National Aeronautics and Space Administration

EXPLORE EARTH

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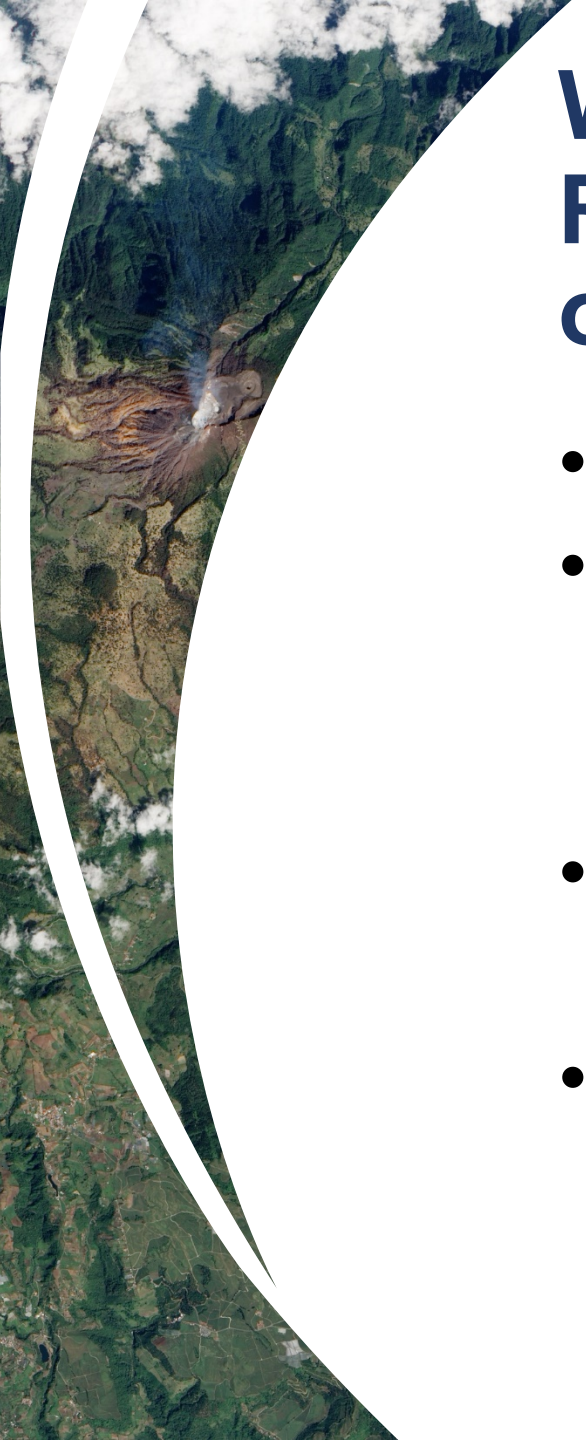
16th JCSDA Technical Review Meeting and Science Workshop on Satellite Data Assimilation

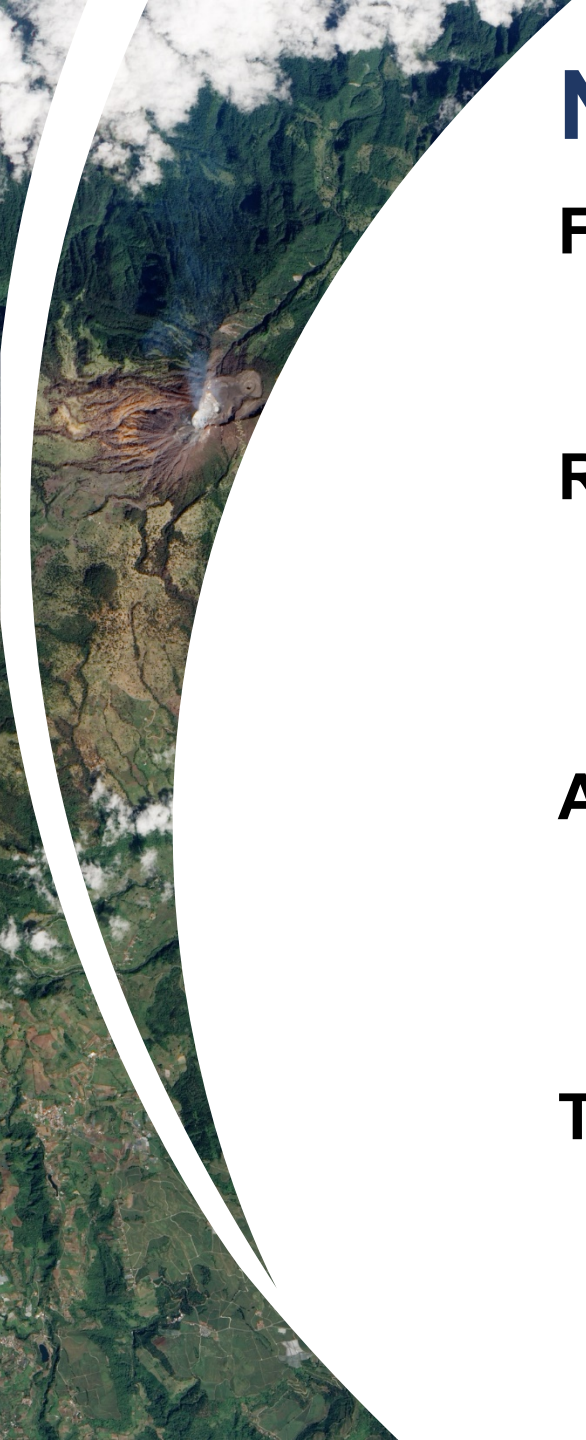
May 29, 2019

* This presentation reflects the work of multiple people at NASA HQ and GSFC



Welcome to the 16th JCSDA Technical Review Meeting and Science Workshop on Satellite Data Assimilation

- NASA is excited about hosting this workshop
- JCSDA represents a major interagency collaboration and is an important component in NASA's overall modeling strategy.
- Data Assimilation is strategically important for the US Federal Weather Enterprise
- Technologies, algorithms, and tools developed at the JCSDA have significant impact on US weather and climate programs



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Oversees NASA data centers.

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Turns measurements from satellite, airborne and land-based missions into understanding of the Earth system.
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Applied Sciences

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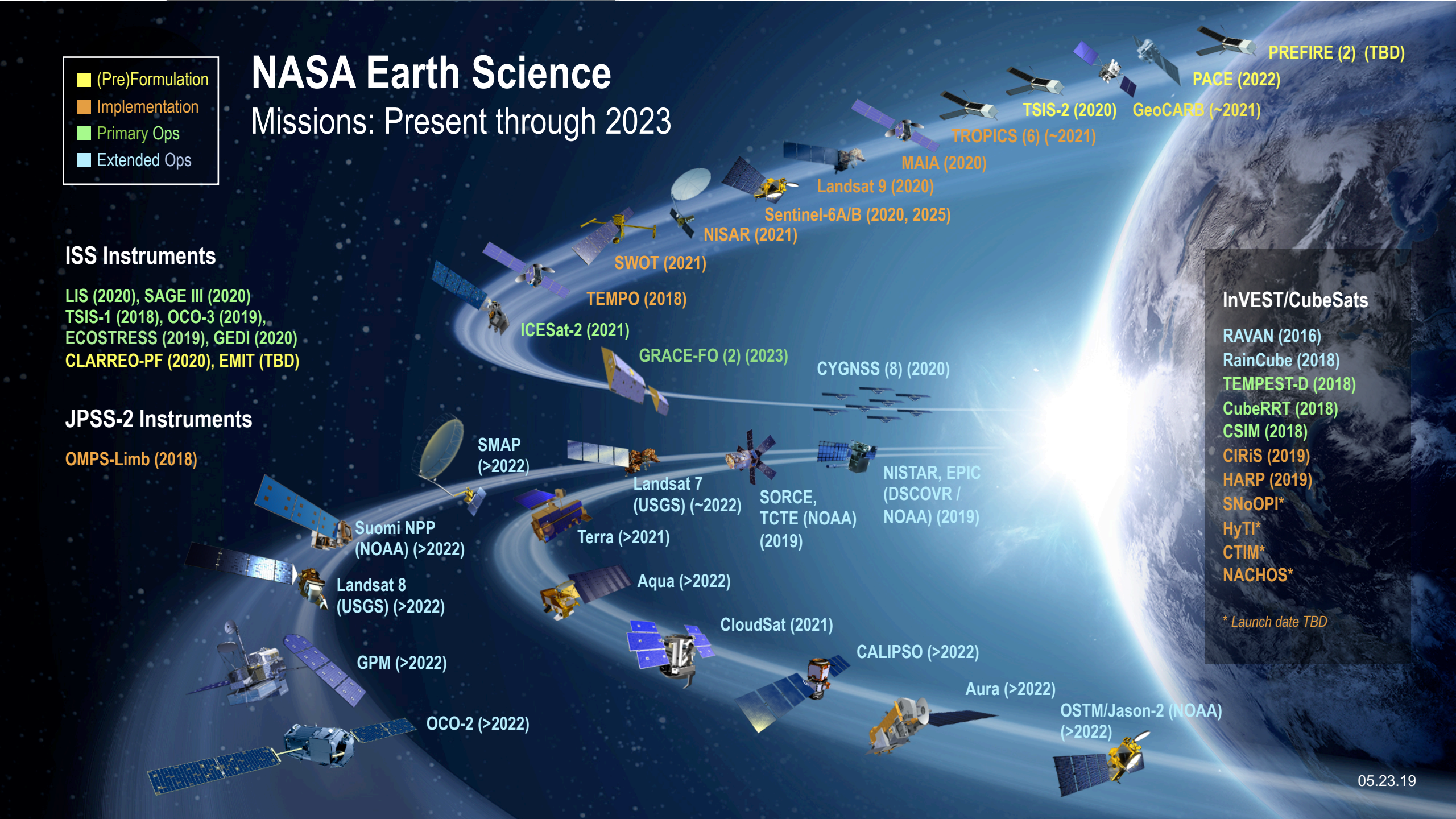
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GPM (>2022)
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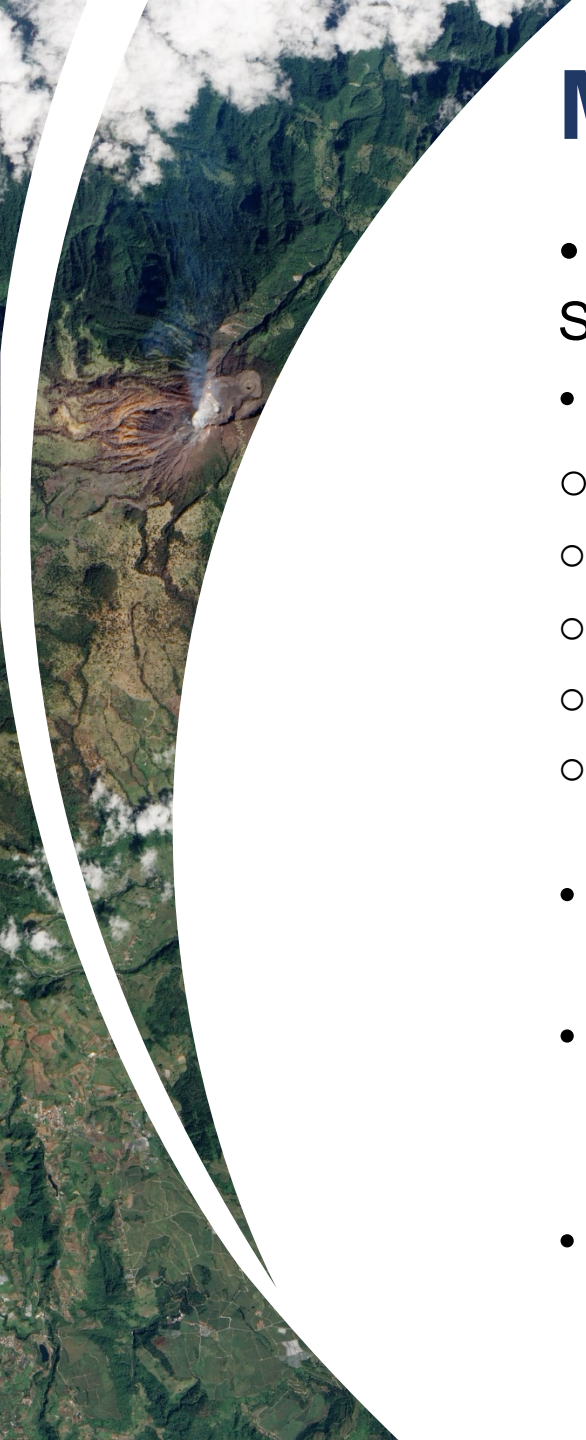
Aura (>2022)
OCO-2 (>2022)
OSTM/Jason-2 (NOAA)
(>2022)
InVEST/CubeSats
RAVAN (2016)
RainCube (2018)
TEMPEST-D (2018)
CubeRRT (2018)
CSIM (2018)
CIRiS (2019)
HARP (2019)
SNoOPI*
HyTI*
CTIM*
NACHOS*
* Launch date TBD
05.23.19



Modeling in NASA's R&A Strategy

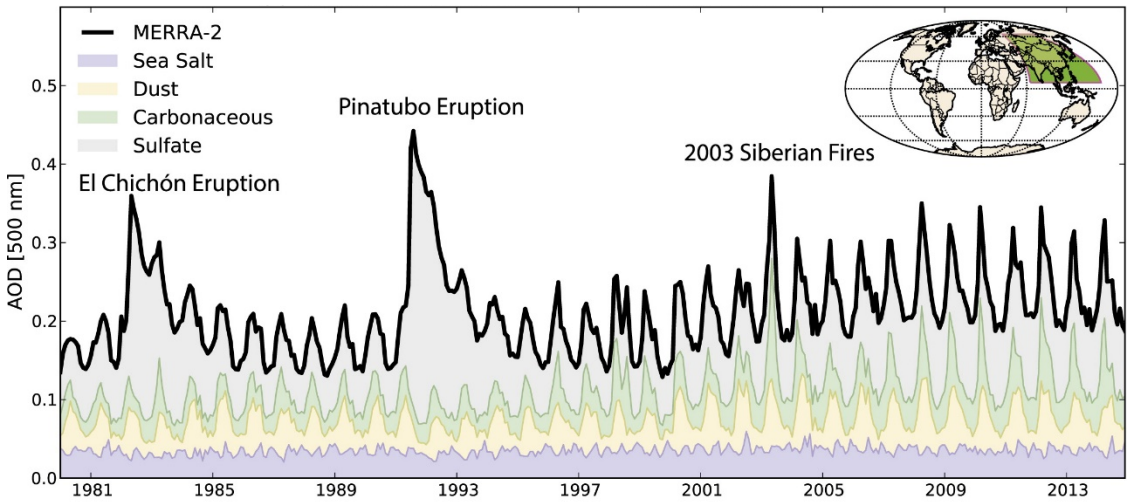
- Models form an important component of NASA's Earth Science Research Strategy
- Role of models in ESD R&A includes the following
  - Hypothesis testing
  - Preparation of products for community use (!)
  - Projection/prediction of future Earth system evolution
  - Guiding fieldwork
  - Helping to understand benefits of and/or contributions of potential future observing system components
- NASA modeling is inextricably linked to observations – hence the paradigm of "observationally-driven modeling"
- NASA's brings an "Earth system science viewpoint" to modeling, so while component models may be developed, those that include linkages among Earth system components are our goal.
- Ability to run models is dependent on availability of high end computing, and assuring synergy between modeling and computing capability and requirements is an important consideration

How DA and Reanalysis Fit in NASA's Observationally-Driven Modeling Strategy

NASA supports a broad, data-driven modeling program to:

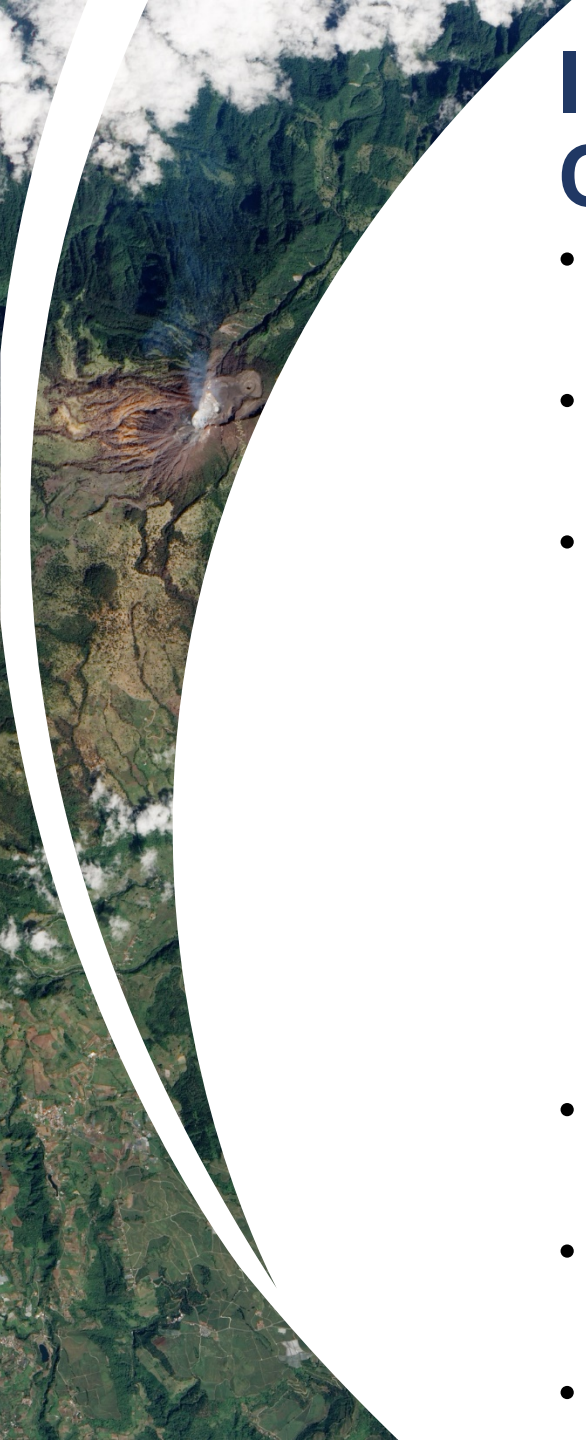
- Show the value of NASA's research data for weather and climate prediction
- Support aircraft field missions through real-time prediction and after-the-fact analysis
- Provide unique reanalyses to the community
- Obtain insight into processes by combining novel observation types with forefront Earth System models
- Provide value-added products (level-4) based on NASA's unique assets

Monthly Aerosol Optical Depth: South and East Asia



- MERRA-2 was the first global, multi-decadal reanalysis to include aerosols and their radiative feedbacks
- Uses NASA's MODIS after 1998 and AVHRR before then
- Major signals, such as sulfate loading from volcanoes and the signal of carbonaceous aerosols from extreme fires are evident in this time series

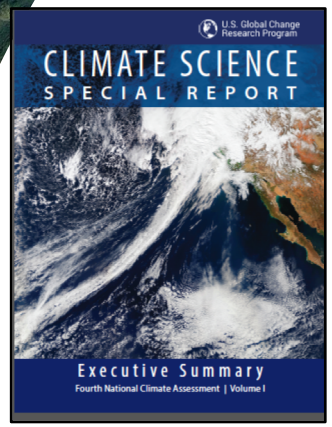
Randles et al. (2016)

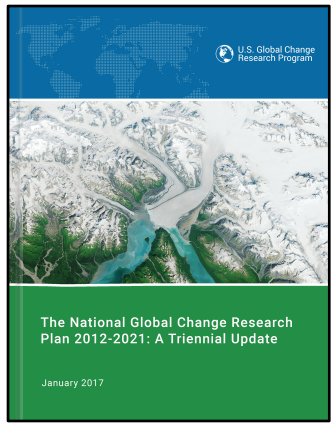


Importance of Interagency and International Cooperation in NASA Modeling

- NASA modeling efforts exist within larger “ecosystem” of models with significant contributions from interagency as well as international partners.
- Challenge of Earth System modeling is greater than what any one agency can be expected to meet.
- A major driver of NASA’s role is ”observationally-driven modeling” that emphasizes use of observations in enhancing models (and vice versa)
  - Initialization
  - Process Representation
  - Assimilation
  - Reanalysis
  - Quantitative Evaluation
  - Observing System Design
- NASA modeling supports national and international assessment activities as appropriate
- NASA models should be full participants in national and international intercomparison and evaluation efforts.
- Extension of NASA research capability into operational use is desired (!).

Interagency Coordination Efforts in Earth Science*





Committee on Environment Co-Chairs: EPA, NOAA, OSTP	
Polar Research*	Earth Observations (USGEO)
Global Change (USGCRP)*	Ocean Science & Tech (SOST)
Water Availability & Quality	Aquaculture*

National Science And Technology Council (NSTC)

Committee on Environment (CoE)

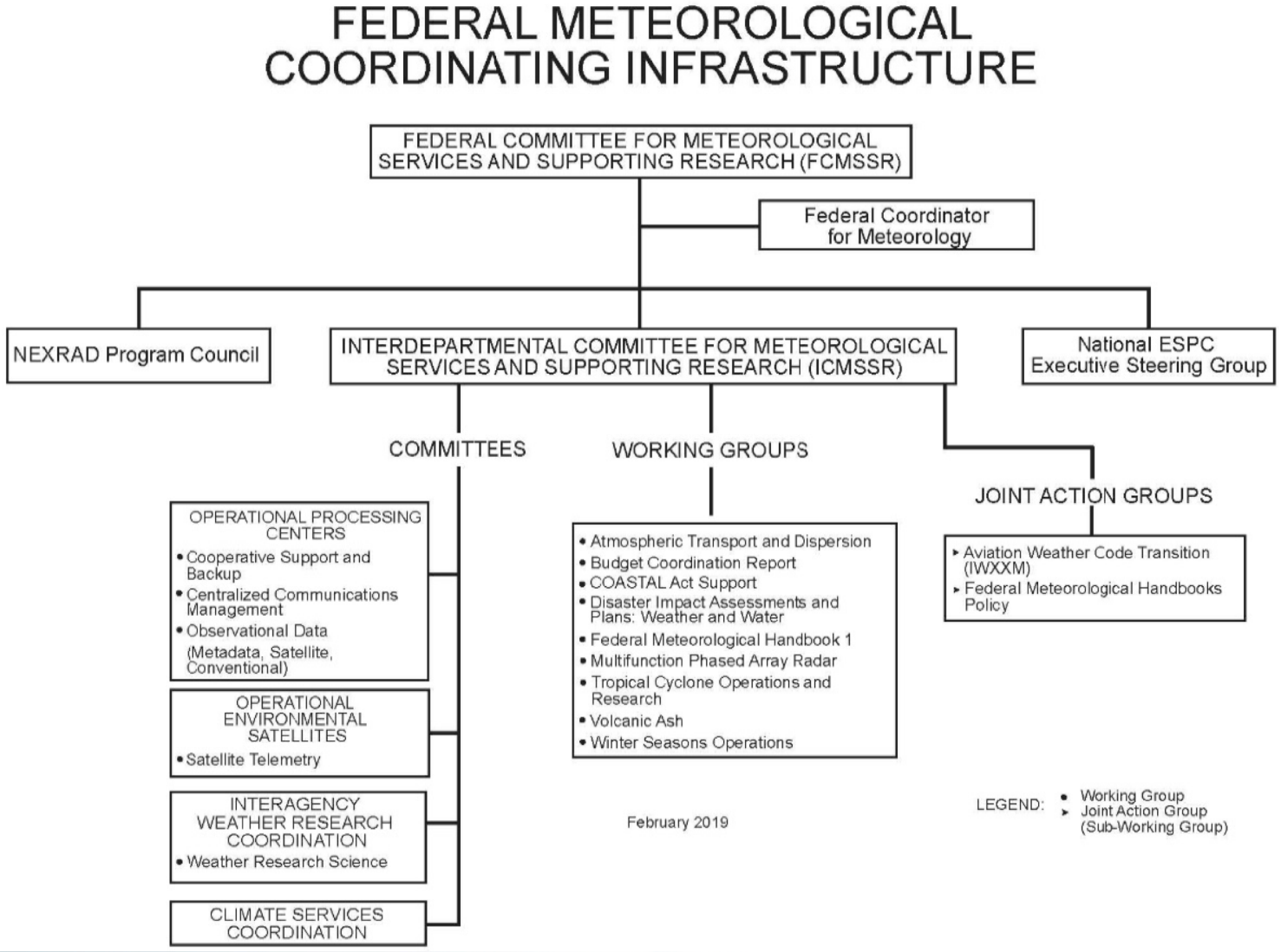
Subcommittee on Global Change Research (SGCR)

U.S. Global Change Research Program (USGCRP)

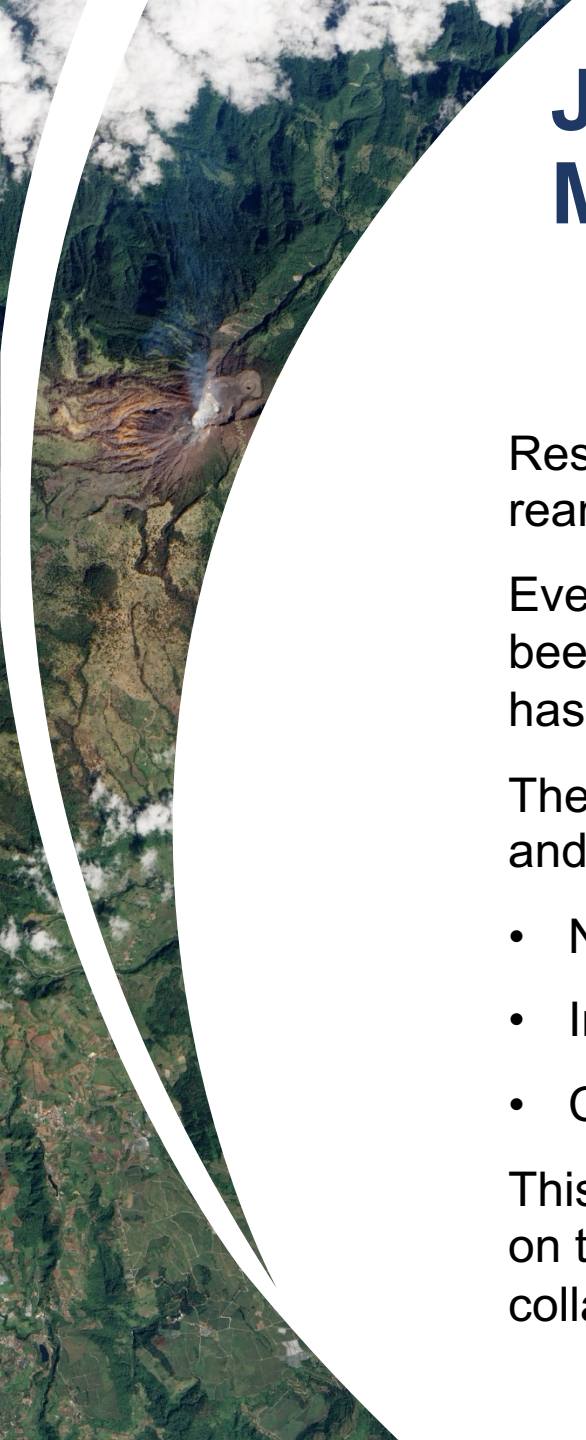
Interagency Coordination in Weather

THE FEDERAL WEATHER ENTERPRISE

Draft --Fiscal Year 2020 Budget and Coordination Report



National ESPC Earth System Prediction Capability



JCSDA Roles in NASA's Observations-Driven Modeling

The whole is more than the sum of the parts

Research studies demonstrate the value of various NASA observations on the quality of reanalyses (MERRA-2) and their impacts on weather prediction (e.g., GPM)

Even with close GMAO-EMC collaborations on assimilation system development, it has been difficult to get NASA's research observations into NOAA's operational systems – it has required repetition of technical development work

The re-structuring of JCSDA over the past three years, as well as the commitment of EMC and GMAO to move to JEDI-based infrastructure, provides an effective R2O pathway:

- NASA software development to implement new data types in JEDI-based systems
- Impacts of NASA observations demonstrated using GEOS system
- Code sharing enables EMC to directly implement NASA observations for testing in GFS

This facilitates effective collaboration among the JCSDA partners: each agency can focus on the aspects that serve their own mission, while simultaneously providing the basis for collaborative success with other agencies

NASA's Pathway to MERRA-3 Reanalysis: A JEDI-Based GEOS System

Hybrid 4D-EnVar
13-km L72 GEOS system
Aerosols
AO Skin SST

Jan 2017

All-Sky Microwave Radiances
Along with model changes and GSI

July 2018

9-km L132 GEOS
Non-hydrostatic
Updated Microphysics
EnKF Perturbed Physics

Early 2020

Circa 2022

JEDI-BASED UNIFIED GEOS SYSTEM for
- ***NWP***
- ***MERRA-3 Reanalysis***
- ***S2S Prediction***

Atmosphere-Ocean-Land-Ice Coupled DAS

Including physical, chemical and biological components

Highlights NASA observations

GEOS CDAS
JEDI Infrastructure
MOM6
New CICE
GSI O-LETKF
LA-DAS

GEOS FP (weather)

Late 2019

S2S v3
MERRA-2 atmosphere
MOM5 0.25º L50
CICE
Catchment-CN
Salinity

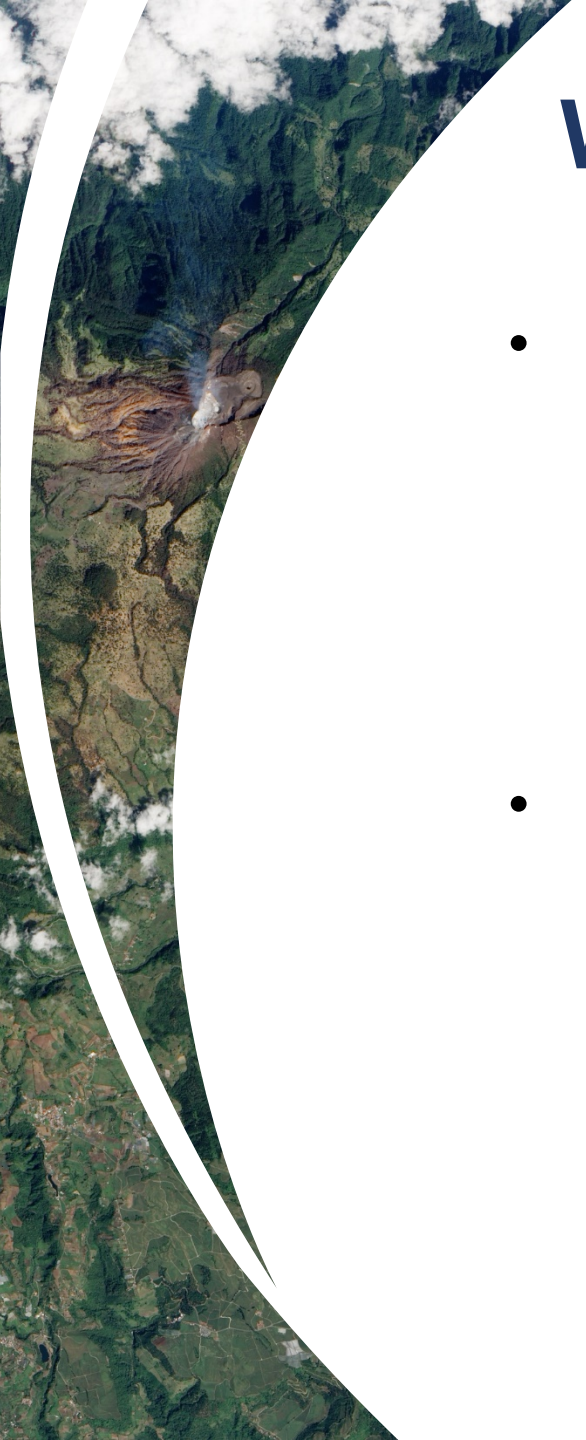
MERRA-2 Ocean product

Oct 2017

S2S v2
MERRA-2 atmosphere
MOM5 0.5º L40
CICE

GEOS S2S (seasonal)

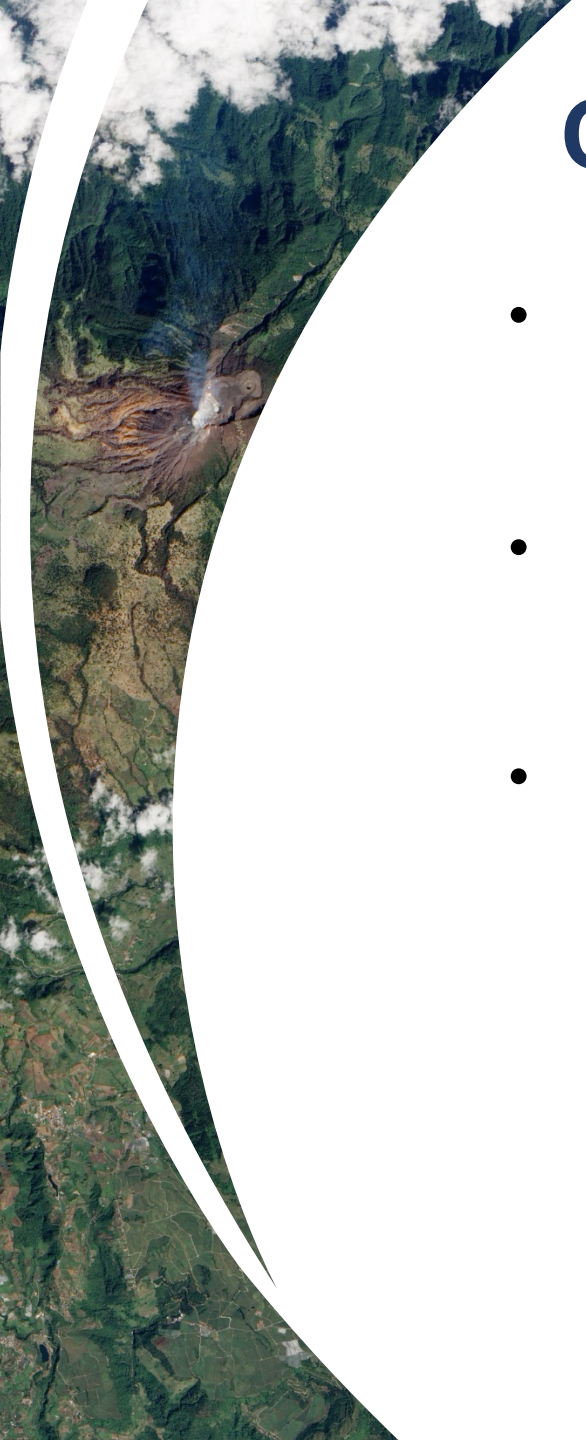
The GEOS system development has begun the transition to a JEDI-based system, with the belief that the new opportunities will help NASA further its own mission and simultaneously accelerate progress in the other national agencies



Why NASA Is Excited about the JCSDA

- NASA is a strong proponent of making changes in the way the JCSDA functions:
  - Organize by functional areas (CRTM, JEDI, FSOI, NOI, etc.)
  - Emphasis on deliverables
  - Commitment and traceability by the partners

- How JCSDA has changed over past three years – what that means for NASA:
  - Potential acceleration of new observations to operations
  - A lot of new work to support NASA's observations-driven modeling strategy
  - Support for building coupled DA system for MERRA-3 reanalysis – a critical component for Earth system modeling



Continuing Challenges

- JCSDA was set up to accelerate the assimilation new satellite observations into the observational environment.

- Although there has been a change in implementation approach in recent years, the overall mission has not changed.

- The ability to quickly assimilate new satellite observations, especially new data types, into operations requires:
  - Common vision and goals be established
  - Strong advanced planning
  - Tight interagency coordination
  - Excellent system engineering, program and project management
  - Unified software framework and standard component interfaces

Backup/Removed Slides

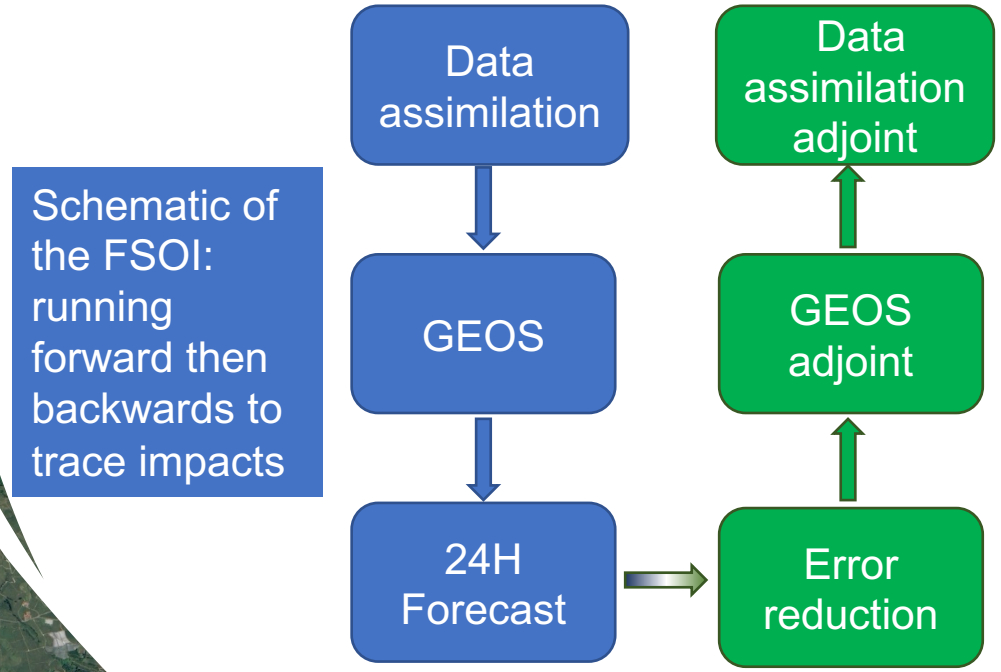
A NASA Contribution to JEDI: the FV3 Adjoint

Adjoint of FV3 was developed in GMAO:

- Used as a key part of the Forecast Sensitivity Observation Impact (FSOI) diagnostics in GEOS
- Is a critical requirement for full 4DVar, which will be implemented in JEDI

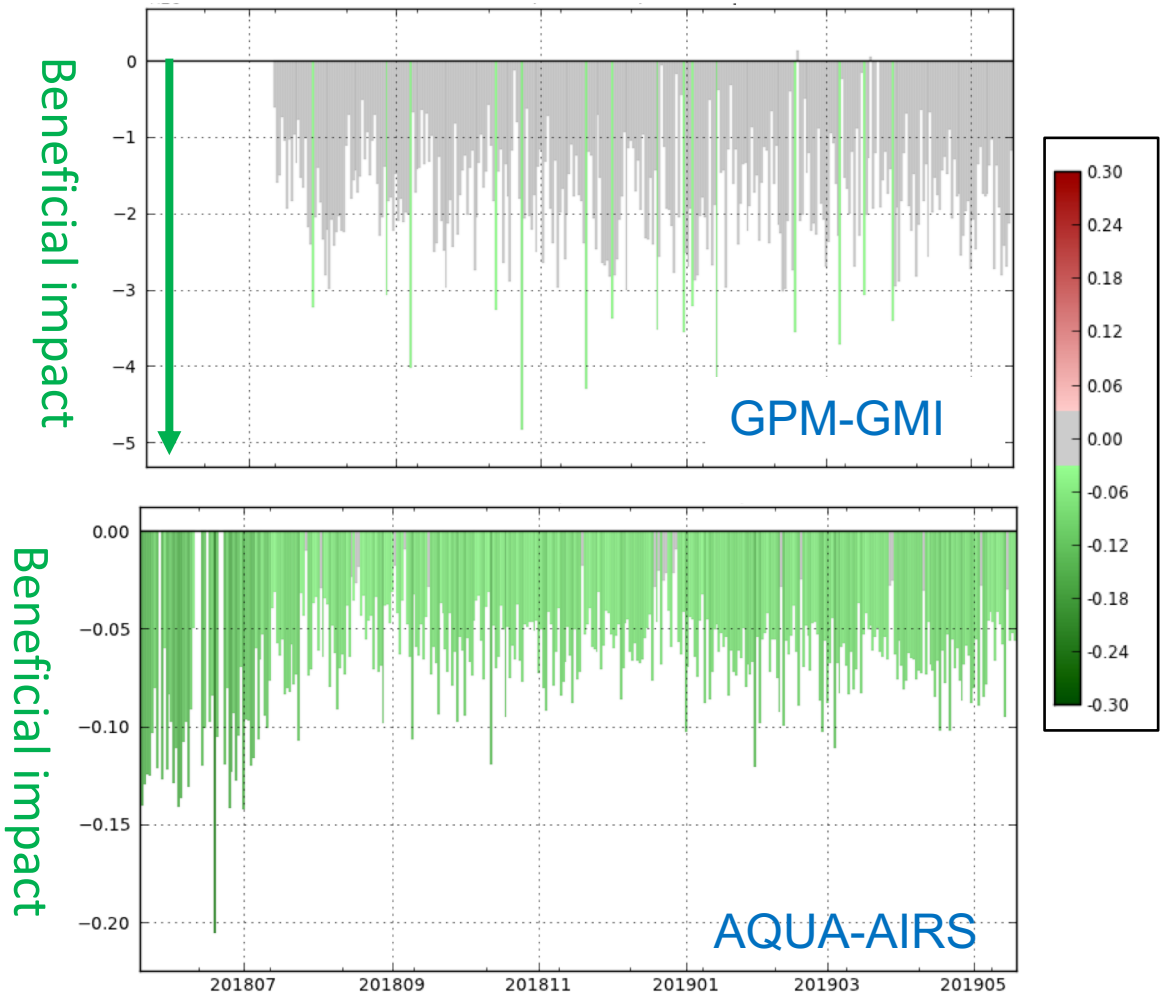
The FV3/GEOS adjoint is now included in the JEDI framework

Can this go in backup? Is this critical for me?

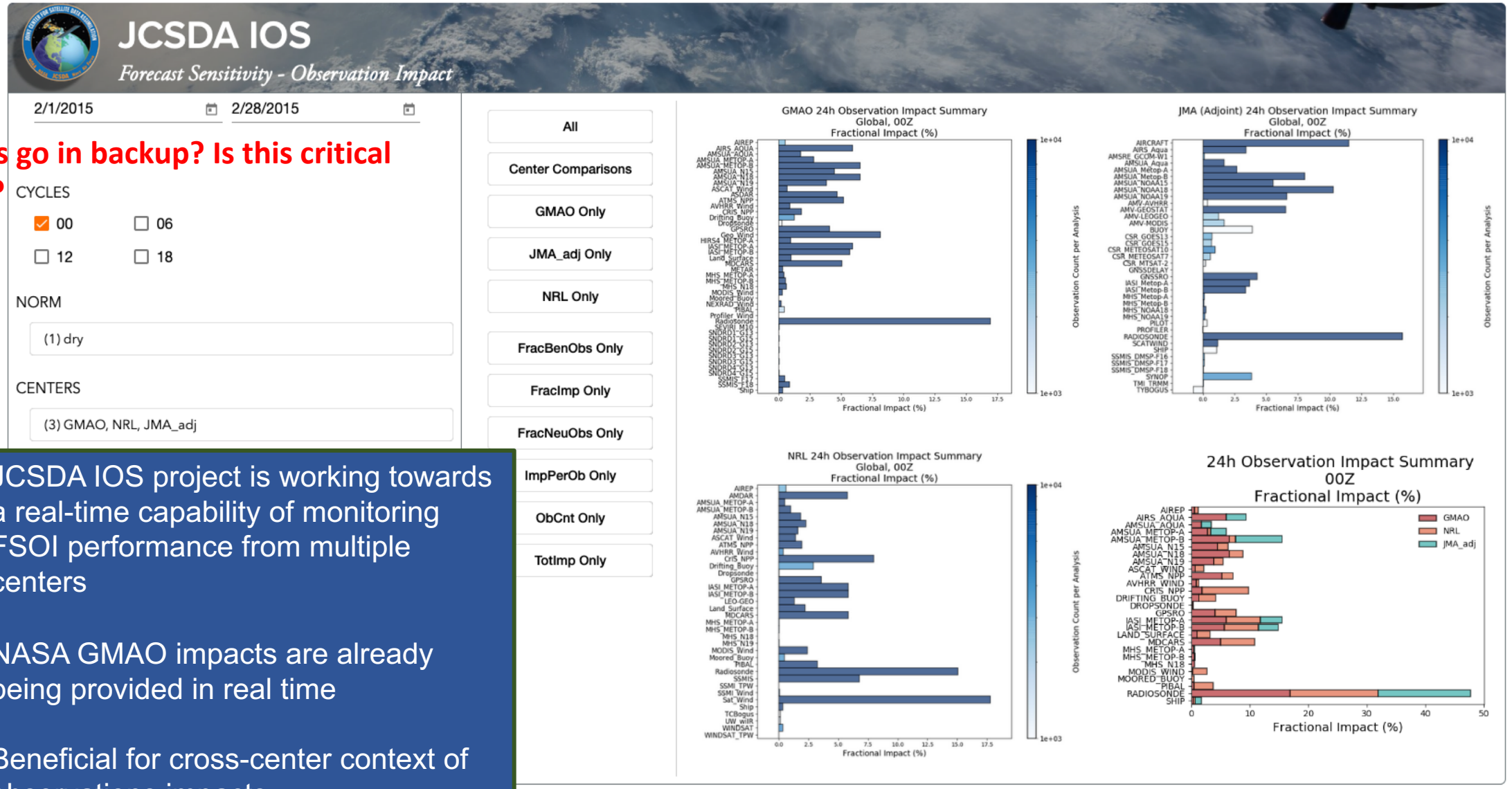


Schematic of the FSOI: running forward then backwards to trace impacts

Forecast Sensitivity-based Observation Impacts (FSOI)



JCSDA Contribution: Inter-Agency Comparison of FSOI

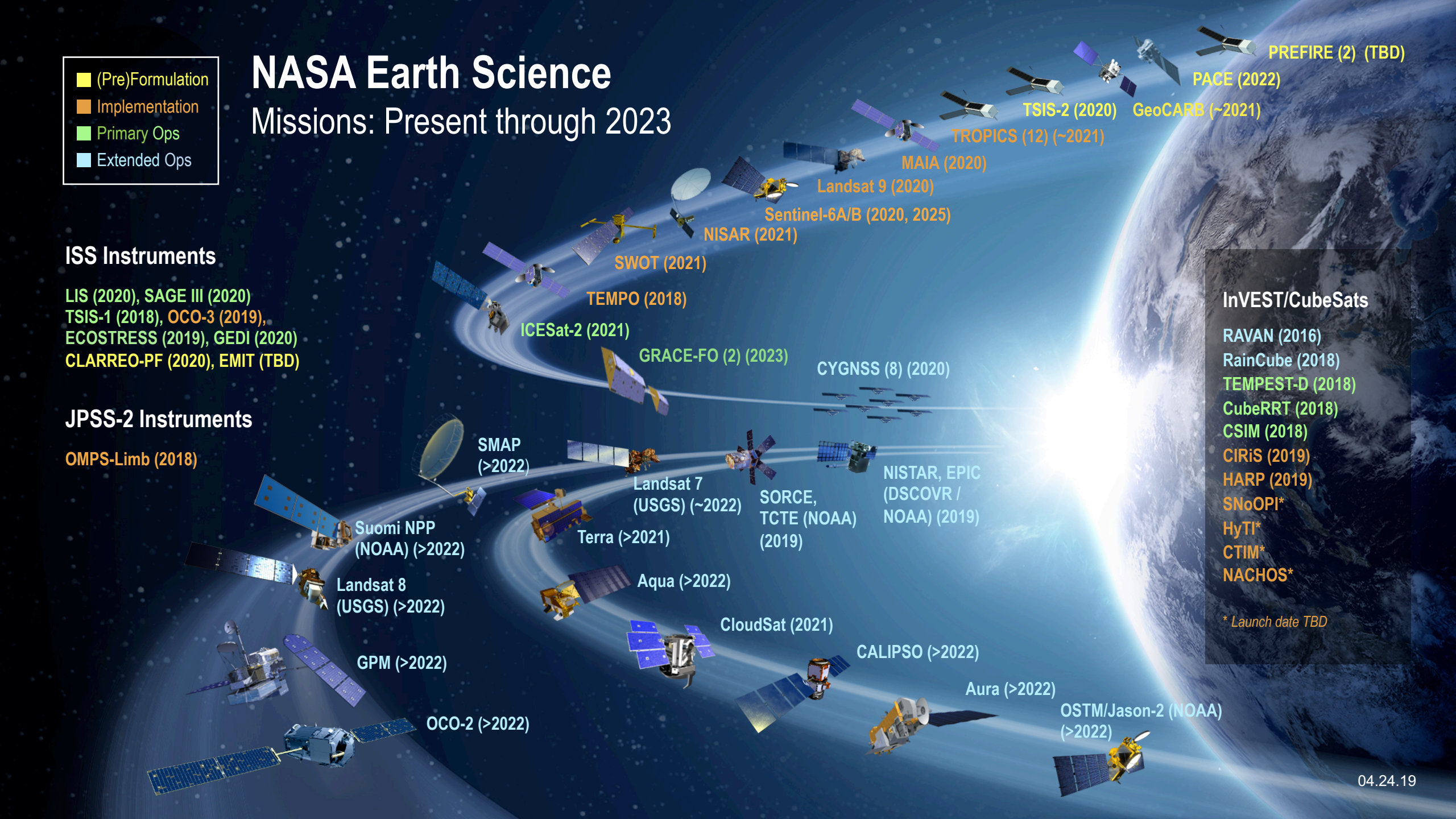


Can this go in backup? Is this critical for me?

JCSDA IOS project is working towards a real-time capability of monitoring FSOI performance from multiple centers

NASA GMAO impacts are already being provided in real time

Beneficial for cross-center context of observations impacts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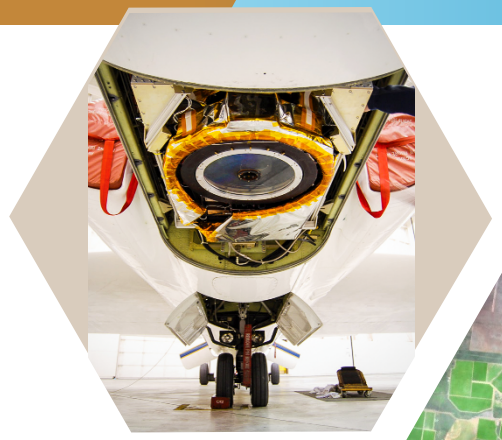

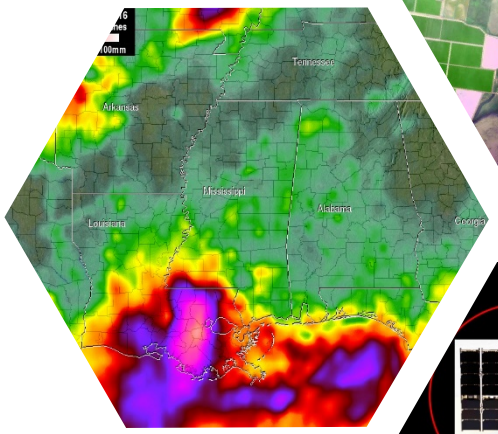

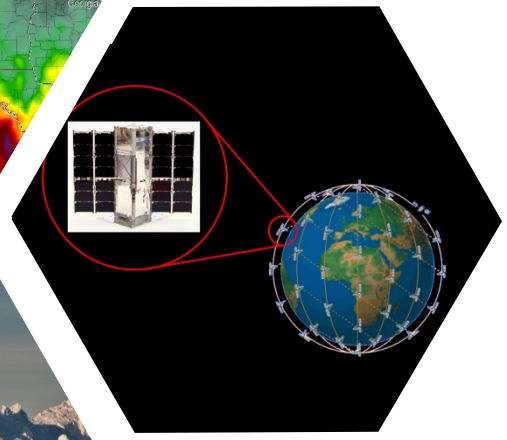

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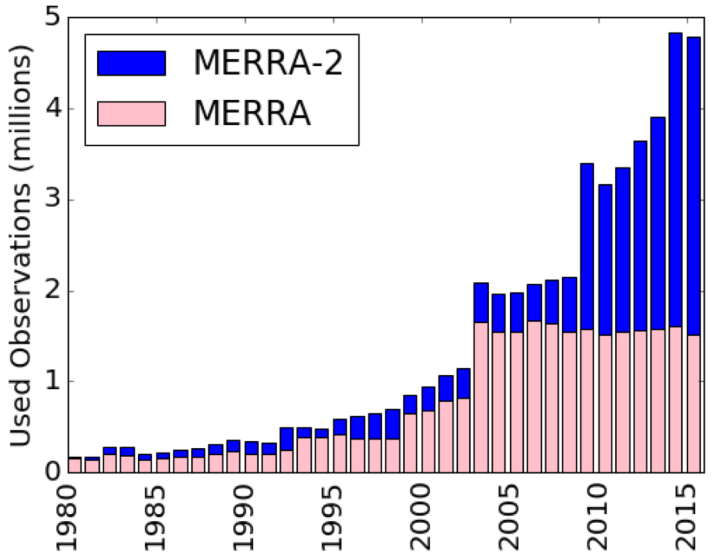
Impacts of Hyperspectral IR Data in Reanalysis and Weather Prediction

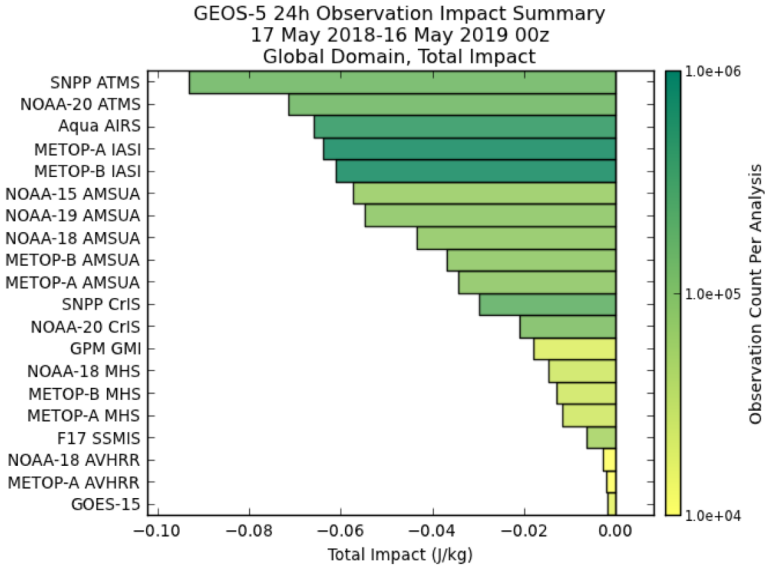
NASA's AIRS instrument established the value of hyperspectral radiance data

JCSDA scientists were instrumental in implementing AIRS data into assimilation systems

AIRS, IASI, and CrIS now play pivotal roles in reanalysis and NWP



Observation count in reanalyses is dominated by growth in hyperspectral IR data. AIRS used in MERRA, IASI, and CrIS are added in MERRA-2



Observation impacts on forecast skill, captured by the FSOI metric, highlight the continued value of AIRS data in weather prediction

Use of GPM All-Sky Radiances in GEOS

Science testing

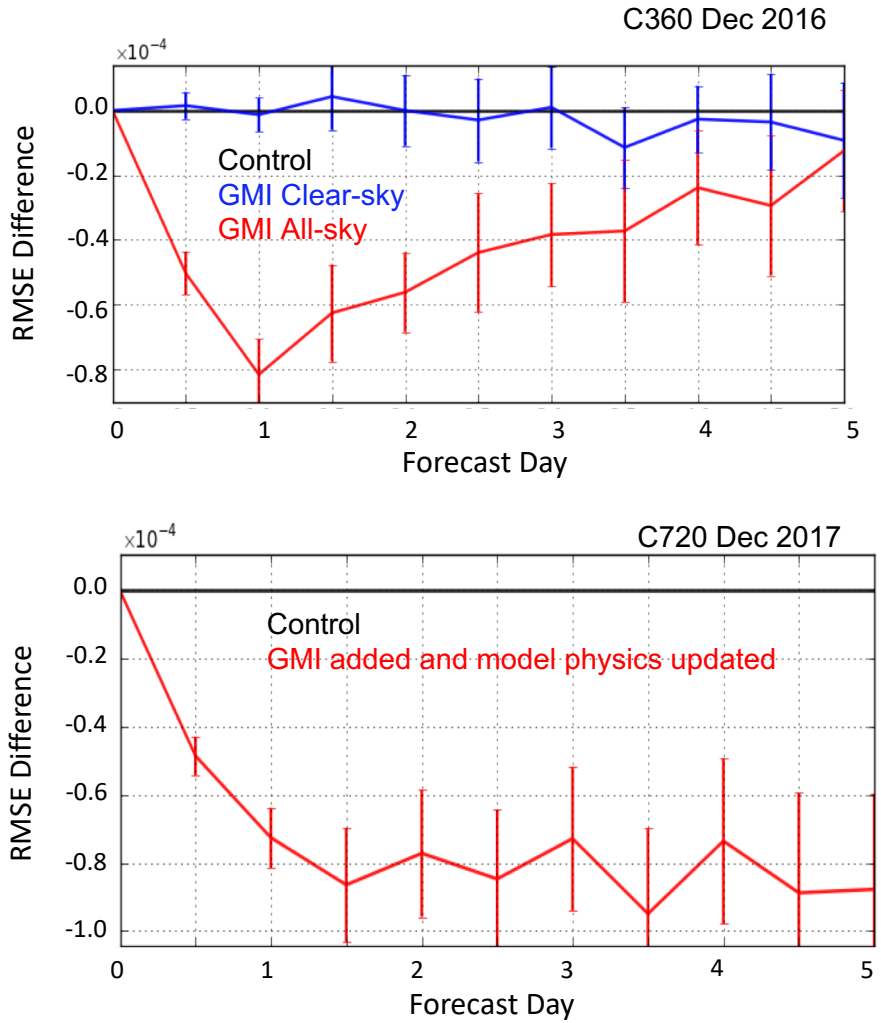
- Adding GMI all-sky radiances improves the initial state and leads to reduced forecast error, especially in the Tropics.
- Largest impact is at day-one, with diminishing impact thereafter.

Additional changes to the GEOS model

- Changes were made to microphysics cloud parameters (effective radii and fall rate of ice crystals) in the GEOS model, which led to these beneficial impacts propagating through the five-day forecast.

These changes were implemented in GEOS FP in July 2018

RMSE Difference in Tropical 850 hPa Humidity



Kim et al. (2019)