Joint WRF/MPAS Users Workshop 2024

NOAA/GSL Model Prediction Development with MPAS

Curtis Alexander
and many collaborators across GSL, NOAA, UCAR, NSF-NCAR

25 June 2024

GLOBAL SYSTEMS LABORATORY

Forecast systems that deliver solutions

Current GSL MPAS Experiments

Global

- GSL grand challenge working towards global convection allowing model (CAM) configuration
  - MPAS 7.5 km global mesh, 48 hr forecast from GFS in 2.5 hrs using 20 AWS cloud instances
- Physics testing for atmospheric rivers, precipitation, snow, clouds, radiation, aerosols
  - MPAS 12+ km global mesh, 24 hr forecast from GFS

Regional CAM

- Deterministic baselines to inform future Rapid Refresh Forecast System (RRFS) designs – NSSL led
  - MPAS 3km CONUS mesh, 48-60 hr forecasts from HRRR and RRFS
- Resolution sensitivity experiments to inform future Rapid Refresh Forecast System (RRFS) designs
  - MPAS 2-4km CONUS meshes, 36 hr forecasts from HRRR
- Members to inform future Rapid Refresh Forecast System (RRFS) ensemble designs
  - MPAS 3 km CONUS mesh, 48 hr forecasts from HRRR and RDAS/GEFS perturbations
- Physics testing including tropical/hurricane prediction
  - MPAS 3 km CONUS + Atlantic basin mesh, 42 hrs from RAP (HRRRv5), 5 day from GFS

Regional Convection Resolving Model (CRM)

- Extreme precipitation estimation for infrastructure resiliency and fire weather prediction for urban-scale
  - MPAS 1 km sub-CONUS meshes, 24-48 hrs, from HRRR

GSL Physics development and code management

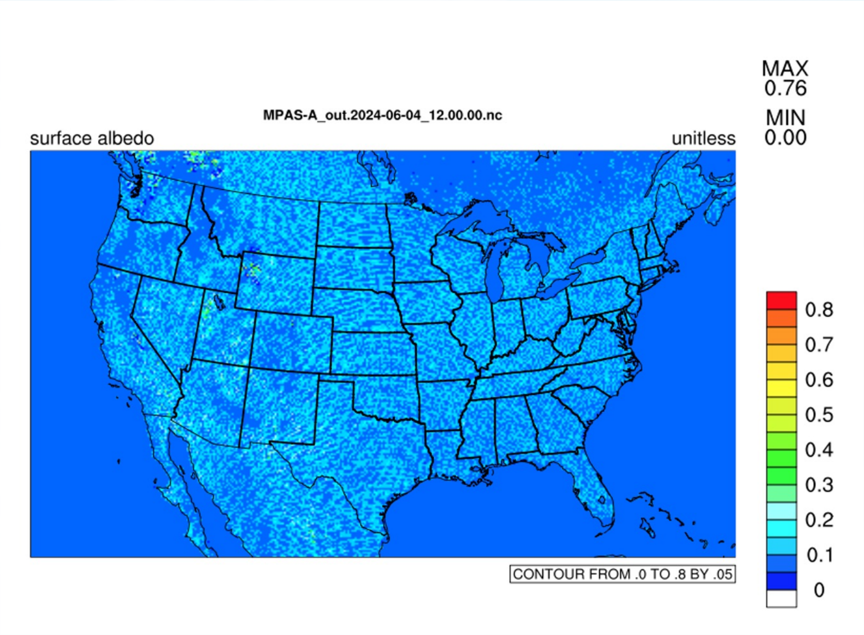
- Physics updated in GSL fork
  - Thompson mp - updated to aerosol-aware
  - GF convection
  - MYNN PBL and sfc
  - RUC LSM
- Thompson mp now updated and in its own repo (TEMPO)
  - Other parameterizations to follow
- Experimental 3-km MPAS-HRRRv5 over CONUS
  - Initialized from RAP
  - Runs 4 times per day: 00, 06, 12 and 18 UTC up to 42-h forecast
  - MPAS 8.1 + NSSL + Updated GSL physics (no GF)

See more details on presentations from
Joe Olson on “Development Strategy for GSL-led to Physical Parameterization for all Model Hosts/Apps”
Georg Grell on “Development and applications of the latest GF parameterization in MPAS”

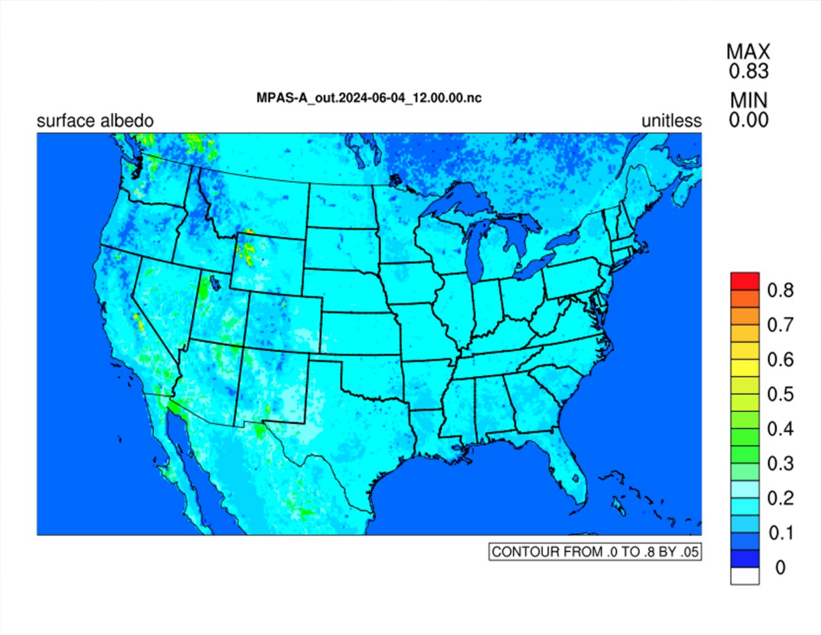
Recent Challenges in real-time 3-km MPAS-HRRRv5

1. Intermittent crashes due to computational instabilities
   - The crash was in mpas_convective_diagnostics.F due to high wind speeds
   - ***Fixed on 5 June 2024***: config_number_of_sub_steps = 4 (originally, it was a default =2)
2. A problem with albedo information in the static file
   - ***Fixed on 5 June 2024***: re-created static file with config_supersample_factor = 3 (=1 before)
3. A lag in the SW radiation
   - Swint_opt available in WRF is not available in MPAS (swint_opt =1 computes radiation in the middle on the radiation time step).
   - ***Not fixed***, but radiation time step is changed from 30 min to 15 min
4. Too opaque clouds
   - Default configuration used poorly specified effective radii.
   - ***Fixed on 31 May 2024*** – using effective radii from microphysics scheme (Anders Jensen)
5. Daytime moist bias in 2-m dewpoint
   - ***Improvement from RUC LSM tuning starting 00 UTC, 7 June 2024***
   - Tuning in other physics parameterization may be needed

2. Albedo



before fix



after fix

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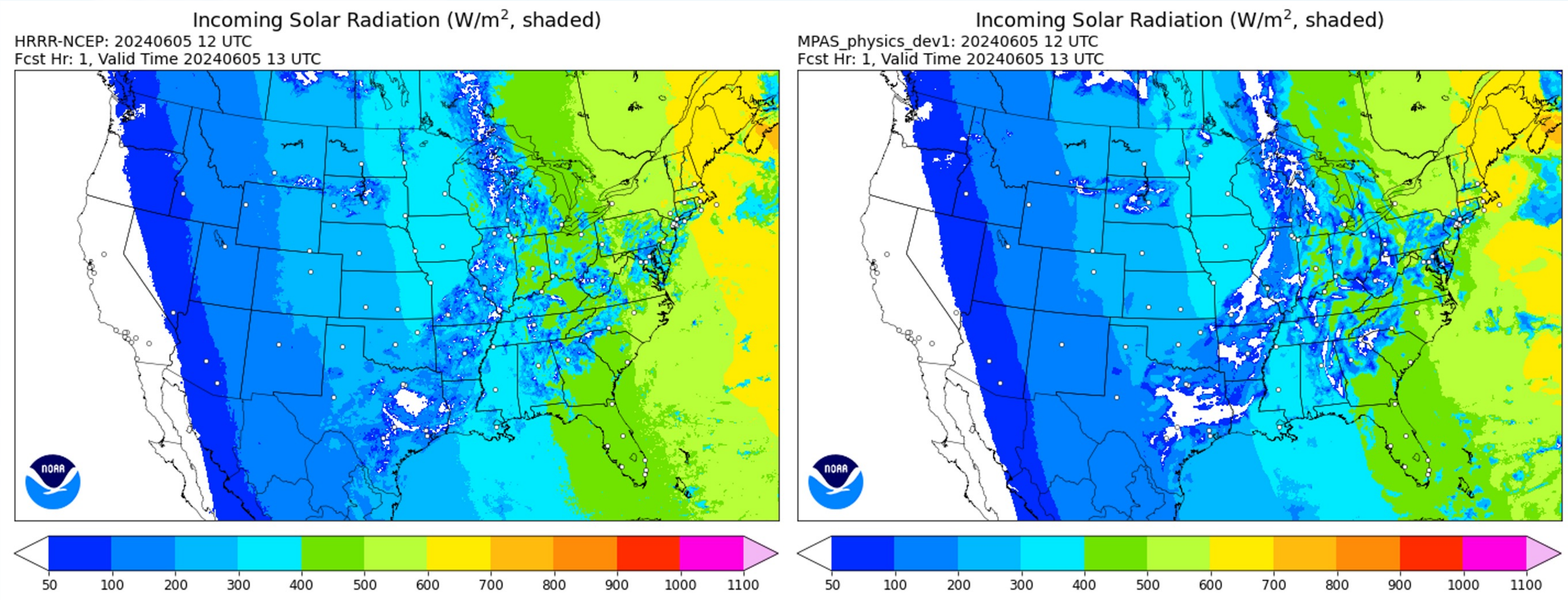
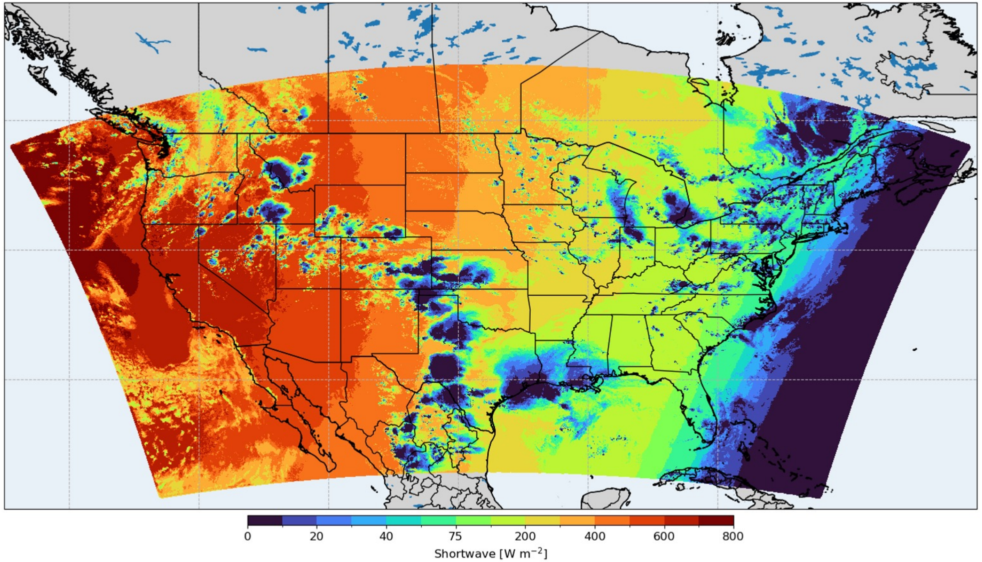
3. A lag in SW radiation



4. Opaque Clouds

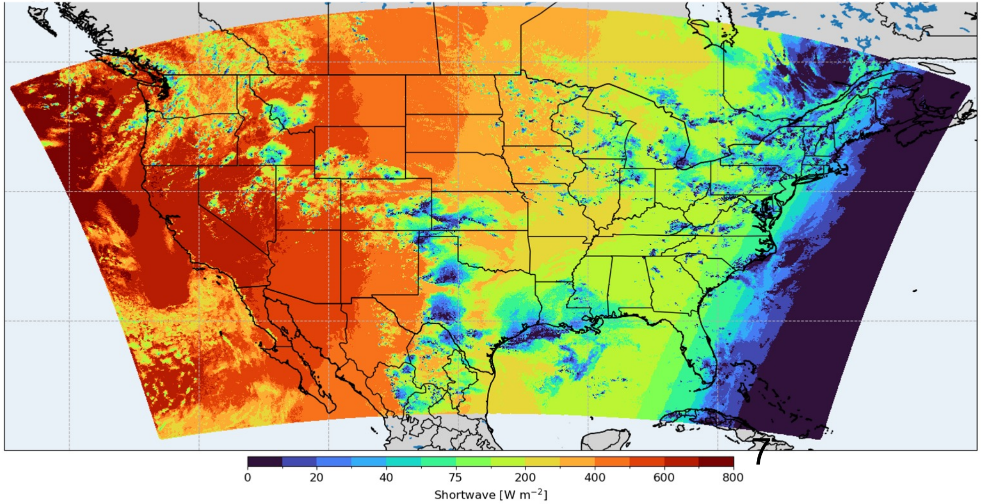
Original Configuration

- was not configured to use the effective radii from the microphysics; defaulted to very poorly set values, making clouds too opaque.



Update to use effective radii from microphysics

- Changed the default value of *config_microp_re* to true
- Currently working on a revision of the macrophysics tailored for MPAS.



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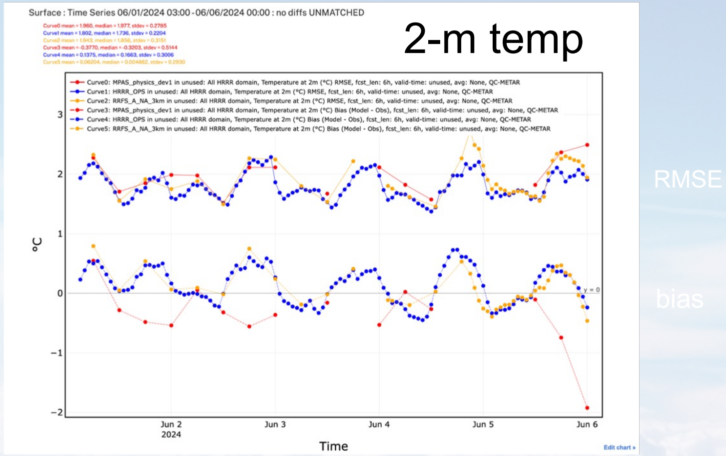
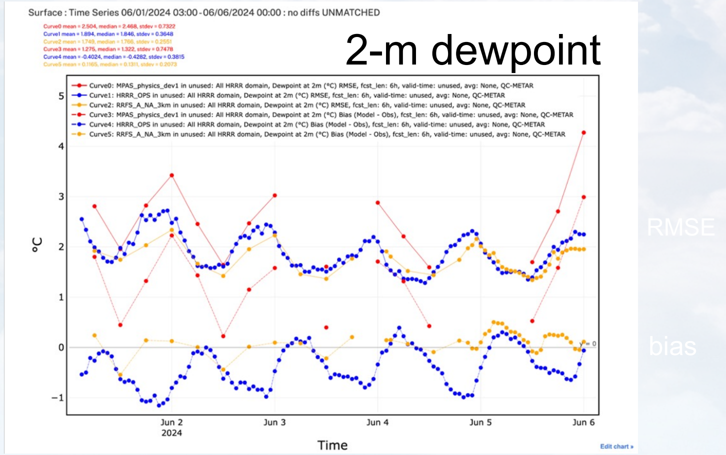
5. Daytime moist bias in 2-m dewpoint

- Tuning of RUC LSM parameters in MPAS
  - Soil resistance to evaporation from HRRR - ***too small for MPAS, overestimated direct soil evaporation;***
  - Irrigation depends on cropland greenness in the updated version of RUC LSM. The climatological greenness fraction in MPAS is higher than real-time VIIRS greenness in RRFS over Western US, as a result ***irrigation is triggered too early, adds soil moisture***
- Fixes:
  - Increased soil resistance to evaporation (as in RRFS)
  - Irrigation is turned off for now.





Red - MPAS
Blue - HRRR
Gold - RRFS

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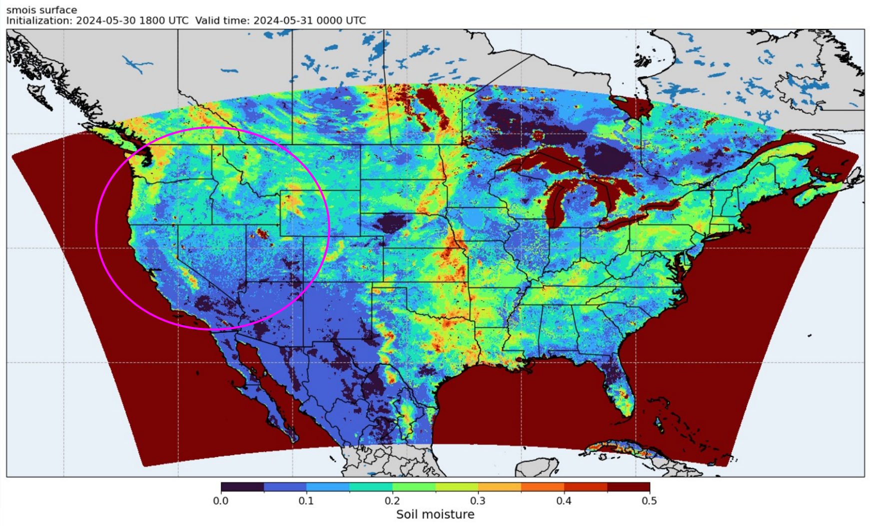
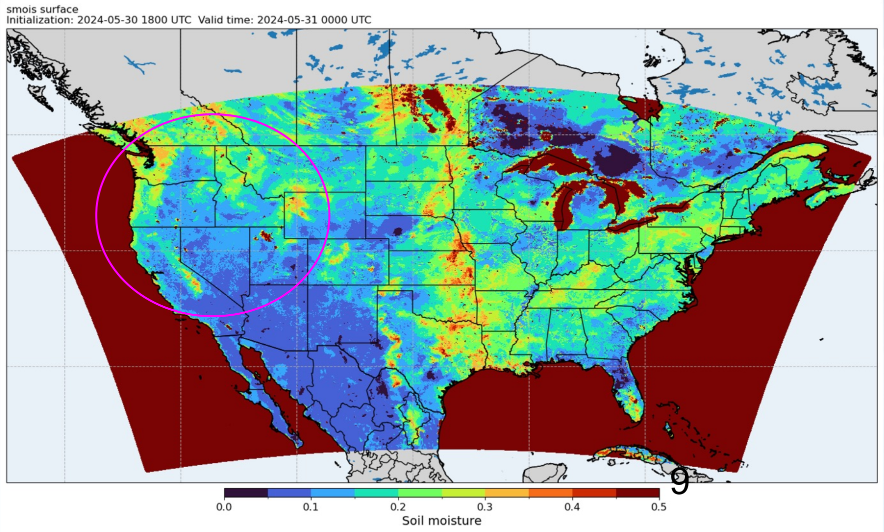
Soil moisture at the surface

Original Code →



6-h fcst, valid at 00 UTC 31 May 2024

Updates from Tanya on 05 June 2024 →



Plots: courtesy Anders Jensen

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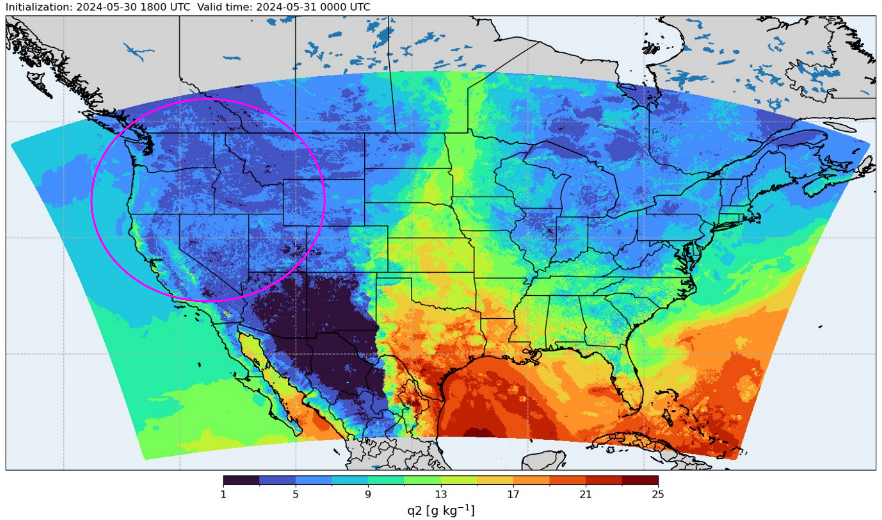
2-m Water Vapor Mixing Ratio

Original Code →



6-h fcst, valid at 00 UTC 31 May 2024

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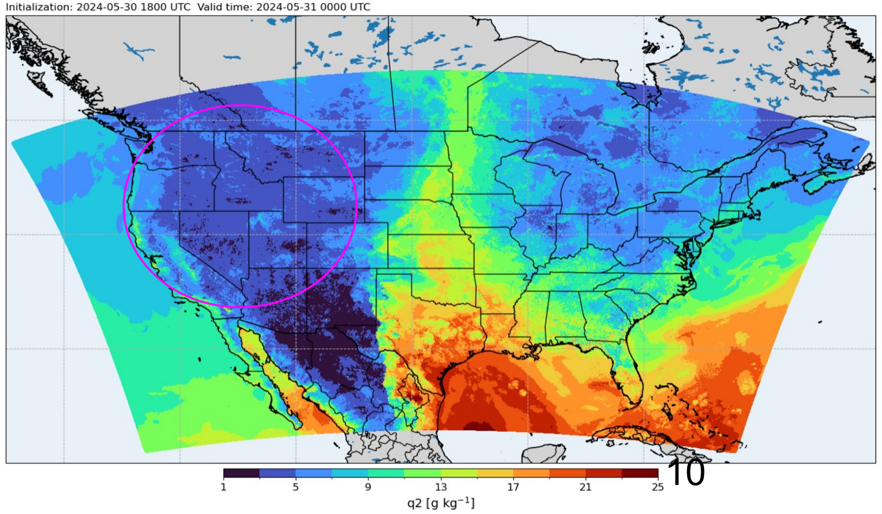

Plots: courtesy Anders Jensen

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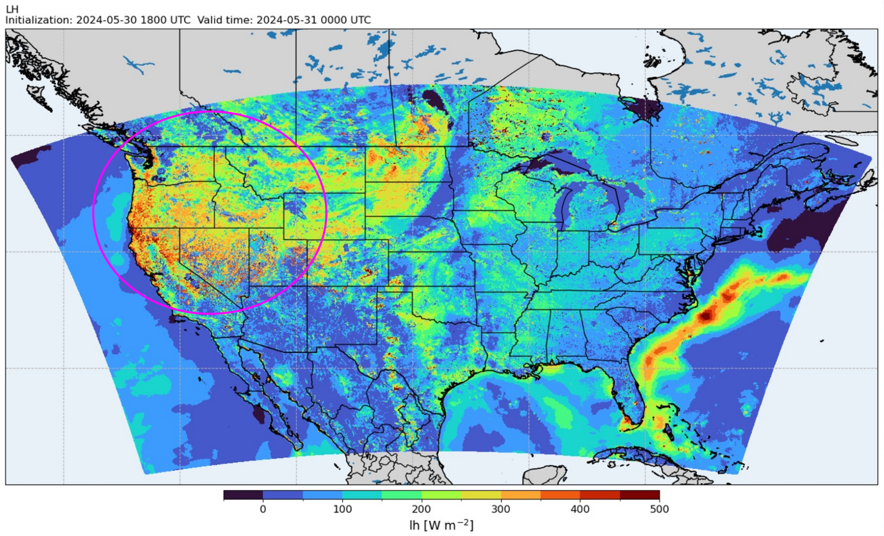
Latent Heat Flux

Original Code



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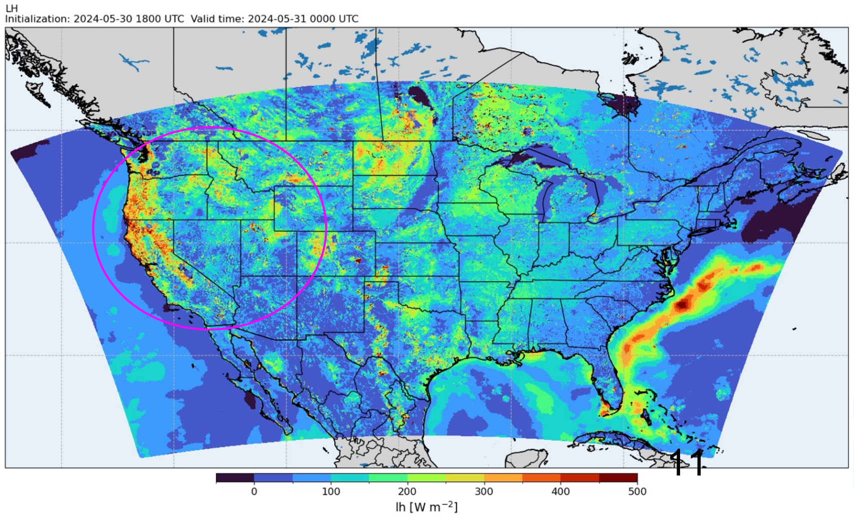

Plots: courtesy Anders Jensen

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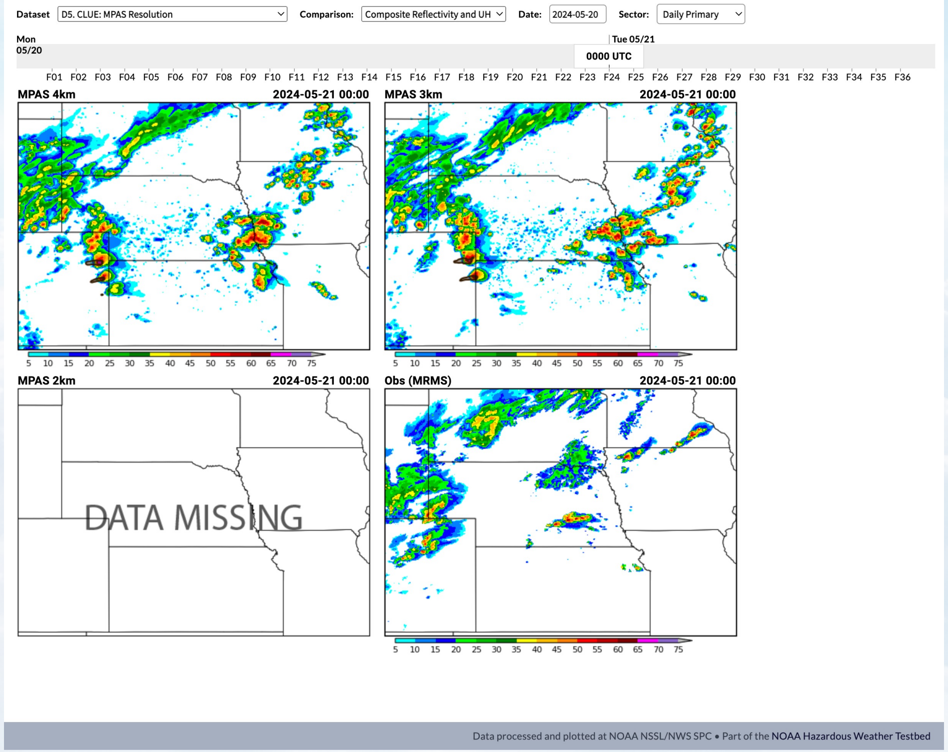
GSL Participation in Experiments and ICs

- **Spring Forecast Experiment (NOAA HWT)**
  - GSL participated with members running “old physics” (without recent updates)
  - A configuration with “new physics” was run for internal scrutiny at GSL (not shared)
- **Flash Flood and Intense Rainfall Experiment (NOAA HMT)**
  - If results look good, we may start piping forecasts to them in late June
- **Hurricane Forecast Improvement Experiment (NOAA HFIP)**
  - If results look good, we will start realtime runs over the Atlantic basin in mid-July
  - Two configurations: with and without GF convection

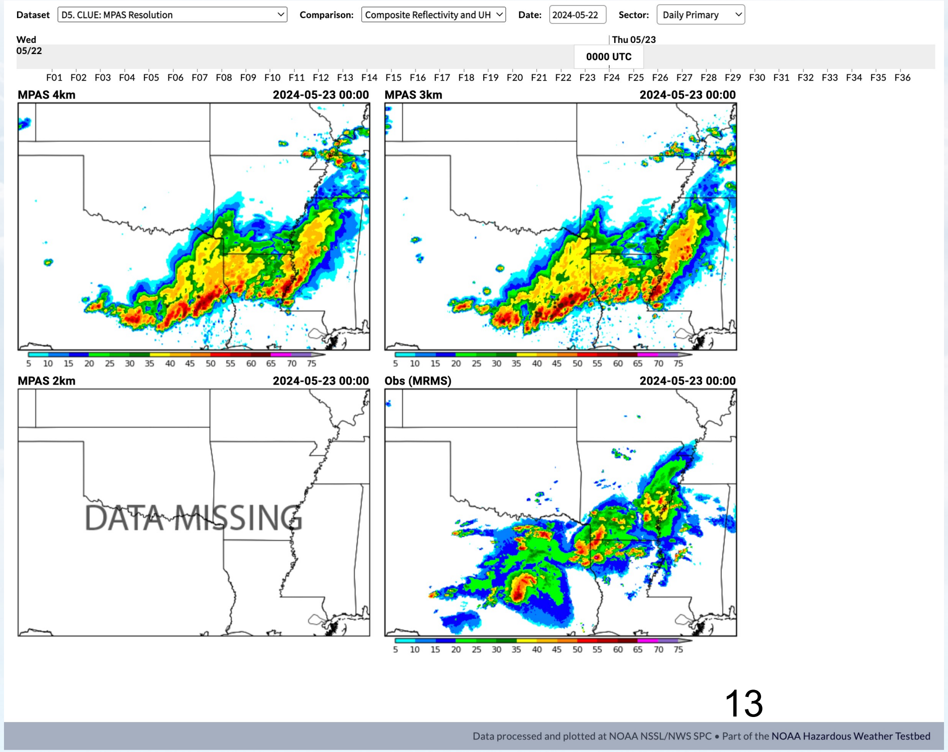
- HWT and HMT configurations initialized from RAP
- HFIP initialized from GFS but soil fields over NA from RAP
  - Uses a procedure called “soil surgery” to initialize RUC LSM

NOAA NSSL/NWS SPC Spring Forecast Experiment 2024



MPAS resolution sensitivity at 3 and 4 km meshes

Forecasting composite reflectivity against MRMS observations



Approximately 25 days evaluated in various convective environments (see NSSL/SPC for results)

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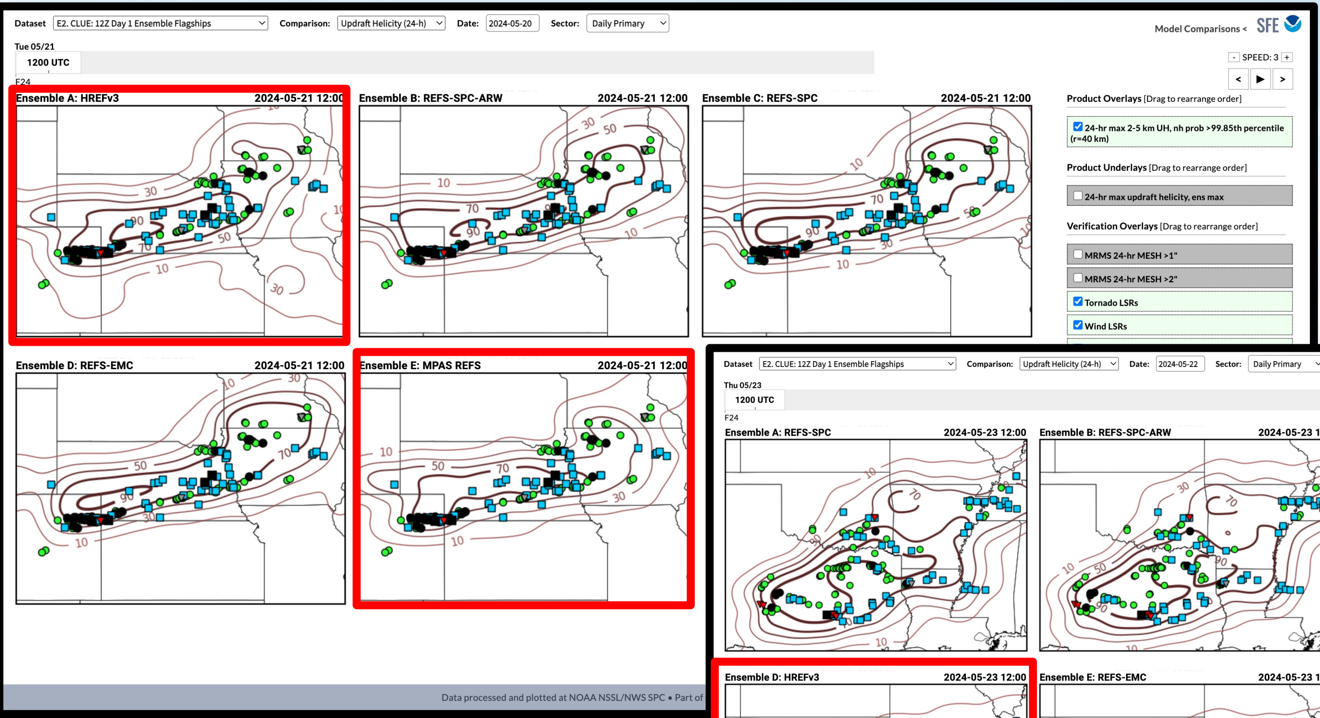
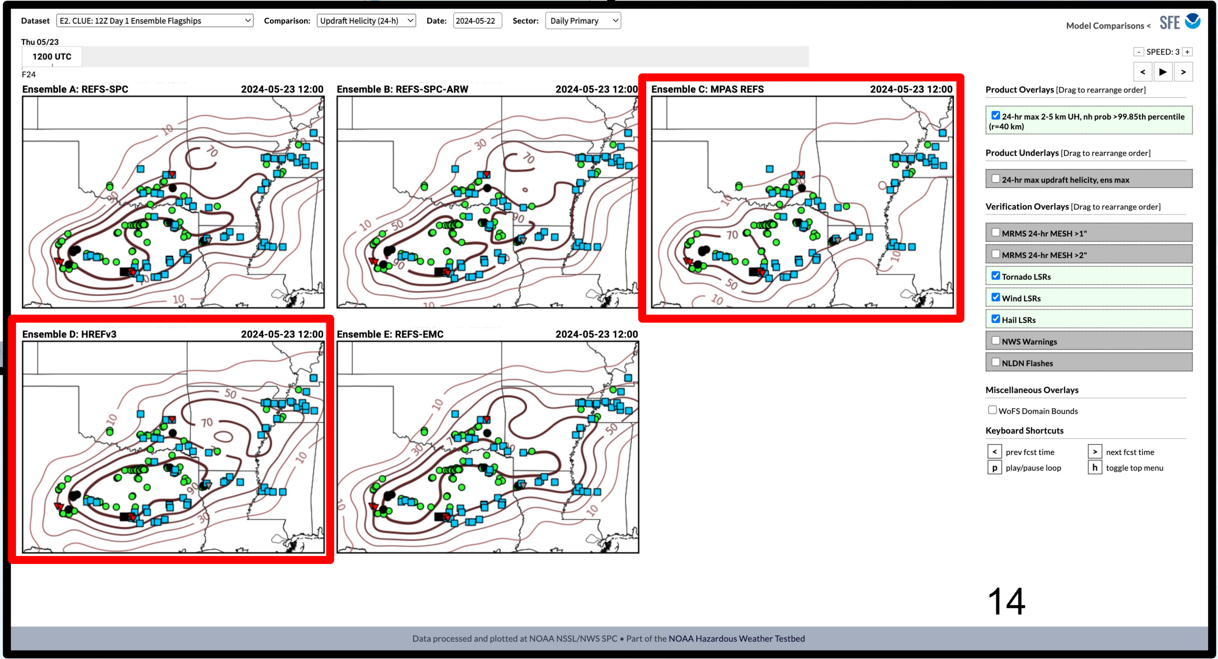
NOAA NSSL/NWS SPC Spring Forecast Experiment 2024



MPAS 3-km Ensemble Design
HRRR+RDAS+GEFS ICs/BCs

Forecasting probabilities of severe convection against tornado, wind and hail storm reports



Approximately 25 days evaluated in various convective environments (see NSSL/SPC for results)

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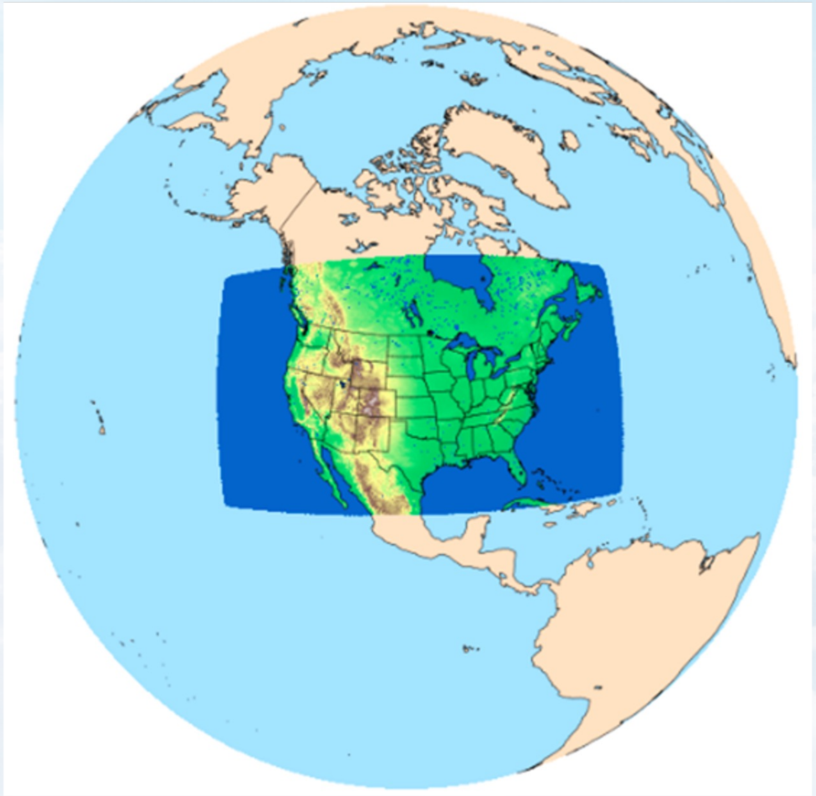
GSL Data assimilation development and code management

RDASApp

https://github.com/NOAA-EMC/RDASApp

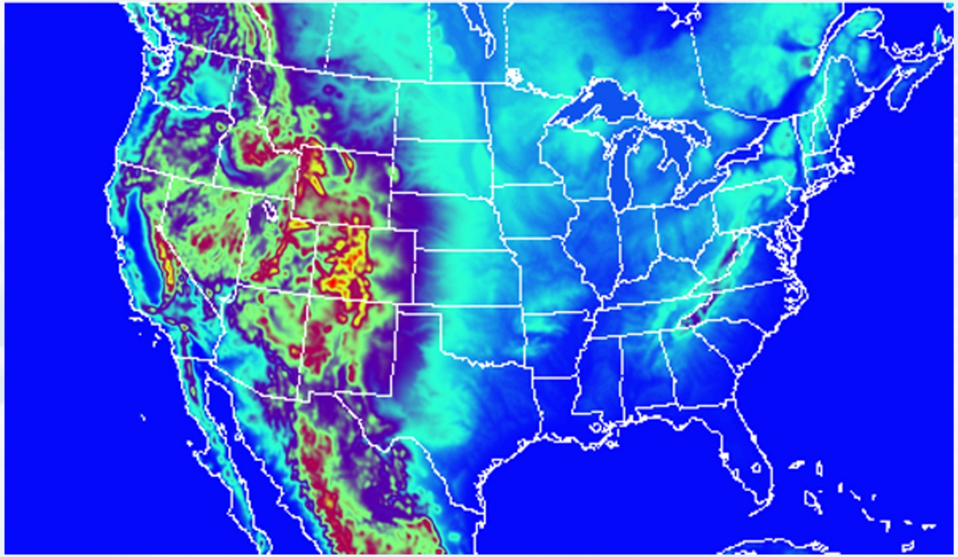
- RDASApp is to replace GSI. It contains all required JEDI components to build, test and run RRFSv2 data assimilation experiments.
- It greatly facilitates the collaboration and discussions between GSL and EMC with issue tracking, PR reviewing and Wiki Documentation
- GSL has participated over 45 issues, 42 PRs so far; contributed to the developing, testing, evaluation, documentation, portability of RDASApp and establishing/maintaining FV3-JEDI, MPAS-JEDI test cases
- We meet bi-weekly and established a preliminary code management and regression test policy

GSL MPAS-JEDI development sandbox

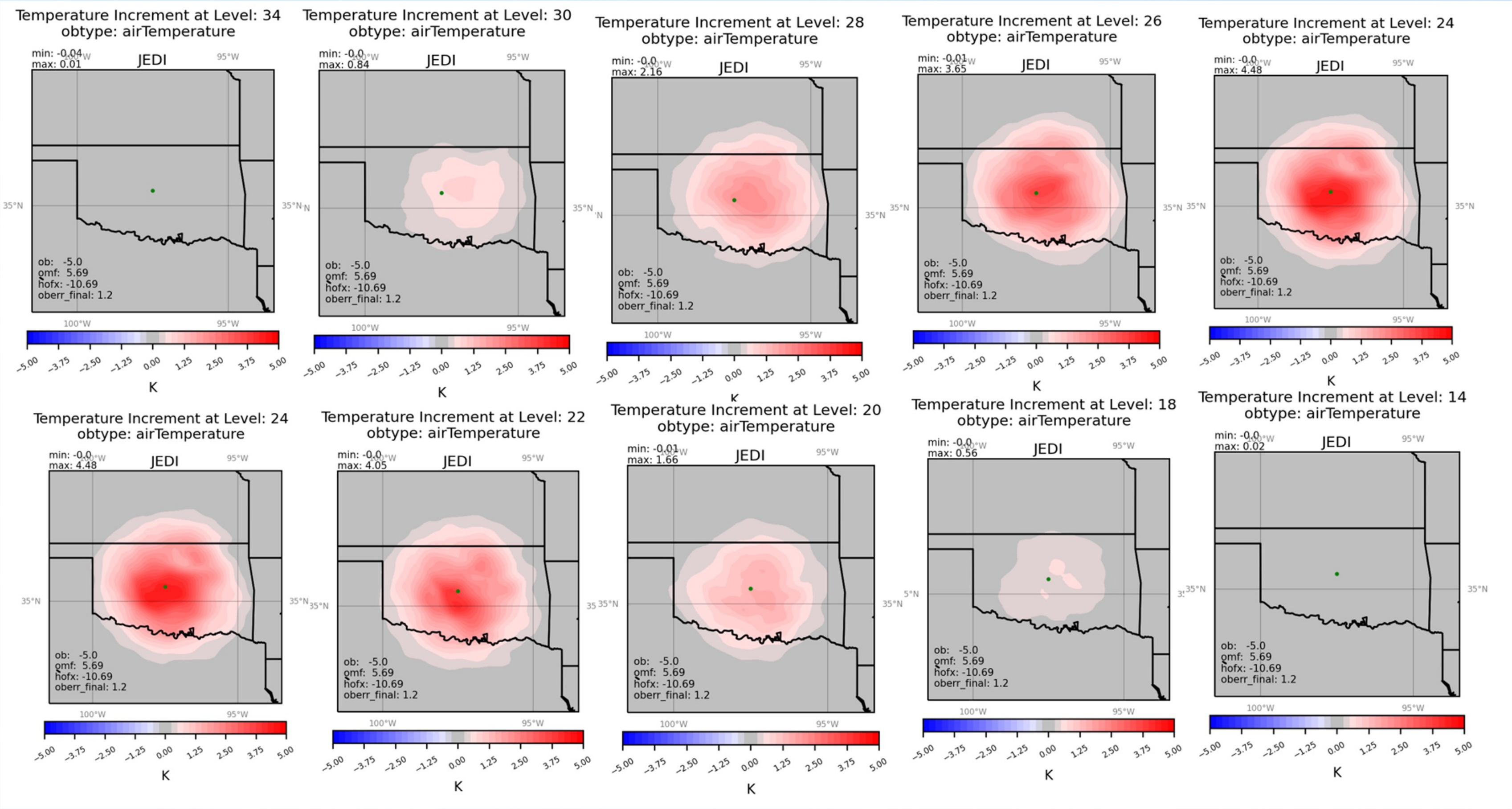


MPAS CONUS 12KM domain
+ 30 ensembles for preliminary tests

Comparable RAP/HRRR-like domain, to be used by GSI baseline tests



Single sonde obs MPAS-JEDI 3DEnVAR experiment with 401km horizontal JEDI radius and **11** vertical levels radius



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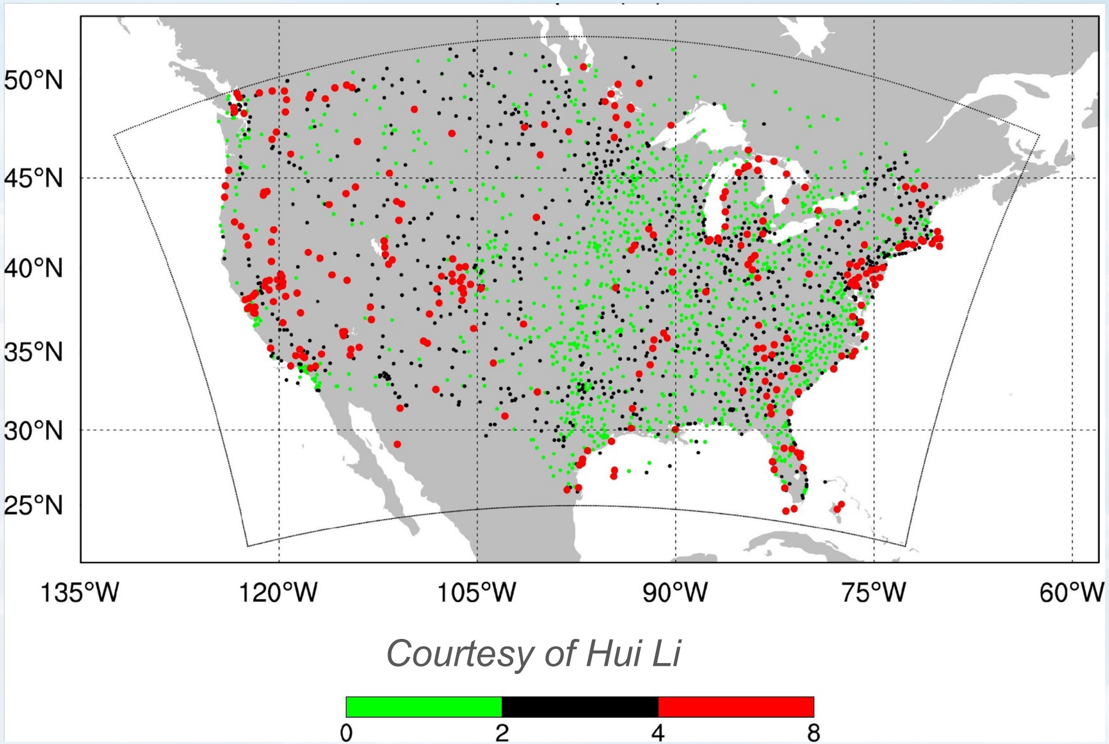
GSL MPAS-JEDI development for surface observations



METAR OBS MPAS-JEDI DA

O-B sanity check

Larger O-B near the coastlines

GSI has special treatment for observation near coastlines

Work is underway to bring this function to MPAS-JEDI

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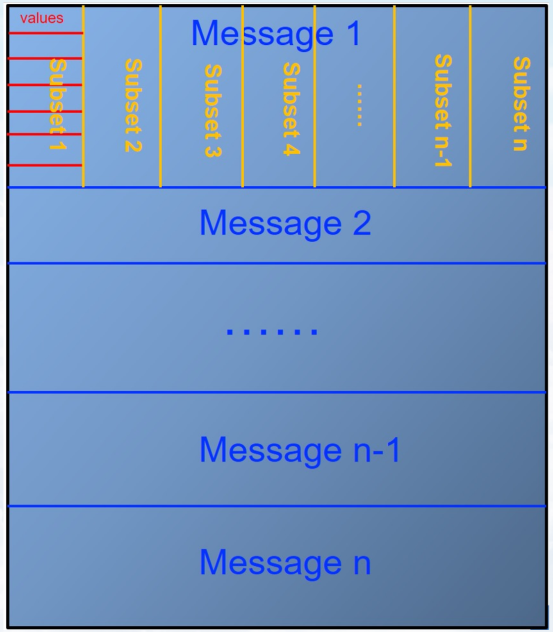
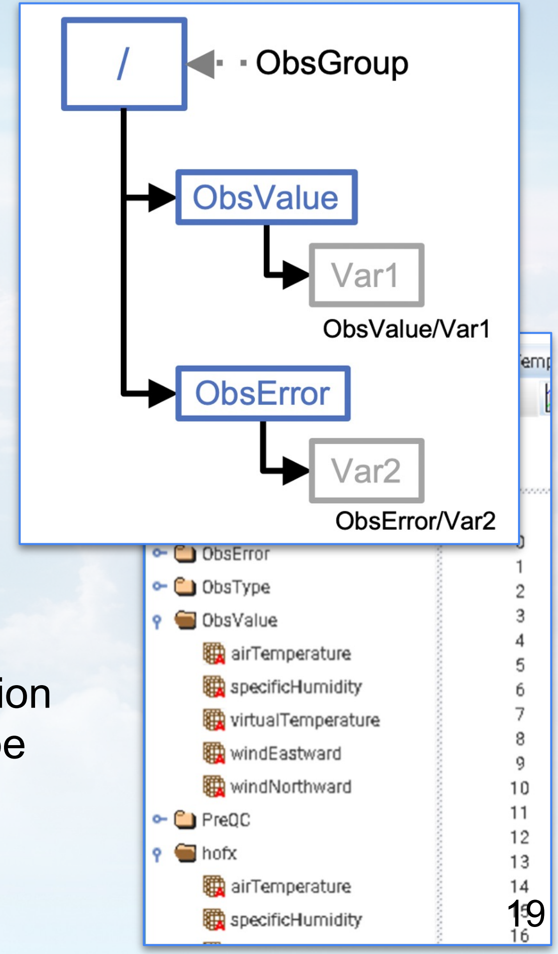
GSL MPAS-JEDI observation processing





GSL tested the BUFR2IODA functionality and, in collaboration with EMC, made sure all operational observation files can be seamlessly and successfully converted to the IODA format needed by MPAS-JEDI

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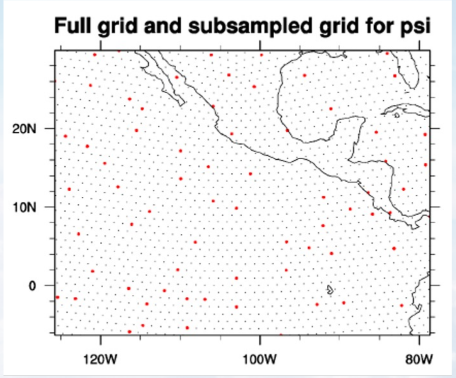
GSL MPAS-JEDI model background error

Static BE

$$B = K_1 K_2 \Sigma C \Sigma^T K_2^T K_1^T$$



Courtesy of BJ

Tests completed using pure 3DEnVAR

Work to generate a reasonable **regional** static BE

Meetings with the NCAR MPAS-JEDI team including BJ

Global test case provided to adapt procedure to generate a suitable static BE for regional MPAS-JEDI cases

MPAS in UFS

- Approach is similar to CAM-SIMA, i.e., add a new dycore to UFS
  - As opposed to running MPAS-A as part of NCEP production suite
- Reason: Having a single modeling system (UFS) simplified the work by NOAA and the community to use, maintain, and develop the system
- **Please see poster by Bernardet et al. on “Expanding the UFS to Include the MPAS Dynamical Core”**

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MPAS in UFS

Generalizing UFS Atmospheric Component (FV3ATM)

- This is a prerequisite for connections to CCPP and external components
- The atmospheric component of the UFS WM is **FV3ATM**
- FV3ATM is a coupling interface between dynamics, physics, atmospheric I/O, and external components
- Parts of FV3ATM tie directly to FV3 dycore
- Needs abstraction and generalization (FV3ATM -> UFSATM)
- Opportunity to clean up and restructure
    - Enhance maintainability of FV3
    - Facilitate introduction of a new dycore, such as MPAS

MPAS in UFS

Code Management

- MPAS will be a submodule under UFS Weather Model (UWM)
- Code will point directly to the MPAS official repository (NCAR MMM)
- MPAS - UWM interface will stay under UWM atmosphere repository
- This is similar to how the MPAS dycore is used in CESM/CAM
- Needs new tests (e.g., regression tests)

MPAS in UFS

Pre-Processing

- There are existing tools to ingest GRIB2 and drive MPAS
- Similarly, there are existing tools to interpolate static datasets to MPAS grid
- These may need to be connected to *ufs_utils*
- Not much development needed on this front (at first)

Data Assimilation

- JEDI DA algorithms and obs operators are model-agnostic
    - Allow for swapping the model interface
- JEDI uses grids provided by model interfaces
    - Native grid DA for both FV3 and MPAS can be used
- Ongoing MPAS-JEDI experiments by MMM and JCSDA
- Can leverage JEDI-UFS work and MPAS-JEDI work at JCSDA (w/ in-kinds)

MPAS in UFS

Stochastic Physics

- SKEB, SHUM, SPP, SPPT
  - Should work since they are model agnostic
  - Some code changes (due to being hardcoded to GFS DDTs)
  - DTC is working on implementing stochastic physics (via the UFS repository) into MPAS stand-alone (specifically the ad-hoc schemes, SHUM, SKEB, and SPPT)
  - DTC has funds to start interfacing CCPP with MPAS, which will allow us to run SPP in the future
- Cellular Automata
  - Will need to be reworked for use in an unstructured grid
  - Not critical for Short-Range applications

MPAS in UFS

Inter-Component Coupling: UFSATM NUOPC Cap

- Drive MPAS dycore through the existing UFSATM NUOPC Cap
  - A NUOPC Cap is a model wrapper with well-defined entry points and model state that is used to create standardized interoperability of models and mediators
- Connections between MPAS and the UFSATM NUOPC Cap
  - MPAS dycore initialization, run (a.k.a. advance), and finalize phases
  - MPAS dycore geometries and domain decomposition (parallelization)
  - MPAS dycore field/data memory for inter-component coupling of import and export states

Some of this functionality already exists in CESM/CAM and can be leveraged

MPAS in UFS

Input/Output - Two Possible Approaches

Note: MPAS outputs files on its native unstructured mesh

- Approach 1: Use MPAS I/O
  - Sufficient for initial testing
  - MPAS outputs in native grid
  - Use *convert_mpas* utility to interpolate from native mesh to lat-lon
- Approach 2: Develop asynchronous IO (*write grid* component) capability
  - Needed to increase performance for operations
  - Set up output field bundles in the MPAS dycore driver code
  - Set up the *write grid* component in UFSATM cap
  - Output history (diagnostic) files on native mesh and other grids

MPAS in UFS

Post Processing - Three Steps

- Run offline UPP from MPAS history files
  - MPAS outputs history files in native mesh
  - *convert_mpas* converts history files to lat-lon grid
  - UPP generates products from history files
  - MPASSIT + UPP set up by NSSL used older locally customized version of UPP (called "UPP_NSSL")
  - GSL tests indicate that the authoritative UPP code can ingest MPASSIT-generated files
- MPAS directly outputs all the Post Processing products
  - Integrate UPP code into MPAS to output in native mesh
  - Use *convert_mpas* to convert to lat-lon grid
- Run inline UPP in *write grid* component
  - Develop *write grid* component to encompass all grids needed for output
  - Call UPP on the *write grid* component

MPAS in UFS

Workflow

- Need to add new tasks to the workflow
  - Similar to WRF's *geogrid, ungrib, metgrid*
- This will be more efficient if done in one place
  - Doing it in Unified, SRW App, RRFS, HAFS, etc. adds cost
- Creating generalized workflow is more complex than customizing workflow
- Proposed approach is to start from a regional workflow, create a branch for MPAS, and manage the deltas
- Upcoming GSL runs will use the MPAS App that invokes Unified Workflow Tools (uwtools)
- **Please see Derrico et al. poster, "An MPAS App with Unified Workflow Tools"**

MPAS in UFS

Resource Estimate - 13.1 FTE

Task	FTE years	Notes
Code Mgmt and Governance	0.5	Ongoing
Generalizing ATM FV3ATM → UFSATM	1.0	
Build system and software stack	0.6	
Pre-processing and data assimilation		Dependent on generalized UFSATM
Post-processing/IO	4	Dependent on generalized UFSATM
NUOPC Cap (inter-component coupling)	1	Dependent on generalized UFSATM
Complete connection to CCPP (physics dynamics coupling)	2	Dependent on generalized UFSATM
Workflow	4	

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GSL Summary

Broad engagement in MPAS development

- Global and regional applications
- Hydrostatic through CAM to convection resolving scales
- Physics testing and development across forecast applications
- MPAS-JEDI data assimilation development including ensemble use
- Infrastructure work with UFS including physics-dynamics coupling, workflow, post, etc…

Wide variety of MPAS mesh generation interests

- Global and limited area meshes
- Hydrostatic to sub-km scales
- Variable resolution and discontinuous grids

GSL is committed to development and testing of MPAS for use in future UFS-based Rapid Refresh Forecast System (RRFS). For information on the status, update and plans for the RRFS along with related discussions on MPAS, please consider attending the UFS/EPIC workshop on 22-26 July 2024:

https://epic.noaa.gov/eventsposts/uifcw-2024/