Adapting MPAS FDDA to use analysis nudging with 3-hour updates

O. Russell Bullock, Jr.

National Exposure Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina

www.epa.gov

O. Russell Bullock, Jr. | bullock.russell@epa.gov | 919-541-1349

Motivation

Four-dimensional data assimilation (FDDA) was previously implemented in the Model for Prediction Across Scales – Atmosphere (MPAS-A) model using an analysis nudging technique with guidance based on the National Center for Environmental Prediction (NCEP) FNL (Final) meteorological analyses produced for 0000, 0600, 1200 and 1800 UTC each day. The FNL analyses are based on all information that eventually feeds into NCEP's Meteorological Analysis and Data Ingest System (MADIS). The 6-h data frequency is generally considered the minimum necessary to resolve diurnal meteorological cycles. It stands to reason that improved model accuracy could be achieved with more frequent updates to FDDA guidance. Of course, this reasoning is based on the assumption that the source of guidance information is more accurate.

Postulation

NCEP also provides initial and forecast fields from the Global Forecast System (GFS) which is applied at the same 6-h time interval as the FNL analyses. The GFS forecast fields include T+3 hour simulation results. Because GFS initial fields must be available before each scheduled model start time, they are often developed from less observational data than the FNL analyses. Nonetheless, these GFS data products offer the ability to update FDDA guidance every 3 hours. This work addresses two basic questions: Are MPAS-A simulations degraded by the use of GFS initial fields instead of FNL analyses? How does adding 3-h GFS forecast fields to the FDDA guidance affect model accuracy?

Investigation

MPAS-A simulations of calendar year 2016 were produced with FDDA guidance updated at 6-h intervals (the original frequency) first from FNL analyses and second using GFS initialization fields. MPAS-A was also applied for all of 2016 with 3-h FDDA updates produced two ways; 1) using GFS initial and T+3 hour forecast fields, and 2) using a mix of FNL analyses and GFS T+3 hour forecast fields.

A 92-25 km variable-resolution mesh with its origin positioned at 40° N, 95° W was used for all simulations. The physics options employed were a special suite of options developed to support air quality simulations. These include the Pleim-Xiu land surface model with soil temperature and moisture nudging (Xiu and Pleim, 2001; Pleim and Xiu, 2003; Pleim and Gilliam, 2009), Pleim surface layer scheme (Pleim 2006), Asymmetric Convective Model, version 2 (Pleim 2007a,b) for the planetary boundary layer, and a modified Kain-Fritsch convection scheme using trigger 1 with sub-grid cloud radiation and mass-flux based convective time scale (Bullock et al., 2015). The radiation schemes used were RRTMG-LW and RRTMG-SW (Iacono et al., 2006). The microphysics scheme used was WSM6 (Hong and Lim, 2006). All simulations were evaluated against surface and upper air observations using the Atmospheric Model Evaluation Tool (AMET) described in Appel et al. (2011).

Conclusion

Comparison of results obtained with 6-h FDDA updates based on FNL analyses versus those obtained with 6-h FDDA updates from GFS initial fields showed very little difference in the context of monthly average error. However, the GFS guidance produced some spurious increases in daily-average error compared FNL guidance. These excursions of error, when they did occur, tended to be on the 16th day of the month.

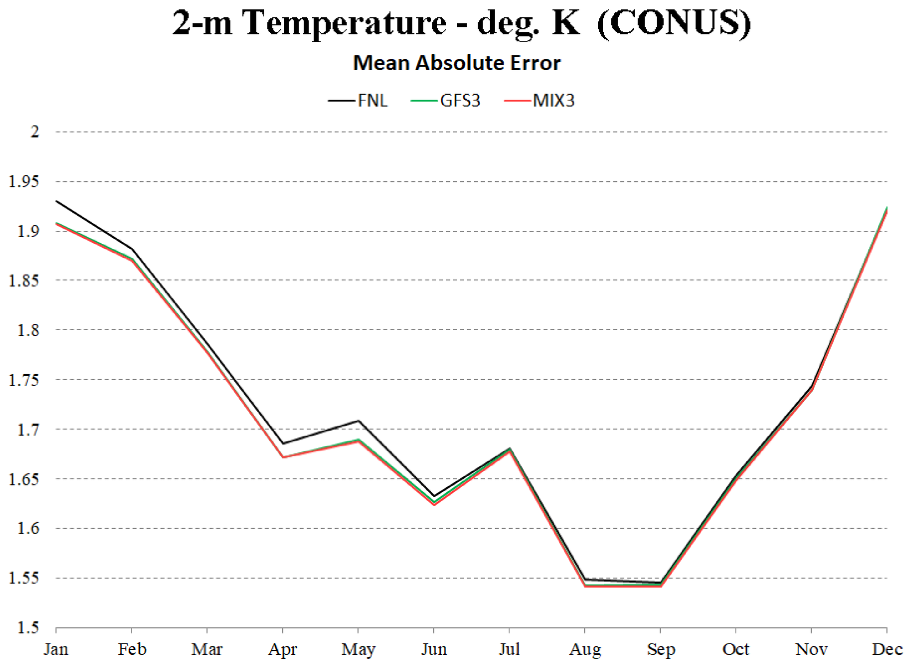
Tests with 3-h FDDA updates from GFS initial and T+3 hour forecast fields showed some error reduction relative to standard 6-h FNL updates. Best accuracy, by a very small amount, was obtained with 3-h FDDA updates from a blend of FNL analyses and T+3 hour GFS forecast fields.

Comparing Results using FNL vs. GFS for FDDA guidance (Standard 6-hour updates)

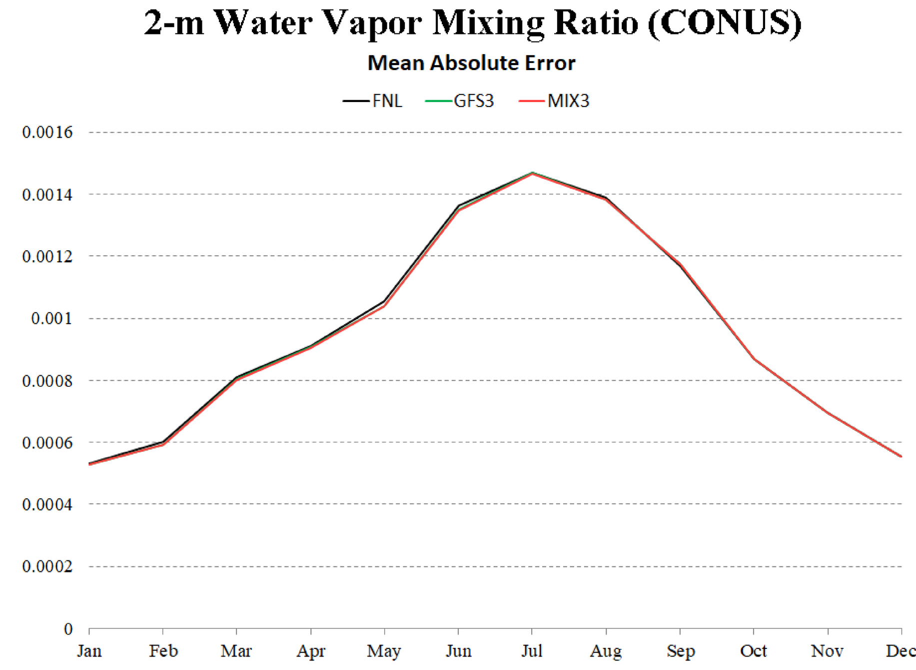
Comparing Standard 6-Hour FNL Updates to Two Methods for 3-Hour Updates

Method 1: GFS initialization fields and GFS 3-hour forecast fields (GFS3) **Method 2: FNL analysis fields and GFS 3-hour forecast fields (MIX3)**

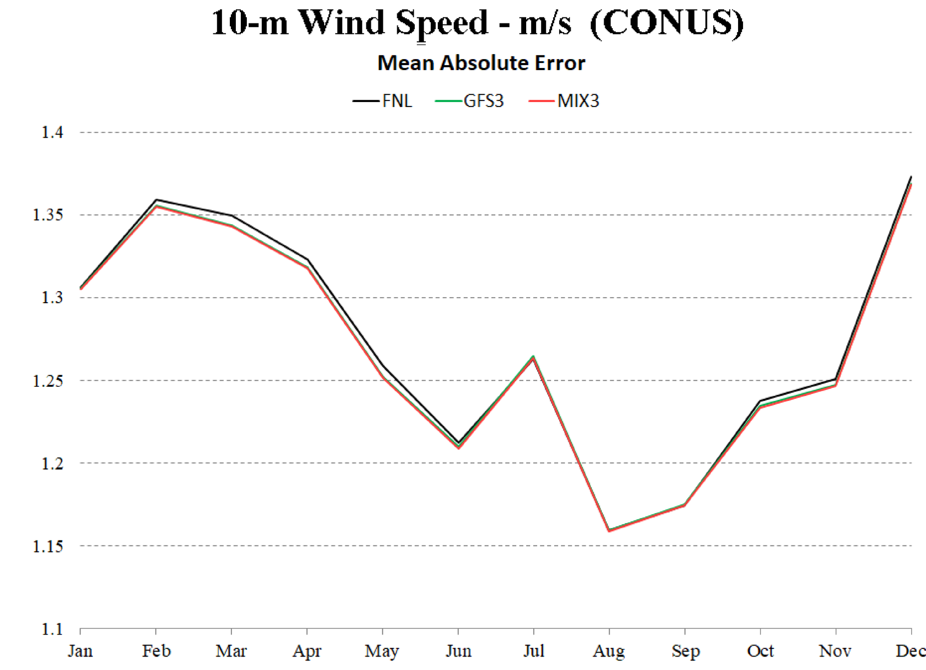
2-m Temperature - deg. K (CONUS)



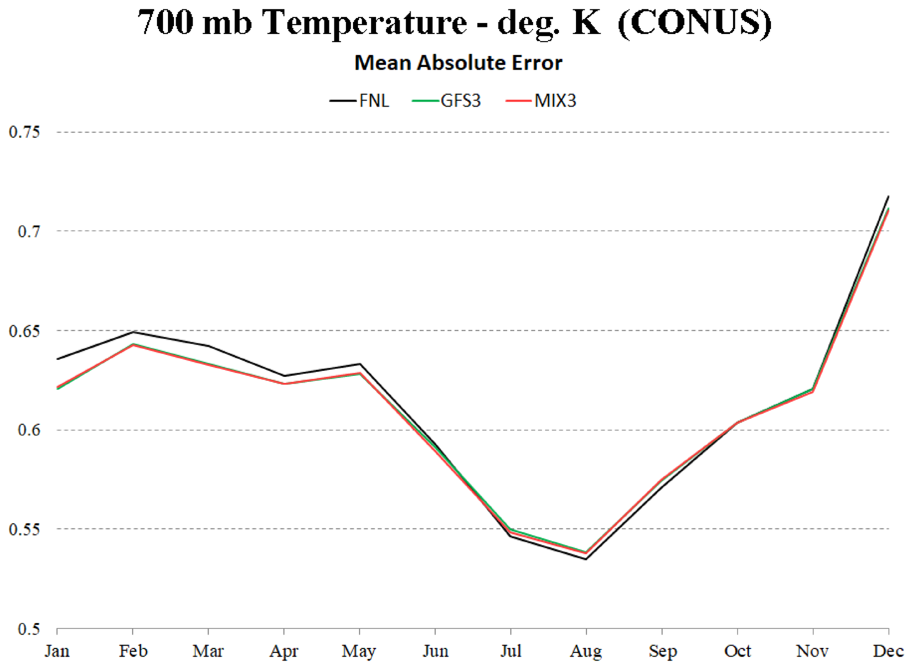
2-m Water Vapor Mixing Ratio (CONUS)



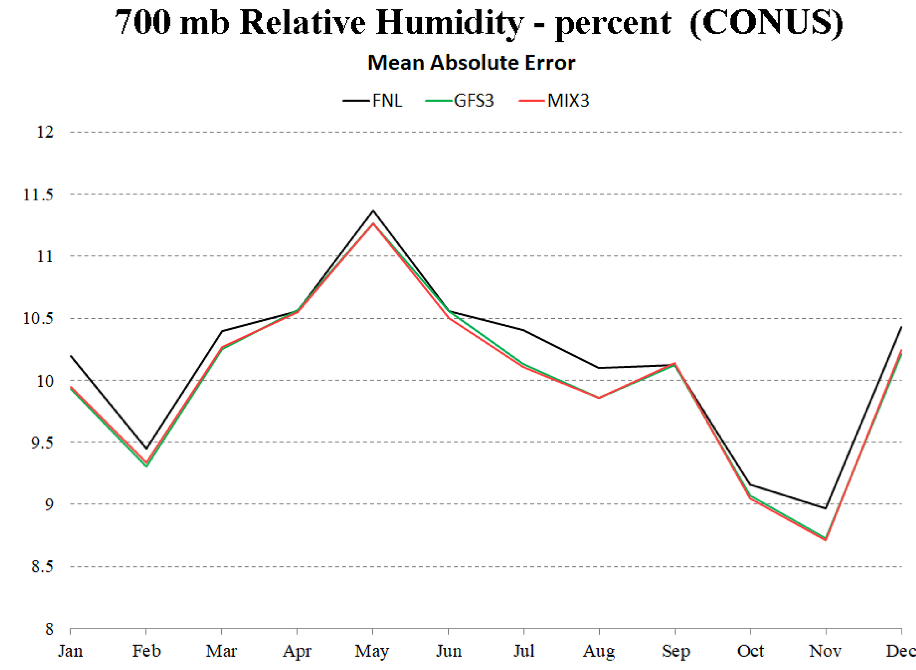
10-m Wind Speed - m/s (CONUS)



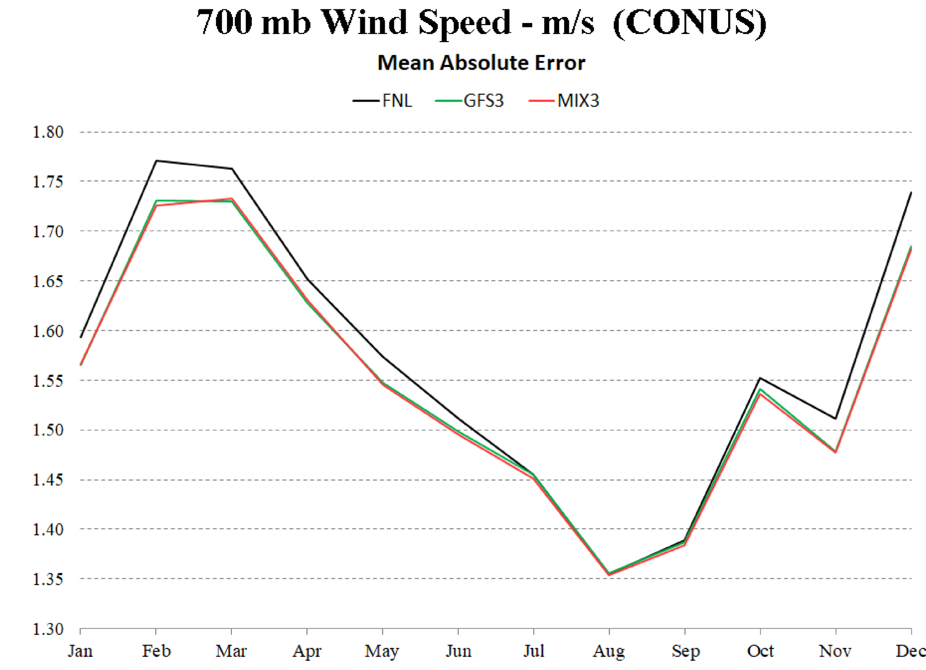
700 mb Temperature - deg. K (CONUS)



700 mb Relative Humidity - percent (CONUS)



700 mb Wind Speed - m/s (CONUS)



References

Appel, K.W., R. C. Gilliam, N. Davis, A. Zubrow, and S. C. Howard (2011), Overview of the Atmospheric Model Evaluation Tool (AMET) v1.1 for evaluating meteorological and air quality models, Environ. Modell. Software, 26, 434–443

Bullock, O.R., K. Alapaty, J.A. Herwehe, and J.S. Kain, 2015: A Dynamically Computed Convective Time Scale for the Kain–Fritsch Convective Parameterization Scheme. Mon. Wea. Rev., 143, 2105–2120.

Hong, S.-Y. and J.-O. J. Lim, 2006: The WRF single-moment 6-class microphysics scheme (WSM6). J. Korean Met. Soc., 42, 129-151.

Iacono, M.J., J.S. Delamere, E.J. Mlawer, M.W. Shephard, S.A. Clough, and W.D. Collins, 2008: Radiative forcing by long-lived greenhouse gases: calculations with the AER radiative transfer models, *J. Geophys. Res.*, **113**, D13103.

Pleim, J. E., and A. Xiu, 2003: Development of a land surface model. Part II: Data assimilation. J. Appl. Meteor., 42, 1811-1822.

Pleim, J.E., 2006: A Simple, Efficient Solution of Flux–Profile Relationships in the Atmospheric Surface Layer. J. Appl. Meteor. Climatol., 45, 341-347.

Pleim, J. E., 2007a: A combined local and nonlocal closure model for the atmospheric boundary layer. Part II: Application and evaluation in a mesoscale meteorological model. Journal of Applied Meteorology and Climatology, 46, 1396-1409.

Pleim, J. E., 2007b: A combined local and nonlocal closure model for the atmospheric boundary layer. Part I: Model description and testing. Journal of Applied Meteorology and Climatology, 46, 1383-1395.

Pleim, J., and R. Gilliam, 2009: An indirect data assimilation scheme for deep soil temperature in the Pleim–Xiu land surface model. J. Appl. Meteor. Climatol., 48, 1362-1376.

Xiu, A., and J. E. Pleim, 2001: Development of a land surface Model. Part I: Application in a mesoscale meteorological model. J. Appl. Meteor., 40, 192–209.