Land Surface Modeling and Dry Deposition

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Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

Outline

- Pleim-Xiu Land Surface Model
  - Model Description
  - Landuse and Soil Parameters processing
  - Data assimilation
  - Model evaluation
- M3Dry
  - Connection w/ PX LSM
  - Surface resistances
  - Model evaluation

PX-LSM Features

- Originally based on Interactions between Soil, Biosphere, and Atmosphere (ISBA) model
  - Noilhan and Planton (1989)
- Soil Moisture and Temp in two Layers
  - Surface (1 cm), Root Zone (1 m)
- Three pathways for evaporation
  - Ground evaporation - f(sfc soil moisture)
  - Wet canopies - f(cwc)
  - Evapotranspiration - f(stomatal resistance)

$$R_{stb} = \frac{R_{st\,\min}}{1/LAI\, F_1(rad) F_2(sm) F_3(rh) F_4(T_a)}$$

PX-LSM Features (cont)

- Detailed Vegetation and Soil Data
  - USGS and STATSGO (1 km)
  - Grid cell aggregate parameters from fractional area LU and soil type data.
- Seasonal Vegetation Growth Model
  - Deep soil temperature for leaf-out
  - Planting dates and growth curves for crops
  - Green Vegetation fraction from AVHRR
- Indirect Soil Moisture Nudging
  - Model-obs surface temperature and humidity

Soil Moisture Nudging

$$\frac{\partial w_g}{\partial t} = \alpha_1\left(T^a - T^f\right) + \alpha_2\left(RH^a - RH^f\right)$$

$$\frac{\partial w_2}{\partial t} = \beta_1\left(T^a - T^f\right) + \beta_2\left(RH^a - RH^f\right)$$

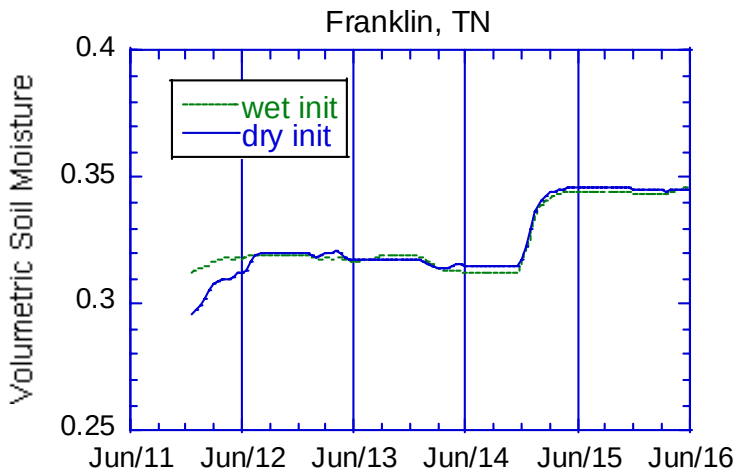
Nudging Strength

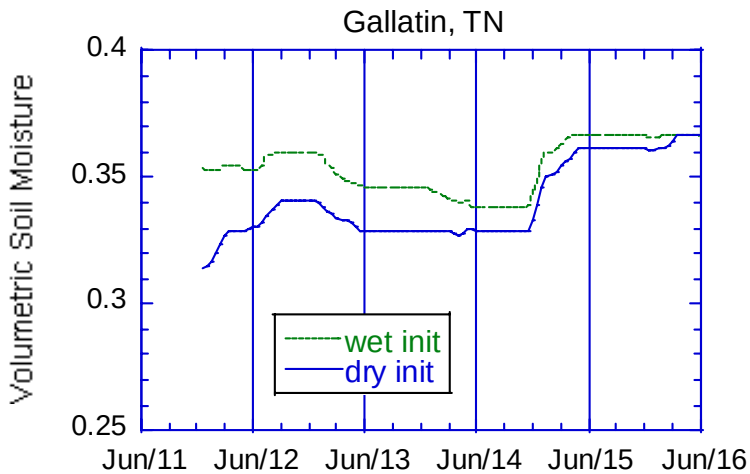
$$\alpha_{1,2} = A_{1,2} \frac{R_g}{S} F_{txt} \frac{R_{a\,\min}}{R_a} (1 - veg)$$

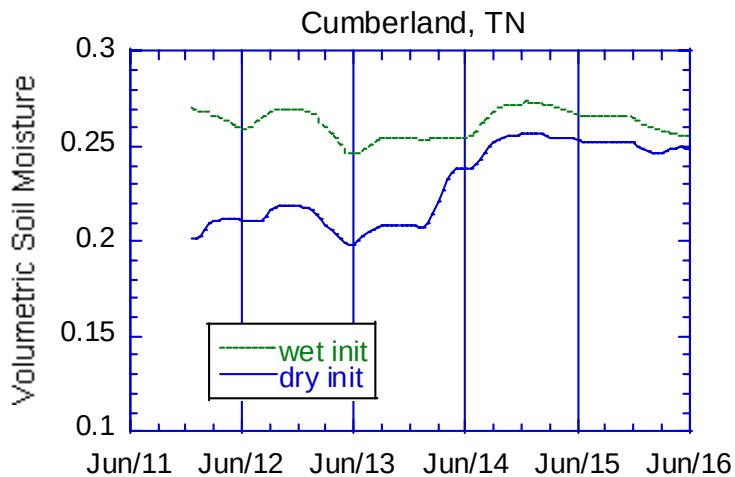
$$\beta_{1,2} = B_{1,2} \frac{R_{c\,\min} F_1 F_4 LAI}{R_{st\,\min}} F_{txt} \frac{R_{a\,\min}}{R_a} veg$$

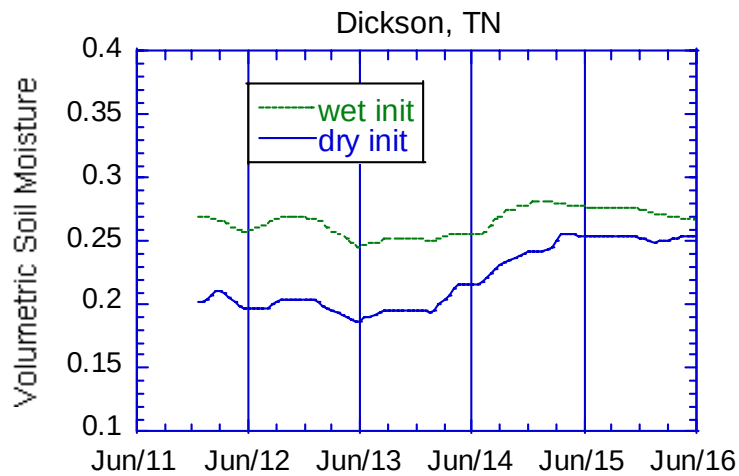
$$F_{txt} = \frac{W_{wlt}(stype) + W_{fc}(stype)}{W_{wlt}(loam) + W_{fc}(loam)}$$

Deep soil moisture initialization

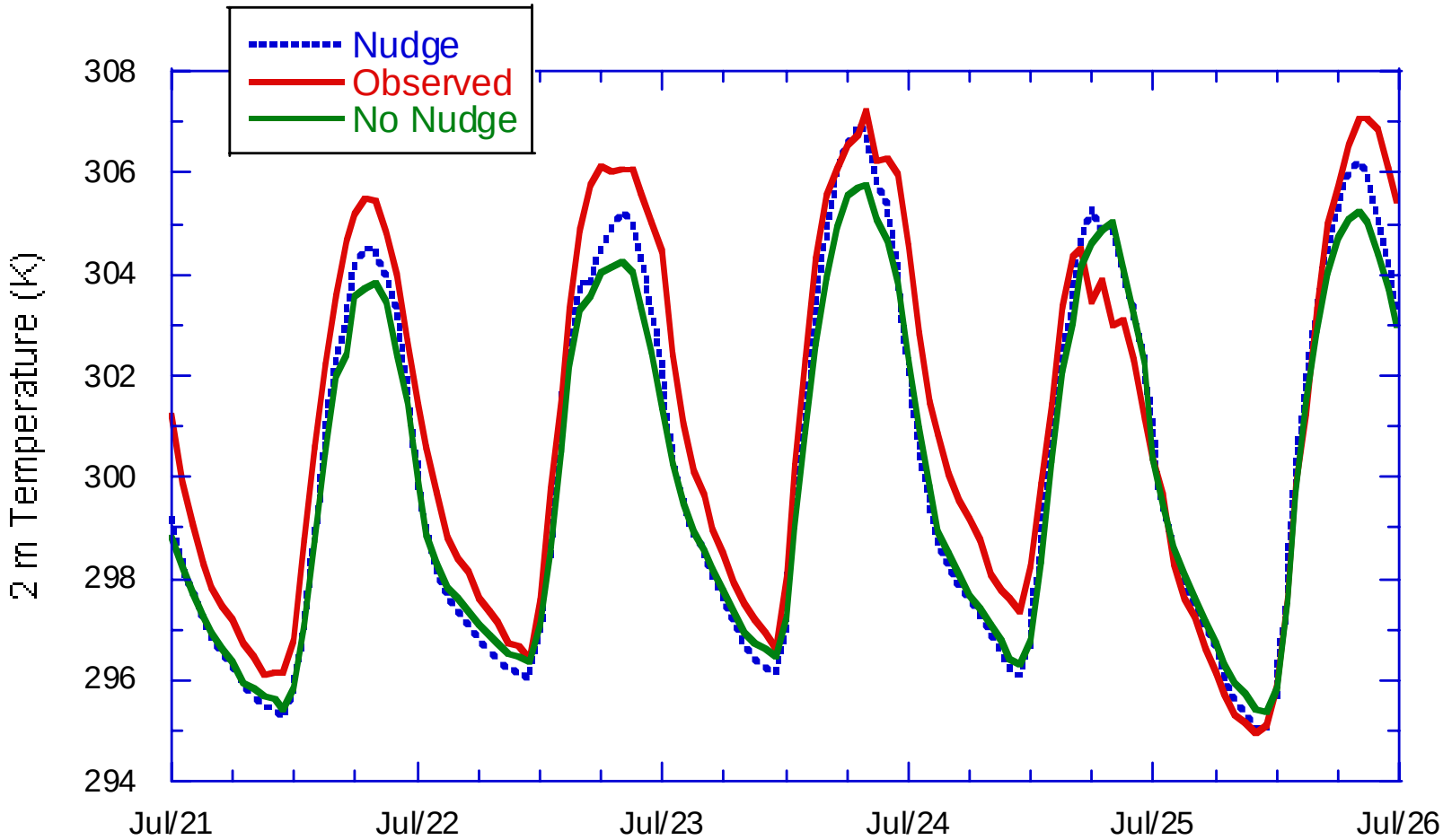




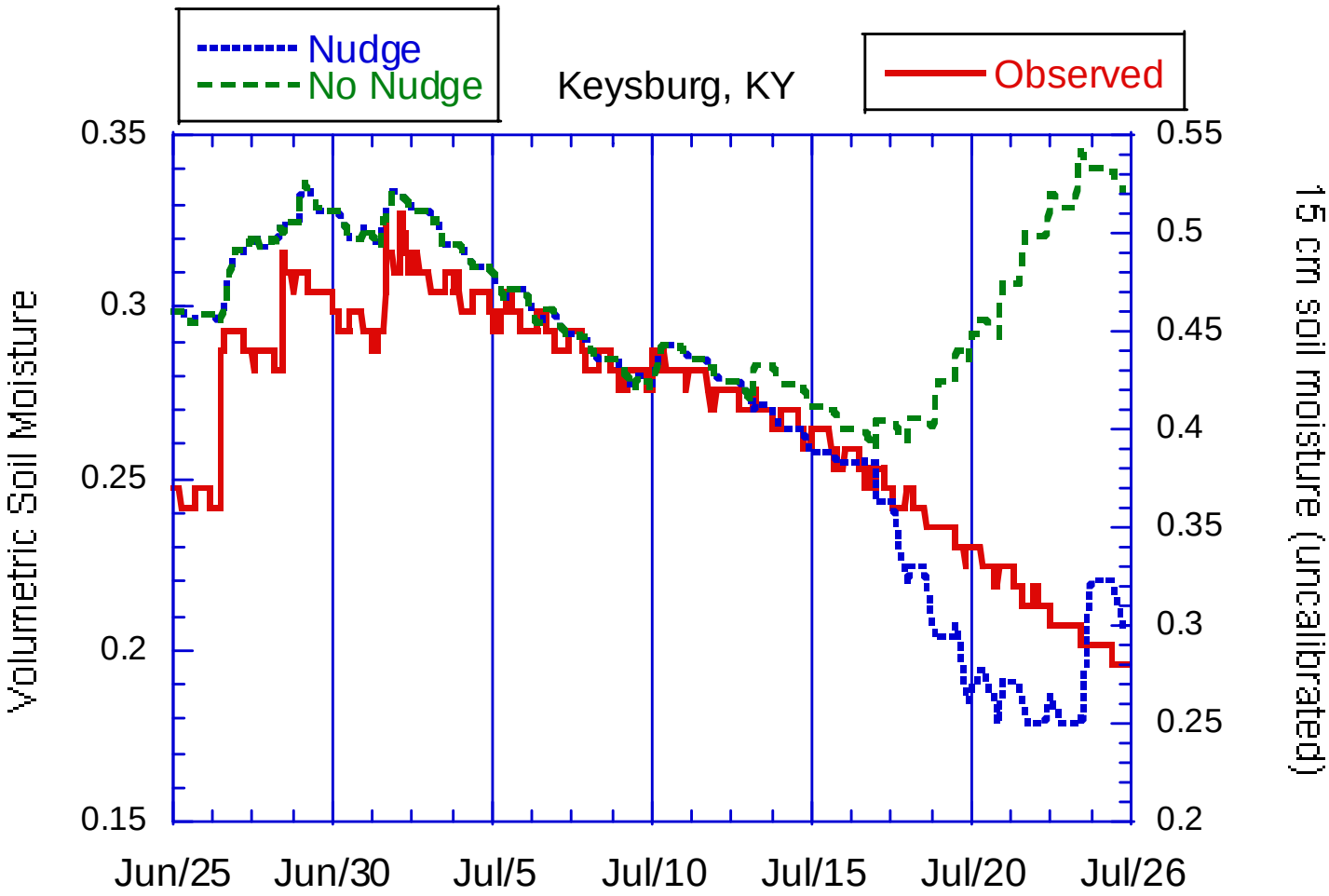




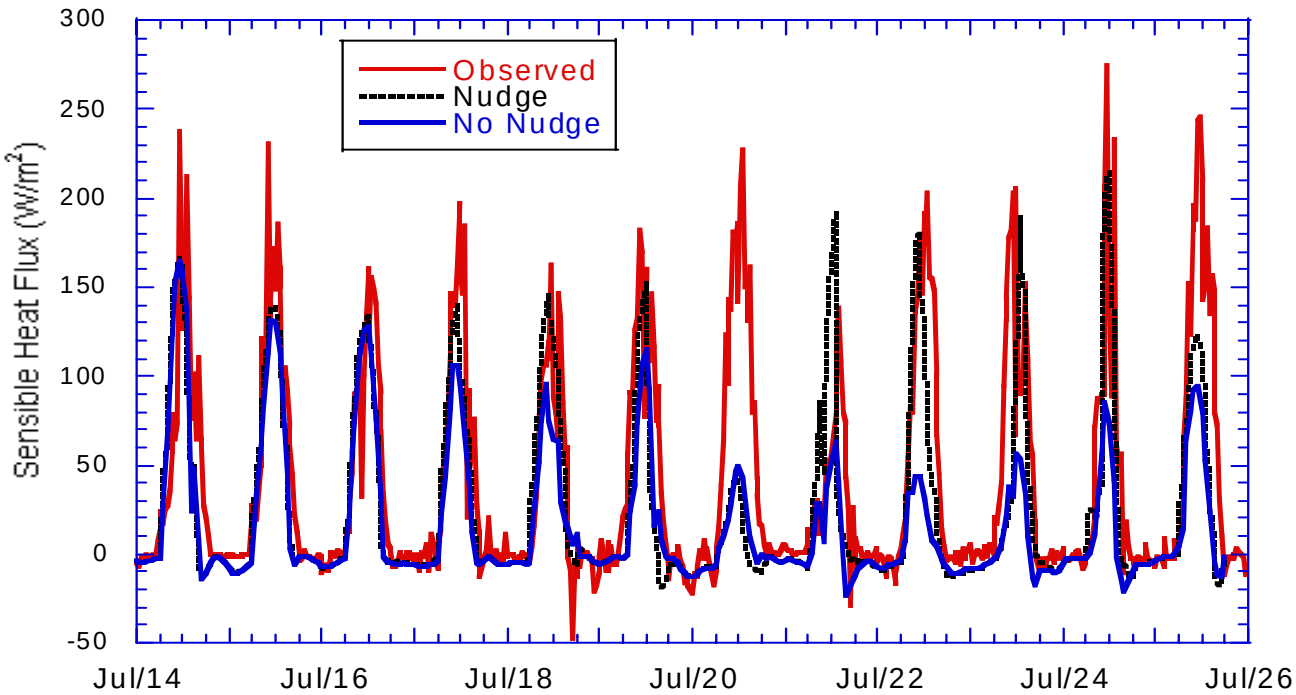
2-m temperature over multi-state region in eastern US



Deep soil moisture



Sensible heat flux



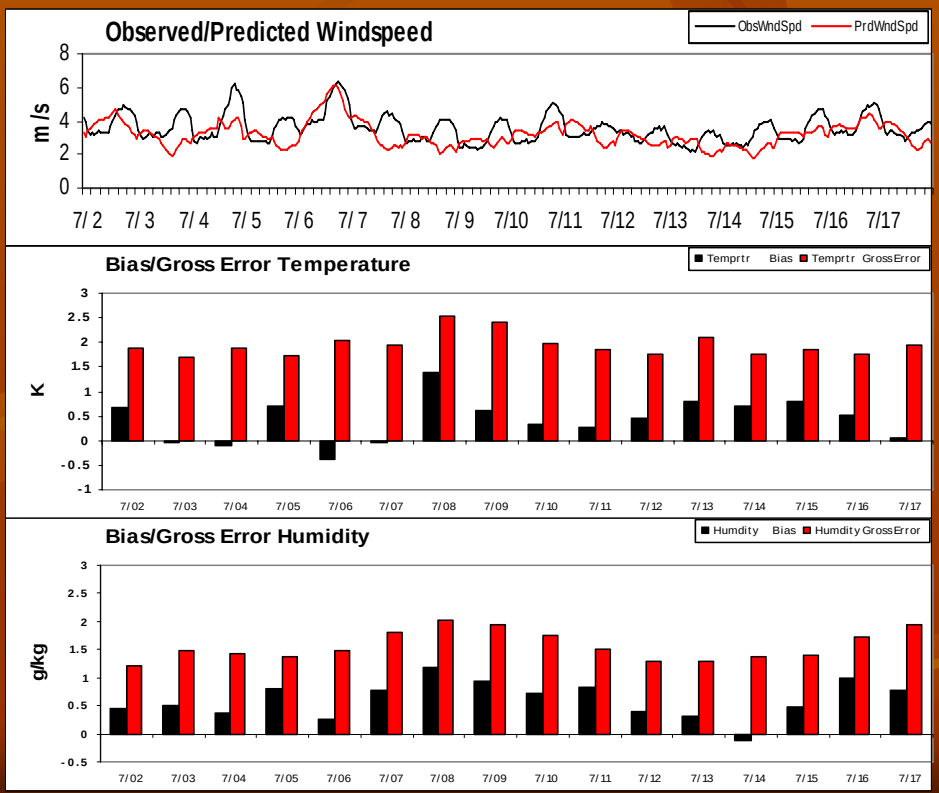
Development and Evaluation

- Field Experiment comparisons
  - 1-D: Wangara, FIFE (Pleim & Xiu 95)
  - MM4: Bondville corn (Pleim et al, 96)
  - MM5: FIFE (Xiu & Pleim 2001)
  - MM5v3: Soybeans in KY and Forest in NY (Pleim et al 2001)
  - MM5v3: SOS 1999 – SM data assimilation experiments (Pleim & Xiu 2003)
- Model releases
  - PX LSM in NCAR release of MM5v3
  - M3dry in 2001 release of CMAQ

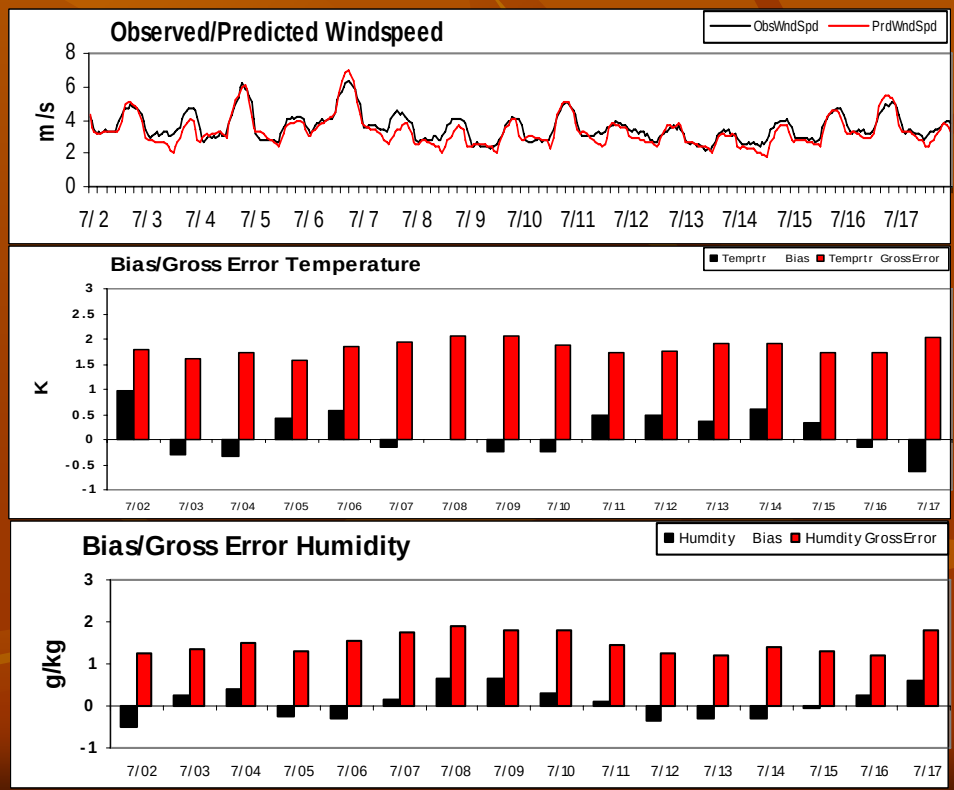
CENRAP Sensitivity testing (Calvin Ku)

- Pleim-Xiu scheme yielded significant & widespread improvements over all configurations in all regions, particularly in July
  - January evaluation shows no clear disbenefits, and minor benefits
- Greatest benefits obtained when PX uses continuos soil T&q fields
  - Requires use of INTERPX & that the 5-day blocks be run sequentially

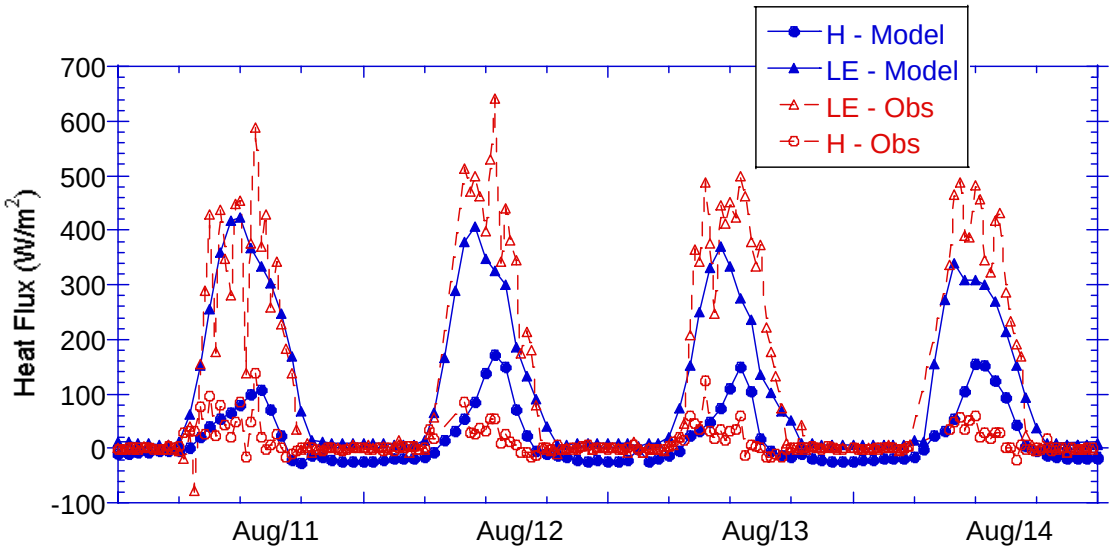
Basecase



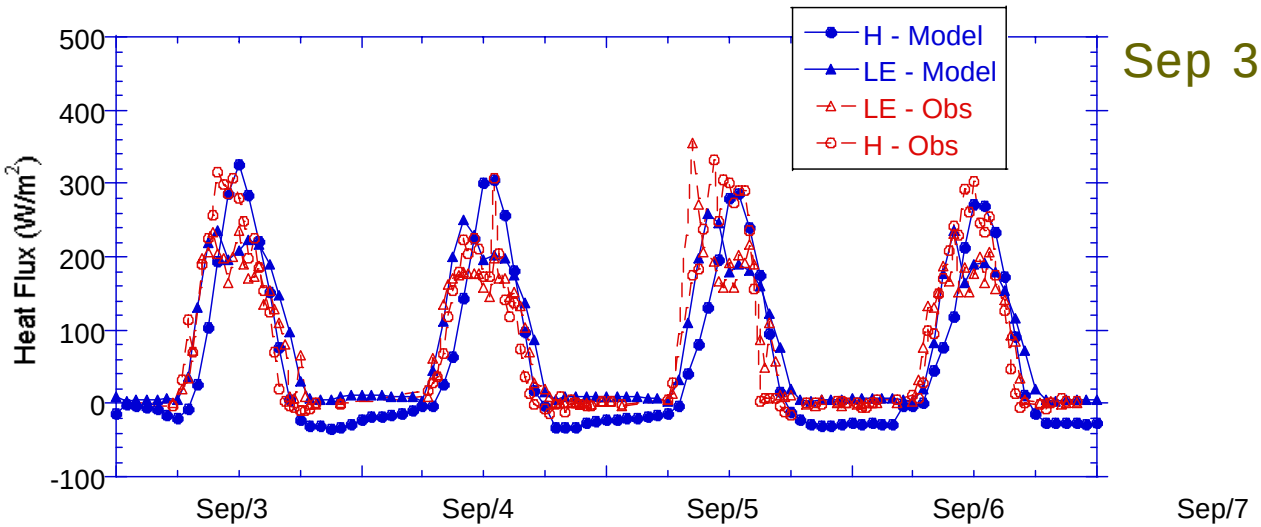
Pleim-Xiu



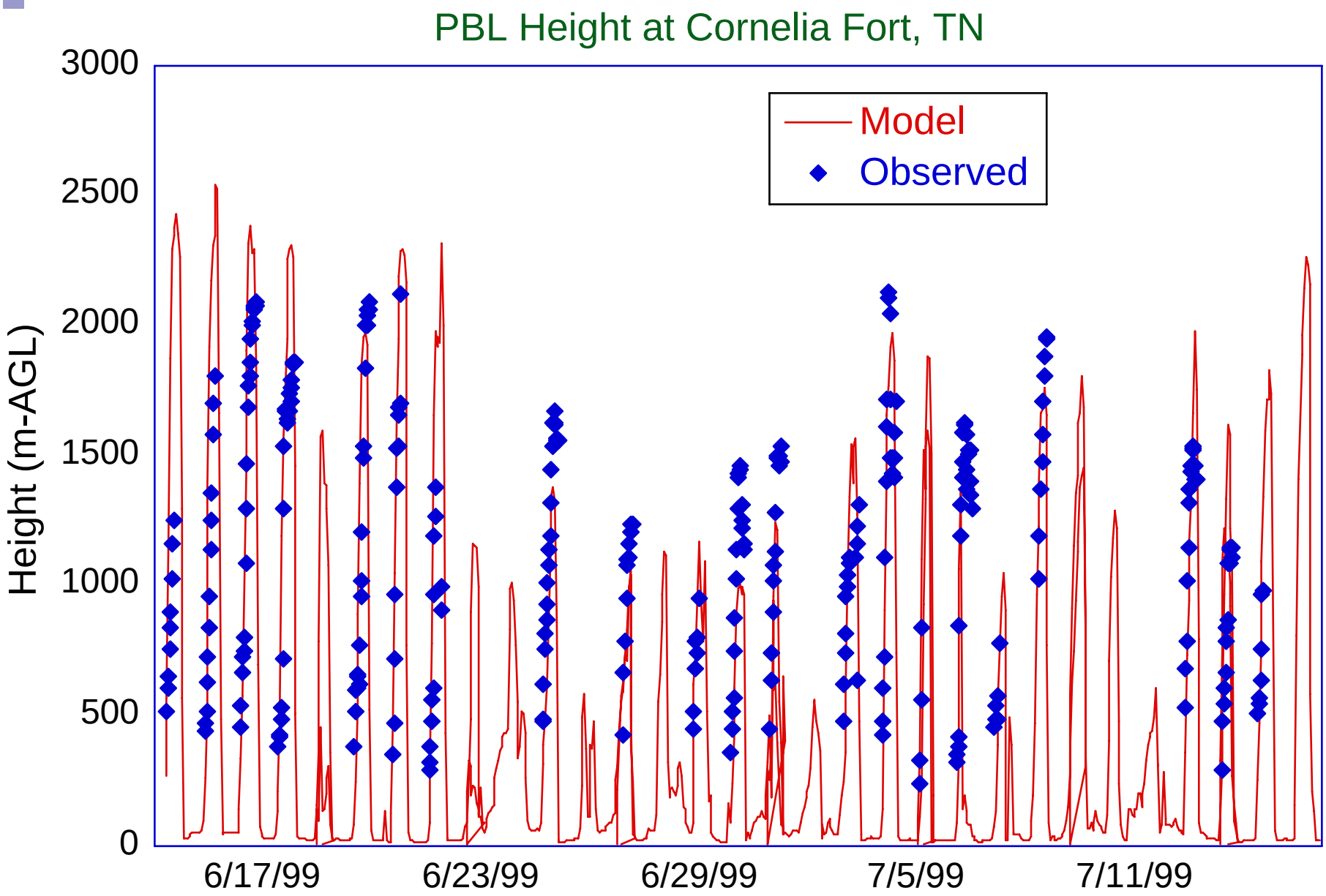
Sensible and Latent Heat Flux



Aug 11-15, 1995



Sep 3-6, 1995


PBL Height at Cornelia Fort, TN
Model
Observed
Height (m-AGL)
3000
2500
2000
1500
1000
500
0
6/17/99
6/23/99
6/29/99
7/5/99
7/11/99

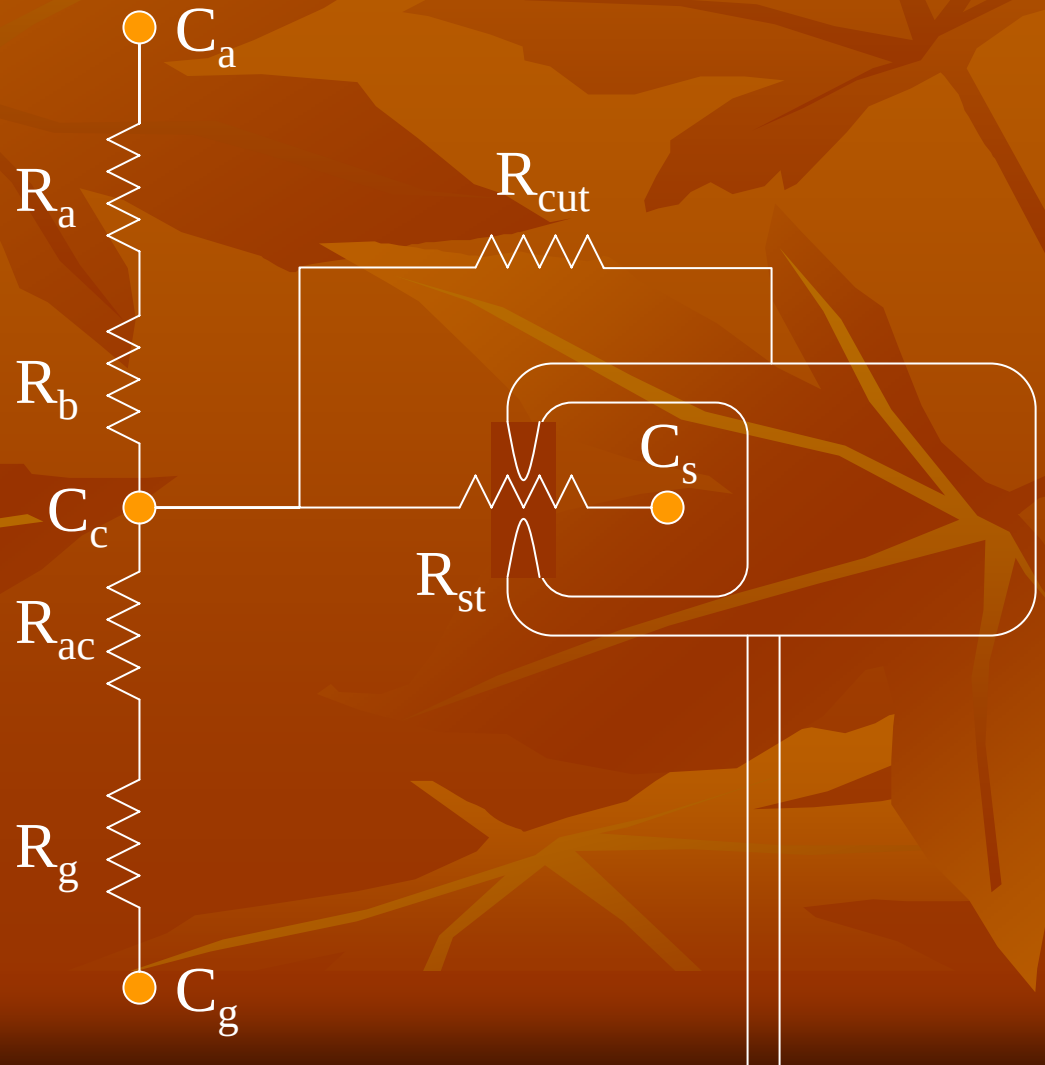
Models-3 Dry Deposition Models

1. M3dry coupled to the PX-LSM (option in MM5v3)
2. M3dry not coupled to LSM
   - Stomatal resistance parameterized without variable soil moisture
3. RADM dry deposition model by Wesely (1989)
   - Component resistances by chemical species and land-use (11 categories)
   - No dependence on soil moisture

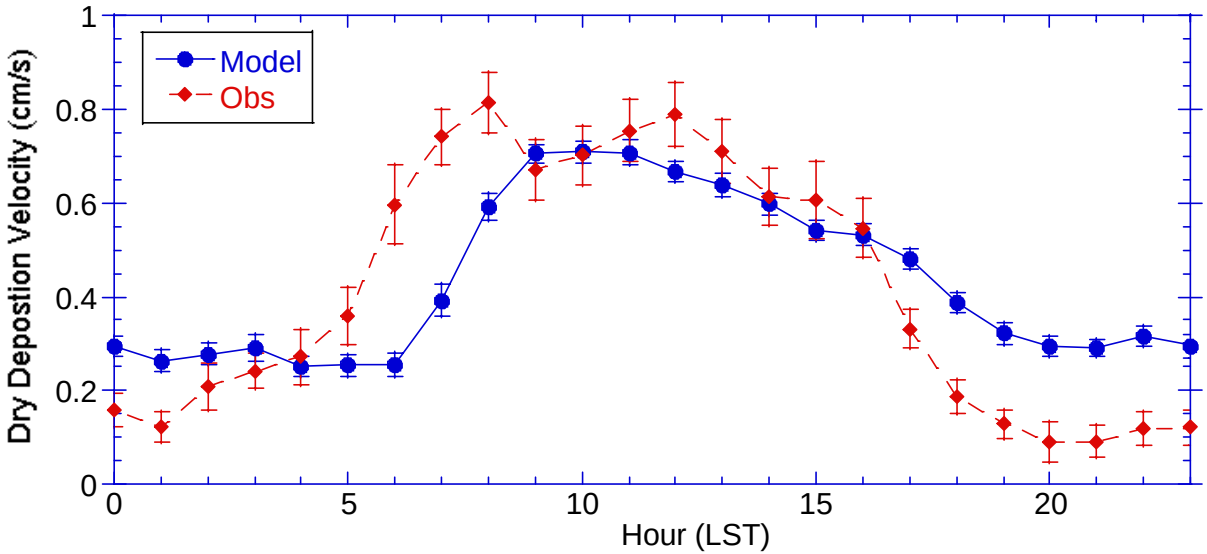
Models-3 Dry Deposition Model (M3dry)

- R_{st} and R_a from LSM
- Benefits of coupling to LSM:
  - Stomatal pathway constrained by surface energy budget
  - Responsive to changing moisture and vegetation
  - Benefits from indirect nudging
- Deposition to leaf cuticle and ground surfaces by solubility and reactivity scaling

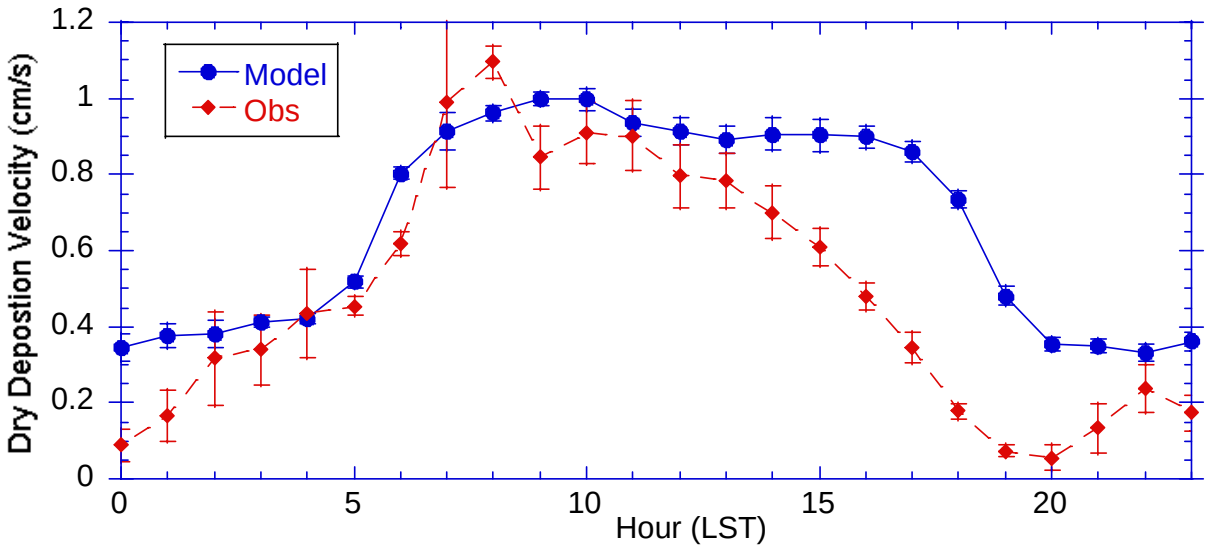
Schematic of resistance model



Dry Deposition Velocity of O_3



Soybeans
Keysburg, KY
Aug 1 – Sep15, 1995



Mixed Forest
Sand Flats, NY
July 13-30, 1998

Recent Dry Deposition developments

- Modifications for MCIP2.2 and CMAQ03
  - Updated Henry's law and Diffusivities
  - Added pathway to wet ground
  - New ammonia cuticle resistance based on Sutton et al. (1998) and Wyers and Erisman (1998):

$$r_{cut} = 4000 \exp(-0.054 RH)$$

  - Added pathway to snowpack:

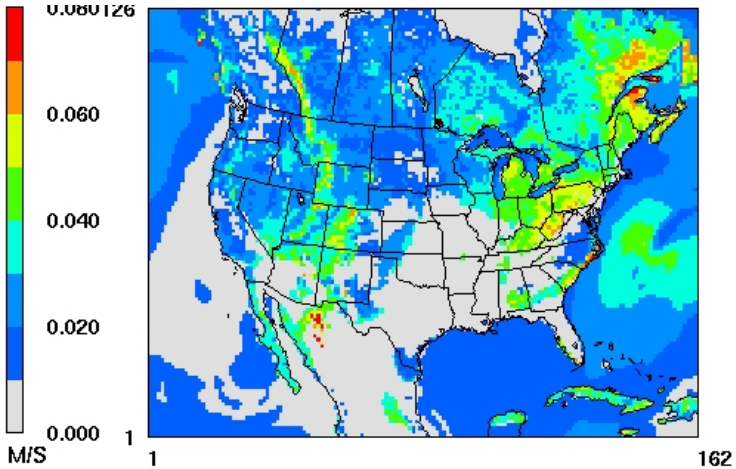
$$G_{snow} = \frac{1 - X_m}{r_{ice}} + \frac{X_m}{(r_{snowdiff} + r_{wet})}$$

$$X_m = 0.02(T_{1.5} - (T_F - 1.0))^2; X_m \leq 0.5$$

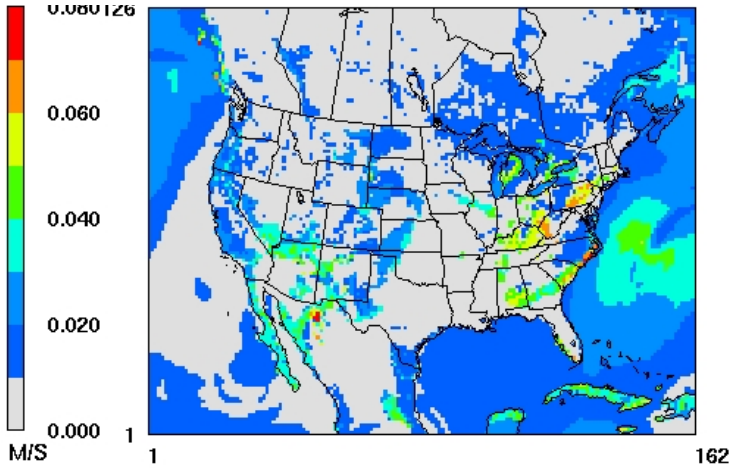
References: Bales et al. (1987), Erisman et al. (1994)

Comparison of winter mods to M3dry

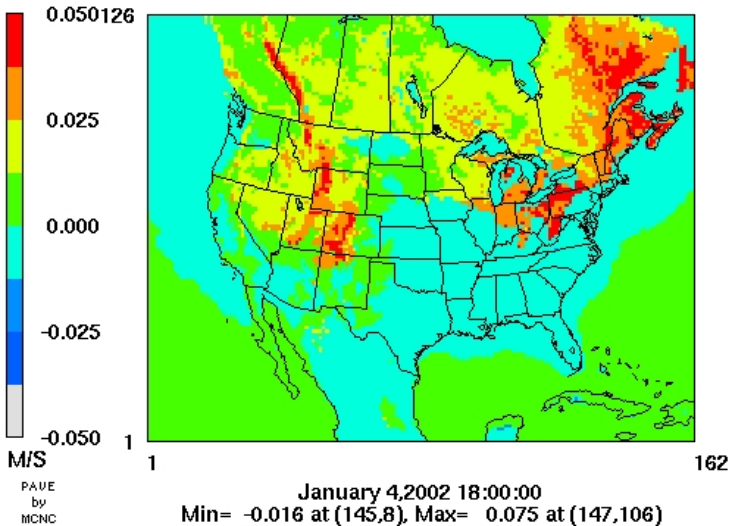
V_d of NH_3 v2.1



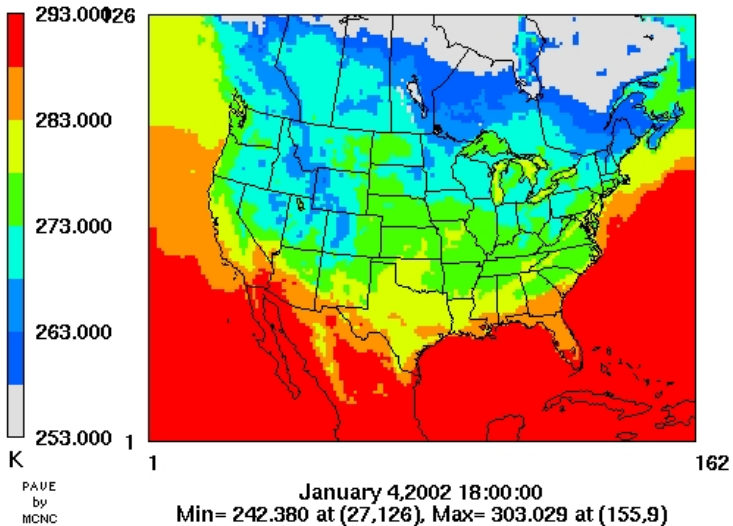
Vd of NH3 v2.2



v2.1-v2.2



T(ground)



Ongoing and Future Work

- Add PX LSM to WRF and include snow model ala NOAH or RUC (in collaboration w/ UNC-CEP, NCAR)
- Assess Photosynthesis based models for LSM and Dry Deposition
- Re-examine aerosol Dry deposition
- Two-way surface exchange for NH_3 (in collaboration w/ NASA GSFC)