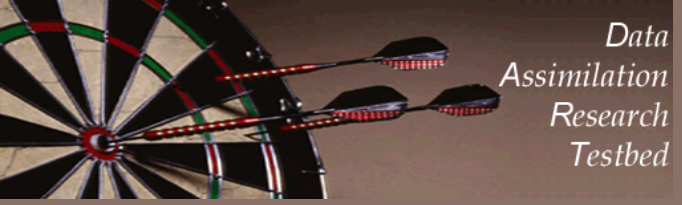


MPAS
Model for Prediction Across Scales

ENSEMBLE KALMAN FILTER DATA ASSIMILATION FOR THE MPAS SYSTEM

So-Young Ha, Chris Snyder, Bill Skamarock, Jeffrey Anderson*, Nancy Collins*, Michael Duda, Laura Fowler, Tim Hoar*

MMM and IMAGe*

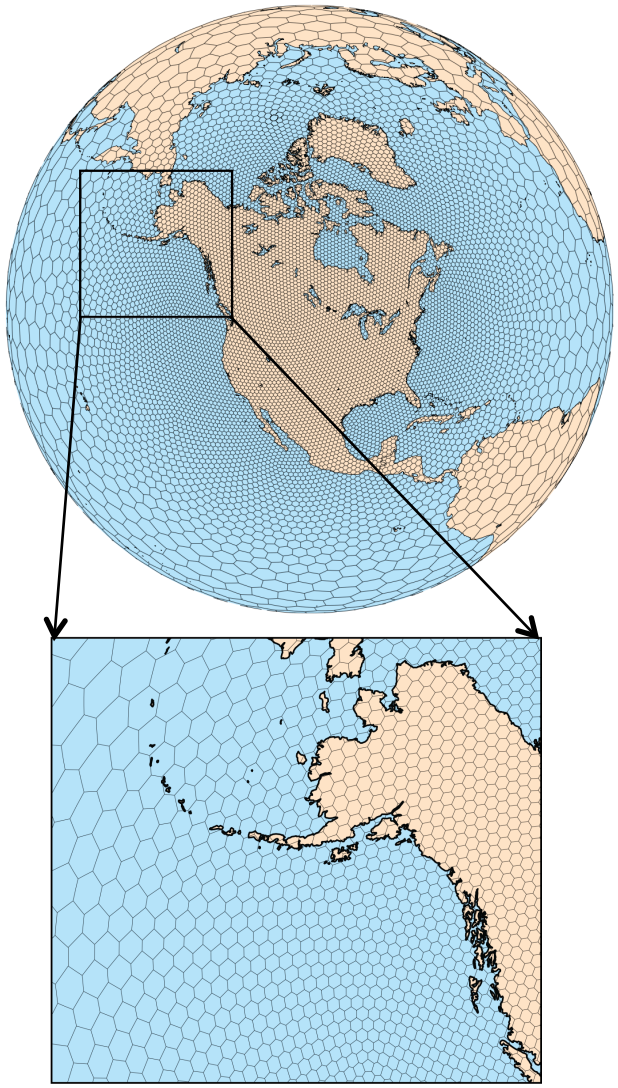
NCAR

June 26, 2013

The 14th Annual WRF Users' workshop

MPAS
Model for Prediction Across Scales

MPAS-Atmosphere



Unstructured spherical Centroidal Voronoi meshes

- Mostly *hexagons*, some pentagons and 7-sided cells.
- Cell centers are at cell center-of-mass.
- Lines connecting cell centers intersect cell edges at right angles.
- Lines connecting cell centers are bisected by cell edge.
- Mesh generation uses a density function.
- Uniform resolution – traditional icosahedral mesh.

C-grid staggering

Solve for normal velocities on cell edges.

Solvers

Fully compressible nonhydrostatic equations

Current Physics

- Noah LSM, Monin-Obukhov surface layer
- YSU PBL
- WSM6 microphysics
- Kain-Fritsch and Tiedtke cumulus parameterization
- RRTMG and CAM longwave and shortwave radiation

For more info, see B. Skamarock's talk tomorrow afternoon!

MPAS/DART: Overview

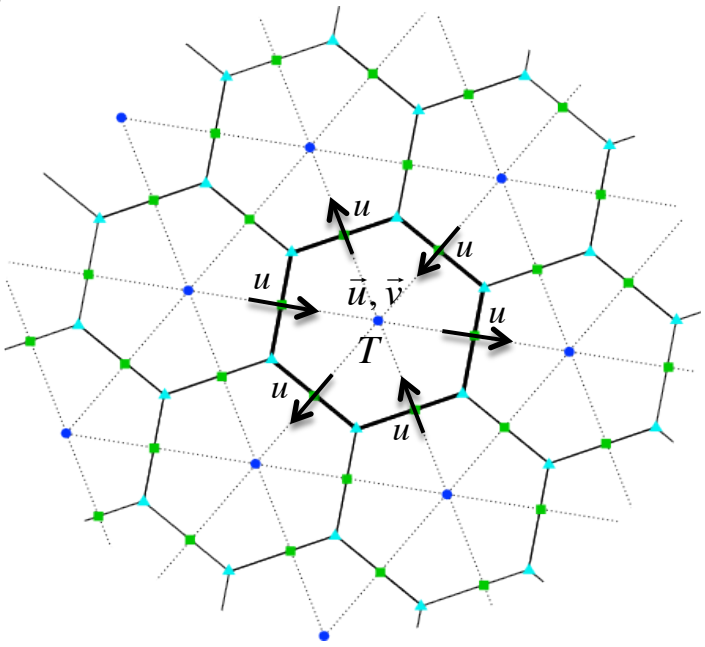
- Ensemble Kalman filter for MPAS
  - Implemented through the Data Assimilation Research Testbed (DART)

- Broadly similar to WRF/DART
  - Interfaces with model, control scripting
  - Forward operators for conventional obs and GPS RO data
  - Vertical localization in different vertical coordinates
  - A clamping option for all hydrometeors
  - Largely independent of model physics; facilitates testing with different schemes during ongoing model development

- New features in MPAS/DART
  - The forecast step runs in a restart mode during cycling
  - Various wind data assimilation options on the unstructured grid mesh
  - Interfaces to both MPAS-A and MPAS-O are available

MPAS/DART: Grid and Variables

- Dual mesh of a Voronoi tessellation
  - All scalar fields and reconstructed winds are defined at "cell" locations (blue circles)
  - Normal velocity (u) is defined at "edge" locations (green squares)
  - "Vertex" locations (cyan triangles) are used in the searching algorithm for an observation point in the observation operator

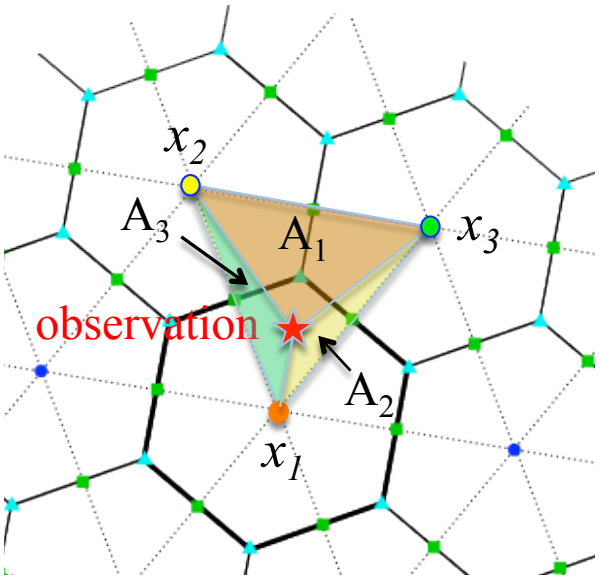


- State vectors in DART: Scalar variables, plus horizontal velocity either reconstructed winds at cell centers ($\vec{u}, \vec{v}$) or normal velocity on the edges (u)

MPAS/DART-Atmosphere: Observation operators

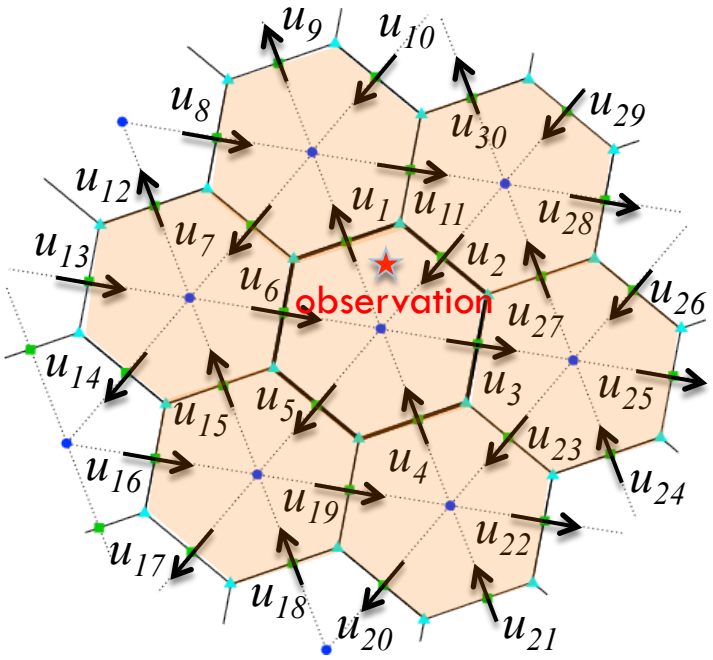
- Assimilation of scalar variables (x)
  - finds a triangle with the closest cell center (●) to a given observation point (★)
  - barycentric interpolation in the triangle

$$y_{obs}^{b} = (A_1 x_1 + A_2 x_2 + A_3 x_3)/(A_1 + A_2 + A_3)$$



MPAS/DART-Atmosphere: Observation operators (cont'd)

- Options for assimilation of horizontal winds
  1. Barycentric interpolation of reconstructed winds (just like scalar variables); converting increment from cell-center winds back to normal velocity at edges. => "Cell_wind" approach
  2. Same as #1, but updating the normal velocity at edges directly in EnKF
  3. Radial Basis Function (RBF) interpolation of normal velocity; update normal velocity in EnKF. No conversion required, but discontinuity at cell boundaries or smoothing effect. Expensive. => "Edge_wind" approach



DART/MPAS-Atmosphere: Namelist (input.nml)

- &model_nml

  use_u_for_wind = .true., or .false. (default),
  use_rbf_option = 1, 2 (default), or 3,
  update_u_from_reconstruct = .true. (default), or .false.,
  use_increments_for_u_update = .true. (default), or .false.,
  …

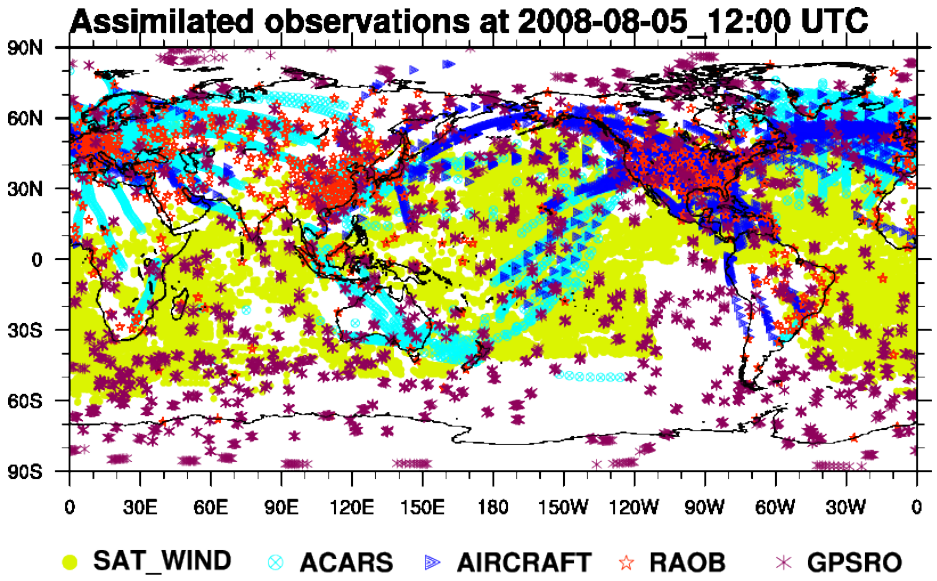
- &mpas_vars_nml

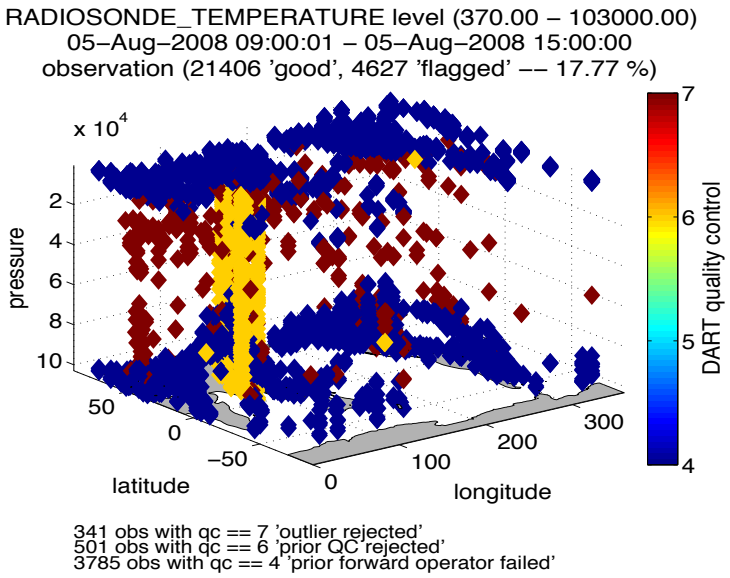
MPAS variable name | DART obs kind

```
mpas_state_variables = 'theta',  'KIND_POTENTIAL_TEMPERATURE',
                       'qv',     'KIND_VAPOR_MIXING_RATIO',
                       …
mpas_state_bounds    = 'qv', '0.0', 'NULL', 'CLAMP',
                       …
```

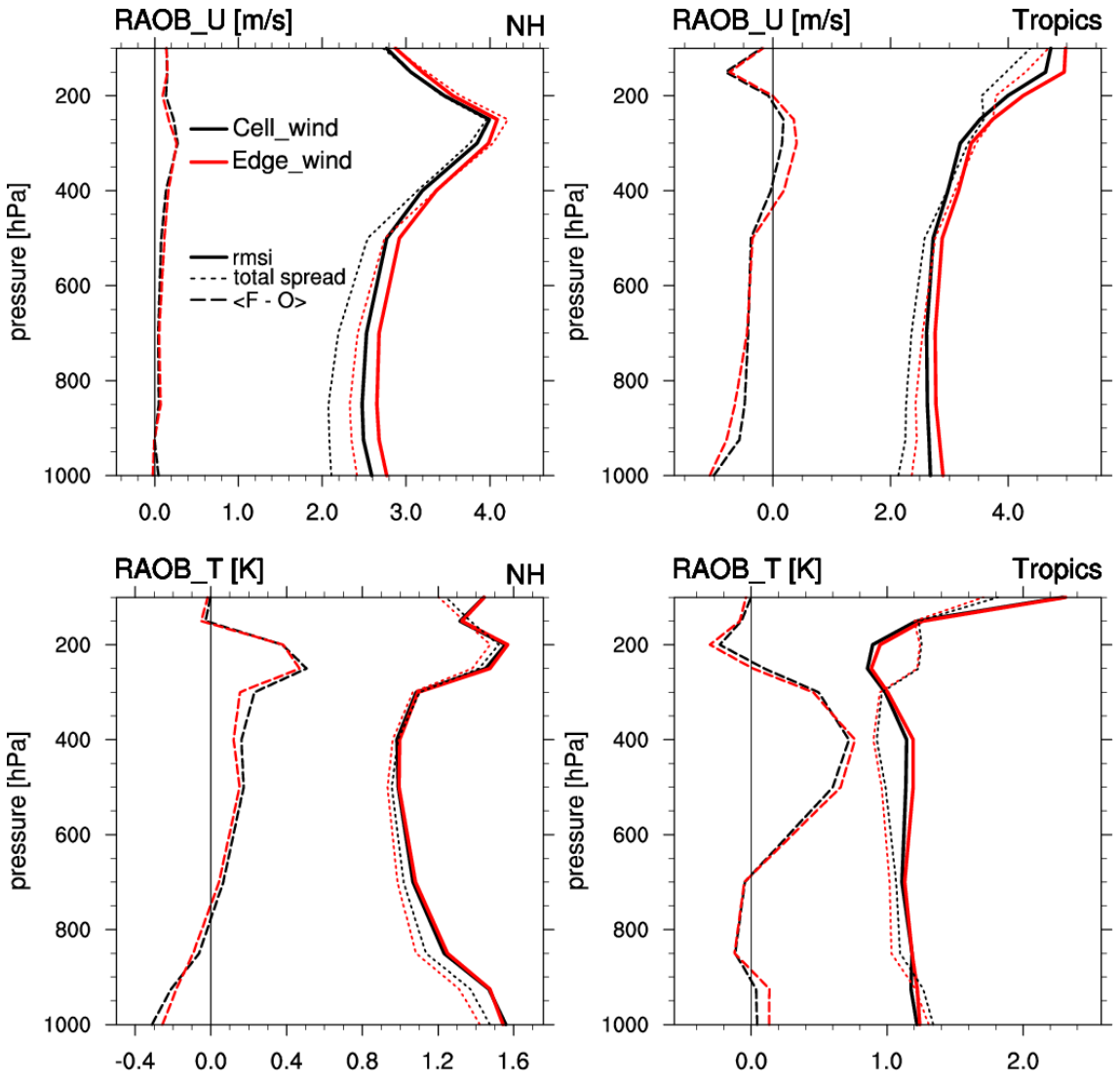
Assimilation of real observations in MPAS/DART

- Model configuration: 96-member ensemble at ~2-degree uniform mesh, 41 vertical levels w/ the model top at 30-km
- Conventional observations (NCEP PrepBUFR) + GPS RO
- Ensemble filter data assimilation design: localization (H/V), adaptive inflation in prior state, 6-hrly cycling for one month of August 2008.
- WRF-Physics: WSM6 microphysics, YSU PBL, NOAH LSM, Tiedtke cumulus parameterization, CAM SW/LW radiation schemes





Assimilation of horizontal winds: Sounding verification of 6-hr forecast



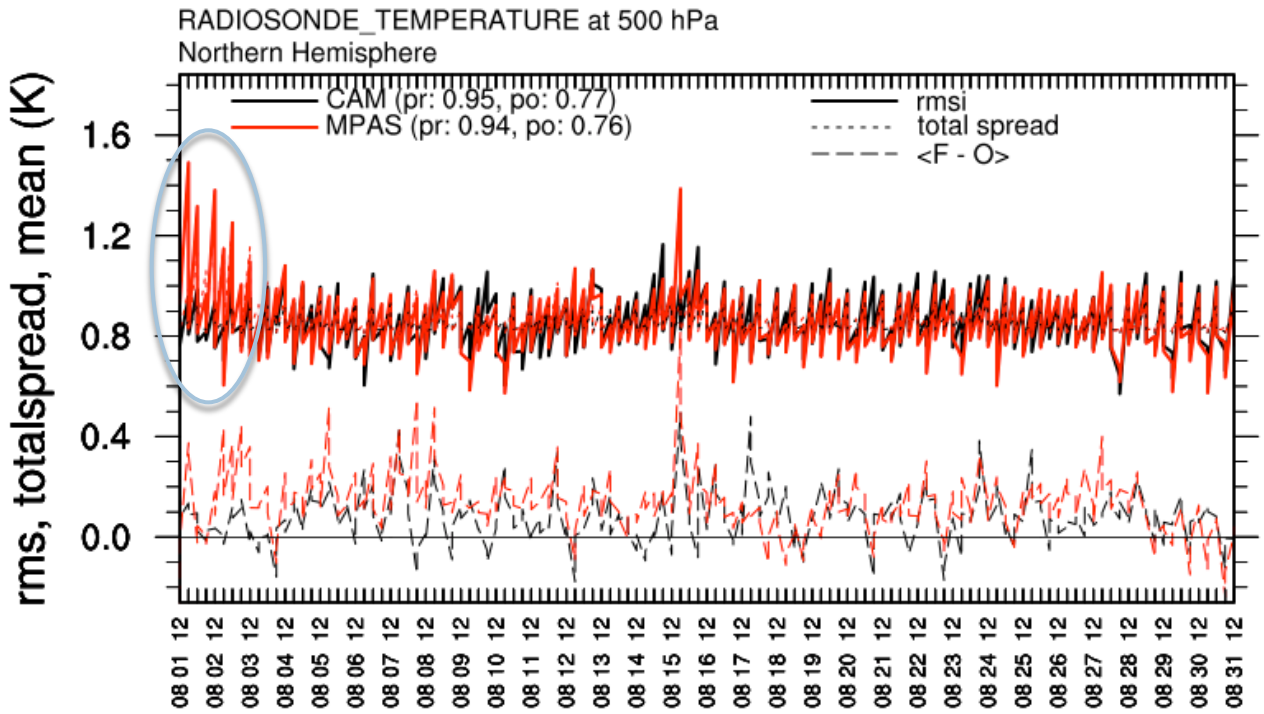
- Two methods are largely comparable in terms of quality.
- Bias errors are almost same.
- Ensemble spread is larger in Edge_wind for horizontal wind.
- Cell_wind using reconstructed zonal and meridional wind is slightly better fitted to sounding observations than Edge_wind in all area.

=> Cell_wind is default.

Comparison w/ CAM/DART

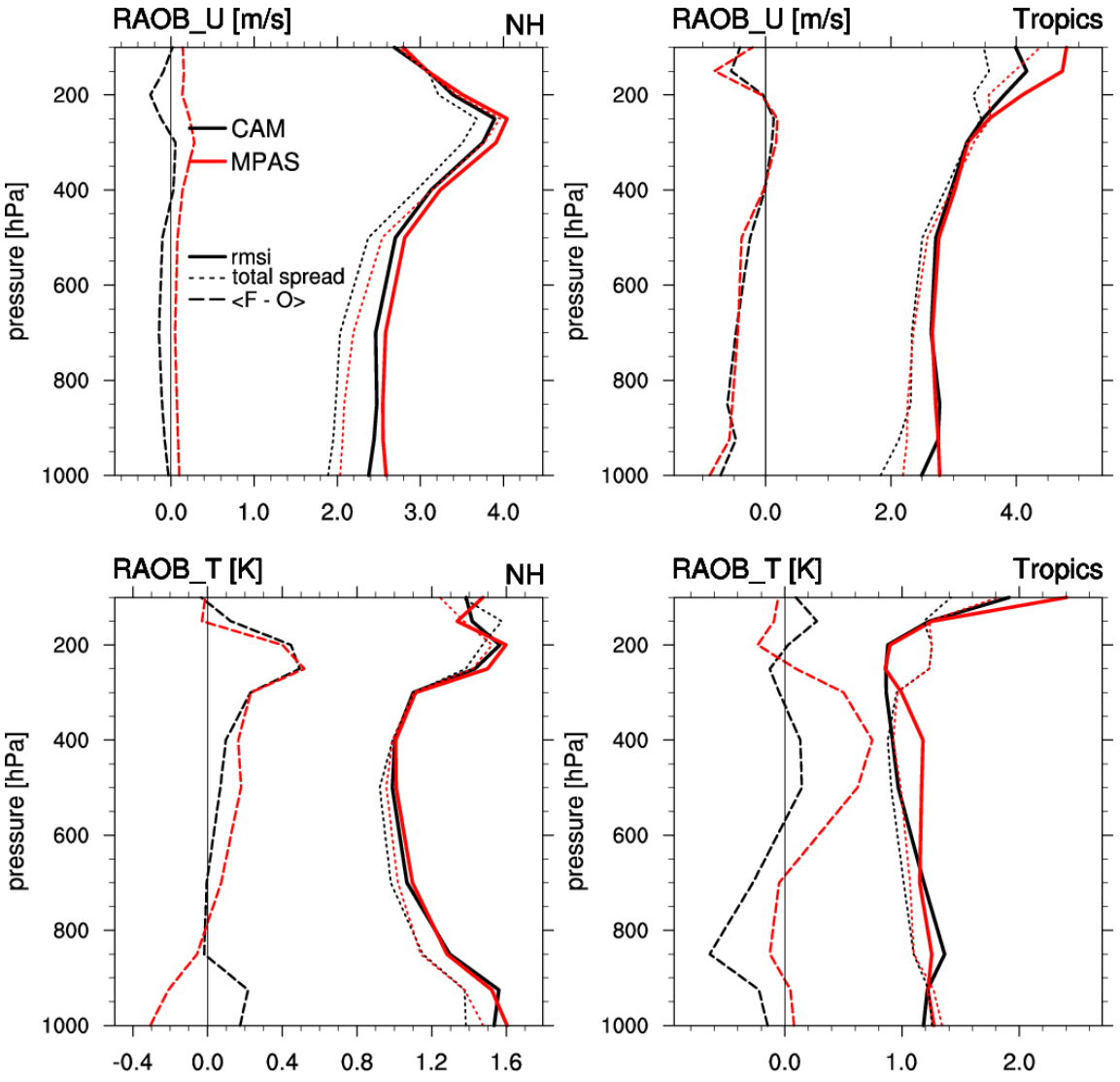
- CAM/DART run by Kevin Reader (IMAGe/NCAR)
- CCSM4.0 at 2-degree resolution w/ the model top at 3 mb
- Assimilating same observations
- Very similar filter configuration
- Climate data assimilation cycling for ~10 yrs starting from 2000
- Verification for the same month of August 2008 in the observation space

Sounding verification: Comparison w/ CAM/DART



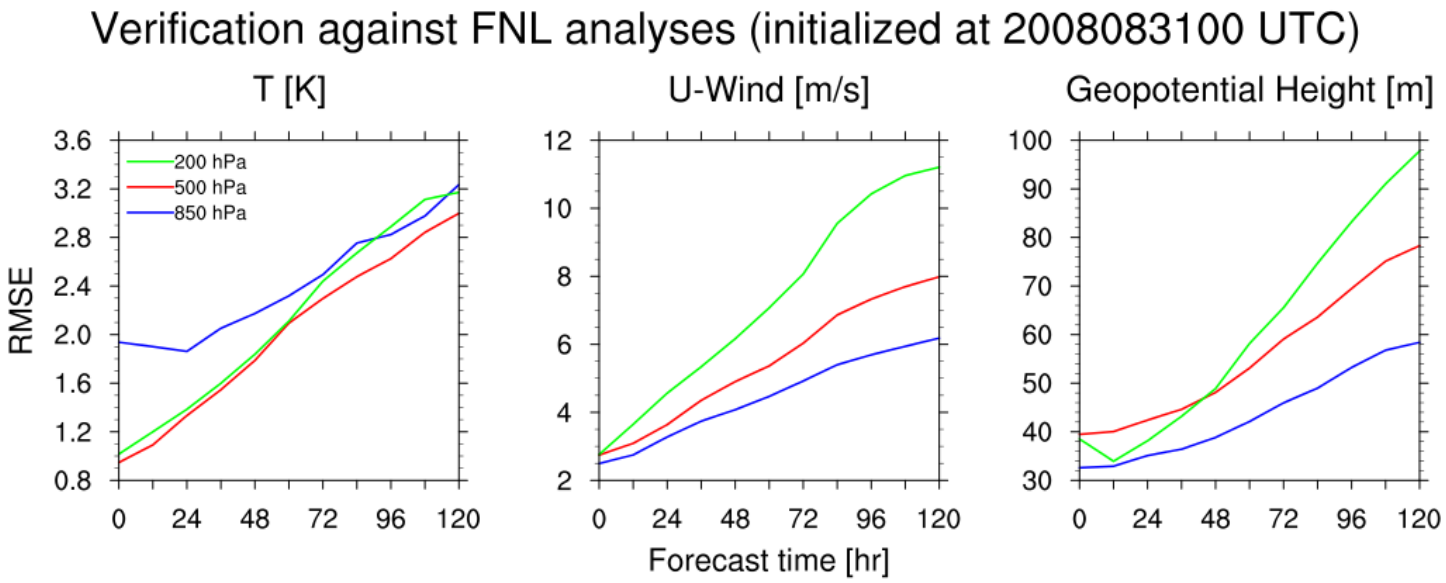
- MPAS/DART looks pretty reliable after a spinup for the first couple of days.
- CAM/DART and MPAS/DART are broadly comparable and reliable.

Sounding verification: 6-h forecast (prior)

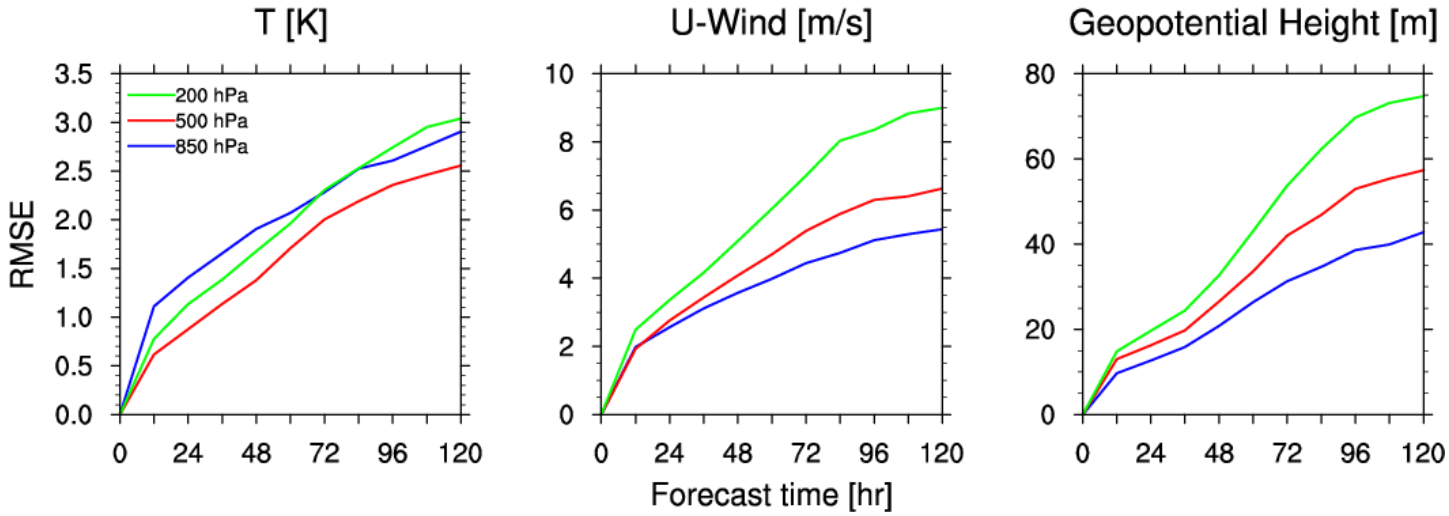


Forecast verification against the FNL analysis

5-day MPAS Forecast from the EnKF mean analysis

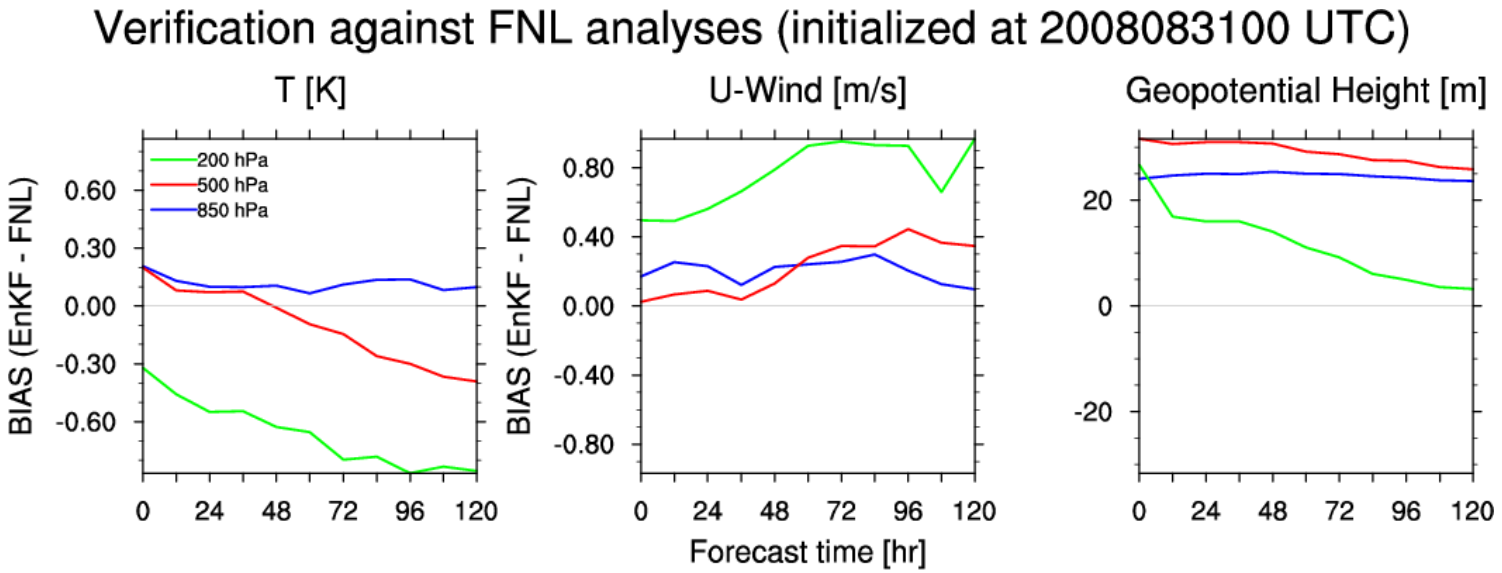


5-day MPAS Forecast from the FNL analysis (FG)

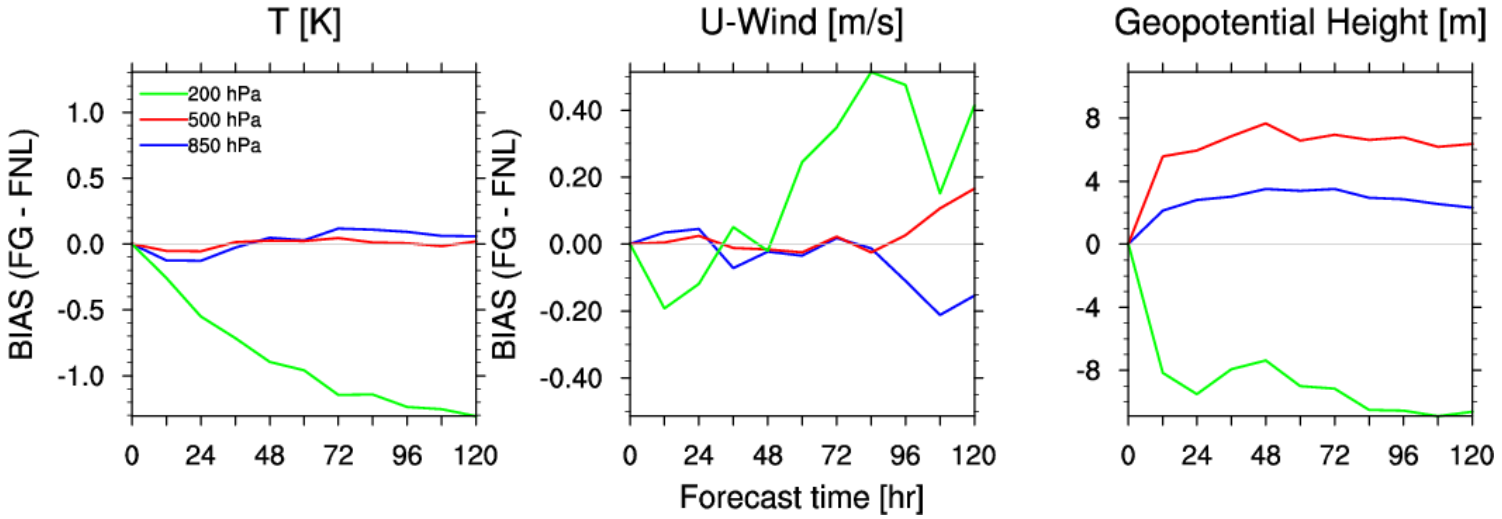


Forecast verification against the FNL analysis

5-day MPAS Forecast from the EnKF mean analysis



5-day MPAS Forecast from the FNL analysis (FG)



Current status

- MPAS Version 1.0 was released on 14 June 2013 (for both MPAS-Atmosphere and MPAS-Ocean core)

  http://mpas-dev.github.io/

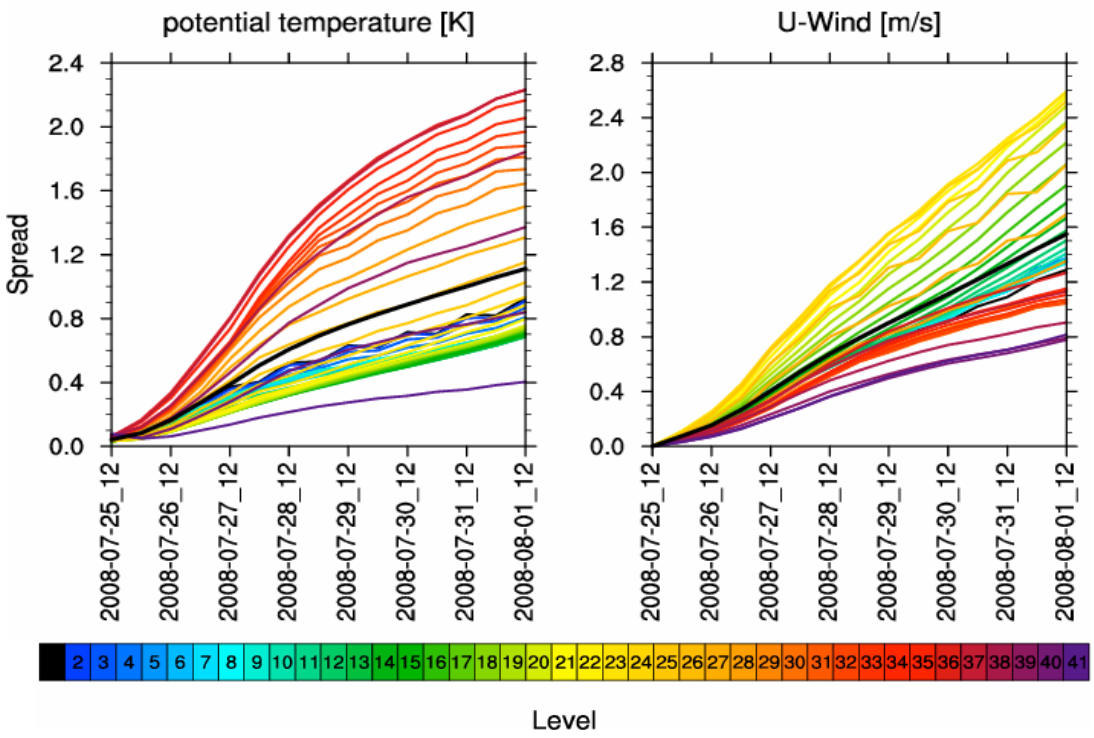
- Beta versions of DART which include the MPAS-A and MPAS-O interfaces are available and will be part of the next release. For more info, email dart@ucar.edu or http://www.image.ucar.edu/DAReS/DART/

Summary and future plan

- The MPAS/DART interface is available with the full capability now, and will be released soon.
- The cycling was successfully tested assimilating real observations for one month of August 2008.
- MPAS/DART seems to be reliable and broadly comparable to CAM/DART.
- The performance skill of MPAS can be further improved by more physics options such as GFS or CAM physics.
- We are working on running another retrospective case over the variable mesh and comparing to WRF/DART over the refined mesh area.
- Any collaborations or contributions? Contact So-Young Ha (syha@ucar.edu) or Chris Snyder (chriss@ucar.edu)

Initial ensemble for MPAS/DART cycling

- 96-member ensemble
- 7-day forecast from small random perturbations to the GFS analysis data



- Domain-averaged ensemble spread at different model levels.
- Each color shows each level.
- Thick black solid lines represent ensemble spread averaged over levels.

DART/MPAS: Overview

- Interface consists of
  - Converters (model_to_dart and dart_to_model)

    Routines that read from/write to MPAS analysis files (including all the grid info) and translate to/from the DART state vectors.
  - Observation operators for each observation kind

    Routines that interpolate the state vectors to an arbitrary location (lat, lon, vertical).
  - Advance_model.csh: A script that controls the forecast step and connects between analysis and forecast steps.
    - Calls dart_to_model
    - Runs the MPAS model from one analysis time to the next
    - Calls model_to_dart (converting the MPAS forecast file back to the DART state vectors) for the next analysis step.
- Both DART/MPAS-A and DART/MPAS-O are available now.

DART/MPAS-Atmosphere: Features

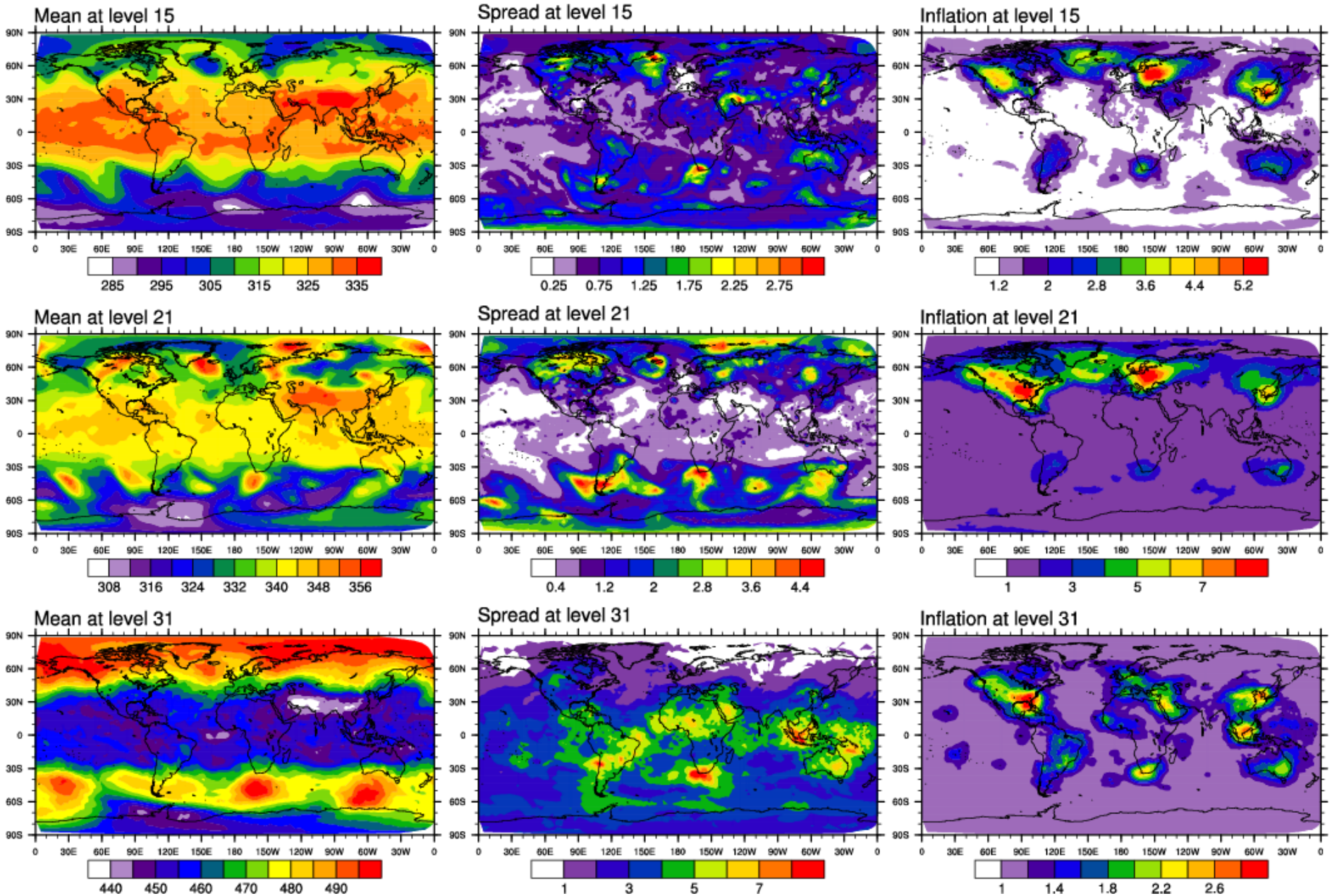
- Similar to the WRF/DART interface in that
  - Vertical localization is available in all different vertical coordinates. Default is in height.
  - Vertical interpolation in pressure uses log P.
  - Clamping options for all hydrometeors are available (to prevent negative moisture after the analysis update).
- New features in MPAS/DART
  - MPAS model runs in a restart mode

    : config_do_DAcycling = .true. in namelist.input
  - Reject observations above a user specified pressure level

    : highest_obs_pressure_mb = 100. in input.nml
  - Wind data assimilation options in input.nml

Prior (6-h forecast)

theta [K] at 2008083100



Analysis increment in potential temperature