Preparing the Model for Prediction Across Scales (MPAS) for global retrospective air quality modeling.

Robert Gilliam, Russell Bullock, Jerold Herwehe, Hosein Foroutan, Jonathan Pleim and Limei Ran

Computational Exposure Division, National Exposure Research Laboratory, U.S. Environmental Protection Agency

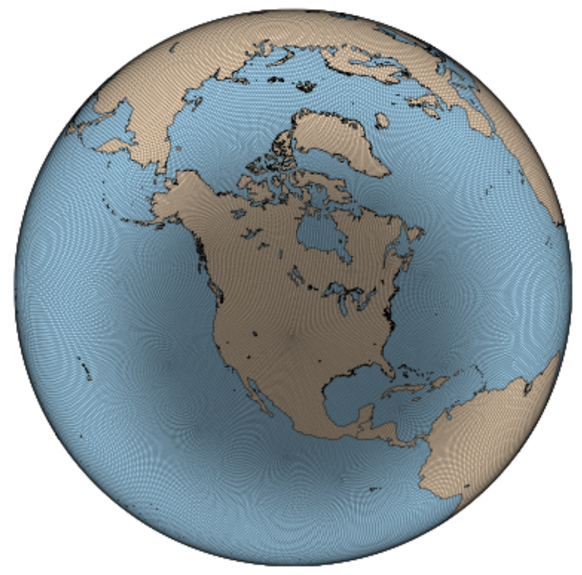
EPA www.epa.gov

Background

The United States Environmental Protection Agency (US EPA) is leveraging recent advances in meteorological modeling to develop a "Next-Generation" air quality modeling system that will allow consistent modeling of pollution issues from the global to local scale. The meteorological model of choice is the Model for Prediction Across Scales (MPAS) that has been developed by the National Center for Atmospheric Research (NCAR) in recent years. While the CMAQ development team has been working on coupling CMAQ components to MPAS for a full global chemical transport model, a group of atmospheric scientists has been preparing MPAS for accurate meteorological simulations.

US EPA's development of MPAS includes the addition of Four Dimensional Data Assimilation (FDDA), commonly termed analysis nudging, which allows for long simulations of historic weather with no error growth (see talk by Russ Bullock). We have also added the Pleim-Xiu land-surface model (PX LSM), Asymmetric Convective Model 2 (ACM2) and Pleim surface layer (PSL) from WRFV3.8. Other development includes the blending of regional and global analyses for better soil nudging, using fractional landuse inputs (release MPAS only considers dominant landuse categories), sub-grid scale convective physics options, and whether or not finer grids improve the global modeling. Our current WRF model is being used as a benchmark for MPAS performance.

MPAS Configuration



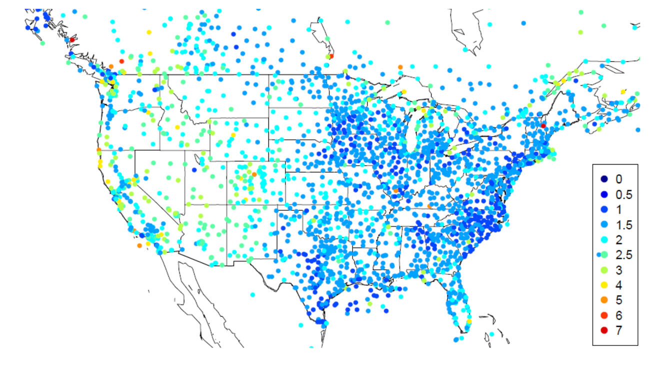
General MPAS Configuration

- 92 km global to 25 km CONUS grid
- July 2013 simulation period
- RRTMG SW and LW radiation
- WSM6 MP
- Kain-Fritsch CP (some updates were tested)
- FNL IC's, SST and ICE update

US EPA Modifications and Tests

- Four dimensional data assimilation (FDDA) (see Bullock oral presentation on Thu. afternoon MPAS session talk 9.5).
- Pleim-Xiu land-surface model, Asymmetric Convective Model V2 (ACM2) and Pleim surface layer.
- Kain-Fritsch subgrid convection scheme was updated to include new WRF options including a second convective trigger option, radiation feedback and dynamic convective time scale.
- MPAS was modified for fractional landuse (MODIS and NLCD40) to leverage the PX LSM ability to consider fractional weighting in LSM properties.
- Blending of regional and global analyses for better fine grid modeling results.

Evaluation and Visualization Tools

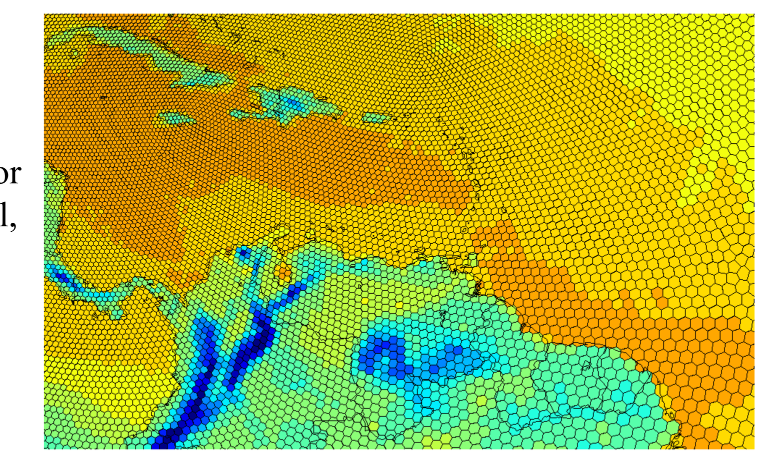


Atmospheric Model Evaluation Tool

- A MM5 and WRF evaluation tool developed ~2006, but recently improved including compatibility with MPAS.
- Pairs observations (MADIS) with model output and stores in MySQL database.
- Analysis scripts query data from MySQL for various statistical products including spatial, time series, daily errors, etc.
- Based on the R statistical language and MySQL database.
- Includes a meteorology and chemistry component.

Visualization Environment for Rich Data Interpretation (VERDI)

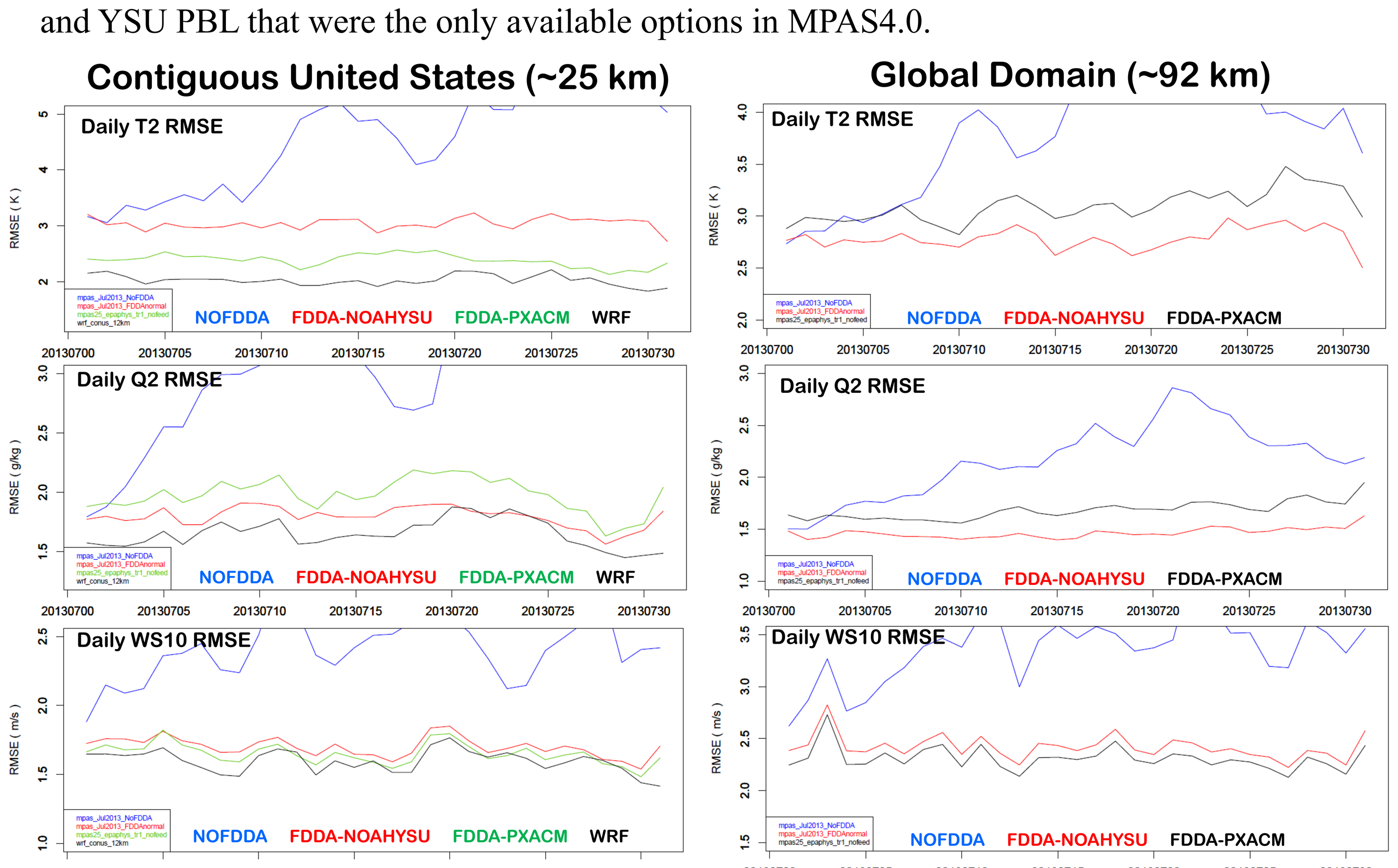
- Java-based visualization tool with a user interface for highly customized plots.
- Compatible with CMAQ, WRF and now MPAS NetCDF output.
- Below is an example of MPAS temperature with grid cell boundaries identified.
- Plotting abilities include plan views like below, cross-sections, time series, calculation of new variables, and difference between simulations.



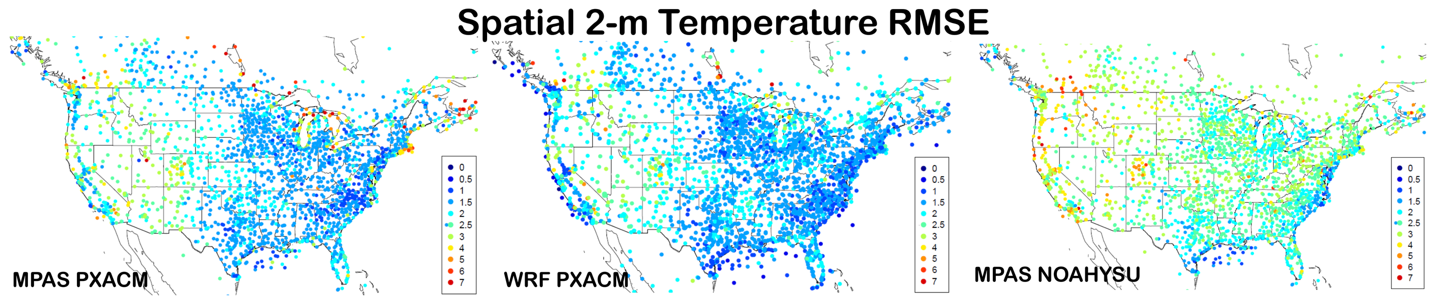
Sensitivity Experiments

Pleim-Xiu LSM, ACM2 PBL and Pleim Surface Layer Physics

The Pleim-Xiu LSM, Asymmetric Convective PBL model version 2, and Pleim surface layer parameterizations have been used in MM5 and more recently in WRF for retrospective meteorological simulations to drive the Community Multiscale Air Quality (CMAQ) model. Pleim-Xiu has been the LSM of choice, in part, because of the indirect soil nudging algorithm that constantly compares the model estimated near surface temperature and moisture with the analyzed values. As deviation occurs between the model and analysis, the soil moisture and deep soil temperature are nudged to force the model back towards the analysis. As a result it was necessary to implement the PX LSM in MPAS for global retrospective modeling. Also, the ACM2 model is used to mix pollutants in CMAQ, so for consistency, it was necessary to put this scheme into MPAS. Below are some evaluations of these new schemes relative to the Noah LSM and YSU PBL that were the only available options in MPAS4.0.

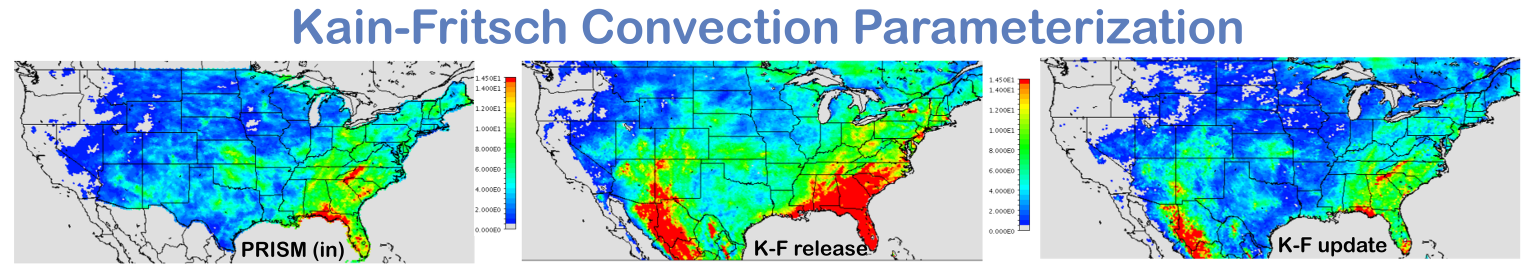


Spatial 2-m Temperature RMSE

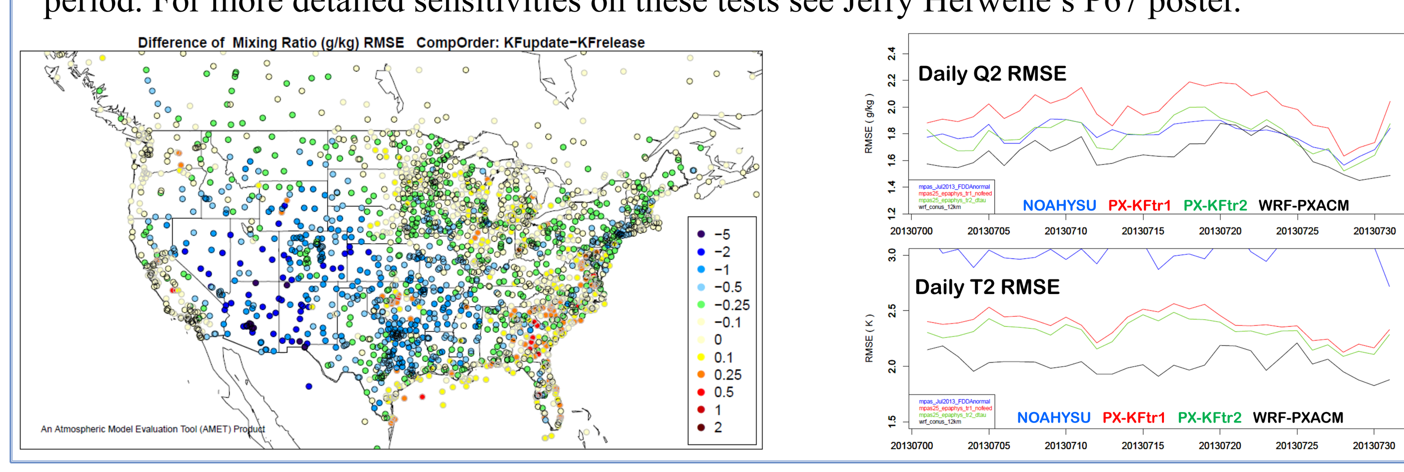


Statistics are provided (left column) above for all sites within the WRF CONUS 12 km domain and all sites outside of the CONUS (right column). The PXACM simulation reduces temperature error substantially over the CONUS domain because of the soil nudging that leveraged the 13 km RUC analysis similar to WRF. The PXACM MPAS run also reduces wind speed error slightly over the CONUS and the rest of the global domain. The NOAHYSU run performs slightly better than the PXACM in terms of water vapor mixing ratio, but this advantage is eliminated when the models are conducted with updates to the Kain-Fritsch, namely the addition of the convective trigger 2, subgrid cloud feedback to the RRTMG radiation and dynamic convective time scale (see next K-F section). Spatial statistics of temperature show MPAS with PXACM is approaching WRF error levels.

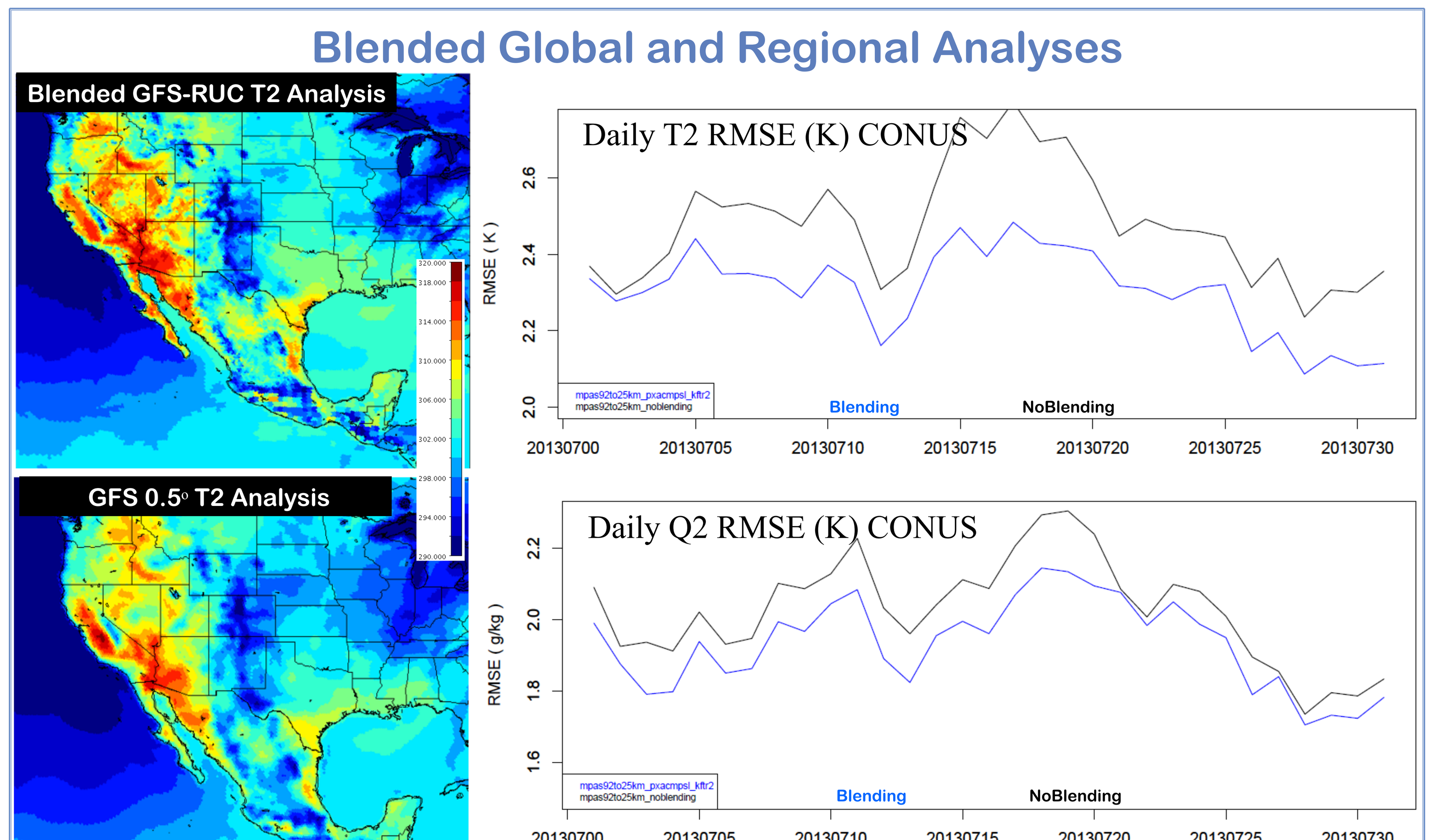
Kain-Fritsch Convection Parameterization



Kain-Fritsch was updated to the WRFV3.8.1 version with conv. trigger 2 option, subgrid-scale cloud to radiation feedback, and dynamic tau (convective time scale). These updates significantly improved an overestimation of rain in the release version (see above) according the PRISM precipitation analysis, and reduced 2-m temperature and moisture RMSE (see below). Analyses consider July 2013 modeling period. For more detailed sensitivities on these tests see Jerry Herwehe's P67 poster.

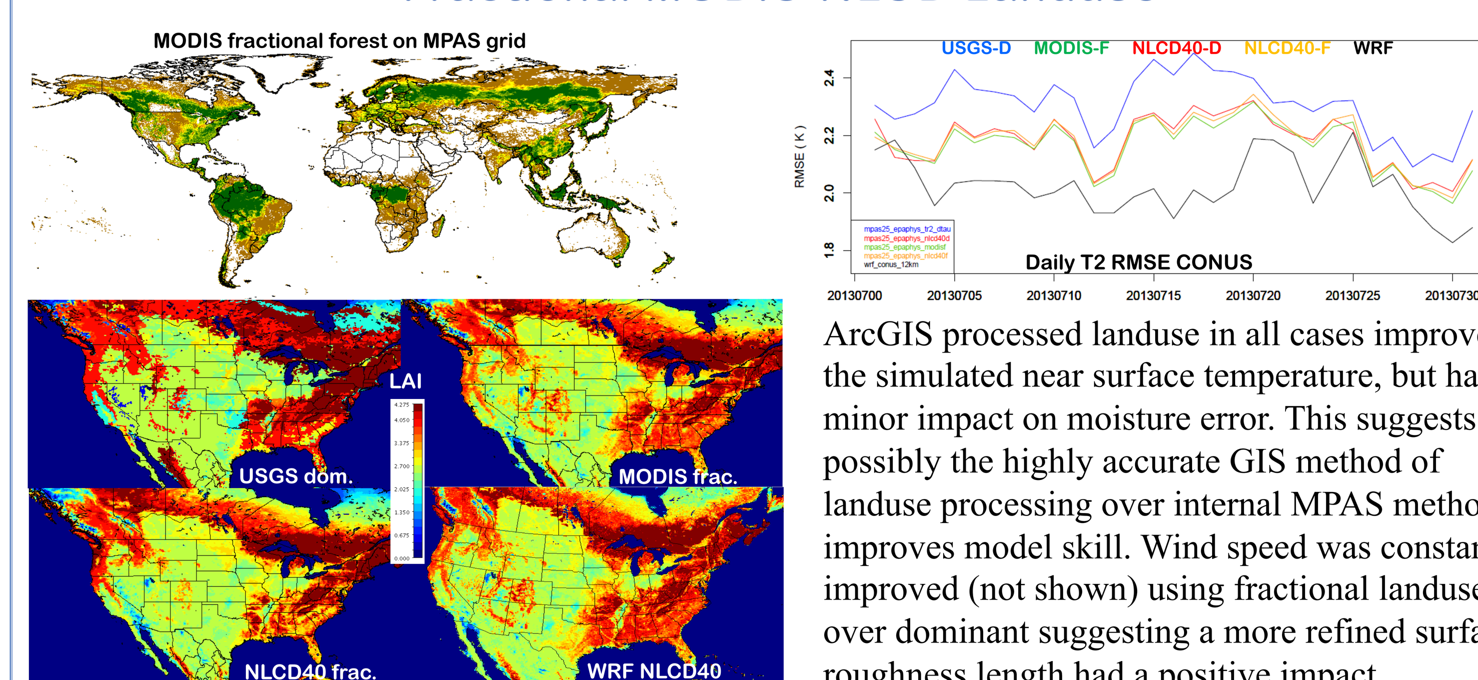


Blended Global and Regional Analyses



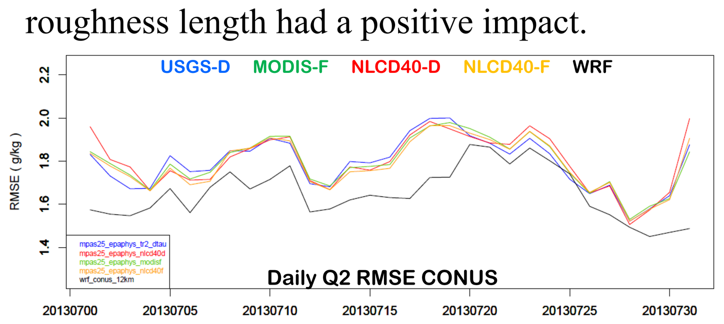
When the PX LSM was initially implemented in MPAS, it was quickly realized that 2-m temperature and moisture analyses needed for soil nudging did not take advantage of the local grid refinement when coarser global fields were used. A 0.5 deg GFS analysis would provide an ~55 km resolved temperature on the MPAS 25 km or less grid. Above shows the impact of blending a 13 km RUC regional analysis with the GFS 0.5 deg global fields. The higher level of detail in nudging inputs directly reduces error.

Fractional MODIS-NLCD Landuse



ArcGIS processed landuse in all cases improved the simulated near surface temperature, but had minor impact on moisture error. This suggests that possibly the highly accurate GIS method of landuse processing over internal MPAS method improves model skill. Wind speed was constantly improved (not shown) using fractional landuse over dominant suggesting a more refined surface roughness length had a positive impact.

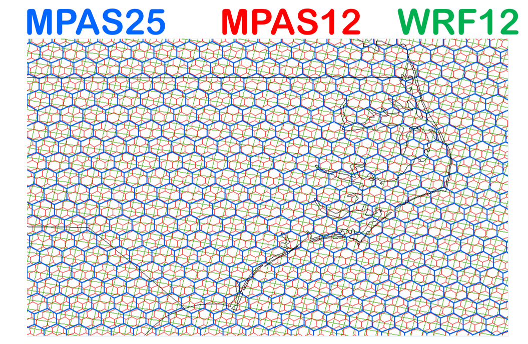
ArcGIS was used to generate the MPAS grid shapefile. The global MODIS and regional NLCD fractional landuse on the MPAS grid were generated by Spatial Allocator Raster Tools for full global MODIS 20 class fractional (MODIS-F), NLCD40 fractional (NLCD40-F) and NLCD40 dominant (NLCD40-D) for testing.

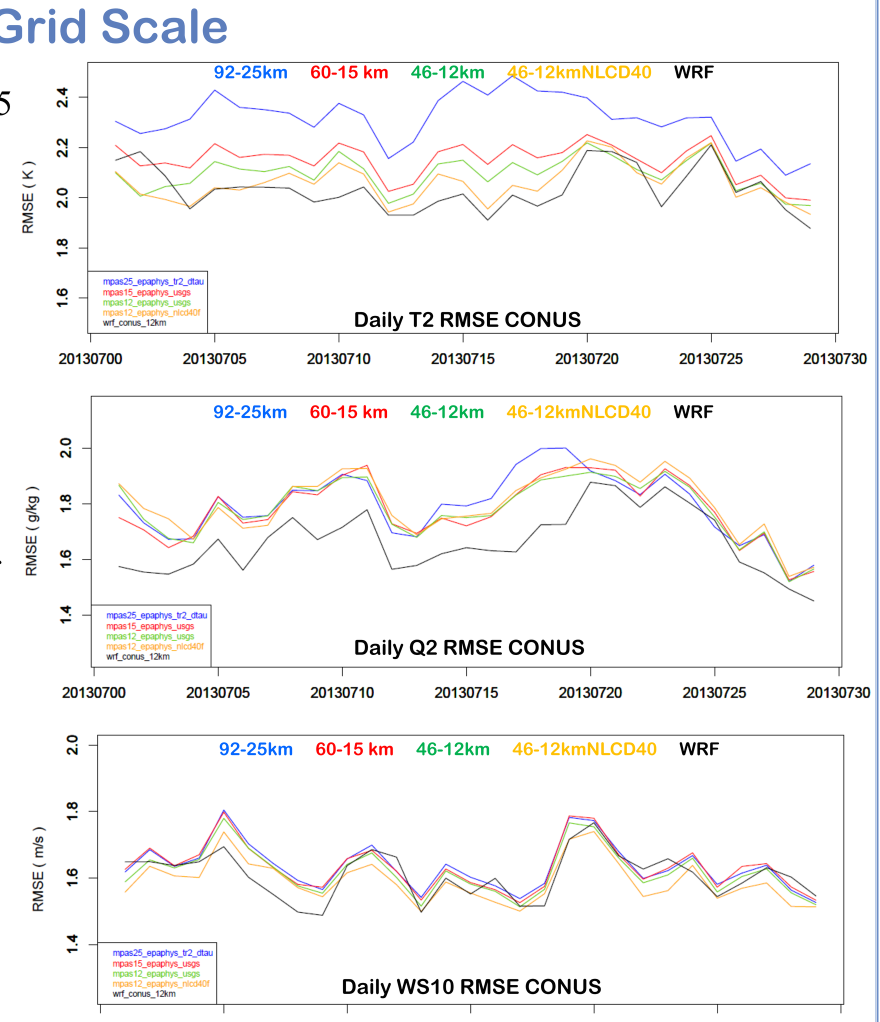


Grid Scale

Testing of the impact of grid scale on MPAS results was done using a 92 to 25 km, 60 to 15 km, and 46 to 12 km grid. The main interest was comparing against our best 12 km WRF CONUS simulations to see how MPAS measures. The 46 to 12 km MPAS grid was also run using NLCD40 fractional landuse to be more directly comparable to WRF.

Daily CONUS statistics indicate a clear improvement in temperature as grid scale decreases. This is due to soil nudging that used the 13 km RUC analysis. Error levels of temperature and wind speed are also approaching, and on some days, improved over WRF.





Acknowledgements:

- NCAR/MMM for the development and maintenance of the Weather Research and Forecasting and Model for Prediction Across Scales modeling systems.
- NOAA's ESRL for the Meteorological Assimilation Data Ingest System (MADIS) observation dataset used here for evaluation and data assimilation.

U.S. Environmental Protection Agency
Office of Research and Development

Robert C. Gilliam | gilliam.robert@epa.gov | 919-541-4593