



# Recent Earth Observation Developments at the U.S. Naval Research Laboratory

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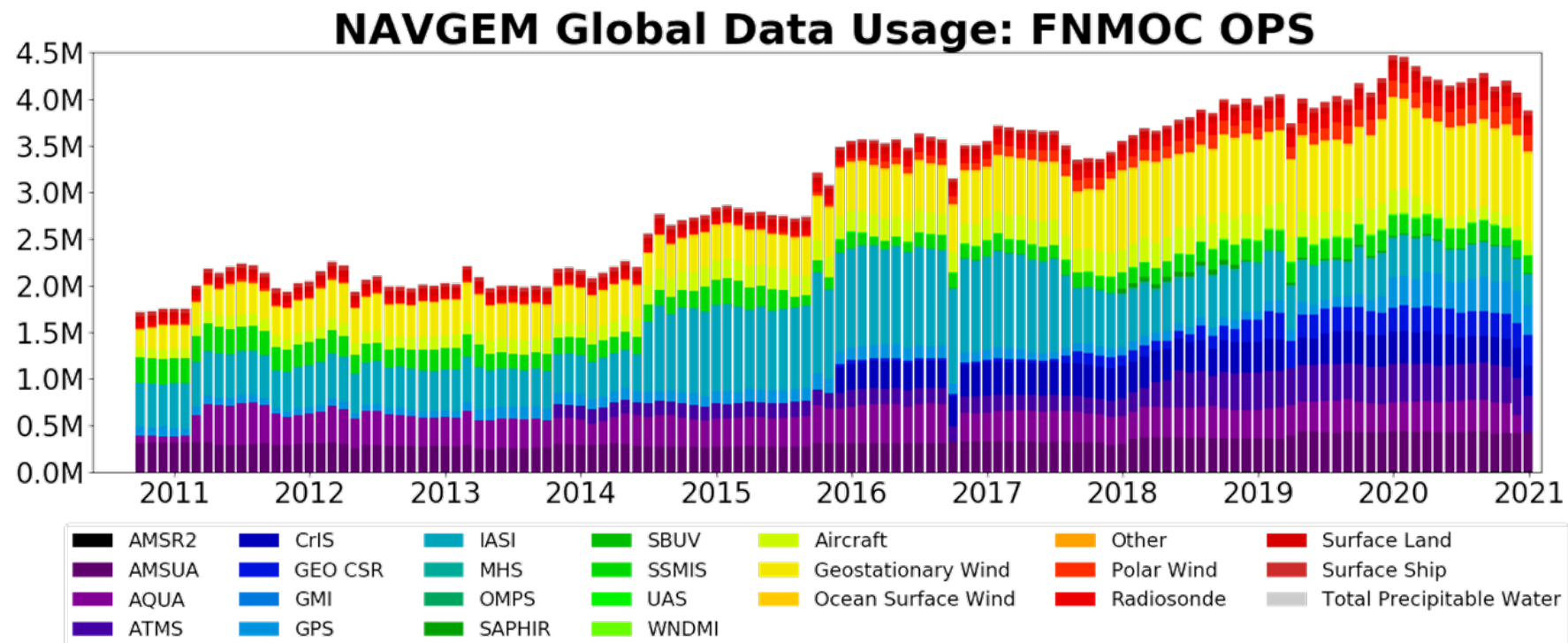


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- NWP models:
  - COAMPS<sup>®</sup>: Coupled Ocean / Atmosphere Mesoscale Prediction System
    - Current operational mesoscale model, multiple regions, triple nested typically 45/10/x km
  - NAVGEM: Navy Global Environmental Model (NAVGEM)
    - Current operational global model at Fleet Numerical Meteorology and Oceanography Center (FNMOC); operational resolution t681l60 (~20km)
  - Navy ESPC: Earth System Prediction Capability
  - NEPTUNE: Navy Environmental Prediction sysTem Utilizing the NUMA\* Engine
    - Next generation model
    - *\*NUMA: Nonhydrostatic Unified Model for the Atmosphere (F. Giraldo NPS)*
  
- Data Assimilation Systems
  - NAVDAS: Naval Research Laboratory Atmospheric Variational Data Assimilation System
    - 3D-Var system used for mesoscale system
  - NAVDAS-AR: NAVDAS-Accelerated Representer
    - Hybrid 4D-Var use for global system; 80-member ensemble; single outer loop
  - JEDI: Joint Effort for Data assimilation Infrastructure
    - NEPTUNE DA will be based on JEDI for UFO and Solver both 3D-Var and hybrid 4D-Var are being targeted
  - NAAPS: Navy Aerosol Analysis Prediction System - 2DVar, 3DVar (research mode), EnKF
  - LIS: Land Information System (COAMPS has a project to implement LIS for land initialization)

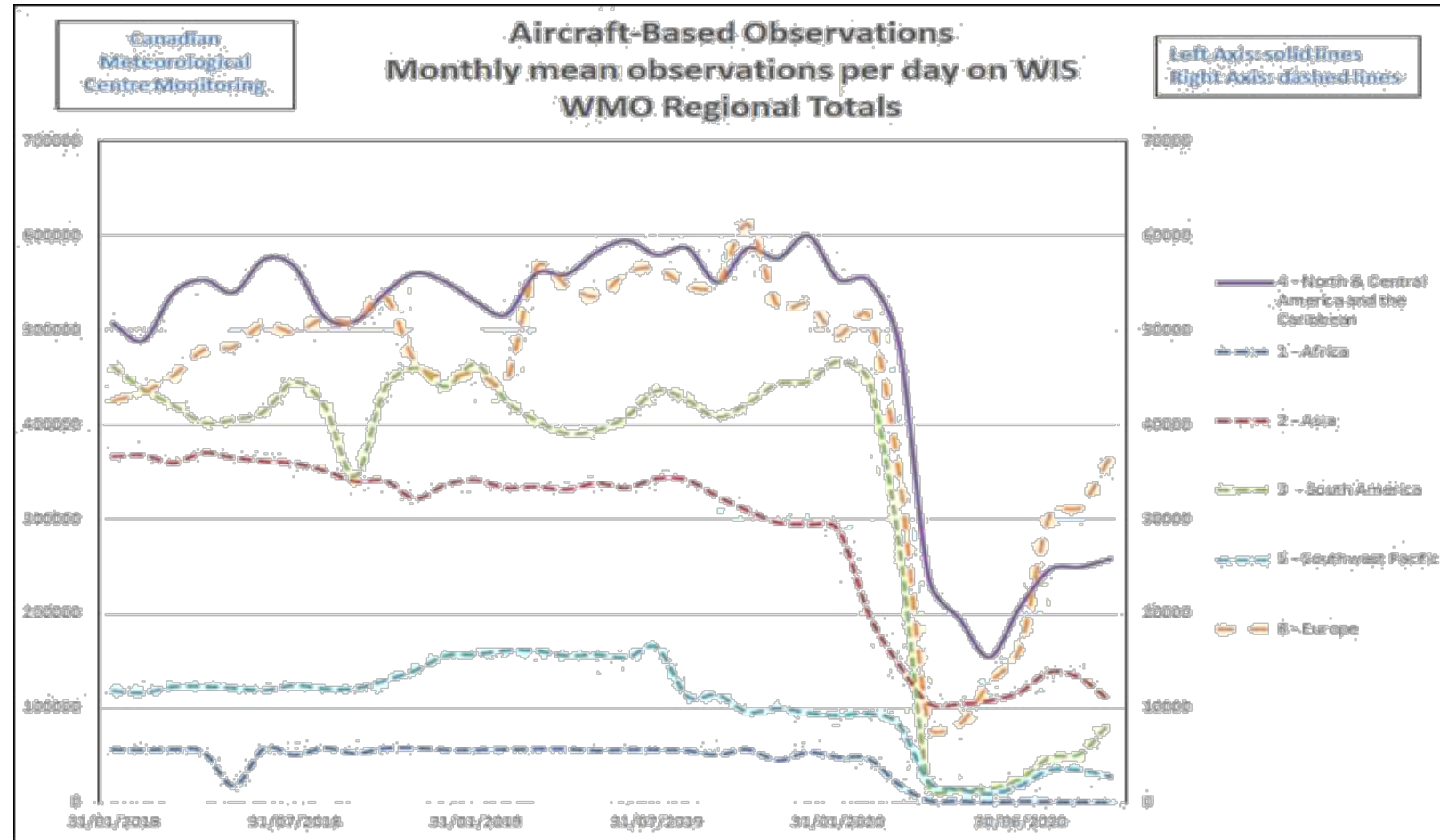
## BLUF: COVID-19 changed the observing system

- Impacts of COVID-19 on Earth observations
- Recent satellite observation changes
- NEPTUNE DA using JCSDA JEDI
- NOAA Commercial Data Program purchase



# COVID-19 Impact on Observing system

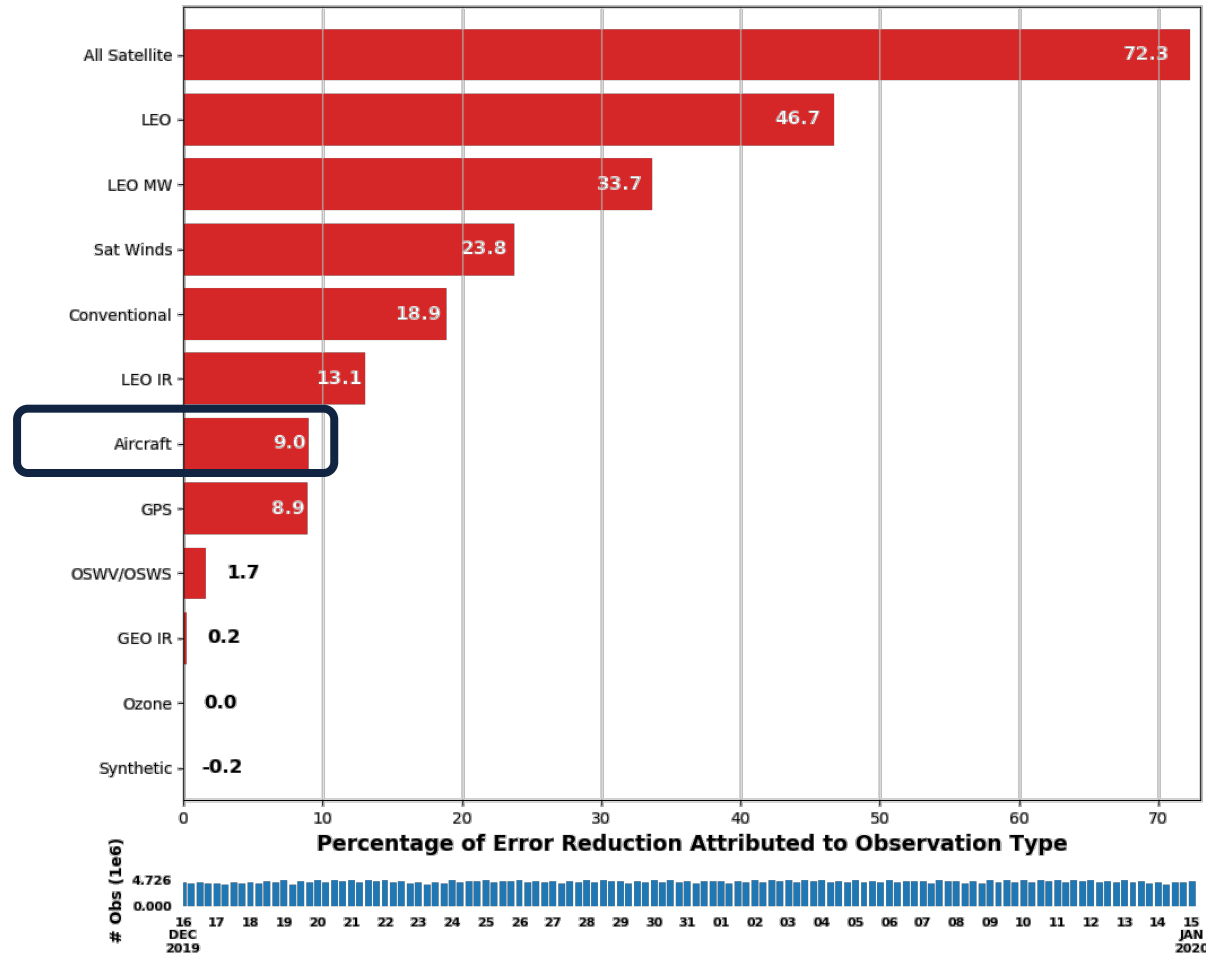
- COVID-19 Pandemic
  - Most world travel shut down in mid March
  - Dramatic decrease in aircraft flights, and therefore, aircraft obs
- Global flight activity relatively uniform through January and February
- Global lockdowns began the first couple of weeks in March



# COVID-19 Impact on Observing system

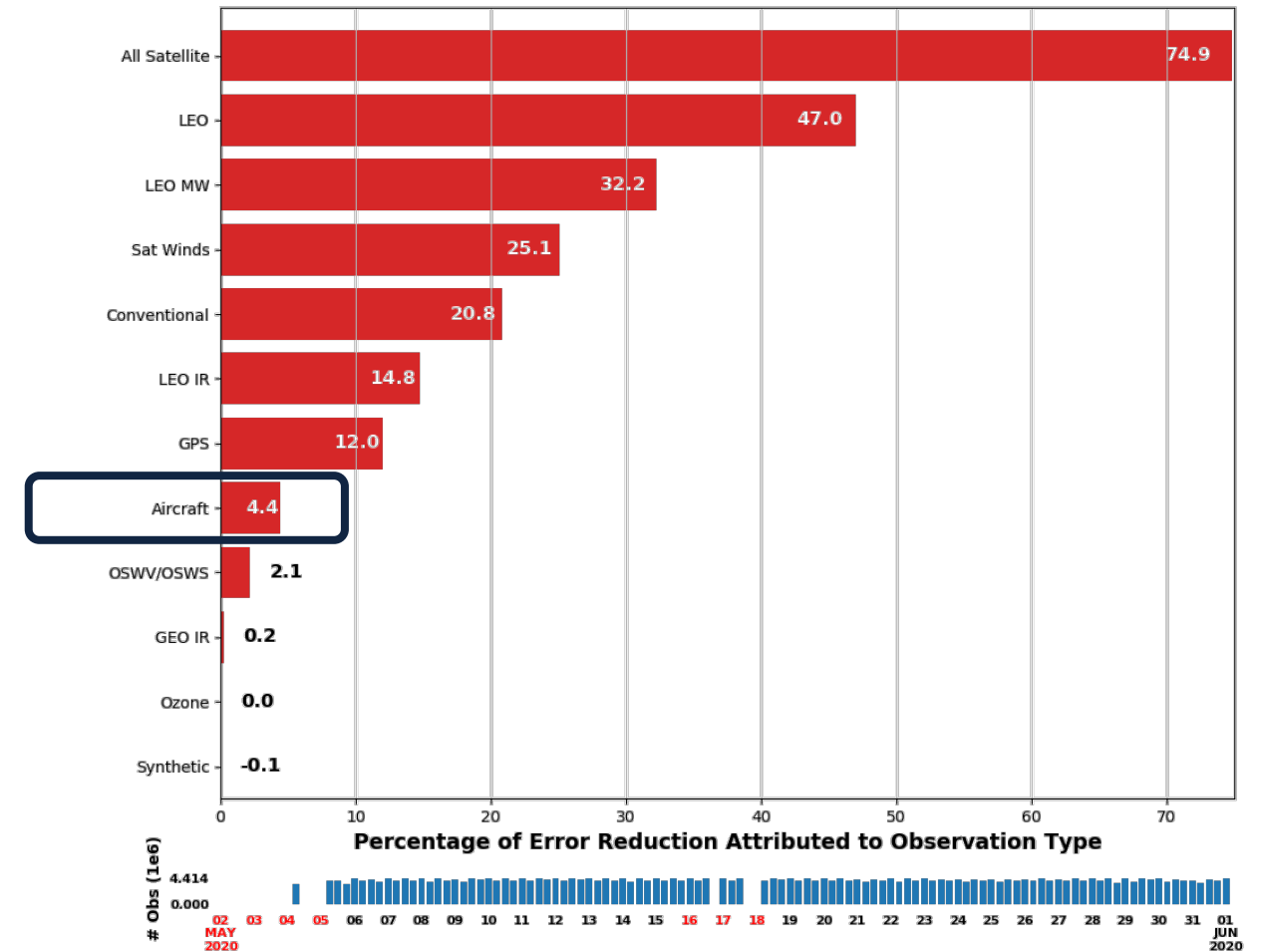
Jan2020

NAVGEM Ob Sensitivity by Category (% of total)



Jun2020

NAVGEM Ob Sensitivity by Category (% of total)



Aircraft data, loss of forecast sensitivity to observation FSOI impact dropped dramatically.  
Partially compensated by Radiosonde and Surface (conventional); Leo IR and GNSS-RO (GPS).

# Recent changes in Satellite Assimilation

- Re-establishing AIRS:
  - FNMOC had never pulled NRT observational data from a NASA service
- IASI MetOp-C
  - Established operational data feed May2020
- OMPS v8 NOAA20 Ozone nadir profiles
  - Product just passed final maturity reviews
- COSMIC-2 GNSS-RO
- GOES-17 GeoCSR and AMVs
- SMOS and ASCAT soil moisture
  - Another NASA product pull for the SMOS product
  - Assembling all the NRT feeds necessary for LIS
- Aeolus wind lidar
  - Data feed established early prototype
- Ground-based GNSS
  - Evaluations underway, initial bias correction developed
- Small Satellite Evaluations
  - TEMPEST-D, COWVR, WSF-M, TROPICS

## Other areas of emphasis:

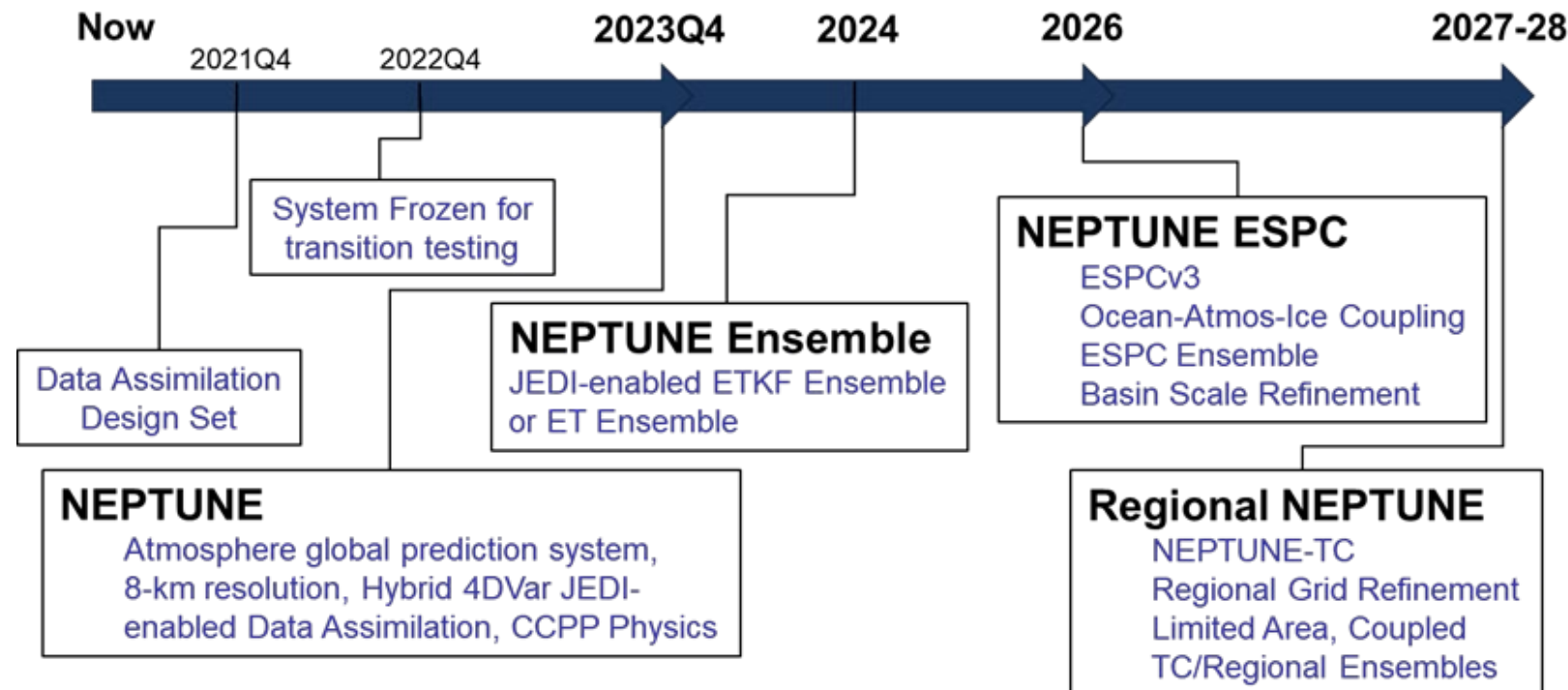
MW and IR all-sky assimilation  
including cloud and aerosol impact

Increased usage of correlated observation error

Dynamic estimation of observation error, thinning and  
quality control (combine with AI/ML methods)

# NEPTUNE: Next-generation unified modeling and DA

- **NEPTUNE is the Navy's next-generation unified modeling and DA system**
  - Applications – global, limited area, coupled, ESPC, ensembles, TC, ...
  - Global Hybrid 4DVar using JEDI
  - New Observation API
  - Observation-based Diagnostics, and Model Verification and Validation
  - CI/CD: Continuous Integration/ Continuous Development
  - Leverage community based tools (JCSDA, JEDI, MET/METplus, CCpp)



Challenge: ambitious timeline coupled with the requirement for ongoing development and support of current systems

# NEPTUNE Adjoint Model

- Goal: Cycle with FALCON 4DVar DA using Navy observations by the end of FY21
  - Necessary requirement for 4DVar is a tangent linear and adjoint model
  - NEPTUNE TLM and adjoint for dry dynamics complete

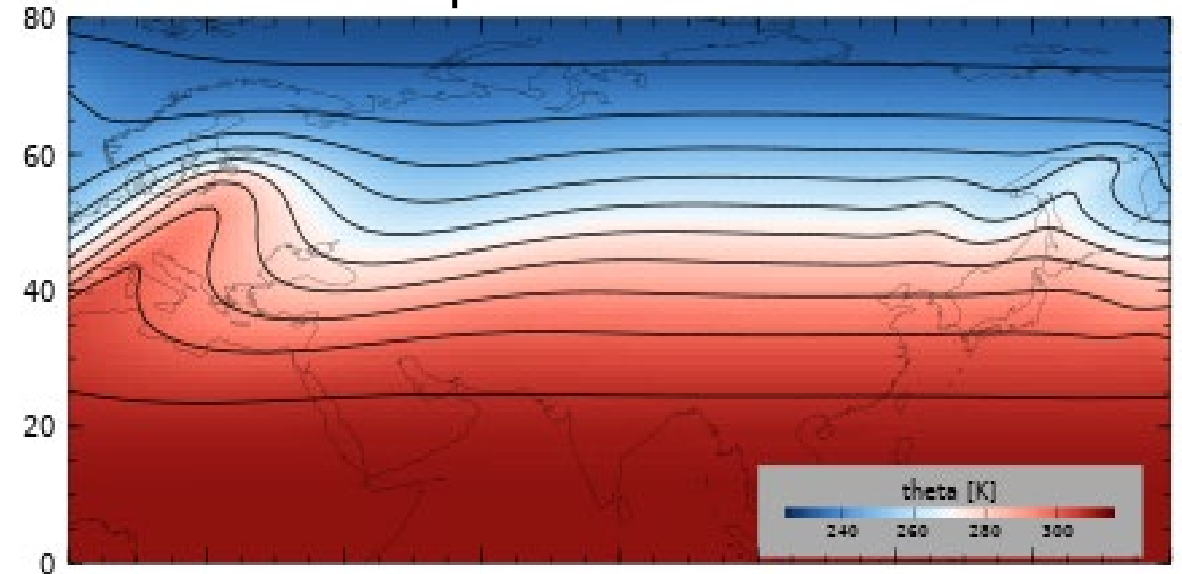
## TLM testing:

- Compare TLM to a perturbed run of the non-linear model
- Use unstable baroclinic wave test case, perturb model after day 10, evolve perturbation in TLM

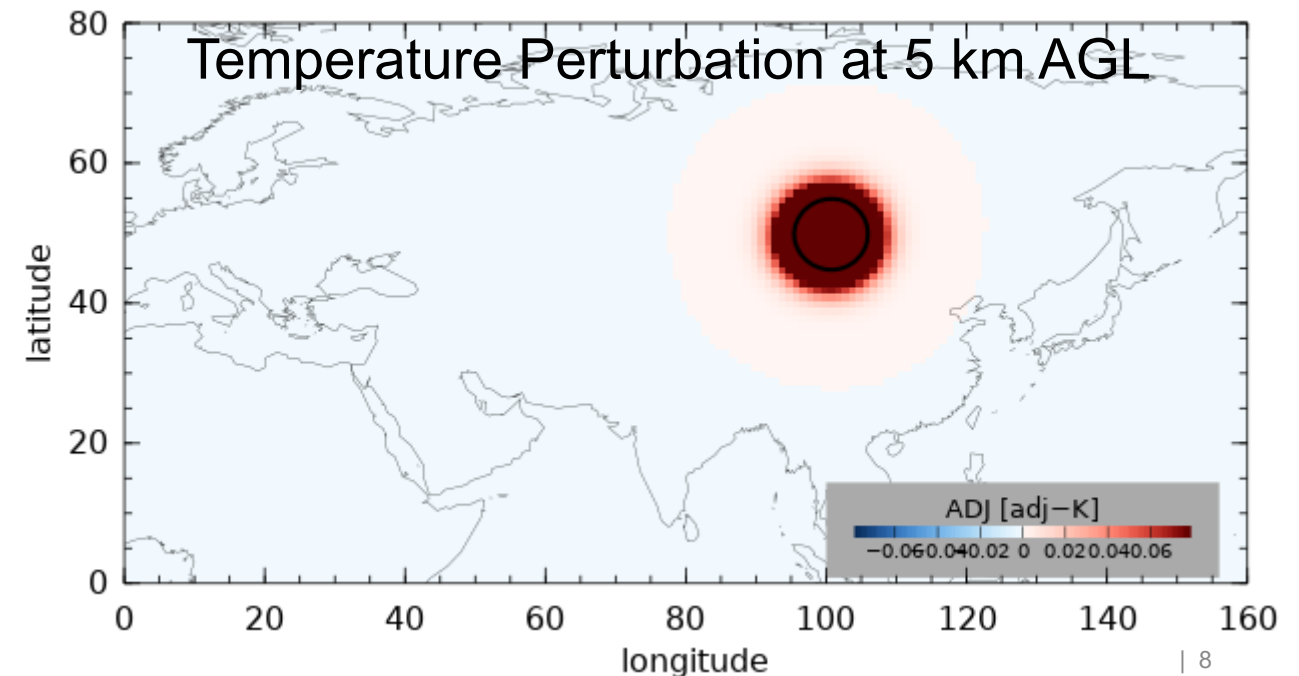
## Adjoint testing:

- First ever atmospheric Spectral Element adjoint model
- Currently validating adjoint of Discrete Galerkin transport

Surface Temperature: 324 h simulation



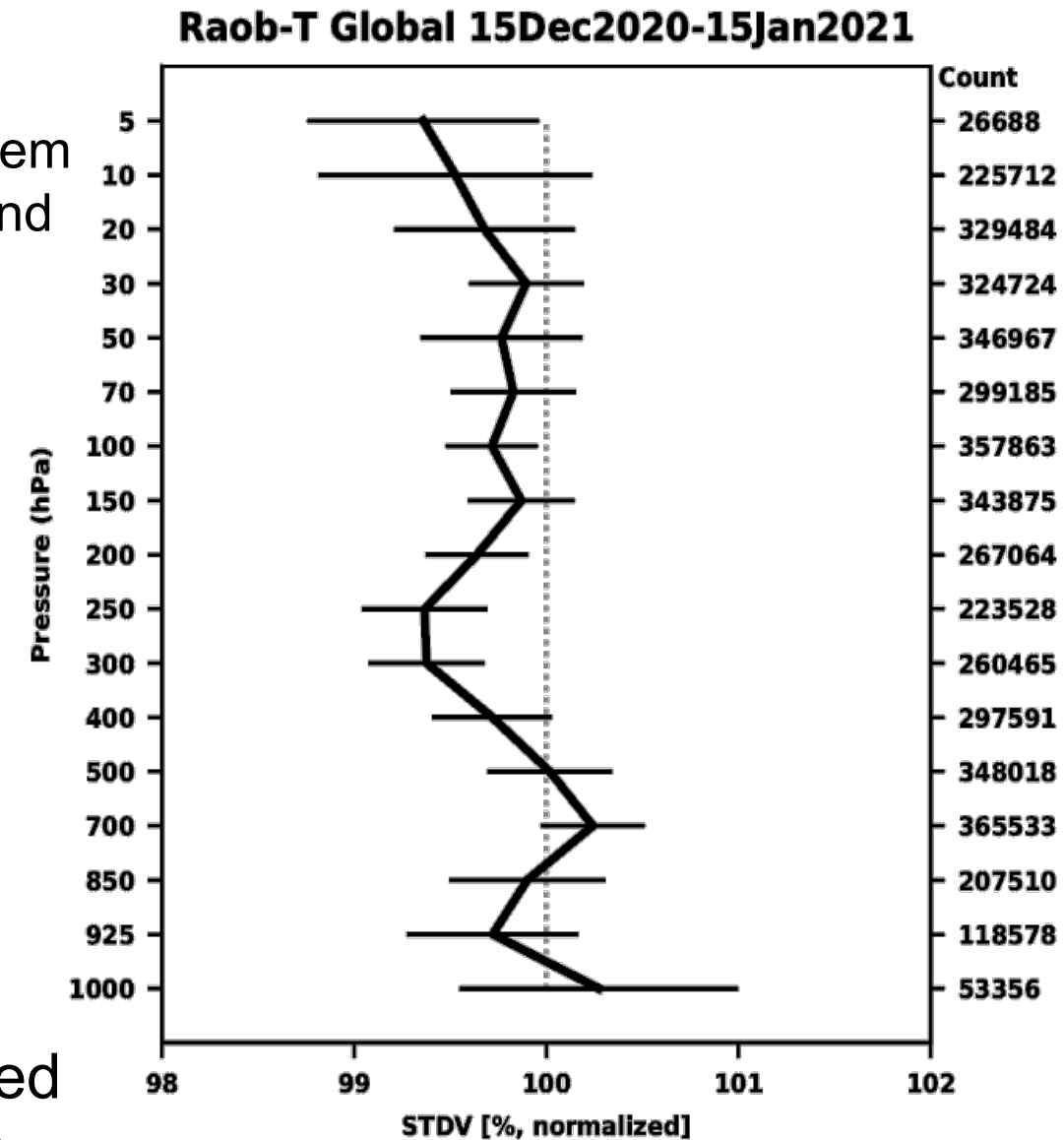
Temperature Perturbation at 5 km AGL





# NOAA Commercial Data Purchase Delivery Order 1 (DO1)

- NOAA provided data from two vendors for a 1 month evaluation period spanning from Dec2020-Jan2021
  - Traditional forecast metrics showed little impact on top of a full system
  - Fit-to-Observation metrics show improvement in both radiosonde and microwave sounders sensitive to temperature around 300-200 hPa
- Differences in the data quality were small; however:
  - Spire provided both rising and setting occultations
  - GeoOptics provides only setting occultations
- Differences in the fit of the observation are seen between rising and setting (setting better) and which transmitter was tracked (GPS better than GLONASS)
- Observation error could be designed to vary depending on mission, rising versus setting and which transmitter is tracked
  - Potential to maximize the impact of the GNSS-RO observation suite



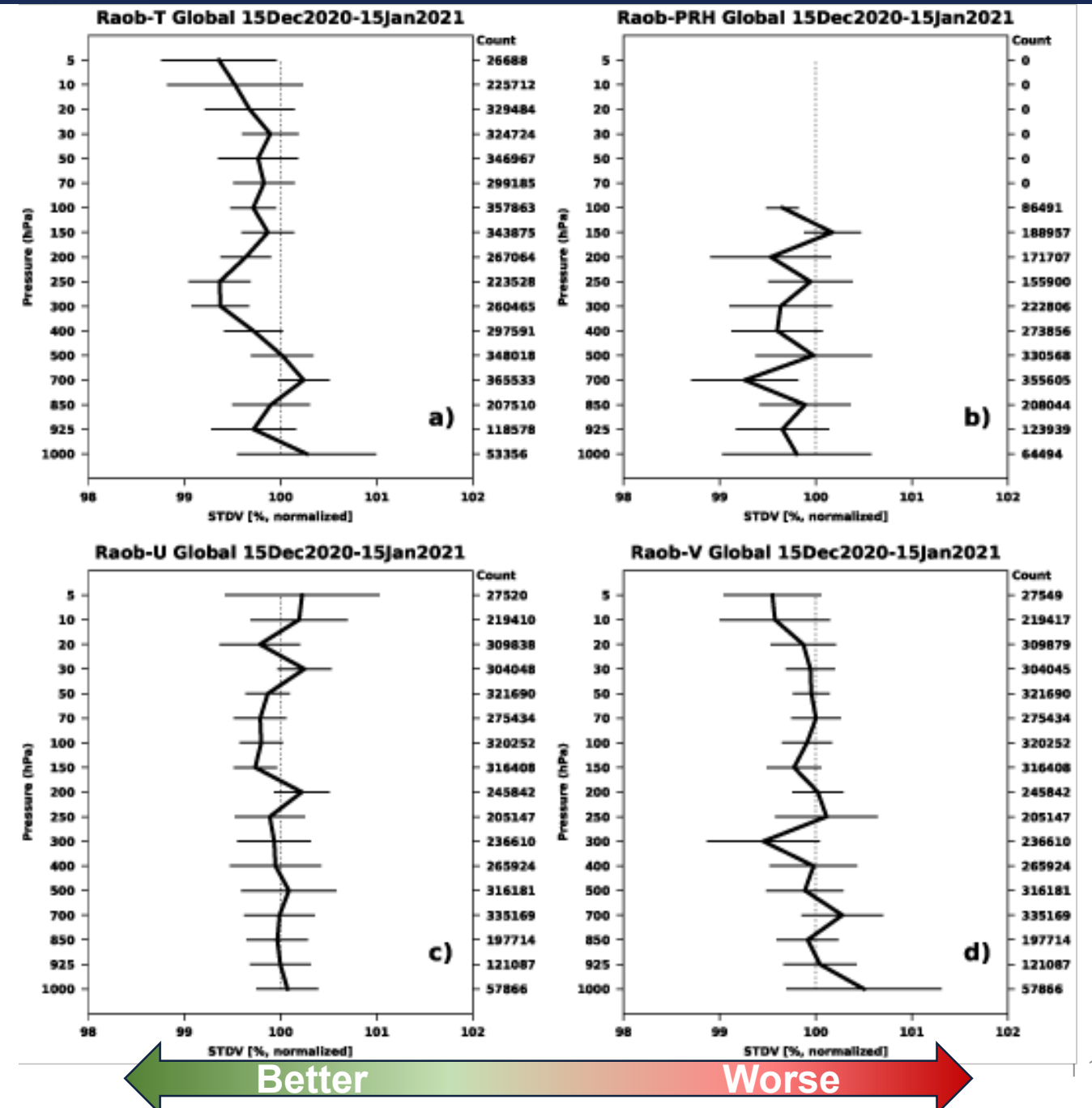
## Fit to Radiosonde

Change in the RMS of the fits to radiosondes between the experiment (DO1) and control

A time series of these differences are used to generate the 95% confidence intervals

Strongest response was seen in the temperature field between 300 – 200 hPa

Very little response in the other fields, positive response in pseudo RH (PRH) at 700 hPa encouraging but unexplained



## Fit to Microwave Radiances

Change in RMS of the fits to ATMS\*  
between DO1 and control

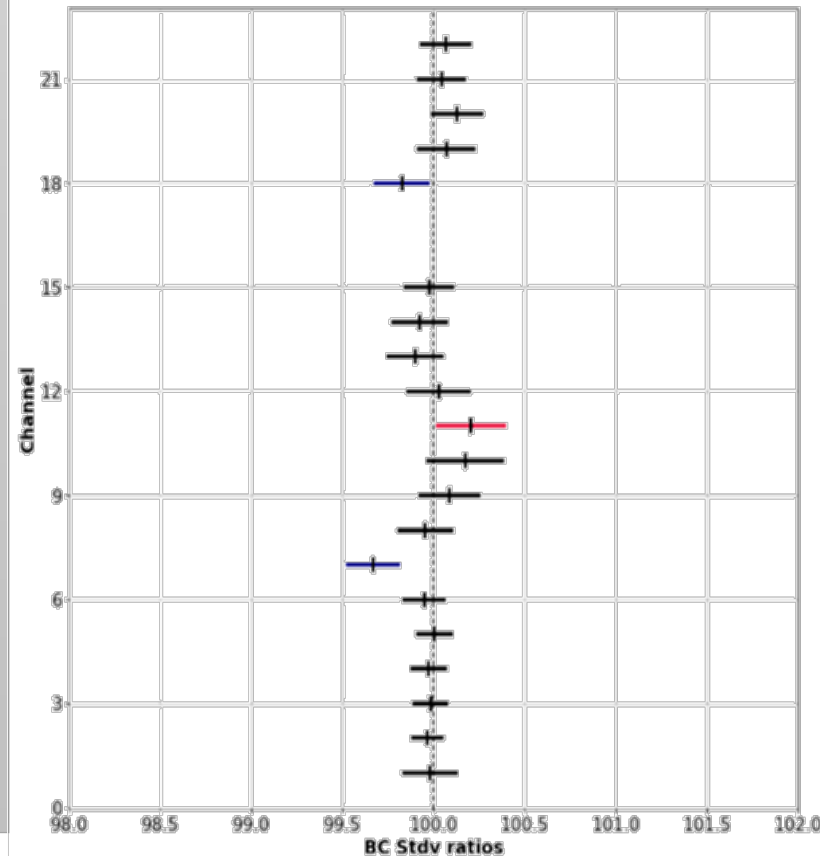
\*Advanced Technology Microwave Sounder

Time series of differences are used to generate the 95% confidence intervals

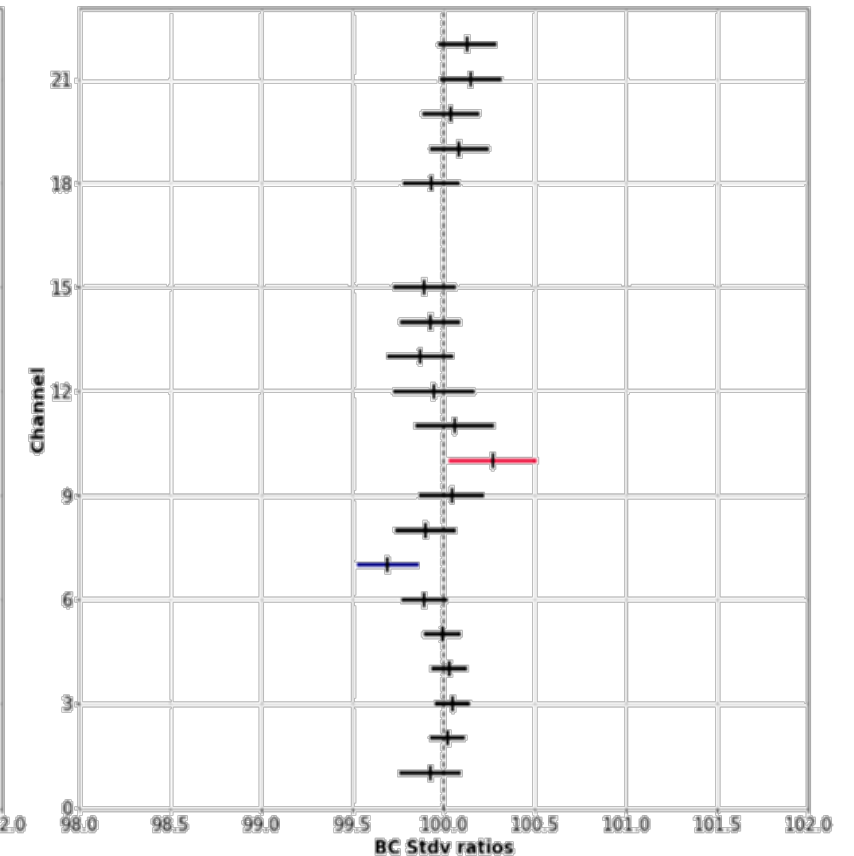
Strongest response in channel 07  
which is sensitive to temperature  
between approximately 300 – 200 hPa

Very little response in other channels

DO1 vs CTL  
NPP\_atms BC Stdv ratios (CI=95.00%)  
20 channels (20 assim, 0 monitor)  
121 dtgs 2020-12-15 to 2021-01-15



DO1 vs CTL  
NOAA20\_atms BC Stdv ratios (CI=95.00%)  
20 channels (20 assim, 0 monitor)  
121 dtgs 2020-12-15 to 2021-01-15



## NRL Updates Summary

- NRL currently develops and assists with multiple modeling and data assimilation systems; spanning global to mesoscale, through coupled modeling and aerosols
- The next-generation NEPTUNE system with JEDI-based DA will unify many of the modeling and data assimilation components under a single system
- COVID-19 impacts on the Earth observing system were directly seen on aircraft observations, but showed a change in the relative weighting of other observations
- NRL continues to aggressively pursue new observations from unique platforms, and SmallSats including data from commercial vendors