Progress Towards Hybrid-4DVar Data Assimilation with FV3-JEDI

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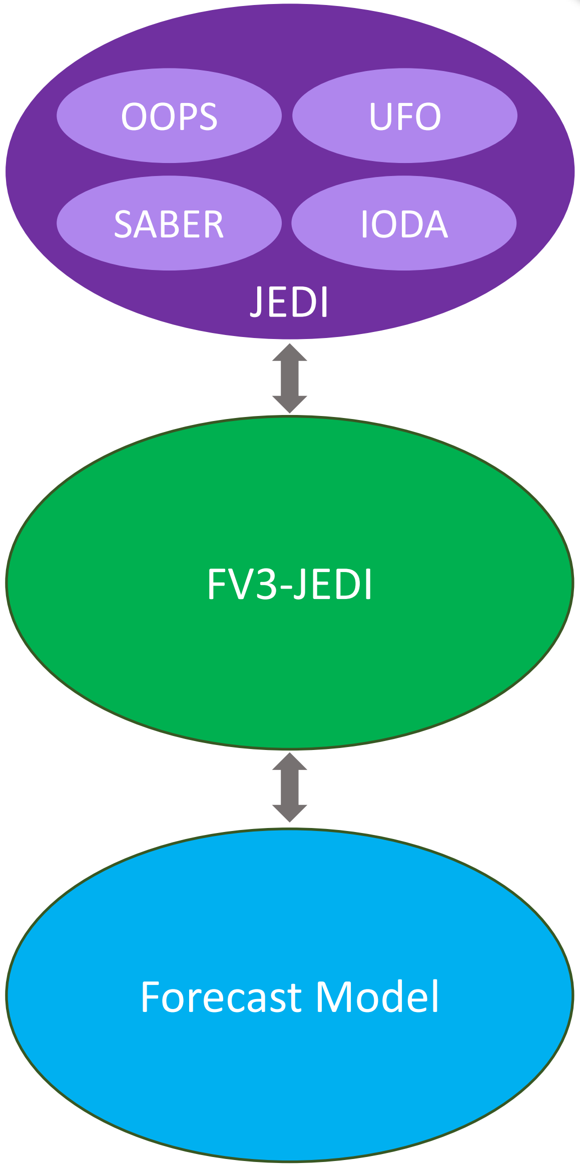
Introduction

FV3-JEDI implements the interfaces, methods, applications and configuration that the generic components of JEDI need, and does so for models using the FV3 cubed-sphere grid.

It provides things like geometry, states and increments, IO, variable changes, interpolation to observation locations, the tangent linear and adjoint and the ability to advance the nonlinear model. It also provides extra regression testing, example configuration scripts to run various applications and infrastructure for building JEDI with the forecast models.



FV3 Based Models

- **NEMSfv3gfs**. NCEP's operational global NWP (coupled) system.
- **GEOS**. NASA's quasi operational NWP and MERRA (coupled) system.
- **JCSDA-NASA FV3-JEDI-LM.** Self contained dynamical core only plus tangent linear and adjoint FV3 + GEOS physics. Encapsulates the geometry, is cheap to run and easy to build.
- **FV3SAR**. NCEP's stand alone regional system.
- **GEOS-CTM.** NASA GEOS chemistry transport model.
- **FV3GFS-GSDChem.** NOAA-ESRM chemistry and aerosol model.

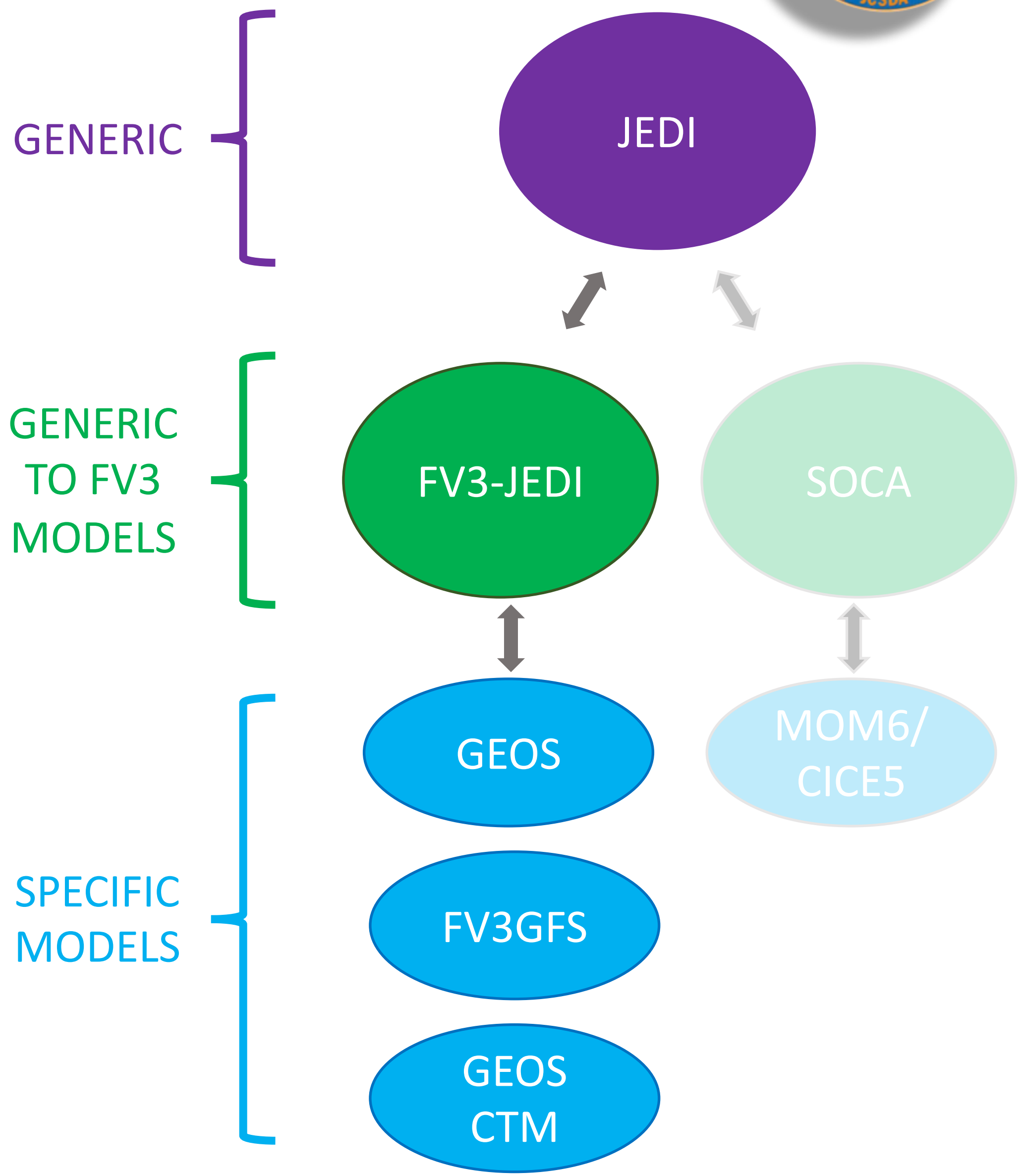
Design

Given the expansive use of the FV3 dynamical core, we are developing the FV3-JEDI interface to be generic, with a single interface being designed to work with all models and sets of variables.

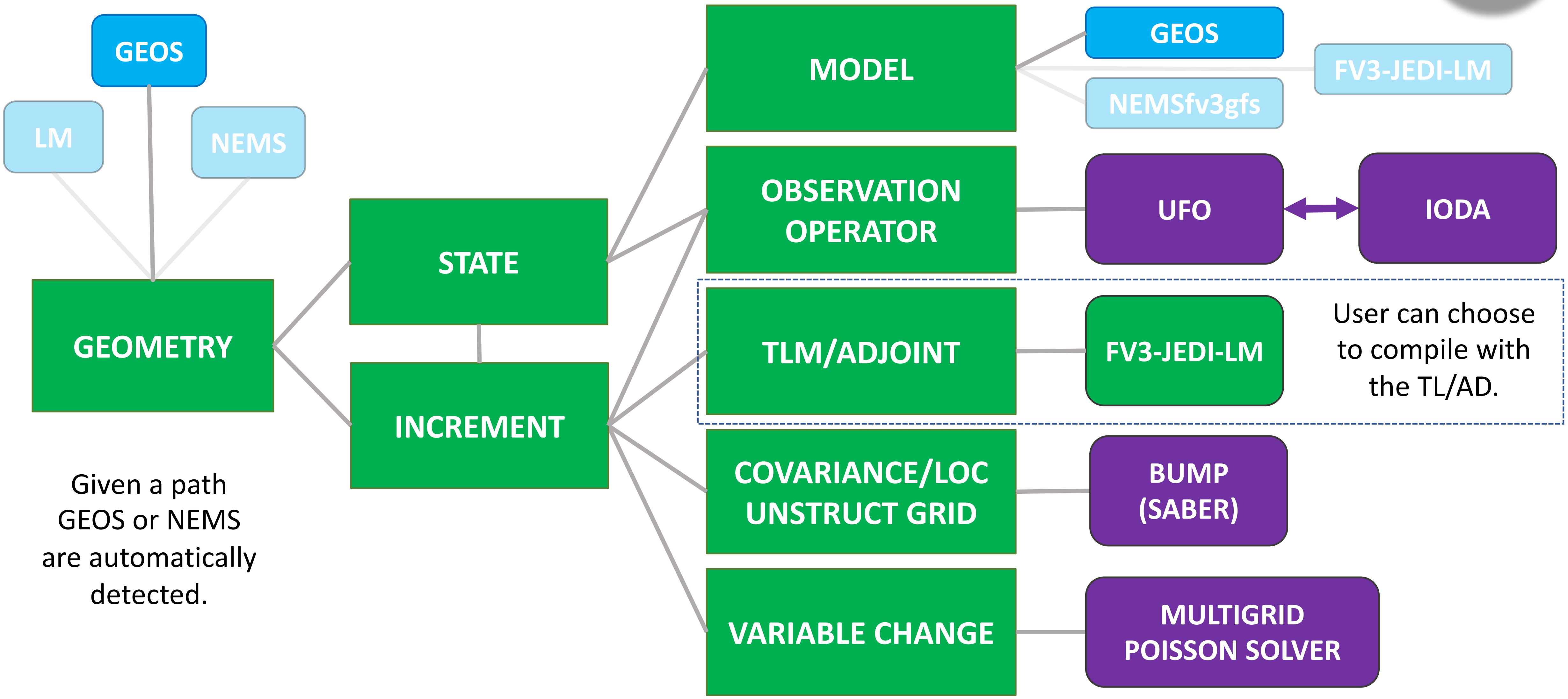
As for the JEDI core components development benefits all centers using FV3.

By and large the behavior of the system is controlled through the configuration at run time and with a few choices made using a flexible build system.

No variables are hardwired in the system.



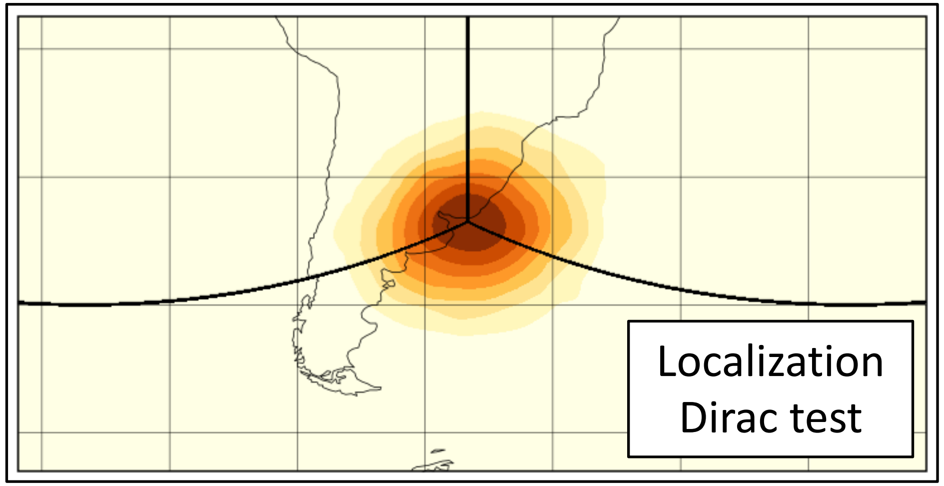
Building the FV3-JEDI building blocks



Data assimilation status

Jb

- Localization using BUMP (prescribed or dynamic).
- Static B with BUMP, prescribed length scales.
- Balance transforms (psi,chi -> u,v)
- Finite element cubed-sphere Poisson solver



Jo

- Radiosonde, aircraft, CRTM (no FOV), sat winds, surface pressure, GNSSRO (GSI and ROPP operators).
- Bilinear interpolation harnessing BUMP.
- QC: blacklisting, background check, domain check, channel sub-setting.
- GEOS tangent linear and adjoint model.

Data assimilation status

With the building status of the building blocks we can perform various flavors of DA:

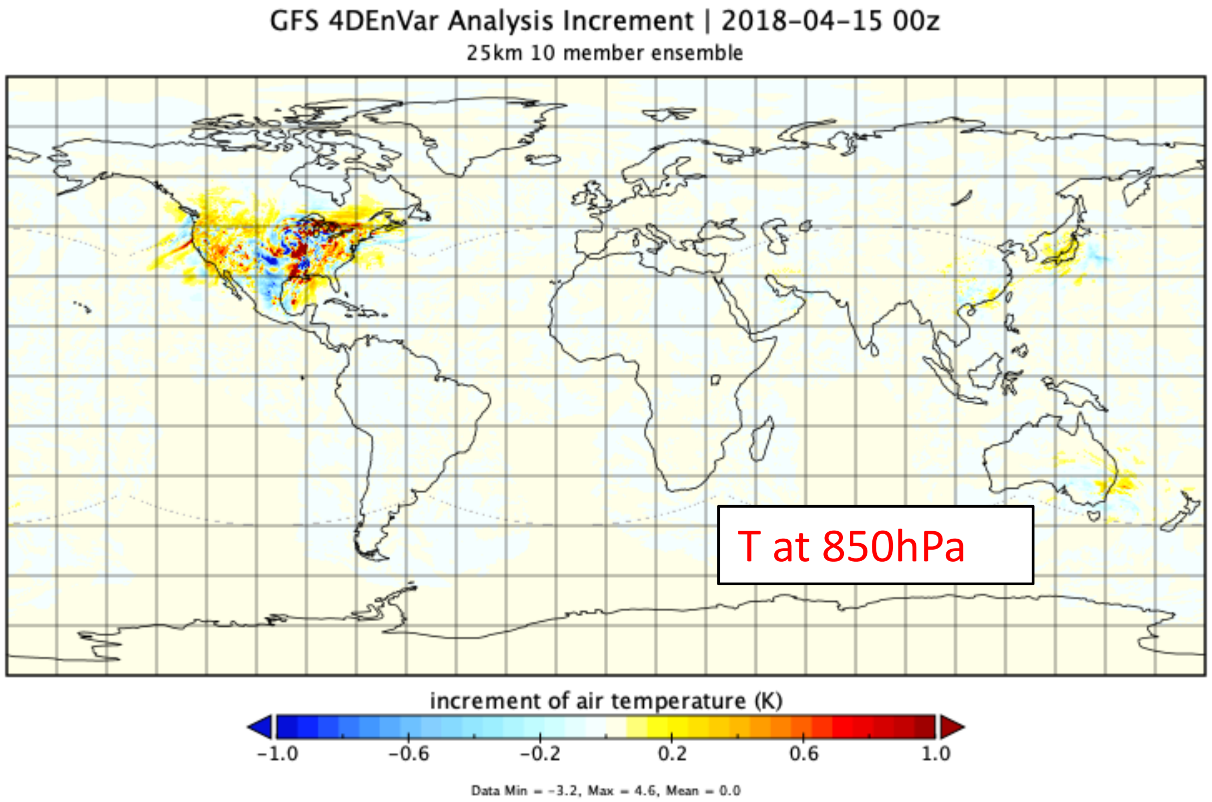
	3DVar	4DVar	4DEnsVar	Hybrid	Multiple outer loops (IO)	Multiple outer loops (in core)	Weak constraint
FV3GFS	✓	DRY TL/AD & PSUEDO MODEL	✓	✓	✓	✗	✗
GEOS	✓	✓ MOIST TL/AD	✓	✓	✓	✗	✗
FV3 Standalone	✓	✓	N/A	✓	✓	✓	✗

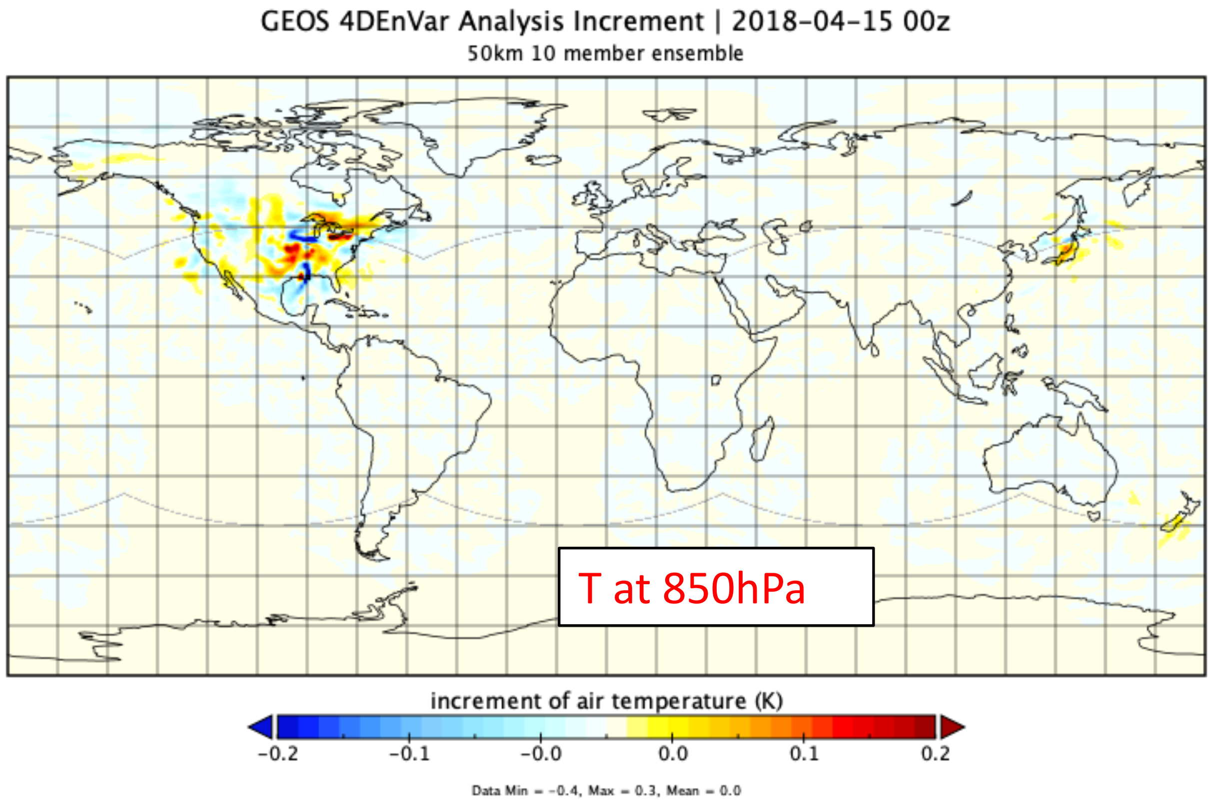
Operational resolution 4DEnVar

GFS
25 km (C364) background
10 members 25km
Observation space minimization

COMMON
BUMP localization
Conventional observations
15 inner loops

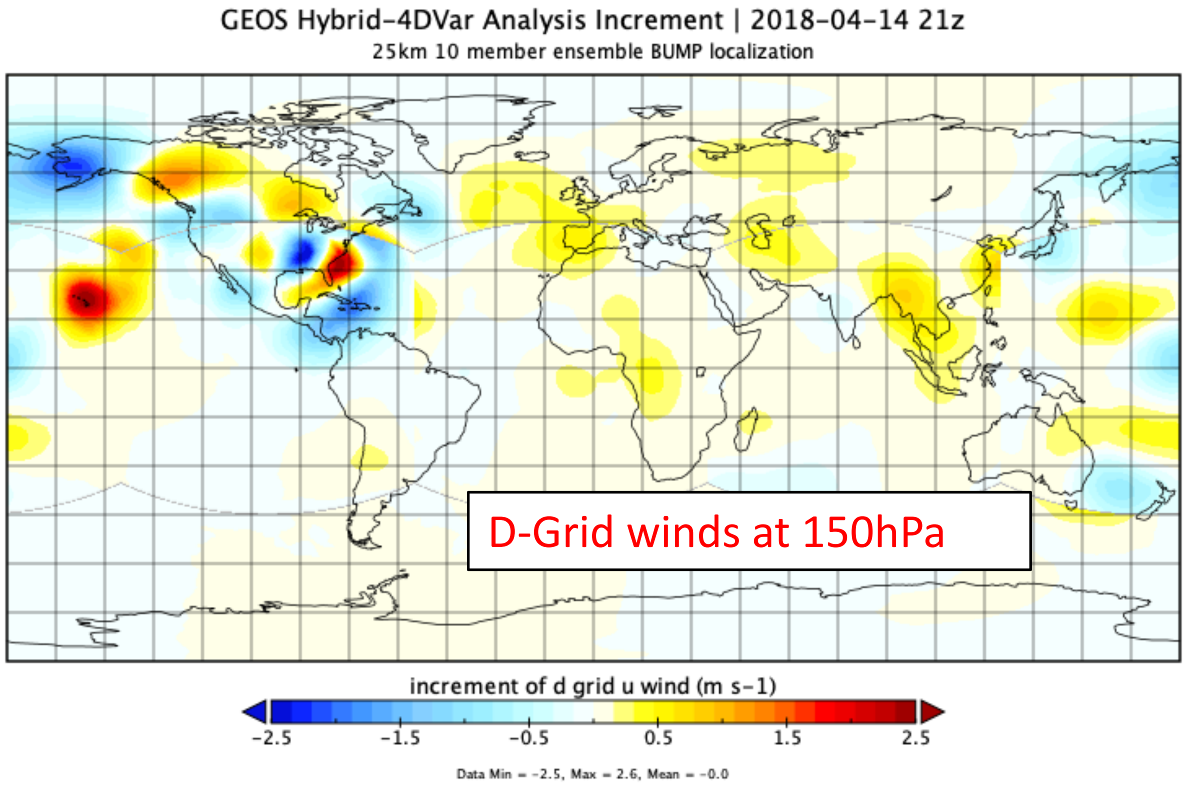
GEOS
50km (C180) background
10 members 50km

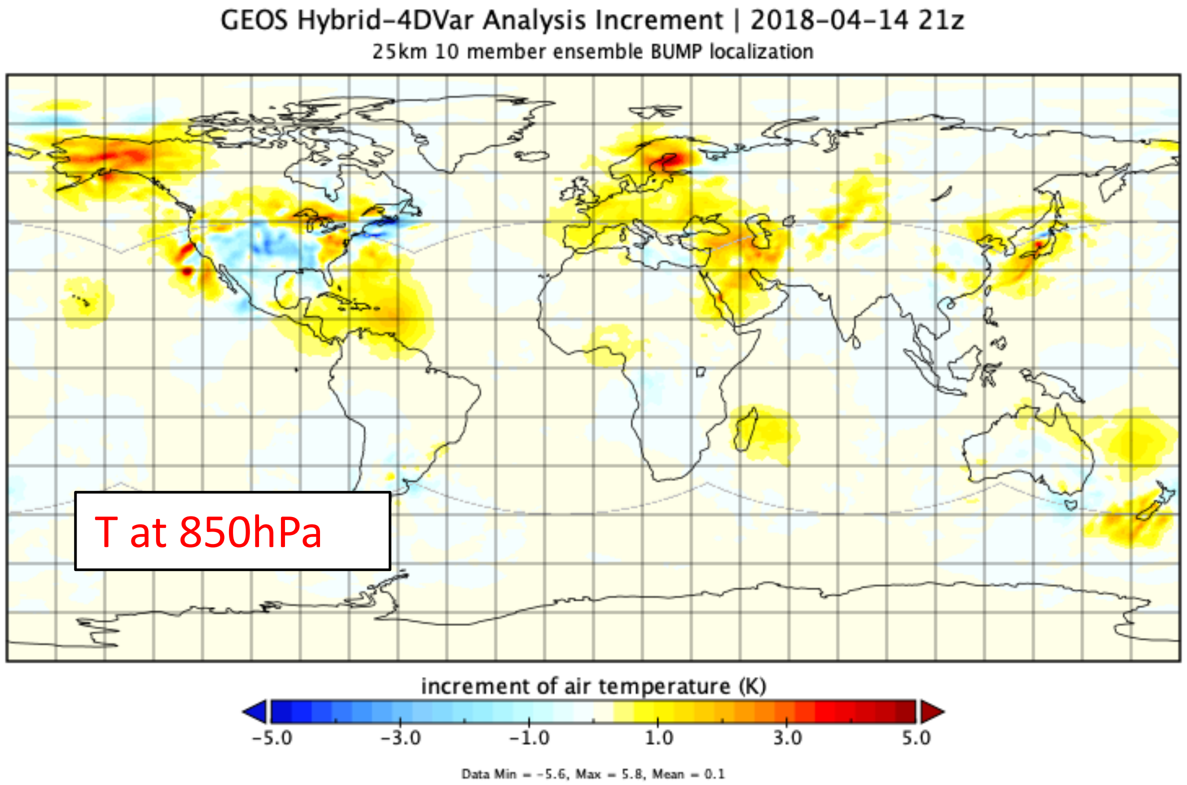




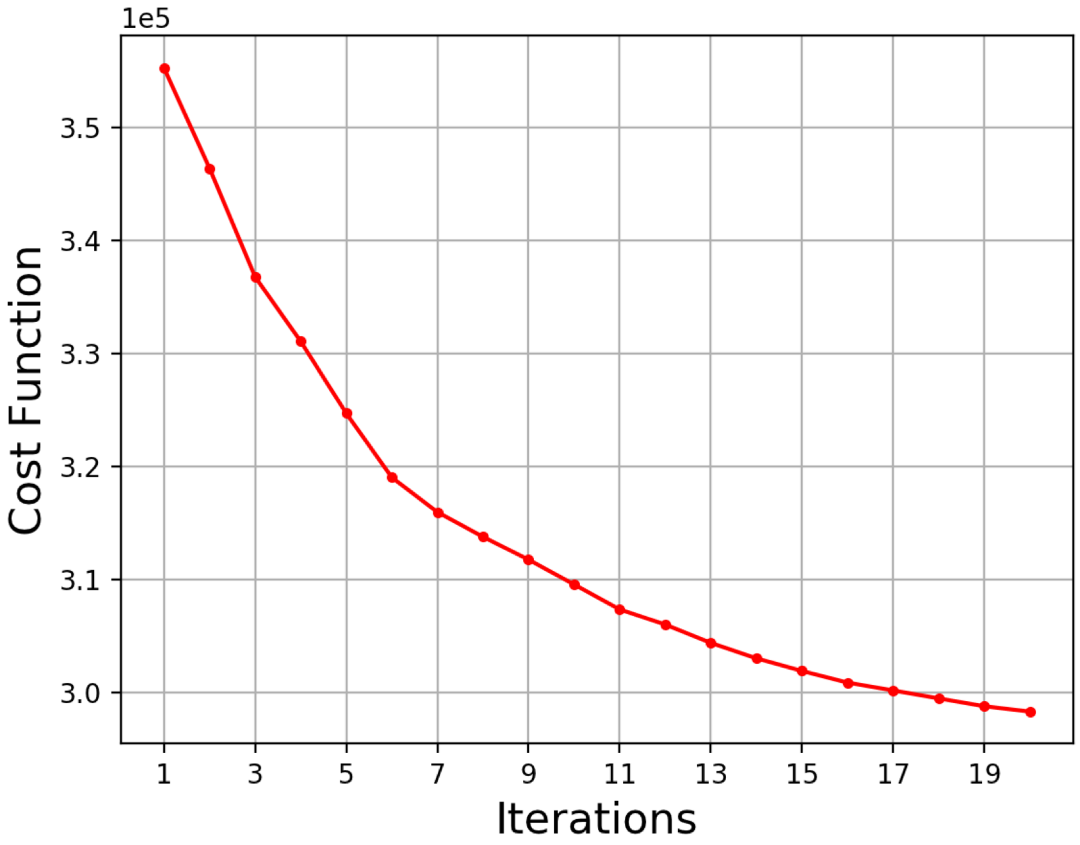
GEOS Hybrid 4D-Var

- GEOS 50km (C180) background and ensemble
- BUMP localization
- BUMP static B (psi,chi)
- Conventional observations.
- Physics in the tangent linear and adjoint model



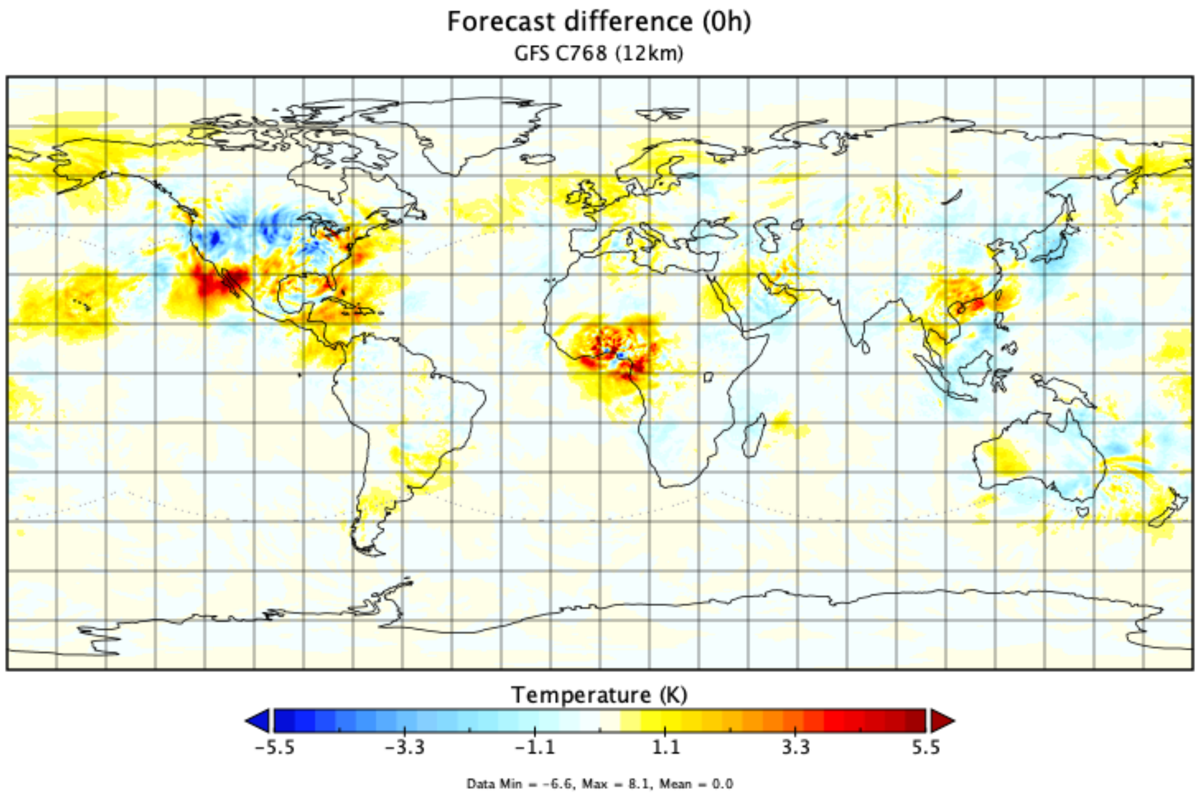


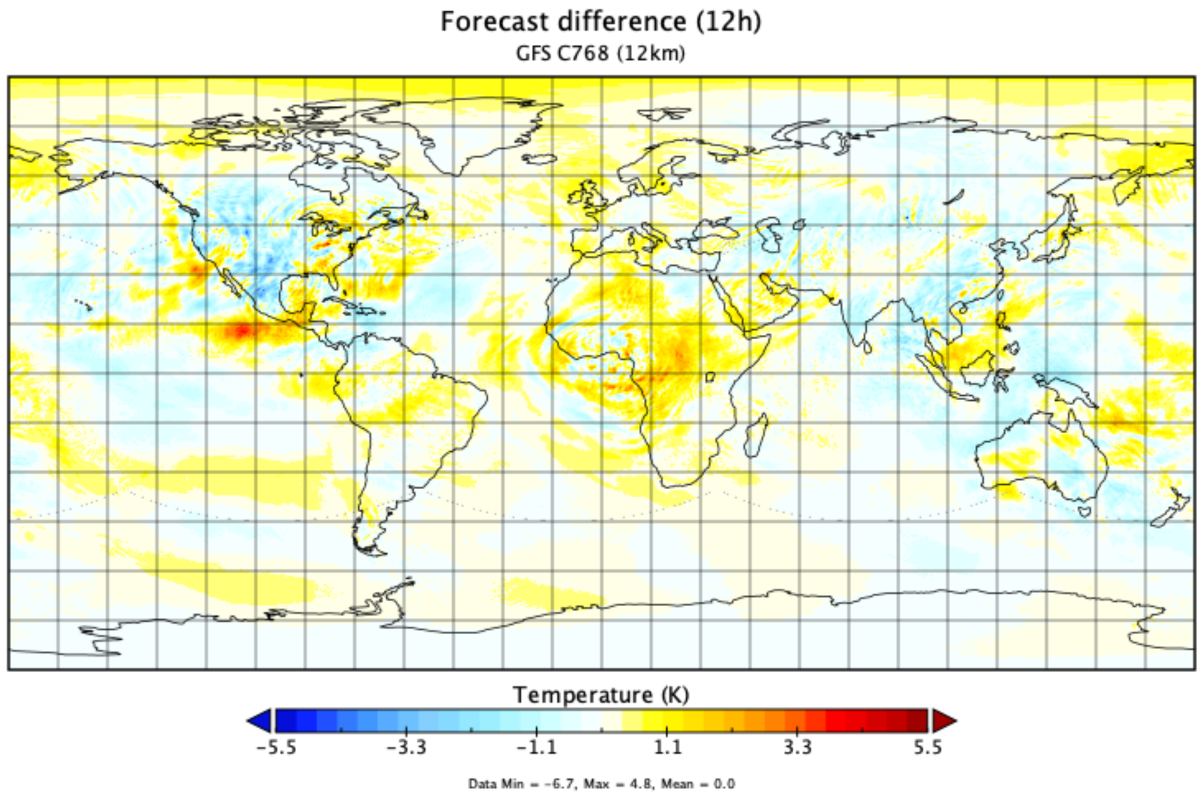
GEOS Hybrid 4D-Var



Towards cycling

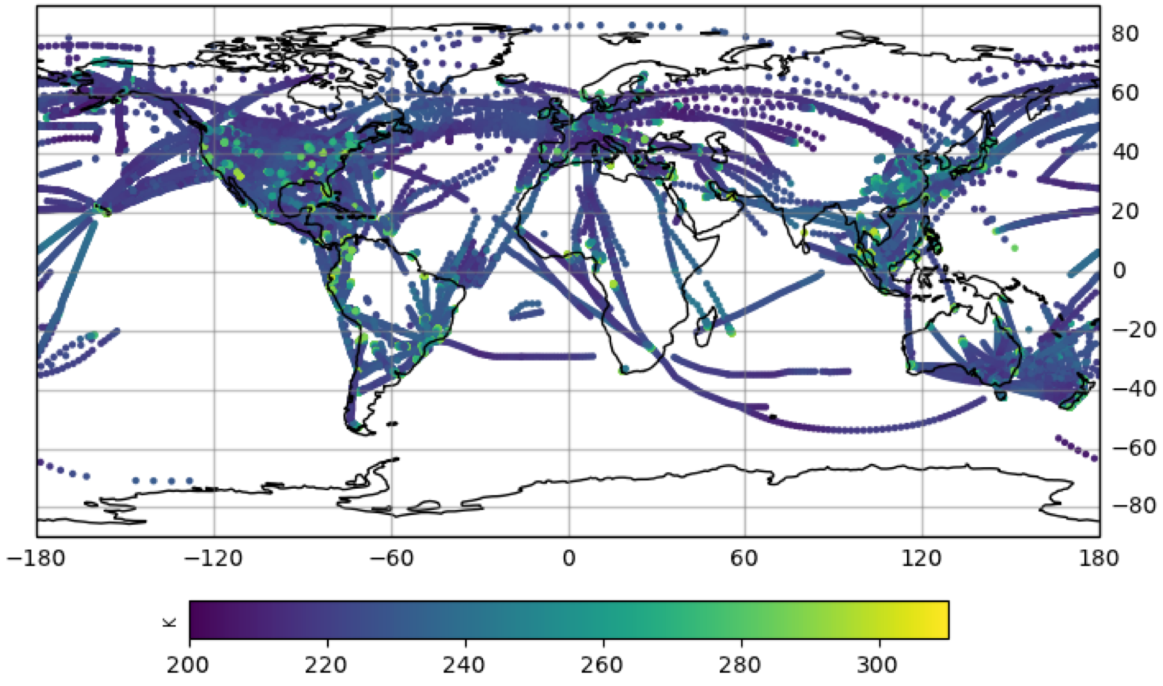
Single 4DEnVar cycle with full GFS C768 24h forecast. Temperature difference at 850hPa.



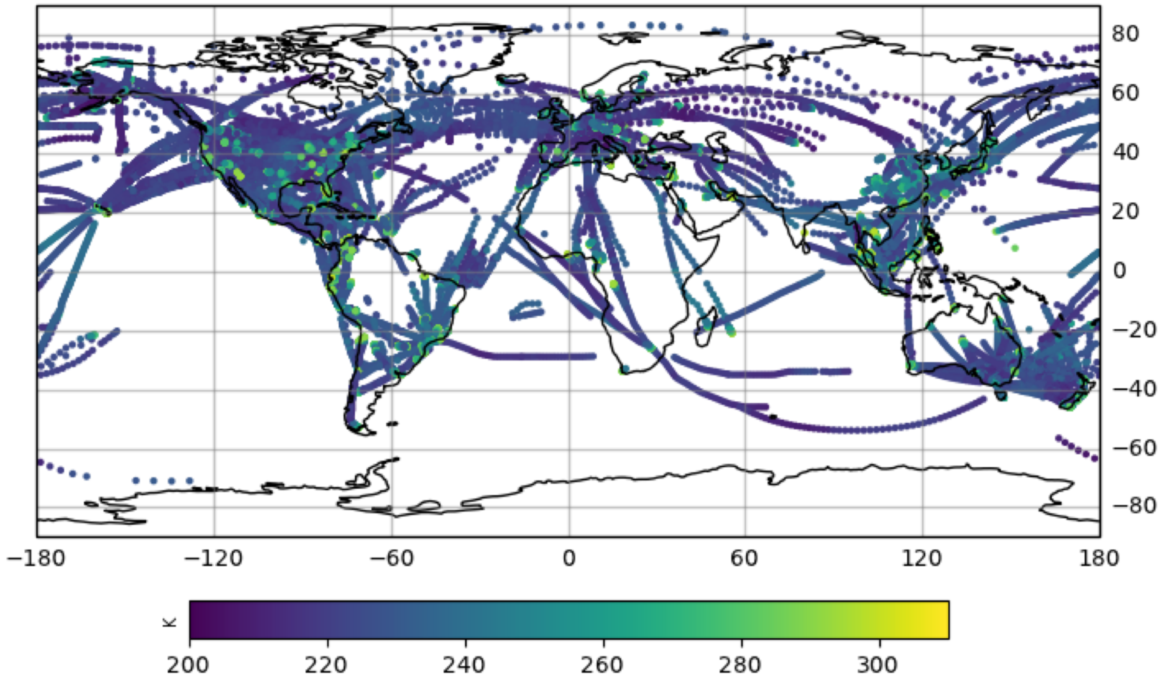


Towards cycling

Aircraft observations



Forecast H(x)



Having in-core H(x) will be very helpful for analyzing cycling experiments

Towards in-core model and data assimilation

JEDI handles the nonlinear, tangent linear and adjoint forecast stepping.

The NASA developed tangent linear and adjoint have been integrated into the JEDI framework and is controlled through JEDI.

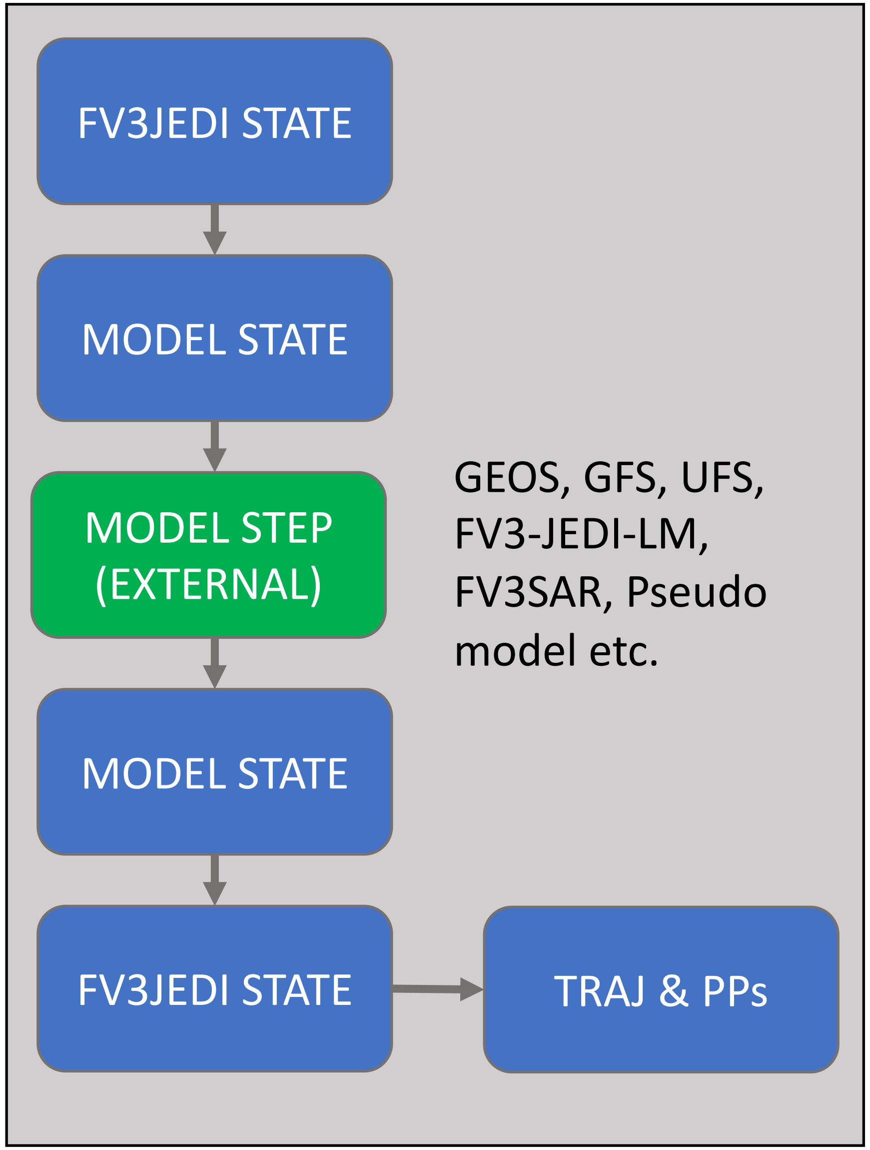
The nonlinear forecast can be handled trough IO for all models and we're working towards in-core. This is important for a number of reasons:

1. When in-core it limits the amount of IO and eliminates need to store 4D state anywhere.

2. Outer loops for FGAT and 4DVar and will likely be impractical without the forecast step in-core.

3. Allows for the calculation of 4D H(x) while running forecasts.

Towards in-core model and data assimilation

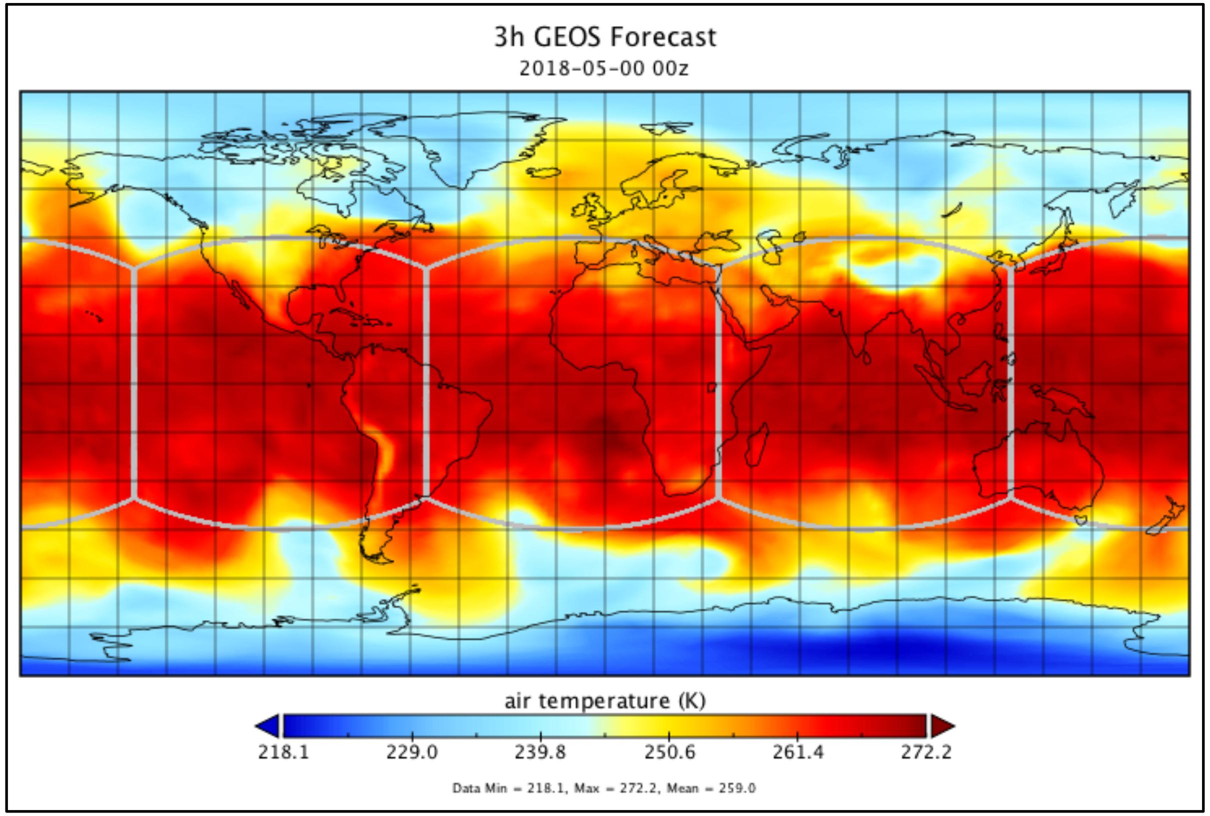


	Create Model	JEDI -> Model	Step the model	Model -> JEDI	Model rewind	TL/AD traj
Pseudo IO (all models)	✓	✓	✓	✓	✓	✓
FV3 Standalone	✓	✓	✓	✓	✓	✓ DRY
FV3GFS / FV3SAR	✓	✗	✓	✓	✗	DRY
GEOS (coupled)	✓	✗	✓	✓	✗	✓ MOIST

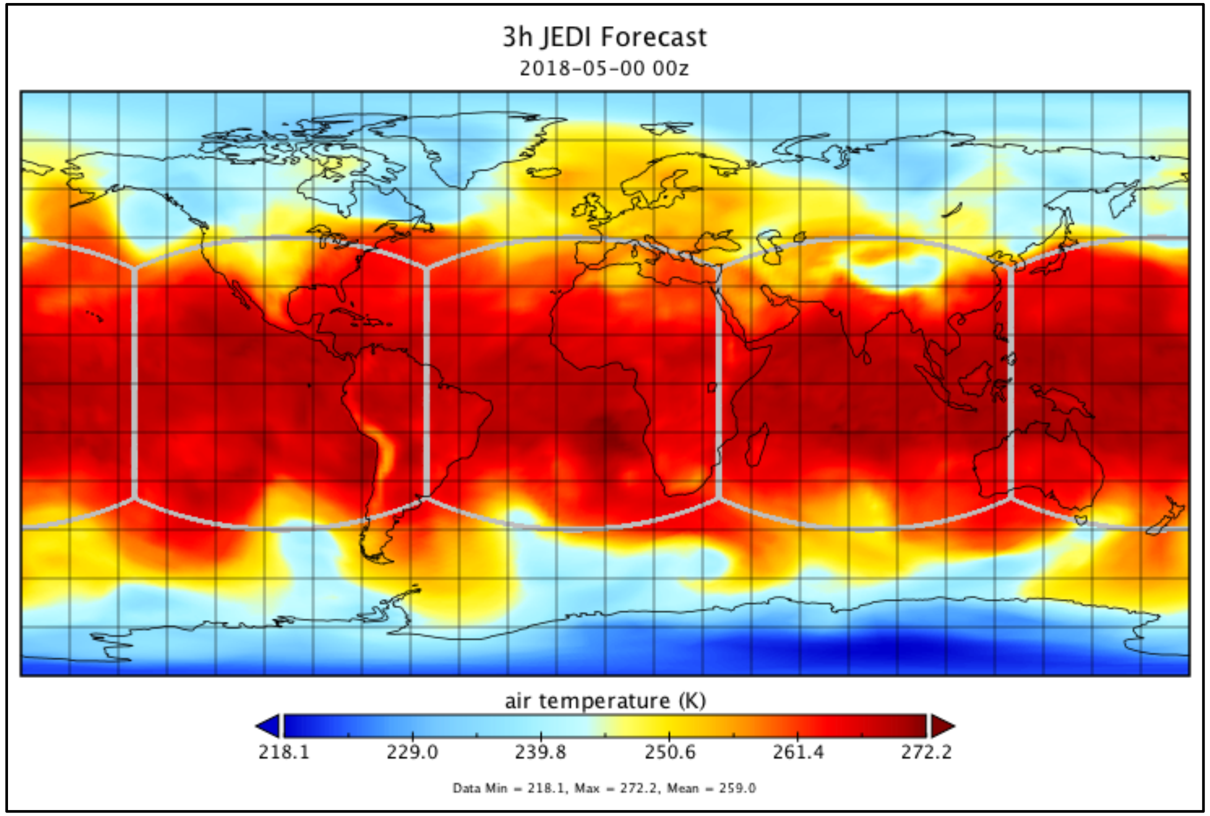
Updating the model state ahead of stepping the model requires some care. We're working on the appropriate way to do so in collaboration with Jun Wang at EMC. It's only needed for outer loops fortunately.

GEOS forecast

GEOSgcm.x

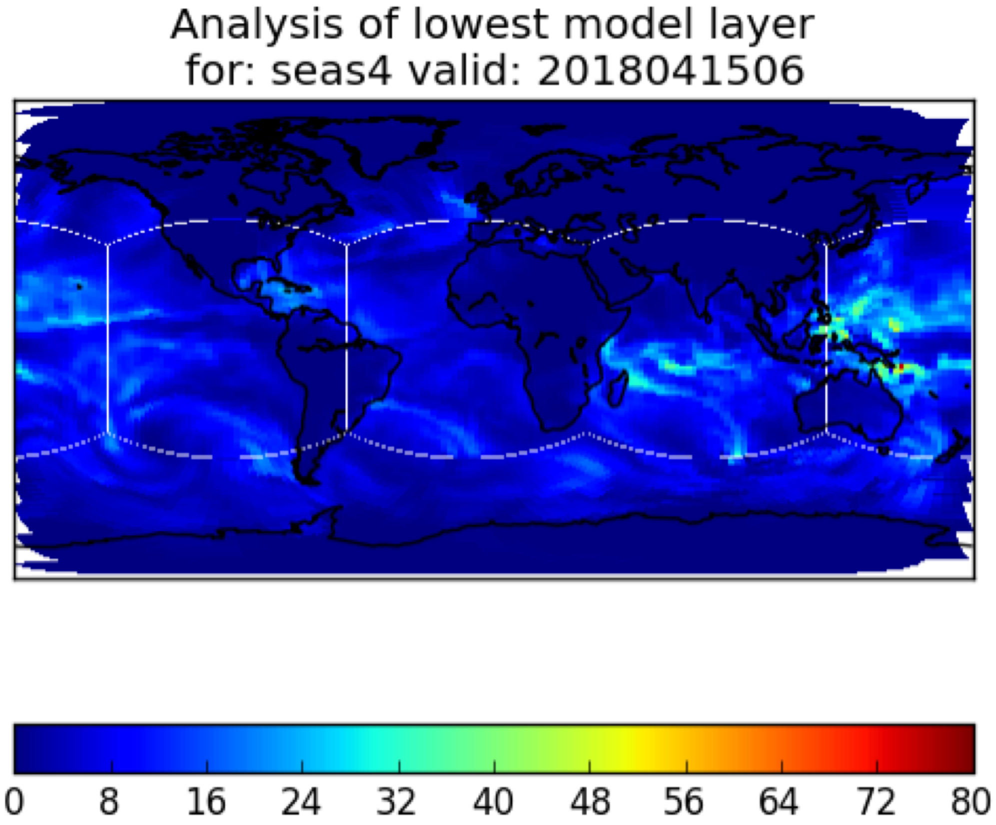


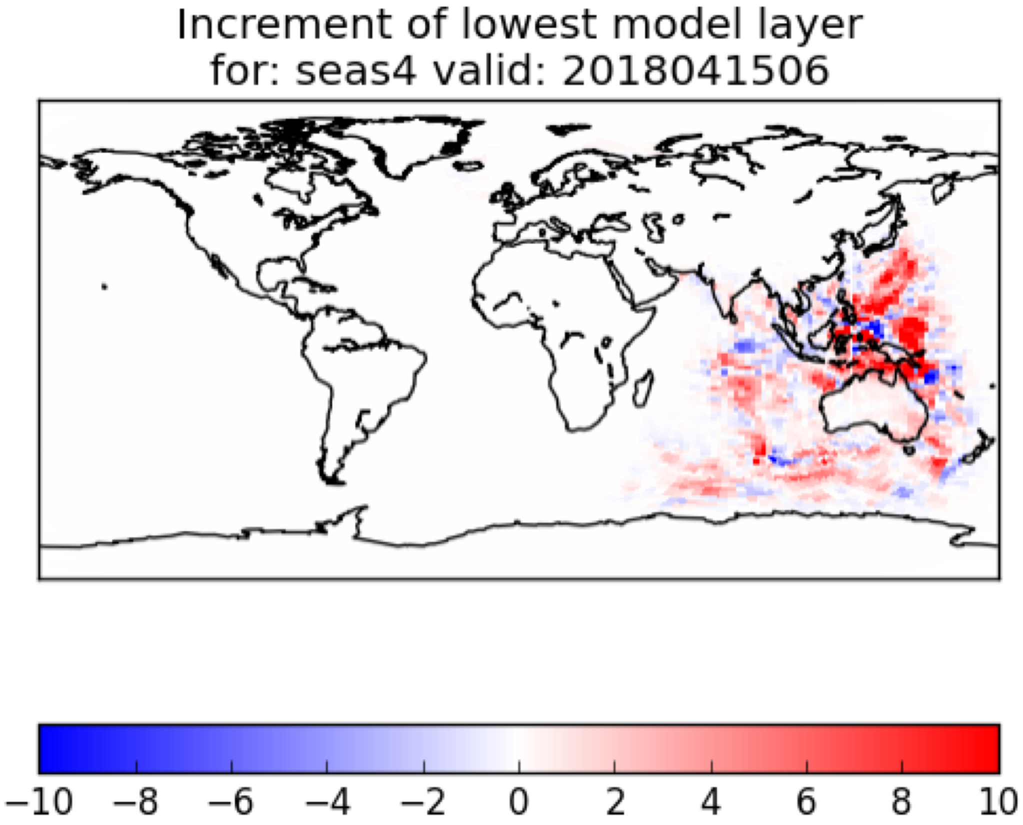
fv3jedi_forecast.x



Aerosol data assimilation with the CRTM

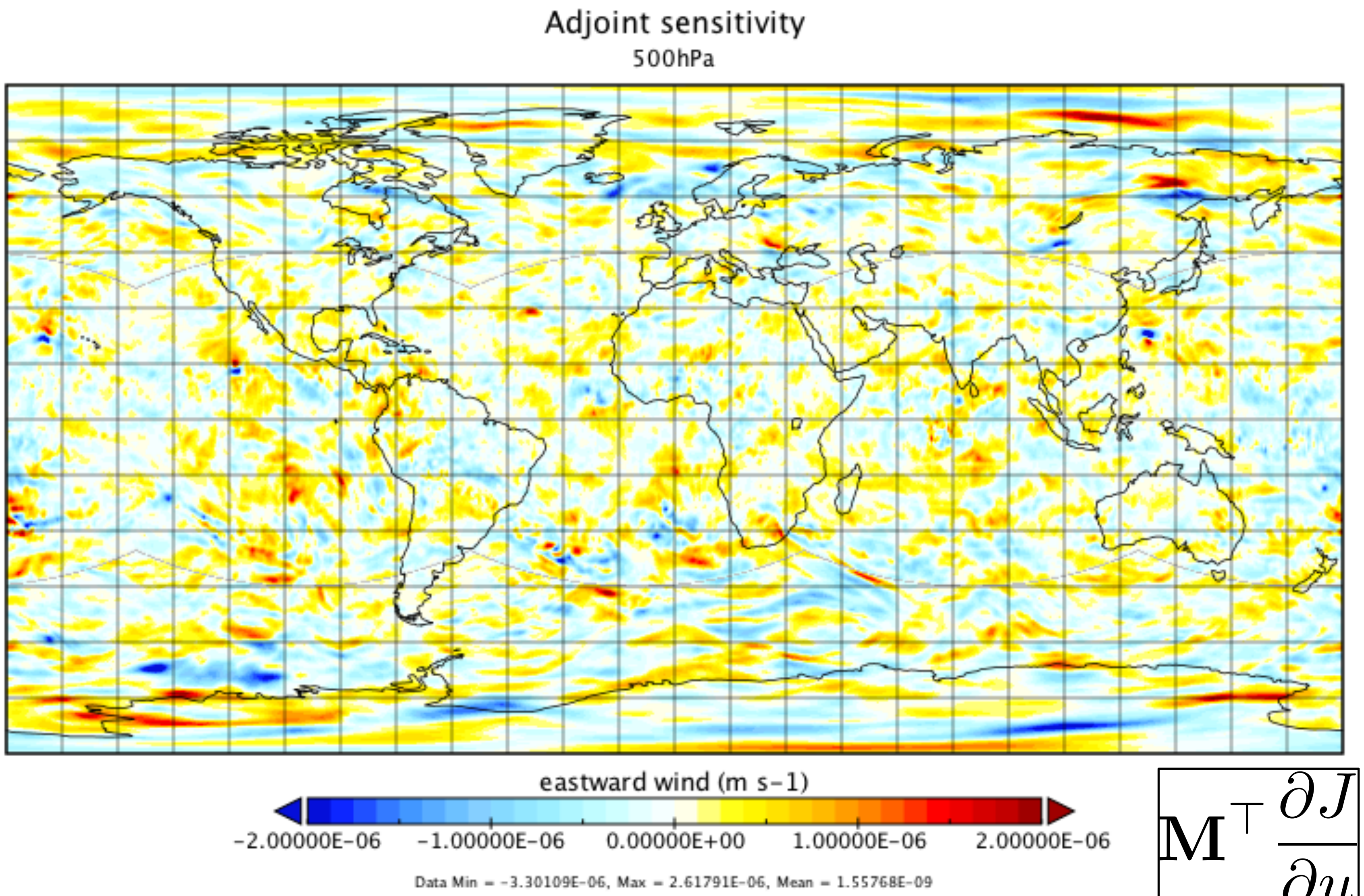
See poster by Mariusz and Cory. The difference between this experiment and those with meteorology is just in the YAML file.





NASA is working on a similar product using AOD observations. It will be possible to do lots of interesting science.

Applications: FSOI



$$\mathbf{M}^{\top}\frac{\partial J}{\partial u}$$

GEOS C180 adjoint forecast.

- Full physics in the adjoint
- Moist energy norm computed on the sphere.
- Trajectory time step of 15 minutes read through the Pseudo model.

Next step is to write the adjoint of JEDI and compute observation impacts.

Upcoming plans

- Connect GFS to the GEOS tangent linear and adjoint physics.
- Parallelize finite element Poisson solver and improve static B operator.
- Hybrid 4D-Var with outer loops with varying resolution.
- Continued effort towards in-core.
- Longer cycling experiments as QC capability increases and B matrix improves.