MPAS-JEDI Overview

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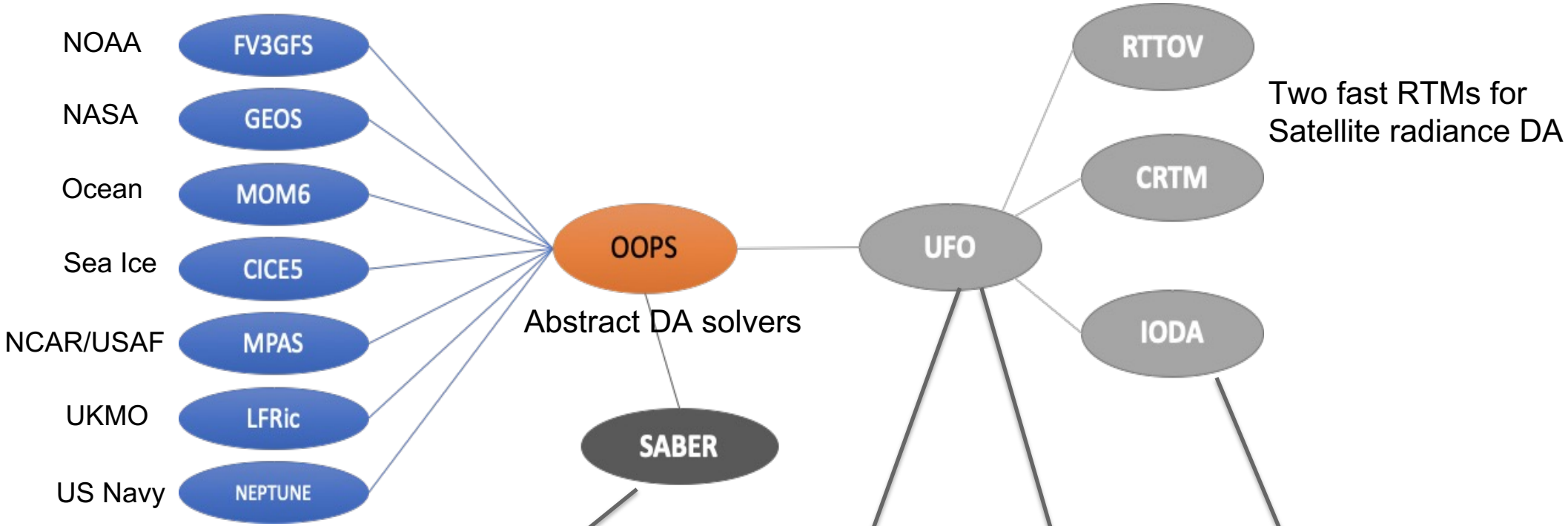
Joint Effort for Data assimilation Integration (JEDI)

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 4) and localization of ensemble covariance
  - **BUMP: Background error on Unstructured Mesh Package, used by MPAS-JEDI**
  - Under development: GSI's grid-point B model, UKMO's spectral B model, diffusion operator
  - 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, radar)
  - 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

MPAS
Model for Prediction Across Scales

https://www2.mmm.ucar.edu/projects/mpas-jedi/tutorial/202309NCAR/

Welcome to the MPAS-JEDI tutorial practice guide

This web page is intended to serve as a guide through the practice exercises of this tutorial. Exercises are split into seven main sections, each of which focuses on a particular aspect of using the MPAS-JEDI data assimilation system.

In case you would like to refer to any of the lecture slides from previous days, you can open the Tutorial Agenda in another window. The test dataset can be downloaded from Here.

You can proceed through the sections of this practical guide at your own pace. It is highly recommended to go through the exercises in order, since later exercises may require the output of earlier ones. Clicking the grey headers will expand each section or subsection.

0. Prerequisites and environment setup

1. Compiling/Testing MPAS-JEDI

2. Converting NCEP BUFR obs into IODA-HDF5 format

3. Running MPAS-JEDI's HofX application

4. Generating localization files and running 3D/4DEnVar with "conventional" obs

5. Running 3DVar and hybrid-3DEnVar

6. Running EDA and LETKF

7. Plotting OMB/OMA from two experiments

8. Running regional MPAS-JEDI

The first MPAS-JEDI tutorial

In September 2023

Plan to make MPAS-JEDI 3.0.0 release, this summer

We use 3.0.0-beta for this tutorial

- Previous releases (1.0.0 and 2.0.0) of MPAS-JEDI use
  - https://github.com/JCSDA-internal/MPAS-Model, 7.x-based
- From MPAS-JEDI 3.0.0, will use the official MPAS model repository
  - https://github.com/MPAS-Dev/MPAS-Model, 8.2.1-based
- MPAS-A/MPAS-JEDI tutorials: Sept. 30 to Oct. 4, 2024, Howard University

Main features of current MPAS-JEDI

- 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**

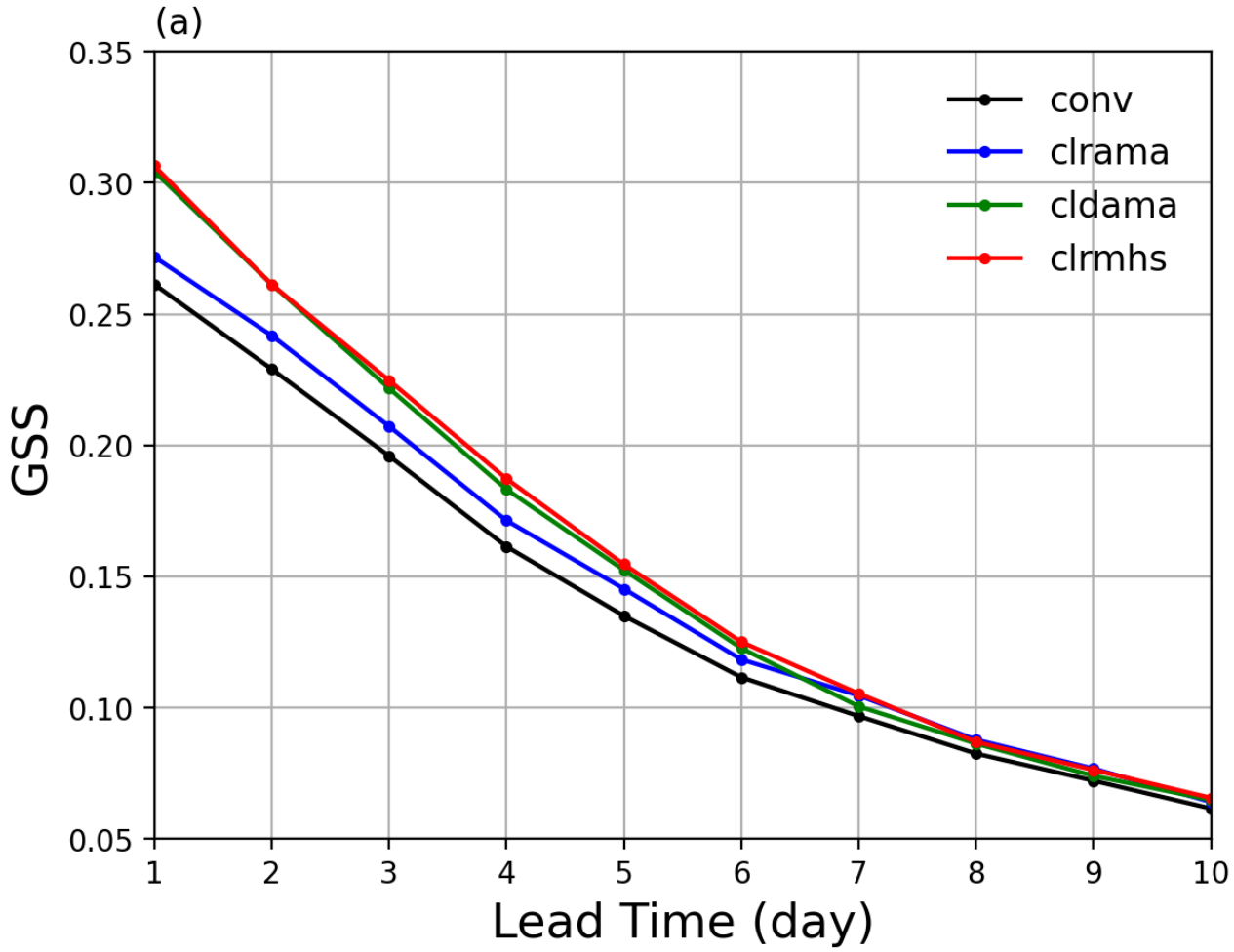
- Analysis variables: (T, Q, U, V, Ps) at cell center, + hydrometeors (optional)

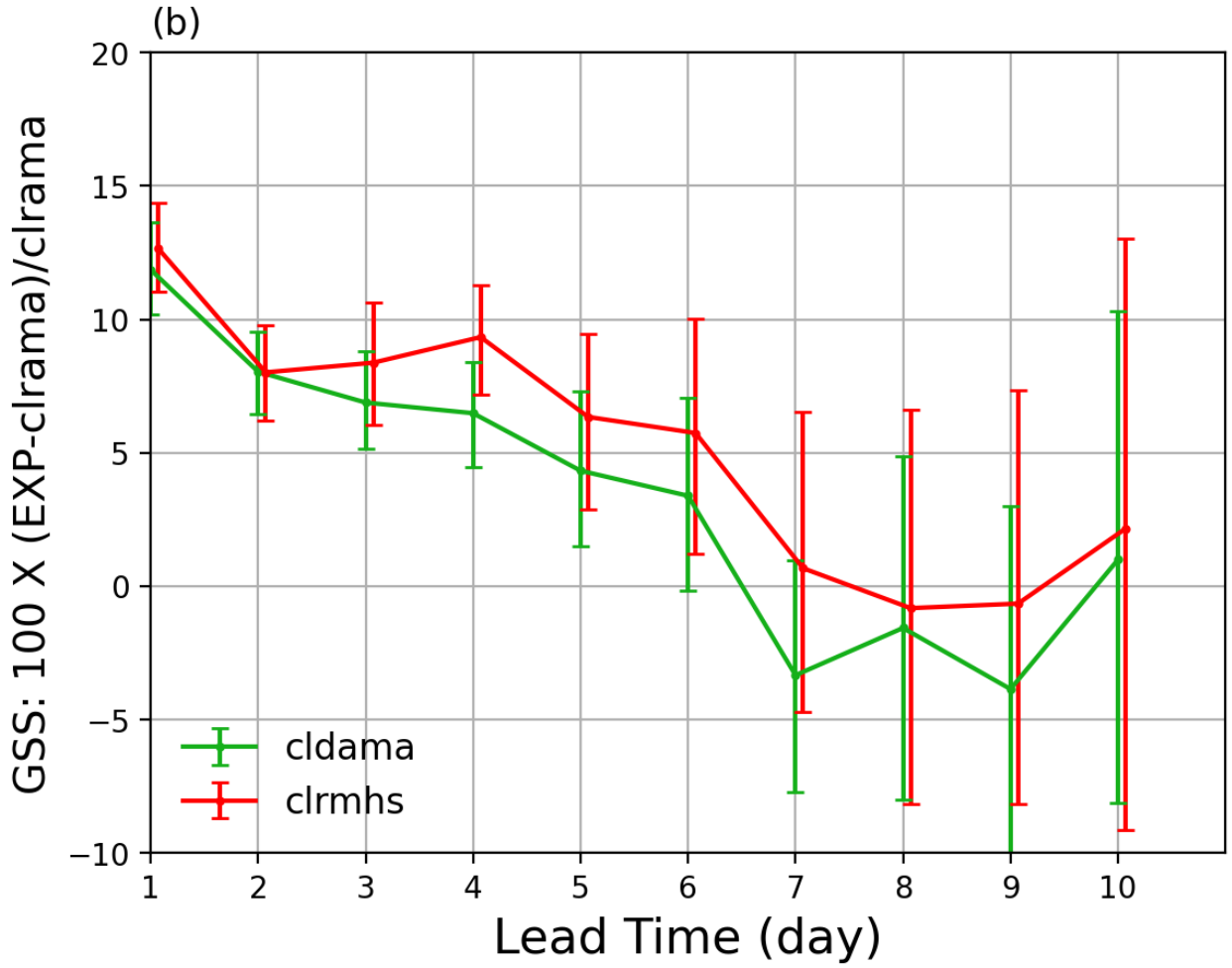
- Appy linear hydrostatic balance constrain to the analysis increment

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

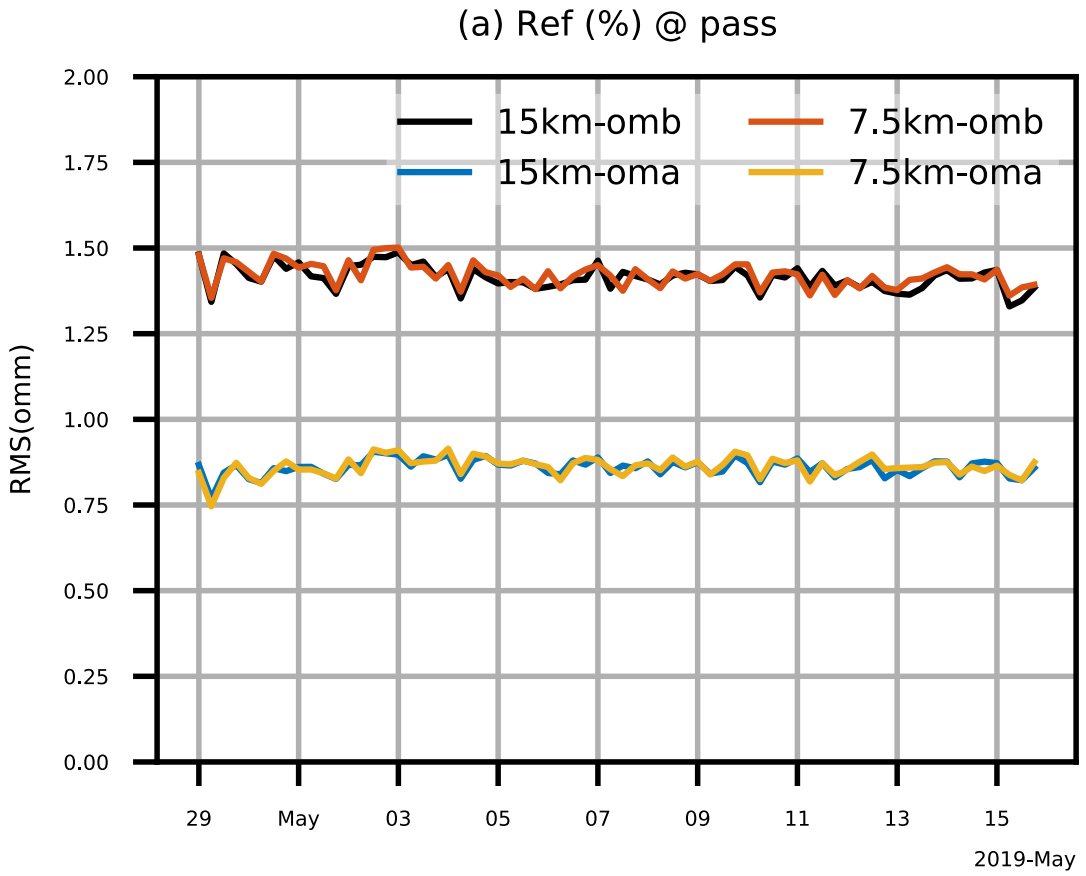




Liu et al., 2022

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

0-6-h accumulated rainfall from 00 UTC, 10 July 2023

Regional MPAS-JEDI at 3.75km grid spacing over US

Stage-IV obs

Hybrid-3DEnVar

This is a billion $ disaster event

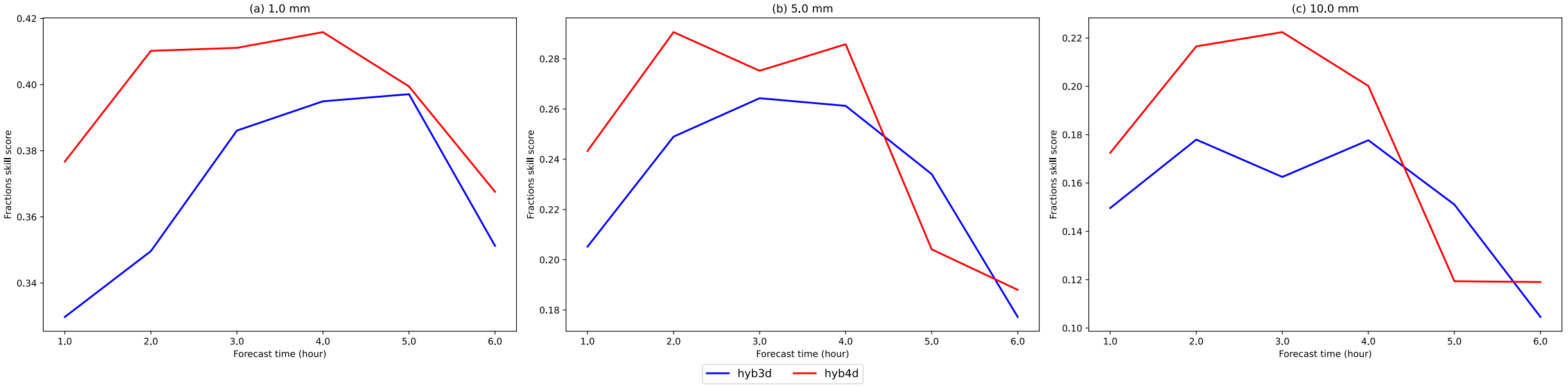
Hybrid-4DEnVar

Hybrid-3DEnVar w/ ABI

Hybrid-4DEnVar w/ hourly ABI

1-h accumulated rainfall forecast FSS scores: 1h - 6h lead time

Hybrid-3DEnVar vs. Hybrid-4DEnVar (without ABI)

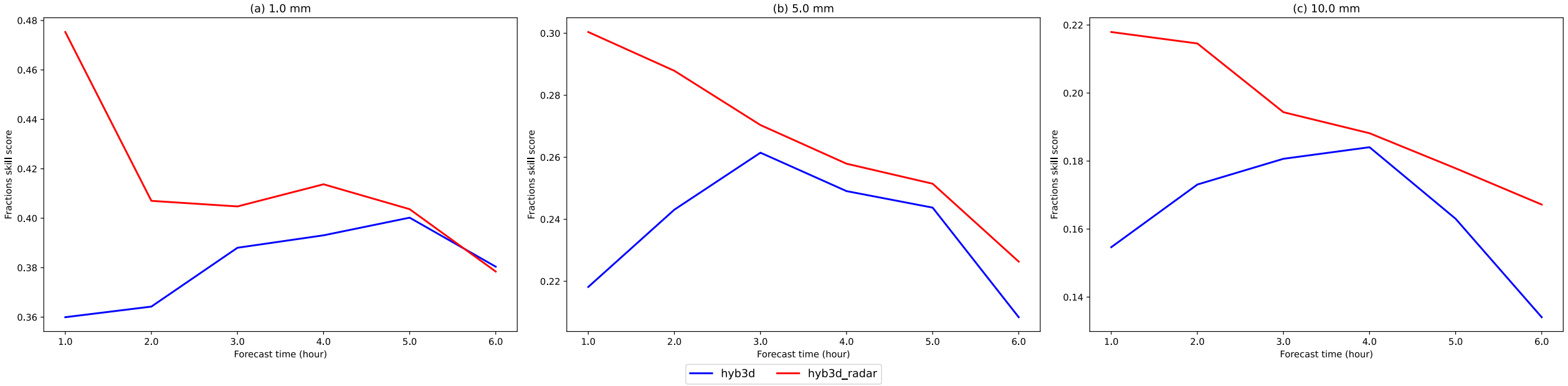


Clear improvement for the first several hours from hybrid-4DEnVar

Fraction Skill Scores (FSS) computed against Stage-IV obs with a radius of 25km, from 21 forecasts from 00 UTC 8 to 00 UTC 13 July.

Preliminary Radar DA

Hybrid-3DEnVar: without vs. with radar (radial wind + reflectivity)



33 forecasts from 00 UTC 9 to 18 UTC 17, July

MPAS-JEDI publications

EnVar and all-sky AMSU-A DA

Liu Z et al., 2022: 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.

EDA

Guerrette, J. J. et al., 2023: Data assimilation for the Model for Prediction Across Scales – Atmosphere with the Joint Effort for Data assimilation Integration (JEDI-MPAS 2.0.0-beta): ensemble of 3D ensemble-variational (En-3DEnVar) assimilations, Geosci. Model Dev., 16, 7123–7142.

3DVar and multivariate background error covariance

Jung et al.. 2024: Three-dimensional variational assimilation with a multivariate background error covariance for the Model for Prediction Across Scales–Atmosphere with the Joint Effort for data Assimilation Integration (JEDI-MPAS 2.0.0-beta), Geosci. Model Dev., 17, 3879–3895.