Developing MCIP to Process WRF-EM Output

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Disclaimer: The research presented here was performed, in part, under the Memorandum of Understanding between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and under agreement number DW13921548. Although it has been reviewed by EPA and NOAA and approved for publication, it does not necessarily reflect their views or policies.

Most Recent Developments in MCIP

- MCIPv3 (to be released w/ CMAQ in Fall 2005)
  - Includes MM5 and WRF capabilities in same code
  - Beta testing program underway
  - Linkage with WRF-EM (WRF-ARW or NCAR core)
  - Incorporated and enhanced U. Houston "WCIP" code
  - Based on WRFv2.0.3.1 (NCAR release, December 2004)
  - Minimize user changes to WRF "Registry"
  - Allow users to transition to WRF with minimal delay
- Optional dry deposition species for Cl (6) and Hg (2)
- Processing of fractional land use, if available
  - Requires MM5's TERRAIN file with "IEXTRA" turned on

Transitioning to WRF

- Will be gradual switch from MM5 to WRF-EM
- Steep learning curve (programs, data, scripts…)
- Critical components for AQM not yet in WRF
  - Four-dimensional data assimilation (FDDA) via Newtonian Relaxation (nudging)
  - Pleim-Xiu land-surface model (PX LSM)
- Demonstration of WRF capability is mandatory
  - Initial evaluation of WRF simulations is underway
  - Suitability of WRF fields for CMAQ is just starting

FDDA via Nudging for WRF-EM

- EPA-funded collaboration with PSU and NCAR
  - Enables EPA to get "first look" at code
    - Already using some preprocessing code (MM5 converter)
    - Apply to and evaluate for AQ modeling applications
  - In-house staff can assist development to accelerate
- Initially develop analysis nudging (3D, surface)
- Will permit CMAQ users to better apply WRF for retrospective simulations
- Expected implementation in WRF: Fall 2005

Pleim-Xiu LSM for WRF-EM

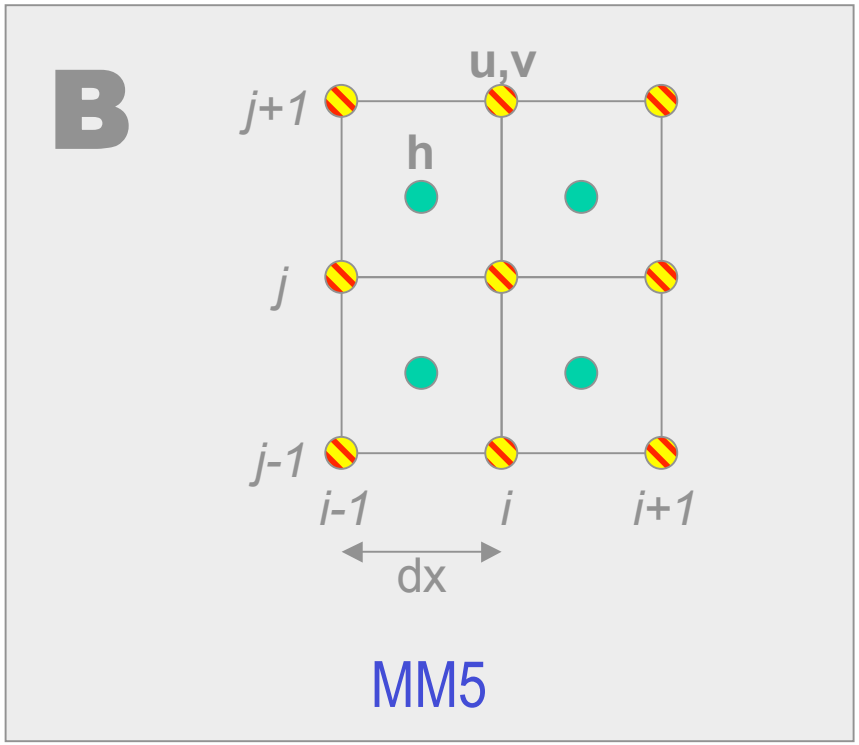
- Collaboration with UNC-CEP and NCAR
- Initial implementation underway
- NCAR mods required to support surface fields
- Soil moisture nudging options follow PSU work
- Will be tested by EPA/ORD
- WRF community release as soon as Fall 2005
- CMAQ to also support WRF PX LSM

Adding WRF Processing to MCIP

- U. Houston "WCIP" was incorporated and enhanced
- Several issues to keep MCIP user-friendly
  - Array convention: (y,x,z_{kmax_1}) changed to (x,y,z_{1_kmax})
  - Horizontal grid
  - Vertical coordinate
  - State variables
  - Definition of density (total vs. dry) and Jacobian
- MCIP generalized to support using both models
  - May facilitate new met models in MCIP by users

Differences Between MM5 and WRF…

_ Horizontal grid (Arakawa and Lamb, 1978)



Differences Between MM5 and WRF…

- Vertical: terrain-following, based on different prs
  - MM5: *p* = reference total prs; WRF: *p* = dry hydrostatic prs

MM5

$$\acute{o} = \frac{p - p_t}{p^*}$$

$$p^* = p_s - p_t$$

WRF

$$\c{c} = \frac{p_h - p_{h_t}}{\grave{i}}$$

$$\grave{i} = p_{h_s} - p_{h_t}$$

Differences Between MM5 and WRF…

_ Meteorology state variables:

MM5

- U- and V-component wind (dot points)
- Temperature
- Water Vapor Mixing Ratio
- Pressure (reference + perturbation)

WRF

- U- and V-component wind (face points)
- Potential Temperature
- Water Vapor Mixing Ratio
- Density (dry)
- Geopotential

Differences Between MM5 and WRF…

- CMAQ state variables based on met state equations

MM5

- Jacobian:

$$J = \frac{p_r^*}{\rho_r g}$$

- Density (ρ_r) = Reference total density
- Pressure (p_r^*) = Reference total pressure

WRF

- Jacobian:

$$J = \frac{\grave{\imath}}{\tilde{n}_d g}$$

- Density (ρ_d) = dry density
- Pressure (μ) = time-varying, dry hydrostatic prs

WRF Data and MCIPv3

- Must be WRFv2.0 or greater.
  - MCIPv3 developed from WRFv2.0.3.1 (Dec. 2004)
- Must be WRF-EM (a.k.a. ARW or NCAR core)
  - WRF namelist variable dyn_opt=2
  - MCIPv3 does not support WRF-NMM (NCEP core)
- Must have WRF I/O API formatted output
  - WRF namelist variable io_form_history=2

WRF Data and MCIPv3 (continued)

- Must use non-hydrostatic dynamics in WRF
  - WRF namelist variable non_hydrostatic=.true.
- Should have, at most, hourly output in WRF
  - WRF namelist variable history_interval=60. (or less)
- Need to add following 2D variables to Registry:
  - Friction velocity (UST)
  - Albedo (ALBEDO)
  - Emissivity (EMISS)
  - Roughness Length (ZNT)

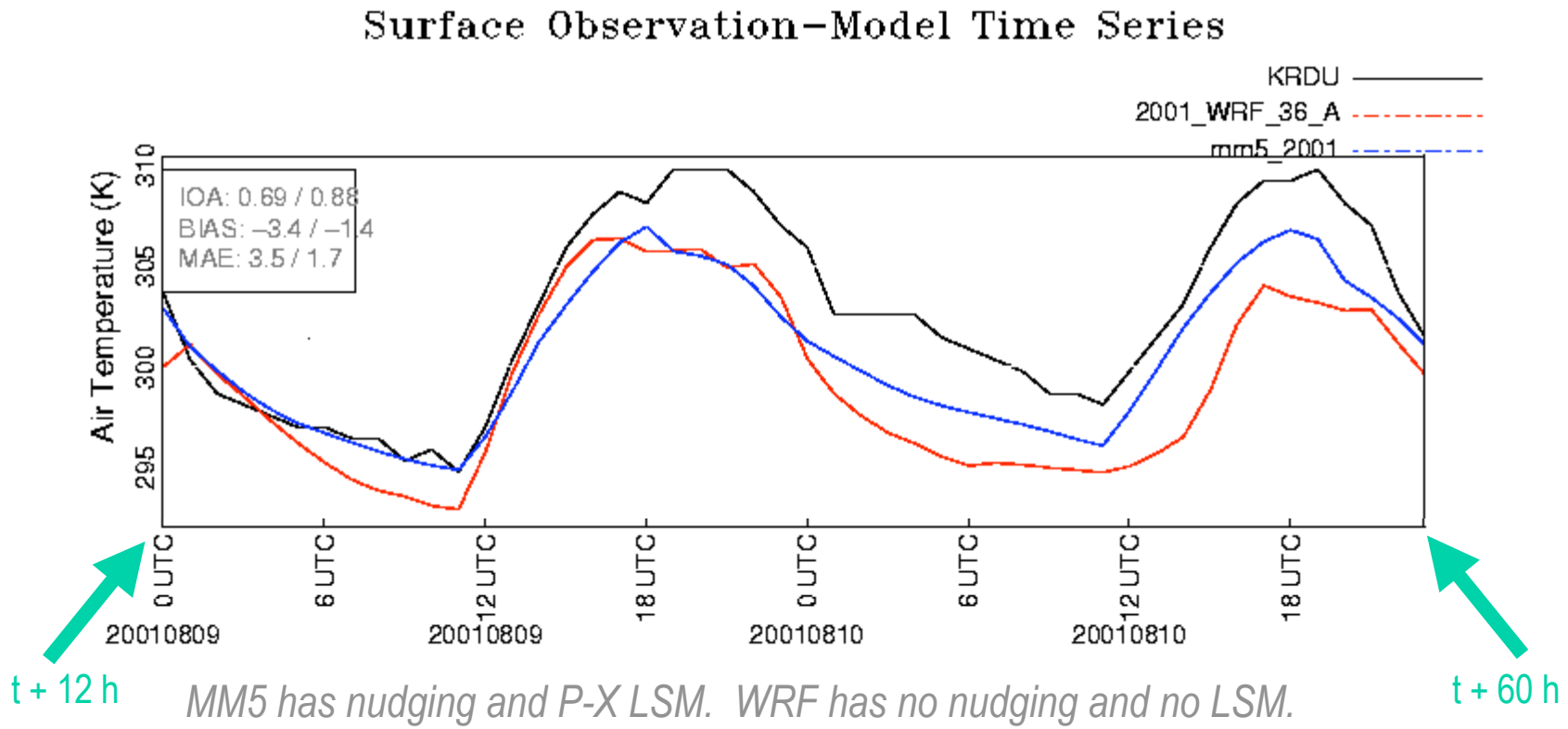
Negative Mixing Ratios in WRF

- Can occur as a result of mass conservation and the advection scheme in WRF-EM
- Will cause problems in CMAQ
- Can zero out or constrain negative mixing ratios to user-definable minimum value in WRF
- MCIP sets minimums on mixing ratios…
  - 1.0×10^{-14} kg/kg for Q_v
  - 1.0×10^{-30} kg/kg for Q_c, Q_i, Q_r, Q_s, Q_g

Simple Comparison of MM5 and WRF

- Yes…this is “apples” vs. “oranges”
- Runs for 12 UTC 19 Jun – 00 UTC 19 Aug 2001
- Use same domain & RAWINS analyses for both
- MM5 in 108-h chunks; WRF in 60-h chunks
  - 12-h spin-up period ignored for both sets
- MM5 w/ FDDA & LSM; WRF w/o FDDA or LSM
- Other options “as appropriate”
- *Is WRF qualitatively OK for retrospective AQM?*

Sample MM5 and WRF-EM

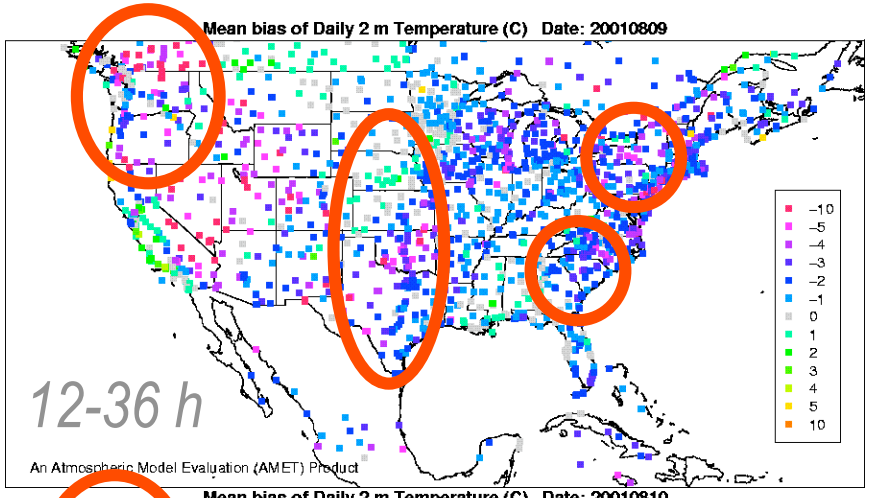


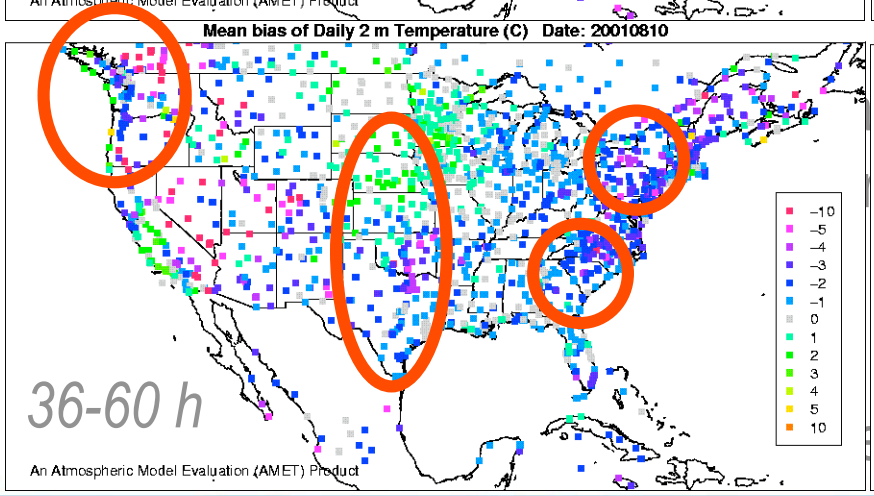
MM5 has nudging and P-X LSM. WRF has no nudging and no LSM.

As expected, WRF simulation (as strictly forecast) is less accurate over time than MM5 simulation with the benefit of nudging and LSM. Using WRF "as is" for AQM today would require much more frequent initialization.

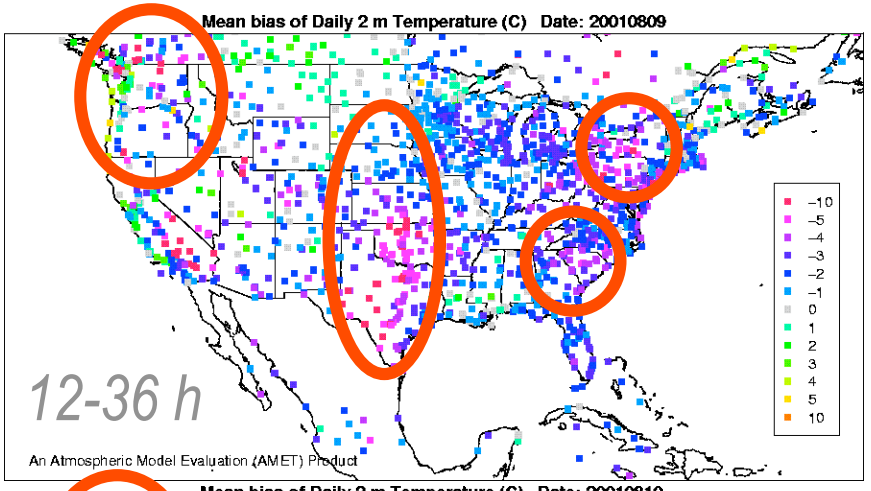
Sample MM5 and WRF-EM

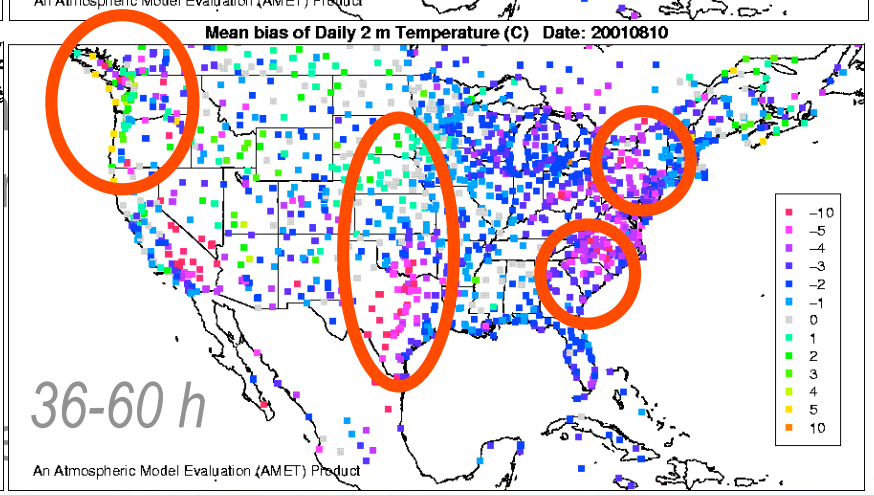
MM5 (with nudging and LSM)





WRF (with no nudging or LSM)

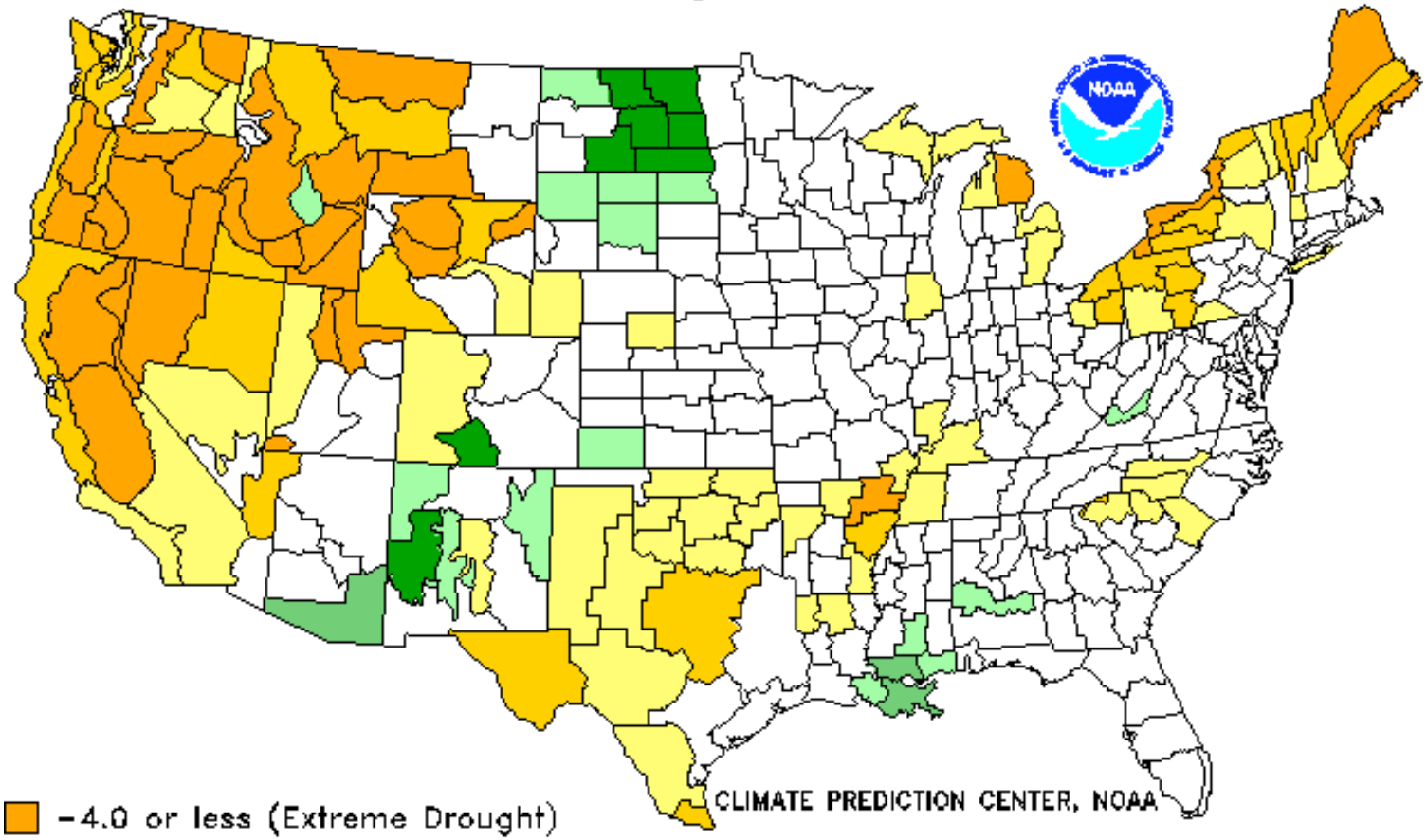




Drought Severity Index by Division

Weekly Value for Period Ending 11 AUG 2001

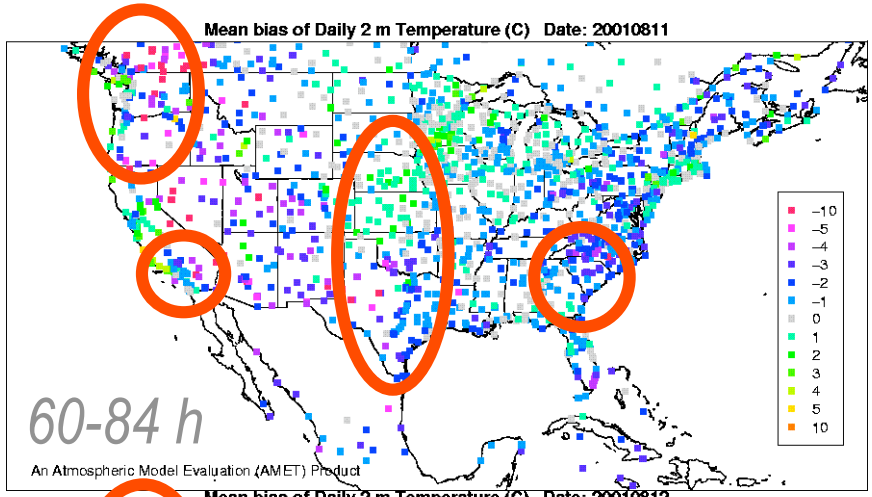
Long Term Palmer

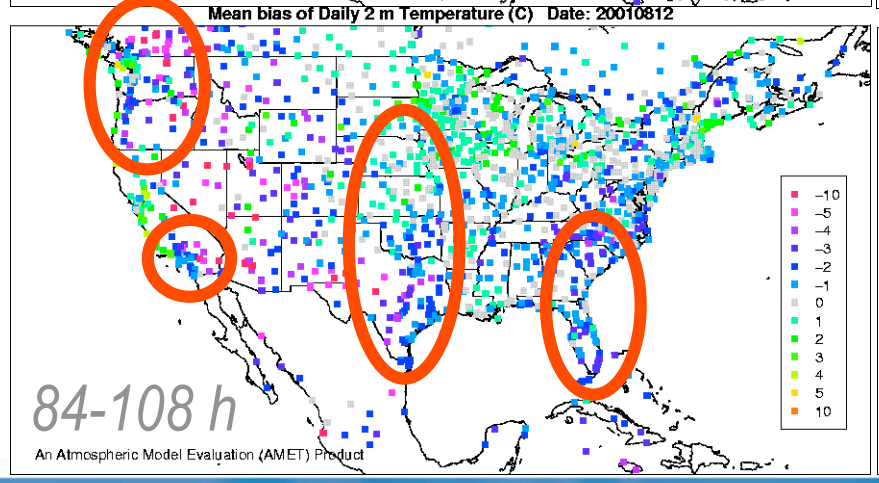


- −4.0 or less (Extreme Drought)
- −3.0 to −3.9 (Severe Drought)
- −2.0 to −2.9 (Moderate Drought)
- −1.9 to +1.9 (Near Normal)
- +2.0 to +2.9 (Unusual Moist Spell)
- +3.0 to +3.9 (Very Moist Spell)
- +4.0 and above (Extremely Moist)

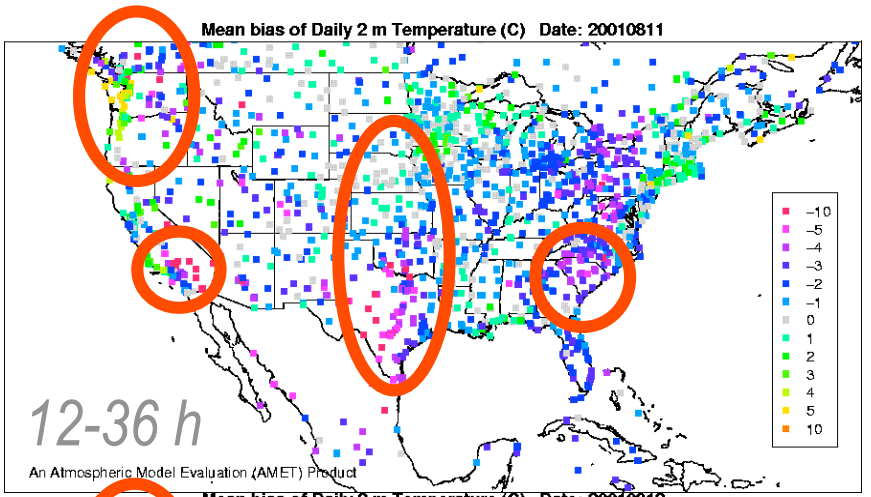
Sample MM5 and WRF-EM

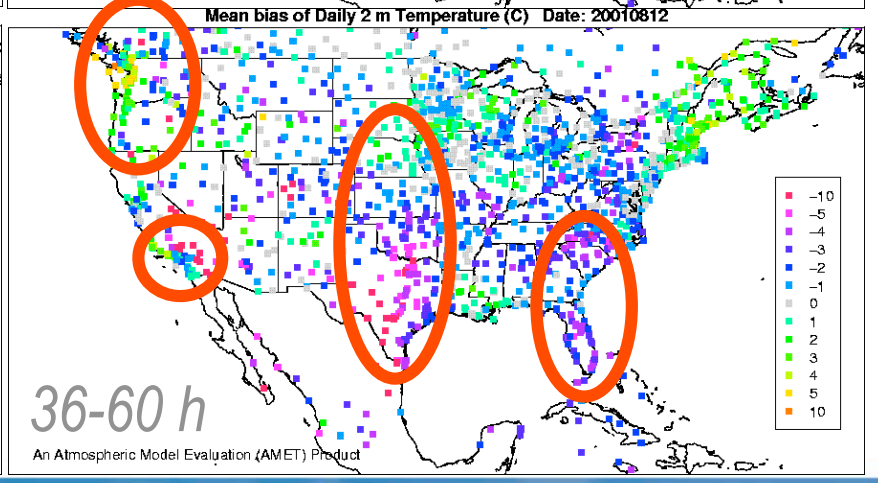
MM5 (with nudging and LSM)



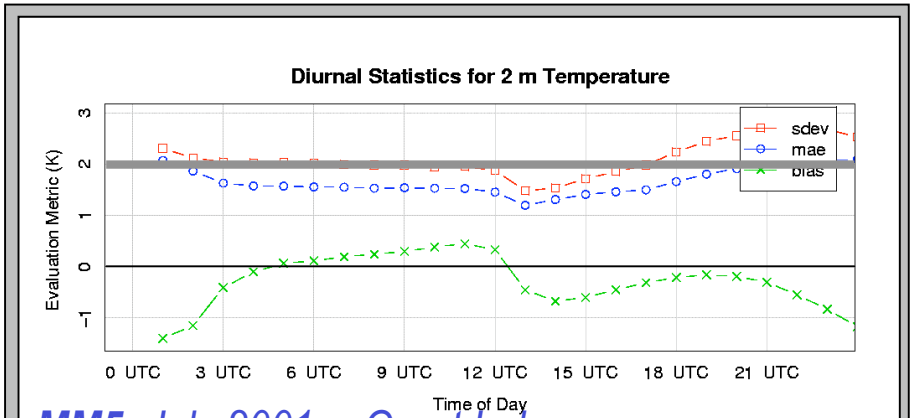


WRF (with no nudging or LSM)

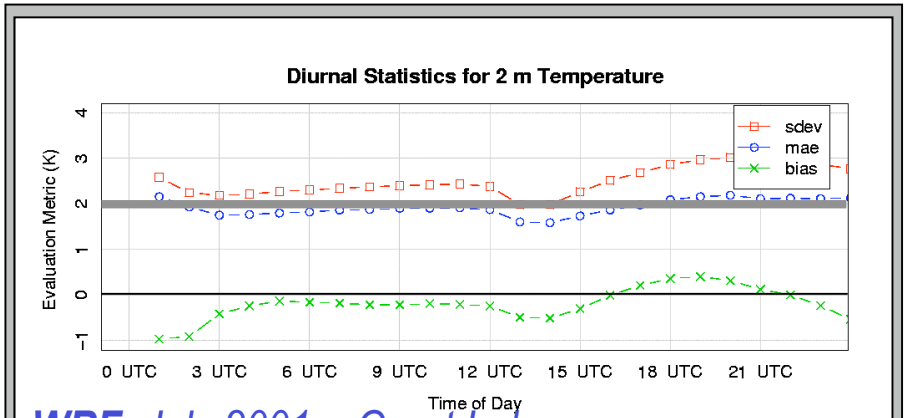




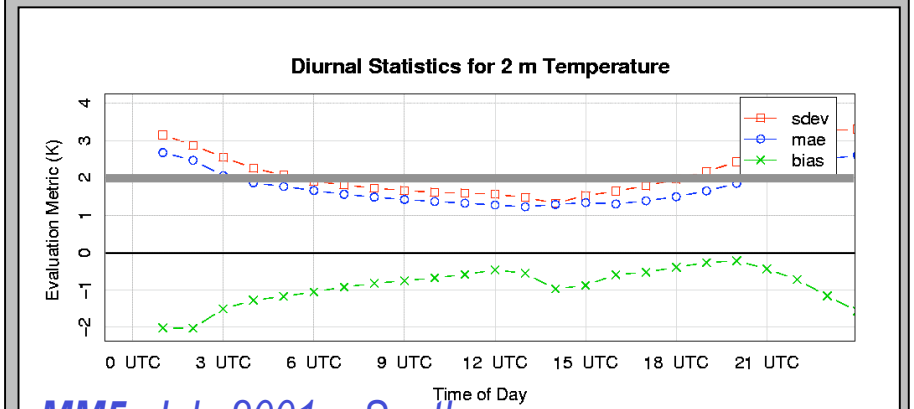
Sample MM5 and WRF-EM



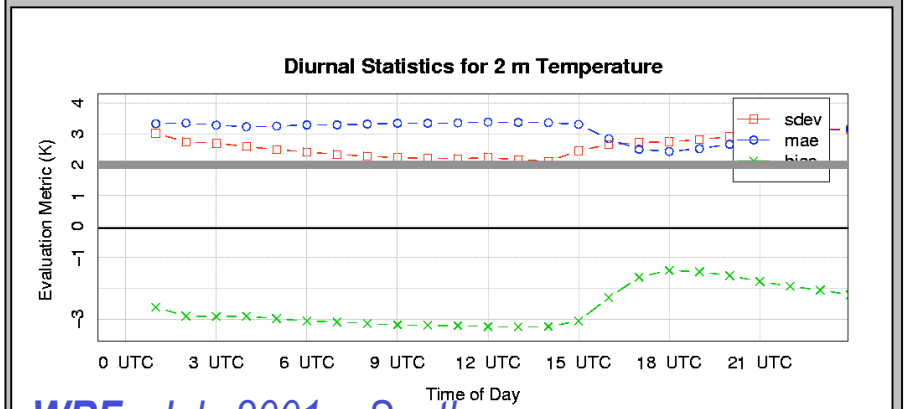
***MM5**: July 2001 _ Great Lakes*



***WRF**: July 2001 _ Great Lakes*

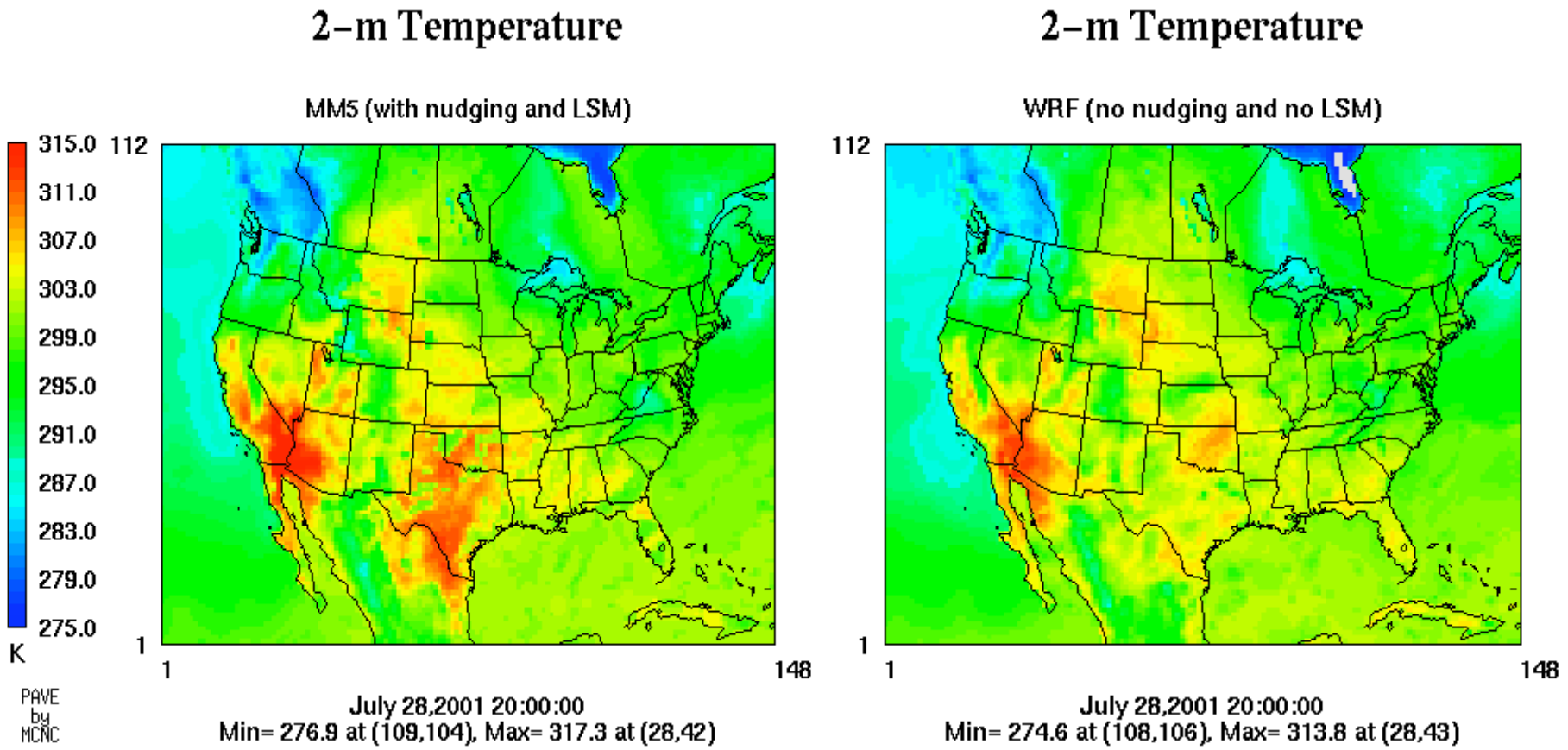


***MM5**: July 2001 _ South*



***WRF**: July 2001 _ South*

MM5 and WRF-EM from MCIPv3



Note: Not a generalization of current or future capabilities.

Future Directions

- Extensive testing and applications with WRF
  - Explore WRF options, model behavior
    - Assess impacts on both meteorology and chemistry
    - Support for WRF options not currently considered
  - Nudging
    - Start with analysis nudging option
    - Extend to obs nudging as it becomes available
  - Pleim-Xiu LSM testing (snow model?)
  - Compare with MM5 runs for similar period
    - Can WRF outperform MM5 for retrospective AQM?