NUCAPS minus ERA5 (g/kg),
(e) NUCAPS+ABI+Sfc minus ERA5 (g/kg)

Example of Moisture Profile: 28 April 2018

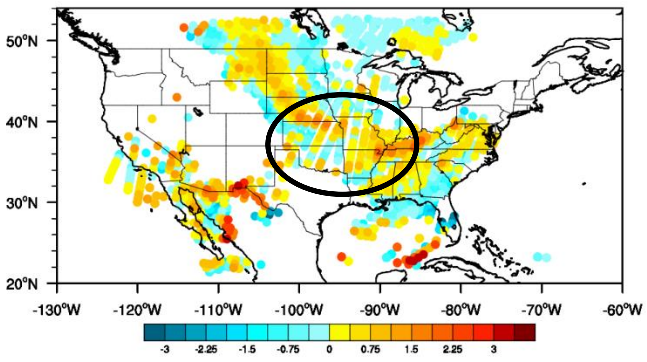


(-94.657°W, 38.892°E)

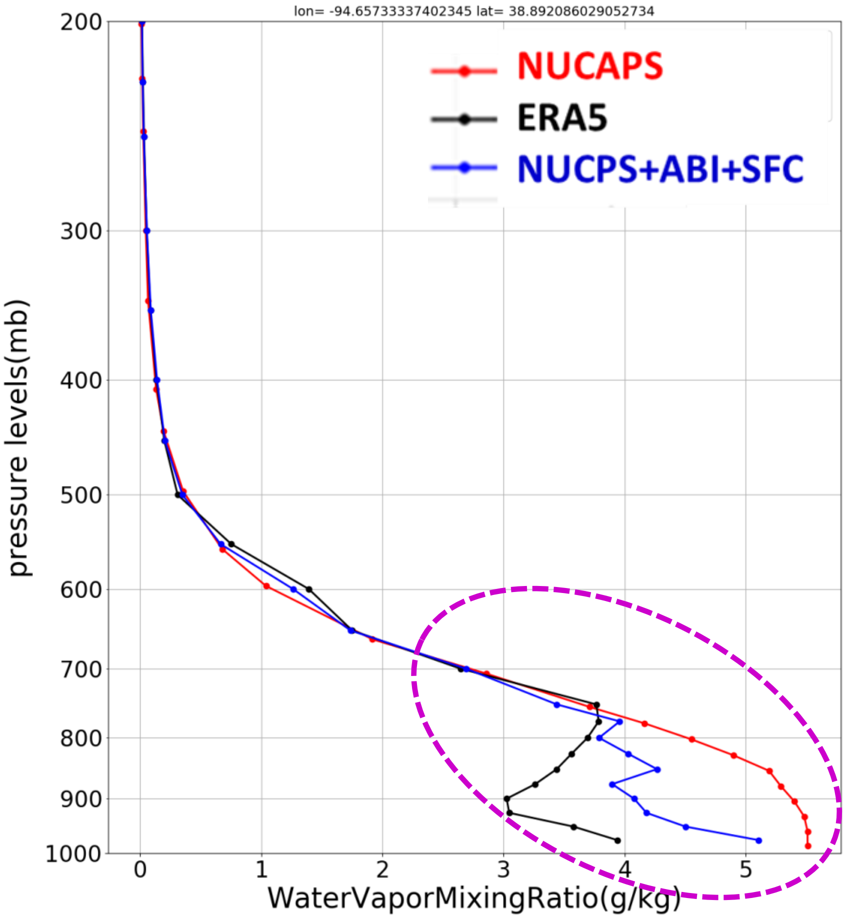
(a) 850 hPa q (g/kg): NUCAPS – ERA5



(b) 850 hPa q (g/kg): NUCAPS+ABI) –ERA5



Example of Moisture Profile: 28 April 2018



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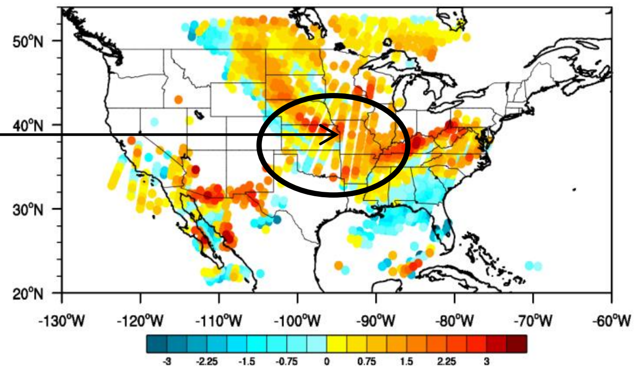
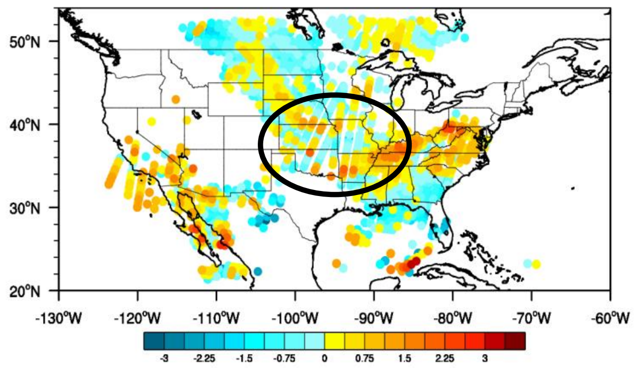
(a) 850 hPa q (g/kg): NUCAPS – ERA5



(b) 850 hPa q (g/kg): NUCAPS+ABI+Sfc) –ERA5



5. Summary and future work

Summary:

- Combining NUCAPS and ABI with AI makes better temperature and moisture soundings. Adding surface T/q observations (or analysis) further improves boundary layer profiles;

Future work:

- Optimize the retrieval model;
- Improve NUCAPS under cloudy skies using clear portion of ABI within Sub-FOR;
- Build one-year training for robust DNN model for NUCAPS improvement;
- Prototype software development for near real-time (NRT) product generation;
- Collaborate with SSEC CSPP team to implement into CSPP after successful case demonstration;
- Collaborate with NOAA NUCAPS team on potential operational transition.

Applications of JPSS and GOES-R for long-term monitoring: The Case for Making (Imager) Climate Data Records

Andrew Heidinger, NOAA/NESDIS

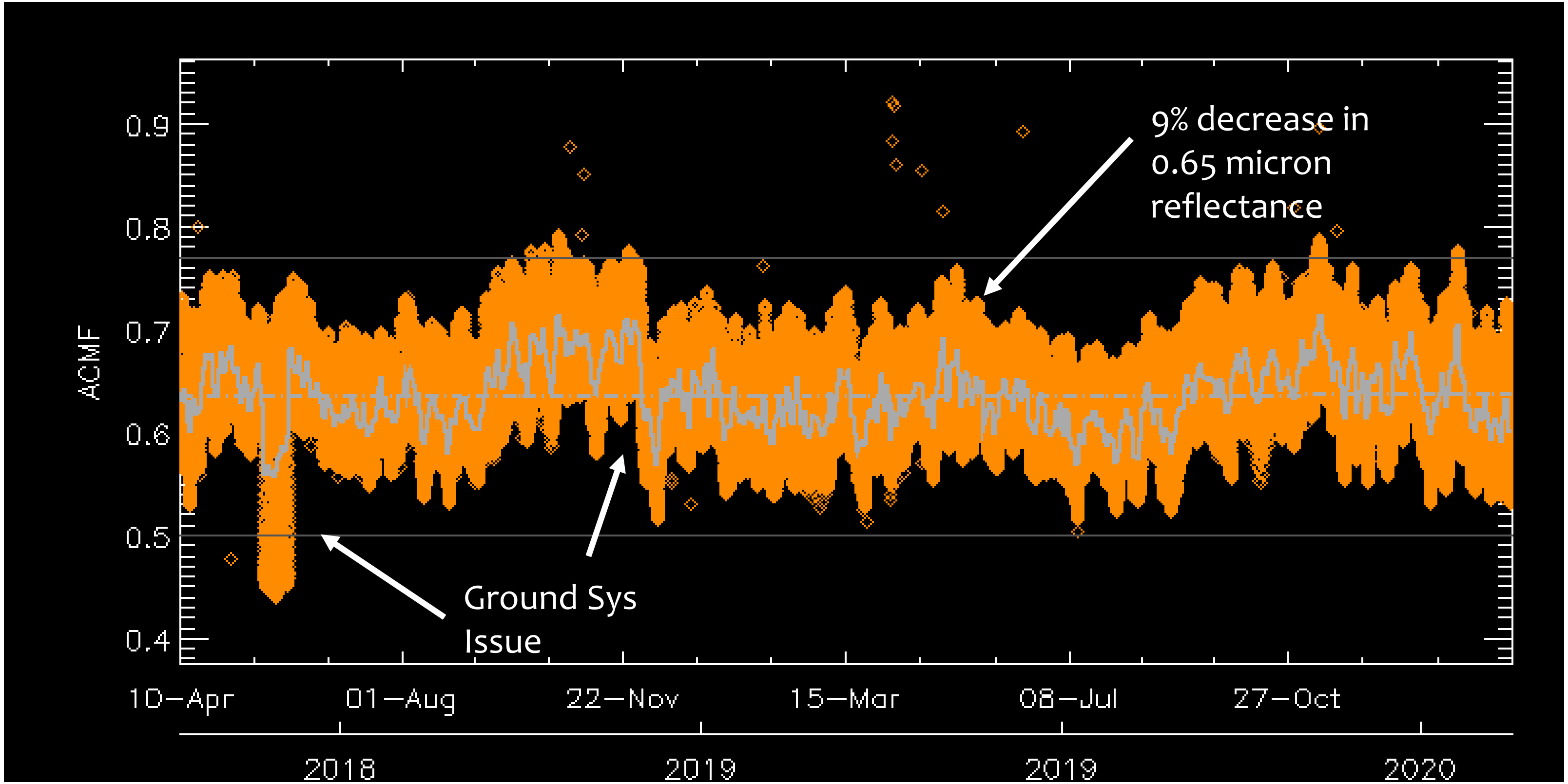
PGRR Summit, Feb 22-25, 2020 NCWCP

Main Points

- Climate projects have users: Reanalysis, Climate Reports (IPCC, Bams SOC), general science.
- NESDIS calibration and algorithm efforts benefit a lot from making and analyzing climate data records. Complements our real-time mission.
- Reprocessing L1 records is important. But so is subsetting them in ways that make climate products useful to a wide audience. (*A reprocessed L2 is not a useful climate product*).
- If we don't reprocess our data, others (EUMETSAT or NASA) will.
- ISCCP-NG is an important multi-agency effort to make homogenize cloud climate records from the advanced geo record. Similar efforts underway for polar (NCEI/VGAC). NESDIS and its climate users should engage in these efforts.

Another Need for Reprocessing: Long-term Stability of GOES-16 Operational Products

Archives of operational products do not typically provide climate data records.

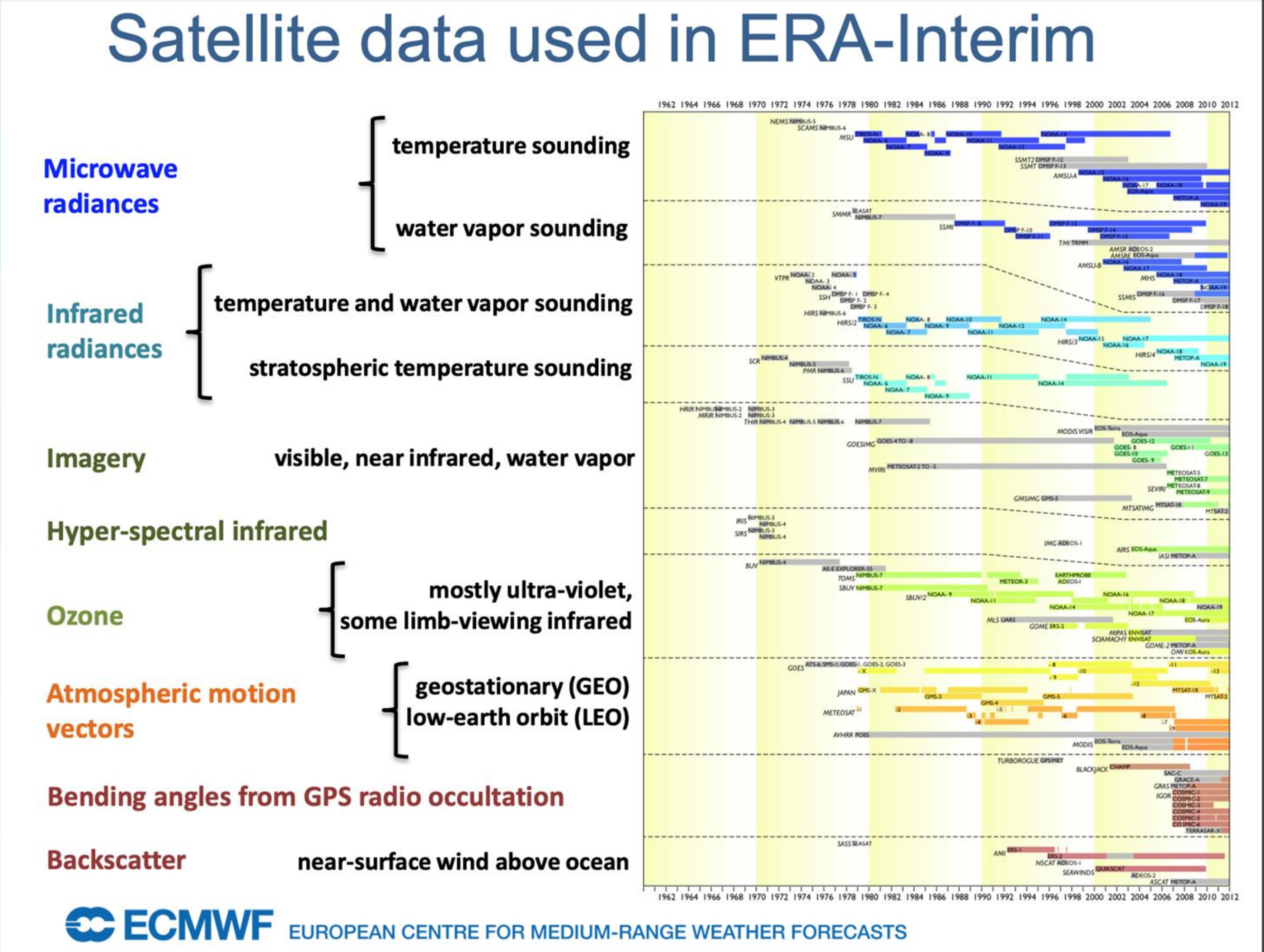


Climate Users: Reanalysis

NESDIS makes all of these products.

ERA uses EUMETSAT/ CM-SAF Versions.

MERRA and CFSR use similar information and what are their needs?

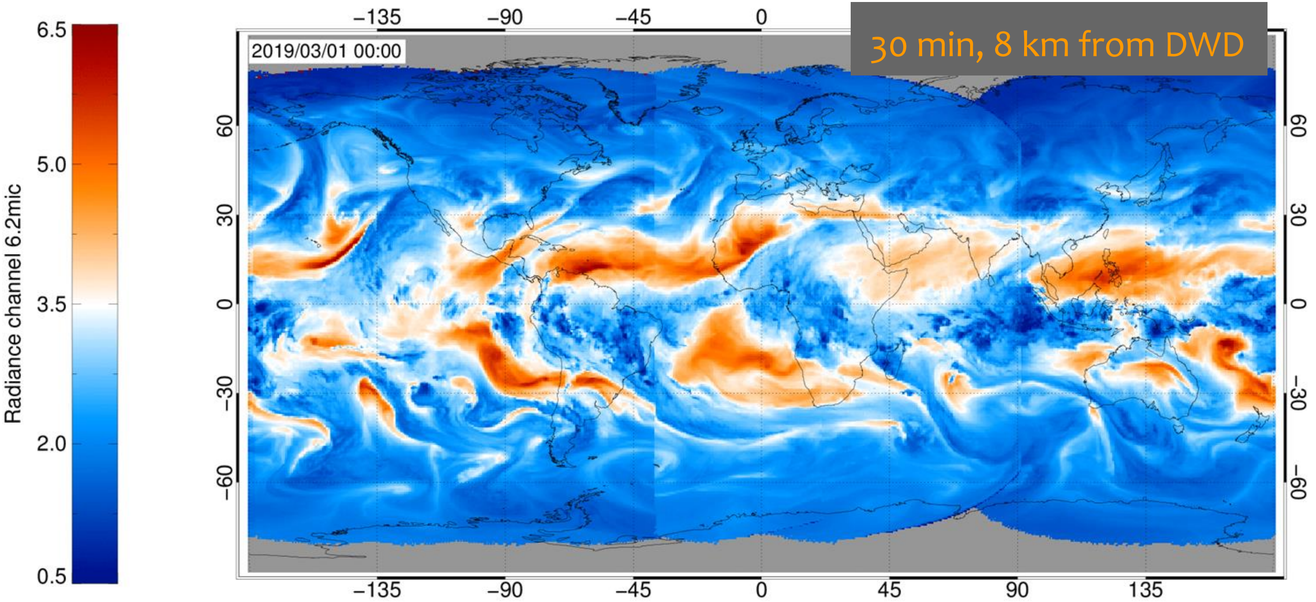


https://www.ecmwf.int/sites/default/files/elibrary/2014/14665-use-satellite-data-reanalysis.pdf

Need for Subsampling for Climate Studies: International Satellite Cloud Climatology - Next Gen (ISCCP-NG)

- ISCCP v1 is one of the oldest satellite climate projects (1983-2020+) and operational at NCEI.
- ISCCP-NG is a reboot of ISCCP that exploits capabilities of next gen geo imagers.
- ISCCP-NG aims to combine the all advanced geo-images into one homogeneous radiance and cloud product climate record.

- **Compared to ISCCP, ISCCP-NG is 2000x bigger in Volume w/o subsetting.**
- How do we subsetting to keep info on cloud dynamics?
- An international effort to define ISCCP-NG is underway!

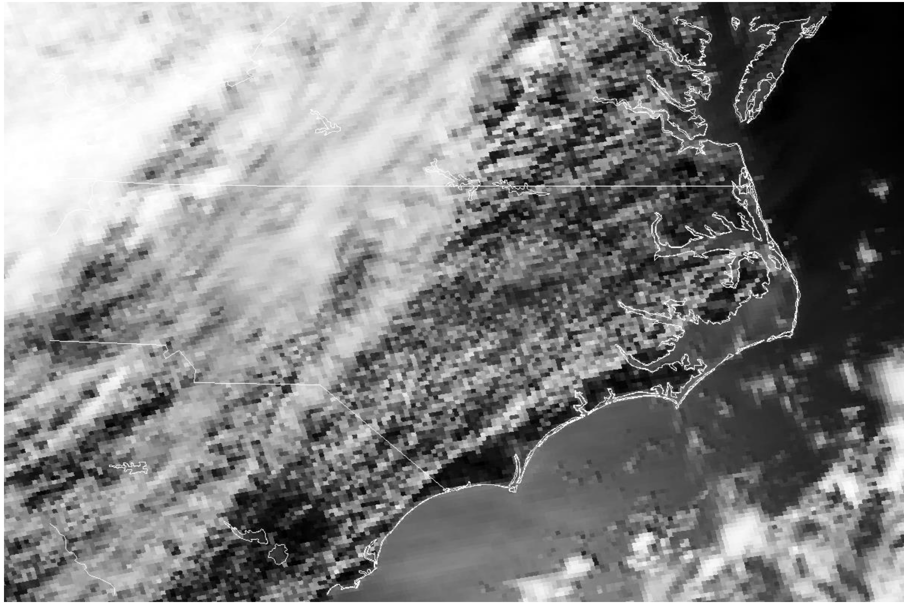


ISCCP-NG will certainly use NESDIS Geo Data. NESDIS can also play a role in CDRs and NOAA Climate Users should provide feedback.

Need for Subsampling for Climate Studies: VIIRS - (VGAC)

- VIIRS is difficult use for climate data records.
- One day of VIIRS is roughly 20000 files and 20 Gb.
- Most climate records are highly averaged or sampled in space and time.
- **Ken Knapp (NCEI)** is proposing a VIIRS - GAC (VGAC) which is 1/30th the size of the VIIRS M-bands (image to the right).
- **A sampled VIIRS L1 would allow many to assess the STAR L1 reprocessed record.**

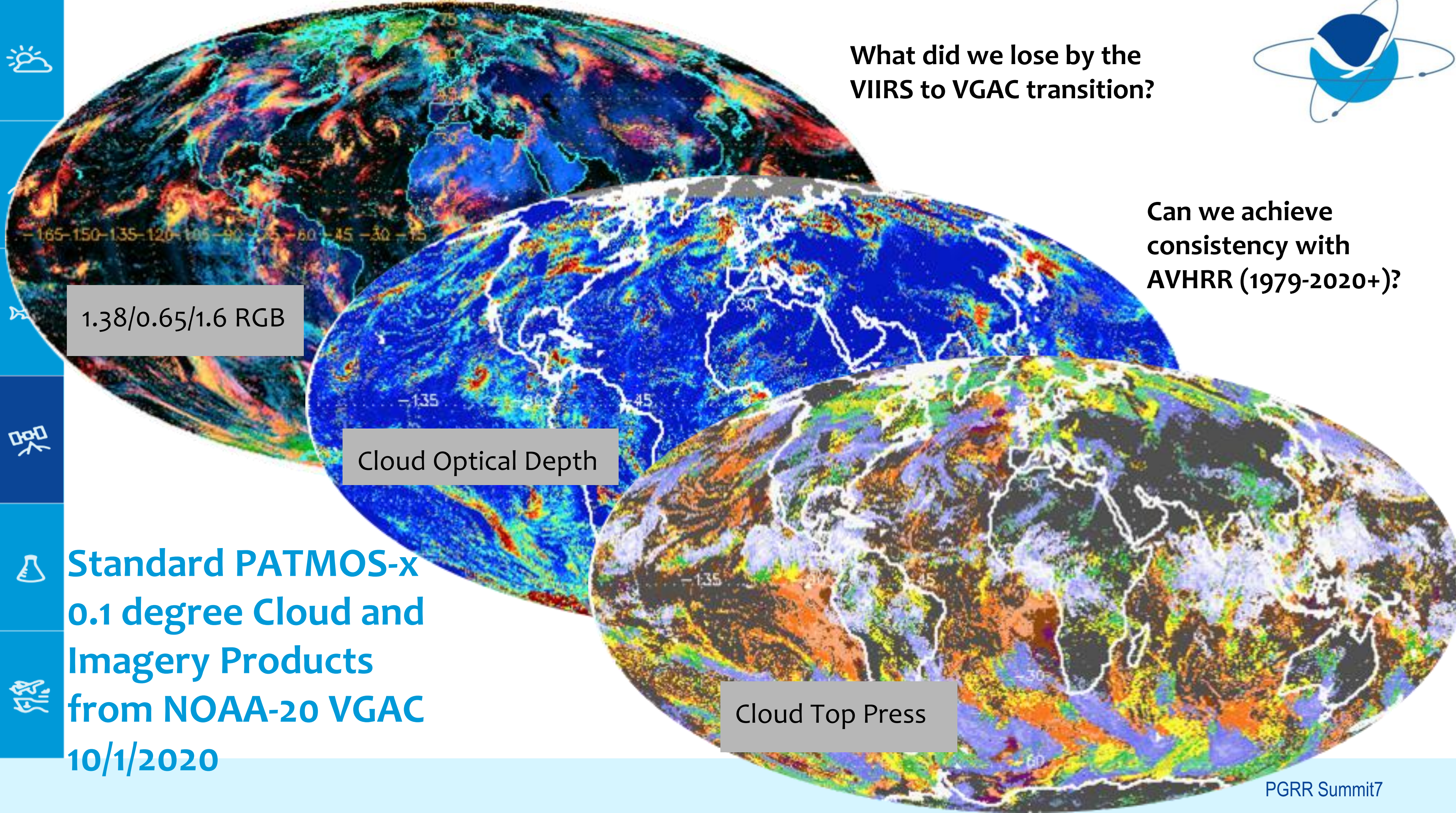
A subsampled VIIRS would allow for quick generation and assessment of proposed calibration or algorithm modifications. (VGAC is VIIRS for the rest of us)



VGAC sample over the Carolinas

What did we lose by the VIIRS to VGAC transition?

Can we achieve consistency with AVHRR (1979-2020+)?



Standard PATMOS-x 0.1 degree Cloud and Imagery Products from NOAA-20 VGAC 10/1/2020

Main Points

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- Reprocessing L1 records is important. But so is subsetting them in ways that make climate products useful to a wide audience. (*A reprocessed L2 is not a useful climate product*).

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- ISCCP-NG is an important multi-agency effort to make homogenize cloud climate records from the advanced geo record. Similar efforts underway for polar (NCEI/VGAC). NESDIS and its climate users should engage in these efforts.

Thank You

JPSS and GOES-R L1 and L2 Advances can Improve Old CDRs

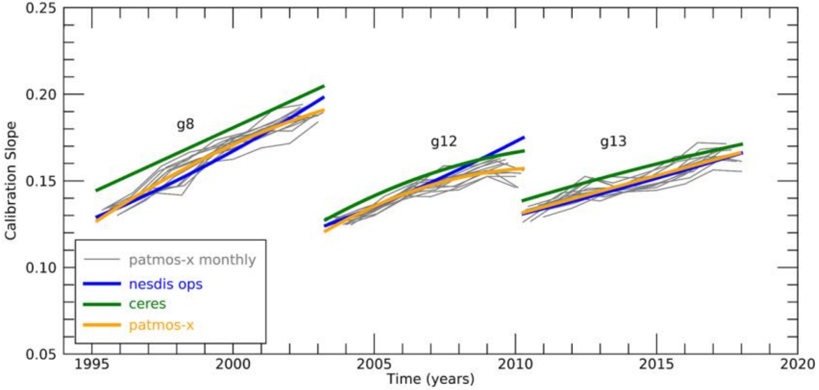
GOES-R/ABI and JPSS/VIIRS are the first operational sensors with on-board solar reflectance calibration.

Make case of using these new sensors with on-board calibration (first for operational sensors) to improve our climate records.

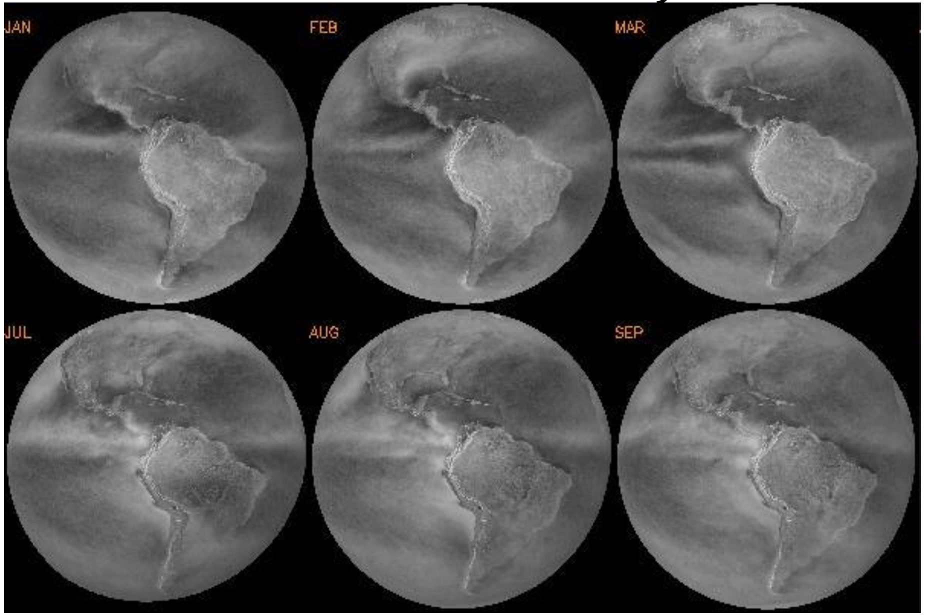
In addition, new processing techniques like AI and Fusion developed on latest sensors can be applied to the old sensor records.

This can also test long-term stability of the new techniques.

GOES-8,12,13 Visible Channel Calibration from GOES-16 18Z Full-Disk Reflectance

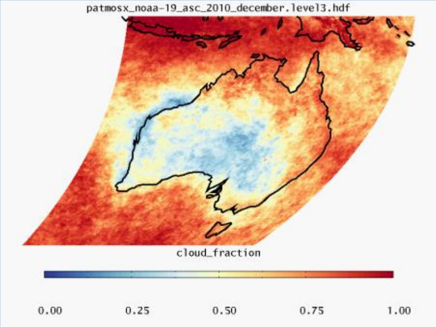


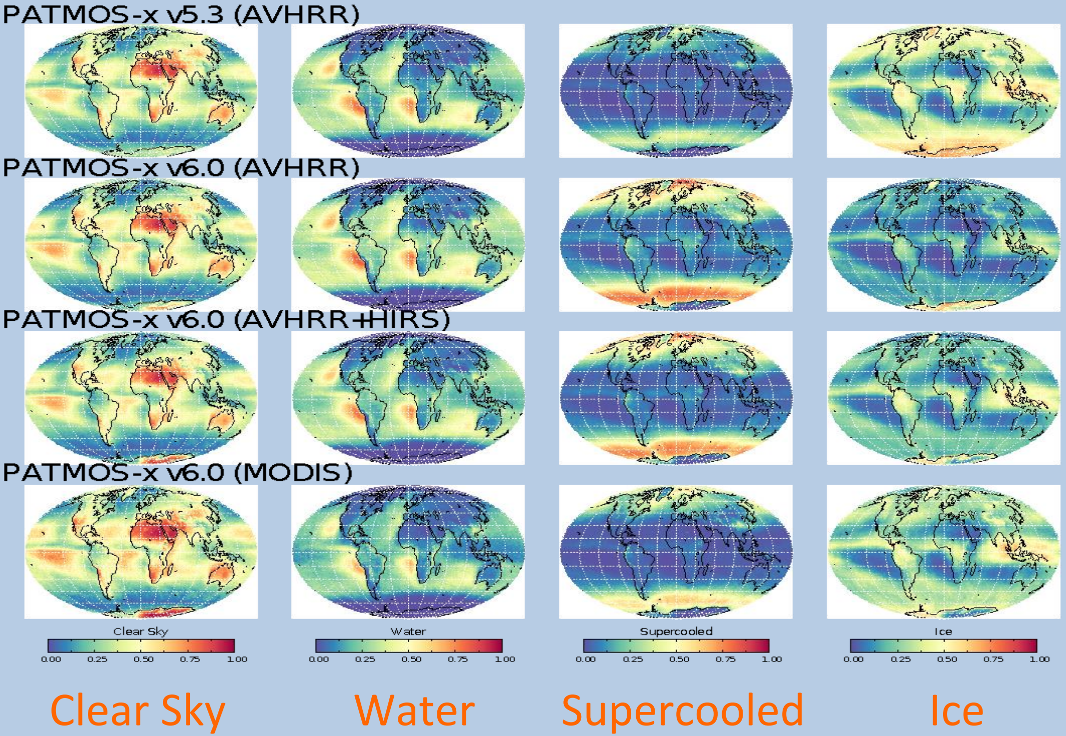
Mean 18Z Ch2 Reflectance 2018-2019 GOES-16



PATMOS-x Cloud Climate Products and Projects

- NOAA National Centers for Environmental Information
  - A ‘fusion’ record has been generated that interpolates HIRS to the AVHRR spatial and sampling resolution
  - This AVHRR+HIRS record serves as the basis for PATMOS-x Version 6.0
- Curtin University in Australia
  - Generating PATMOS-x cloud record in a new level 3 format for collaborative climate studies over Australia



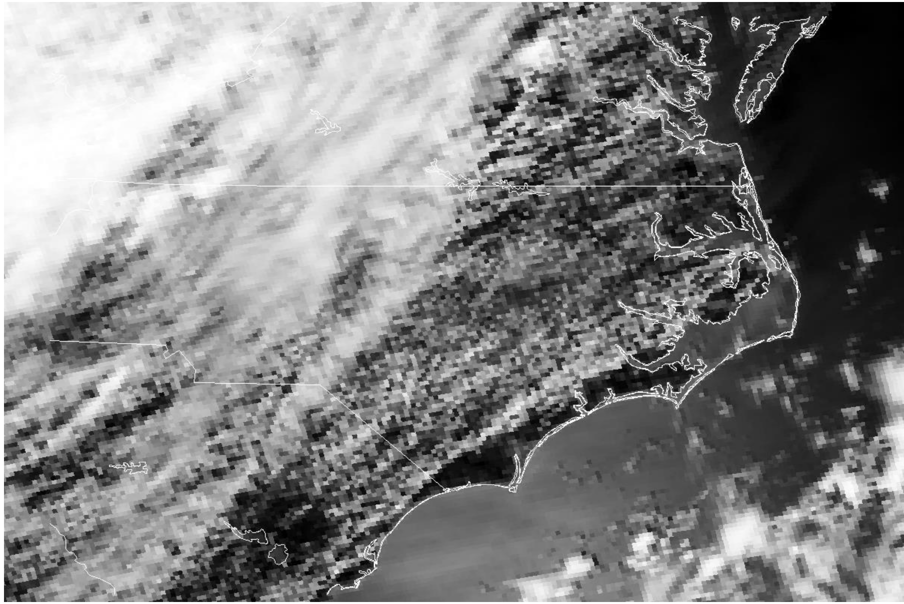


Mike Foster, Andrew Heidinger, Paul Menzel, Elisabeth Weisz, Denis Botambekov, Ray Garcia, Andi Walther, Charles White, Yue Li

Need for Subsampling for Climate Studies: VIIRS - (VGAC)

- VIIRS is difficult use for climate data records.
- One day of VIIRS is roughly 20000 files and 20 Gb.
- Without remapping, the data is not spatially continuous (gaps and overlaps)
- While cloud computing offers opportunities to handle this, most climate records are highly averaged or sampled in space and time.
- **Ken Knapp (NCEI)** is proposing a VIIRS - GAC (VGAC) which is 1/30th the size of the VIIRS M-bands (image to the right).
- VGAC is M-band only and roughly 4km (missing DNB, I-bands).
- Something like VGAC will put the VIIRS record into the hands of many users. *(VGAC is VIIRS for the rest of us)*

A subsampled VIIRS would allow for quick generation and assessment of proposed calibration or algorithm modifications.



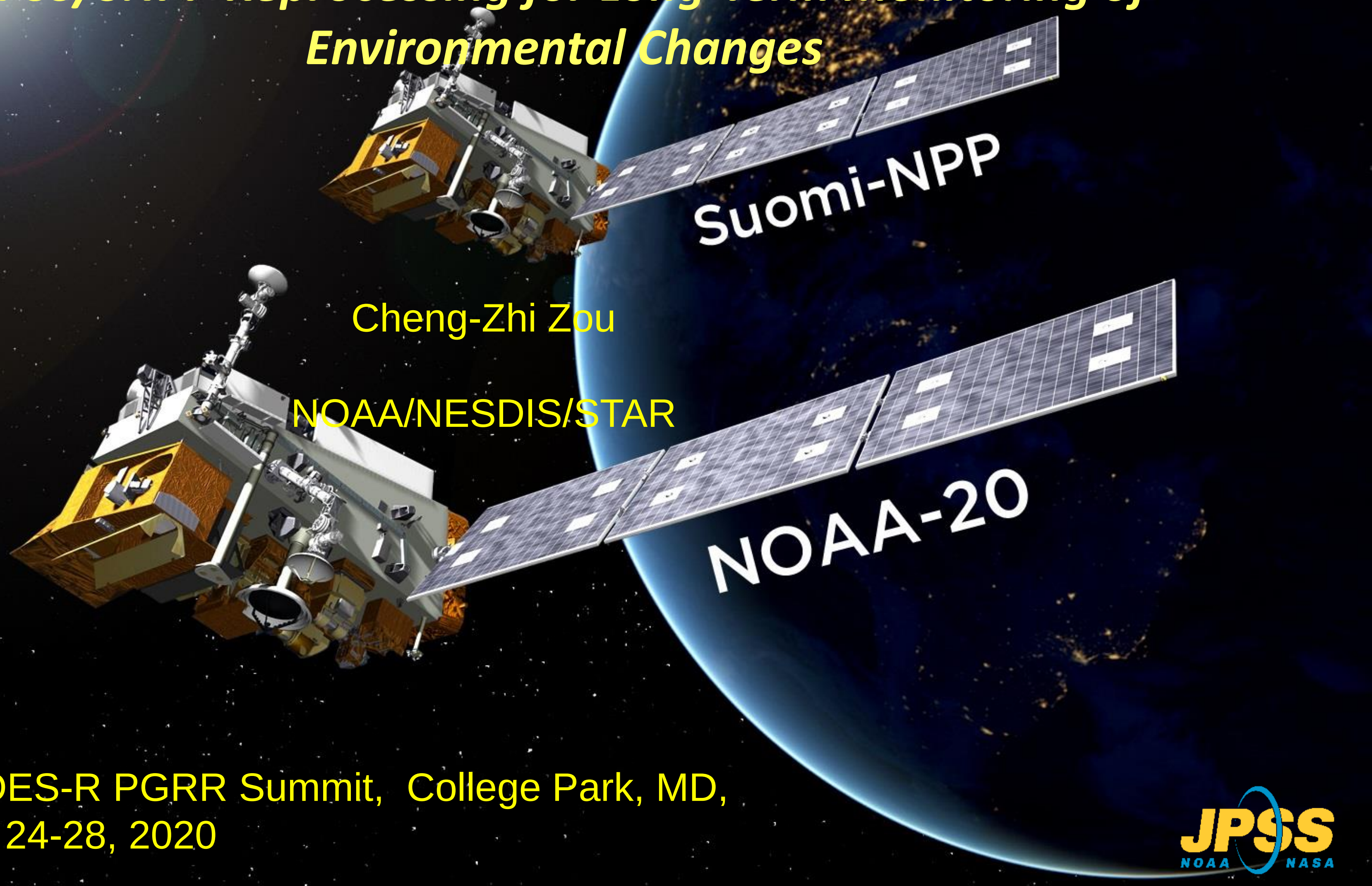
VGAC sample over the Carolinas

ken.knapp@noaa.gov

NOAA Satellites and Information

National Environmental Satellite, Data, and Information Service

JPSS/SNPP Reprocessing for Long-Term Monitoring of Environmental Changes



Cheng-Zhi Zou

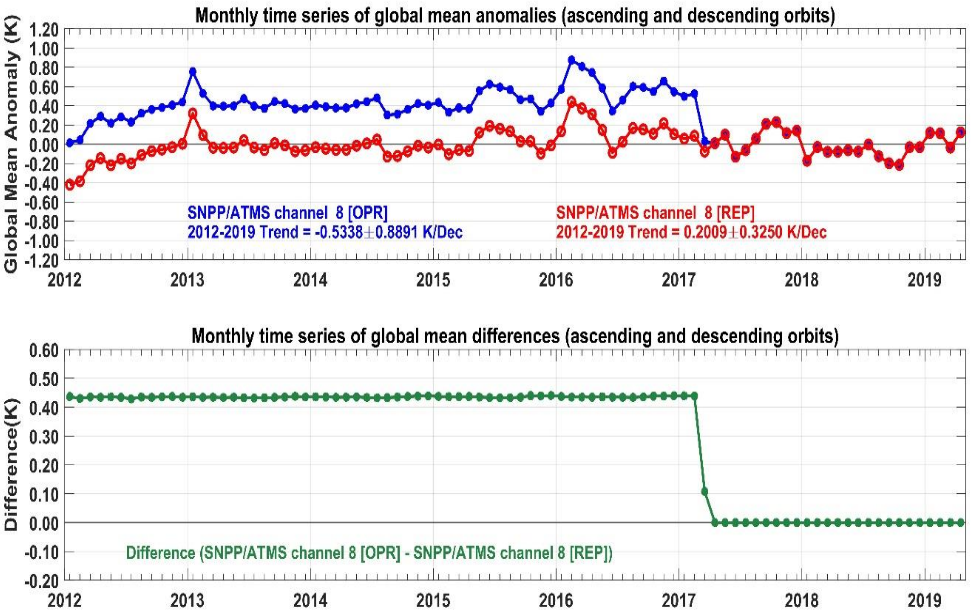
NOAA/NESDIS/STAR

JPSS/GOES-R PGRR Summit, College Park, MD, February 24-28, 2020

JPSS NOAA NASA

Reprocessing of JPSS/SNPP Sensor Data Records (SDRs)

- Operational calibration algorithms improve and update over time, resulting in bias jumps in SDR time series
- Generate reprocessed and consistent SDRs for each JPSS/SNPP instrument through their life-cycle using most recently updated, unified calibration algorithms
- Calibration accuracy achieves those from the latest operational calibration algorithm
- STAR has reprocessed four SNPP instruments: ATMS, CrIS, VIIRS, OMPS
- Reprocess JPSS instruments as data are long enough

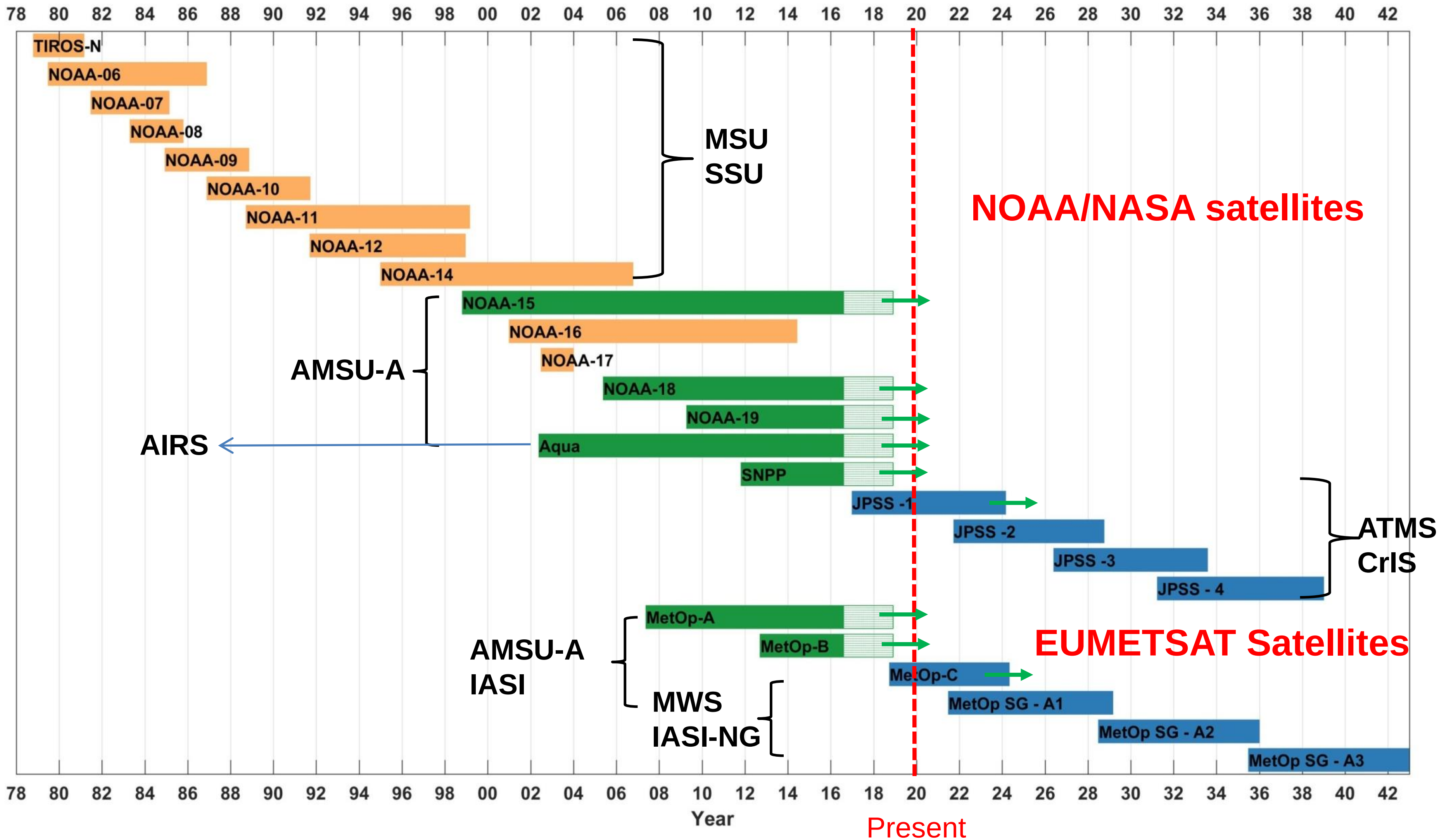


Monthly global mean T_b anomaly time series for ATMS channel 8 from operational calibrated (blue, top) and reprocessed (red, top) sensor data records and their differences (green, bottom). The global means are calculated using limb-adjusted scan positions from 29 to 68 for both operational calibrated and reprocessed datasets. The bias jump between the operational calibrated and reprocessed data found in March 2017 was caused by the calibration update for the operational calibration on 7 March 2017. After that date, the two datasets are identical since they use the same calibration algorithm.

Benefit of Reprocessing

- Allow stability assessment after removal of bias jumps due to operational calibration changes
- Consistent satellite retrievals
- Improve EDR products
- Building blocks for climate data record development
- Improve climate reanalyses as input datasets

- Satellites are the only means available to provide upper-air temperature observations with global coverage for long-term monitoring
- NOAA satellites have been continuously observing upper-air temperatures for over 40 years
- JPSS Program carries the NOAA operational temperature sounding capability into the future
- Inter-satellite calibration and satellite merging are needed to develop climate data record (CDR) for long-term monitoring



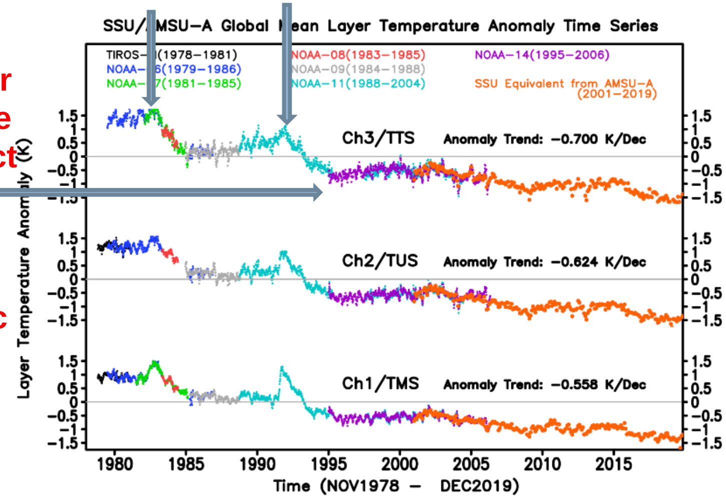
Long-Term Monitoring of Upper-Air Temperatures

Benefit/Users:

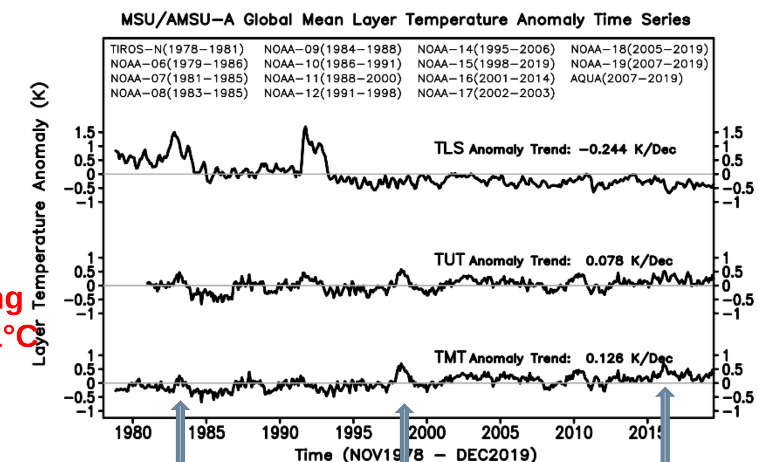
- National and international climate assessment programs: IPCC, WCRP, NOAA/National annual State of Climate report, NOAA/NCEI monthly climate assessment report, etc.
- Climate modelers for validating climate model simulations of the past climate changes
- NWP centers for data assimilation in climate reanalyses and assessment of climate reanalysis products
- Provide references for satellite Cal/Val programs

Volcano Eruption of
El Chichon (1982) Pinatubo (1991)

Solar cycle effect



Total decrease in upper stratospheric temperature during 40 years: 3.0±0.2°C

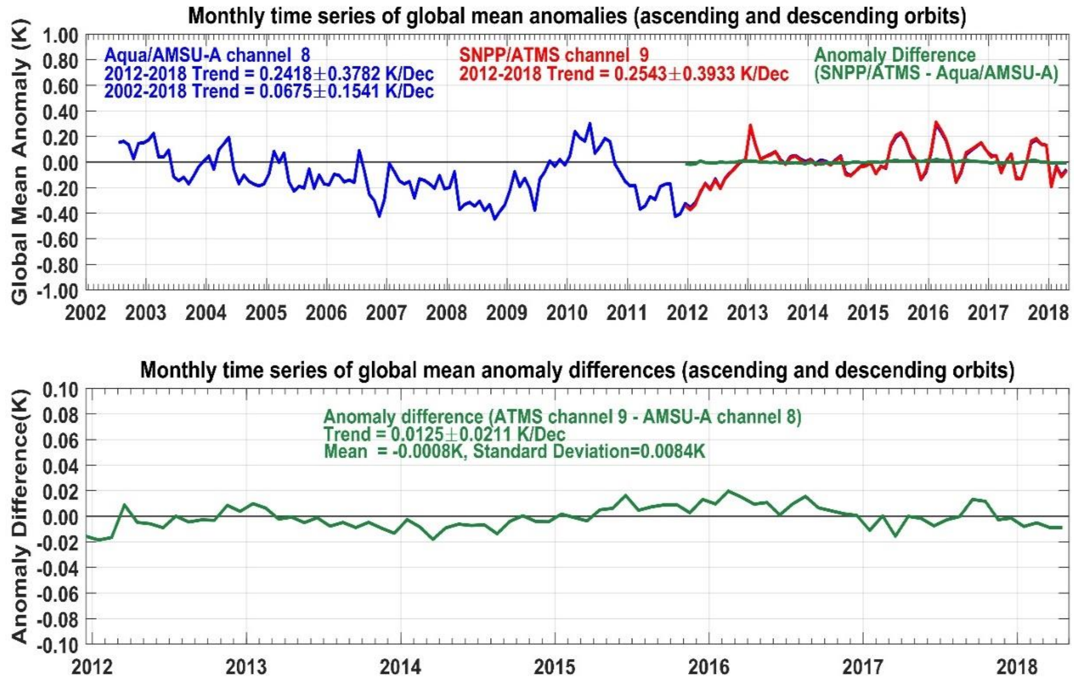


Total increase in mid-tropospheric temperature during 40 years: 0.7 ± 0.1°C

EL Nino (1983) El Nino (1998) El Nino (2016)

Stable SNPP Orbit Makes ATMS A Reference for Long-Term Monitoring

- Comparison between Aqua/AMSU and SNPP/ATMS suggests that both instruments achieve a radiometric stability within 0.004K/Year
- Stable observations from SNPP and Aqua are being used as references in CDR development
- MSU/AMUS/ATMS merging is ongoing for long-term monitoring
- Higher merging accuracy is expected with stable SNPP/ATMS observations as references



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).

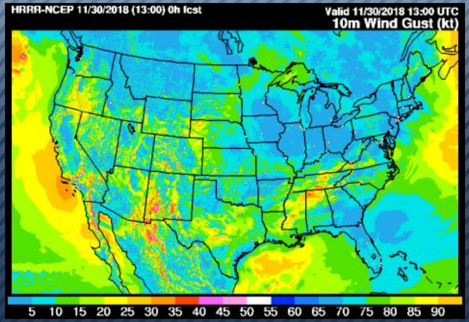


Lessons Learned from ProbSevere and VOLCAT

Michael Pavolonis

NOAA/NESDIS

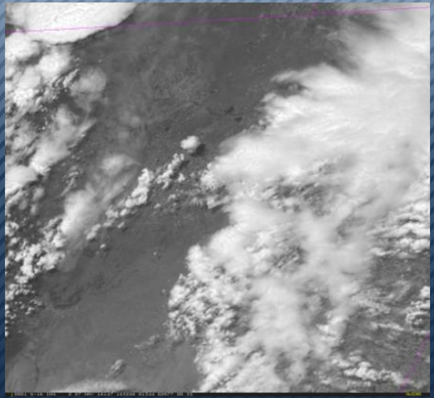
NOAA / CIMSS ProbSevere Model



High-resolution NWP Data

↓

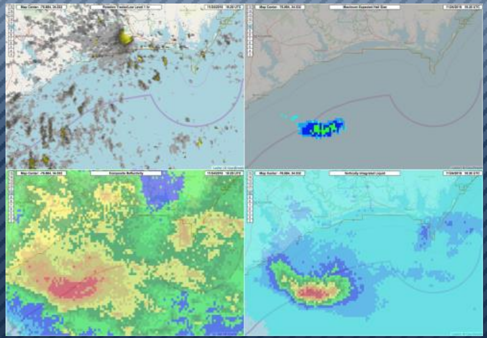
<u>storm environment</u>



GOES Imagery and Derived Products

↓

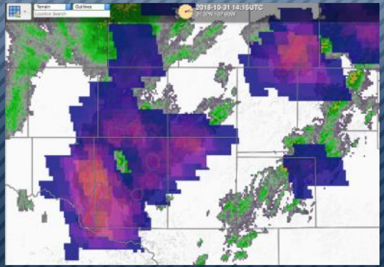
<u>evolution of cumulus to cumulonimbus</u>



MRMS Products

↓

<u>storm tracking and hydrometeor properties</u>



Total Lightning

↓

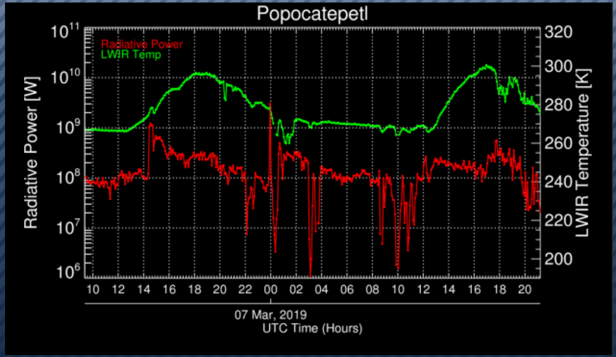
<u>storm electrification</u>

Probability a thunderstorm will produce severe hail, wind, or tornado in the future (up to 90 minutes)

Images are from NOAA and UW-CIMSS

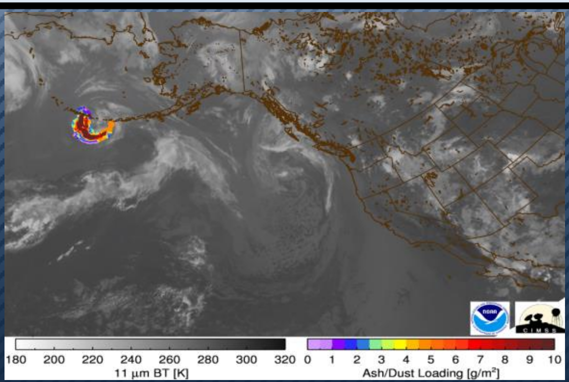
VOLcanic Cloud Analysis Toolkit (VOLCAT)

1). Thermal Output

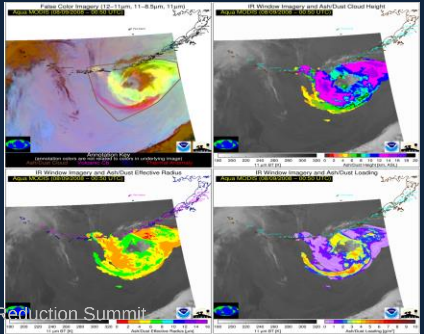


2). Eruption Alerts

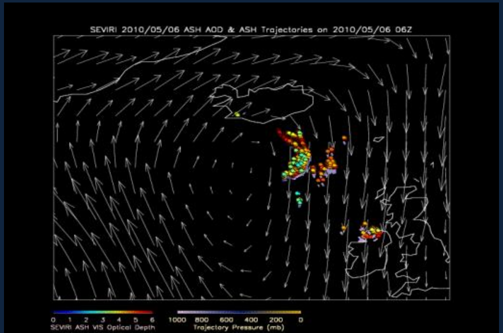
3). Volcanic Cloud Tracking



4). Volcanic Cloud Characterization



5). Dispersion Forecasting



The Benefit: Higher Order Products

- From fire hose to sprinkler
- Workflow harmony
- “Automated assistant”
- A different kind of stovepipe

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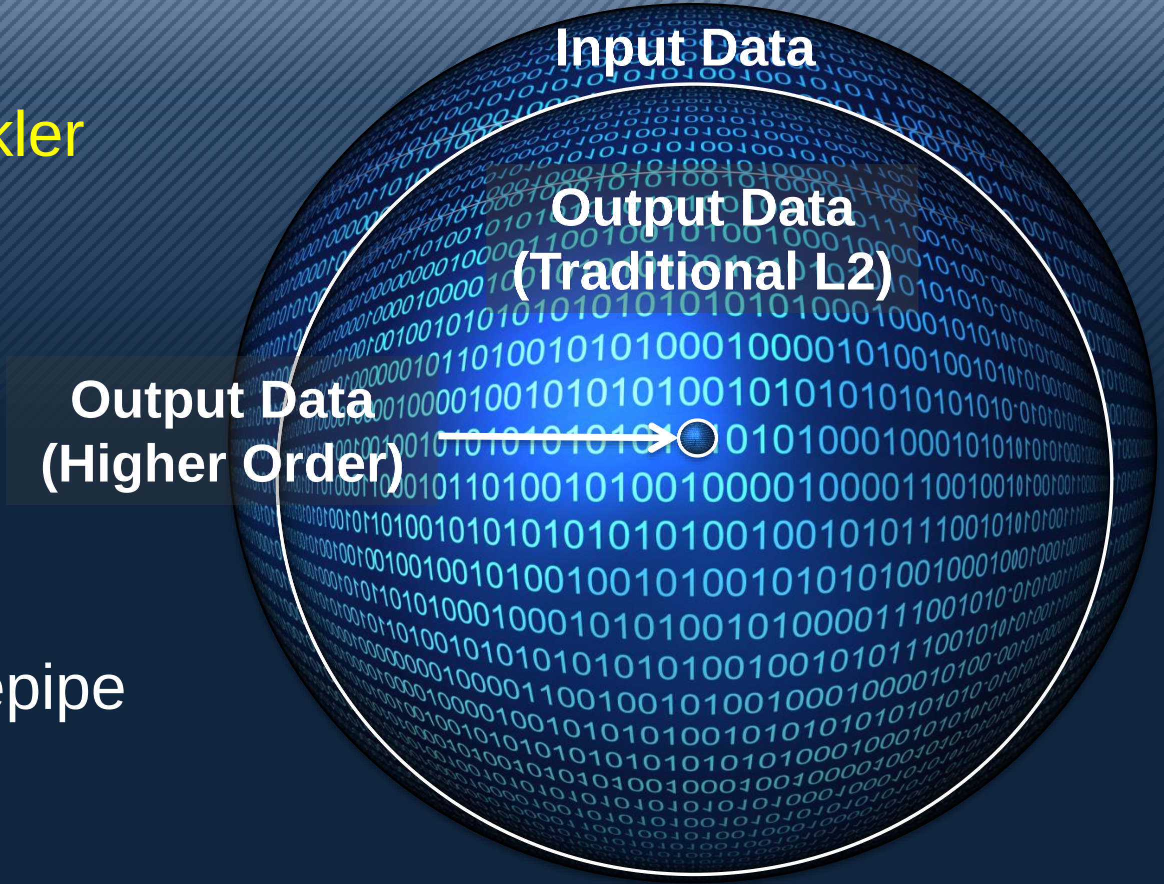
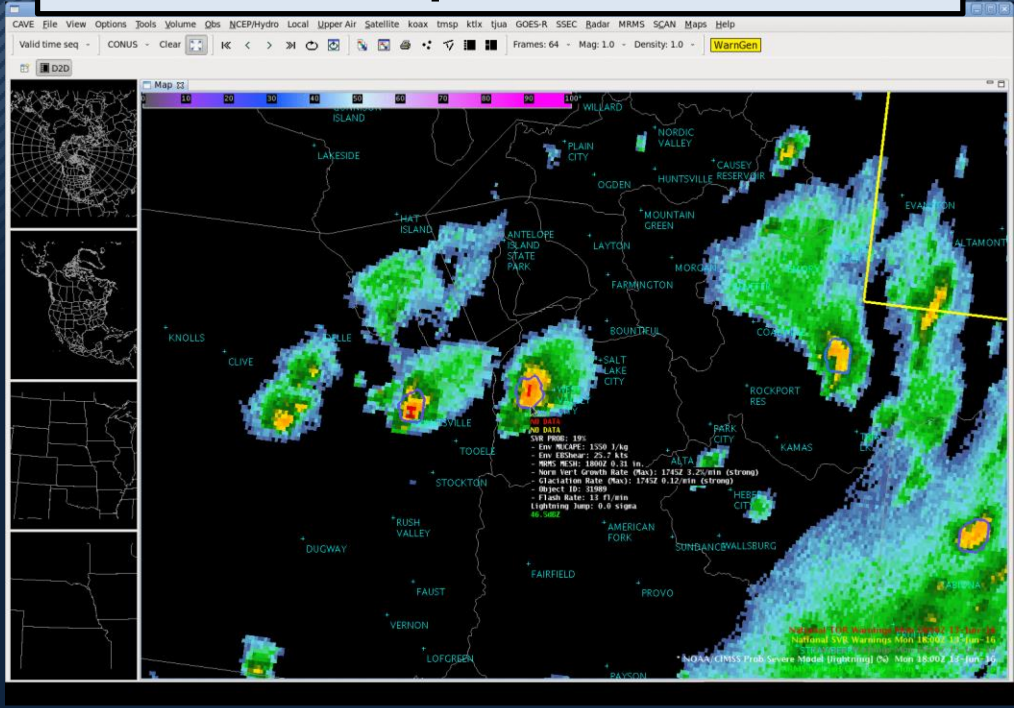


The Benefit: Higher Order Products

Monitor space, time, and base data are precious!

- From fire hose to sprinkler
- Workflow harmony
- “Automated assistant”
- A different kind of stovepipe

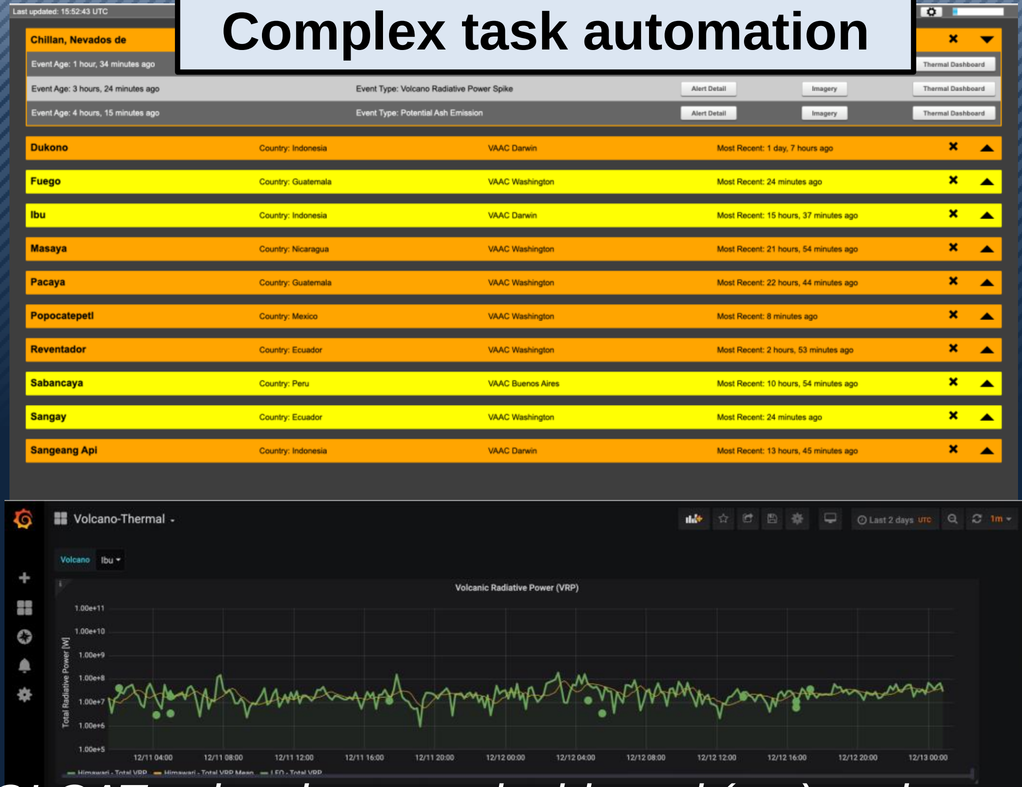


ProbSevere display is part of base radar display

The Benefit: Higher Order Products

- From fire hose to sprinkler
- Workflow harmony
- “Automated assistant”
- A different kind of stovepipe

Complex task automation

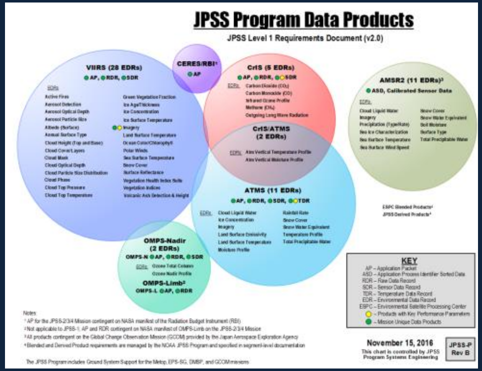


VOLCAT volcanic event dashboard (top) and interactive thermal output monitoring tool (bottom)

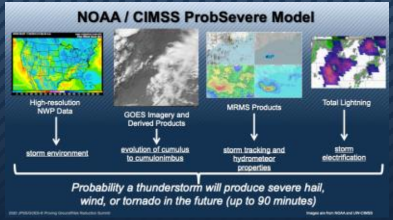
The Benefit: Higher Order Products

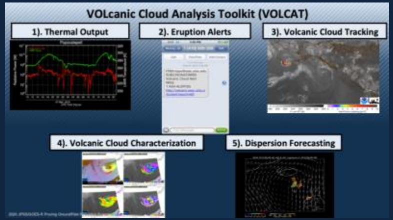
- From fire hose to sprinkler
- Workflow harmony
- “Automated assistant”
- A different kind of stovepipe

Mission Specific Products



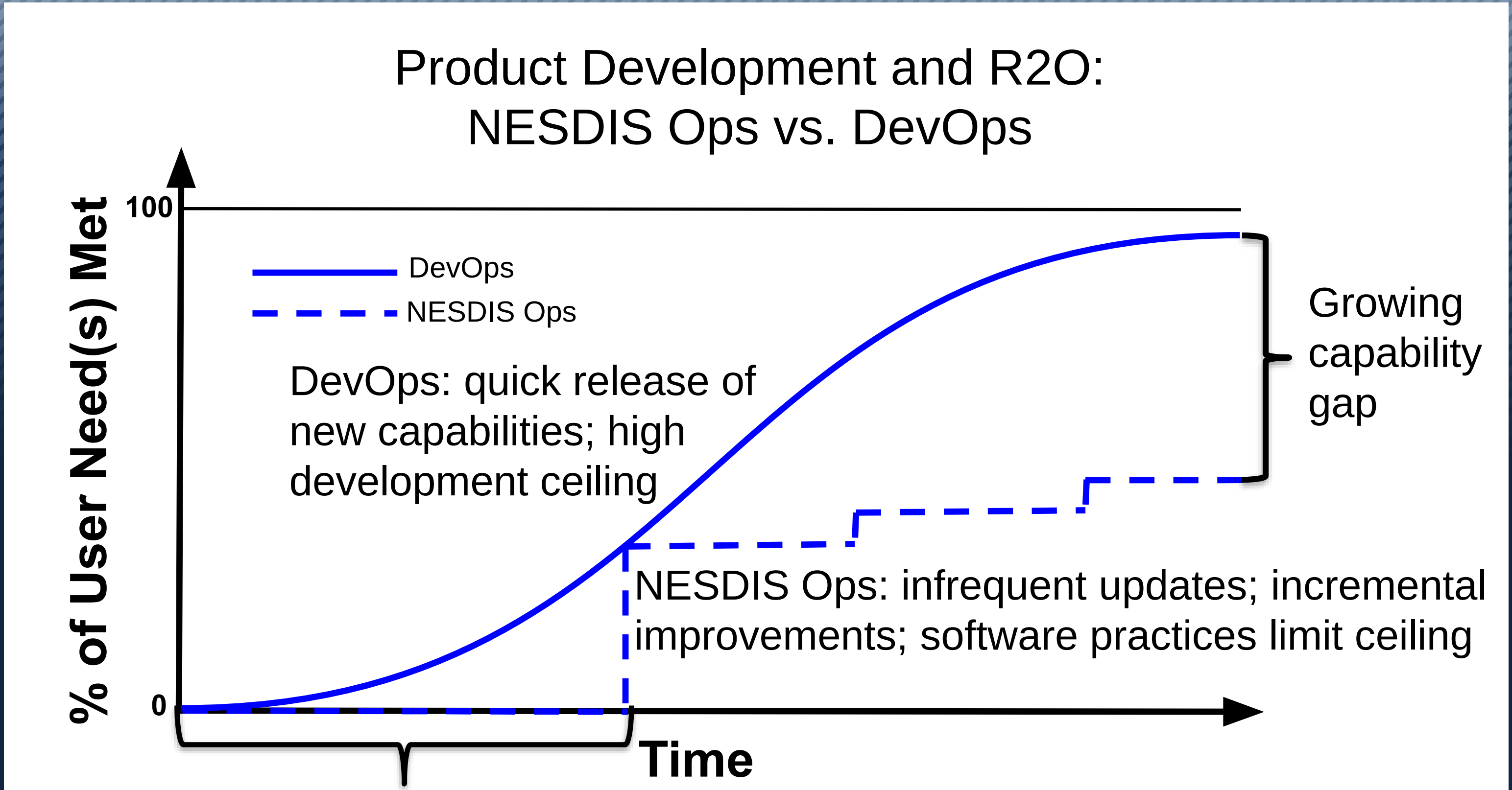
Thematic Applications





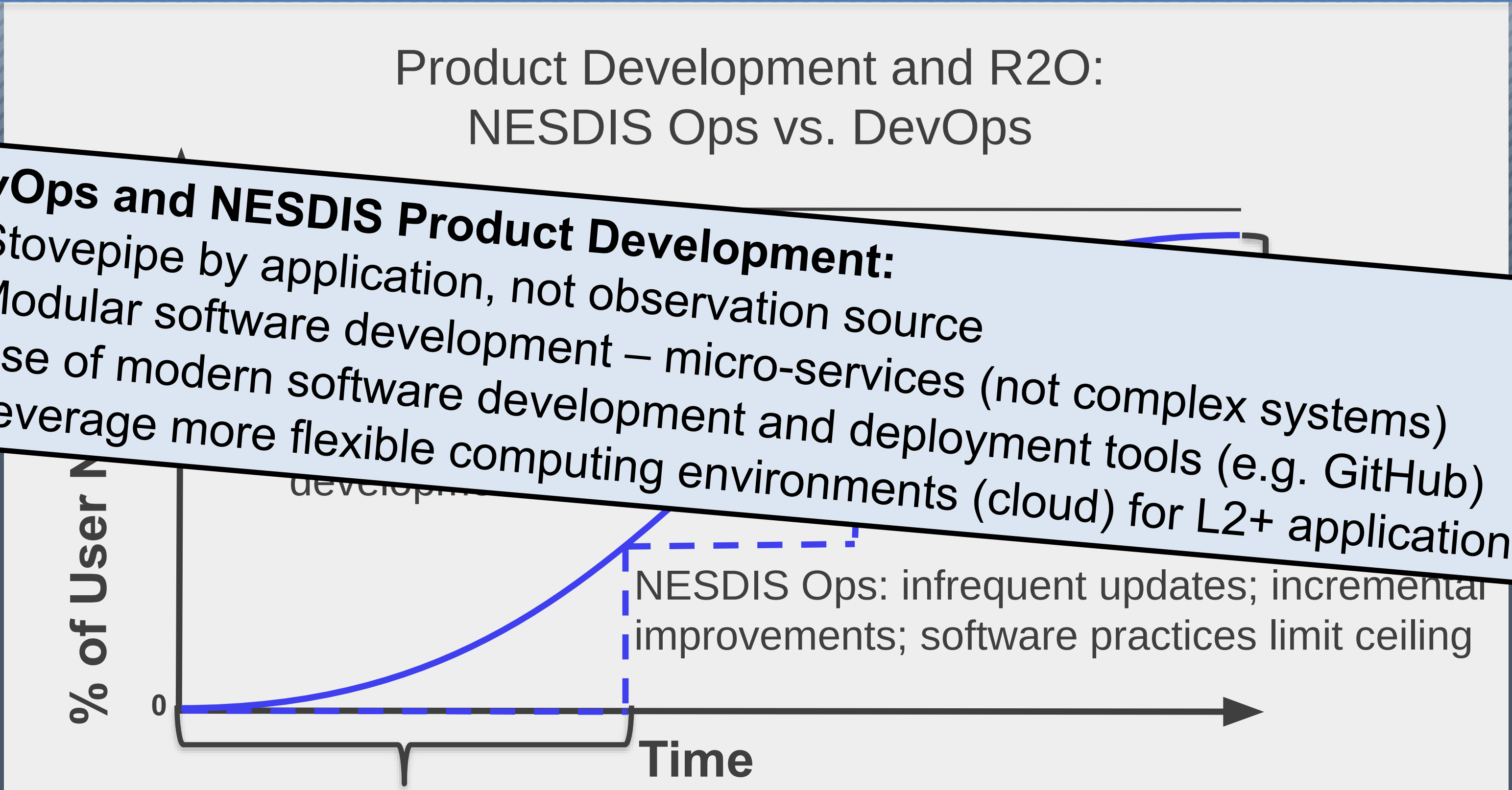
Many other possibilities!

The Disruption: Development and R2O Cycle



Time required for development, testing, and R2O transition

The Disruption: Development and R2O Cycle

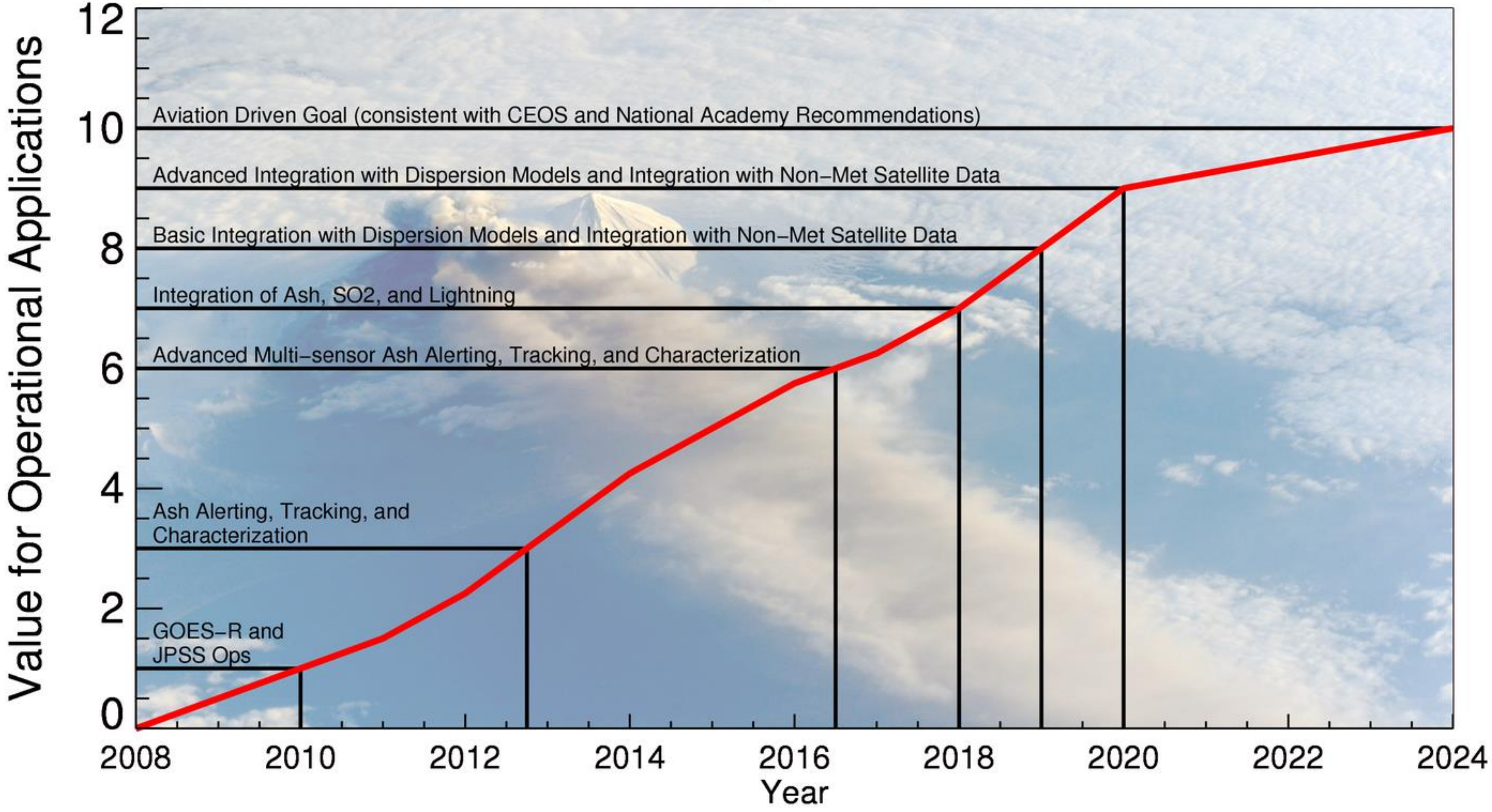


Time required for development, testing, and R2O transition

DevOps and NESDIS Product Development:

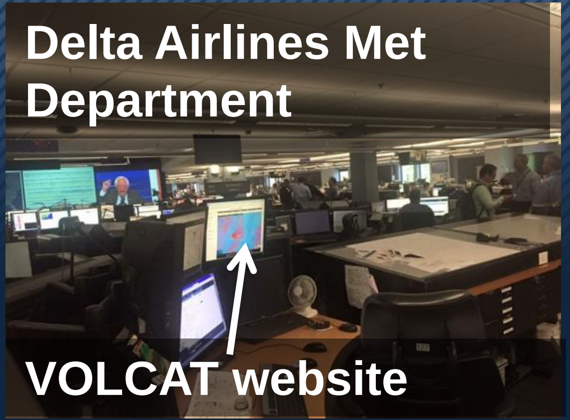
- Stovepipe by application, not observation source
- Modular software development – micro-services (not complex systems)
- Use of modern software development and deployment tools (e.g. GitHub)
- Leverage more flexible computing environments (cloud) for L2+ applications

VOLCAT Development and Benefits



Other Thoughts

- Traditional derived product definitions are inadequate and confusing



- Government and private sector roles
- Too much specialization?
- Many more thematic applications are possible
- What about product requirements?

NOAA
Satellite and Information Service

The NESDIS Cloud Framework

A Common, Data-Agnostic Cloud Computing Solution

28 February 2020

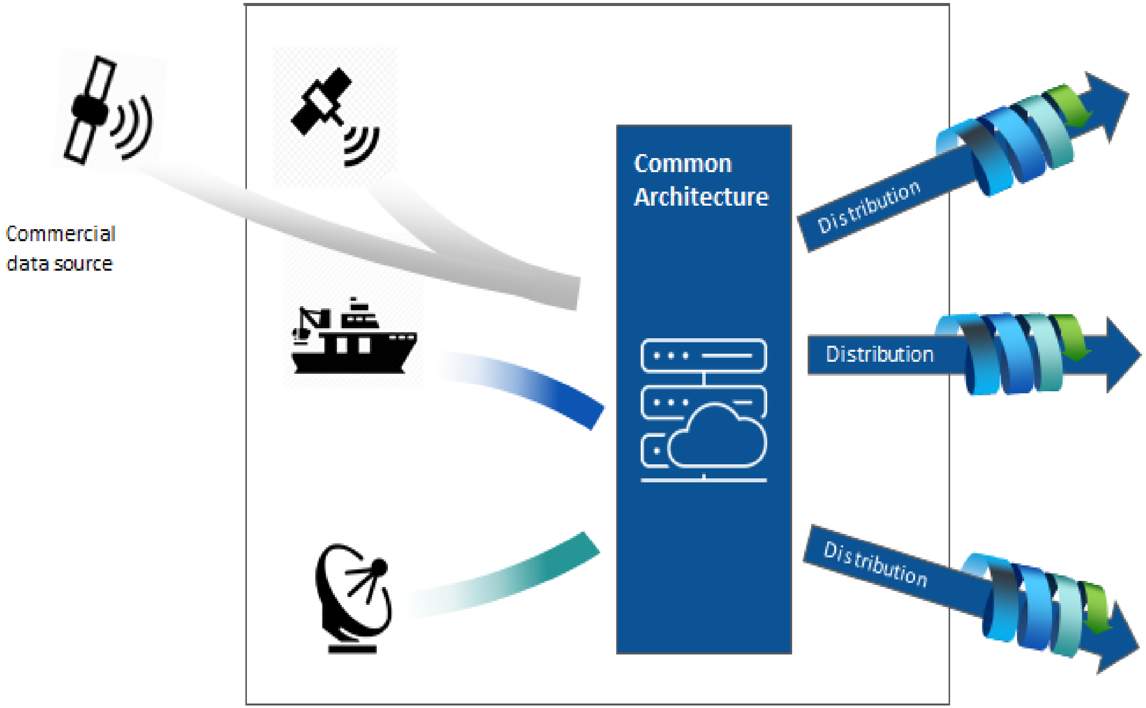
Kathryn Shontz
NOAA Office of System Architecture and Advance Planning

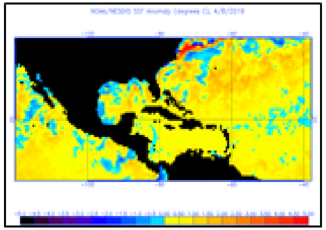
NESDIS Strategic Objectives

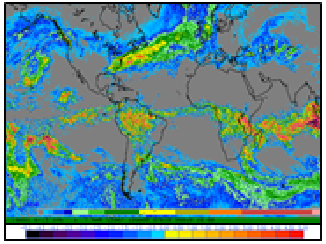
Advance observational leadership in geostationary and extended orbits	**Evolve LEO architecture to enterprise system of systems that exploits and deploys new observational capabilities**	**Develop agile, scalable ground capability to improve efficiency of service deliverables and ingest of data from all sources**	**Provide consistent ongoing enterprise-wide user engagement to ensure timely response to user needs**	**Deliver integrated program development to provide a suite of products and services**

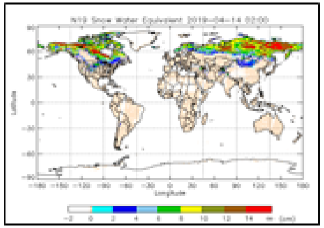
- The next generation ground service capability will **need to scale** to accommodate ever increasing data source volumes and **be flexible** enough to bring in any type of data
- Lean into innovation solutions by asking: ***Why not the commercial cloud?***

The NESDIS Cloud Vision





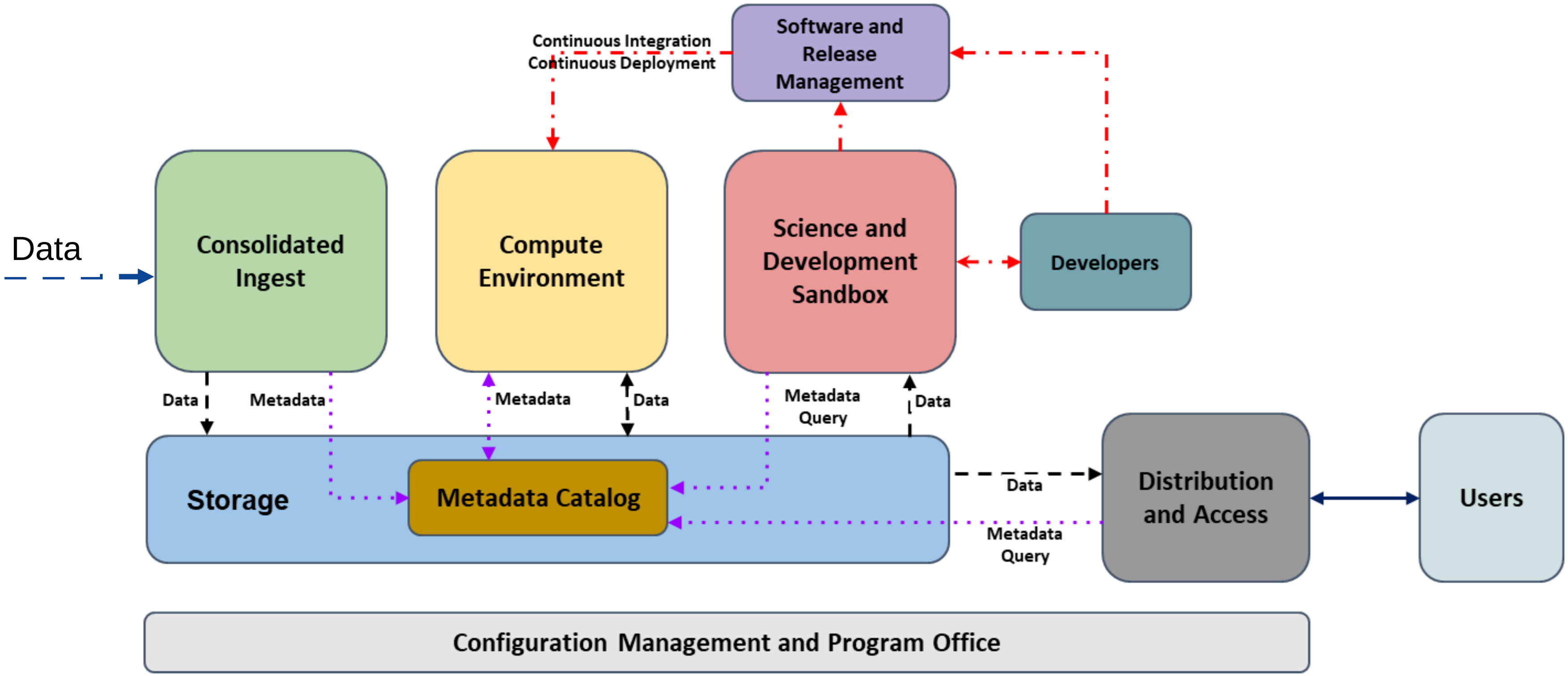




Centralize all NESDIS data holdings and bring the processing to the data

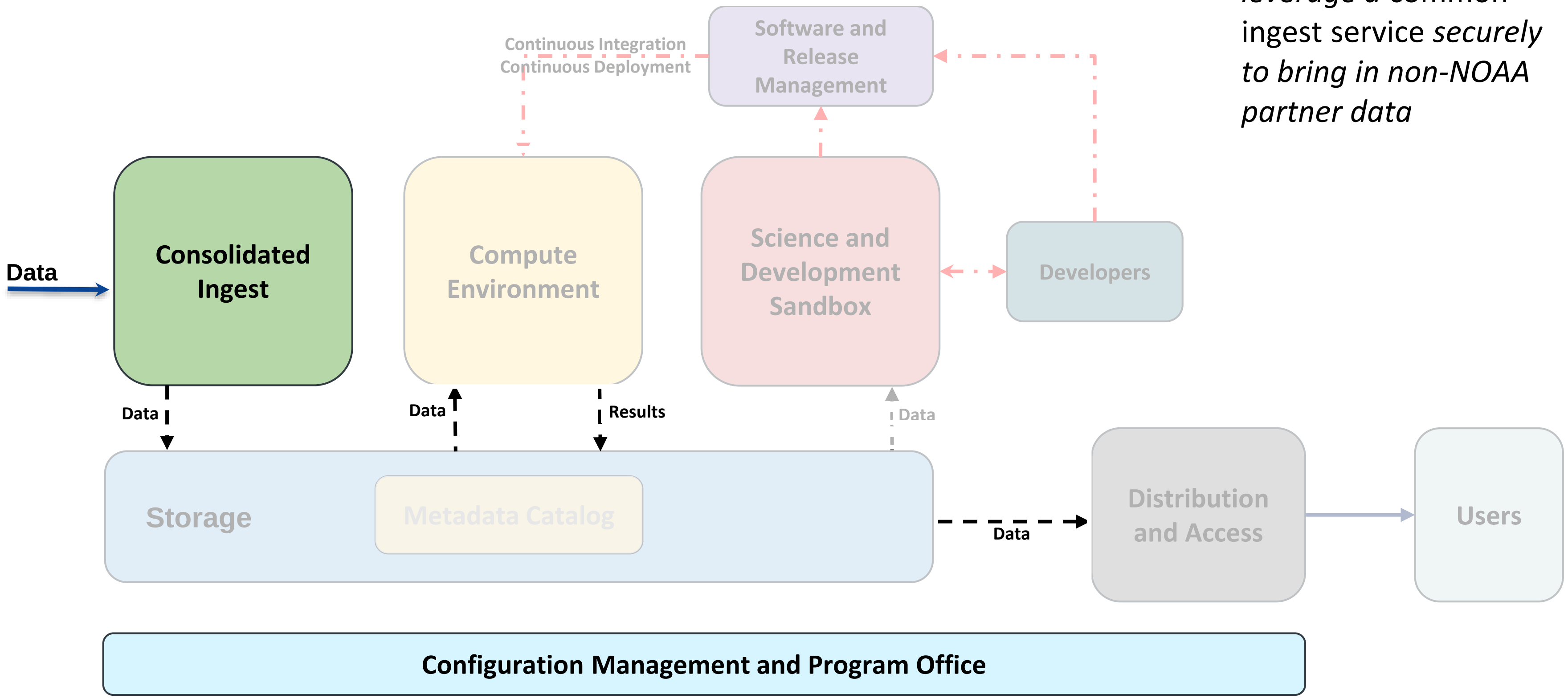
NESDIS Cloud Framework Architecture

- **Framework** - Enables a set of services to work together to deliver mission value
- **Service** - How to meet the core NESDIS IT functions
- **Tool** - Cloud software application(s) used to implement the service



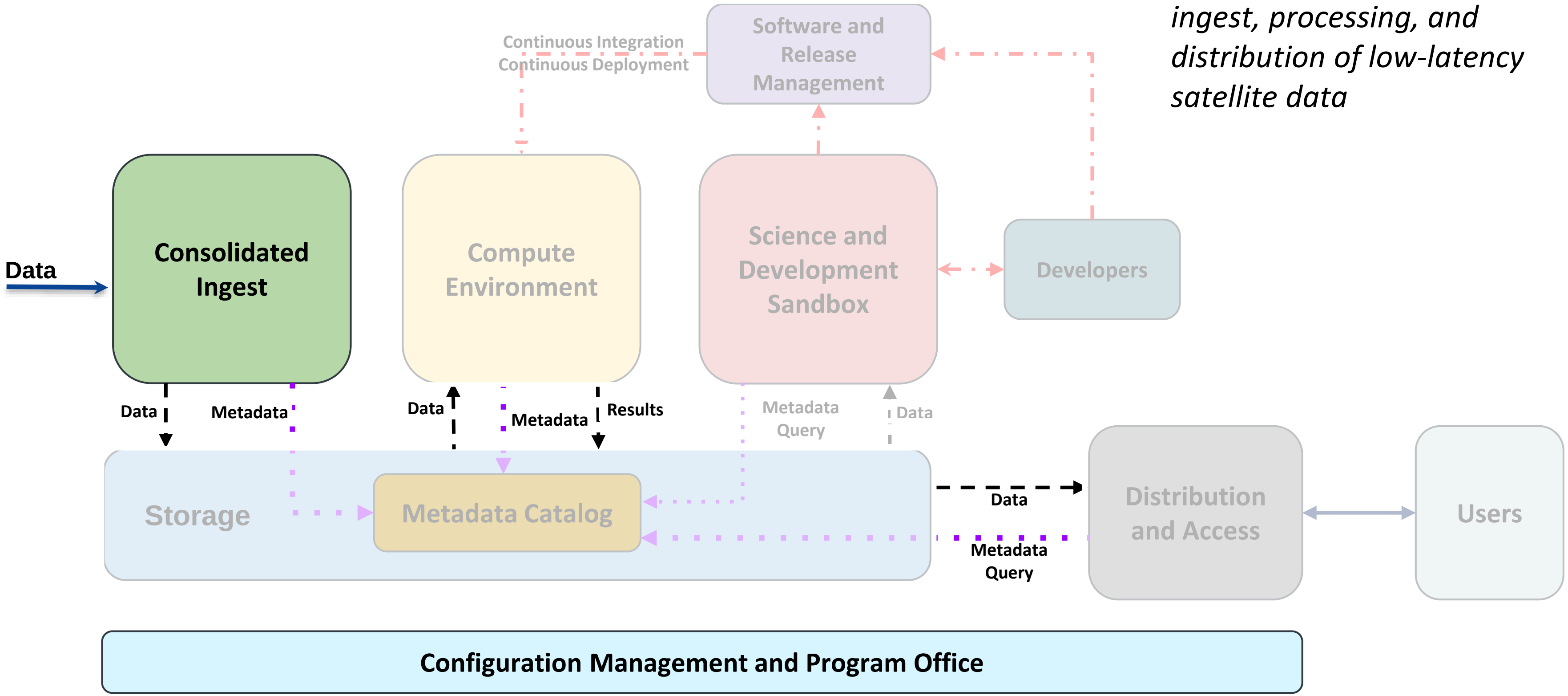
Cloud Framework Use Case – Secure Data Ingest Workflow

This depicts how to leverage a common ingest service *securely to bring in non-NOAA partner data*

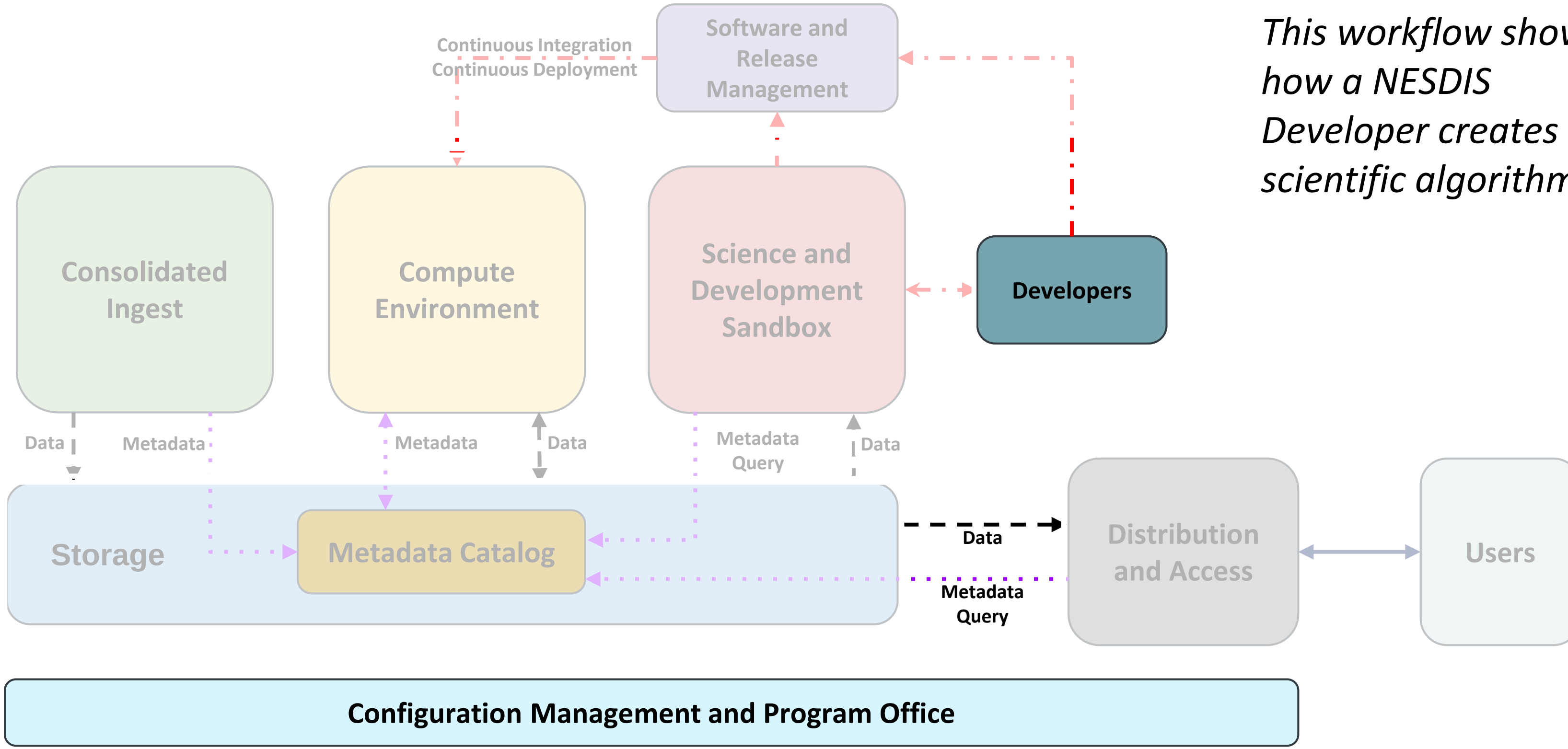


Cloud Framework Use Case – Satellite Data Processing Workflow

This represents a nominal workflow of operational ingest, processing, and distribution of low-latency satellite data



Cloud Framework Use Case – Science Development Workflow



This workflow shows how a NESDIS Developer creates a scientific algorithm

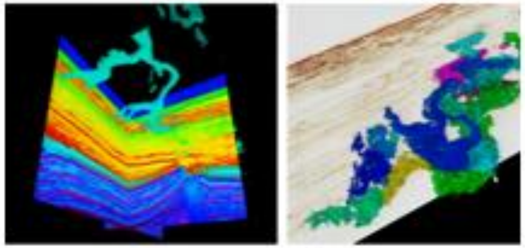
Future NESDIS Cloud Development

Cloud Native Data Format

Objective: Explore Zarr as the cloud-native data format to facilitate improved science data usability.

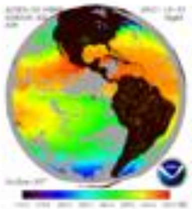
Automation

Objective: Implement an enterprise automated Continuous Integration (CI) and Continuous Deployment (CD) pipeline.

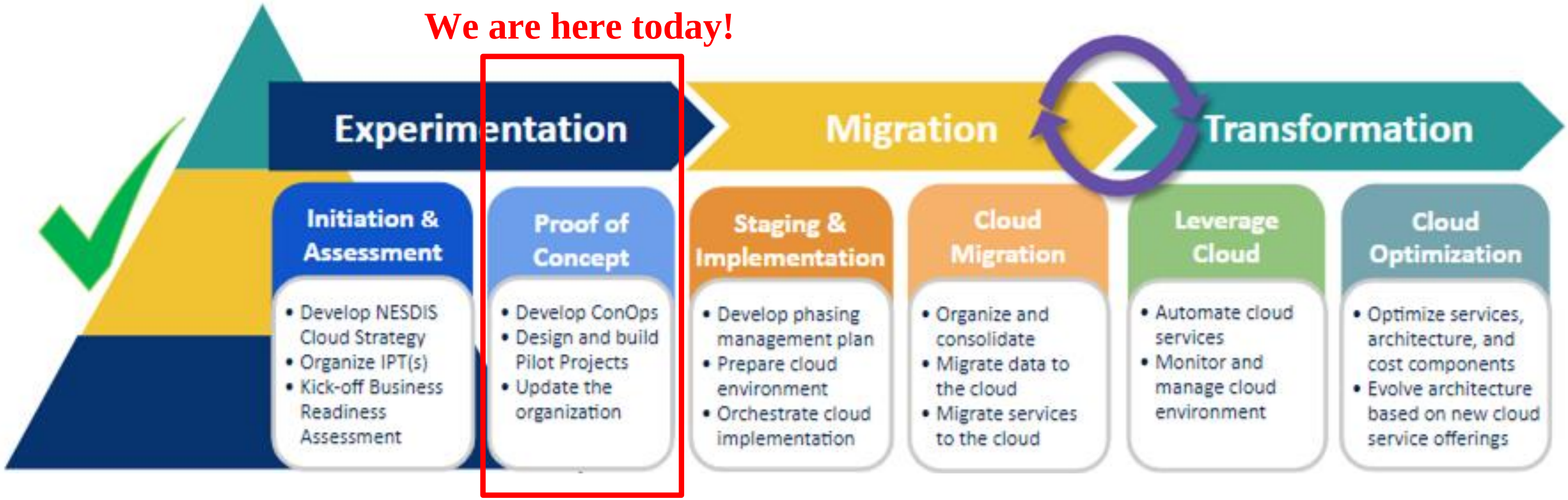


Data Visualization

Objective: Evaluate the performance of data visualization tools.

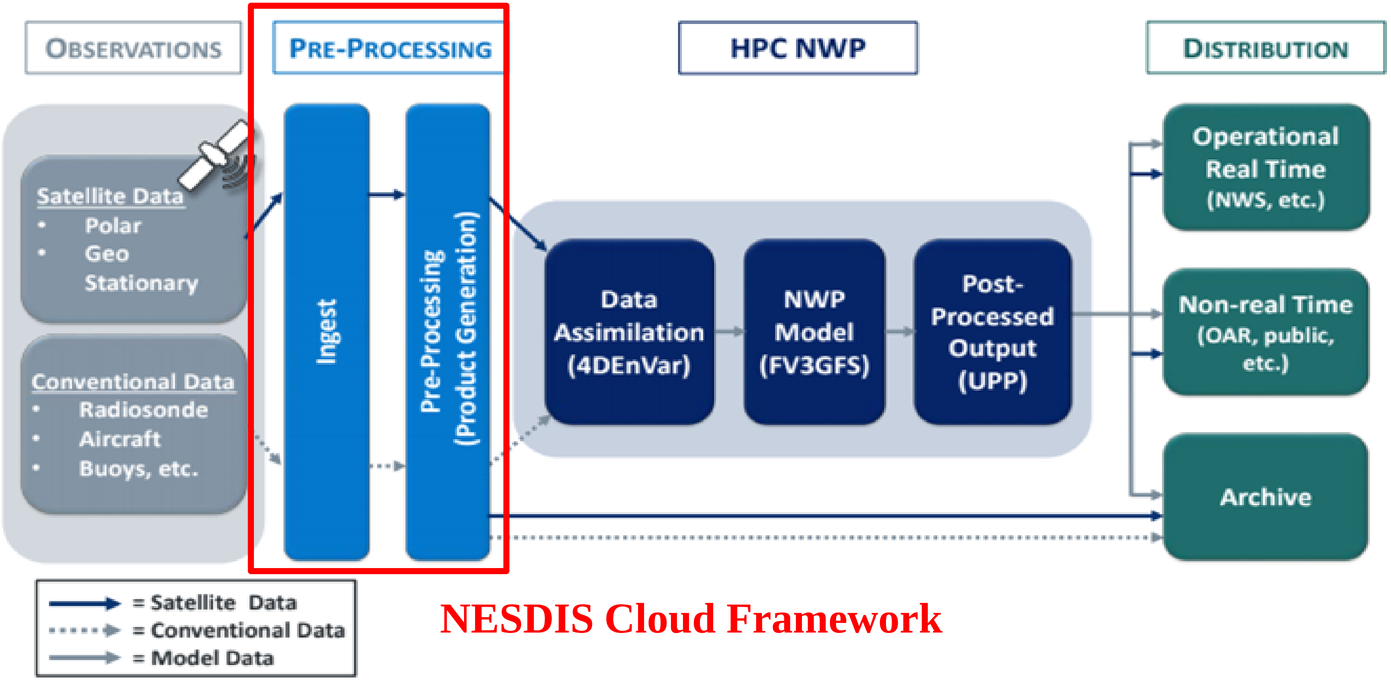


NESDIS Cloud Transformation Roadmap



- NESDIS demonstrated that there is an advantage to bringing the processing to the data through a ***lean-in approach to innovation***
- Adoption of an enterprise cloud framework fundamentally alters the business and processes we use today, so we are tackling that head on with a ***dedicated change management team***

A NESDIS Solution for All of NOAA



- **NESDIS developed the Cloud Framework from High Performance Computing (HPC) Industry best practices**
- **Working with OAR to test viability of the NESDIS Cloud Framework for Numerical Weather Prediction**

A Better Infrastructure Future

- **Secure** – FISMA-compliant FedRAMP Moderate Cloud supports all Cloud Framework Services, tailoring controls to High in applicable areas
- **Fault-Tolerant** – **redundant and highly available** services provide robust applications
- **Scalable** – capacity to **accommodate all current and future workloads**
- **Data Agnostic** – enable any data type and workflow within the framework
- **Decoupled** – **services are independent** of each other and are interchangeable
- **Cloud Agnostic** – workloads and services run in **any cloud service provider**
- **Resources On-Demand** – **rapid provisioning** of cloud framework services based on business needs
- **Agile** – support **faster transition to operations** with DevOps

User-Driven Innovation

Renata Lana, NESDIS
renata.lana@noaa.gov

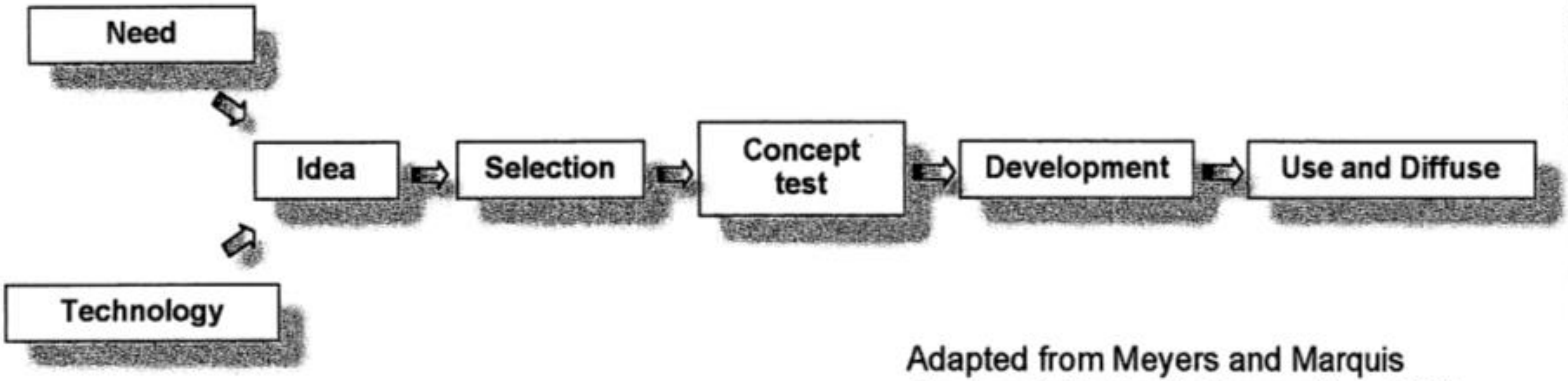
What is Innovation?

Innovation is . . .
technological invention used and adopted

“The adoption of a new idea almost always entails the sale of a new product.” (1962, Sociologist E.M. Rogers)

Figure 1

The Model of Innovation



Adapted from Meyers and Marquis
Successful Industrial Innovation, 1969.

What are user “needs,” and how do you identify those?

Needs ≠ Requests ≠ Requirements

“This year we will sell about one million quarter-inch drill bits. Our customers do not need quarter-inch drill bits. Our customers need quarter-inch holes.”

(Director of Marketing, Electric tool maker.)

Asking Users What They Need Doesn't Work

- They don't know what's possible. Or . . .
- They will only share with you what they think you can take care of. Or . . .
- Users tend to think of "features", not needs. Or . . .
- They will tell you everything you can do for them, but what they ask for may be way down in their list of what is <u>really</u> important to them.

What’s the real need?

Request: “We need a way to reduce wrinkles”

Need: We need a way for wrinkles <u>not to be seen</u>

How do we uncover needs?

Observe our users, observe the environment, and ask the right questions.

1. *How could users do their job faster, with less variability, or more efficiently?*
2. *How are our users modifying our existing products or creating workarounds?*
3. *How does the user react to the initial prototype?*
4. *What drivers will emerge when current drivers are satisfied?*
5. *How will the future affect users? (trends, tech forecasting, scenarios, etc.)*

Which of these strategies does NOAA use to identify user needs?

- User interviews
- Diary studies
- Persona building
- Task analysis
- Journey mapping
- Pluralistic walkthrough
- Card sorting
- Social media monitoring
- Forum post analysis
- Benchmark testing
- Search-log analysis
- Ethnographic research
- Longitudinal studies
- Online surveys
- First-click testing
- Heuristic evaluations
- Scenario-based tabletop exercises
- Observational field studies

So What Now? In 2020 we will:

1. Create a playbook for conducting coordinated and innovative user engagement across NESDIS

2. Create a centralized enterprise data repository for compiling and sharing user needs

3. Create a plan to increase staff skills in the area of user engagement

4. Create a protocol for assessing how useful, usable, and used our products and services are

5. Establish an enterprise-wide process to adjudicate between user needs.

6. Establish role clarity between product development and user engagement with checkpoints for user engagement across the product development lifecycle

7. Develop a plan for capturing and incorporating user needs into design decisions for next generation satellites (starting with GEO XO)

“The riskiest thing we can do is just maintain the status quo.“

Bob Iger, CEO of The Walt Disney Corporation, 2005 to 2020

Air Force Space-Based Environmental Monitoring (SBEM) Update

HQ USAF Directorate of Weather (AF/A3W)

28 February 2020

Dr. Michael Farrar, Chief Scientist

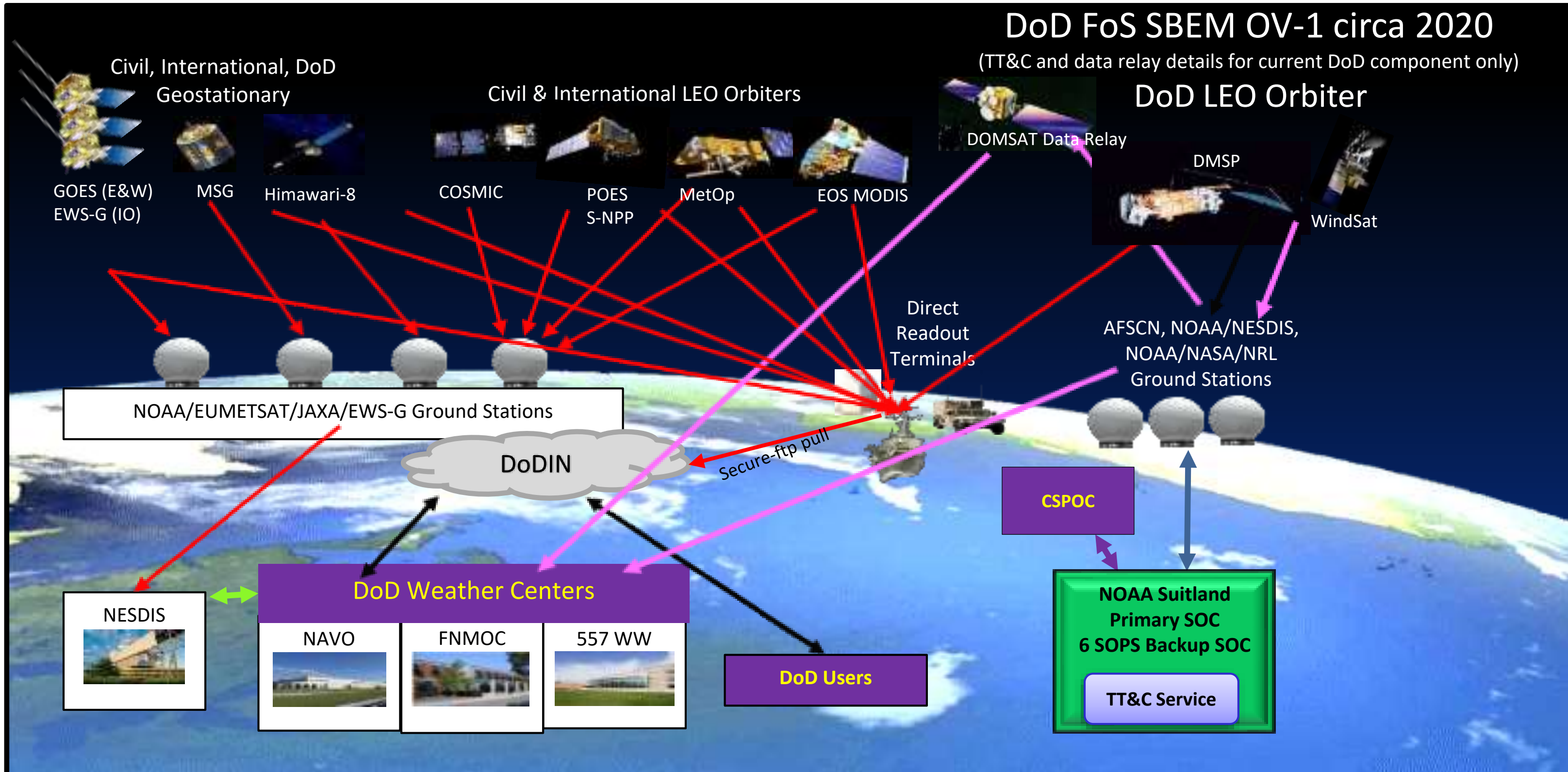
Lt Col Adam DeMarco, SBEM Subject Matter Expert

U.S. AIR FORCE

Space-Based Environmental Monitoring (SBEM) Overview

- **The Air Force, and now the Space Force, is responsible for providing the Joint forces with SBEM capabilities (atmospheric, ocean, and space weather)**
- To provide global coverage, we rely on a Family of Systems (FoS) from civil, international and military satellites
- We own and operate a LEO constellation called Meteorological Satellite Program (DMSP) providing imagery (Vis/IR/microwave) and a space weather capability
- Recently procured a GEO satellite (GOES-13) from NOAA
- We ingest a myriad of satellite data into the 557th Weather Wing
  - Feeds into our global model & various cloud, land surface, and space weather models
  - Shared with weather forecasters that support global military operations

Family of Systems (FoS) Operational View 2020



DoD Spacecraft Command & Control, Status &Telemetry
Stored Mission Data
Data and Products
Federated Gateway
System Status Data
Real-time SBEM Data

557 WW: 557th Weather Wing CSpOC: Combined Space Operations Center DoDIN: Department of Defense Information Network EWS: Electro Optical/Infrared Weather System ESBMC2: Enterprise Space Battle Management Command and Control EUMETSAT: European Organization for the Exploitation of Meteorological Satellites FNMOC: Fleet Numerical Meteorology and Oceanography Center JAXA: Japanese Aerospace Exploration Agency MUS: Mission Unique Software NASA: National Aeronautics and Space Agency NAVO: Naval Oceanographic Office NESDIS: National Environmental Satellite, Data, and Information Service NSDC: National Space Defense Center SAAS: SBEM As A Service SOC: Satellite Operations Center SpEAR: Space Environment Anomaly Resolution TT&C; Telemetry, Tracking, & Commanding WSF-M: Weather System Follow-on, Microwave

Space-Based Environmental Monitoring (SBEM) Future

- **The AF is restructuring its SBEM architecture and acquisition strategy to focus on resilient constellations vs single point of failure**

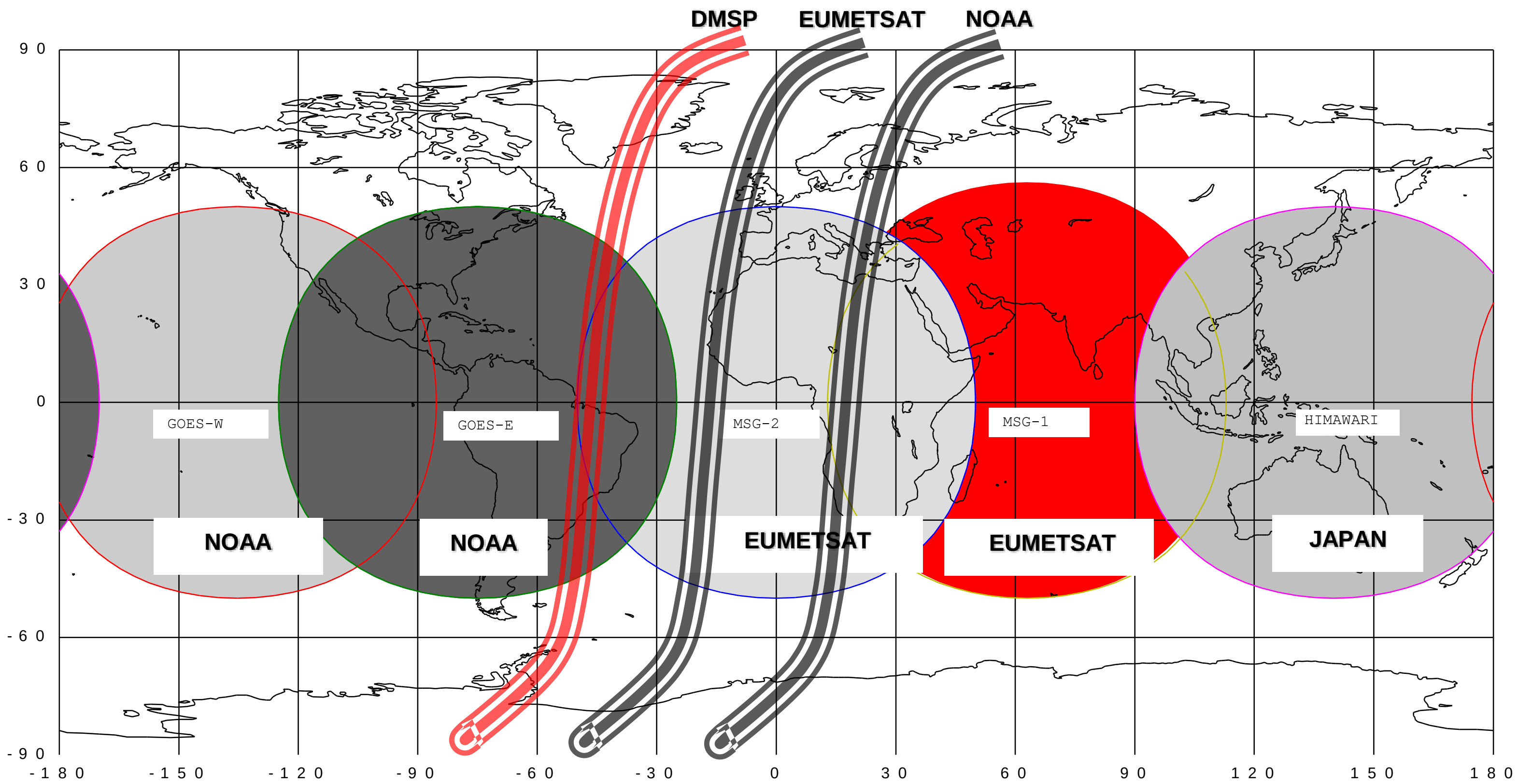
- **Initial focus on Electro-Optical/Infrared (EO/IR) – Cloud Characterization (CC) & Theater Weather Imagery (TWI) – Our top sensing priority**
  - Replaces current Defense Meteorological Satellite Program (DMSP) capabilities
  - Increases resiliency & scalability
  - Better balances DoD reliance on civil & international partnership architecture (Family of Systems (FoS))
  - Potential to grow into other SBEM capabilities (*e.g.;* ocean surface vector winds & tropical cyclone intensity)
  - Aligns with congressional interest in promoting commercial capabilities for space and weather services

- **This distributed LEO Strategy has associated risk**
  - Key DMSP sensors projected to reach end of life (EoL) prior to IOC
  - Smaller sensors for distributed LEO (d-LEO) architecture need to be matured
  - d-LEO risk to be mitigated w/ high TRL sensor into legacy architecture (if required)

On-ramps affordable, resilient capabilities for SBEM Joint users

Family of Systems (FoS) Potential Gaps

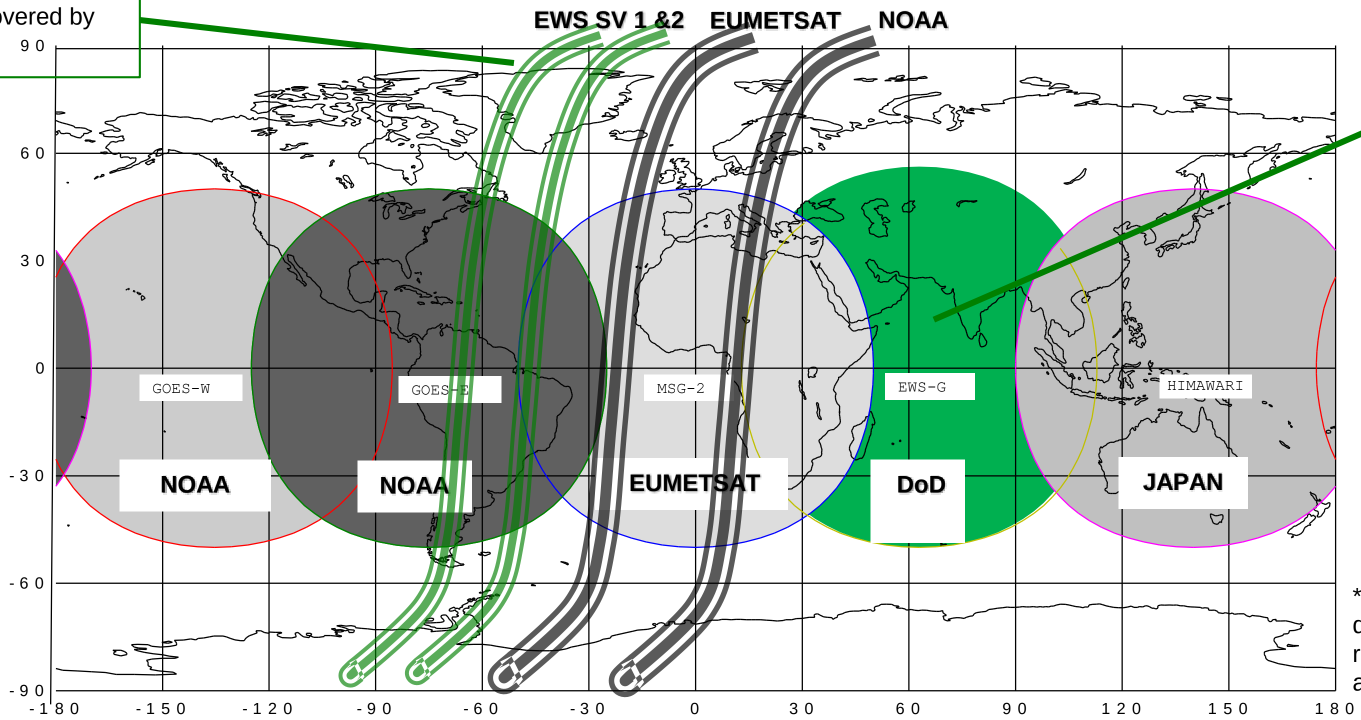
- DMSP Operational Line Scanner (OLS) sensor Projected End of Life (EoL) 4Q2023
- MET-8 Projected EoL mid 2022



EO/IR Weather System – Geostationary (EWS-G) and EO/IR Weather System (EWS)

- EWS-G in-place, Full Operational Capability (FOC) expected mid-2020, EoL 2023-2025
- EWS Initial Operational Capability (IOC) ~2025

High latitude Refresh Gap to be covered by EWS IOC

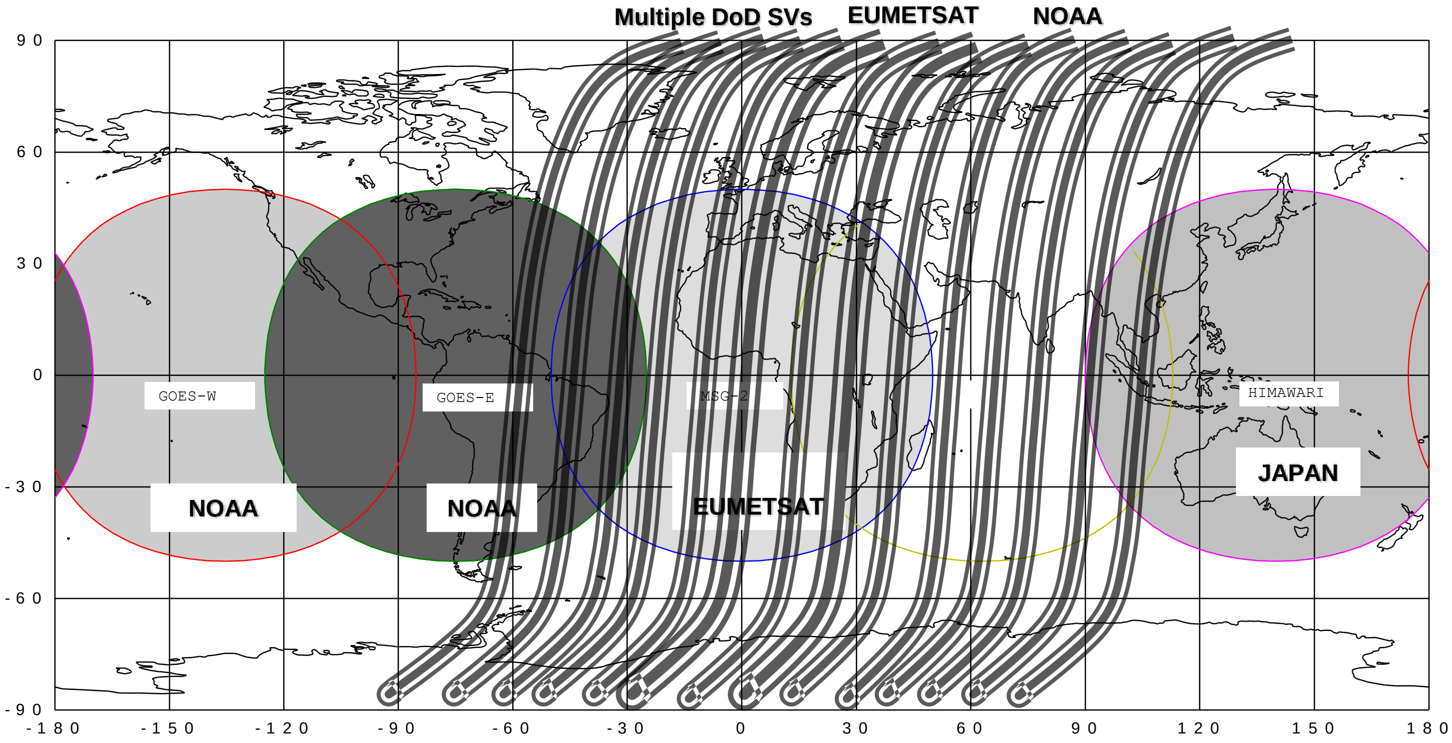


EWS-G to cover Indian Ocean Gap, discussion w/ NOAA beginning for Space Vehicle-2 (potentially GOES-14/15)

*Notional EWS IOC design that may not represent final architecture

EO/IR Weather System (EWS) Full Operational Capability

- EWS FOC ~ 2030 depending on investment
- Fills both Indian Ocean and High Latitude Gaps with d-LEO solution



*Notional design that may not represent final architecture

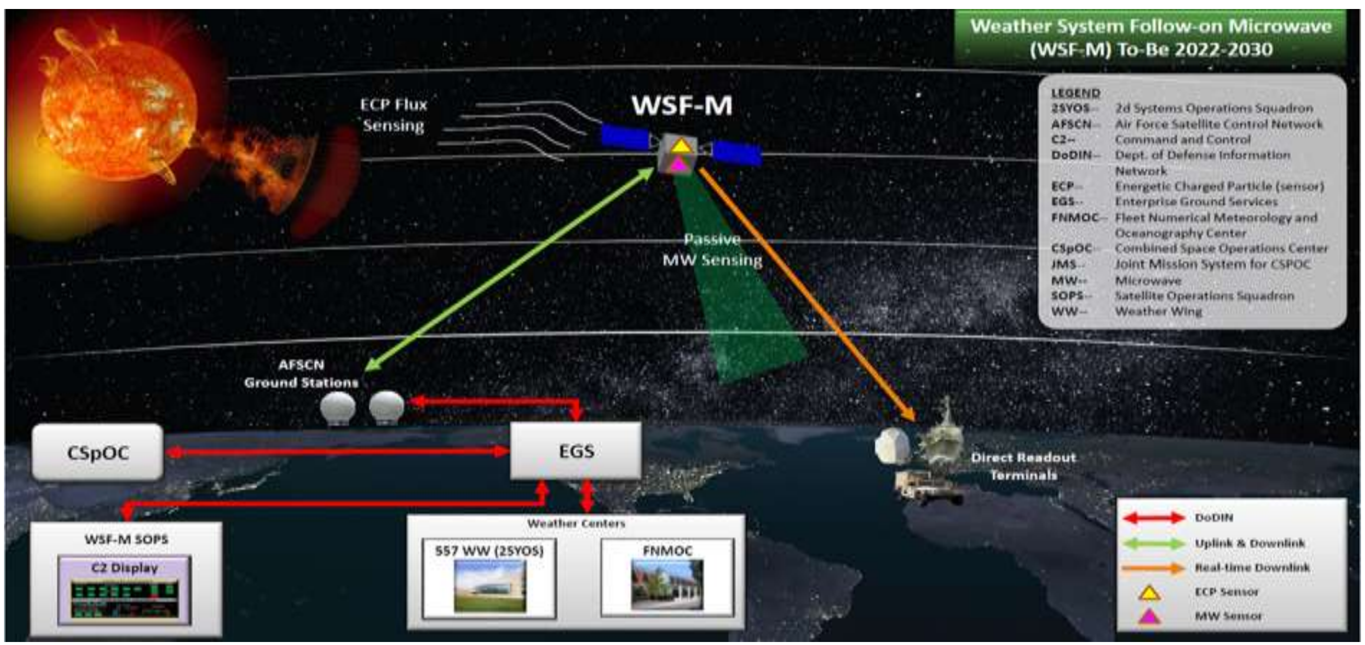
Integrity - Service - Excellence

Weather System Follow-on – Microwave (WSF-M)

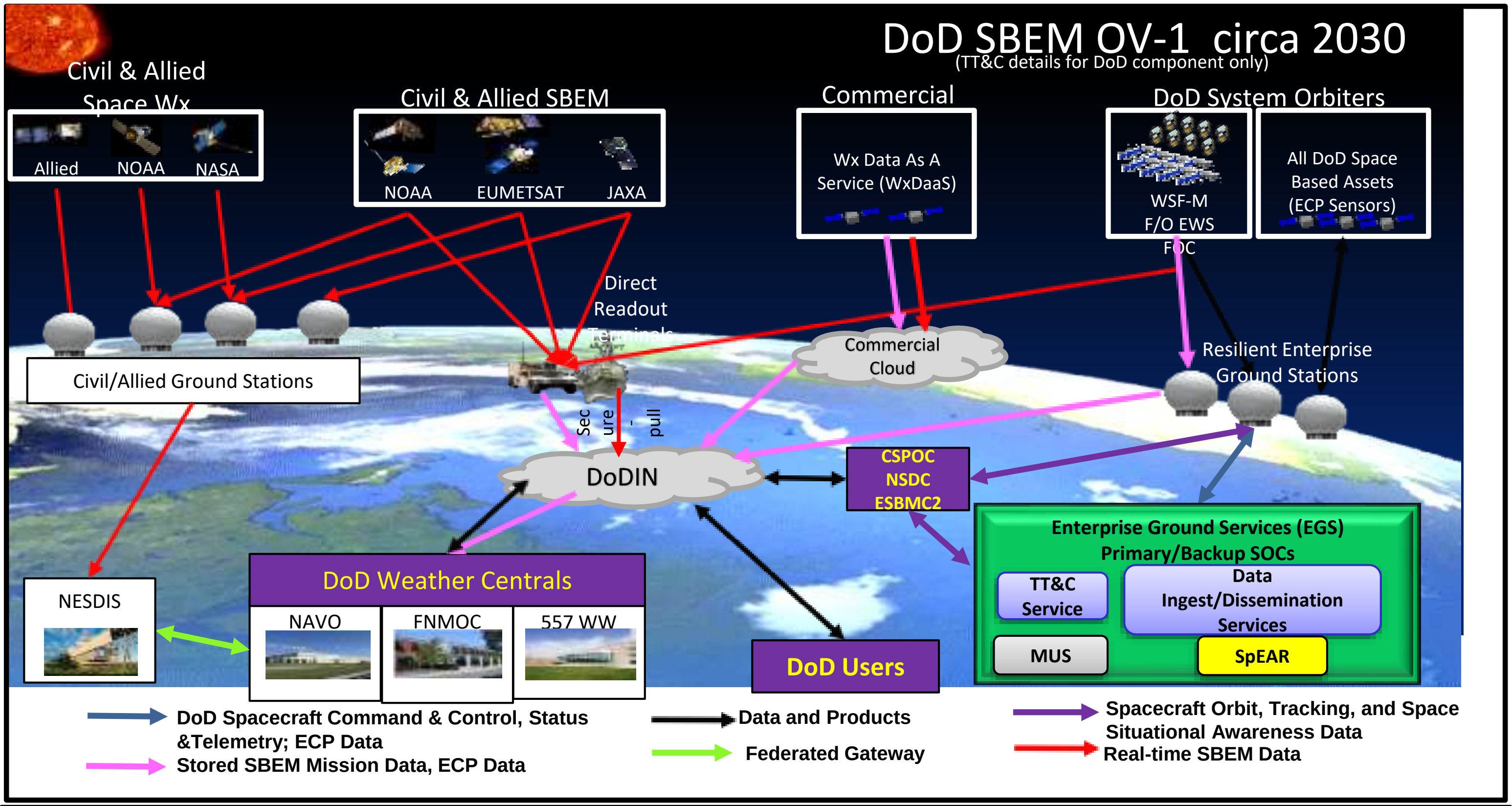
What:
- Joint Requirements Oversight Council directed a material solution to address Ocean Surface Vector Winds & Tropical Cyclone Intensity
  - Addresses SECAF hosted-sensor mandate for SBEM Energetic Charged Particles
- Low Earth Orbit (LEO), Sun-synchronous
- Ball Aerospace awarded design/build contract (Dec 17)

Ongoing Activities
- Milestone B approved – 5 Sep 19
- CDD JS Approved - Feb 20
- WSF-M Design/Build contract with Ball Aerospace
  - Multiple design reviews (Aug 19 - Mar 20)
  - System CDR - Mar 20

Initial Launch Capability - Nov 23
IOC/FOC – 2024/2025



Family of Systems (FoS) Operational View 2030



557 WW: 557th Weather Wing CSpOC: Combined Space Operations Center DoDIN: Department of Defense Information Network EWS: Electro Optical/Infrared Weather System ESBMC2: Enterprise Space Battle Management Command and Control EUMETSAT: European Organization for the Exploitation of Meteorological Satellites FNMOC: Fleet Numerical Meteorology and Oceanography Center JAXA: Japanese Aerospace Exploration Agency MUS: Mission Unique Software NASA: National Aeronautics and Space Agency NAVO: Naval Oceanographic Office NESDIS: National Environmental Satellite, Data, and Information Service NSDC: National Space Defense Center SAAS: SBEM As A Service SOC: Satellite Operations Center SpEAR: Space Environment Anomaly Resolution TT&C; Telemetry, Tracking, & Commanding WSF-M: Weather System Follow-on, Microwave

U.S. AIR FORCE

Strategy Opens Spectrum of Commercialization Opportunities

Legacy Approach, Single System

Gov't-Built, Gov't-Operated, Distributed Smallsats

Gov't Sensors on Commercially-Produced Satellites

Gov't Sensors Embedded in Commercial Constellations

Weather Data As A Service

Increasingly Commercialized

U.S. AIR FORCE

Summary

- **The AF ensures all services receive their meteorological and oceanography satellite needs through a combination of civil, international and military capabilities.**

- **Our future environment and our way forward**
  - VIIRS path produced unaffordable, single platform system that does not progress toward JROC-directed objective or Congressional interests
  - Move now to path that balances cost, performance, and schedule; on-ramps commercial capabilities & adds resiliency through proliferation

- **Key Attributes**
  - Introduces a pipeline of sensor maturation
  - Integration of commercial capability
  - Leveraged opportunities presented by SpaceX constellations

- **AF Global Weather Vision & NDS**
  - Lethality: Drive to reduced revisit rates to meet true warfighter needs
  - Balances alliances & partnering: multiple sources reduces mission risk

Questions?

Back-up

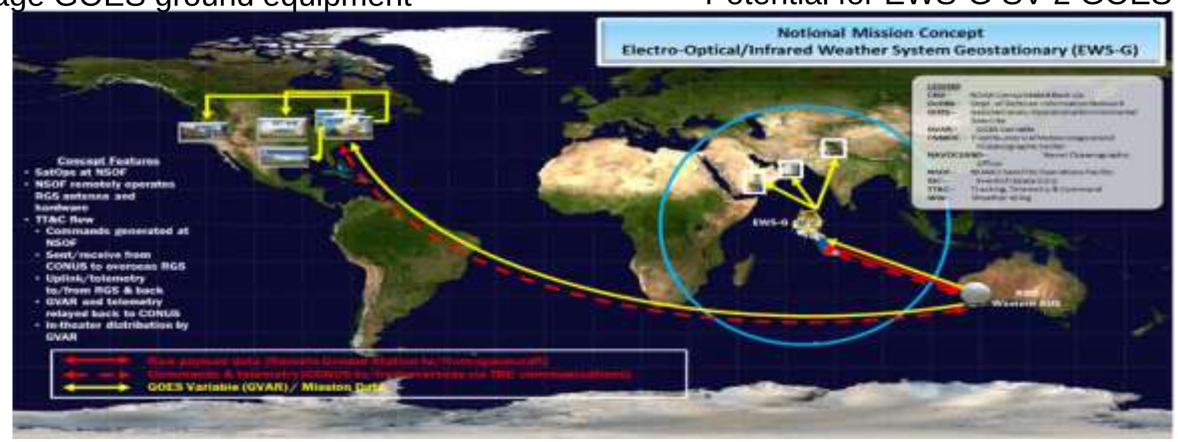
EO/IR Weather System-Geostationary (EWS-G)

<u>What:</u>

- JROC directed a temporary non-material solution for Cloud Characterization & Theater Weather Imagery over the Indian Ocean
    - Based on projected EUMETSAT MET-8 End-of-Life
- Moving a legacy National Oceanic and Atmospheric Administration (NOAA) Geostationary satellite (GOES-13)
- Leveraging NASA to establish remote ground station in Western Australia for operations and data relay
    - Using heritage GOES ground equipment

<u>Ongoing Activities</u>

- Satellite drift began - Jul 19
- Initial antenna transport to AUS began - Jul 19
- Nov 19 - Remote ground station reconstruction complete
- Nov/Dec 19 – Ground Station testing w/GOES-13
- Satellite arrived at final location (61.5 E) – 18 Feb 20
- IOC - Apr 2020, FOC - ~Jun/Jul 2020
- EOL ~ 2023 based on fuel for station-keeping, w/ potential to extend to 2025 w/ software mods
- Potential for EWS-G SV-2 GOES transfer



USAF Commercial Weather Data Pilot

- USAF provided CWDP funds via Congressional adds starting in FY2017
- First contract focused on GPS-RO given availability of multiple vendors with more mature capabilities
- New BAA established to fund multiple smaller projects to address multiple SBEM gaps
- Future challenges:
  - Sustain CWDP efforts outside congressional adds
  - Transition of prototypes to ops + data buys
  - Evolve modeling system to exploit data from multiple data paths, including ability to rapidly assimilate new data into NWP models

NOAA's Current and Future Space Weather Architecture

NOAA Satellite and Information Service
www.nesdis.noaa.gov

Feb 28, 2020

Dr. Elsayed Talaat
Director, Office of Projects, Planning, and Analysis

2020 JPSS/GOES-R PGRR Summit

NOAA Space Weather Prediction Center

- The Nation's official source of space weather alerts, watches and warnings

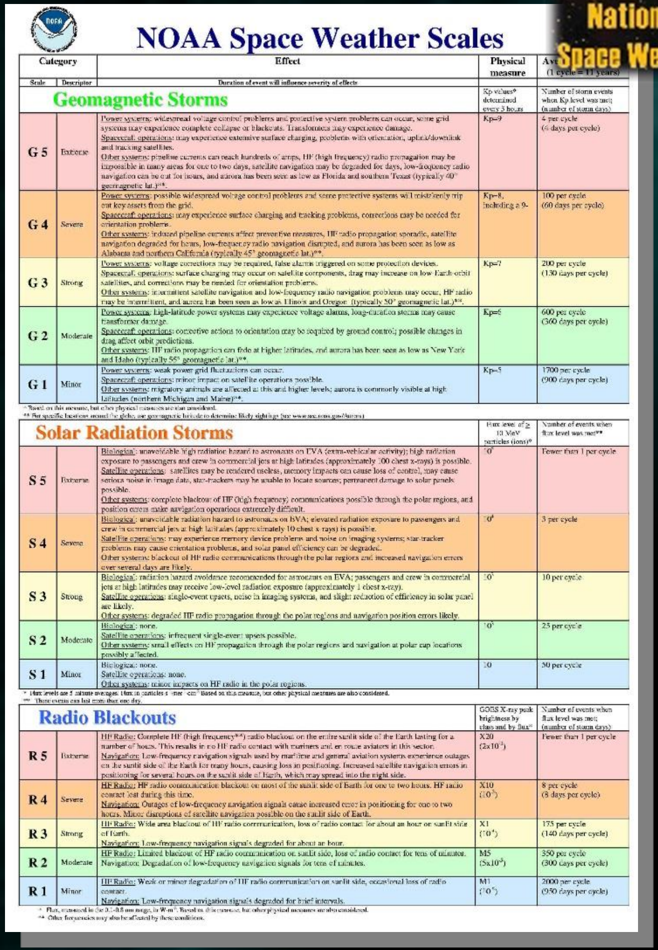
- Provides 24x7 analysis and forecasting of space weather storms

NOAA Space Weather Watches and Warnings are based on the NOAA Space Weather Scales:

Geomagnetic Storms (G-scale)
(Magnetic field)

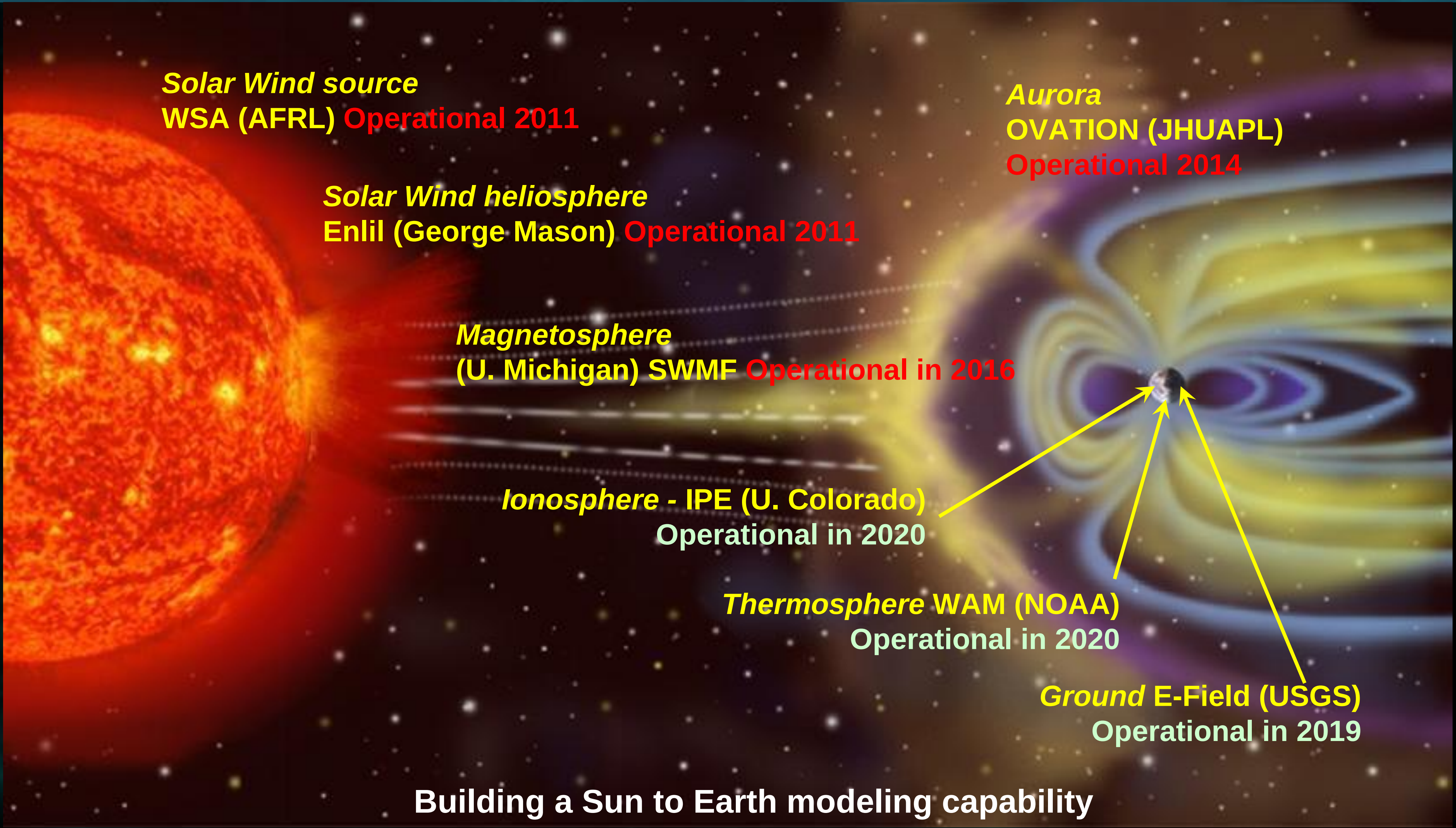
Solar Radiation Storms (S-scale)
(Energetic charged particles)

Radio Blackouts (R-scale)
(Electromagnetic radiation)



DoD services provided by USAF 557th Weather Wing

NOAA Space Weather Modeling



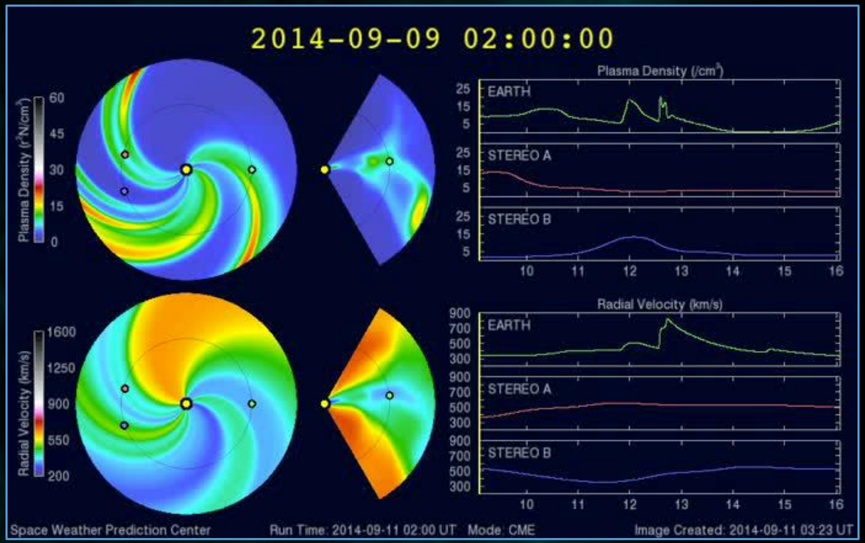
Building a Sun to Earth modeling capability

Observations and Measurements

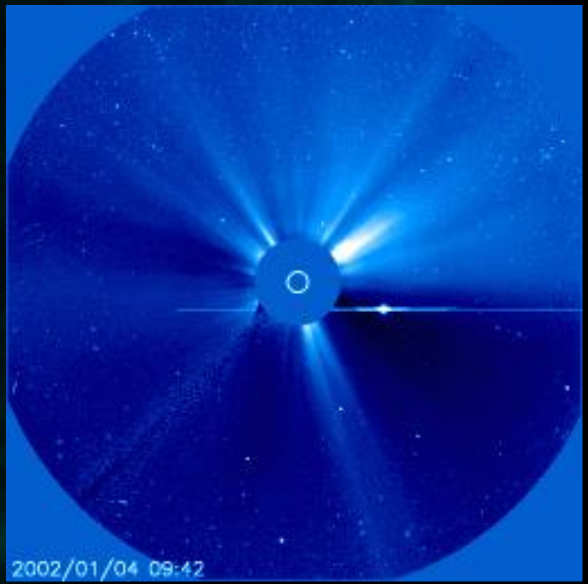
- Low-Earth Orbit: In-situ measurements provided by instruments on LEO satellites, and GNSS radio occultation measurements providing total electron content, produce the current state of ionosphere
- Geostationary Orbit: In-situ measurements of the space environment and the magnetic field of the magnetosphere provide advanced warning of space weather events. Imaging of the Sun in the x-ray and ultraviolet bands allow detection of solar flares, which supports forecasting; Coronagraph imaging of the Sun for CMEs provides 1-4 day advanced warning of geomagnetic storms
- L1: In-situ measurement of the solar wind speed and magnetic field provides 15-60 minutes of advanced warning of arrival at Earth; Coronagraph imaging of the Sun for CMEs provides 1-4 day advanced warning of geomagnetic storms
- L5: Enhanced performance may be obtained by a potential ESA L5 mission that support forecasting and complementary measurements by providing an “off-axis” view of the Sun.

Solar Wind and CME Imagery for Space Weather Prediction

- Coronal Mass Ejection (CME) Imagery
  - Visible light imagery of CMEs used for 1-4 day warnings of geomagnetic storm conditions
  - Primary source: ESA/NASA Solar and Heliophysics Observatory (SOHO, 1995) - solar power limited to 2025
  - Backup: *none*

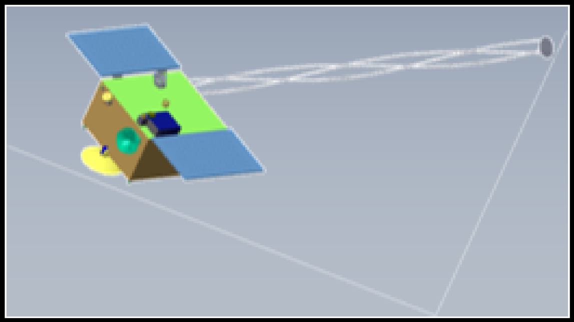


- Solar Wind In-Situ at Sun-Earth Lagrange – L1
  - Solar wind magnetic field and bulk plasma provide 15-60 minute warning of geomagnetic storm conditions
  - Primary source: NOAA/Deep Space Climate Observatory (DSCOVR), launch 2015
  - Backup: NASA Advanced Composition Explorer (ACE) launch 1997 – propulsion limited to 2026

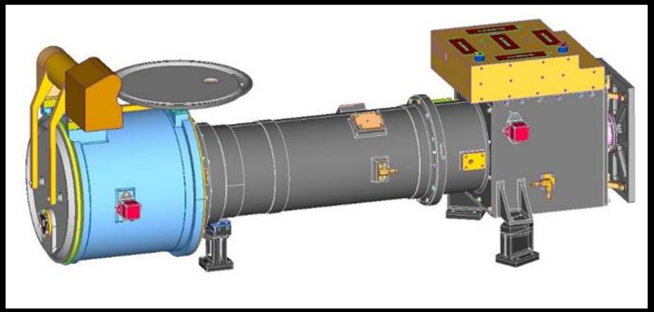


SWFO Program Key Technical Components

3-Axis Stabilized ESPA Class Spacecraft

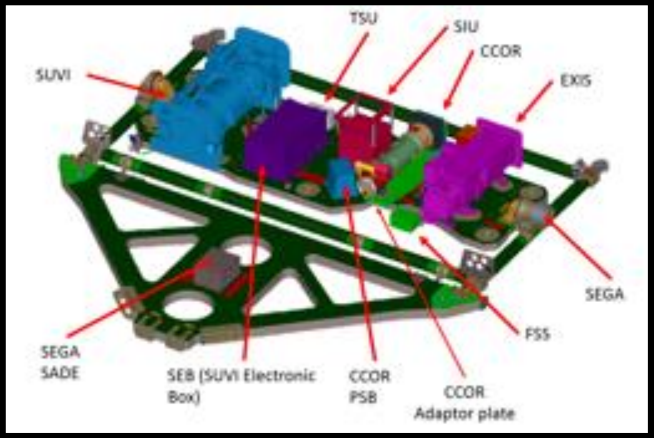


Compact Coronagraph (CCOR)



GOES-U Solar Pointing Platform (SPP)

CCOR + SUVI + EXIS



SWFO-L1 Mission Overview

- Space Weather Operational Observation at Earth-Sun Lagrange Point 1
- IAA with NASA to procure an ESPA Grande compatible spacecraft and a SWIS (Solar Wind Instrument Suite)
- NOAA ground services
- Rideshare with NASA IMAP
- Nominal orbit: L1
- Nominal launch: 2024
- SWFO-L1 Instruments: CCOR, SWIS
- Potential ESA contributed instrument (X-Ray flux monitor)

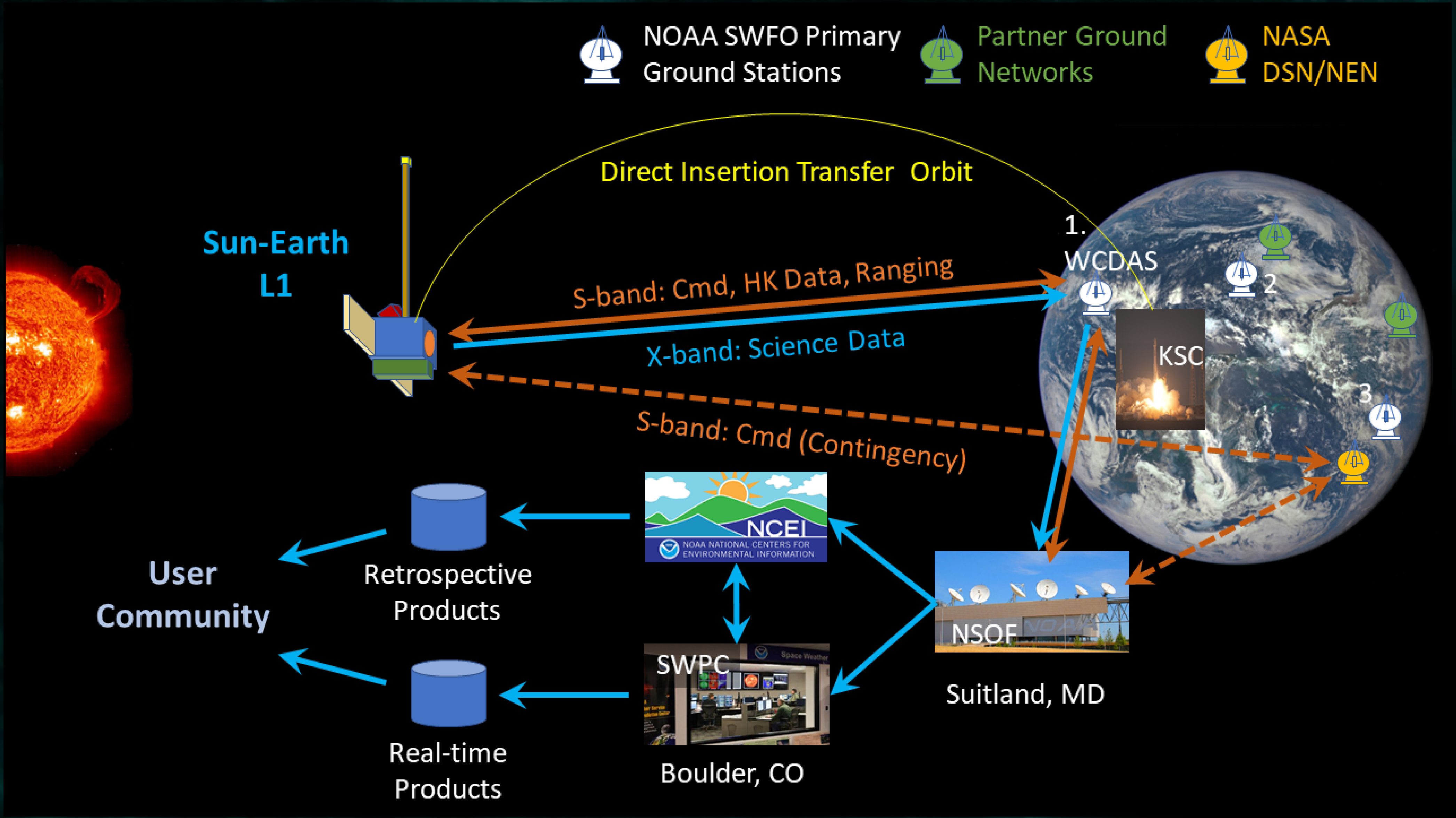
Coronagraph Project

- Compact Coronagraphs under development by NRL via an IAA
- CCOR for SWFO-L1 Satellite, deliver 2022
- CCOR for GOES-U, deliver 2021
- Potential CCOR for ESA-L5 Satellite, deliver 2023

Coronagraph Accommodation on GOES-U

CME imaging from geostationary orbit
CCOR Integrated onto GOES-U SPP
Commanding and data flow through GOES-R ground services
Nominal launch: 2024

SWFO Mission Architecture



SWFO Procurement Status

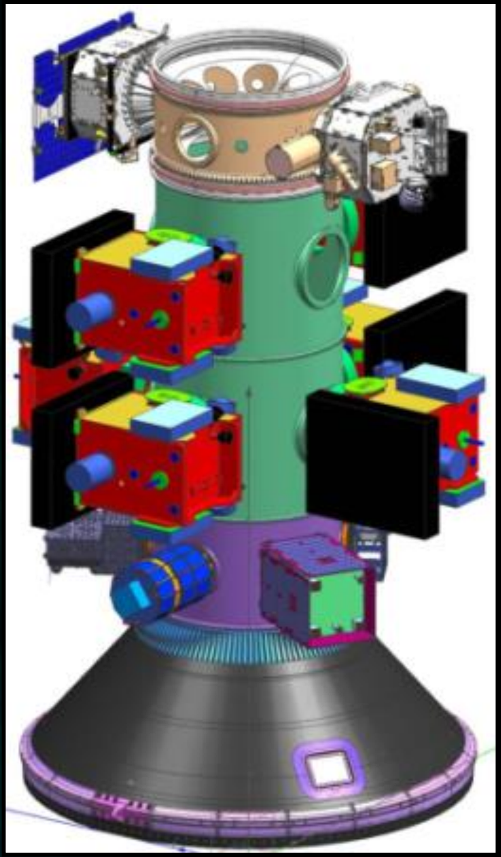
- Instrument RFPs have been amended and posted to https://beta.sam.gov/
  - ~~Solar Wind Plasma Sensor (SWiPS)~~
    - ~~Proposal due date: January 10, 2020~~
  - ~~Magnetometer (MAG)~~
    - ~~Proposal due date: January 21, 2020~~
  - ~~Supra Thermal Ion Sensor (STIS)~~
    - ~~Proposal due date: January 31, 2020~~

- SWFO-L1 Spacecraft RFO posted
- SWFO Antenna Network (SAN) RFI was posted to https://beta.sam.gov/

  Response due date: December 19, 2019

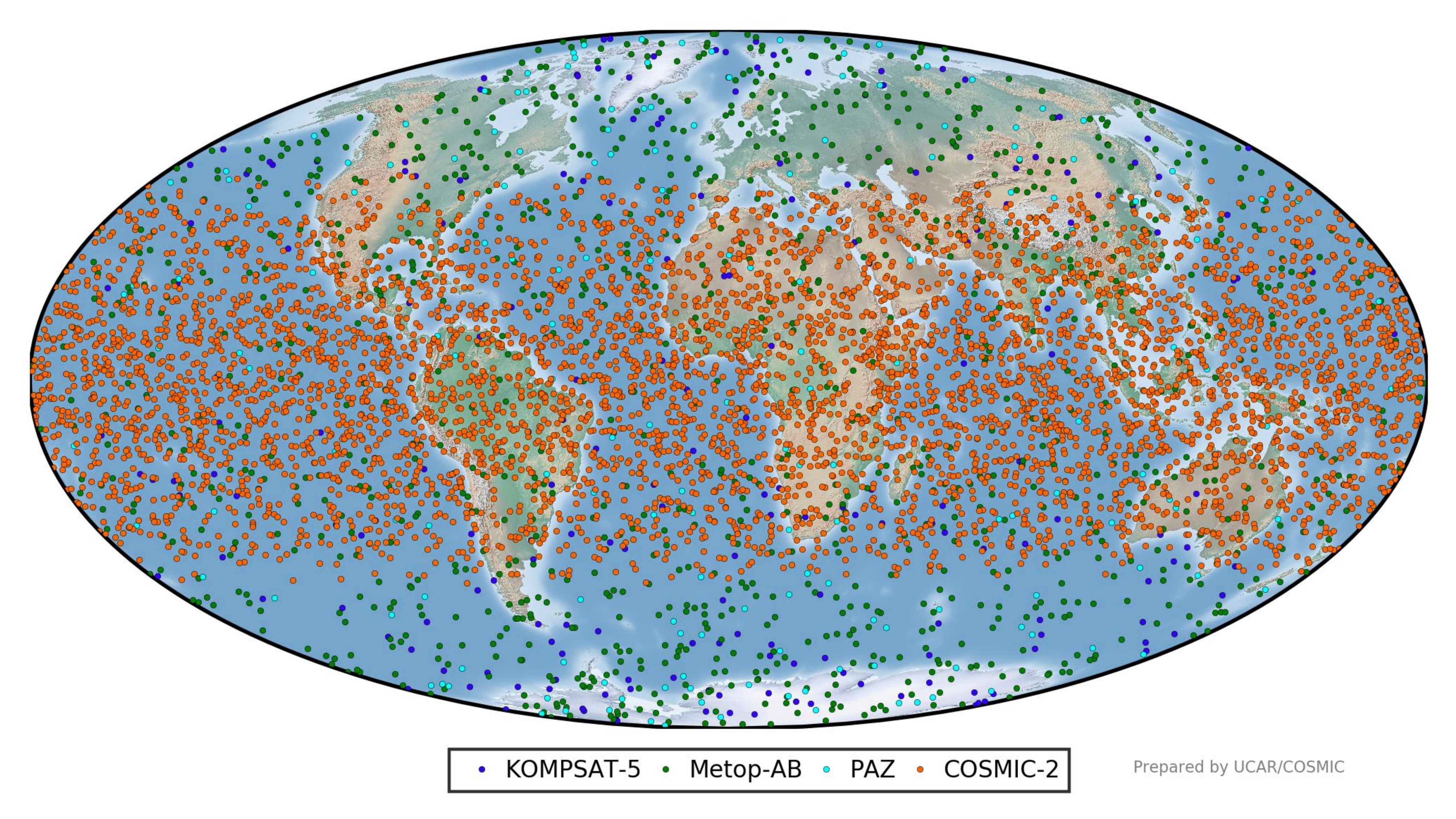
COSMIC-2/FORMOSAT-7 Mission

- 6 Satellite constellation around the equator (24 degree inclination orbit)
- Each satellite has 3 instruments:
  - TriG GNSS-RO receiver (TGRS) – Primary Instrument
  - Ion Velocity Meter (IVM) – Secondary Instrument
  - RF Beacon – Secondary Instrument
- Mission Design Life: 5 years
- Launch Date: June 25, 2019
- Launch Vehicle: Falcon Heavy (STP-2 mission stack shown in right figure)
- All weather coverage (4,000+ occ/day) with 30 min avg data latency

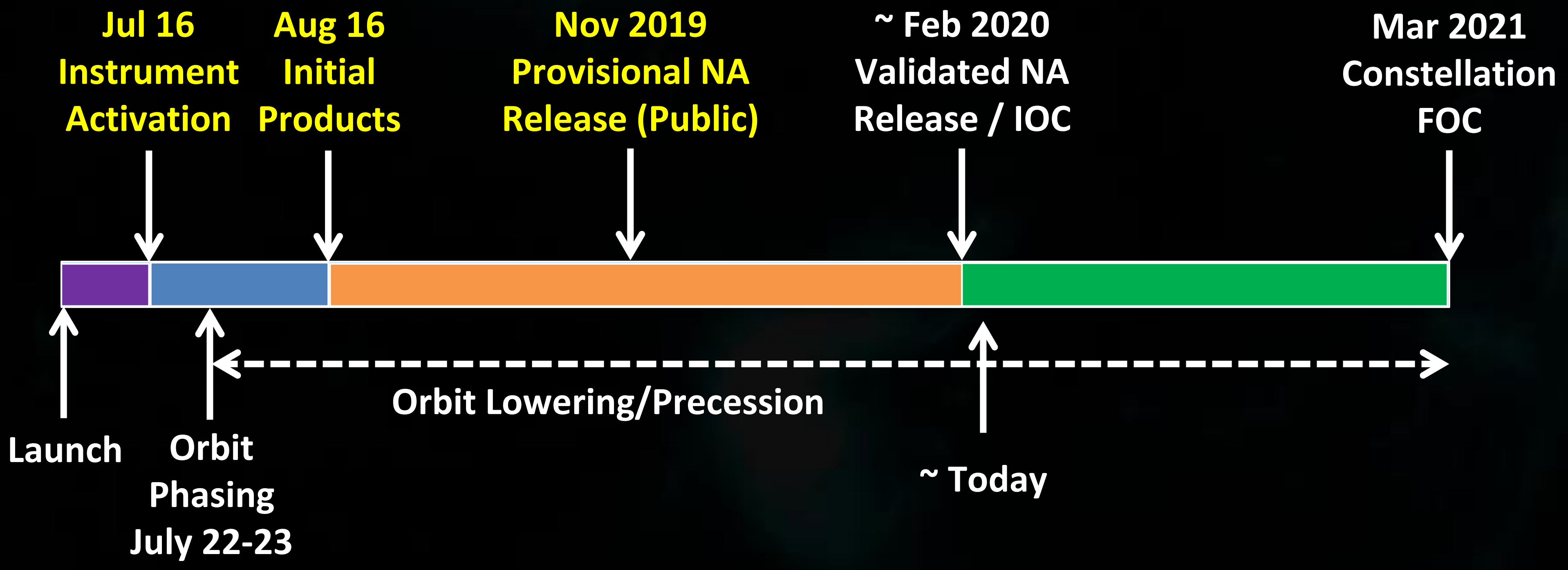


COSMIC-2 Spacecraft in STP-2 Launch Stack

COSMIC-2 and Partner Data



COSMIC-2 Data Release Timeline



- Launch and early orbit operations
- Checkout and commissioning
- Weather cal/val
- Weather operations

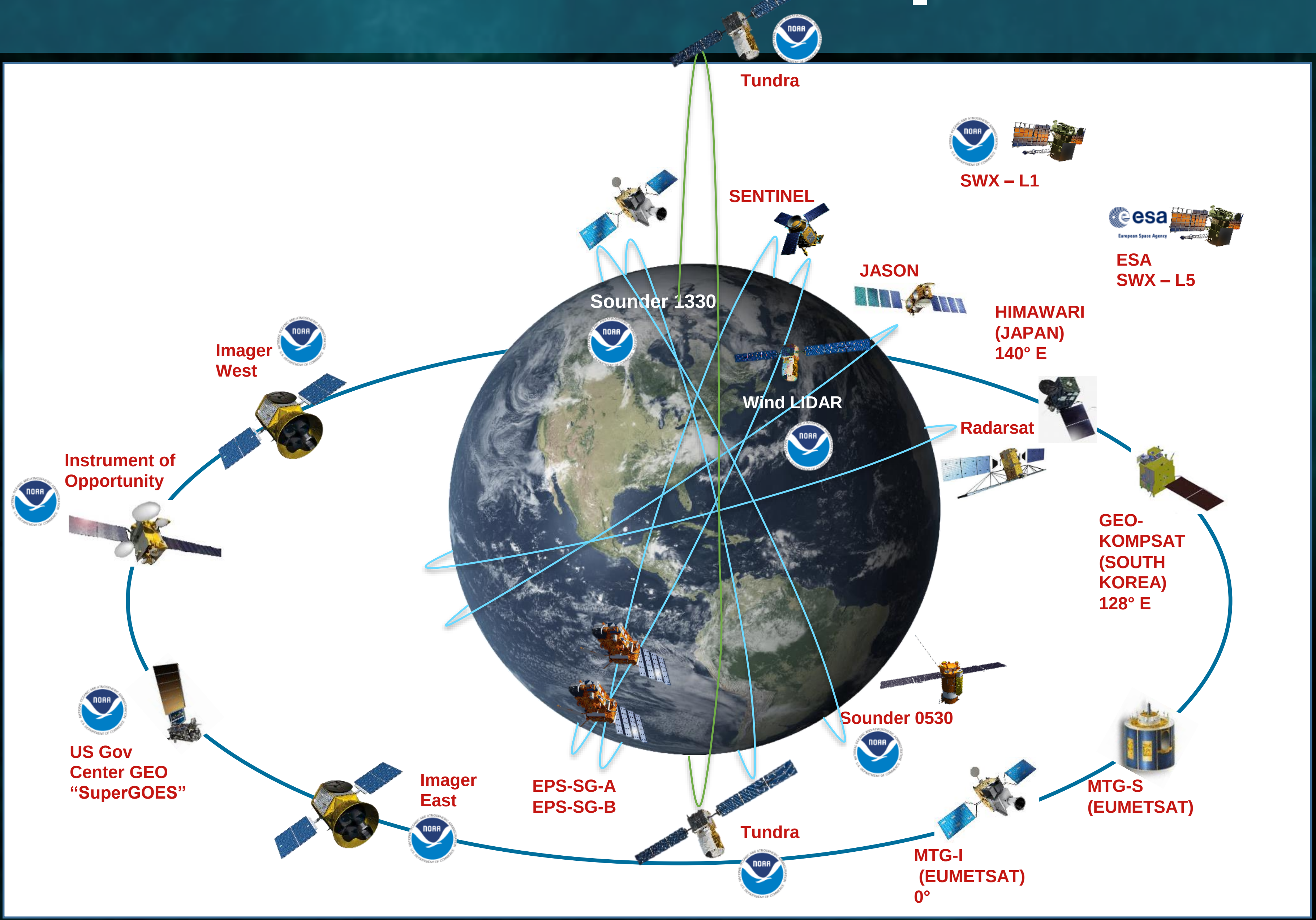
IOC = Initial Operational Capability
FOC = Full Operational Capability
NA = Neutral atmosphere
TEC = Total electron content

SWFO– in the last two years …

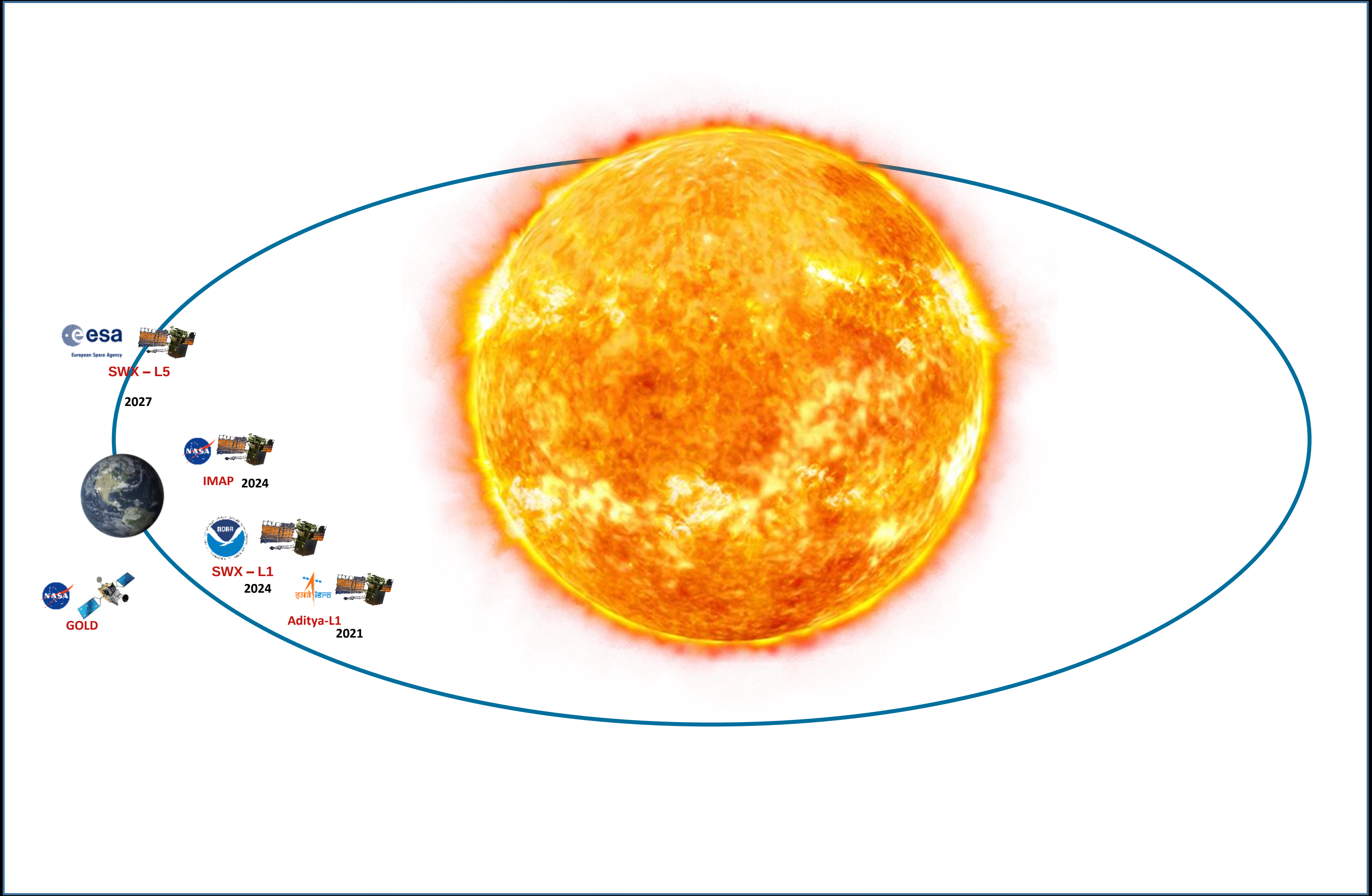
NESDIS has established the baseline operational Space Weather Follow On (SWFO) Program

- Funded in the NOAA budget for L1 coverage
- Began flight fabrication of the Compact CORonagraph (CCOR) with NRL
- Funded in the NOAA budget for CCOR on GOES-U
- Established a joint project office with NASA for SWFO
- Established an agreement with the NASA IMAP mission for a rideshare for SWFO-L1
- Let procurement RFPs for instruments, RFO for spacecraft
- Launched the COSMIC-2 mission with Taiwan
- Initiated arrangements with ESA for data sharing with the L5 mission
- Negotiating with ESA for potential ground-station and instrument cooperation

Evolution of NOAA and Partner Space Architecture



Evolution of Space Weather Architecture



Space Weather Operations and Research Infrastructure Workshop

- National Academies via an appointed ad hoc committee will organize a workshop that will consider options for continuity and future enhancements. Objectives include:
  - Review current and planned U.S. and international space weather-related observational capabilities;
  - Discuss baseline space weather observational needs;
  - Identify programmatic and technological options to ensure continuity of the baseline, giving particular attention to options to extend the Space Weather Follow On (SWFO) program; and
  - Consider options for technology, instrument, and mission development to support in situ and remote sensing space weather observations from either ground- or space-based vantage points, the latter including L-1, L-5, L-4, GEO, and LEO.

Space Weather Operations and Research Infrastructure Workshop - Charter

The NASEM will conduct a workshop via an ad hoc organizing committee to examine the future observing infrastructure which is intended to supply critical input to the space weather notification system that characterizes and forecasts space weather events

A report of the workshop proceedings will be produced

The workshop results will present options to the Space Weather Follow On (SWFO) Program that will sustain a set of space-based observations and measurements that will ensure continuity of critical operational data

Space Weather Operations and Research Infrastructure Workshop - Scope

The NASEM will conduct a workshop via an ad hoc organizing committee to examine the user needs for the space weather notification system supported by operational observations (Phase 1).

The workshop will examine present infrastructures and investigate options for improvement beyond the baseline capabilities of the present operational program (2030-2030 timeframe, post SWFO1)

Infrastructure Workshop Phase 2 will address items beyond the scope of Phase 1, e.g. future research needed to understand the sun-earth system

Space Weather Operations and Research Infrastructure Workshop – Scope (cont.)

- User needs defined by the SWPC scales of notification, e.g. G1-5 indicating the severity of geomagnetic storm intensity
- Needs further defined by the observations and input needed to generate these notifications
- Operational models in the SWPC system need baseline observations but could benefit from improved input

THANK YOU!

For more information visit: **www.nesdis.noaa.gov**

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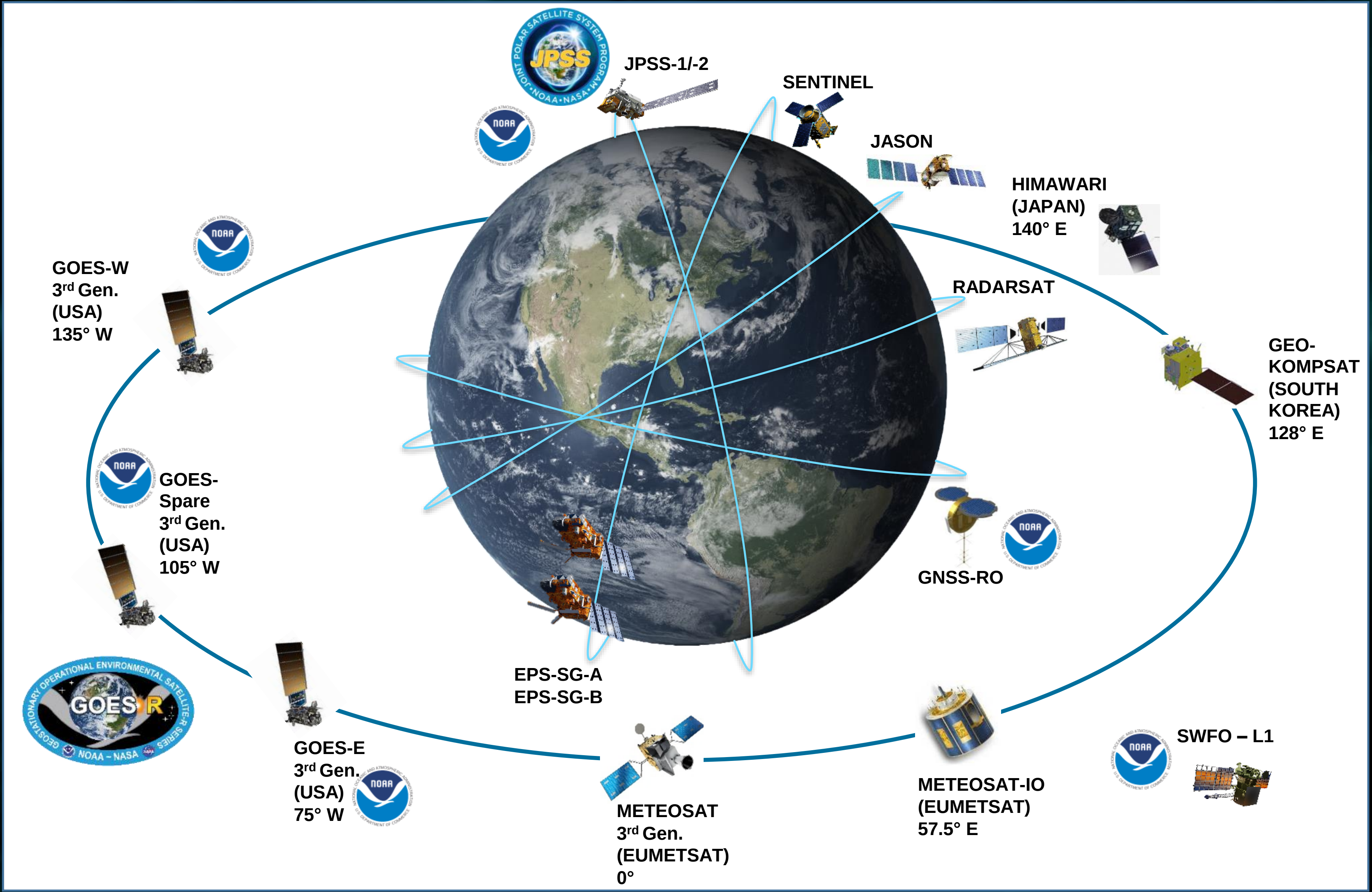
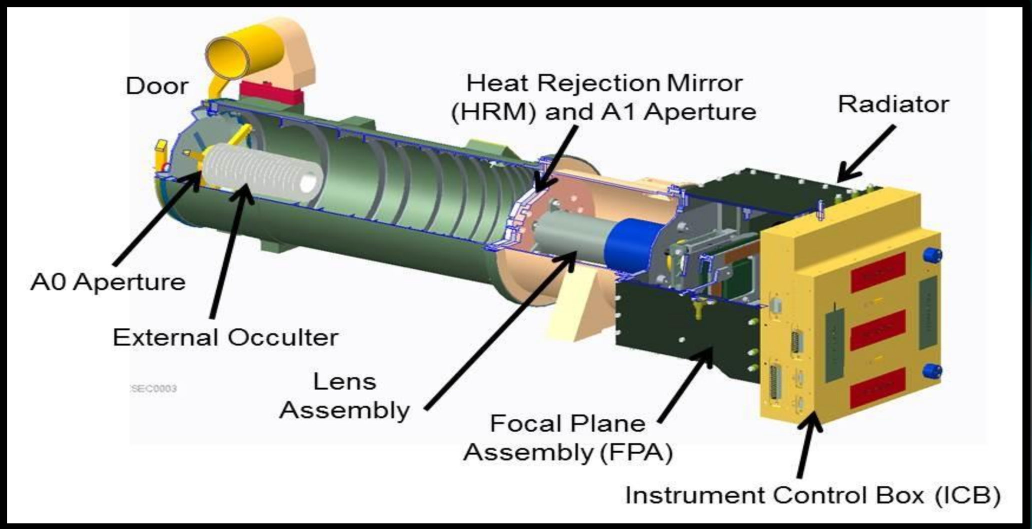
Near-Term Observational Capability



A Space Telescope for the Corona: CCOR

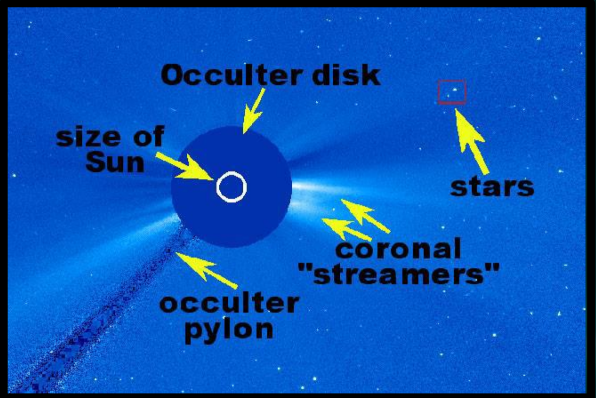
Compact CORonagraph



CCOR Description

- A Research To Operations (R2O) project in close collaboration with the Naval Research Laboratory (NRL)
- Telescope features:
  - Innovative optical and electronic components Planned to replaces SOHO/LASCO
  - High heritage from STEREO/SECCHI, PSP/SoloHi instruments
  - 50% reduction in mass; 2/3 length from earlier designs.
- To operate at a 15-min cadence; shorter if necessary

Coronal Image



Mission Overview

- First CCOR to be placed on board GOES-U
- Second CCOR to be placed on NOAA's SWFO solar wind monitor at L1
- NRL to deliver the units in 2021, 2023

Instrument Requirements

Parameter	Threshold	Goal
Field of View (FOV)	3-17 R_{SUN}	3-22 R_{SUN}
Pointing Knowledge	25 arcsec	12.5 arcsec
Knowledge of Solar North	1 deg	0.5 deg
Spatial Resolution	50 arcsec	
Photometric Accuracy	10%	
Image Cadence	15 min	5 min
Data Latency	15 min	5 min

Space Weather Operations and Research Infrastructure Workshop - Status

- The NASEM has approved the Space Weather Operations and Research Future Infrastructure Workshop
- The NASEM has put together an ad hoc organizing committee
- This week NASEM held a meeting of the organizing committee to address the agenda and space weather experts' participation
- The workshop is expected to be mid-year 2020, in the DC area, and is an open meeting
- A likely follow on workshop (NASA and NSF supported) will be held to address out-of-scope issues from the first workshop