JEDI Applications

Jedi Academy IV, Monterey CA

26th February 2020

JEDI Applications

- Numerical weather prediction (global and regional)
- Marine data assimilation (ocean and sea-ice) *
- Constituent data assimilation *
- Land and snow data assimilation *

* JCSDA project directives

NWP Projects

- FV3 (GEOS, GFS, FV3SAR) – cubed sphere
- MPAS – icosahedral
- UM – lat/lon
- LFRic – cubed sphere
- Neptune – cubed sphere
- WRF – regional

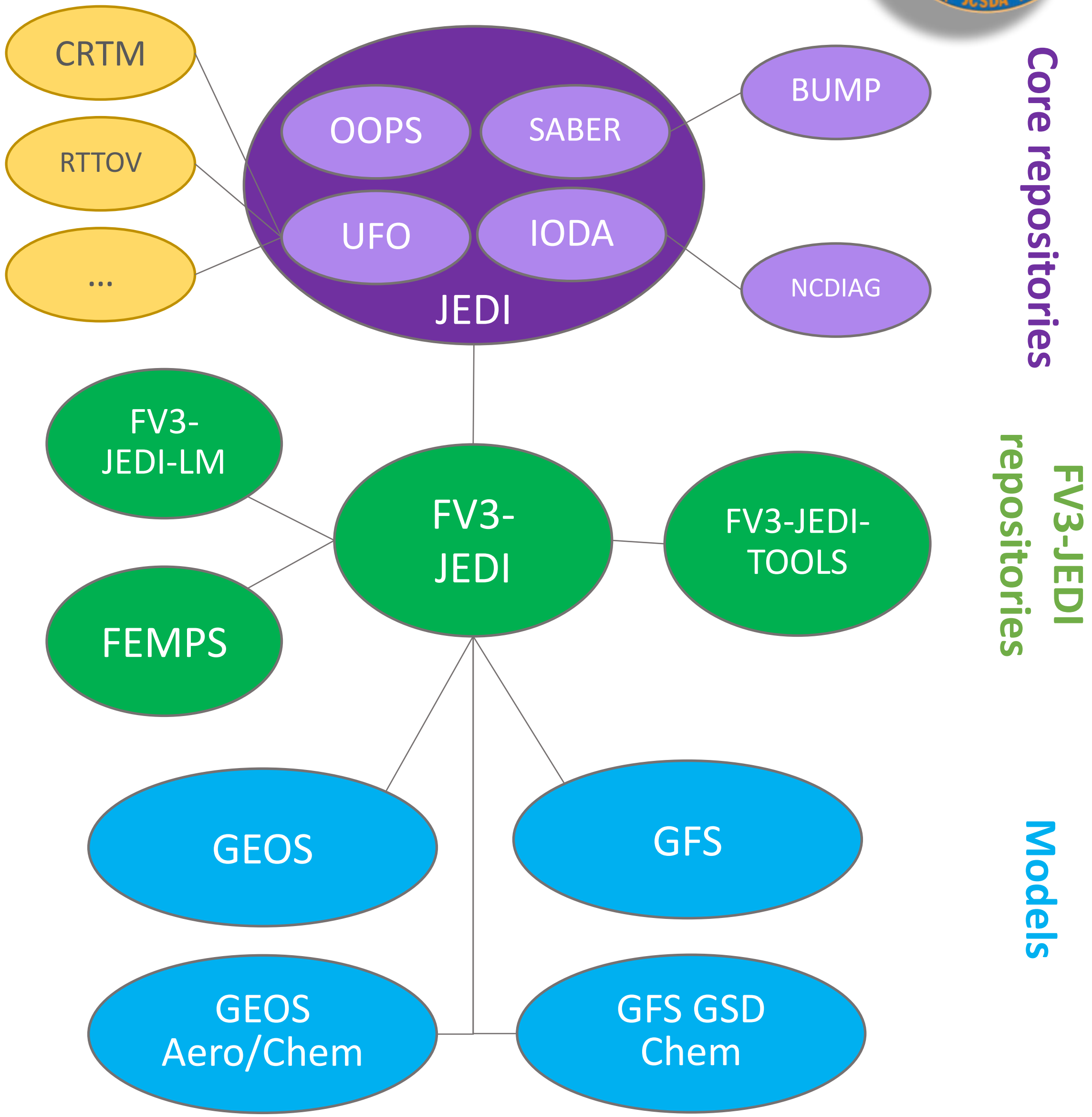
Future

- FV3SAR
- Hurricane

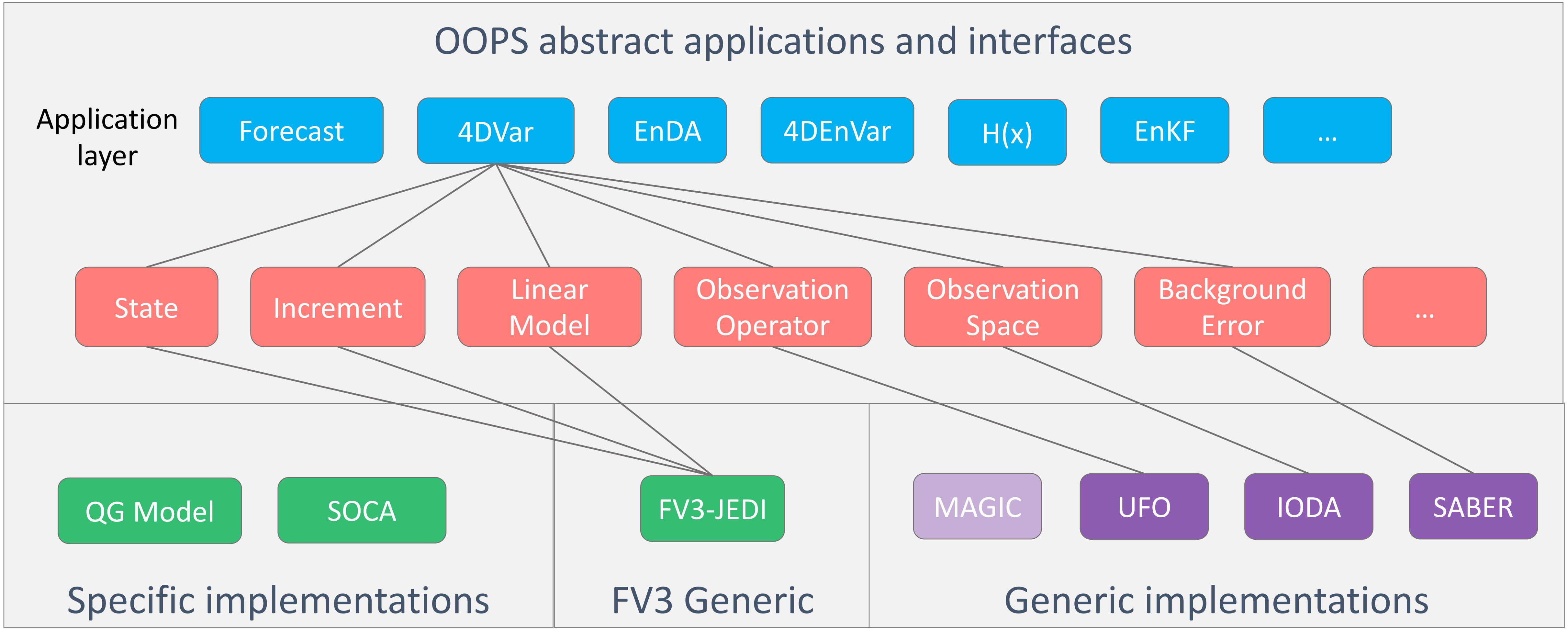
FV3-JEDI

FV3-JEDI overlaps the generic interfaces, methods, applications and configuration of the JEDI system with models that use the FV3 dynamical core. It aims to implement various data assimilation applications directly on the cubed sphere grid.

Specifically it implements geometry, states and increments, parallel IO, variable changes, interpolation to observation locations, the forecast model tangent linear and adjoint and the ability to advance the nonlinear model. It also provides specific unit testing, example configuration scripts for running applications and infrastructure for building JEDI with the forecast models.



FV3-JEDI Interfaces



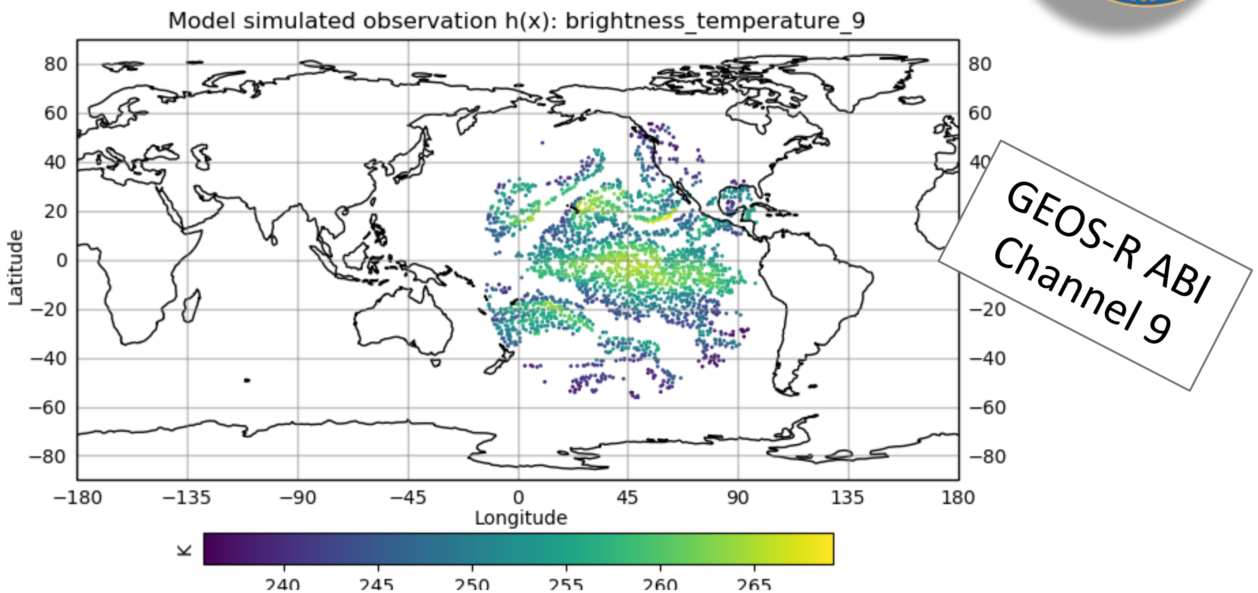
GEOS, GFS, FV3SAR, GEOS-CHEM, GFS GSDChem, GFDL

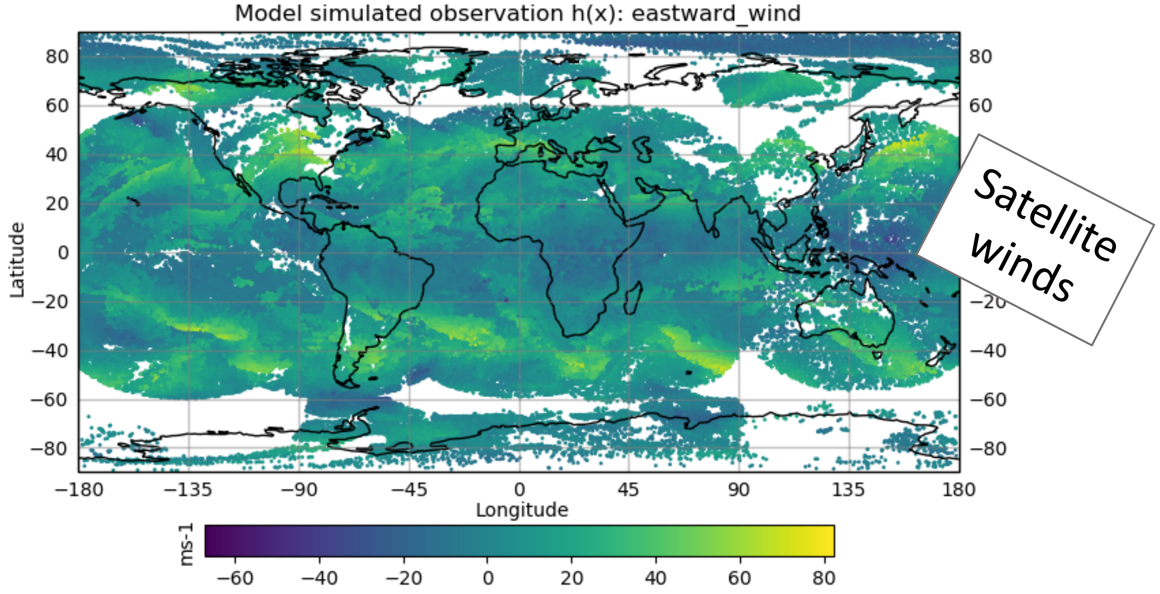
FV3 Model interfacing status

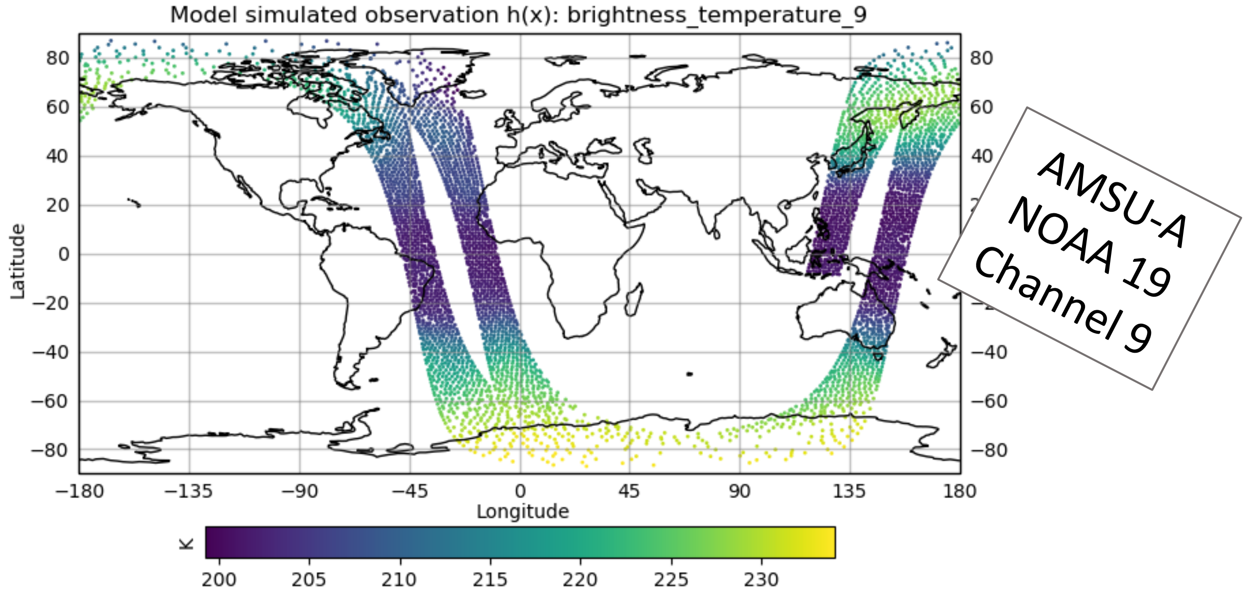
Milestone	GFS	GEOS	FV3 Solo
3DEnVar		✓	
4DEnsVar	✓	✓	NA
4DVar	✓	✓	✓
4DVar with linear physics	✗	✓	NA
Ensemble H(X)		✓	
4D H(x) in-core	✓	✓	✓
Multiple outer loops (IO)		✓	
Multiple outer loops in-core	✓	✗	✓
Multiple resolutions		✓	
EDA		✓	
Multiple resolution outer loops	✗	✗	✓ (simple B)

In core data assimilation – H(x)

- GFS C768 (~12km) forecast model called from FV3-JEDI for 6 hour window beginning 2019-11-18 18Z.
- GFS v16 model.
- Background from operations.
- H(x) calculated in core as a post processor of the model step, no storing of 4D State anywhere.
- Interpolation is from C768 cubed sphere grid to observation locations.

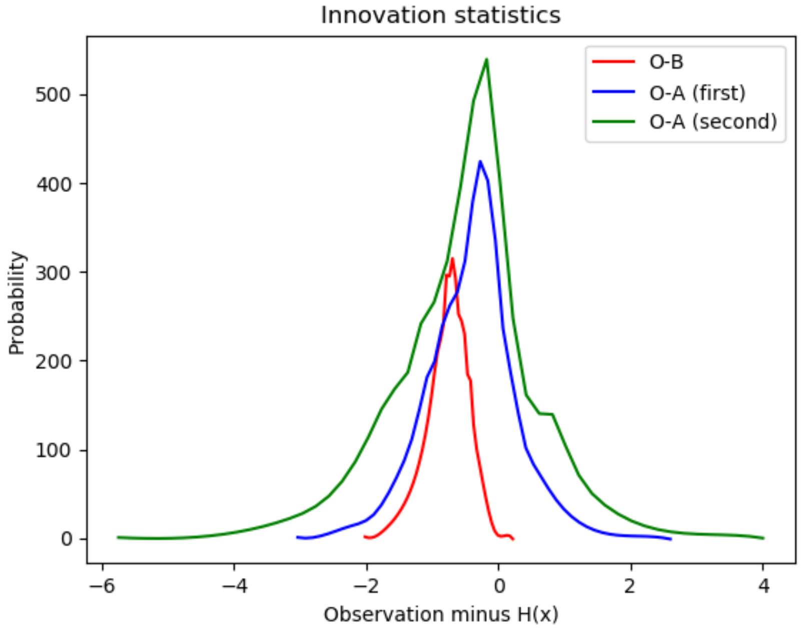


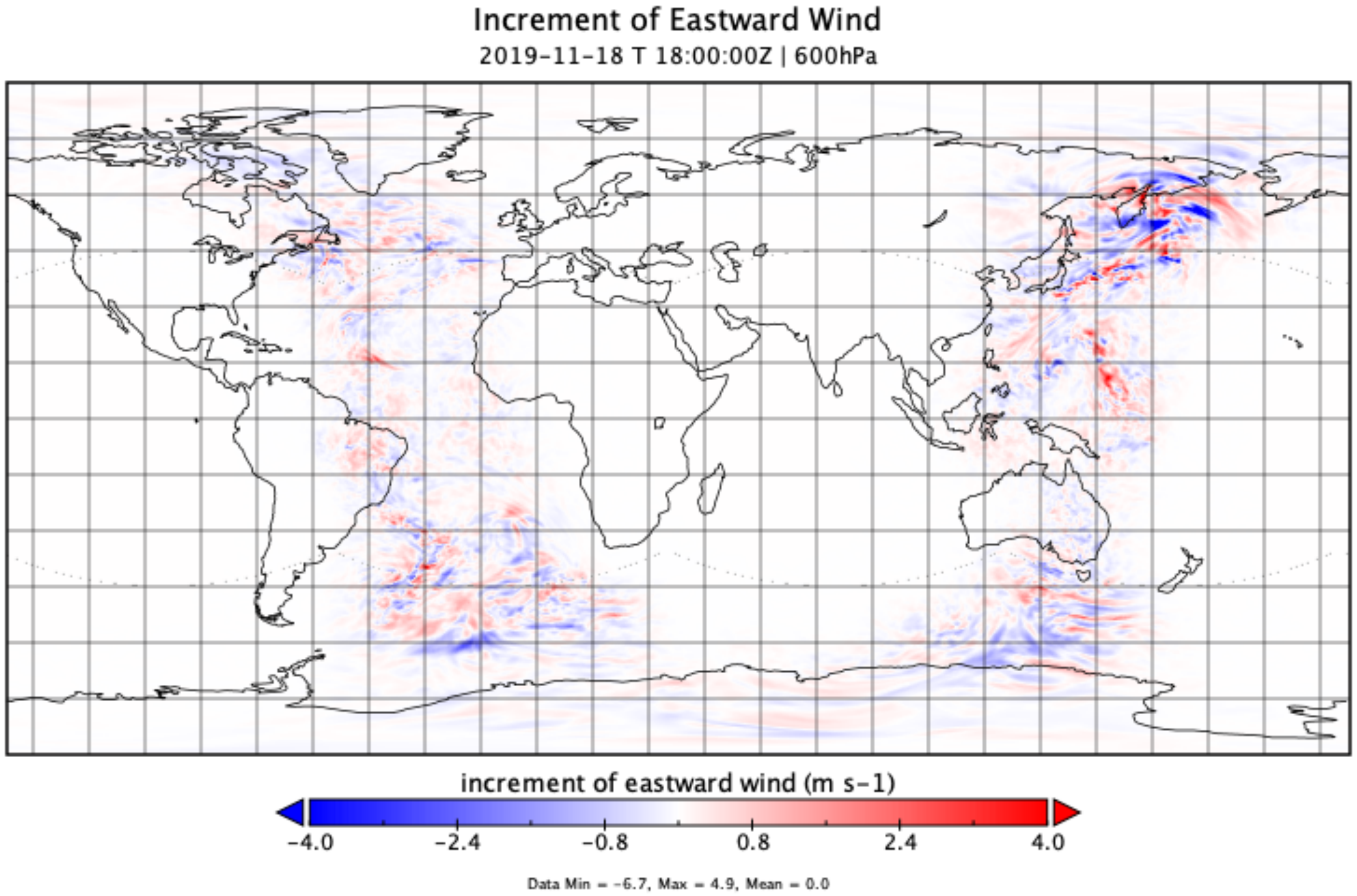




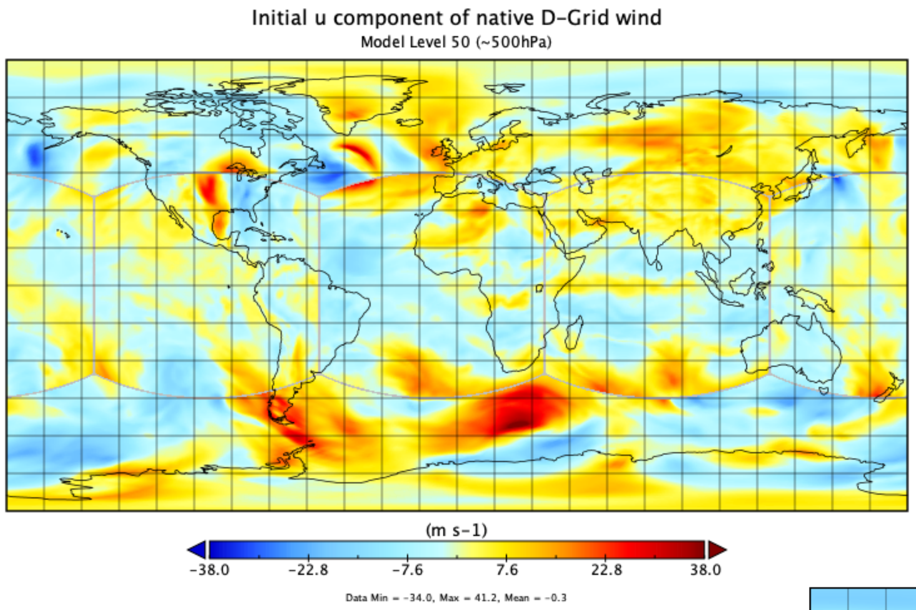
In core data assimilation – 4DVar

- C768 background (from ops) and forecast.
- Native grid and resolution observer.
- Pure ensemble B matrix from C384 (25km) 40 member ensemble (from ops).
- C192 (50km) increment.
- All AMSU-A NOAA 19 (~20,000 obs).
- 3 hour window
- 2 outer loops **in-core**.
- BUMP for localization, interpolation etc.





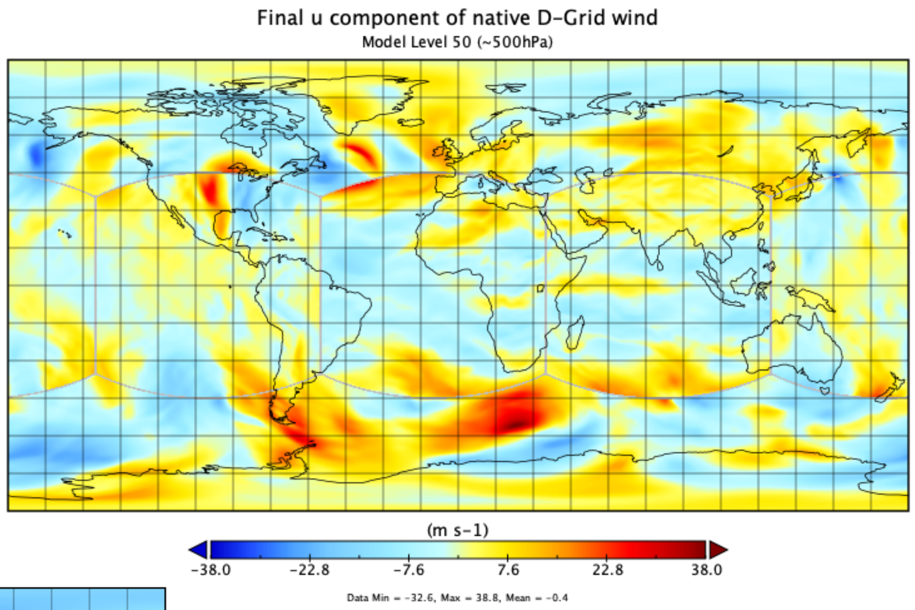
Static B and cubed-sphere Poisson Solver

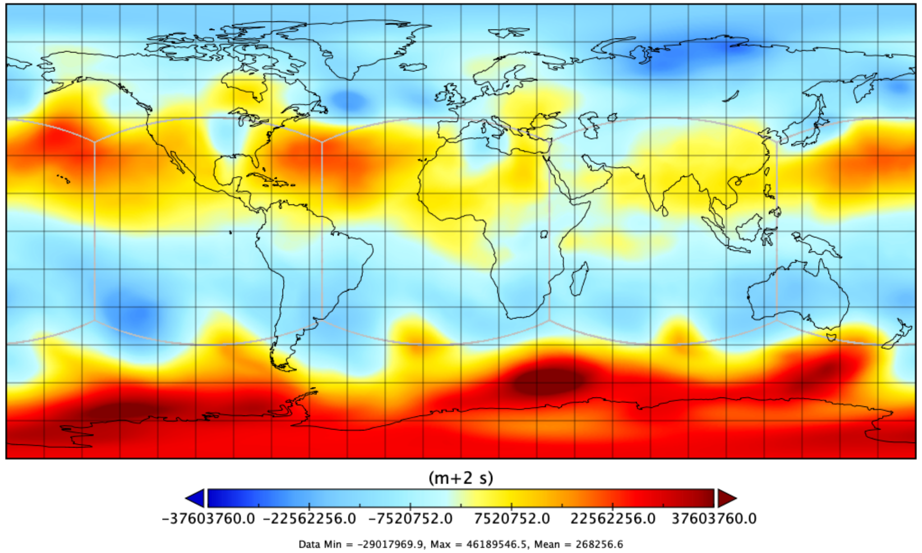


Initial D-Grid winds (correlation length scales ~200km)

Final D-Grid winds

Poisson





Stream function (and velocity potential)

Correlation length scales ~4000km

$$B = K_h K_v D C D^\top K_v^\top K_h^\top$$

D : Standard deviation

C : Correlation (BUMP)

K_h : Horizontal Balance (Poisson solver)

K_v : Vertical balance (BUMP)

Work done with John Thuburn (University of Exeter, UK) and Benjamin Menetrier (JCSDA)

MPAS-JEDI

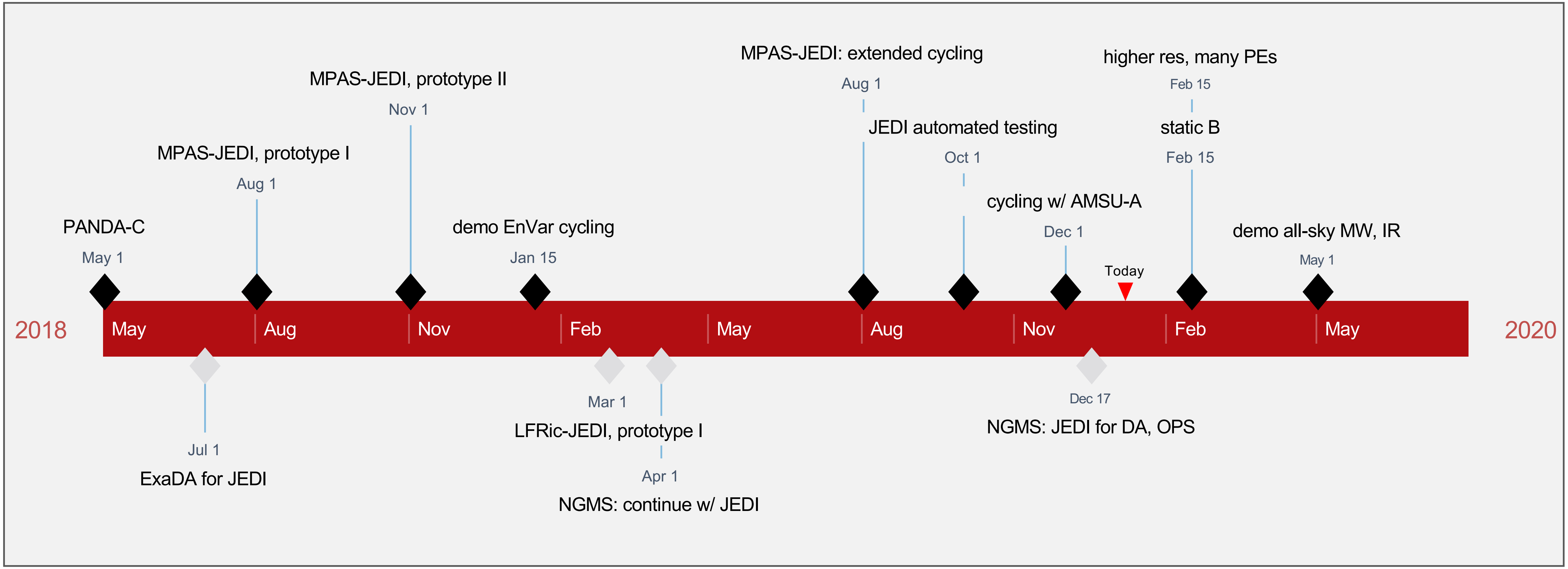
For MPAS the focus is on Cloud Analysis and Forecasting (CAF)

- Important, unsolved problem for data assimilation
  - Multivariate: Can’t analyze cloud in isolation from other fields
  - Multiscale: Fast/small scales with sensitive dependence on slower, larger scales
  - Reliance on remotely sensed observations with strongly nonlinear forward operators
  - Substantial errors in both forecast models and observation operators
- Not a priority application for existing operational global DA systems
- CAF is a top priority for the USAF.

MPAS-JEDI PANDA-C

PANDA-C = *Prediction and Data Assimilation for Cloud*

- USAF funded
- Joint NCAR-JCSDA project
- Coordination with Met Office



MPAS Cycling Experiments

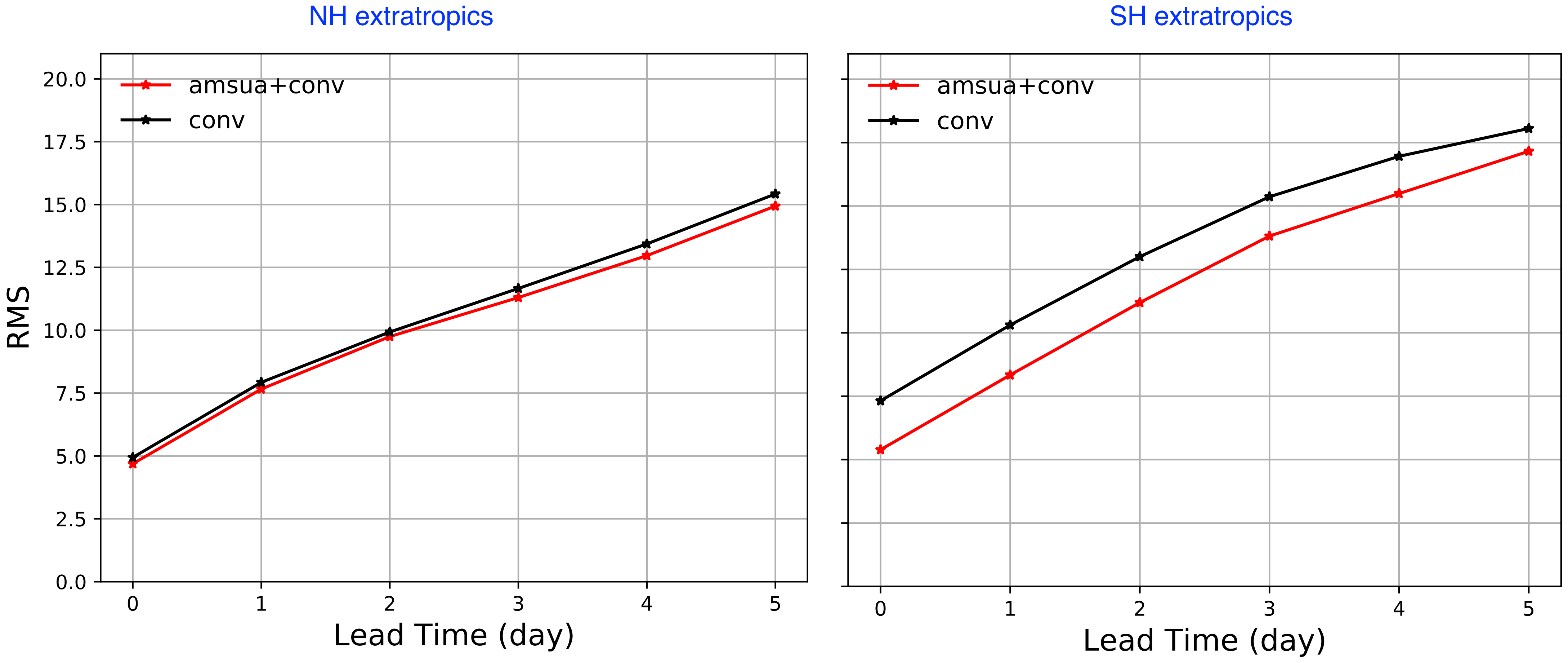
- 6-hourly cycling for 15 April-15 May 2018, 120-km MPAS mesh

- Observations from NCEP/EMC
  - Processing, “pre-QC,” and bias correction of radiances from GSI

- EnVar (pure ensemble)
  - First background is 6-h forecast from GFS analysis (18Z 14 April 2018)
  - 20 ensemble members, 6-h forecasts from GEFS ICs
  - Localization: 2000 km, 5 vertical levels
  - Running on 36 processors (NCAR cheyenne)

Effects of AMSU-A Assimilation

- Forecast fit (m/s) to GFS analysis, 300-hPa meridional wind, NH extratropics



Future plans

- FV3-JEDI
  - Moving to running cycled near real time and retrospectively for GEOS with 4D data assimilation.
  - Complete static B matrix model.
  - Refactoring towards more generic State, Increment and GetValues.
  - Fully in-core with GEOS and GFS.
- MPAS
  - Multivariate static background covariance
  - Ensemble generation
  - Experiments at higher resolution
  - Configure MPAS with higher model top
- Met Office
  - Building out an interface based on Atlas for the Unified Model (UM)

Marine Projects

- MOM-6 ocean – tripolar grid
- SIS2 sea-ice – tripolar grid
- CICE6 sea-ice – tripolar grid

These projects come under the SOCA project within the JCSDA,
Led by Guillaume Vernieres

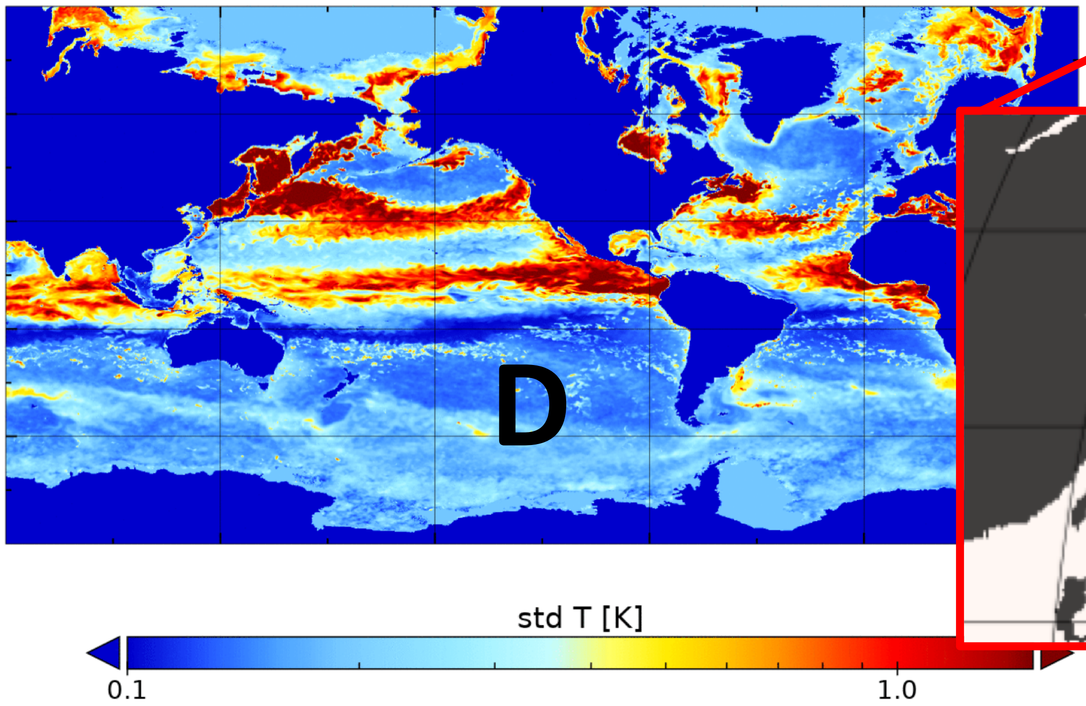
What is SOCA?

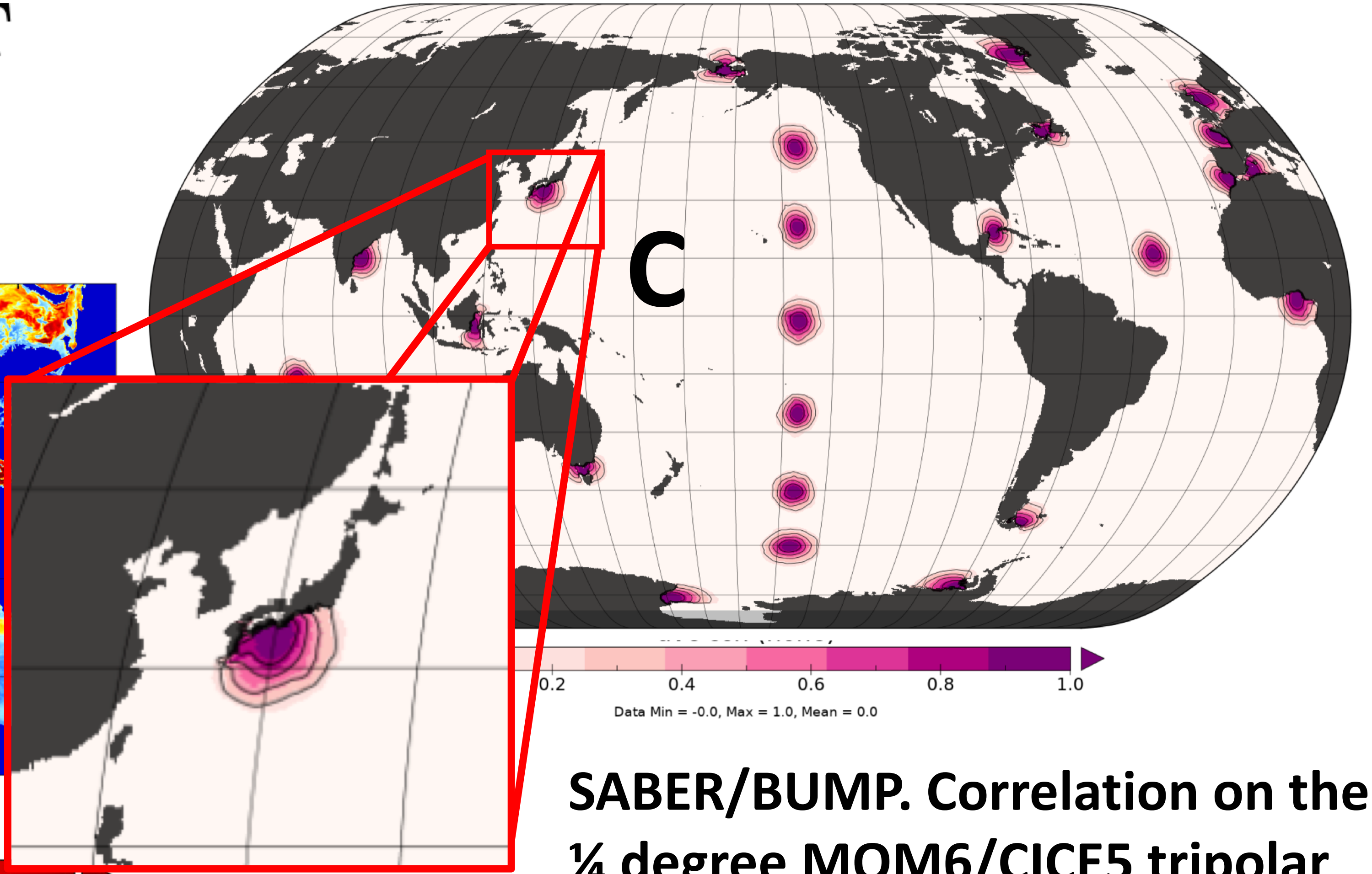
Sea-ice Ocean Coupled Assimilation (SOCA)

- Towards the integration of marine JEDI in NASA/GEOS
- Multidomain observing operator (direct radiance assimilation)
- Continuous Integration and Real time ocean monitoring testbed at the JCSDA
- Implementation of a JEDI based marine DA system at EMC/NOAA
- MOM6 interface to JEDI

Background dependent parametric “B-matrix”

$$\mathbf{B} = \mathbf{K}\mathbf{D}\mathbf{C}\mathbf{D}^{\mathrm{T}}\mathbf{K}^{\mathrm{T}}$$

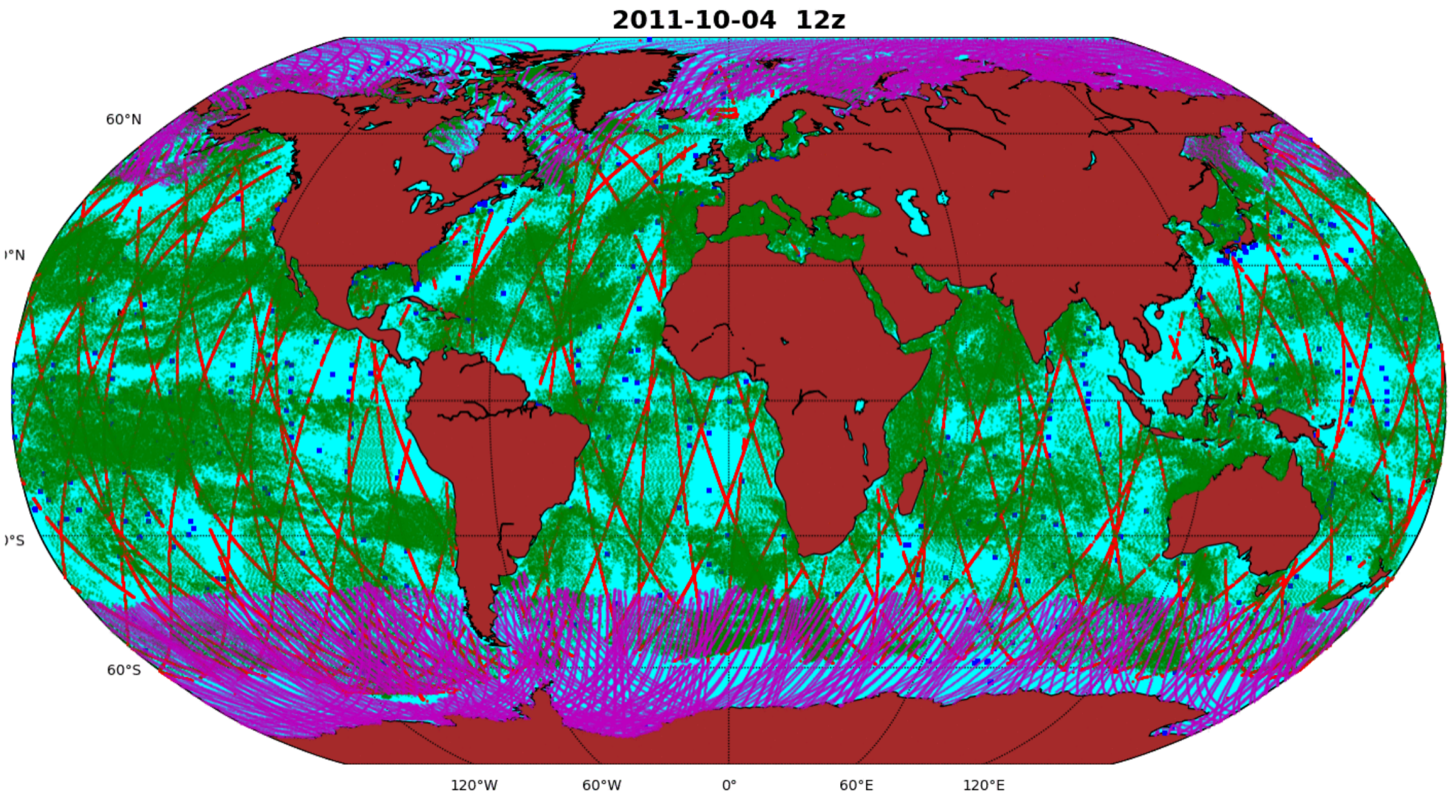




SABER/BUMP. Correlation on the ¼ degree MOM6/CICE5 tripolar grid

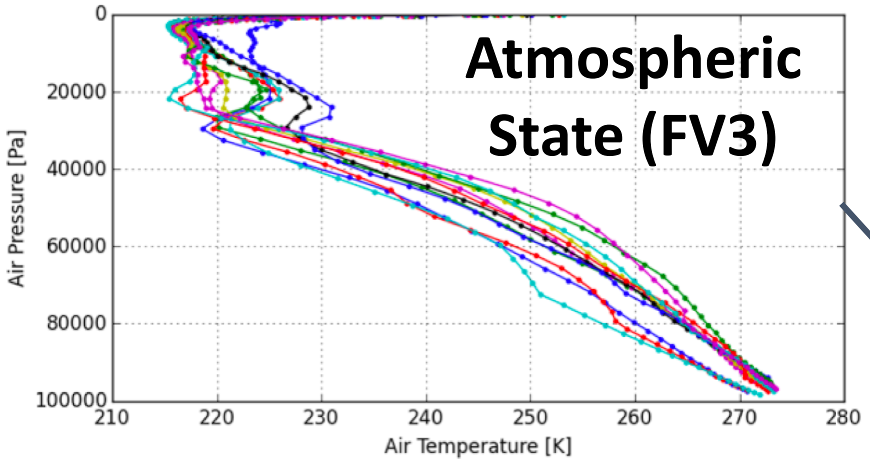
Cycling experiment

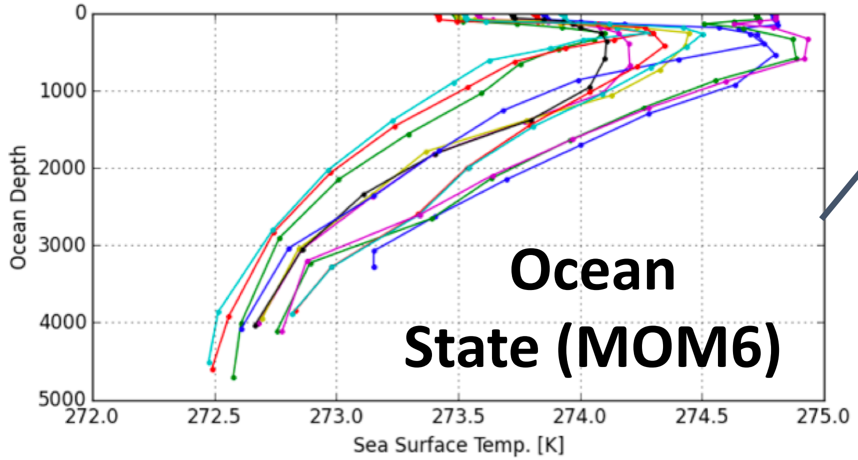
- **October 1, 2011 to November 2, 2011**
- **Forecast model: MOM6-CICE5-DATAATM at ¼ degree resolution**
- **24hr window ~1M obs per cycle**
- **3DVAR with background dependent parametric B**



	Sensor	Satellite	In Situ
SST-IR	AVHRR	NOAA-19 METOP-A	
SST-MW	WindSat	WindSat	
ADT		Jason-1 Jason-2 CryoSat-2	
Ice con.	SSMI SSMIS	F-16 F-17	
Temp **~~Salt~~**			Argo, CTD, XBT, TAO, PIRATA, RAMA, ...

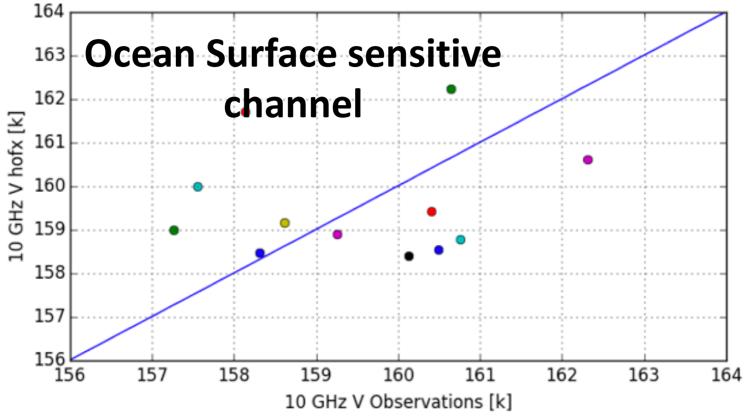
Prototype multi-domain UFO (ocean/atmosphere):

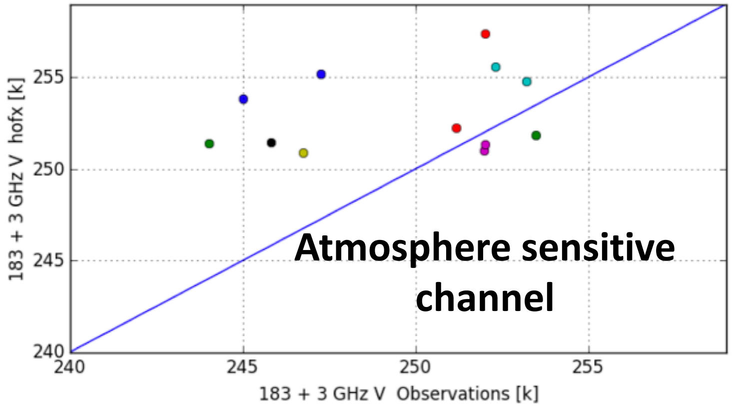




Example of GMI for April 15, 2018

CRTM UFO for GMI





Future plans

Towards a 30 year ocean sea ice reanalysis: GODAS project (EMC). Due July 2020.

- LETKF in workflow
- Hyb-EnVAR + LETKF perturbations implemented in the EMC workflow
- Observations: Freeboard, SST retrievals prior to 2003
- **Muli-Domain UFO: Direct assimilation of radiances to constrain SST & SSS**

Constituents

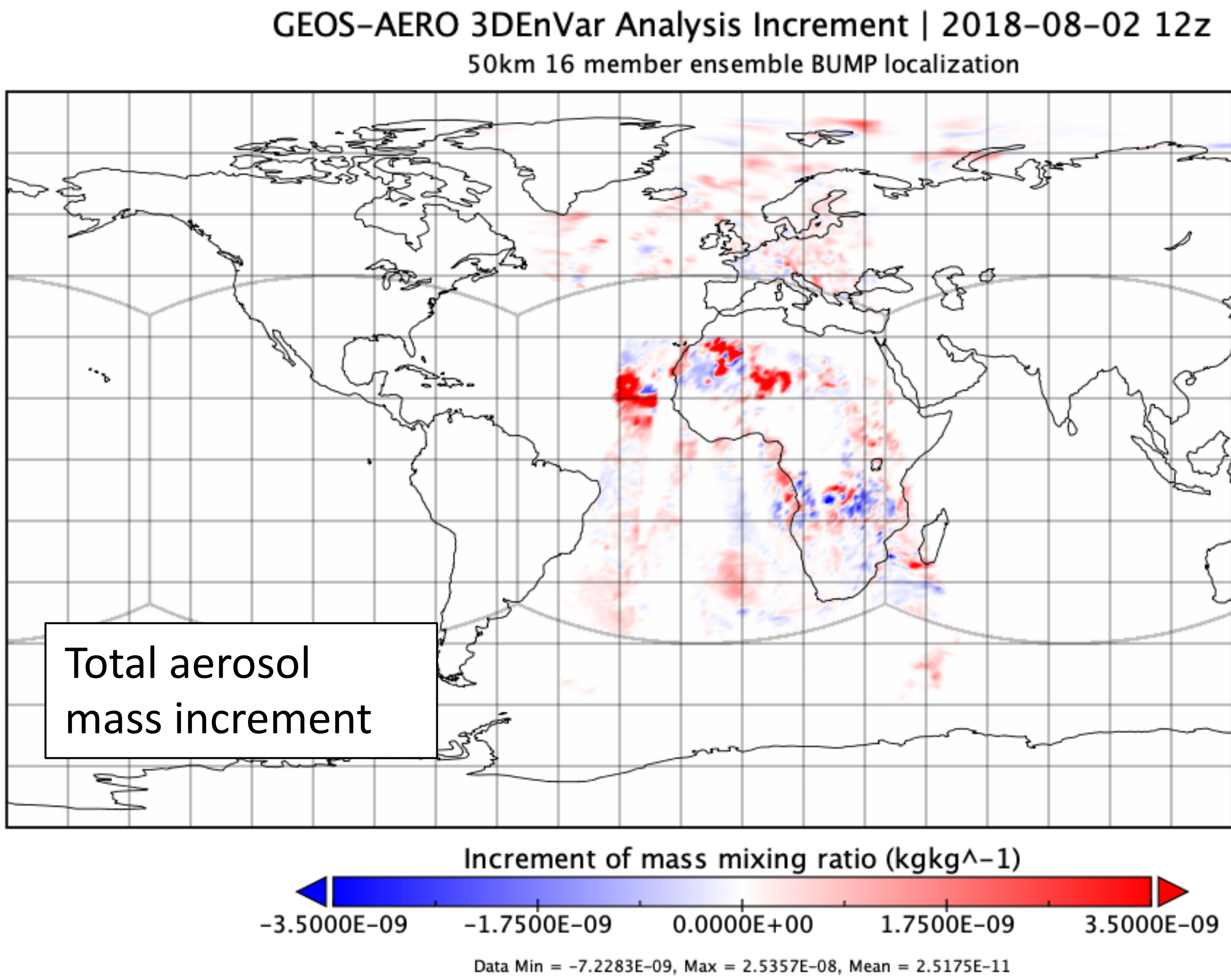
- NASA GEOS-CHEM – cubed-sphere
- NOAA GFS GSDChem – cubed-sphere

Constituents are a project within the JCSDA, led by Sarah Lu.

FV3-JEDI for aerosols

Both of NOAA and NASA’s efforts leverage the fv3-jedi interface to build constituent data assimilation. The classes behave identically to the way they do in the global NWP applications but with different fields allocated. The code is built to be generic (to FV3 grid applications)

GEOS-CHEM



<u>GEOS-CHEM GOCART</u>

C90 (~100km) 3DEnVar

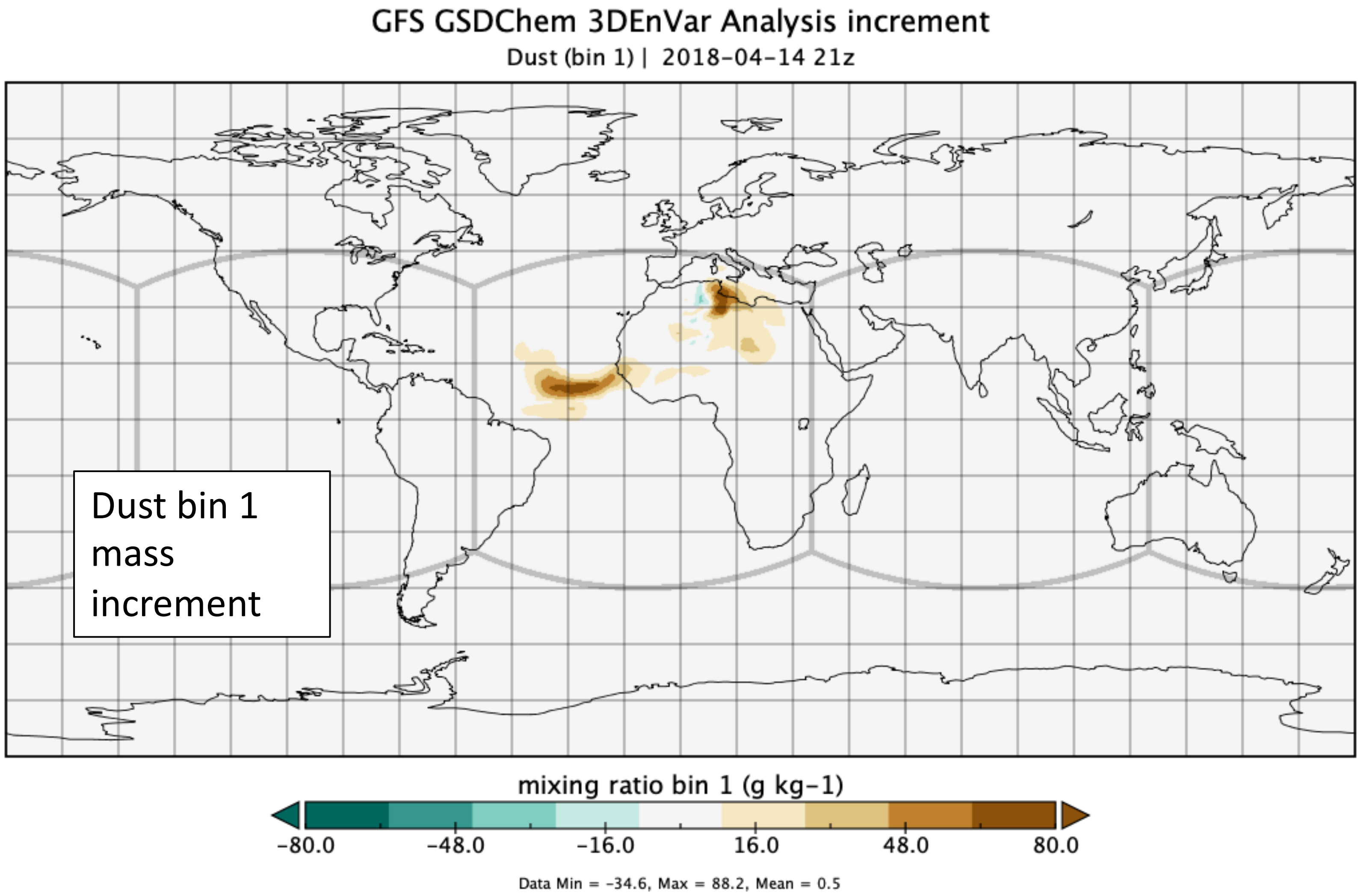
20 members

550nm Neural Network Retrieval of AOD

~70,000 observations

Work done with Virginie Buchard (NASA GMAO)

GFS GSDChem



<u>GFS GSD Chem</u>

C48 (~200km) 3DEnVar

10 members

CRTM simulated aerosol optical depth

VIIRS and SUOMI-NPP

Work done with Mariusz Pagowski (NOAA ESRL)

Future plans

GSDChem

- Development of 4DEnVar with FV3-GOCART model
- Cross channel error correlation
- Thinning and variational bias correction
- Development of 3DVar system for FV3-CMAQ.
- Improved static background error representation.

GEOS-CHEM

- Develop a 3DEnVar system for GEOS aerosols
  - Aerosol concentrations or profiles of extinction as control variable
  - Coding UFO (without using CRTM) for AOD at one or multiple wavelengths
    - using aerosols concentrations
    - using profiles of extinction
  - using ensemble members produced by the GEOS meteorological system
    - perturbation of emissions to increase ensemble spread

Snow and Land DA

- Noah-MP

Land/Snow is a project within the JCSDA, led by Andy Fox.

Land and snow

1. Snow DA into the National Water Model
   - NOAA's operational implementation of WRF-Hydro for CONUS
   - Land surface model: Noah-MP
   - Observations: *In-situ* snow depth and Snow Water Equivalent (SWE)

2. Snow and soil moisture DA into the Unified Forecast System
   - Aim to support coupled and standalone offline capabilities
   - Land surface model: TBD
   - Observations: Interactive Multisensor Snow and Ice Mapping System (IMS) and *in-situ* SWE

Future plans

- Soil moisture assimilation
- Advanced observation operators
- Additional observations (e.g. LAI, LST, albedo, SIF, roughness, biomass)
- Additional land models (e.g. Community Terrestrial System Model)
- Advancing algorithms