Effective noise control in the MPAS global ensemble analysis

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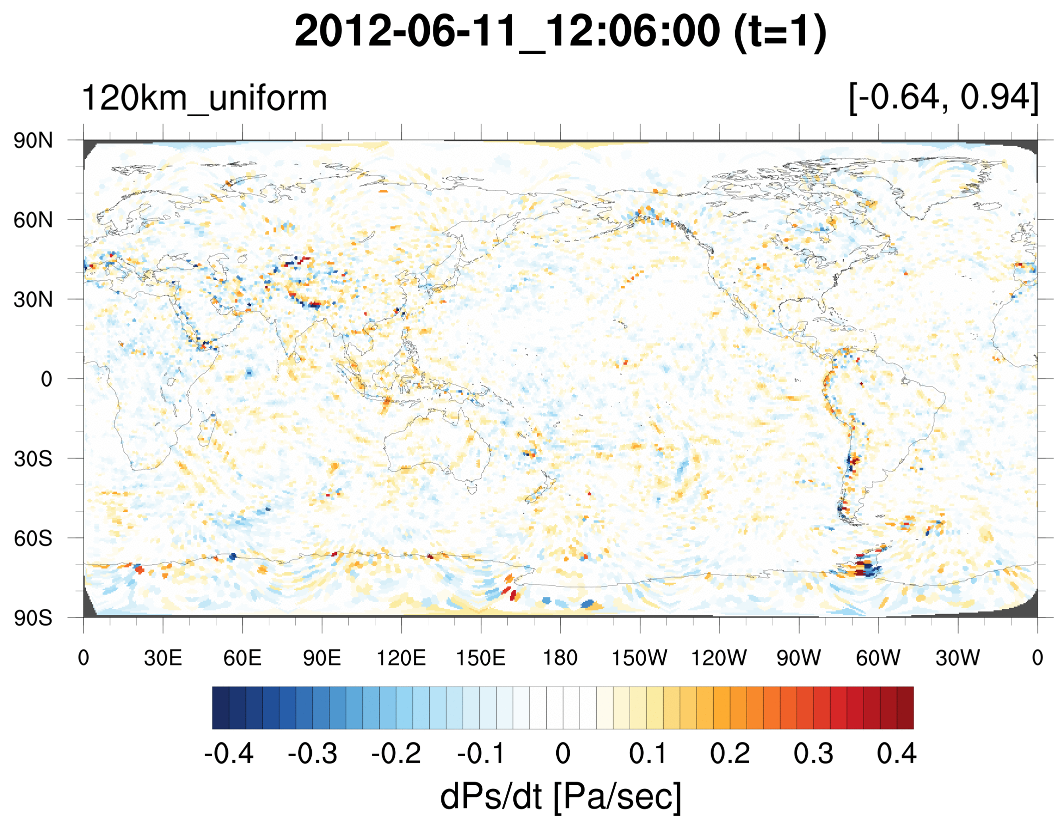
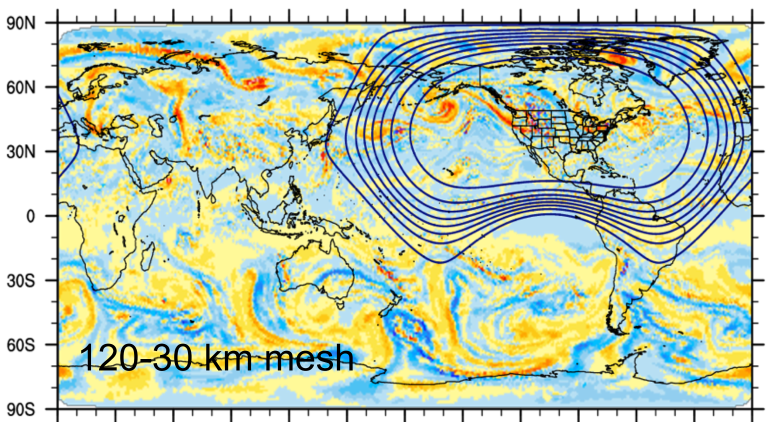
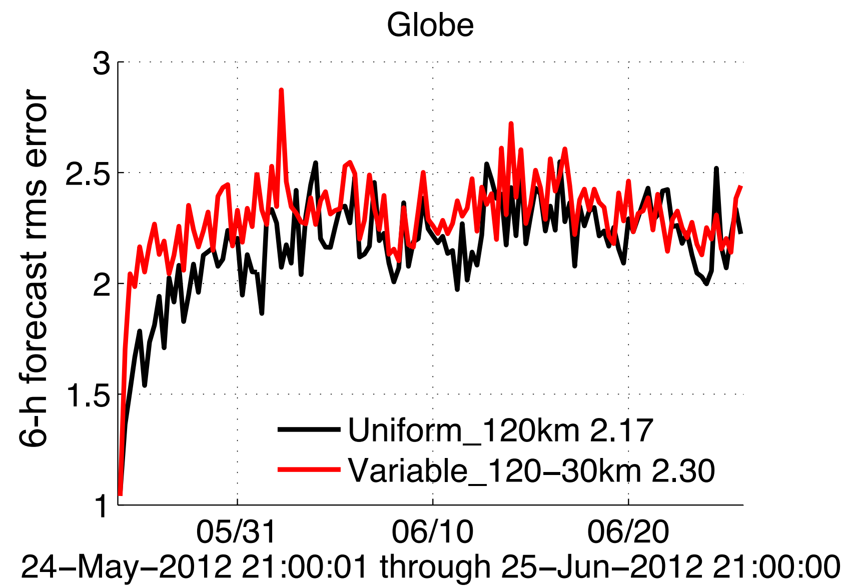


Collaborators: Bill Skamarock, Chris Snyder, Michael Duda, Joe Klemp, and Jeff Anderson

Introduction

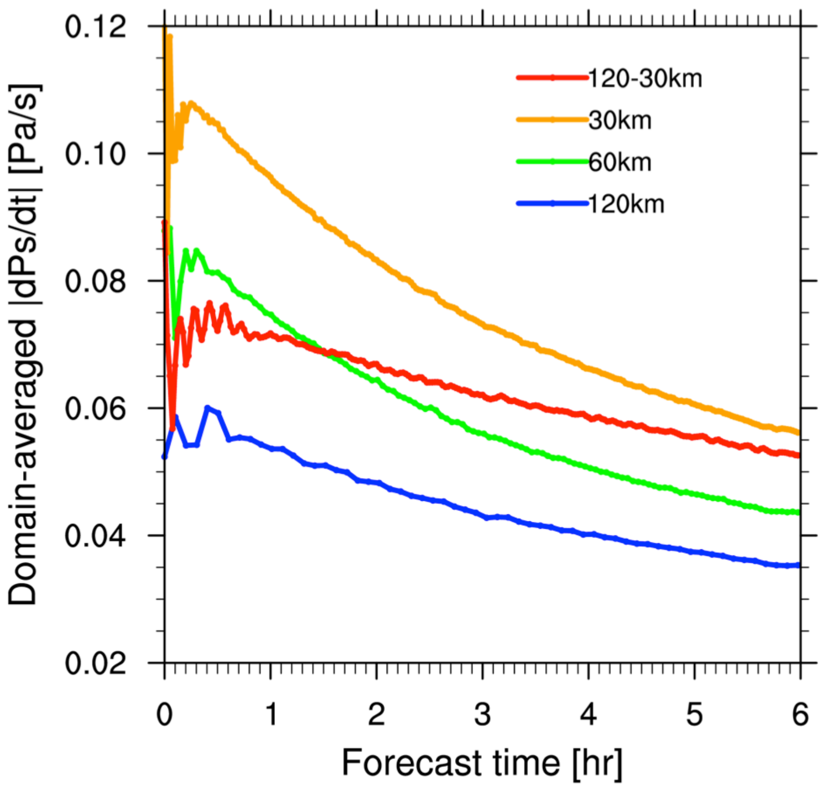
- Ensemble cycling DA has been well tested thru the MPAS/DART system in both quasi-uniform and variable-resolution meshes.
- The global cycling DA on the variable mesh showed poor fits to surface pressure observations, compared to the one on the coarse uniform mesh.





=> Associated with any noise over the higher resolution area at the analysis time?

Noise in MPAS forecasts over different meshes

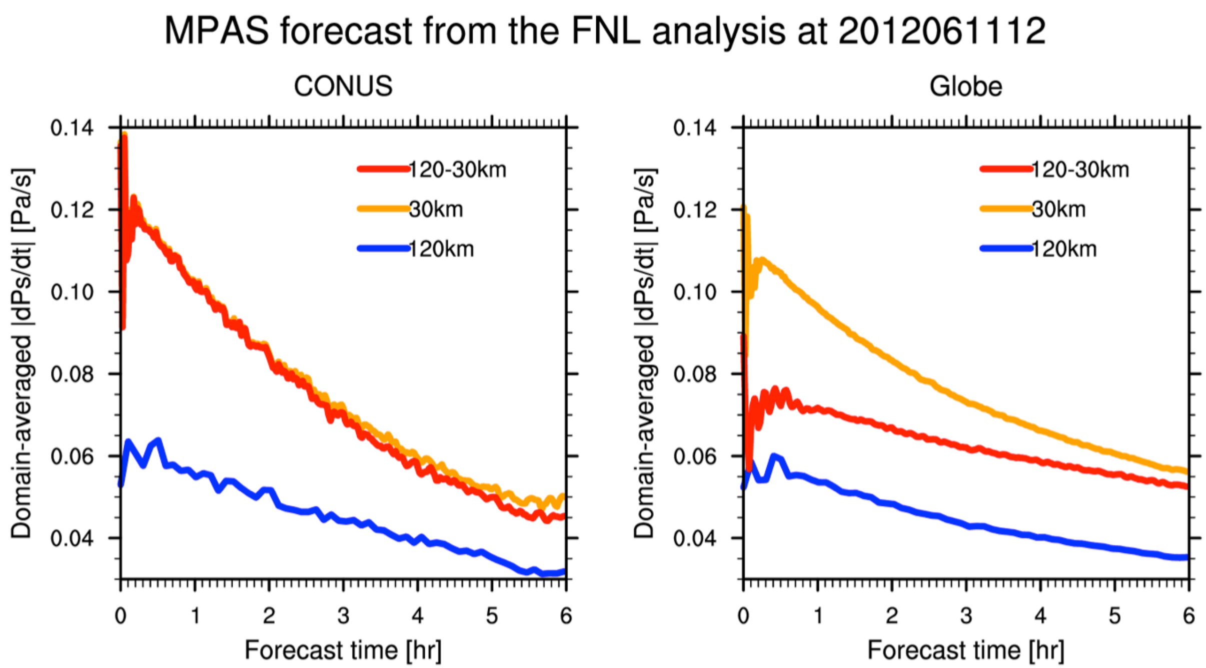


Surface pressure tendency (dPs/dt) at every time step, computed as an area-weighted mean over the globe

Initialized from the same FNL analyses valid at 2012-06-11_12:00 UTC, over different grid resolutions

- Higher resolution produces more noise (30-km > 60-km > 120-km)
- Noise in the variable resolution (120-30 km) mesh lies between 120-km and 30-km, but decays slower than those in quasi-uniform meshes
- Noise decreases with time, but still remains for 6-h forecast => Bad for cycling DA

Noise in MPAS forecasts over different meshes (cont'd)

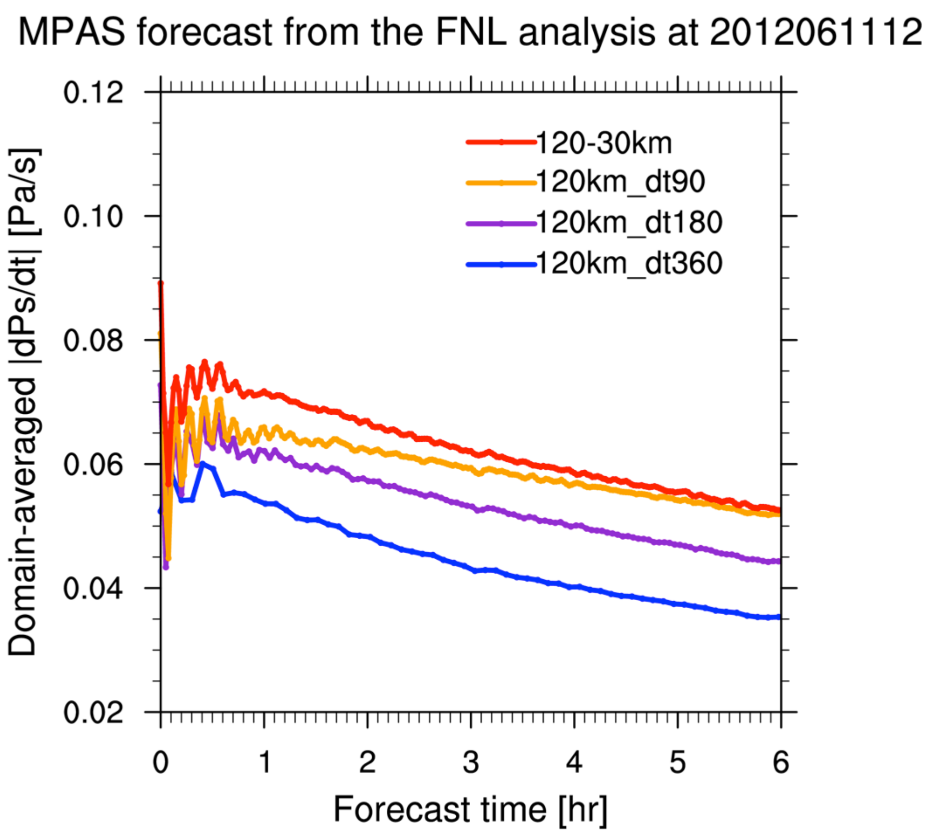


- ➢ Over the CONUS, the initial noise level in the 120-30 km variable and the 30-km uniform mesh is high and very similar to each other.
- ➢ The three experiments used the exactly same model configurations except for the time step (dt) which is set based upon the finest grid spacing in each mesh.

  dt = 90 sec in 120-30 km variable and 30-km uniform meshes

  dt = 360 sec in 120-km mesh

Sensitivity to the Runge-Kutta time step (dt)



=> Even over the same 120-km uniform mesh, by using different dt, the noise level and its decay rate change significantly, regardless of areas.

=> Smaller time steps produce higher noise which decays slower.

=> With the same time step of 90 sec, 120-km uniform mesh (orange) and the variable mesh (red) produce the similar noise magnitude at 6-h forecast.

=> Noise is sensitive to dt, not to the mesh *per se*.

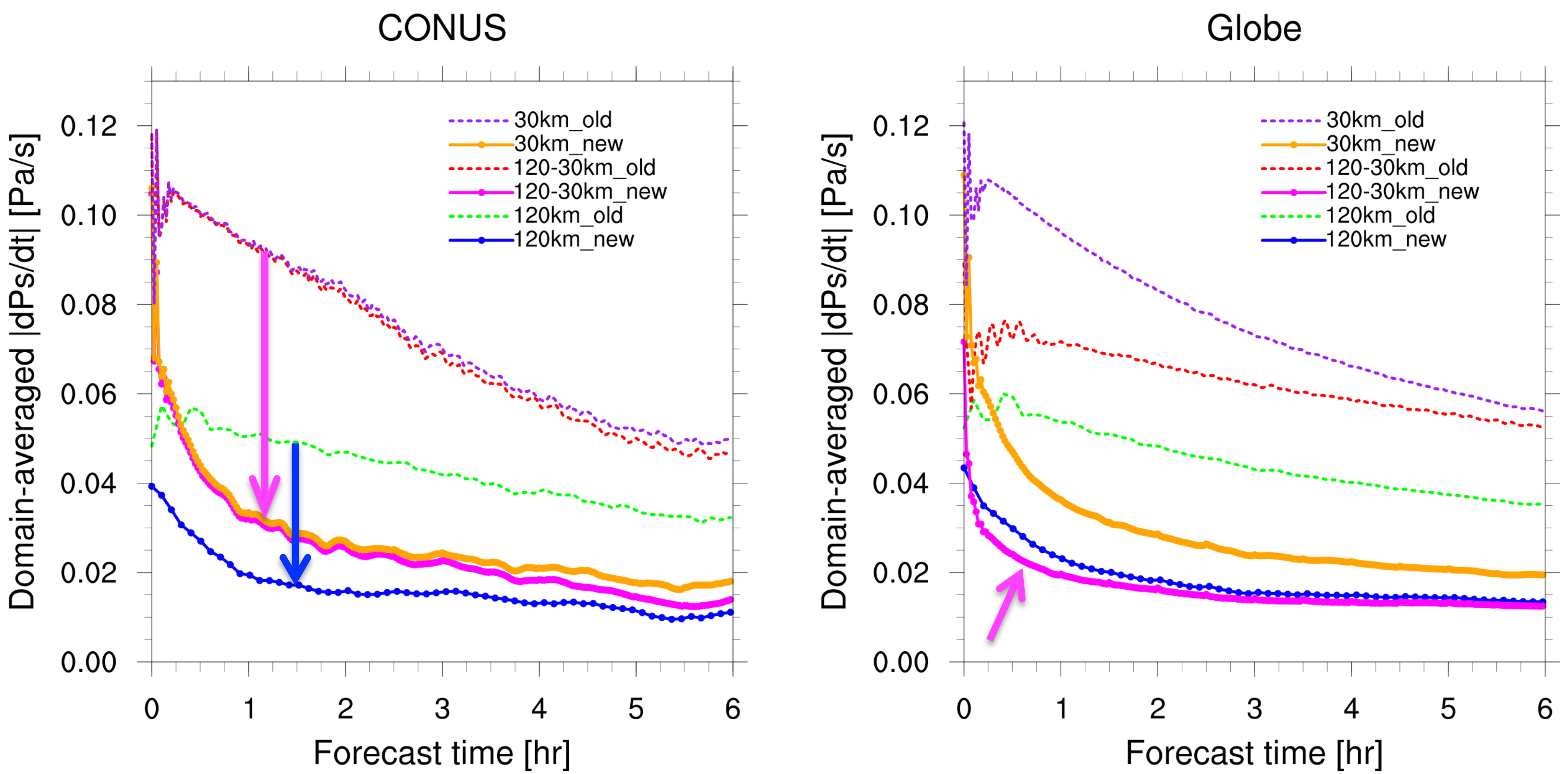
MPAS model filters

- Higher-resolution models are supposed to better resolve small-scale features.
  However, they produce more noise (due to the smaller dt).

- MPAS has spatial/temporal dissipation terms and several filtering options, but still produces a large noise initially.

- We recently improved the noise control by adjusting the acoustic filter to work on the first acoustic sub step and tuning some filter parameters. => “noisefix”

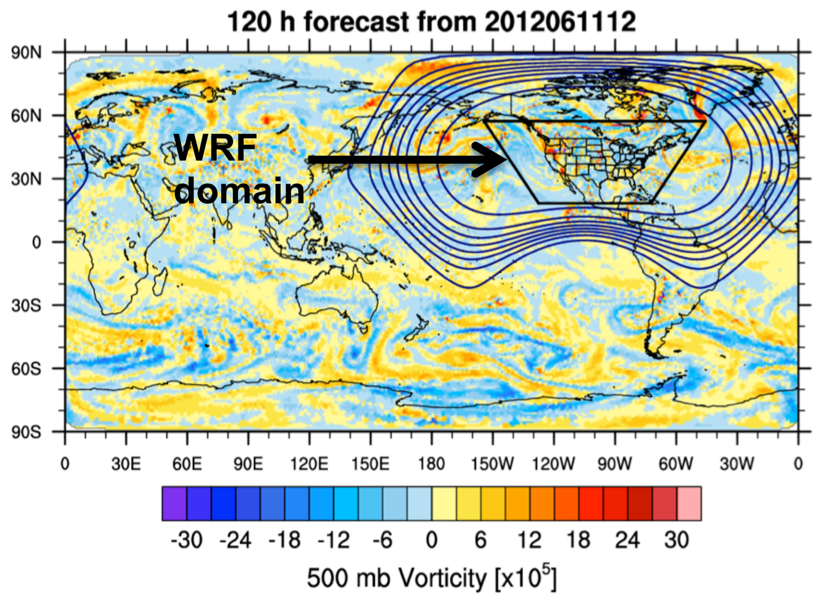
“Noisefix” on different meshes

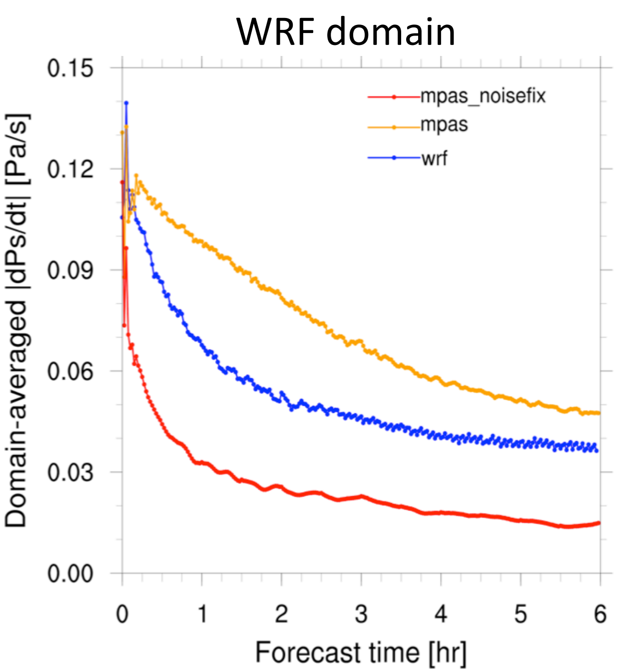


- The new parameter settings reduce noise on all different grids everywhere.
- High-resolution grids show the largest benefit from the new settings.
- The variable mesh (“120-30km_new”) produces the smallest noise over the globe.

MPAS vs. WRF

- WRF simulations over the CONUS at the same 30-km resolution
- The model configurations are matched as much as possible (e.g., time step, physics options, etc.)
- Unlike MPAS (w/ a rigid model top), WRF has an external mode filtering on top of all other filtering methods as in MPAS.

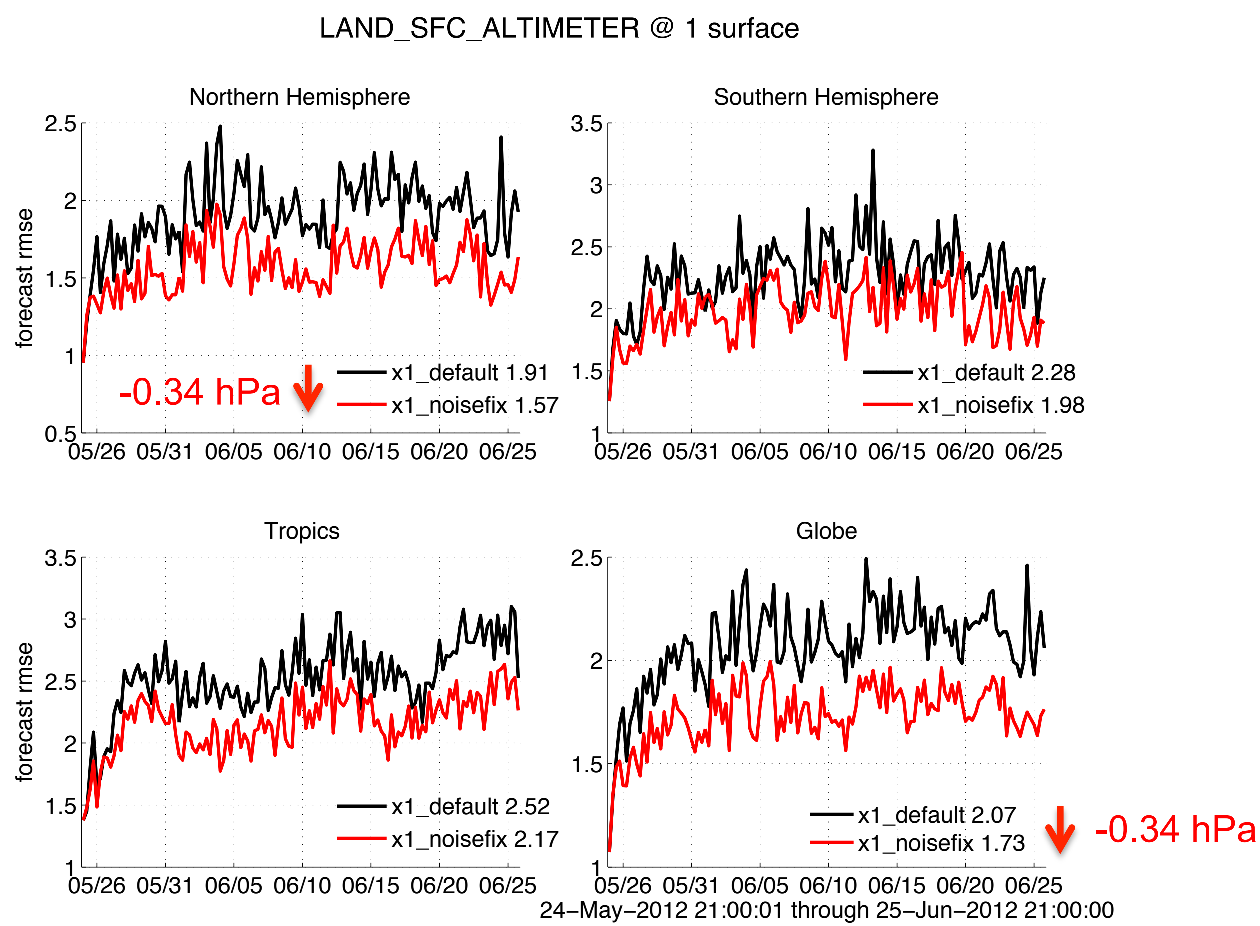




With the noise fix, MPAS now produces noise smaller than WRF throughout 6-h forecast leads.

The noise fix in the MPAS/DART cycling test

- 120-km uniform mesh, 55 vertical levels up to 30 km
- 96-member ensemble analysis/forecast
- Cycling for May-June 2012 every 6-hr, assimilating real observations



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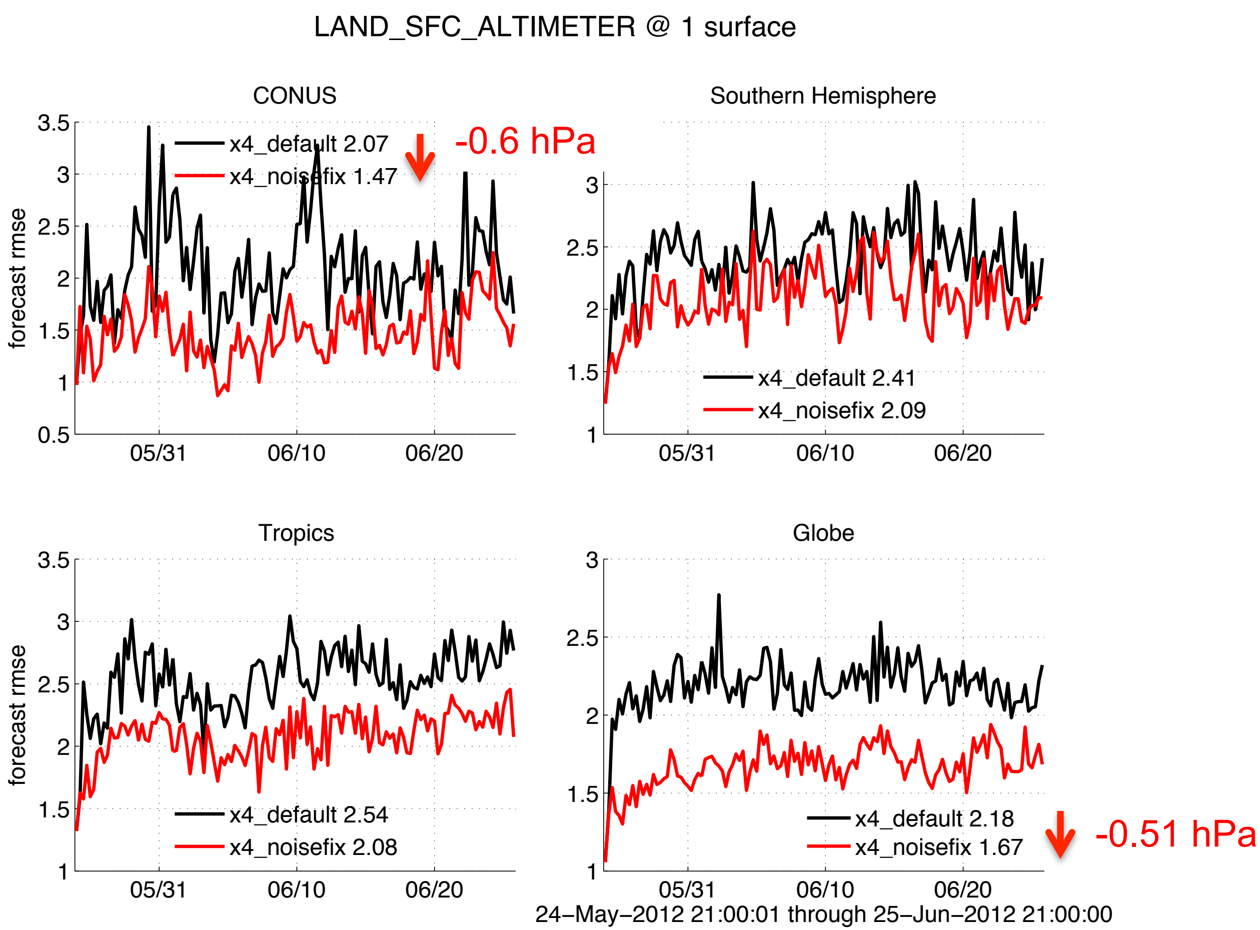
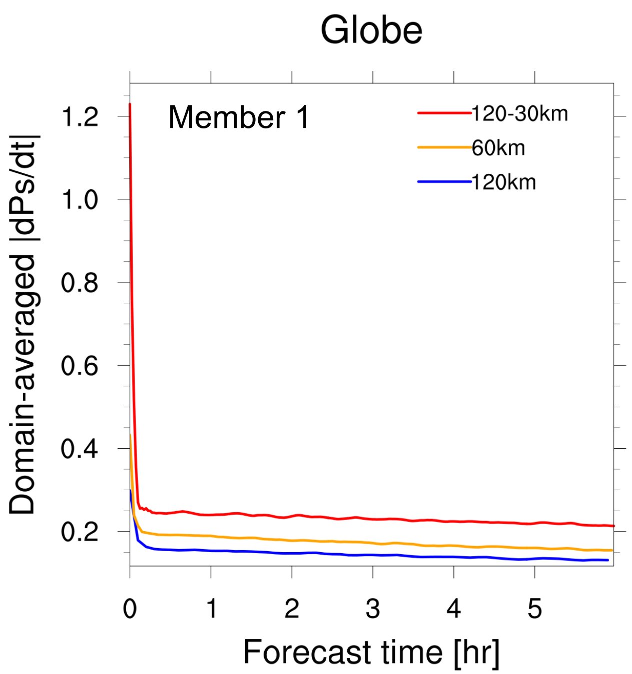


Noise in the MPAS EnKF analysis

- The EnKF analysis produces the noise in one order magnitude bigger than the one in the cold-start run.
- In the EnKF, covariance inflation and localization are commonly used to deal with sampling error, which can produce dynamical imbalances and noise in the analysis.
- Can we effectively reduce the noise in the EnKF analysis?



Incremental Analysis Update (IAU) in MPAS

For prognostic variables *X* in MPAS,

$$X = (\Theta_m, Q_i, U, W) = \tilde{\rho}_d \cdot (\theta_m, q_i, u, w)$$

$$where\ \ \theta_m = \theta(1 + \frac{R_v}{R_d} q_v)\ \ and\ \ \tilde{\rho}_d = \rho_d / \zeta_z$$

$$\zeta_z \equiv \nabla_z \zeta\ \ in\ the\ height\ coordinate\ z = \zeta + A(\zeta) h_s(x, y, \zeta)$$

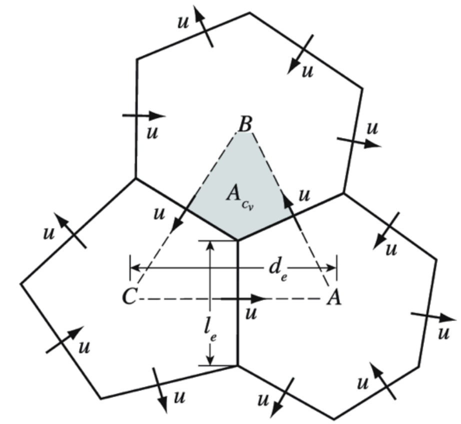


FIG. 1. Depiction of the horizontal C-grid staggered Voronoi mesh.

Skamarock et al. (MWR 2012)

After the analysis update, we compute the analysis increment (Δx).

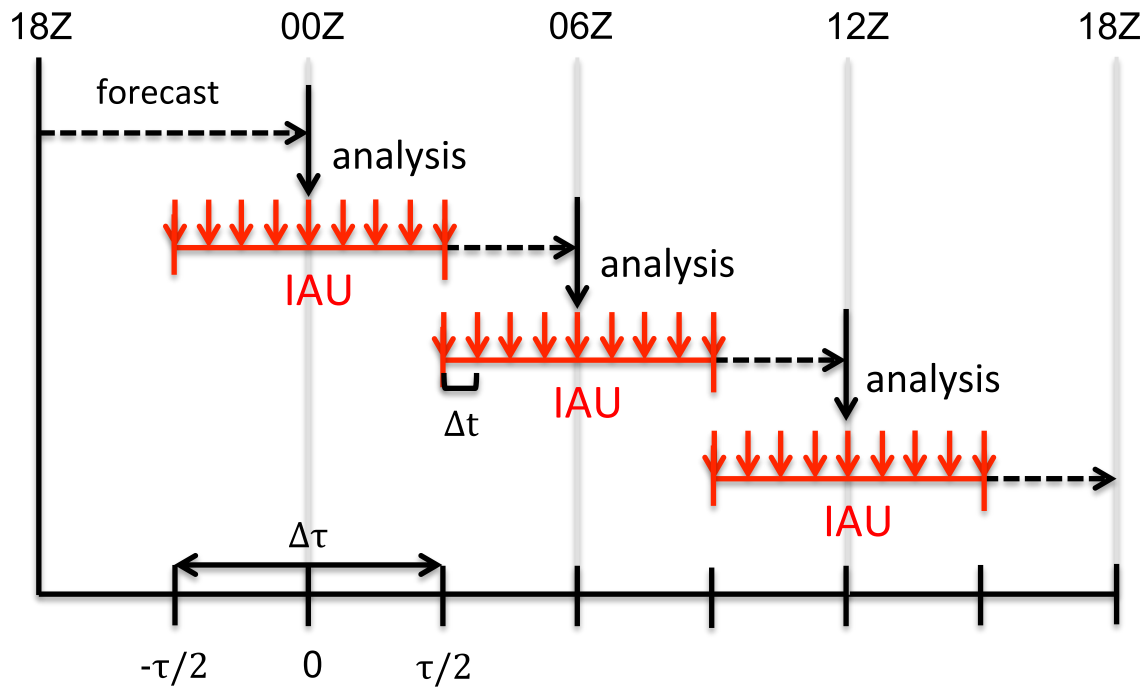
$$x^a = x^b + \Delta x \quad where\ \ x = (\theta, q_i, u, w, \ldots)$$

$$\left.\frac{\partial X}{\partial t}\right|_{anal\_incr} = f(\tau) \frac{\Delta X}{\Delta t} \quad where\ \ f(\tau) = \frac{\Delta \tau}{n_\tau}$$

In the model integration, total tendencies can be modified by adding the new forcing from the analysis increment.

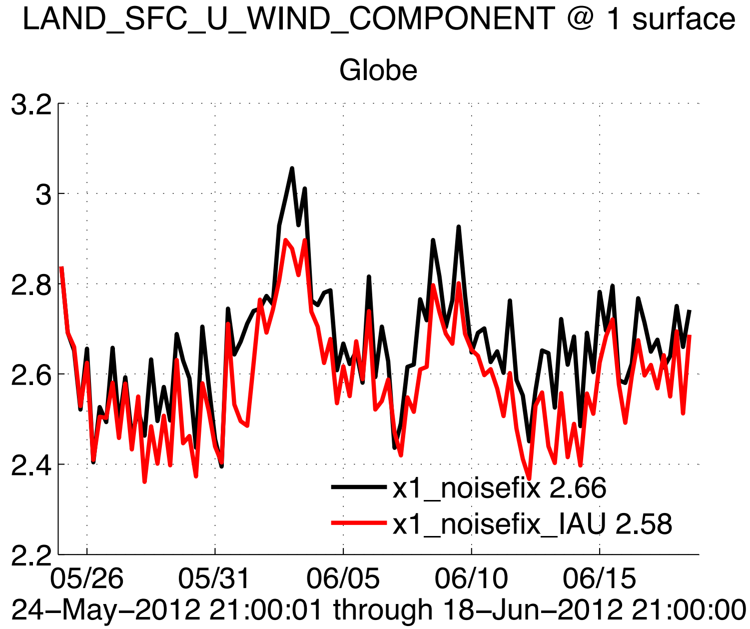
$$\left.\frac{\partial X}{\partial t}\right|_{total} = \left.\frac{\partial X}{\partial t}\right|_{dynamics} + \left.\frac{\partial X}{\partial t}\right|_{physics} + \left.\frac{\partial X}{\partial t}\right|_{anal\_incr}$$

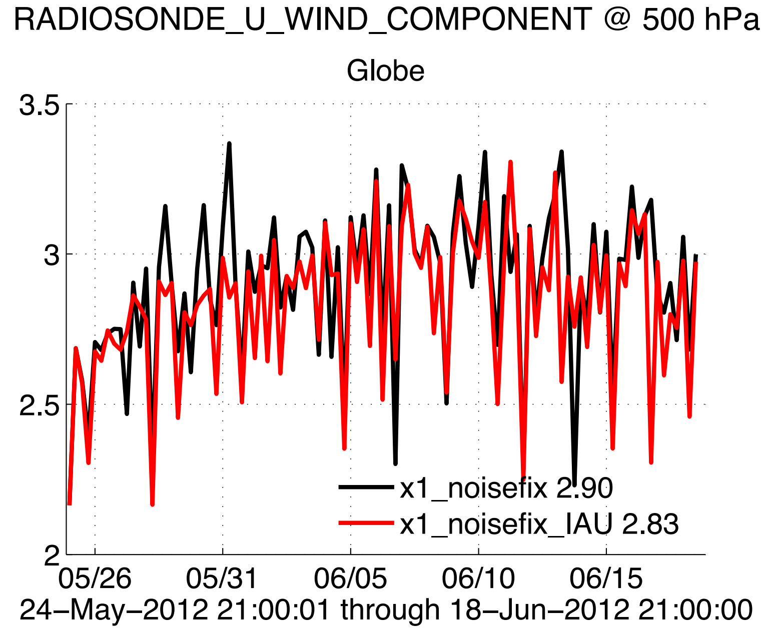
IAU in MPAS/DART



Preliminary results from IAU in MPAS/DART

6-h forecast rmse against observations over the globe





Further improvements of the forecast error
when IAU is applied on top of the latest noise fix.

Summary

- It is critical to control noise accumulation and imbalances for short-range forecasts, especially in the global ensemble analysis/forecast cycling.
- The noise level is sensitive to the Runge-Kutta time step, and not specific to the grid resolutions (or variable-resolution mesh).
- An updated acoustic filtering in the MPAS model turns out to be most effective in the noise control, producing the noise level lower than the one in WRF.
- To reduce the spurious noise generated from the EnKF analysis, we recently implemented the incremental analysis update (IAU) in MPAS/DART. Preliminary results are encouraging.