Integrating Remote Sensing Products to Improve the Representation of Vegetation and Transpiration Processes in the Noah LSM Model

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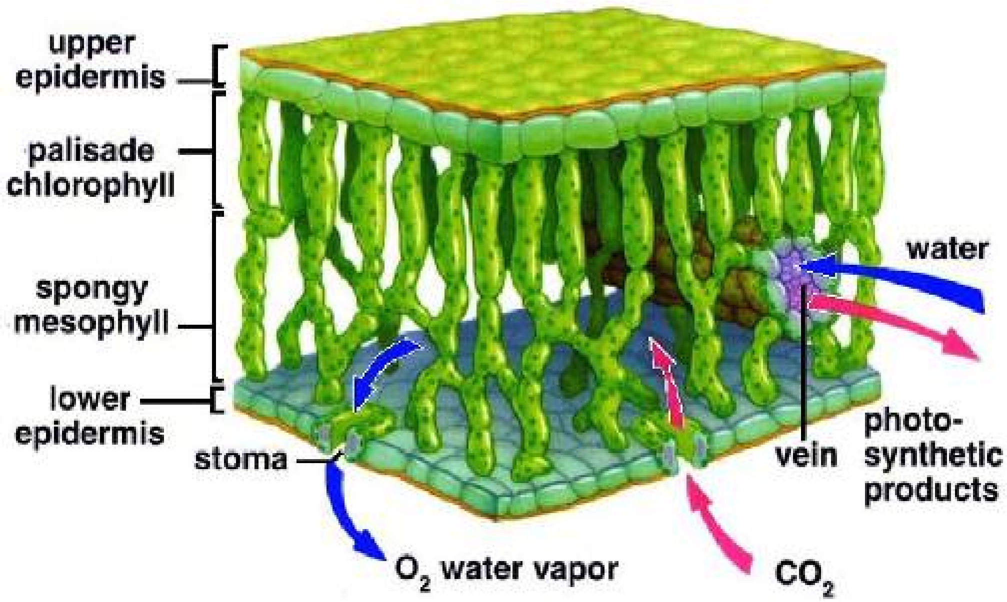
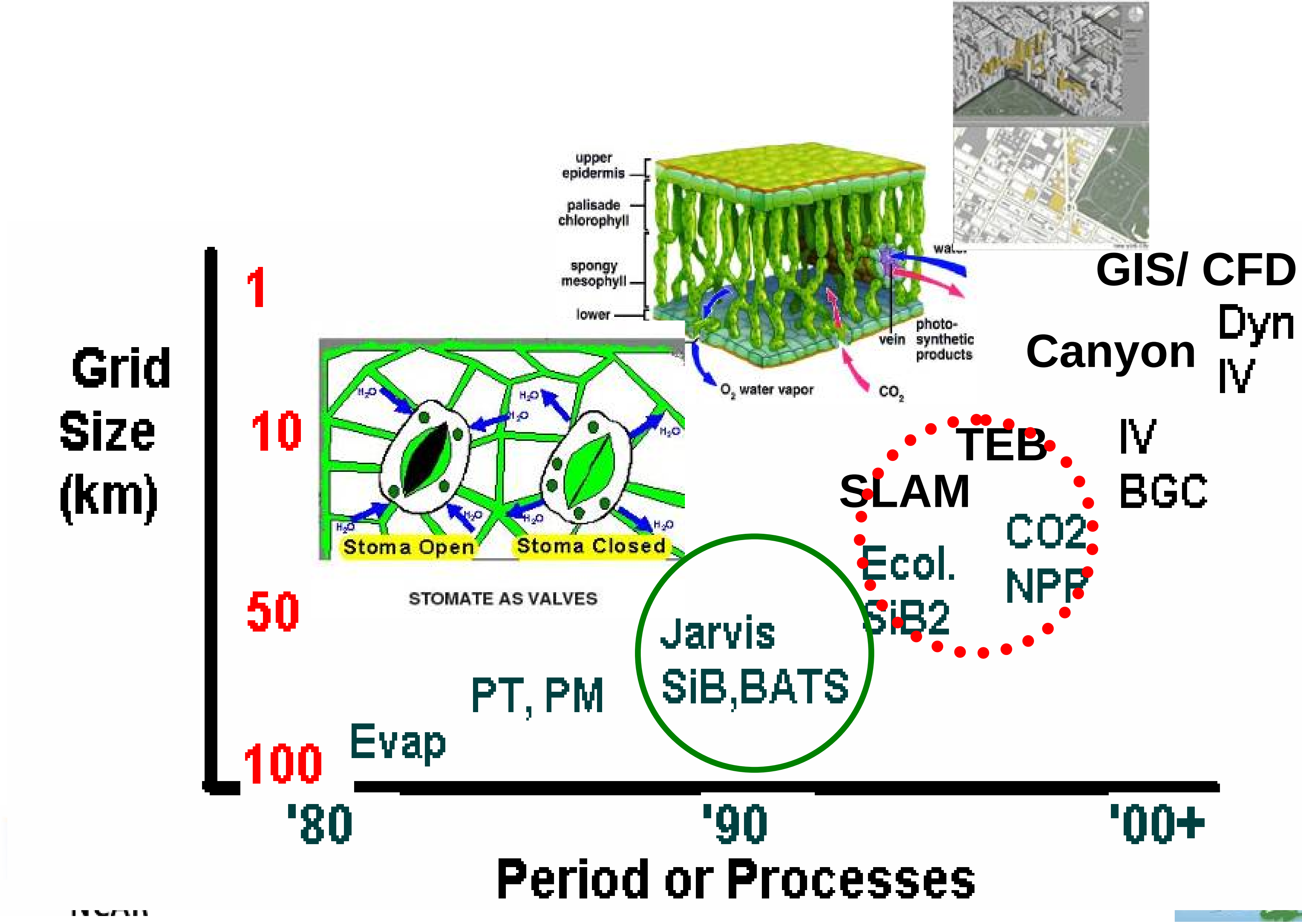
Motivations

- Evapotranspiration is the most effective and sustainable way to transport water vapor to the atmosphere
- Jarvis-type canopy resistance (Rc) formulation still widely used in coupled NWP/LSM models (e.g., WRF/Noah)
  - Jarvis-type scheme relies on minimum stomatal resistance (difficult to measure)
- This effort explores the use of advanced Rc schemes and modern-era remote-sensing data to improve
  - water vapor in WRF/Noah
  - deposition velocity in WRF-Chem/Noah
- Study conducted in
  - Long-term uncoupled runs
  - Coupled WRF/Noah runs
  - USGS and the new MODIS LULC dataset



Land Surface Models ‘Trends’ (as function of grid size)



Jarvis Scheme vs Ball-Berry Scheme

Jarvis scheme

$$R_c = \frac{R_c\_\min}{LAI \times F1 \times F2 \times F3 \times F4}$$

LAI – Leaf Area Index,
F1 ~ f (amount of PAR)
F2 ~ f(air temperature: heat stress)
F3 ~ f(air humidity: dry air stress)
F4 ~ f(soil moisture: dry soil stress)

Fundamental difference: evapotranspiration as an ‘inevitable cost’ the foliage incurs during photosynthesis or carbon assimilation

A_n: three potentially limiting factors:

1. efficiency of the photosynthetic enzyme system
2. amount of PAR absorbed by leaf chlorophyll
3. capacity of the C3 and C4 vegetation to utilize the photosynthesis products

Ball-Berry scheme in GEM (Gas Exchange Model)

$$g_s = m\frac{A_n}{C_s}h_s p_s + b \qquad R_c = \frac{1}{g_s}$$

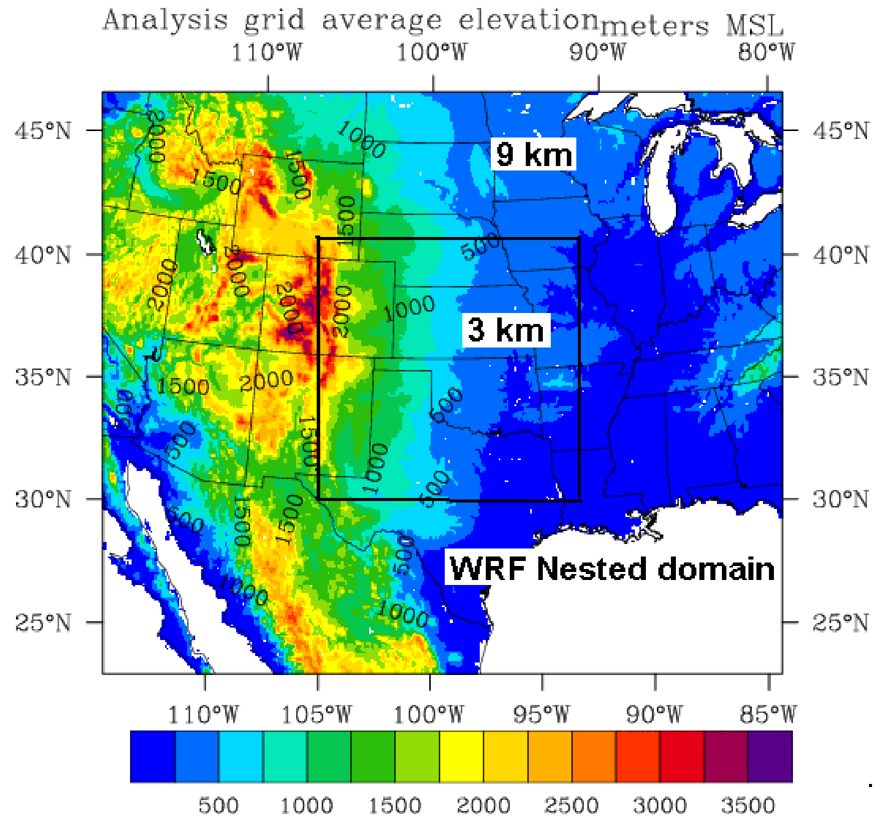
hs – relative humidity at leaf surface
ps – Surface atmospheric pressure
An – net CO2 assimilation or photosynthesis rate
Cs – CO2 concentration at leaf surface
m and b are linear coeff based on gas exchange consideration

GEM model reference: Niyogi, Alapaty, Raman, Chen, 2007: JAMC, in revision.

NCAR High-resolution Land Data Assimilation System:

Capturing Small-Scale Surface Variability

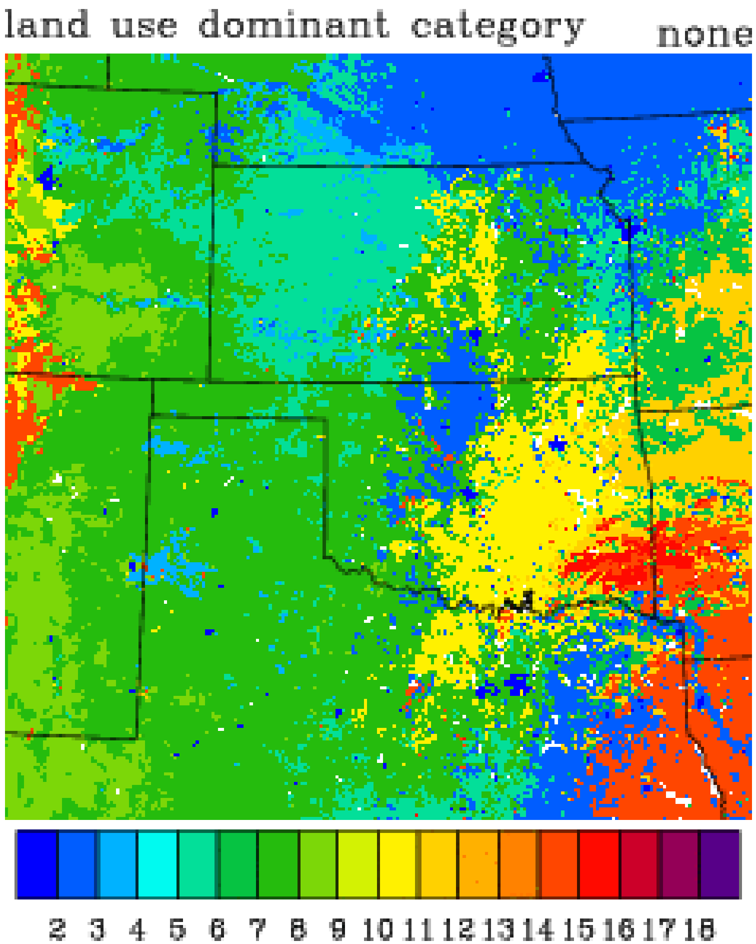
- Input:
  - **4-km hourly NCEP Stage-II rainfall**
  - **1-km landuse type and soil texture maps**
  - 0.5 degree hourly GOES downward solar radiation
  - 0.15 degree AVHRR vegetation fraction
  - T,q, u, v, from model based analysis
- Output: long term evolution of multi-layer soil moisture and temperature, surface fluxes, and runoff

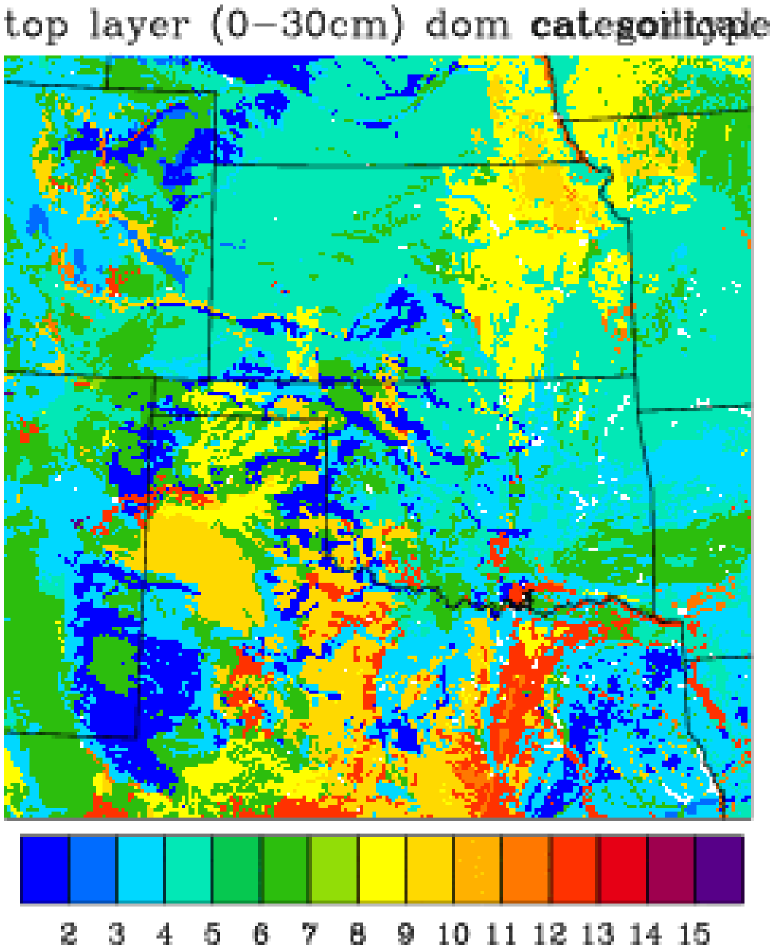


HRLDAS executed from January 2001 - July 2002

HRLDAS reference: Chen et al., 2007 (JAMC, in press)

USGS Land-use Type and Soil Texture in 3-km HRLDAS Domain





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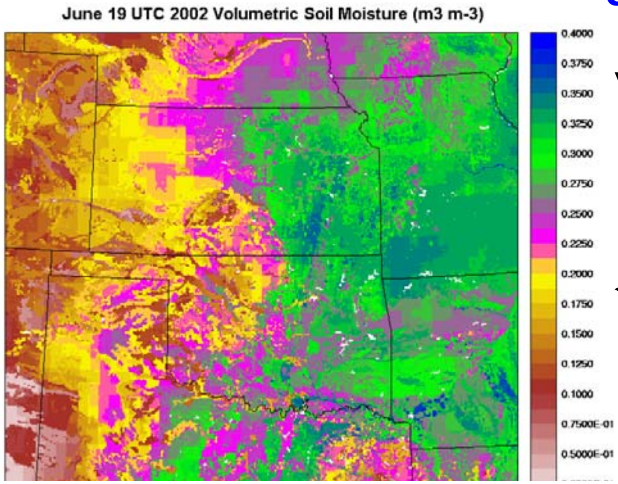
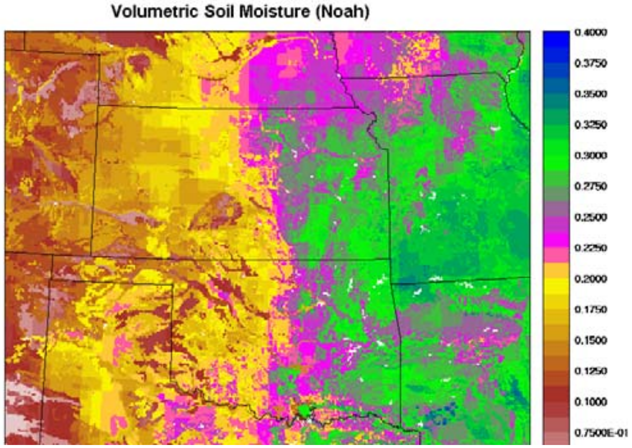
HRLDAS results valid at 1900 UTC June 1, 2002 after 18-month spin-up

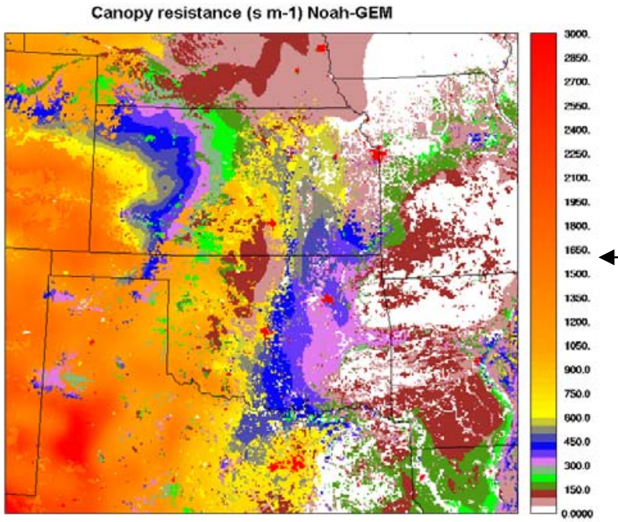


Volumetric soil moisture

Noah-GEM

Noah-JARVIS

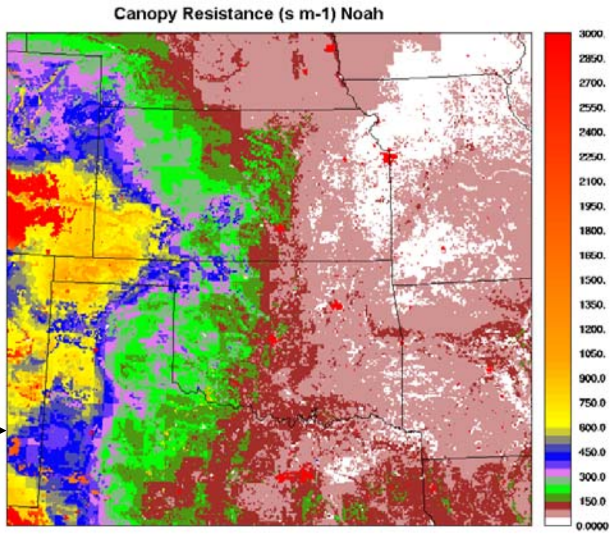




Canopy resistance

Noah-GEM

Noah-JARVIS



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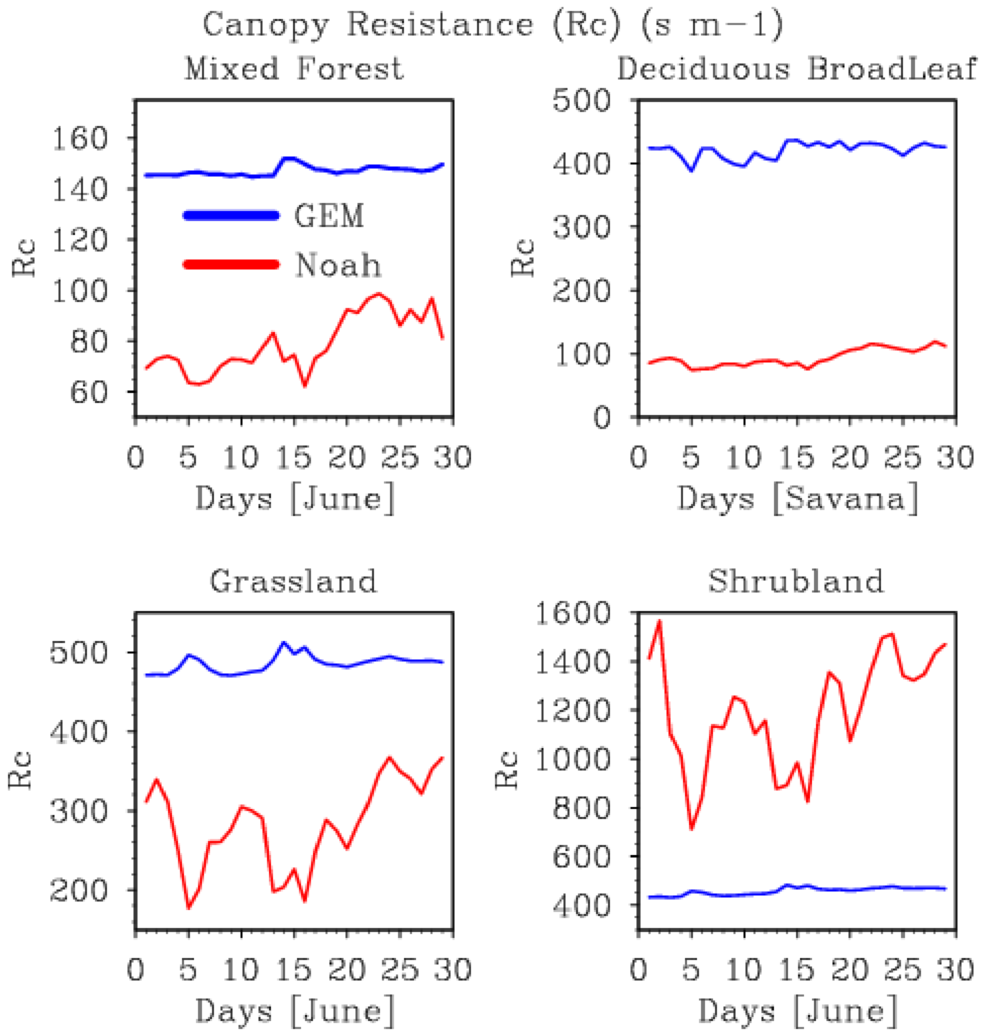
Rc Differences simulated by Noah-Jarvis and Noah-Gem

midday-mean and averaged for the same land-use types for June 2002



Higher Rc in Noah-GEM and less day-to-day variability for forested sites

Uncertainty in current land-use data to discern C3 and C4 grass (will be important for crops)

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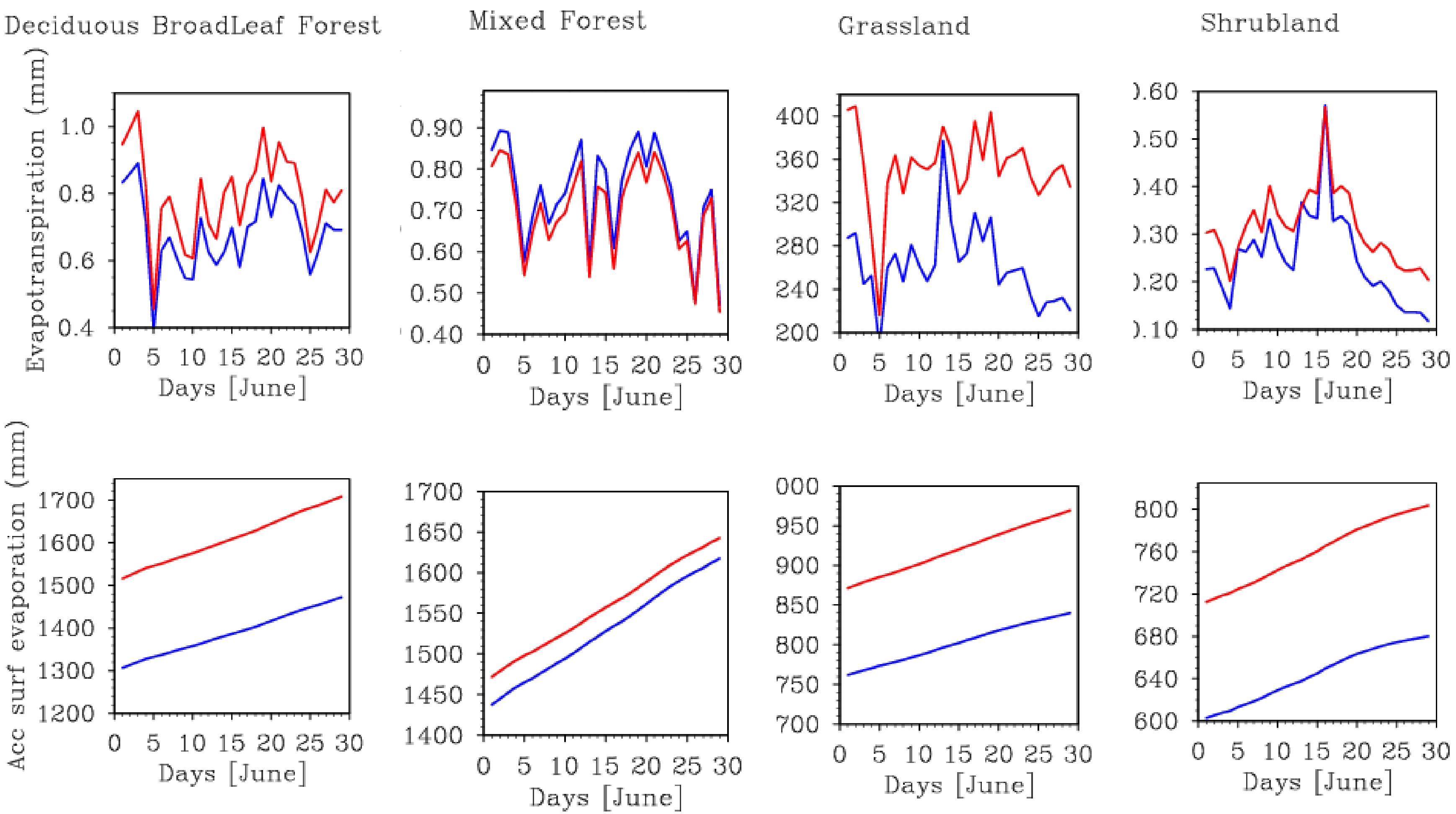
Uncertainty Introduced by Treating Vegetation Phenology

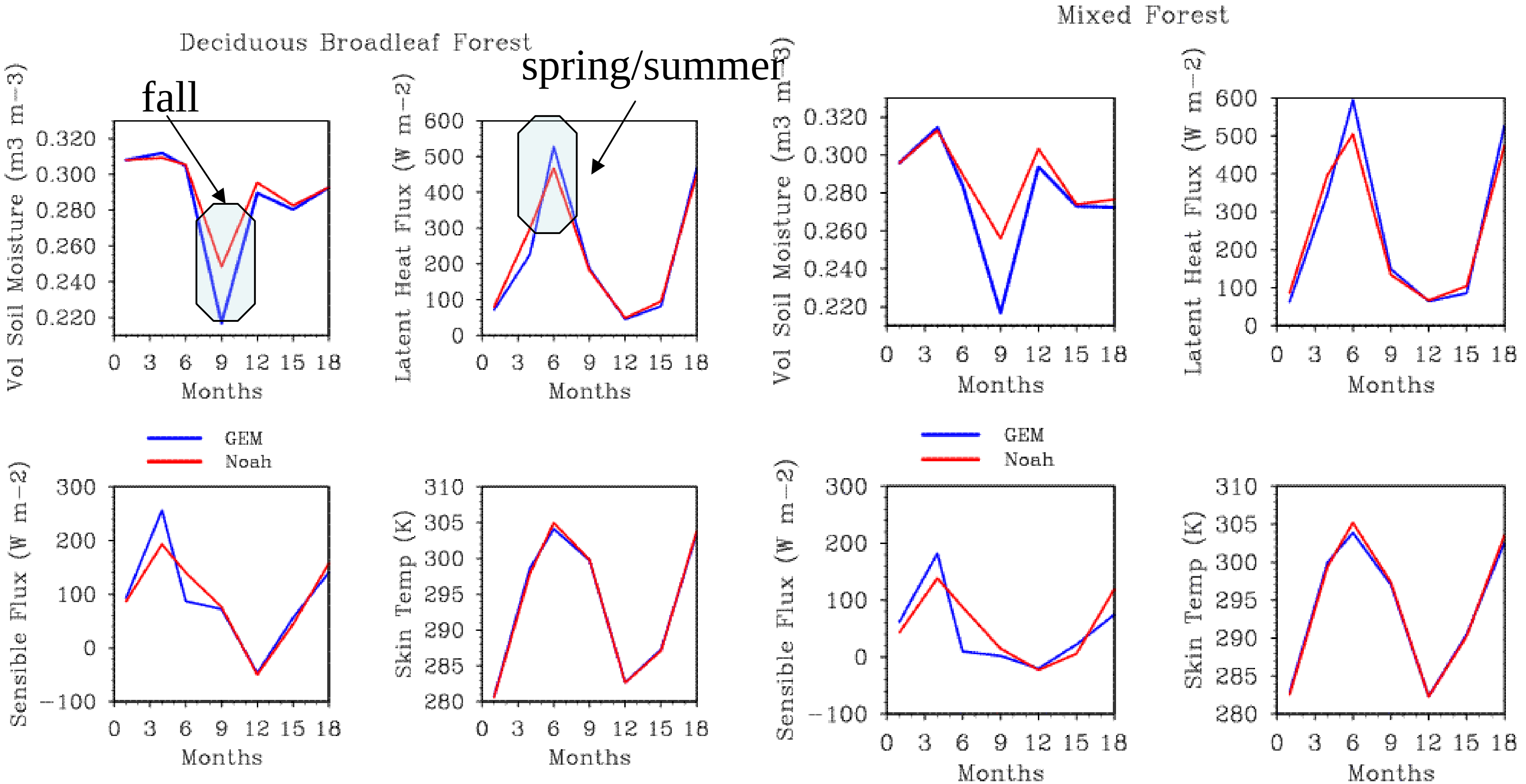
midday-mean evapotranspiration and accumulated total evaporation

Red: Noah-GEM with constant LAI, Blue: Noah-GEM with time-varying LAI



Different LAI can cause difference in evaporation ranging from 50 mm to 150 mm for the month of June

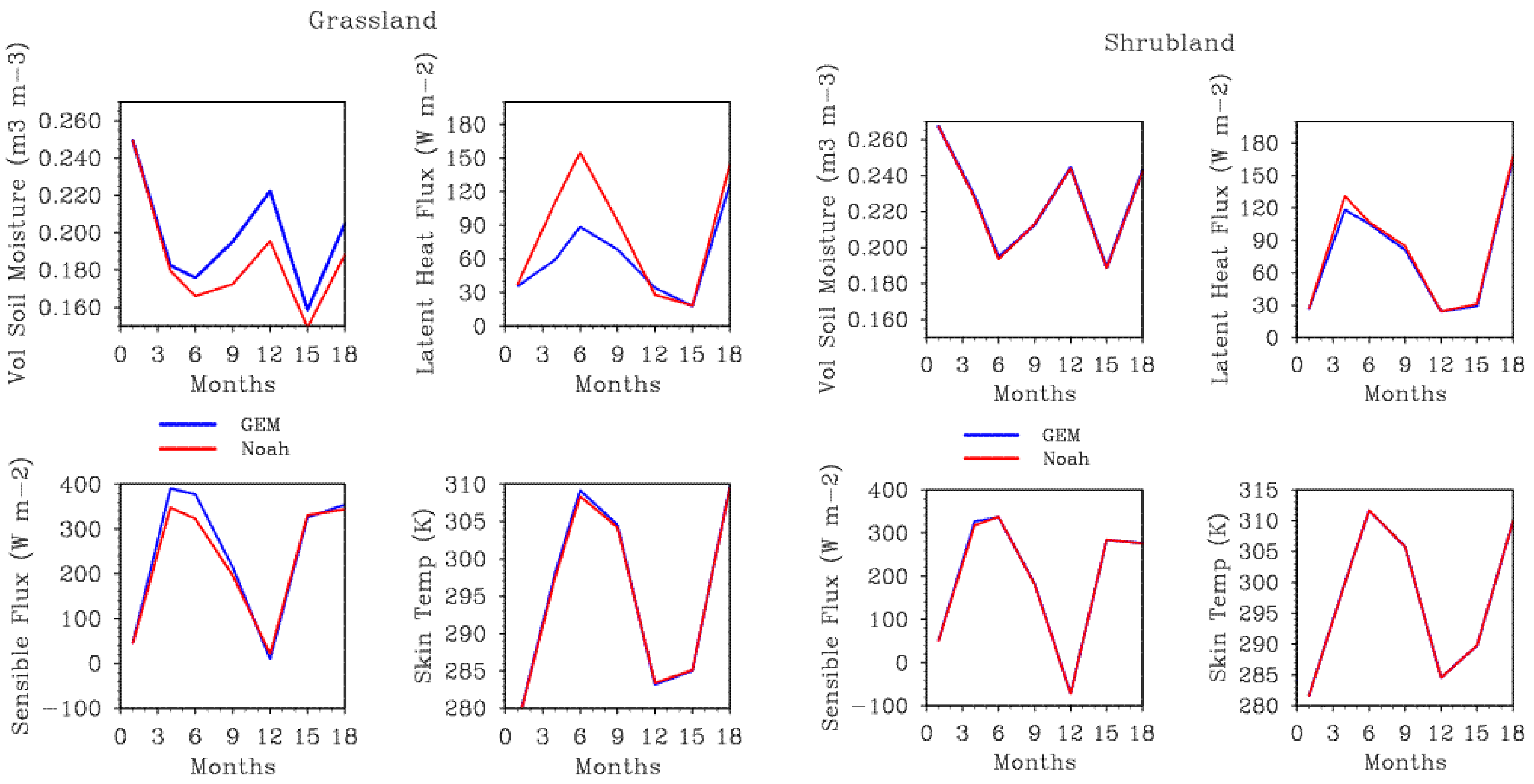
Differences in HRLDAS Long-Term Evolution of Soil Moisture and Fluxes



midday values at 30th of each month from Jan 2001-June 2002

GEM produce higher evaporation (spring and summer) and lower soil moisture in fall

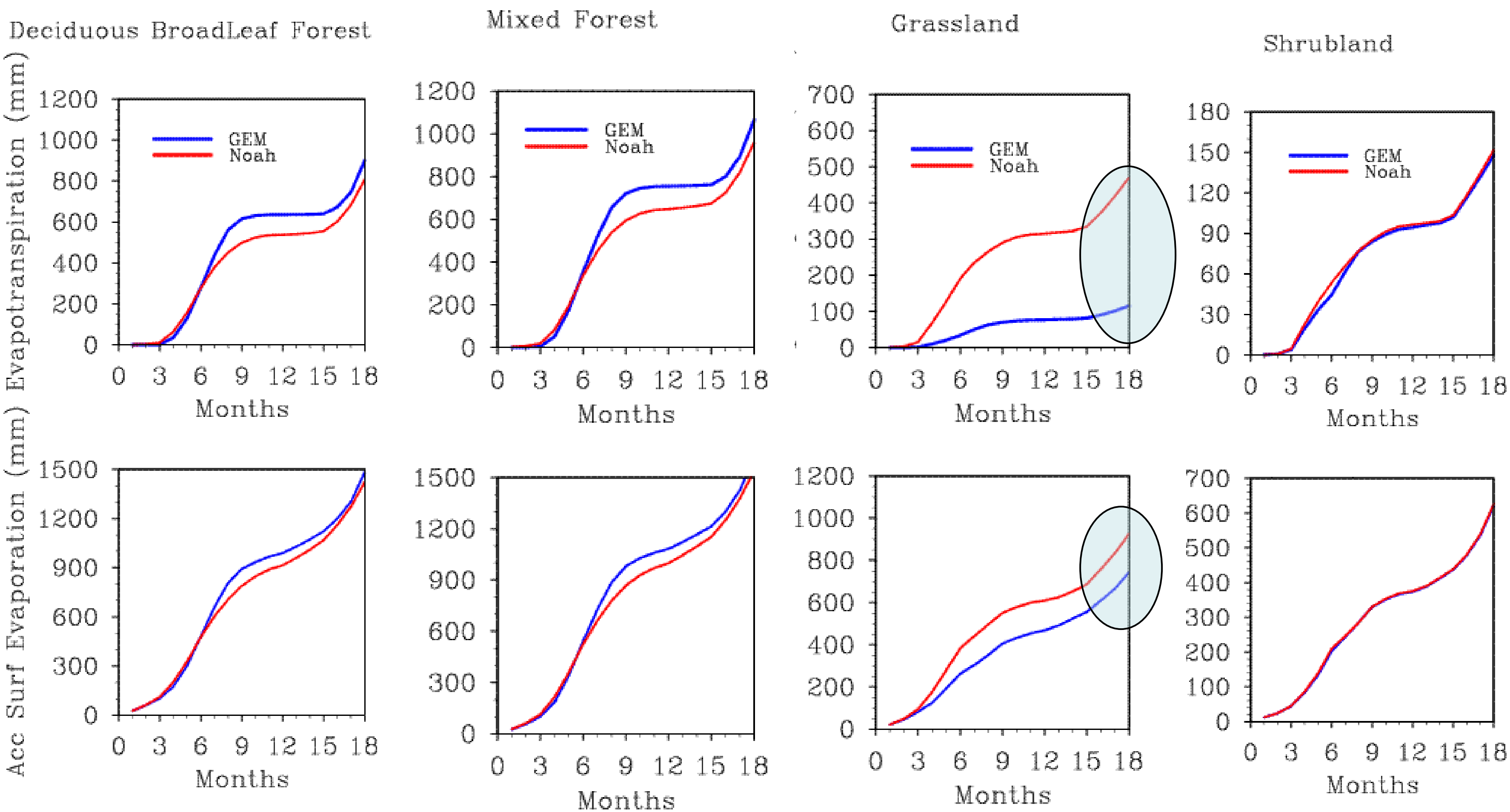
Differences in HRLDAS Long-Term Evolution of Soil Moisture and Fluxes



midday values at 30th of each month from Jan 2001-June 2002 averaged for all grassland and shrub sites.

GEM produce lower evaporation and higher soil moisture from spring to summer for grass

Differences in HRLDAS Long-Term Evaporation



Large differences in evapotranspiration is offset by surface evaporation

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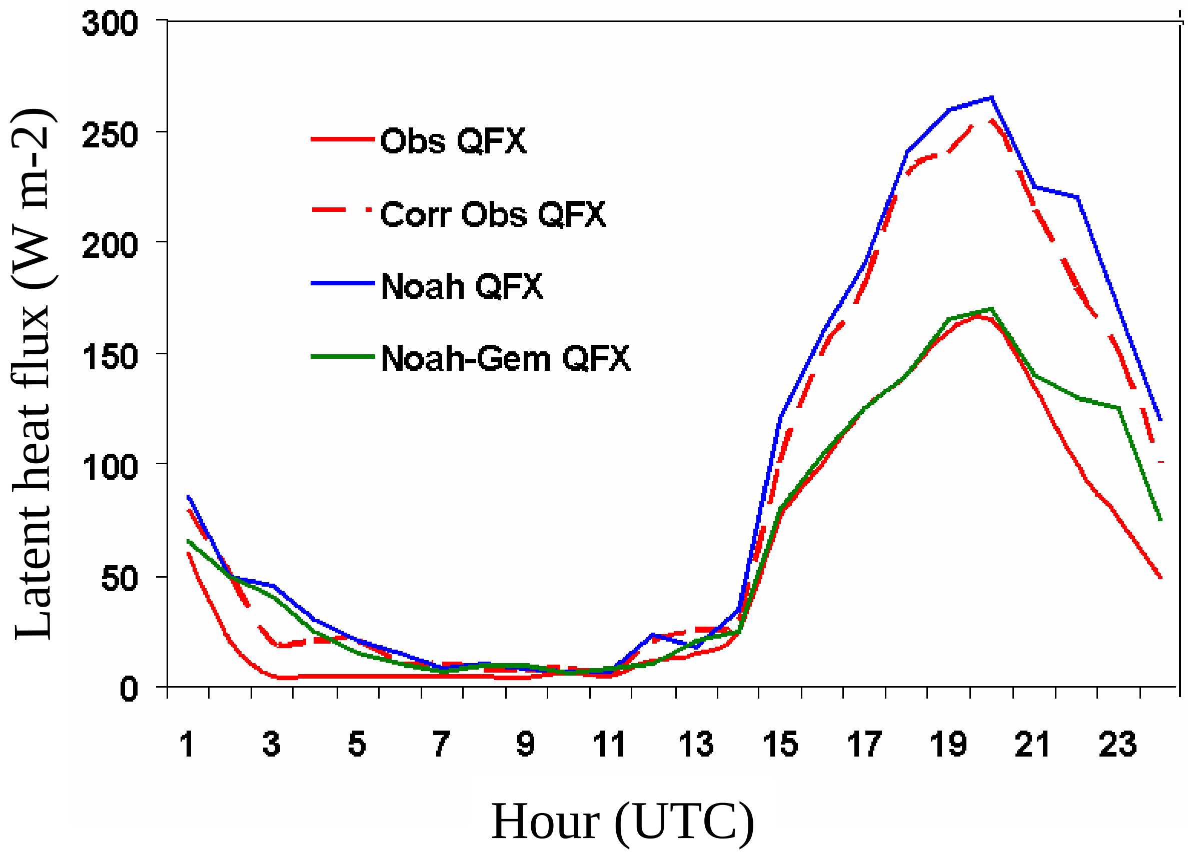
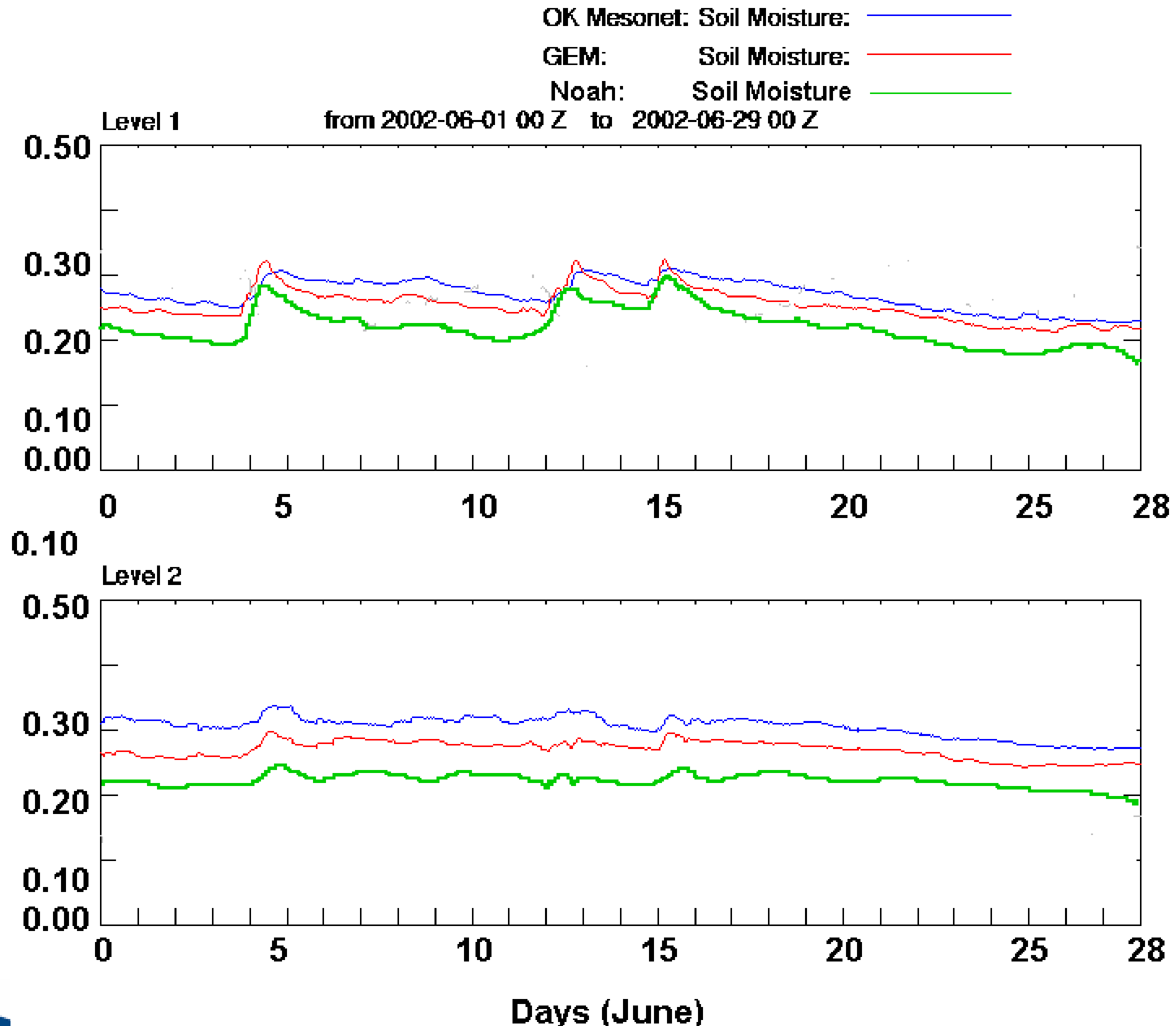
Preliminary Evaluation of Noah-GEM
averaged over nine IHOP_02 sites and for June



Preliminary Evaluation of Noah-GEM

soil moisture averaged over ~80 Oklahoma Mesonet Stations



GEM improved simulation of soil moisture at both 5-cm and 25-cm depths

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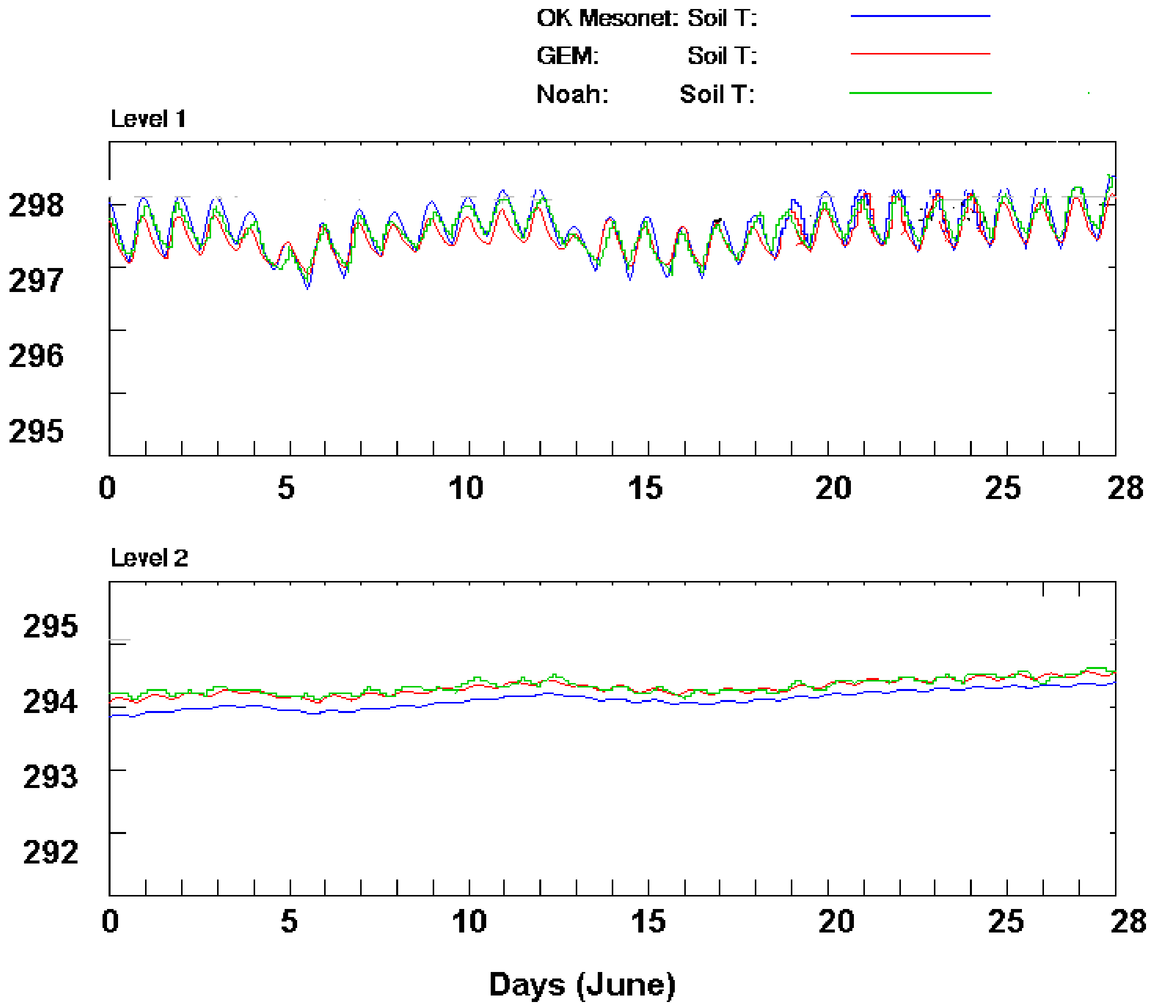
Preliminary Evaluation of Noah-GEM

soil temperature averaged over ~80 Oklahoma Mesonet stations



Lessons Learned

- Responses of Rc to environmental and soil conditions are fairly different in Jarvis and GEM formulations.
- That leads to large differences in soil moisture and latent heat fluxes (especially for evergreen forest and grassland).
- Incorporation of GEM in Noah is sensitive to description of land use (C3, C4 grass) vegetation phenology (LAI, vegetation fraction, etc). Need to develop C3, C4 or mosaic representation
- Noah-GEM produce better latent heat flux and soil moisture. Need to evaluate with AMERIFlux data.
- Need to explore a better use of today's high-resolution (temporal and spatial) remote-sensing data (particularly these recently developed in JCSDA)

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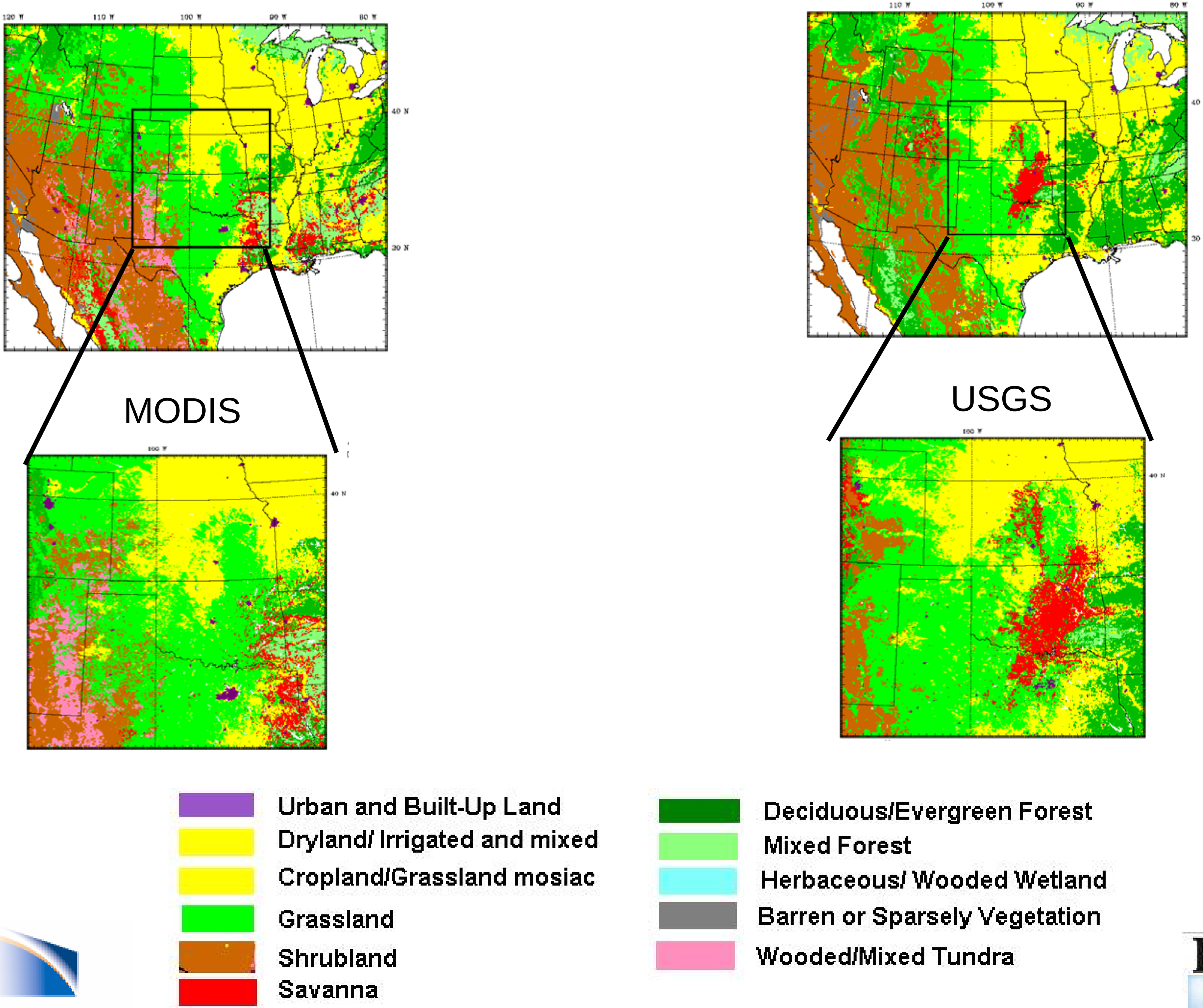

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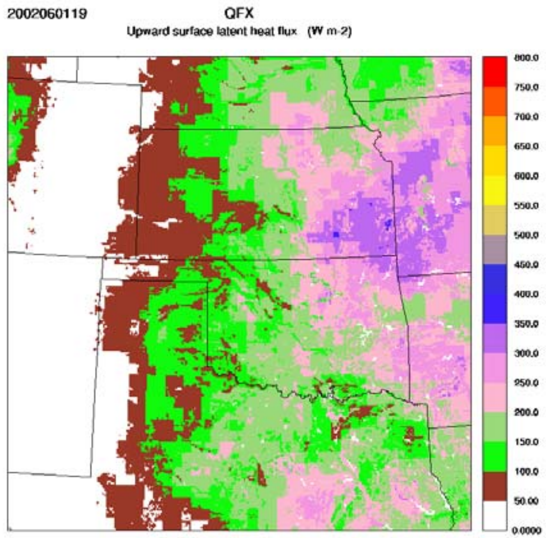
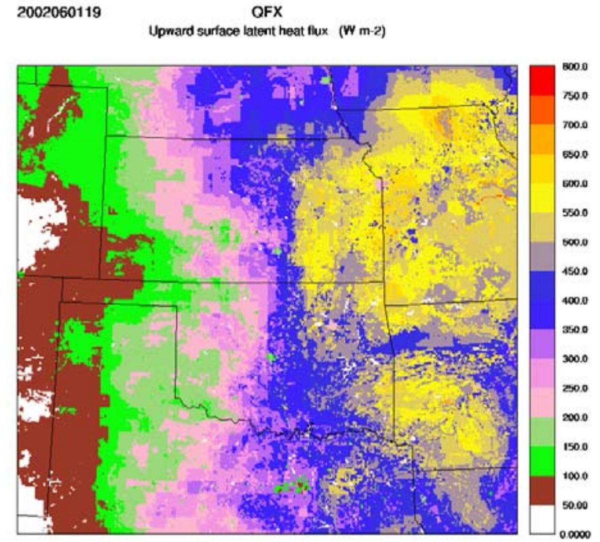
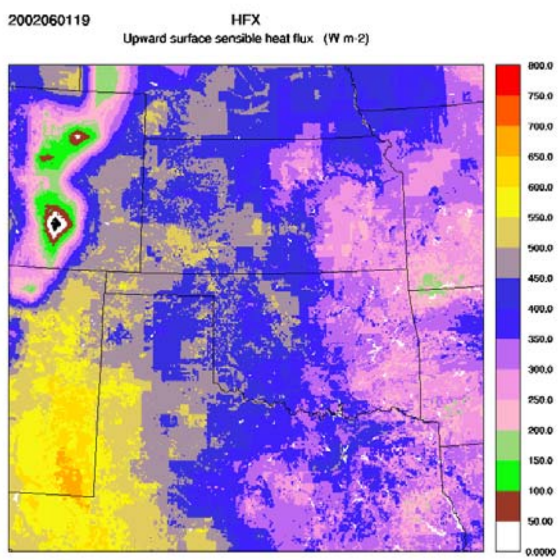
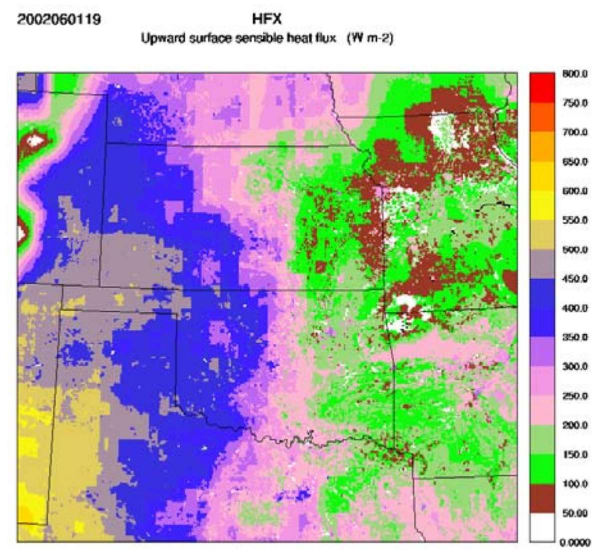
Horizontal 2D plots for 19 UTC 1 June 2002





← Latent heat Flux →





◂Sensible heat Flux▸

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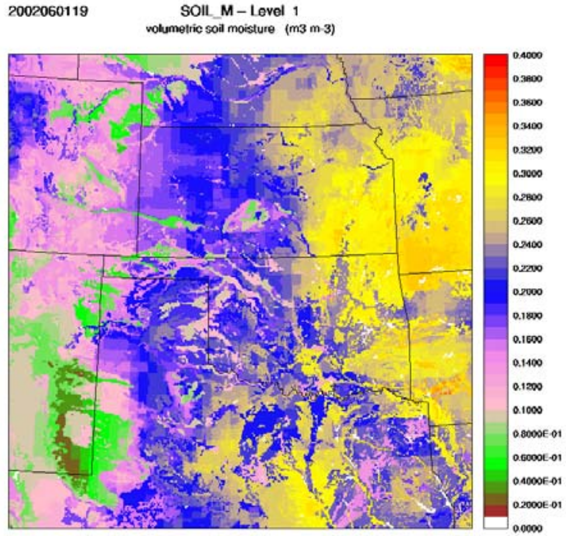
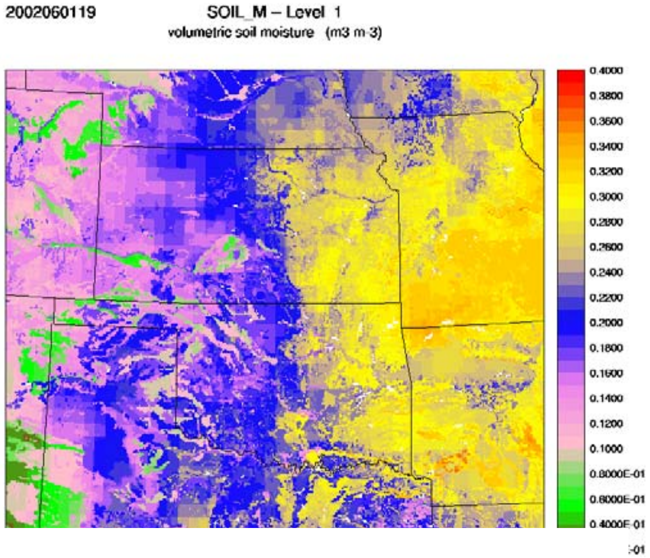
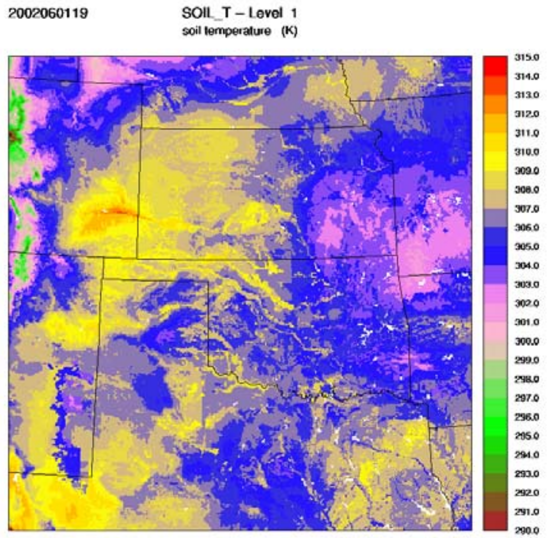
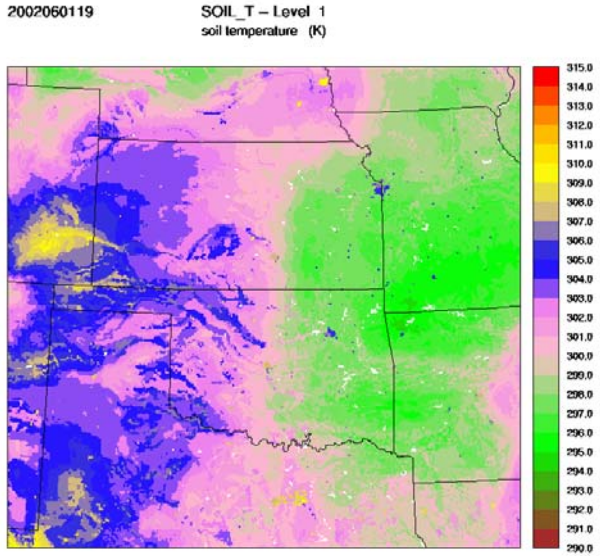


← Vol Soil moisture →
(m3 m-3)





← Soil Temperature →
(K)



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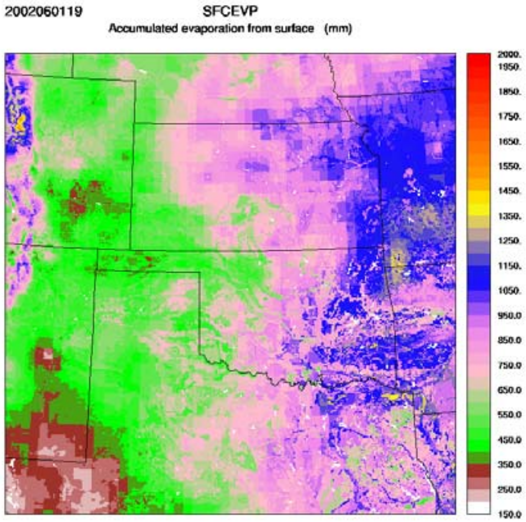
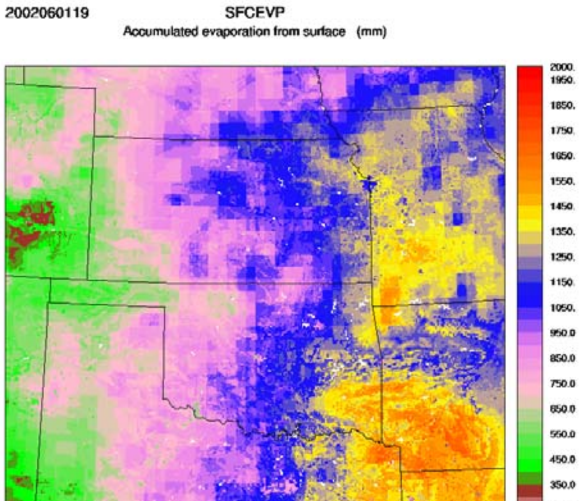
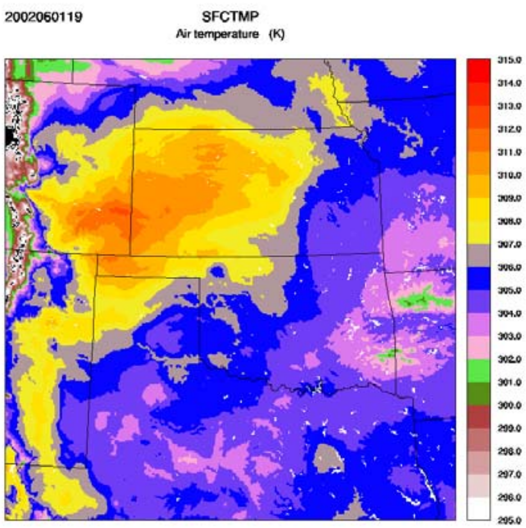
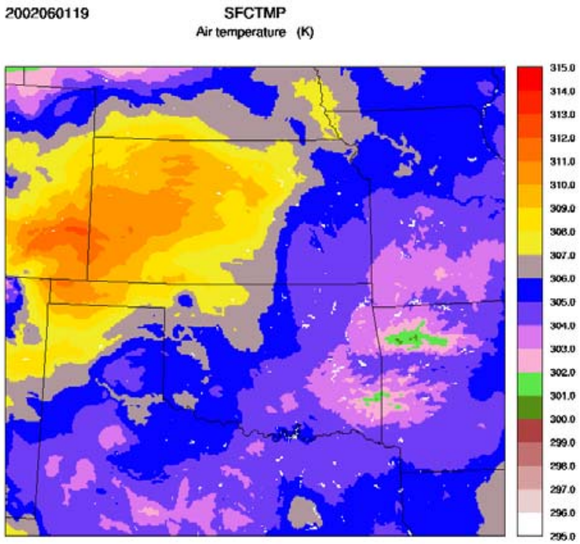




← Acc Evaporation from Surface (mm) →





← Air Temperature (K) →

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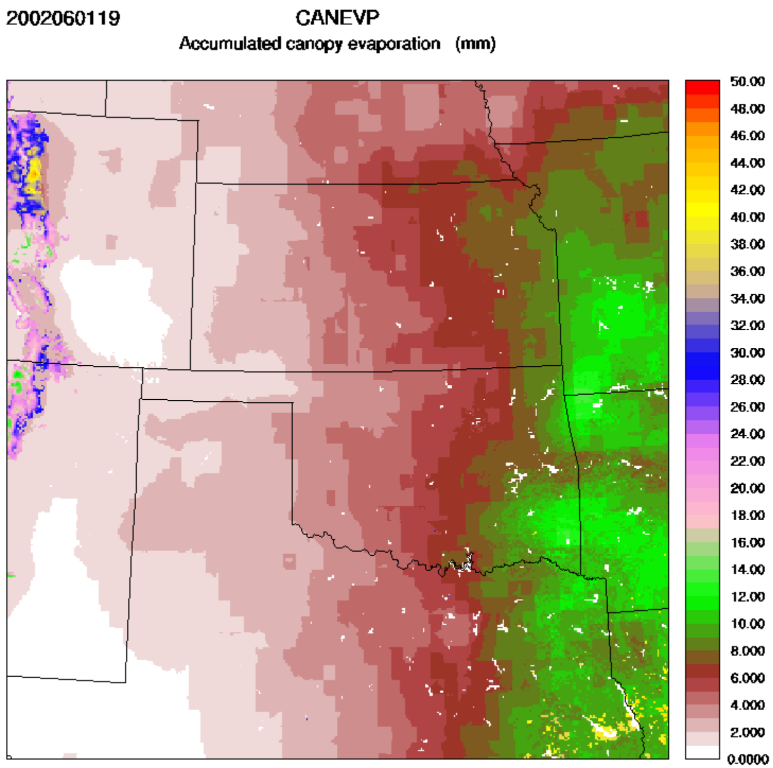
Horizontal 2D plots for 19 UTC 1 June 2002



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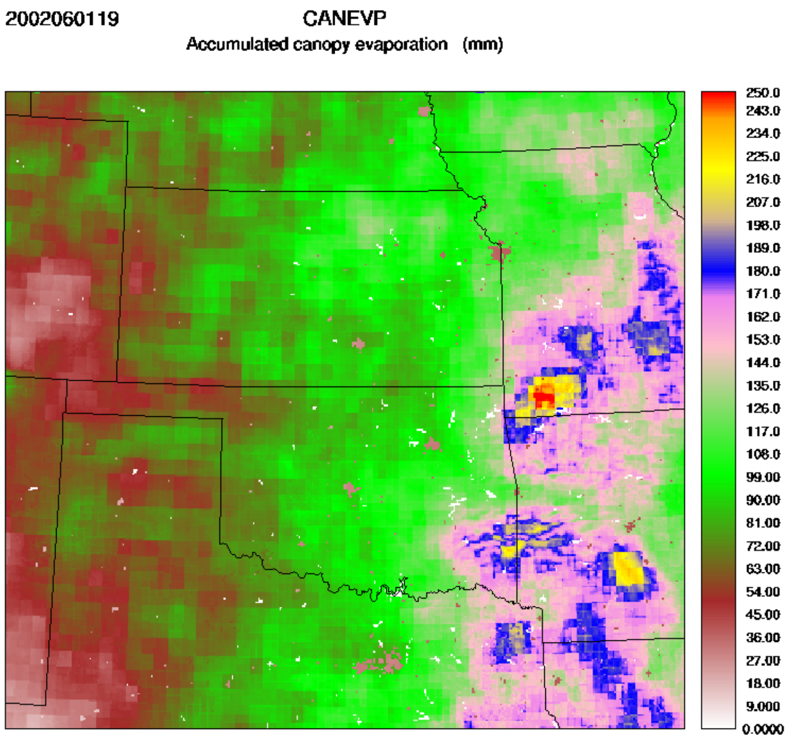

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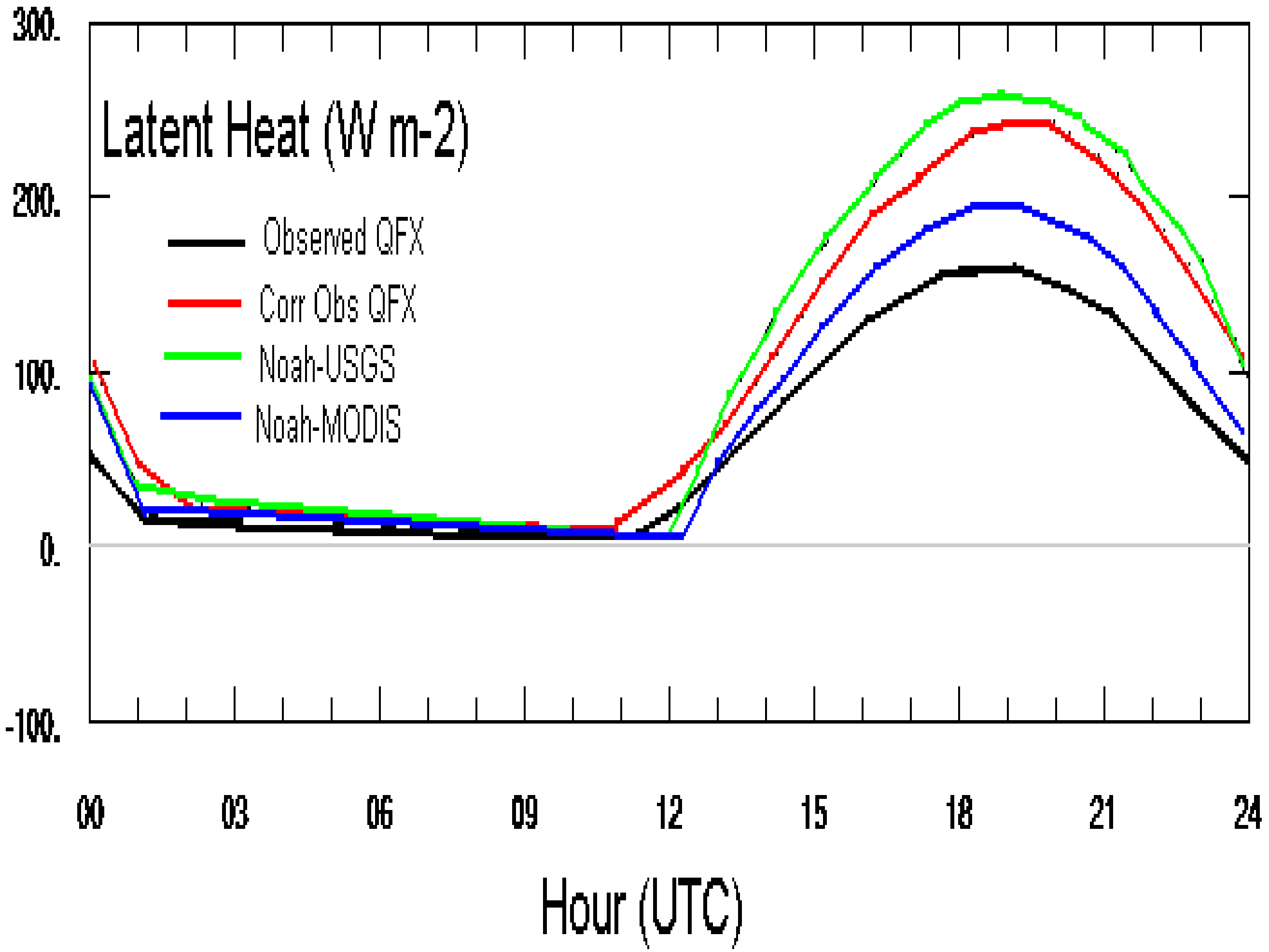
Model Evaluation: Compared with Diurnal averaged latent heat flux over 10 IHOP station site



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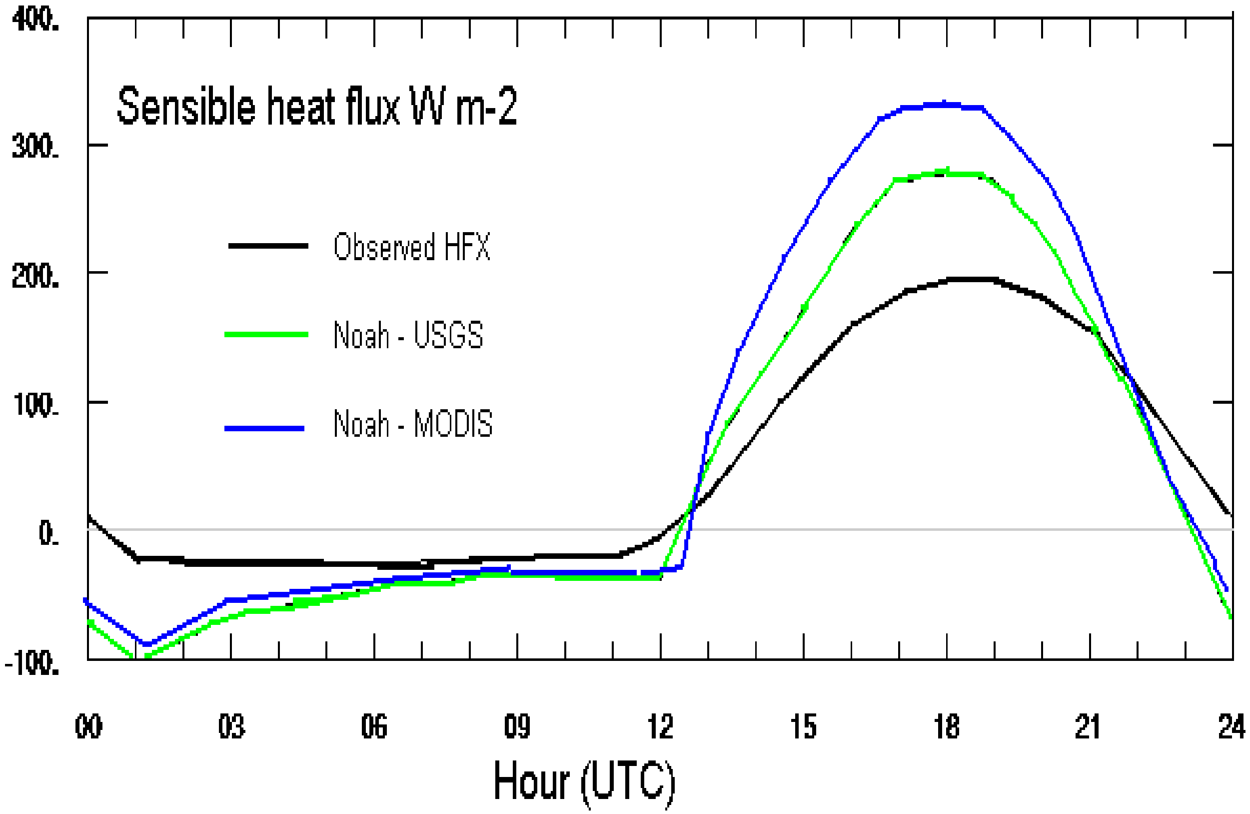
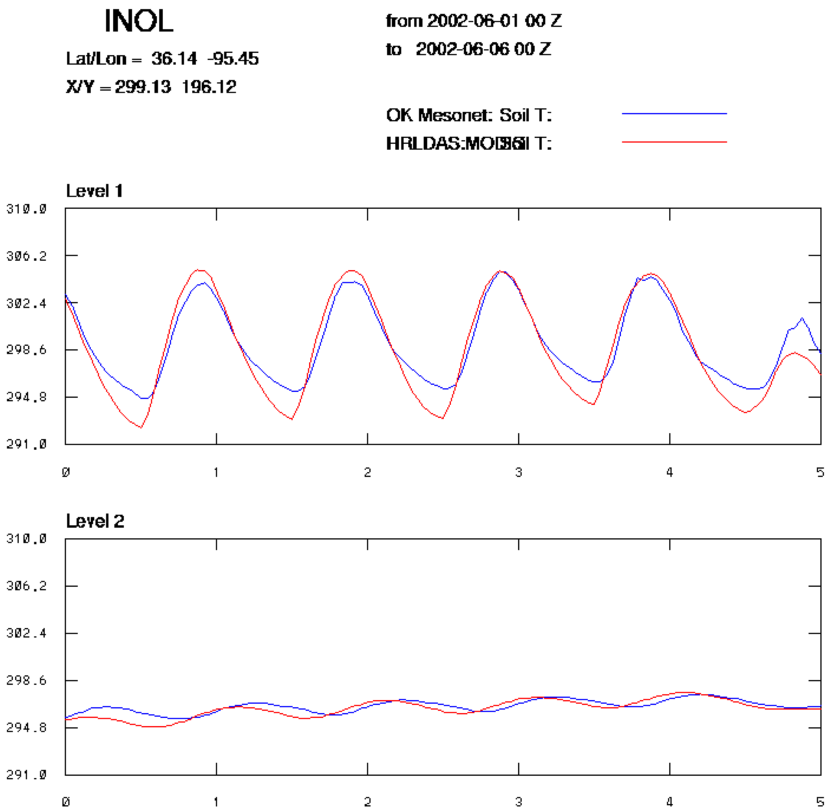
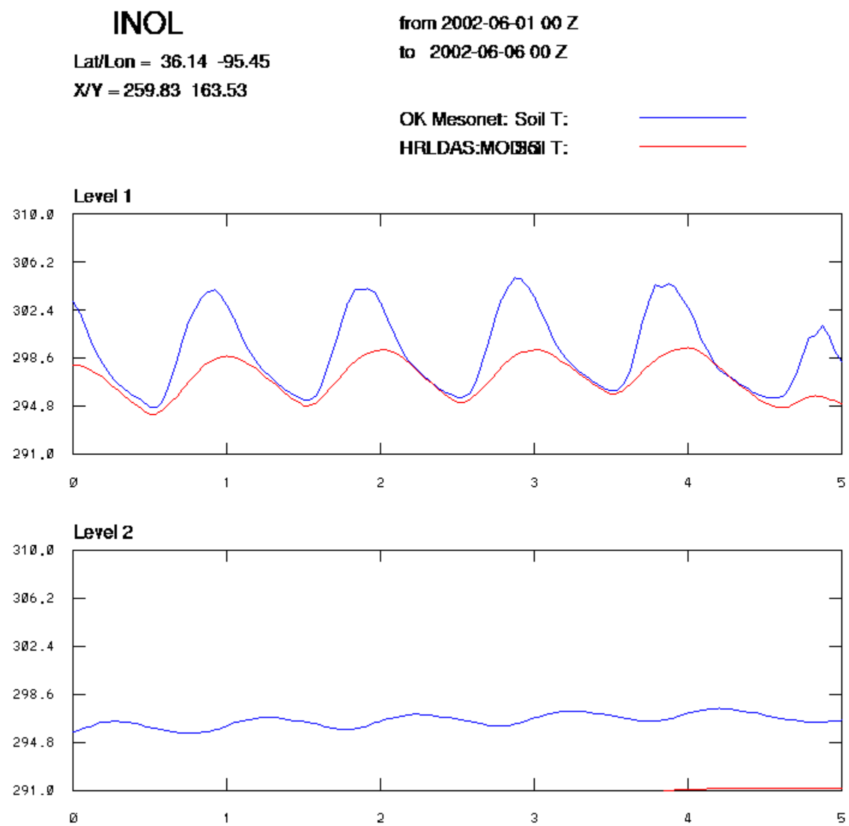


Time series for Soil Temperature (1June to 5 June 2002)
Station: INOL (OK Mesonet)





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Observed

Model

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Recalculate Minimum Canopy Resistance (Rc_min) from GEM Calculation

$$Rc = Rc\_min / (LAI * F1 * F2 * F3 * F4)$$

$$Rc\_min = Rc * (LAI * F1 * F2 * F3 * F4)$$

From Noah-GEM

From Noah-Jarvis

F1 – PAR limitation; F2 – Atmospheric vapor pressure deficit factor;
F3 – Air temperature stress; F4 – Soil moisture stress

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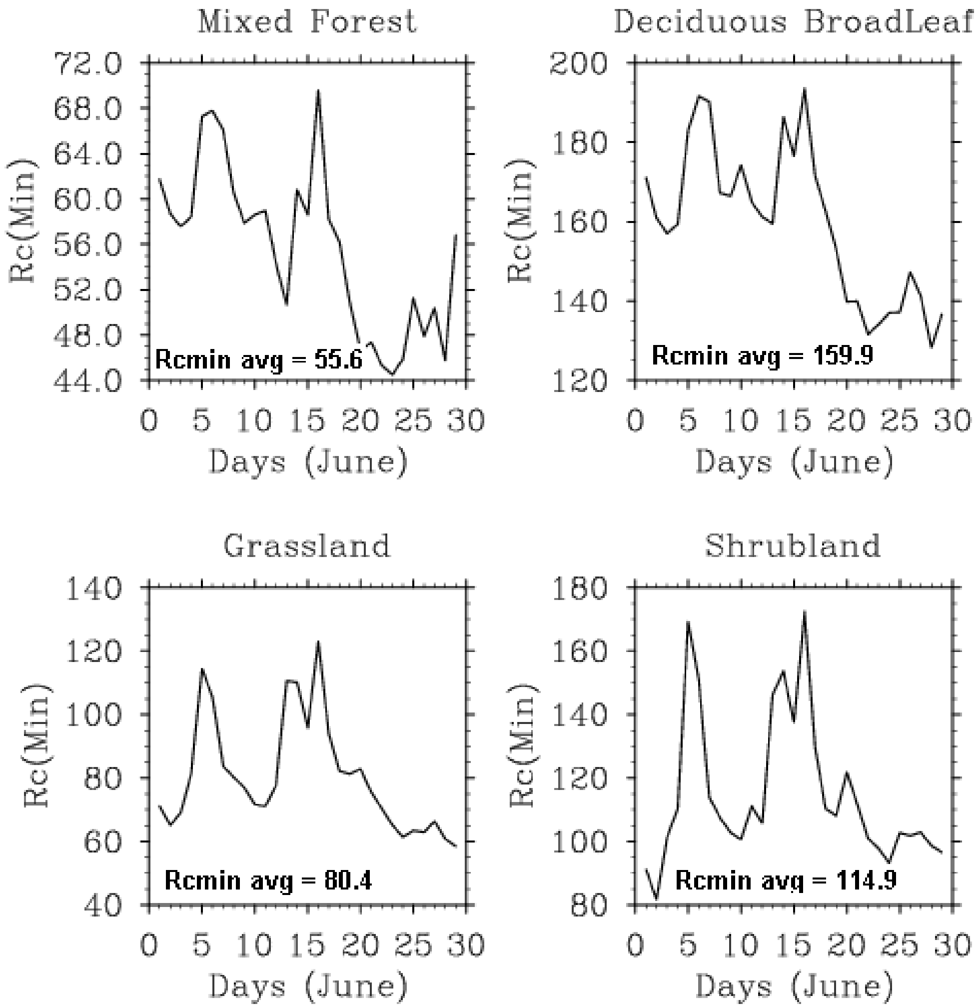
Recalculate Minimum Canopy Resistance (Rc_min) from GEM Calculation

Default: 125
GEM: 55.6

Default:100
GEM: 159.9



Default: 40
GEM: 80.4

Default: 300
GEM: 114.9

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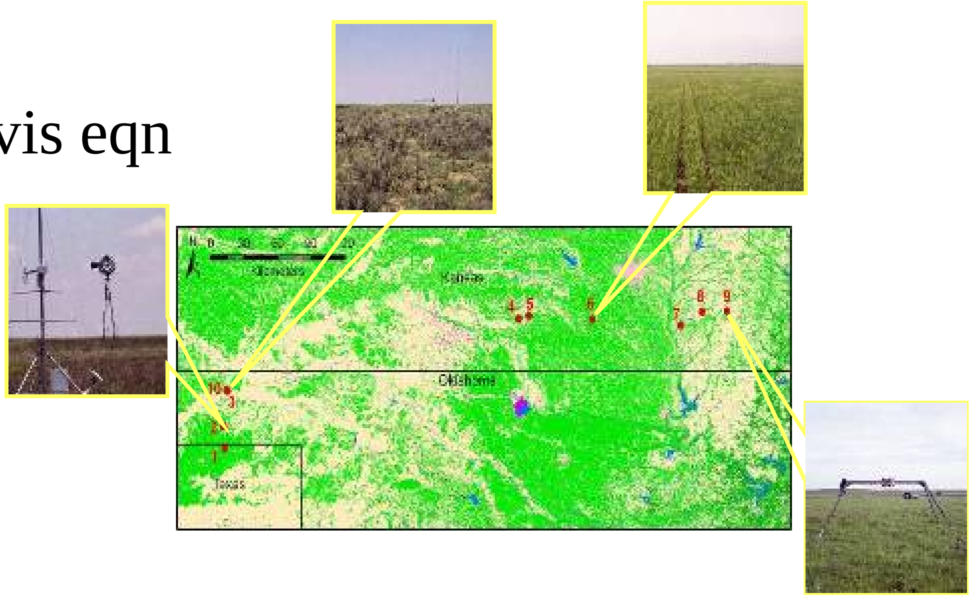
2002 International H_2O Project:

Micrometeorological and surface properties data collected at 10 surface sites.

Rcmin back calculated using Jarvis eqn

While the analysis was conducted using data from all of the site, the focus here is on four representative sites:

- Site 2 – Grassland
- Site 3 – Sagebrush
- Site 6 – Winter Wheat
- Site 9 – Pasture



The IHOP_2002 domain and location of the surface site presented here are shown.

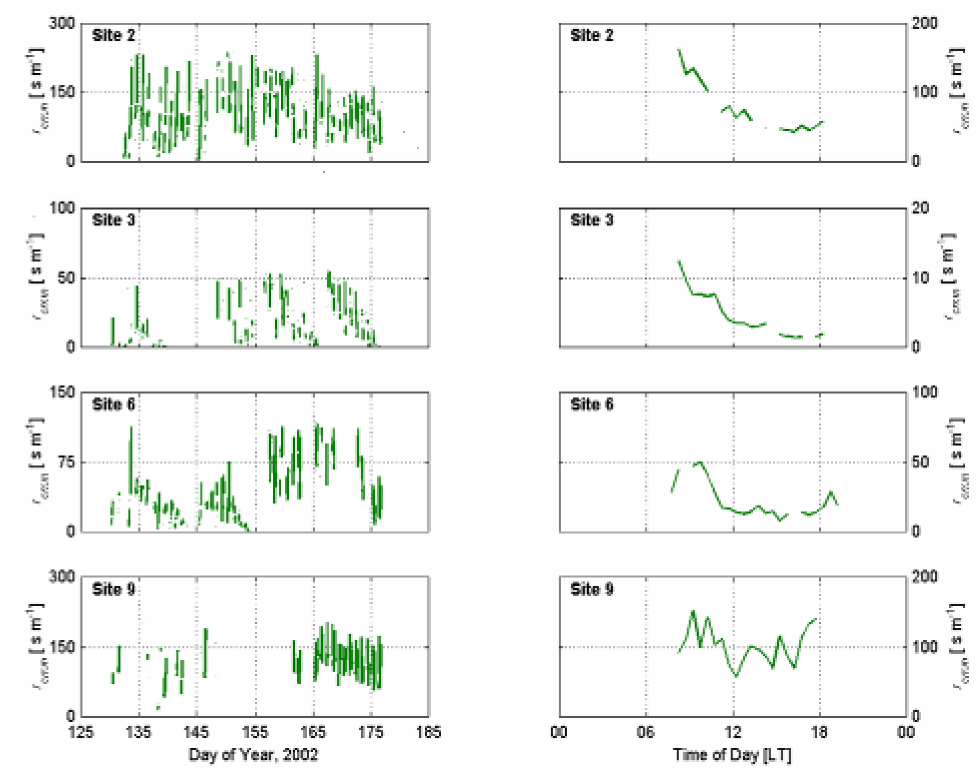
Spatial and Temporal Variability in Rc min:

Mean low = 18 s m^{-1} Site 3 Mean high = 168 s m^{-1} Site 10

Std. devn 17 and 94 s m^{-1} resp

- overal mean 98 s m-1 (+/- 46 s m-1)

- Noah default
 for IHOP_2002 domain,
Dryland Cropland and Pasture and *Grassland*, 40 s m-1.
Shrubland, (Site 3), 300 s m-1.
Observed mean value for Winter Wheat 62 s m-1;
for grassland site 125 s m-1; and,
for the sagebrush site 18 s m-1.



Time series showing both the long term and diurnal variations in Rcmin for selected IHOP_2002 surface sites.

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