MPAS-JEDI Overview

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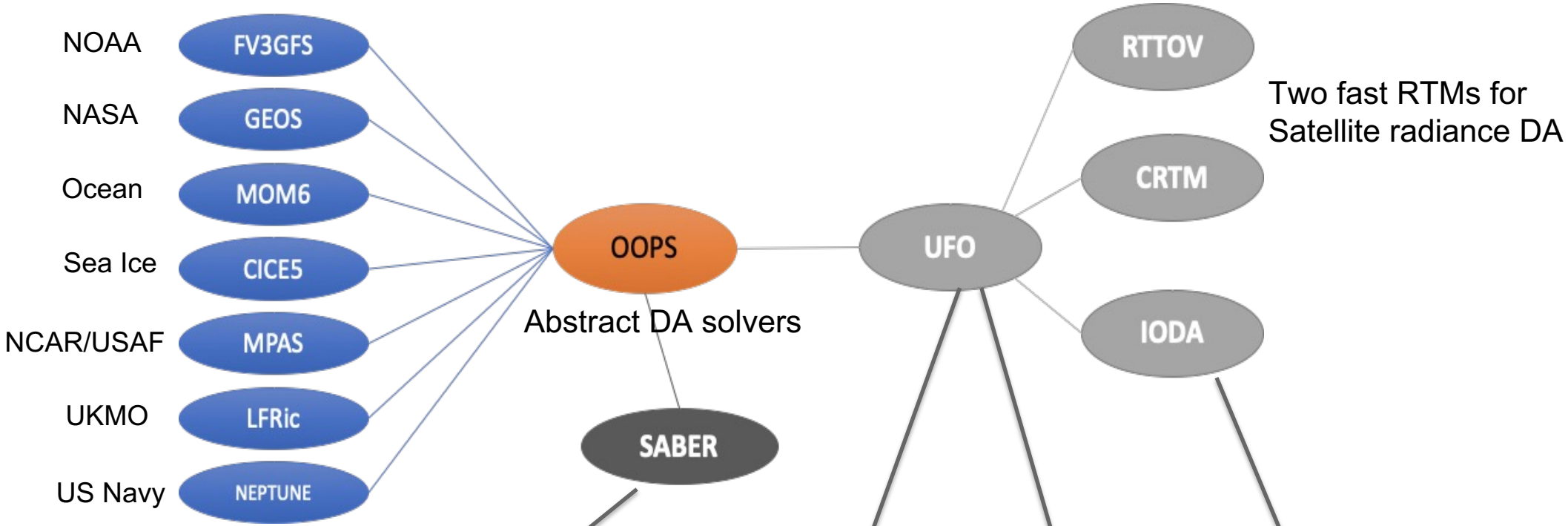
Joint Effort for Data assimilation Integration (JEDI)

led by Joint Center for Satellite Data Assimilation (JCSDA)



$$J(\boldsymbol{x}) = \frac{1}{2}(\boldsymbol{x}-\boldsymbol{x}_b)^{\mathbf{T}}\mathbf{B}^{-1}(\boldsymbol{x}-\boldsymbol{x}_b) + \frac{1}{2}[H(\boldsymbol{x})-\boldsymbol{y}]^{\mathbf{T}}\mathbf{R}^{-1}[H(\boldsymbol{x})-\boldsymbol{y}]$$

JCSDA and all partner groups contributing to JEDI's development

https://github.com/JCSDA/mpas-jedi/blob/release/2.0.0/src/mains/mpasVariational.cc

MPAS-JEDI
C++ main program
for Variational DA

```
8   #include <oops/runs/Run.h>
9   #include <oops/runs/Variational.h>
10
11  #include <saber/oops/instantiateCovarFactory.h>
12  #include <saber/oops/instantiateLocalizationFactory.h>
13
14  #include <ufo/instantiateObsFilterFactory.h>
15  #include <ufo/ObsTraits.h>
16
17  #include "mpasjedi/Traits.h"
18
19  int main(int argc,  char ** argv) {
20    oops::Run run(argc, argv);
21    saber::instantiateCovarFactory<mpas::Traits>();
22    saber::instantiateLocalizationFactory<mpas::Traits>();
23    ufo::instantiateObsFilterFactory();
24    oops::Variational<mpas::Traits, ufo::ObsTraits> var;
25    return run.execute(var);
26  }
```

Model-agnostic components of JEDI

- OOPS: Object Oriented Prediction System, https://github.com/JCSDA/oops
  - Originally from ECMWF, JCSDA's OOPS version is diverged from ECMWF
  - Abstract definition of data assimilation elements, e.g., x, B, y, R, H etc.
  - Multiple minimization algorithms for variational DA
  - DA solvers for ensemble of DA and LETKF
  - Actual DA implementation for toy models like Lorenz95 and QG model
  - Mostly written in C++ with some Fortran

- SABER: System-Agnostic Background-Error Representation, https://github.com/JCSDA/saber
  - Implementation of static B models (currently 3) and localization of ensemble covariance
  - **BUMP: Background error on Unstructured Mesh Package, used by MPAS-JEDI**
  - Under development: GSI's grid-point B model and UKMO's spectral B model
  - BUMP mostly written in Fortran

Model-agnostic components of JEDI

- UFO: Unified Forward Operator, https://github.com/JCSDA/ufo
  - Implementation of observation operators (including Tangent Linear/Adjoint/Jacobian) or interface to observation operators (e.g., CRTM/RTTOV for satellite radiance, ROPP for GNSSRO)
  - Quality control of observations
  - Thinning of observations
  - Observation error modelling
  - Bias correction, e.g., variational bias correction for radiance data
  - C++ and Fortran

- IODA: Interface for Observation Data Access, https://github.com/JCSDA/ioda
  - In-memory observational data structure
  - In-disk file I/O: HDF5 (used by mpas-jedi now) and ODB
  - C++ and Fortran

MPAS-specific interface to JEDI

- https://github.com/JCSDA/mpas-jedi
  - Horizontal and vertical model grids
  - Prognostic variables to/from analysis variables
  - Adoption of static B model
  - Supply input variables of observation operators in UFO
  - State variable data structure, parallelism, I/O follows that of MPAS-A model, **so need MPAS-A model code in the compilation of MPAS-JEDI**
  - Mostly written in Fortran
- https://github.com/JCSDA-internal/MPAS-Model
  - A modified version of the MPAS-A model, currently used by MPAS-JEDI
  - Will be merged back to the official MPAS repository
  - Note: we use ‘mpasout’ (instead of ‘restart’) file for DA background and analysis

MPAS-JEDI 2.0.0, code as of early June 2023

Begin development from early 2018

- MPAS-JEDI: a collection (bundle) of github code repositories with
  - **Model-agnostic components**, led by JCSDA and contributed by all partners
  - **MPAS-specific interfaces**, led/developed by NCAR/MMM
- MPAS-JEDI 2.0 code accessible from
  - https://github.com/JCSDA/mpas-bundle/tree/release/2.0.0

Model-agnostic components:
https://github.com/JCSDA/oops
https://github.com/JCSDA/saber
https://github.com/JCSDA/ufo
https://github.com/JCSDA/ioda

MPAS-A model and model-specific interfaces:
https://github.com/JCSDA-internal/MPAS-Model
https://github.com/JCSDA/mpas-jedi

Python-based Diagnostic/Verification package included in:
https://github.com/JCSDA/mpas-jedi/tree/release/2.0.0/graphics

Observation processing, format conversion:
https://github.com/NCAR/obs2ioda

Data assimilation cycling Workflow based on cylc:
https://github.com/NCAR/MPAS-Workflow

Main features with MPAS-JEDI 2.0.0

- Deterministic analysis:
  - **3DVar, 3D/4DEnVar**, and **hybrid-3D/4DEnVar with dual-resolution capability**
  - Multivariate static B modeling follows WRFDA/GSI, but via BUMP

- Ensemble analysis:
  - Ensemble of EnVar (**EDA**) with perturbed observations
  - **LETKF (newly enabled in MPAS-JEDI 2.0.0, recently began cycling experiments)**

- Analysis directly done on **MPAS unstructured grid** for uniform or **variable-resolution mesh, global** or **regional mesh**

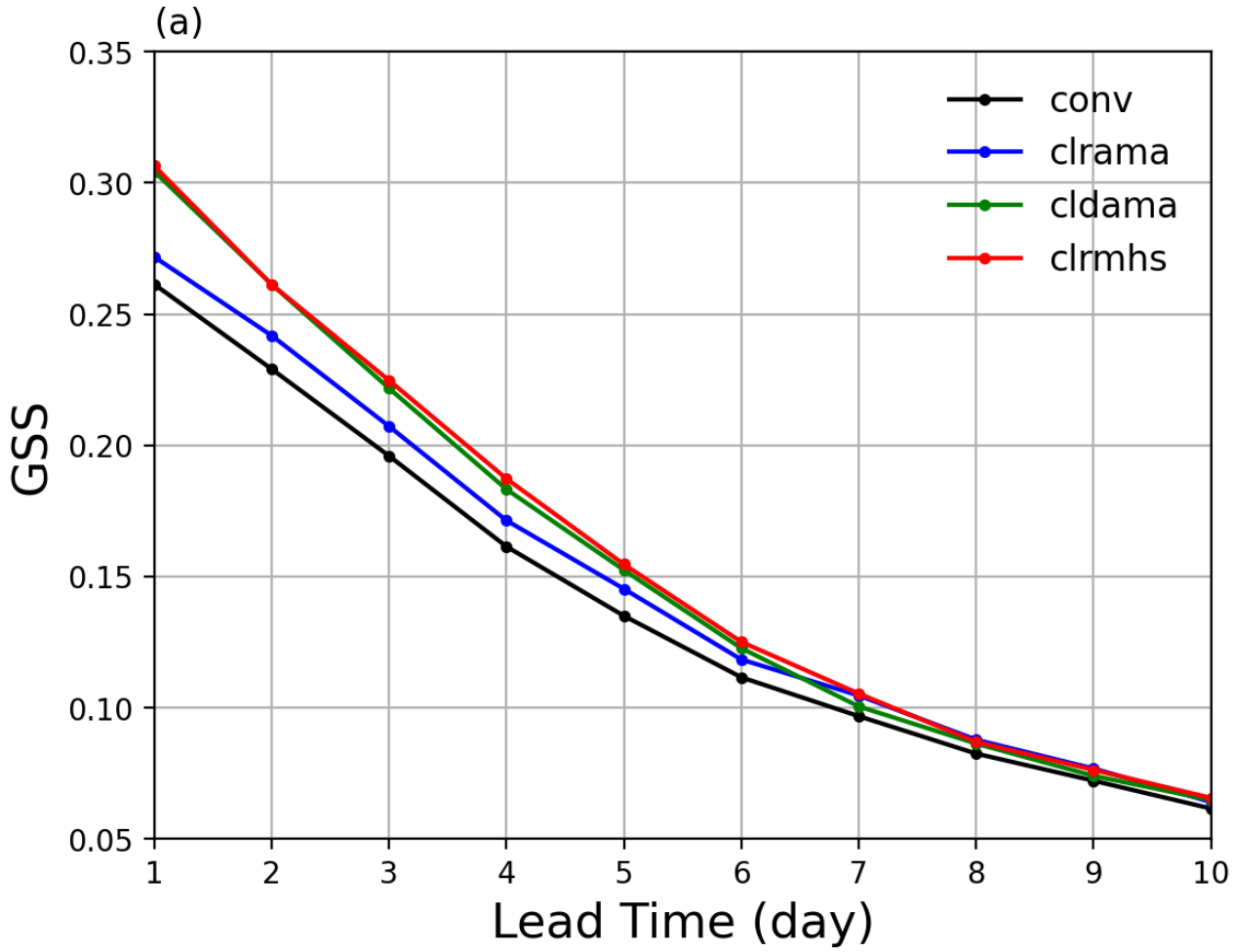
- Analysis variables: (T, Q, U, V, Ps) at cell center, + hydrometeors (optional)

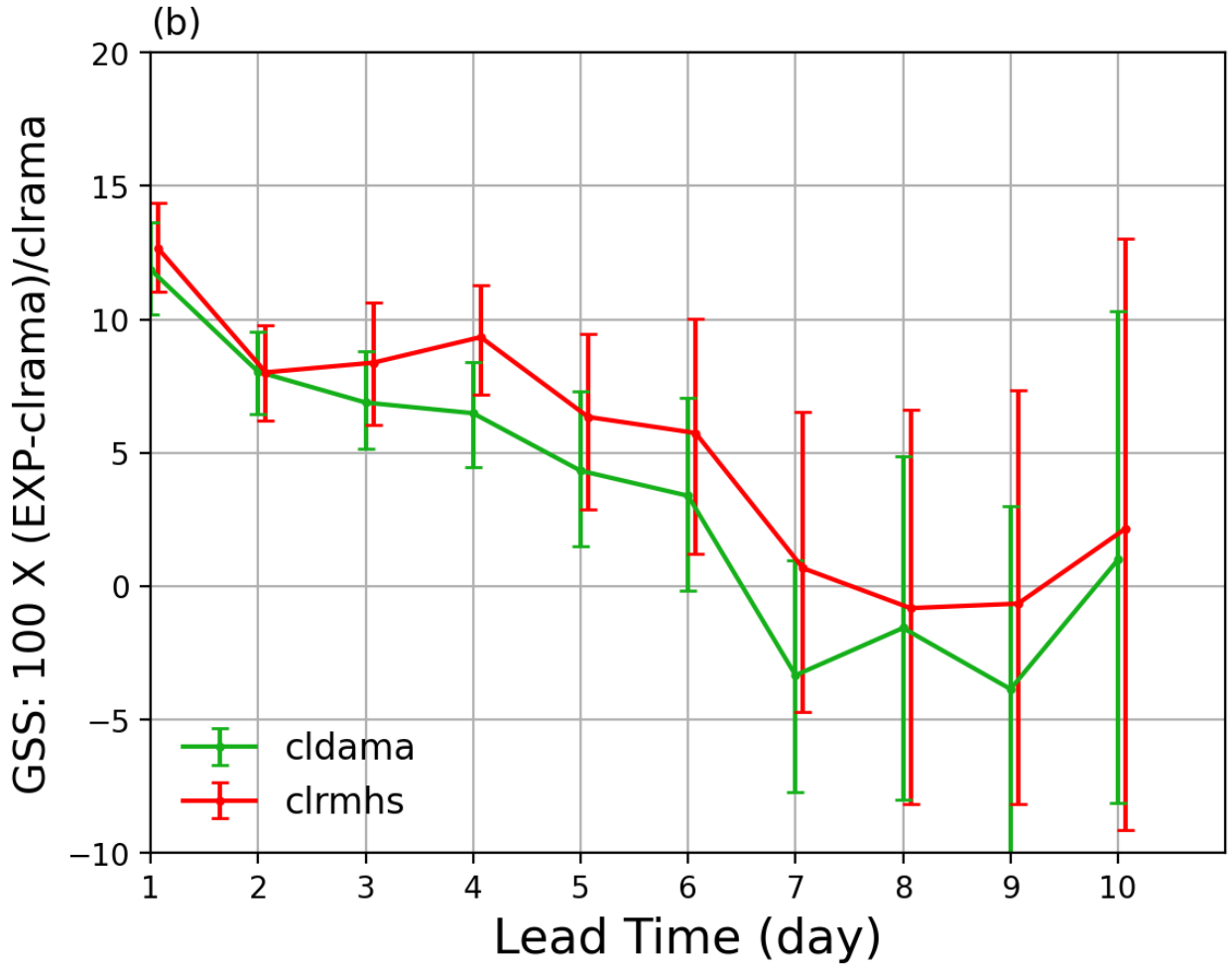
- Appy linear hydrostatic balance constrain to the analysis increment

Satellite Radiance DA capability with MPAS-JEDI

- So far MMM's MPAS-JEDI team mostly uses CRTM for radiance DA, though RTTOV could also be used
- Leverage comprehensive satellite radiance DA capability contributed by multiple groups
- Allow all-sky radiance DA with mixing ratios of hydrometeors as part of analysis variable
- So far MMM's MPAS-JEDI team have experimented several MW and IR sensors
  - Microwave: AMSU-A, MHS, ATMS
  - Infrared: ABI, AHI, IASI

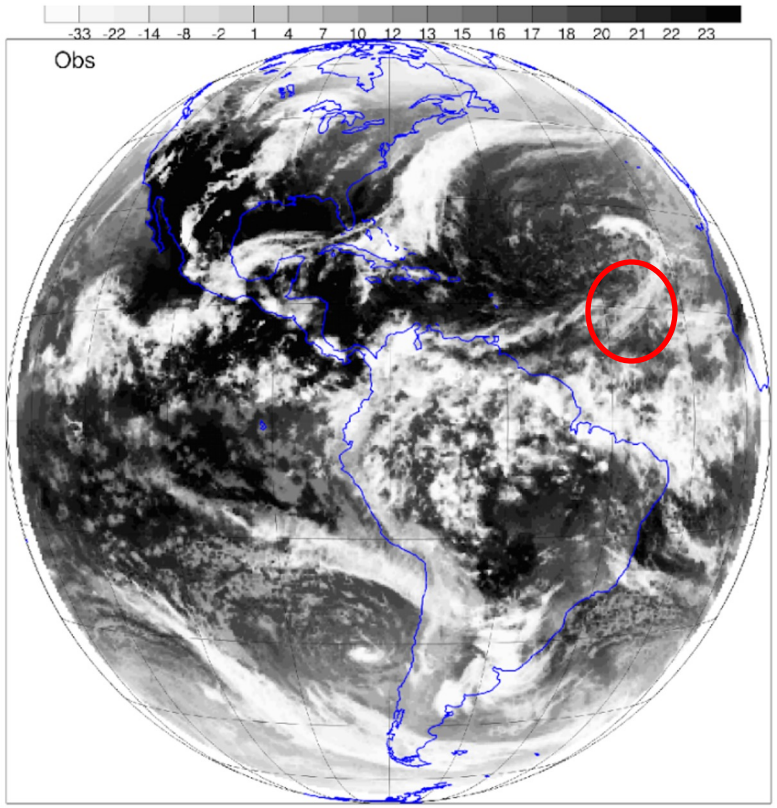
ETS Score for 1-10-day rainfall forecast w.r.t. CMORPH obs



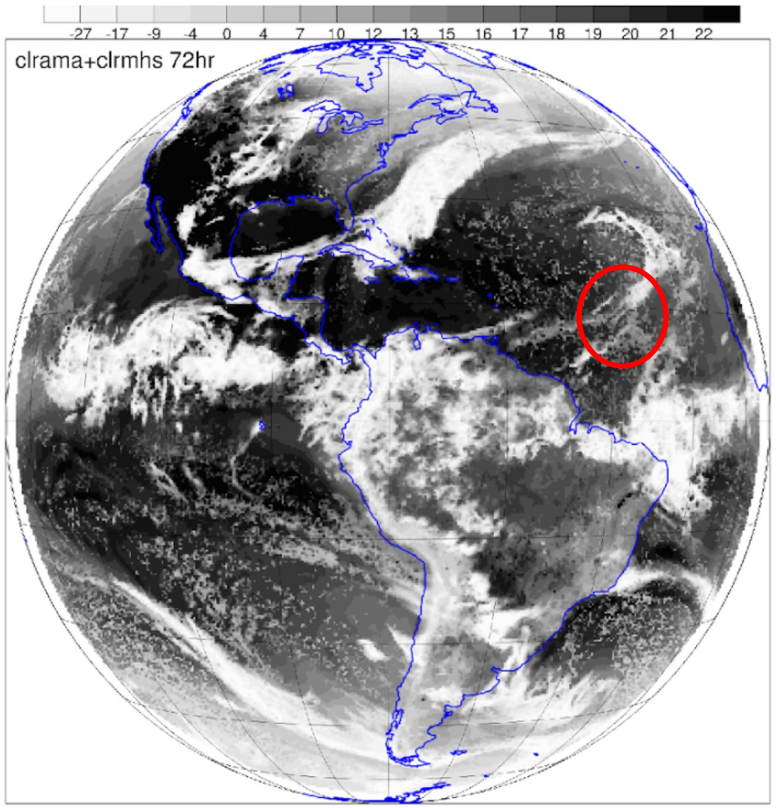


Observations vs. Day-3 forecast

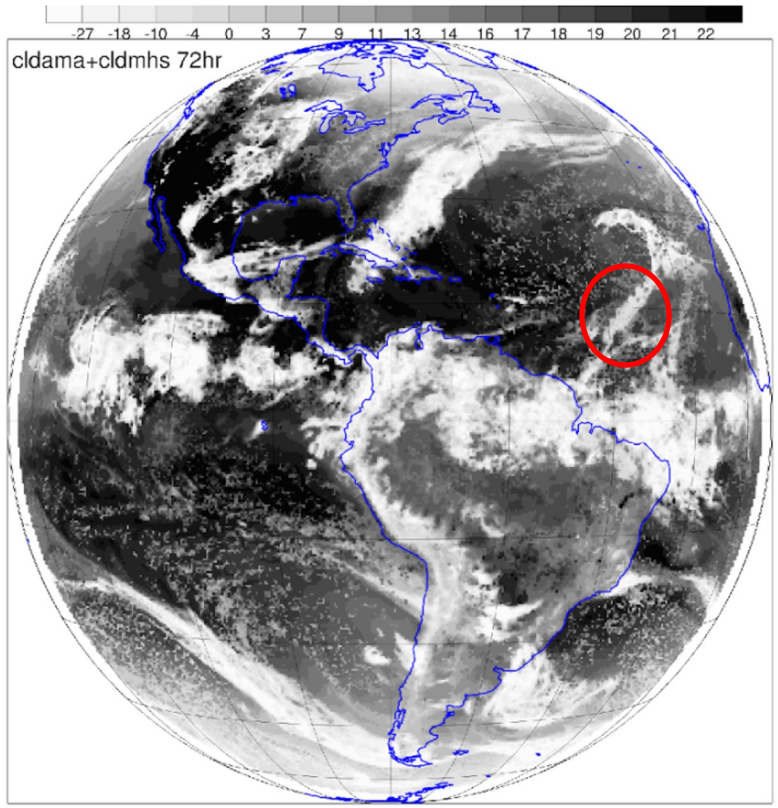
Observations



Baseline System



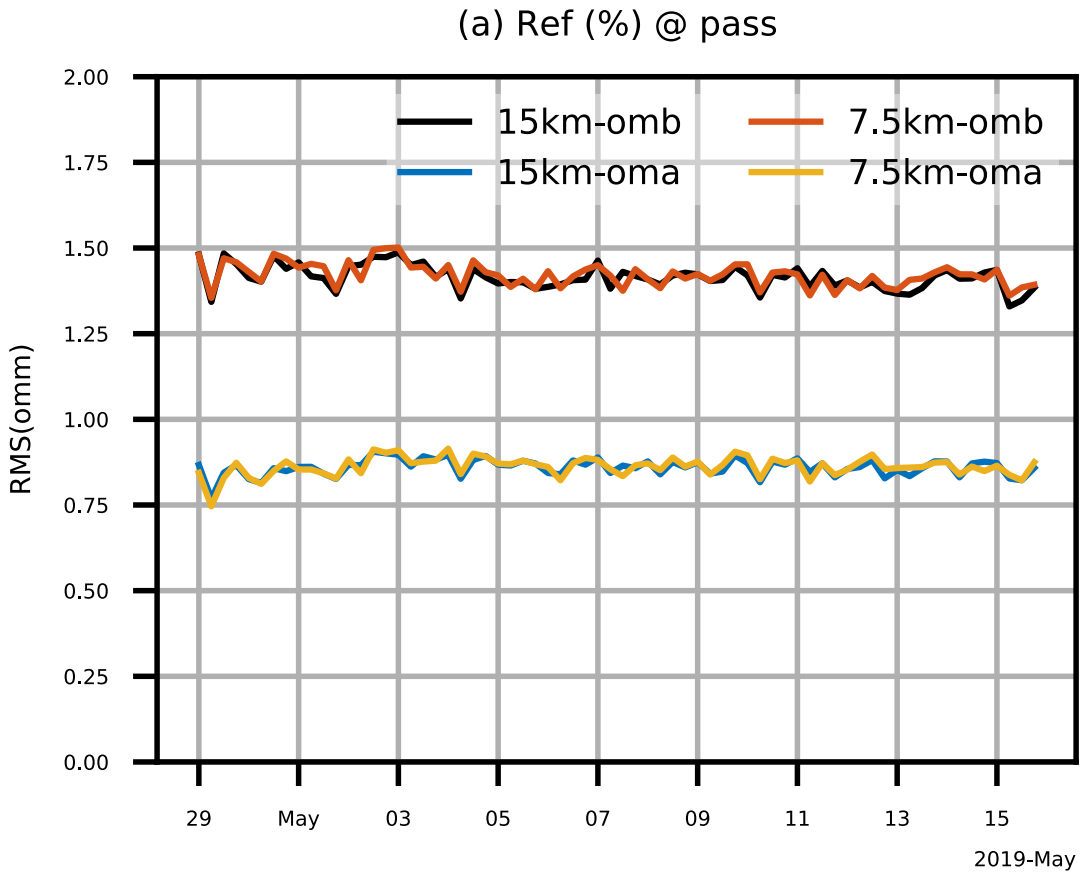
Cloudy DA System



ABI channel 13 BTs (degree C) valid at 00 UTC 9 May 2018

2.0 code allows high-resolution global DA at 7.5km (>10M cells):

7.5km-15km dual-res. 3DEnVar with 80-member 15km ensemble input



OMB/OMA of GNSSRO Refractivity

References

Liu, Z., Snyder, C., Guerrette, J. J., Jung, B.-J., Ban, J., Vahl, S., Wu, Y., Trémolet, Y., Auligné, T., Ménétrier, B., Shlyaeva, A., Herbener, S., Liu, E., Holdaway, D., and Johnson, B. T.: Data assimilation for the Model for Prediction Across Scales – Atmosphere with the Joint Effort for Data assimilation Integration (JEDI-MPAS 1.0.0): EnVar implementation and evaluation, Geosci. Model Dev., 15, 7859–7878, https://doi.org/10.5194/gmd-15-7859-2022, 2022.

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