MCIPv3: Using WRF-EM Output with CMAQ

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MCIP Version 3.0 — Highlights

- Process MM5 or WRF fields with same code
- Optional dry deposition species for Cl (6) and Hg (2)
- Corrections for Southern Hemisphere domains
- Optimizations for processing met fields to MCIP arrays
- Don't need to specify vertical structure if same as met
- Expanded maximum number of input met files
- MM5v3 layer heights consistent with NCAR formulae
- Define MM5 winds on C-grid with less interpolation

MCIP Version 3.0 — Highlights (cont.)

- Use 10-m wind components directly from MM5 or WRF (if available) for output 10-m wind speed and direction
- Use fractional land use (if available) to derive % urban for new min K_z algorithm in CMAQ and for RADMdry
- I/O API 3: consistency check for params in I/O API
- Changed meteorology ingest arrays to (x,y,z)
- Updated compiler options for IBM, PGF90, and Intel
- Updated script
- New "Frequently Asked Questions" List (FAQ)

Transitioning to WRF

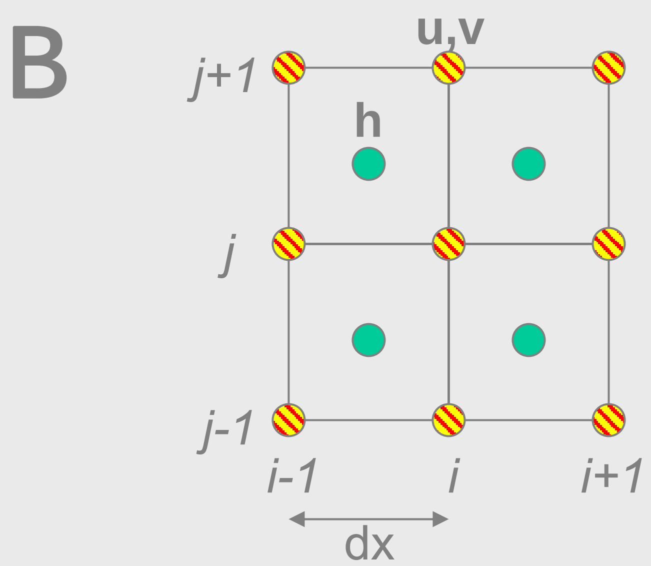
- Will be gradual switch from MM5 to WRF-EM
- Steep learning curve (programs, data, scripts…)
- Critical components for AQM under development
  - Four-dimensional data assimilation (FDDA) via nudging
  - Pleim-Xiu land-surface model (PX LSM)
- Demonstration of WRF capability is mandatory
  - Initial evaluation of WRF simulations is underway
  - Suitability of WRF fields for CMAQ is just starting

Adding WRF Processing to MCIP

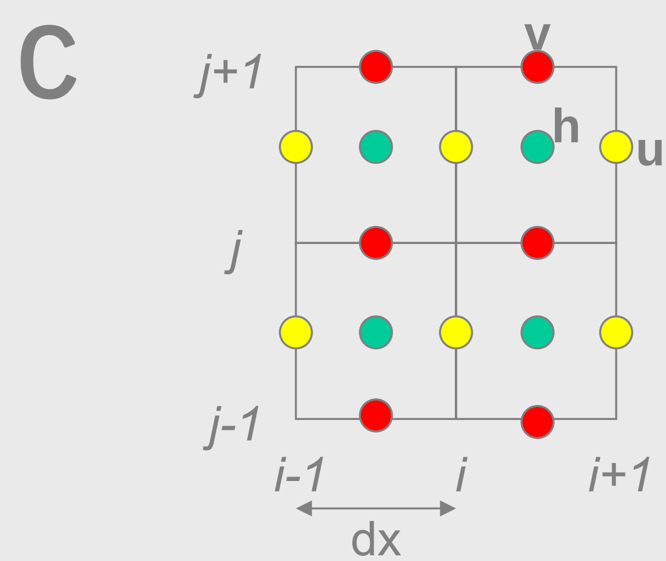
- U. Houston "WCIP" was incorporated and enhanced
- Several issues to keep MCIP user-friendly
  - Array convention: $(y,x,z_{kmax \rightarrow 1})$ changed to $(x,y,z_{1 \rightarrow kmax})$
  - Horizontal grid, vertical structure, state variables
- Minimize user changes to WRF "Registry"
- Allow users to transition to WRF with minimal delay
- MCIP generalized to support using MM5 and WRF
  - May facilitate new met models in MCIP by users

Differences Between MM5 and WRF…

- <u>Horizontal</u> grid (Arakawa and Lamb, 1978)



MM5



WRF-EM, CMAQ, RAMS

Differences Between MM5 and WRF…

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

MM5

$$\sigma = \frac{p - p_t}{p^*}$$

$$p^* = p_s - p_t$$

WRF

$$\eta = \frac{p_h - p_{h_t}}{\mu}$$

$$\mu = p_{h_s} - p_{h_t}$$

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
- Reduced Pressure (p_r^*) = reference total pressure

WRF

- Jacobian:

$$J = \frac{\mu}{\rho_d g}$$

- Density (ρ_d) = dry density
- Reduced Pressure (μ) = time-varying, dry hydro. 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 2D variables to output via Registry:
  - Friction velocity (UST)
  - Albedo (ALBEDO)
  - Emissivity (EMISS)
  - Roughness Length (ZNT)

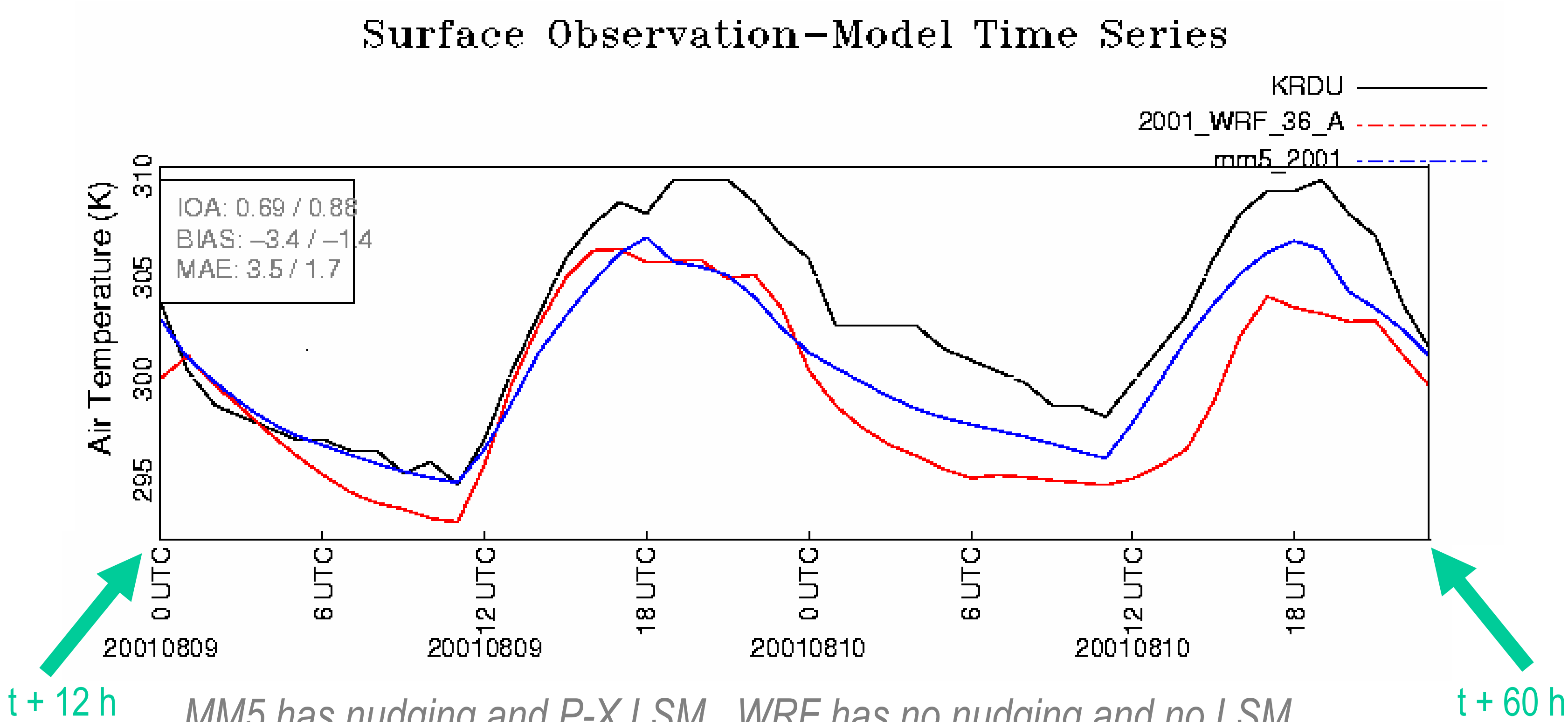
Negative Mixing Ratios in WRF

- Can occur as a result of the non-positive-definite 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”
- Run 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

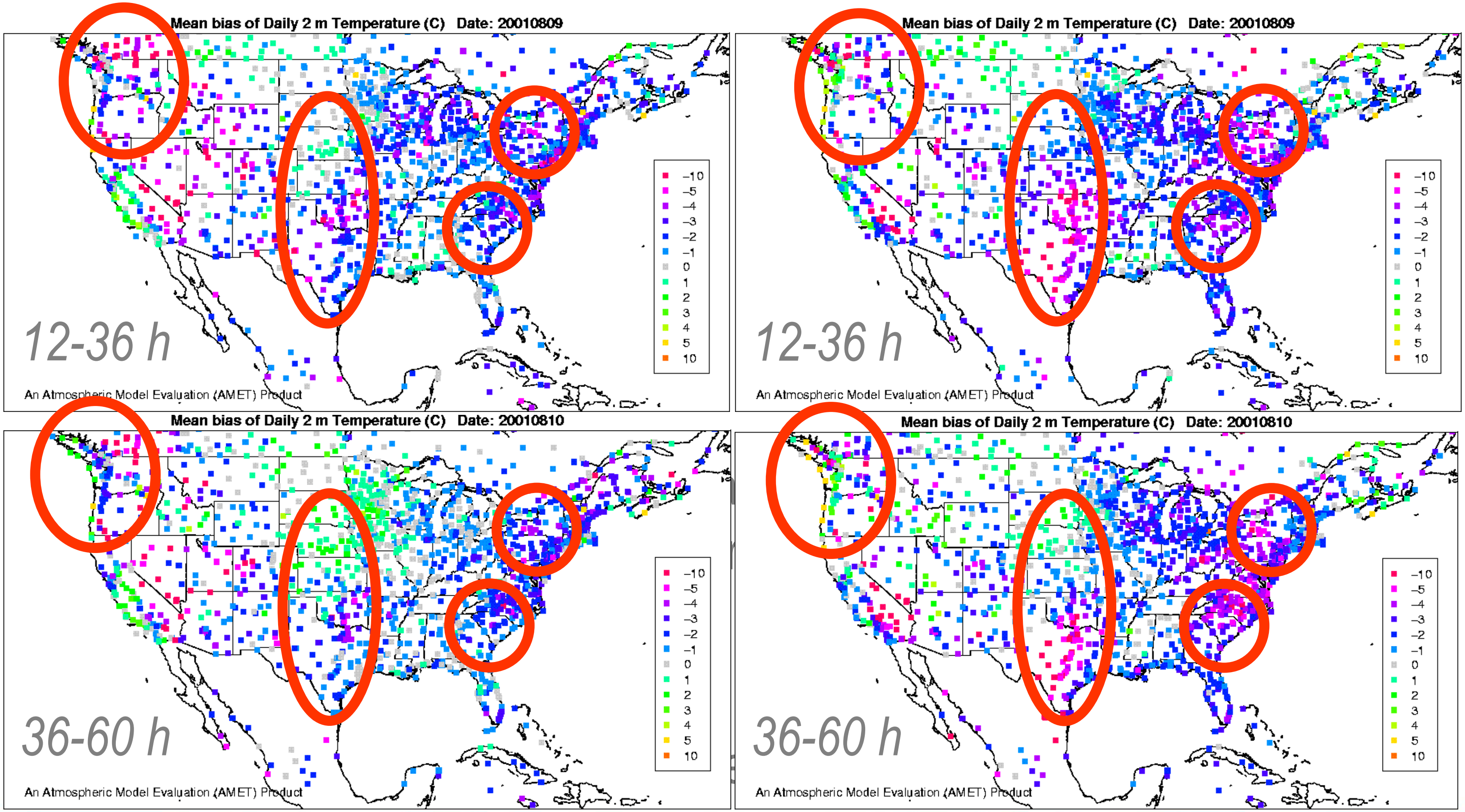


MM5 has nudging and P-X LSM. WRF has no nudging and no LSM.

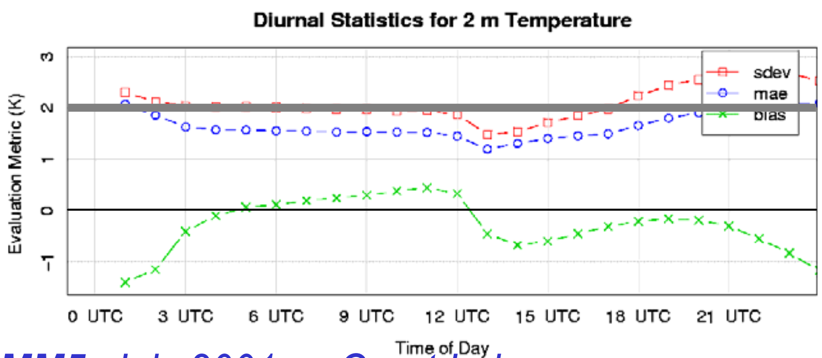
As expected, WRF simulation (as strictly forecast) is less accurate over time than MM5 simulation with the benefit of nudging and LSM. Using WRF "as is" for AQM today would require much more frequent initialization.

Sample MM5 and WRF-EM

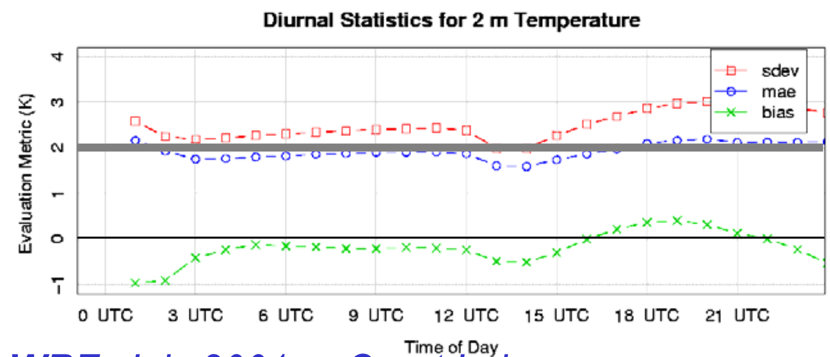
MM5 (with nudging and LSM) | WRF (with no nudging or LSM)



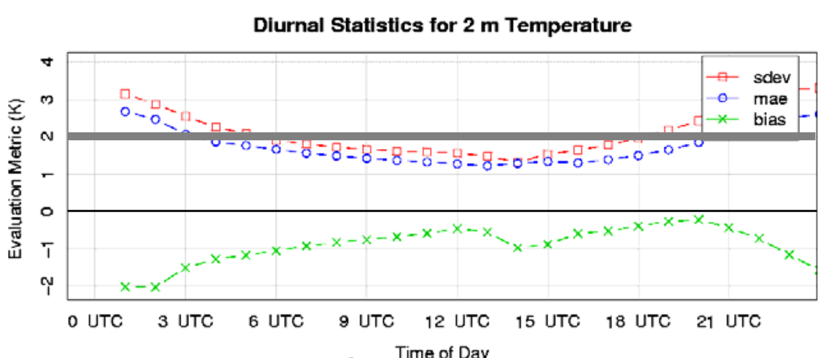
Sample MM5 and WRF-EM



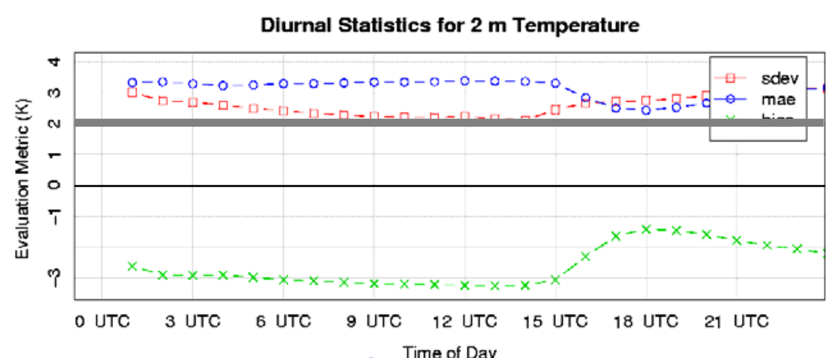
MM5: *July 2001 — Great Lakes*



WRF: *July 2001 — Great Lakes*



MM5: *July 2001 — South*



WRF: *July 2001 — South*

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
  - Compare with MM5 runs for similar period
    - Can WRF outperform MM5 for retrospective AQM?

Credits

- S.-B. Kim and D. Byun (U. Houston) – WCIP
- R. Gilliam (NOAA) – Use of AMET
- G. Sarwar (EPA) – Cl dry dep
- R. Bullock (NOAA) – Hg dry dep
- W. Hutzell (EPA) – Dry dep reorg
- P. Sanhueza (U. Santiago, Chile) and C. Wiedinmyer (NCAR) – Southern Hemisphere issues
- Z. Adelman (UNC) – Use all met layers without specifying *a priori*
- D. Wong (Lockheed Martin) – MCIP optimizations
- D. Byun (U. Houston) – Fractional land use for RADMdry

- MCIPv3 Beta Testers…especially:
  - K. Baker (LADCO)
  - K. Smith (WeatherSmith, LLC)
  - P. Sanhueza (U. Santiago, Chile)
  - Q. Mao and T. Cook (TVA)
  - M. Prodanova (Bulgarian Academy of Sciences, Bulgaria)
  - F. Ngan (U. Houston)
  - Z. Wang (U. California, Riverside)