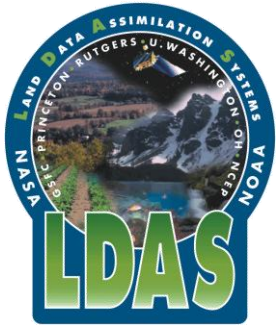

The Multi-Institution North American Land Data Assimilation System Project (N-LDAS)

Ken Mitchell
NCEP Environmental Modeling Center

P. Houser, E. Wood., A. Robock, J. Schaake, D. Lettenmaier, D. Lohmann, B. Cosgrove, J. Sheffield, L. Luo, Q. Duan, W. Higgins, R. Pinker , D. Tarpley, J. Meng

HPCC Land Information System Kickoff Meeting (IGES/COLA)
04 March 2002

N-LDAS Collaborators

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John Augustine

Univ. Maryland
Rachel Pinker

NOAA **NASA** **Universities**

http://ldas.gsfc.nasa.gov

LAND DATA ASSIMILATION SYSTEMS:

- **Modern NWP & seasonal forecast climate models must model and initialize the entire "Earth System"**
  - Atmosphere
  - Ocean
  - Land
    - soil (water / ice / temperature), snowpack and vegetation state

- **Land Data Assimilation Systems, which provide above initial land states, typically follow one of three broad forms:**
  - **1)** Coupled Land/Atmosphere 4DDA
    - precipitation forcing at land surface is from parent atmospheric model
    - surface insolation at land surface is from parent atmospheric model
    - precipitation/insolation may have large bias: >large soil moisture bias
  - **2)** Uncoupled Land 4DDA (land model only)
    - observed precipitation/insolation used directly in land surface forcing
  - **3)** Hybrid Land 4DDA
    - Coupled land/atmosphere, but observed precipitation replaces model precipitation for driving the land surface

N-LDAS Design
(our uncoupled approach)

1. Force models with Eta model 4DDA analysis (EDAS) meteorology, except use actual observed precipitation (gage-only daily precip analysis disaggregated to hourly by radar product) and hourly downward solar insolation (derived from GOES satellites).

2. Use 4 different land surface models:

- MOSAIC (NASA/GSFC)
- NOAH (NOAA/NWS/NCEP)
- VIC (Princeton University/University of Washington)
- Sacramento (NOAA/OHD)

3. Evaluate results with all available observations, including soil moisture, soil temperature, surface fluxes, satellite skin temperature, snow cover and runoff.

LDAS Implementation

LSM Models: MOSAIC, VIC, NOAH, Sacramento

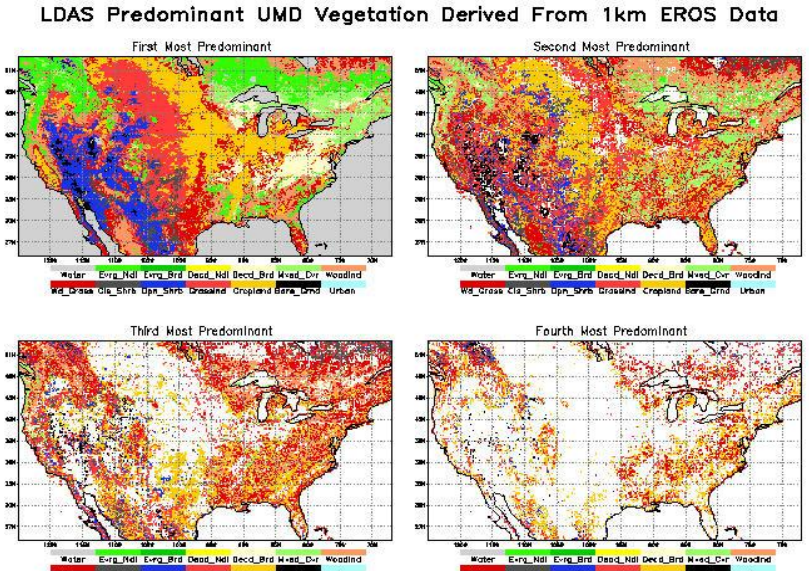
- 1/8-degree resolution, hourly output
- Runoff routing: calibration, validation

Surface Characteristics:

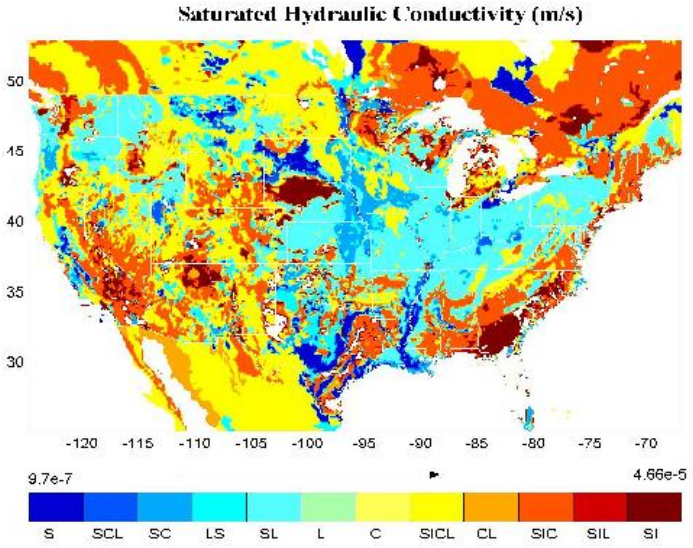
Vegetation: UMD, EROS IGBP, NESDIS greenness, EOS products

Soils: STATSGO, IGBP; *Terrain / Land-Mask*: 1-km digital elevation

LDAS predominant vegetation from 1km EROS data



Soil type on LDAS grid



LDAS Implementation (cont.)

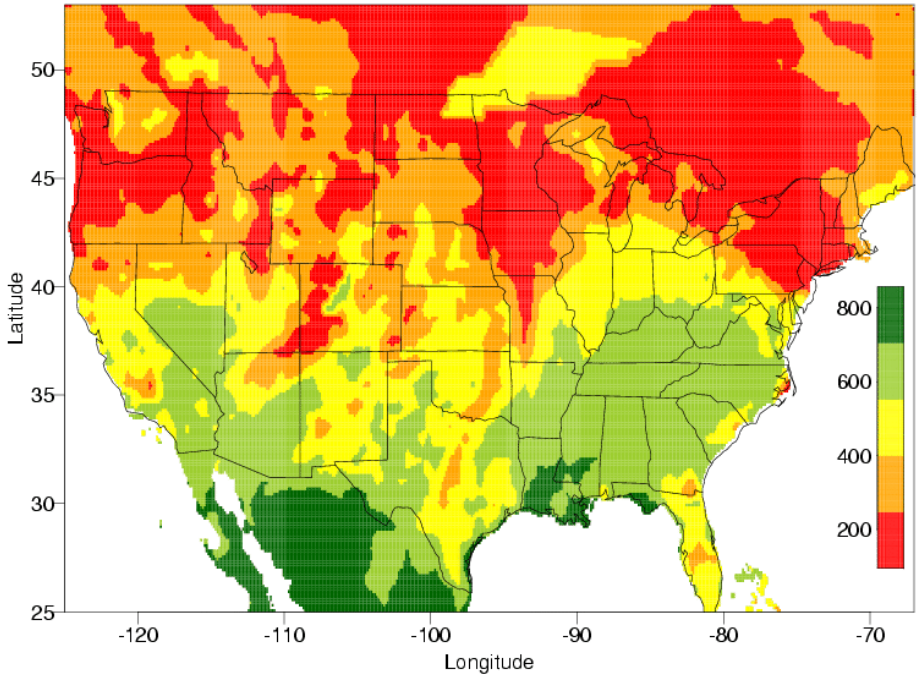
Forcing: (top two are non-model based)

Precipitation: 24 hour gauges, NCEP/OH Stage IV gage/radar precipitation

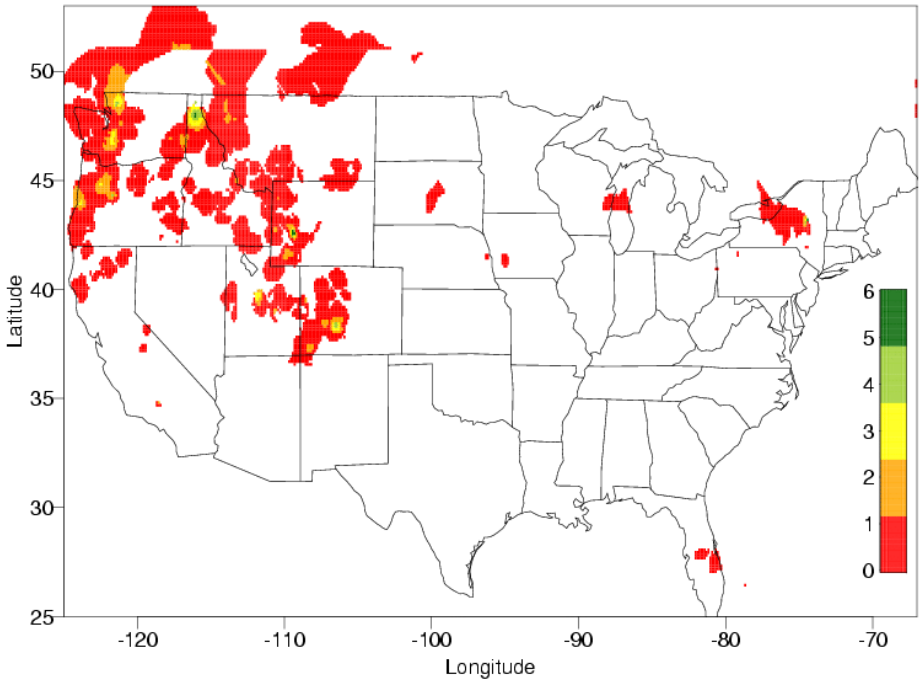
Radiation: NESDIS 0.5-degree hourly GOES solar insolation

Meteorology: NCEP EDAS (Eta 4DDA) analysis (wind, temperature, pressure, humidity, downward longwave)

GOES shortwave radiation [W/m^2] 20011101 18Z



Gauge / Stage IV precip [mm] 20011101 18Z



LDAS Run Modes:
1) Realtime, 2) Retrospective

1) **REALTIME: 15 Apr 1999 to 15 Dec 2001**

   -- NCEP realtime forcing

2) **RETROSPECTIVE: 01 Oct 1996 to 30 Sep 99**

   -- NASA-assembled retrospective forcing

   --- Higgins NCEP/CPC reprocessed precipitation forcing:

   ---- more gages obs, more QC

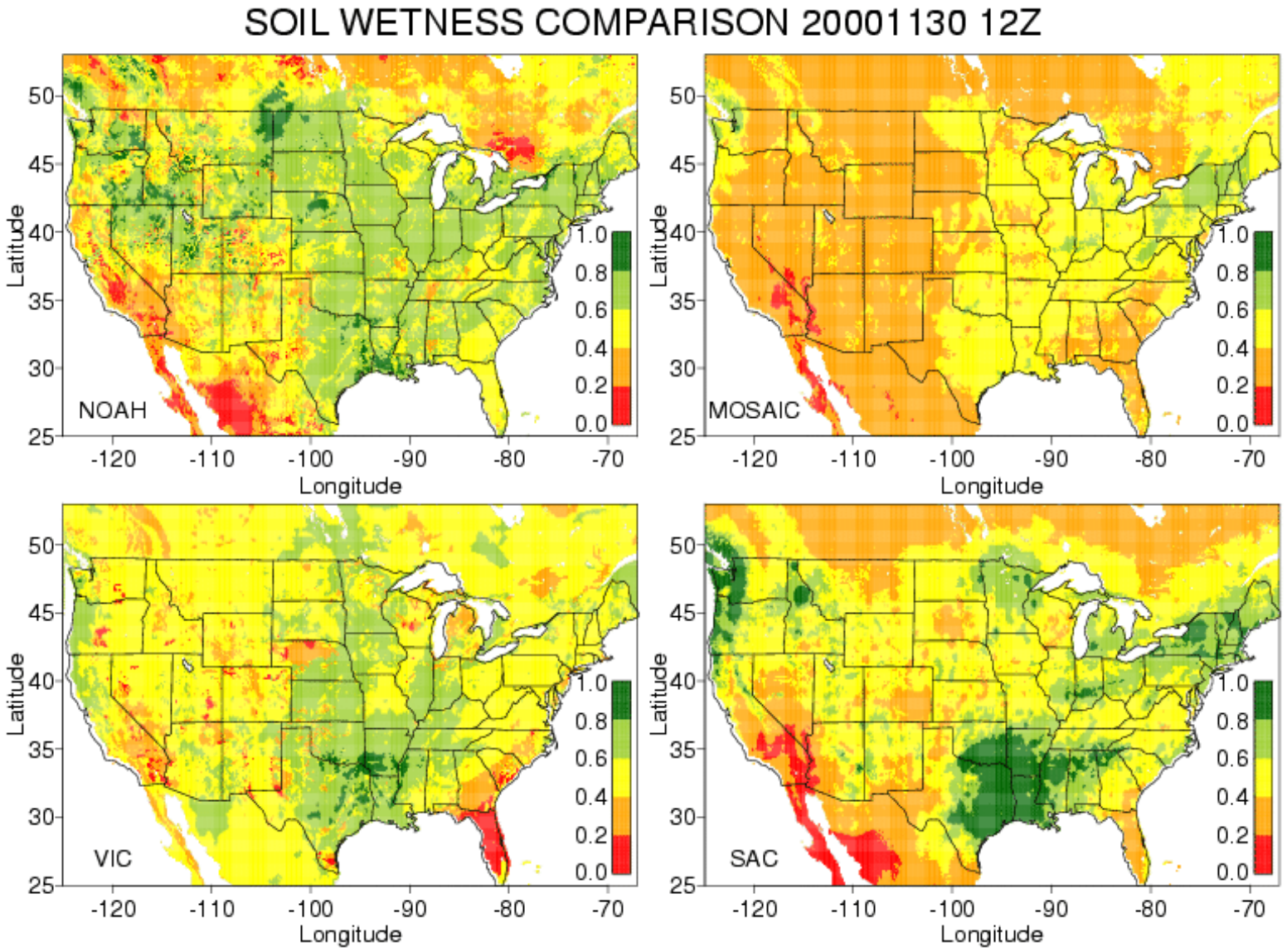
   --- Pinker U.Md reprocessed solar insolation forcing

   ---- better cloud screening, more QC

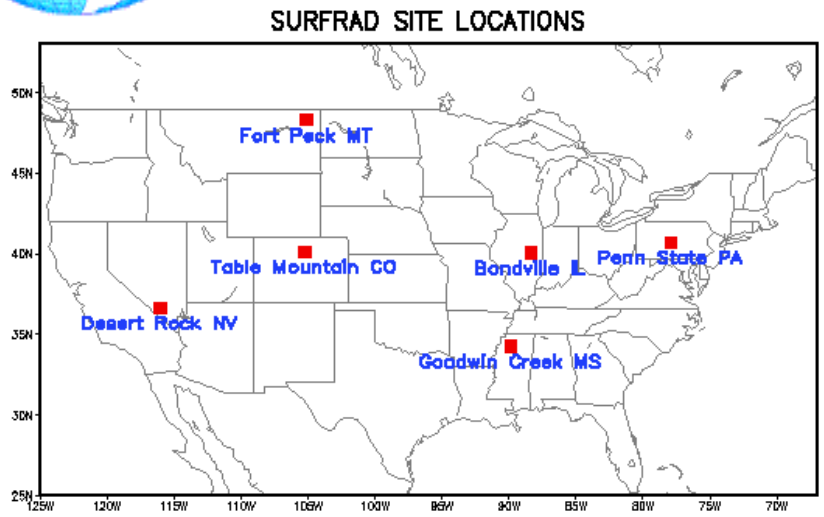
Rutgers University compared the soil moisture, soil temperature, surface flux results from the retrospective LDAS runs to observations over Oklahoma/Kansas for last retro year.

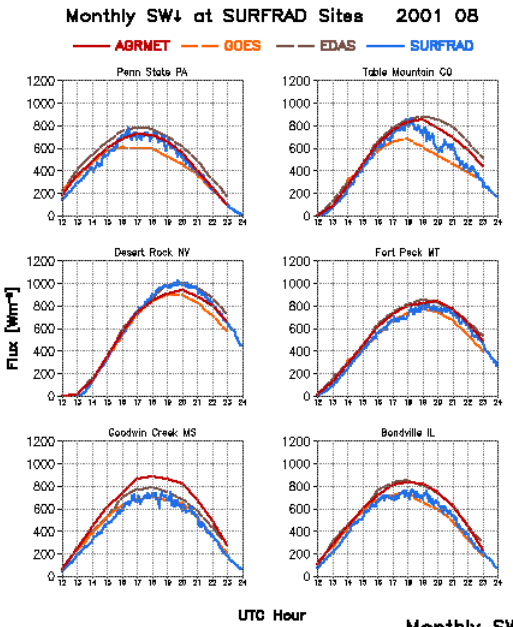
LDAS Soil Wetness Comparison

LDAS realtime output example (similar spread as in PILPS-2c)



LDAS Forcing Validation 2001 08-11





Monthly mean diurnal solar insolation intercomparison

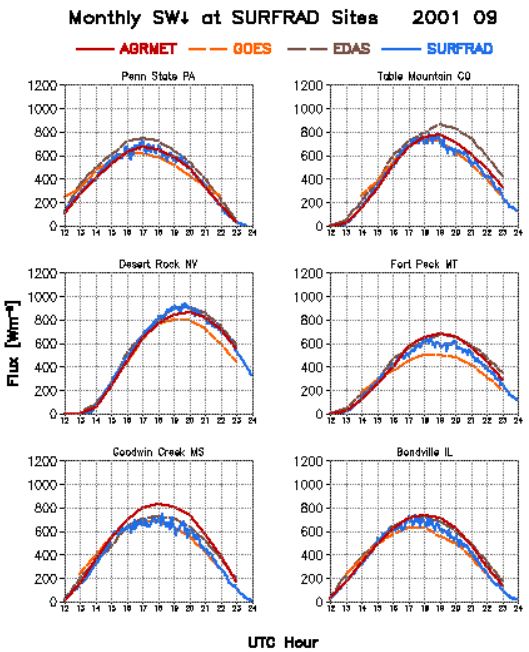
GOES

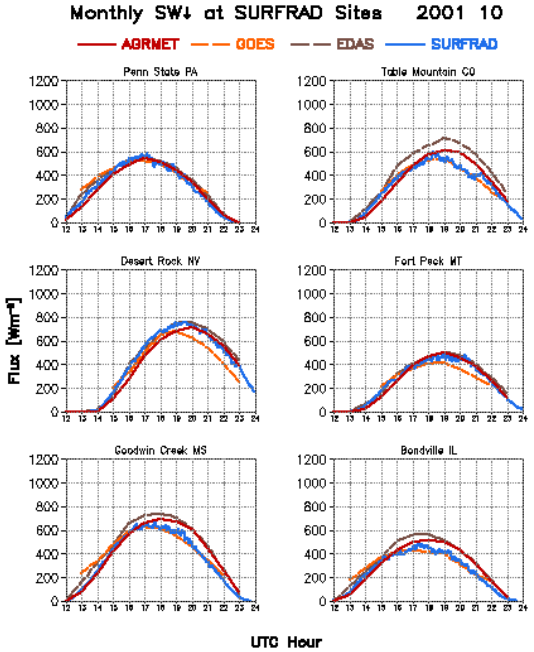
EDAS

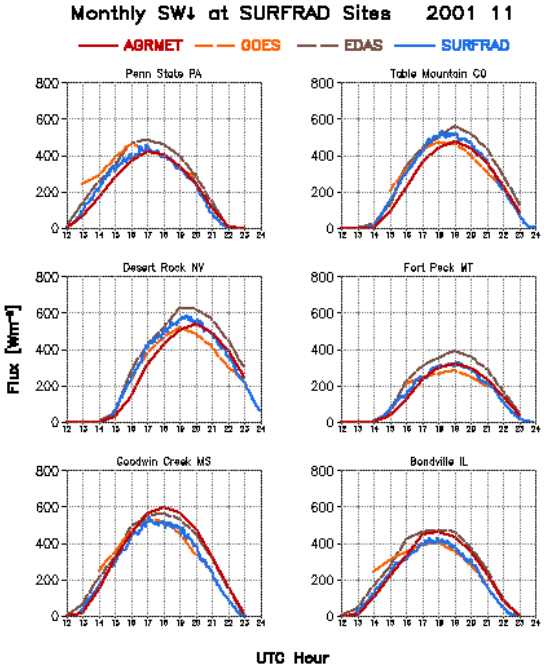
AGRMET

vs

SURFRAD





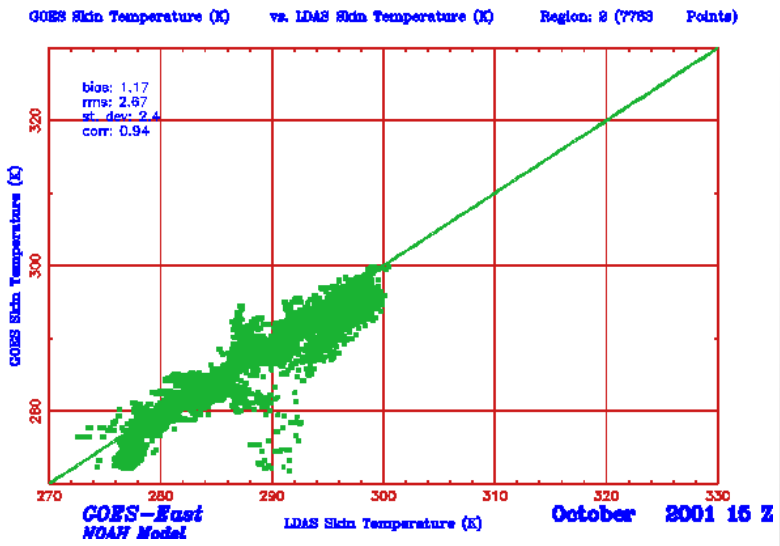


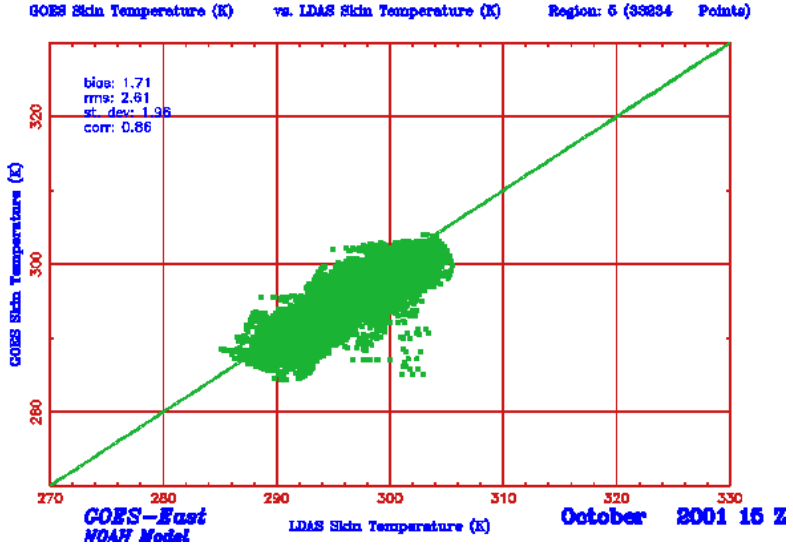
LDAS-NOAH Skin Temperature October 2001 Validation cont.

Region 2

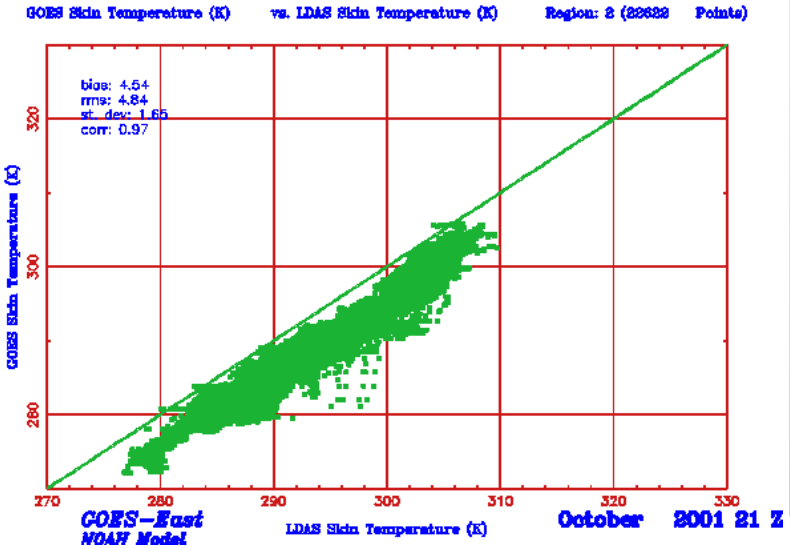
Region 5

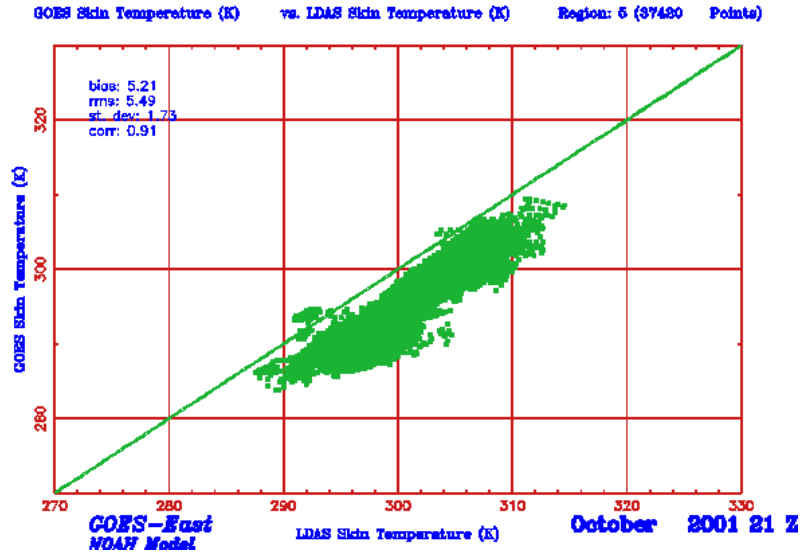
15 Z





21 Z



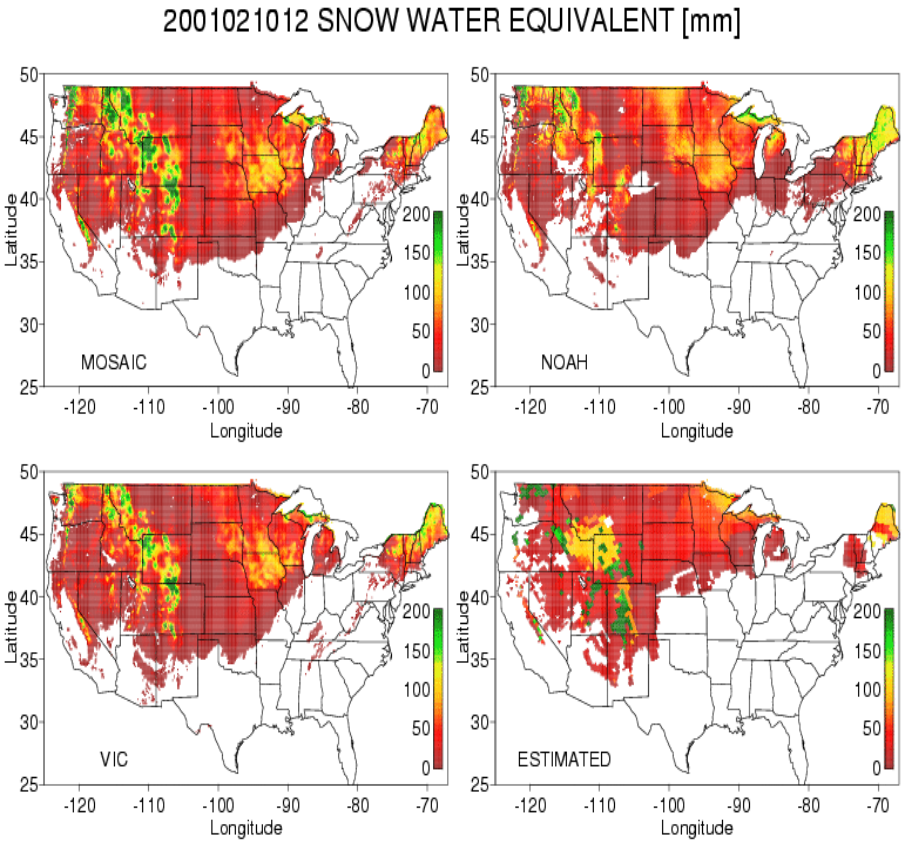


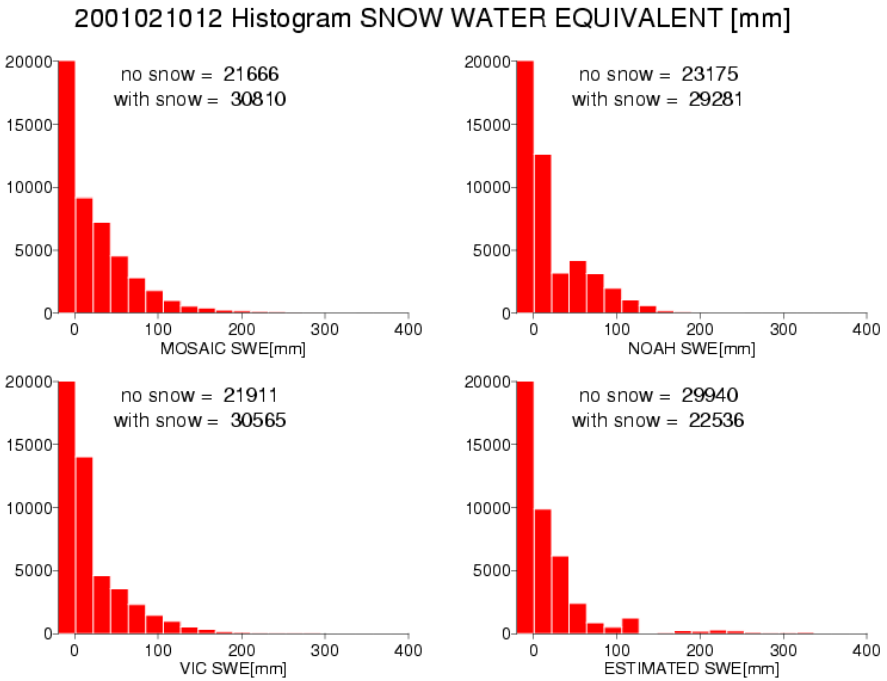
Snowpack Simulation Comparison

Snow depth from USAF, cover: global 1/8 bedient, unit [in], daily

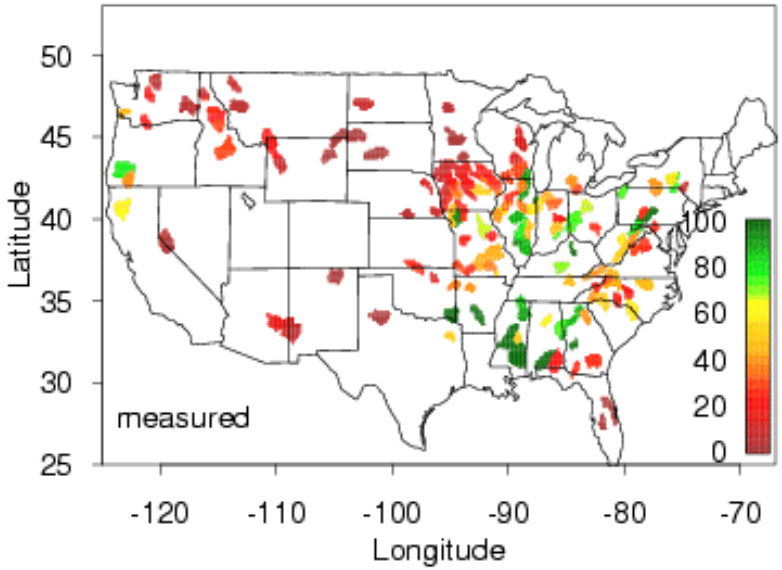
Snow cover product from NESDIS daily, cover: 1/16 bedient N.Hemisphere grid, flag

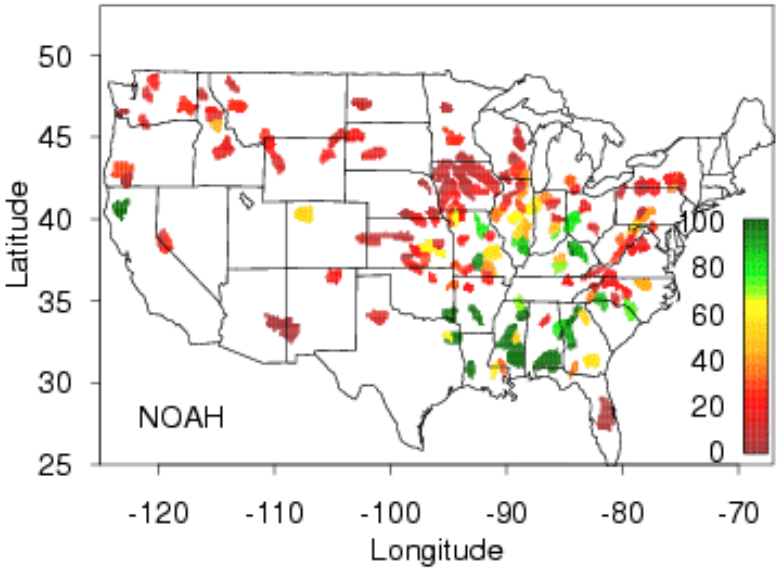
= estimated

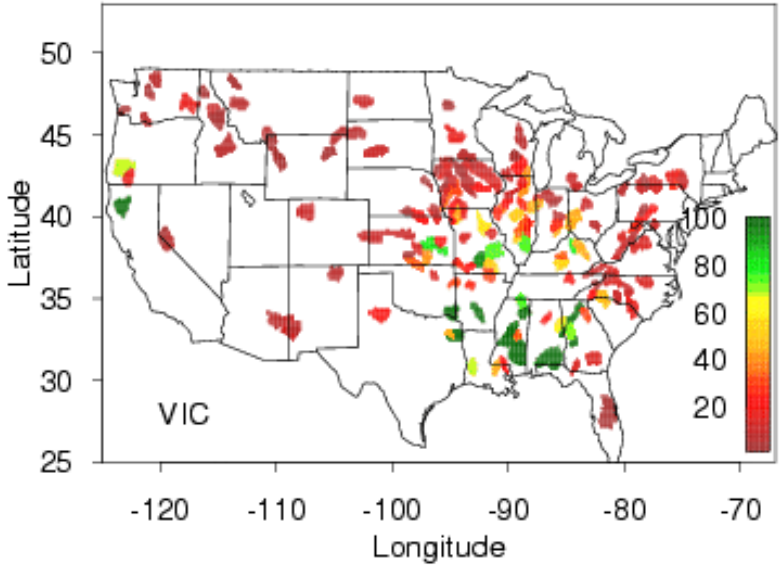


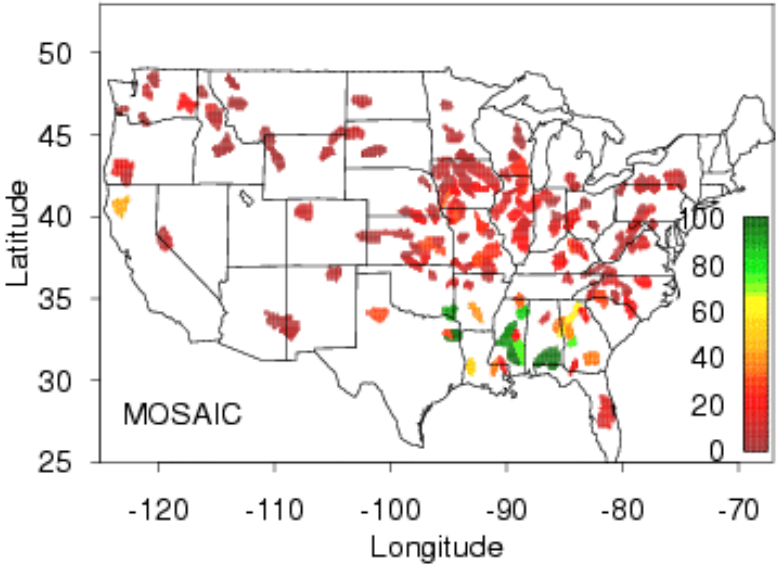


LDAS Models Total Runoff
Nov. 2000 – July 2001

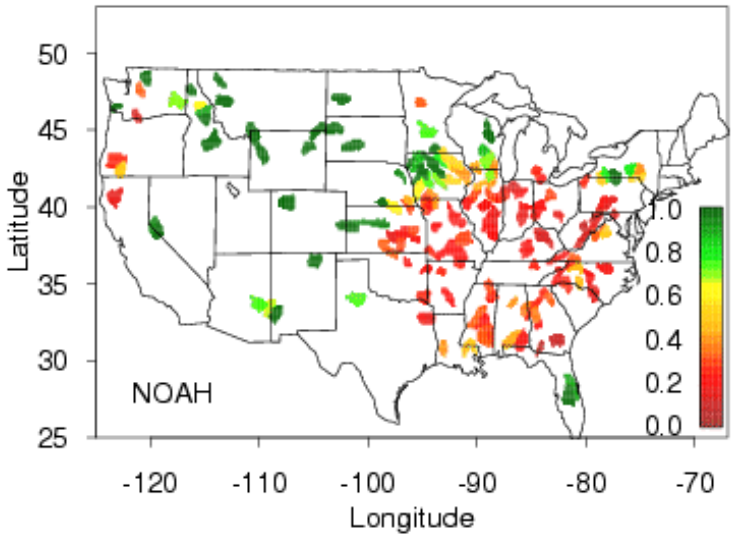


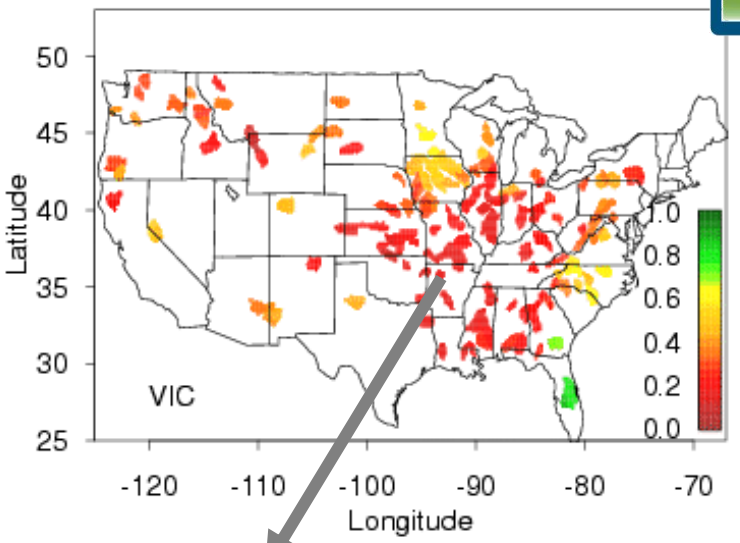




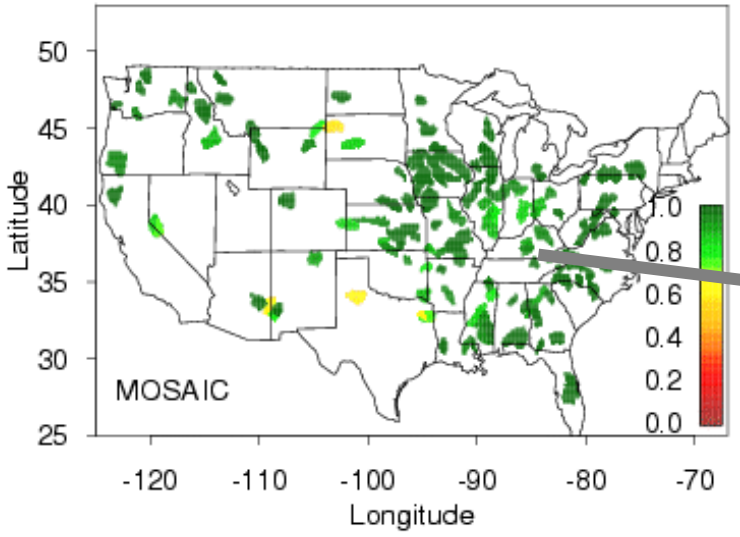


LDAS Models
Surface Runoff / Total Runoff





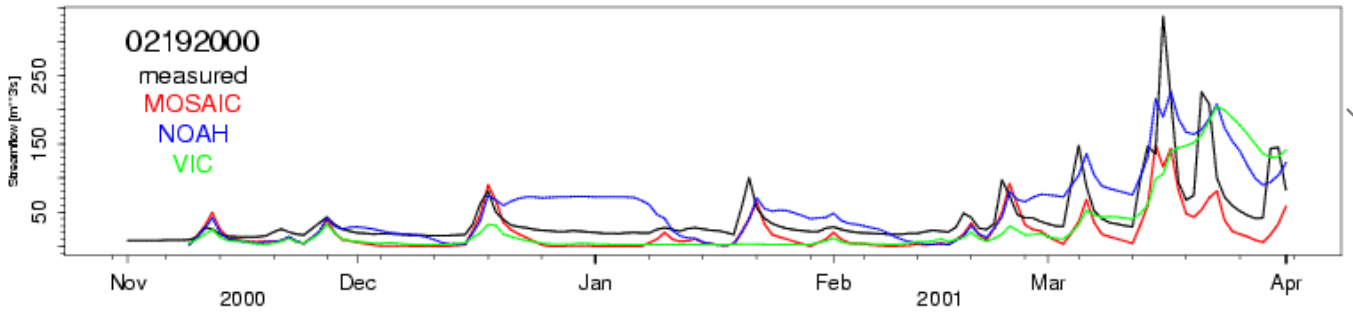
Dominant Sub-Surface Runoff

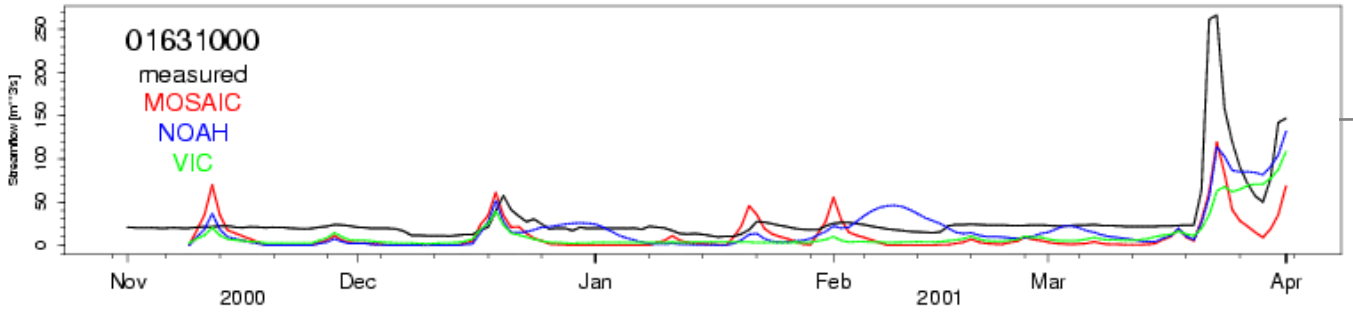


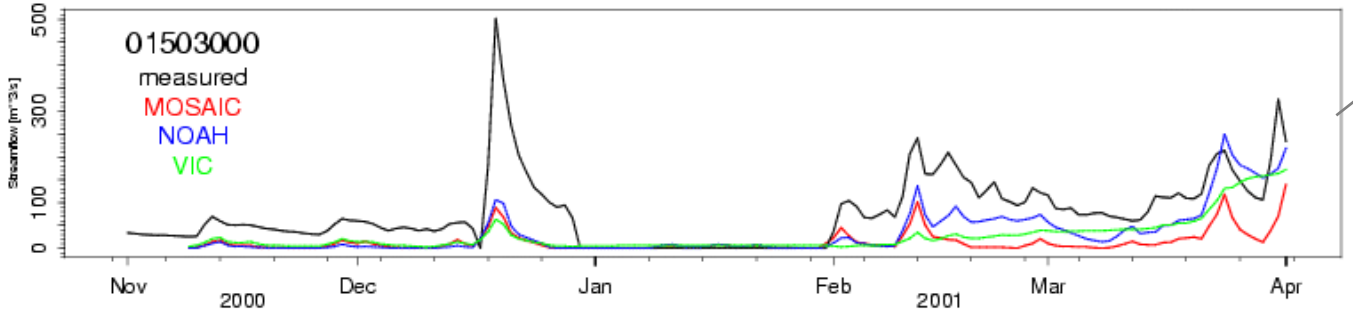
Dominant Surface Runoff

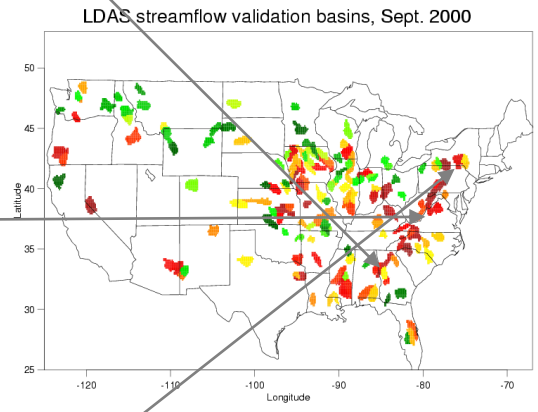
LDAS Models Streamflow

02192000 = Broad River, GA, 1430 sq. miles
01631000 = Shenandoah River, VA, 1642 sq. miles
01503000 = Susquehanna River, NY, 2232 sq. miles









LDAS Scientific Questions

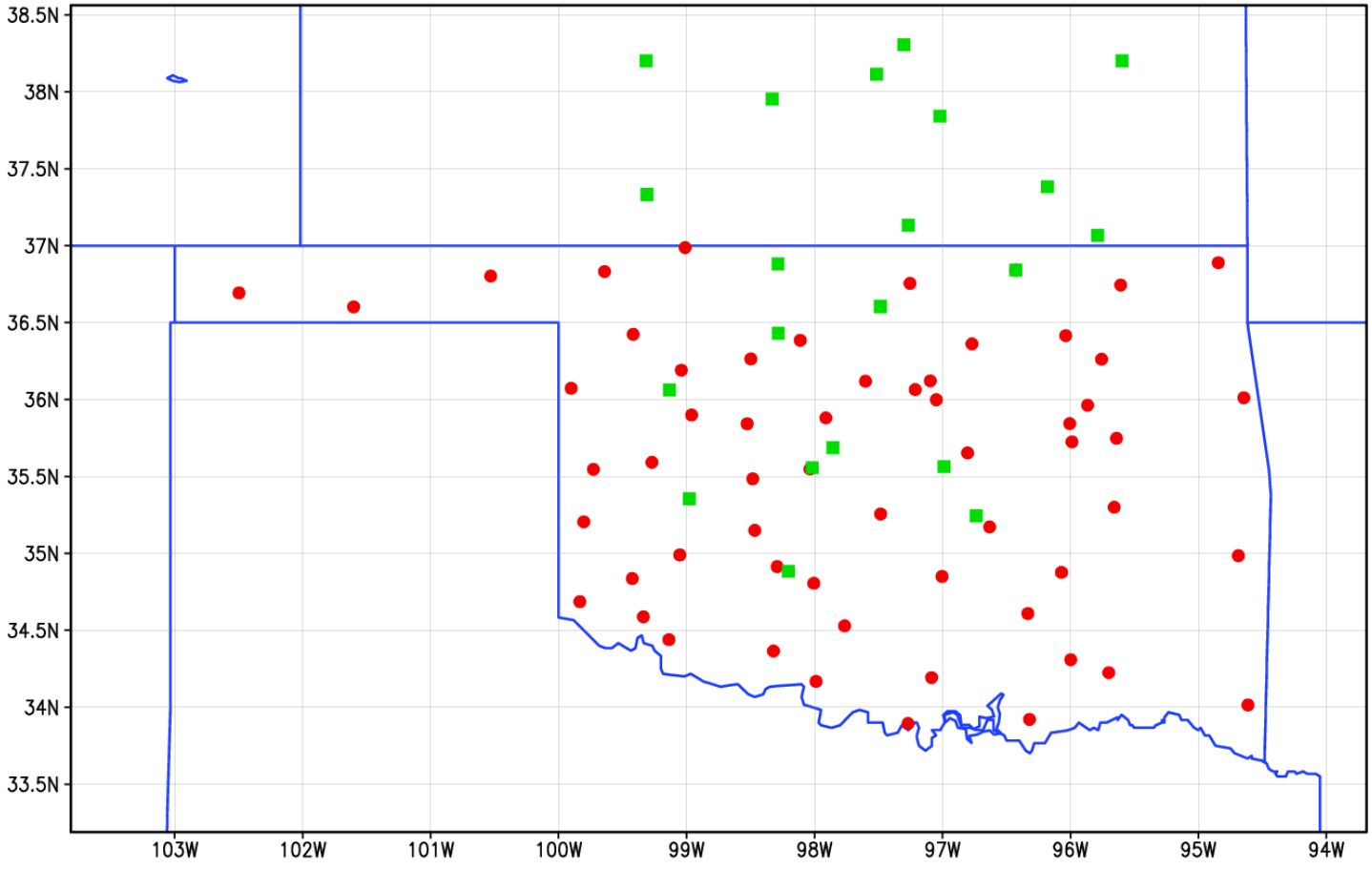
1. **Can land surface models forced with observed meteorology and radiation reproduce point-wise soil moisture/temperature states and surface fluxes?**

2. **If not, what are the relative contributions to the differences between models and observations owing to a) errors in the soil-state/surface-flux observations or b) differences in the following between model and observed:**

   a. **Forcing?**
   b. **Soil properties?**
   c. **Vegetation characteristics?**
   d. **Scales of representativeness?**
   e. **Vertical resolution?**
   f. **Other (e.g. tiling, variable infiltration assumptions)**

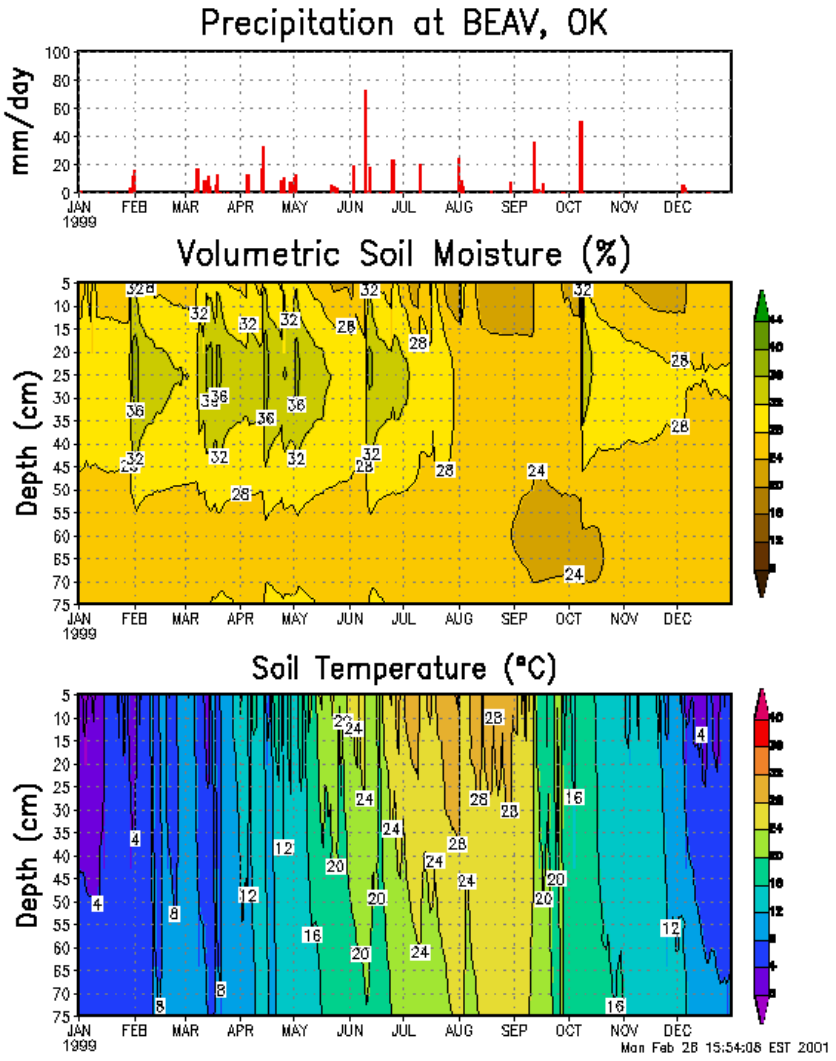
Soil Moisture/Temperature Observations

▪ *ARM/CART sites* • *Oklahoma Mesonet sites*



Oklahoma Mesonet

- 115 Mesonet stations covering every county of the state
- Meteorological observations are taken at 5 min intervals:
  - Relative Humidity at 1.5 m
  - Air Temperature at 1.5 m
  - Average Wind at 10 m
  - Precipitation
  - Station Pressure
  - Solar Radiation
- 72 stations have soil moisture and soil temperature observations taken at 15 min intervals.

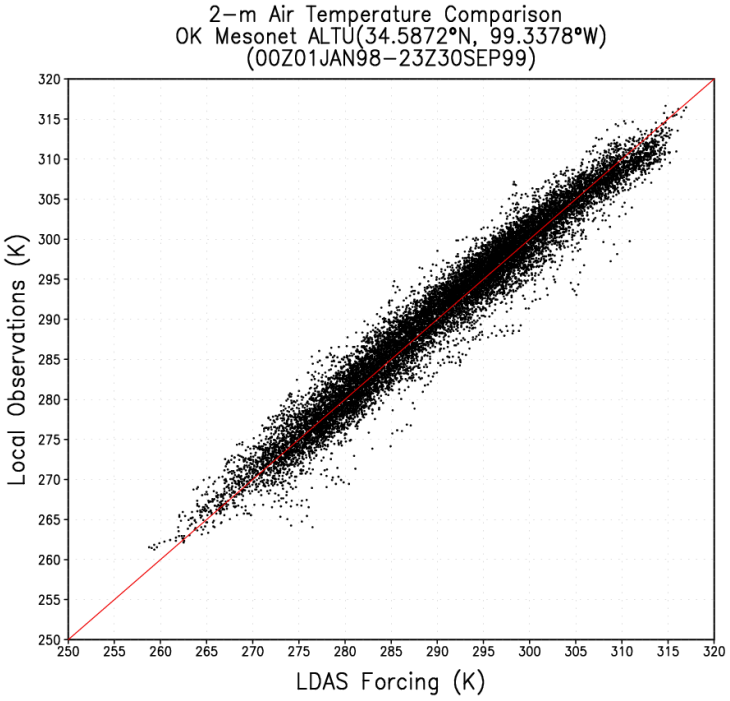


LDAS Forcing Validation: 2-m Temperature / Humidity

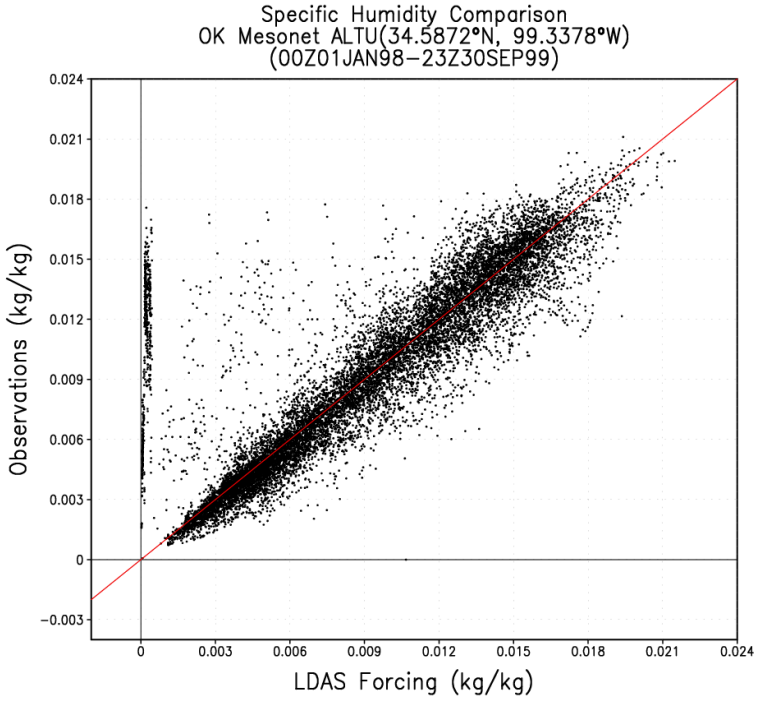
(Gridded LDAS 1/8-th degree vs Pointwise Station)

Jan 98 – Sep 99

Temperature



Humidity



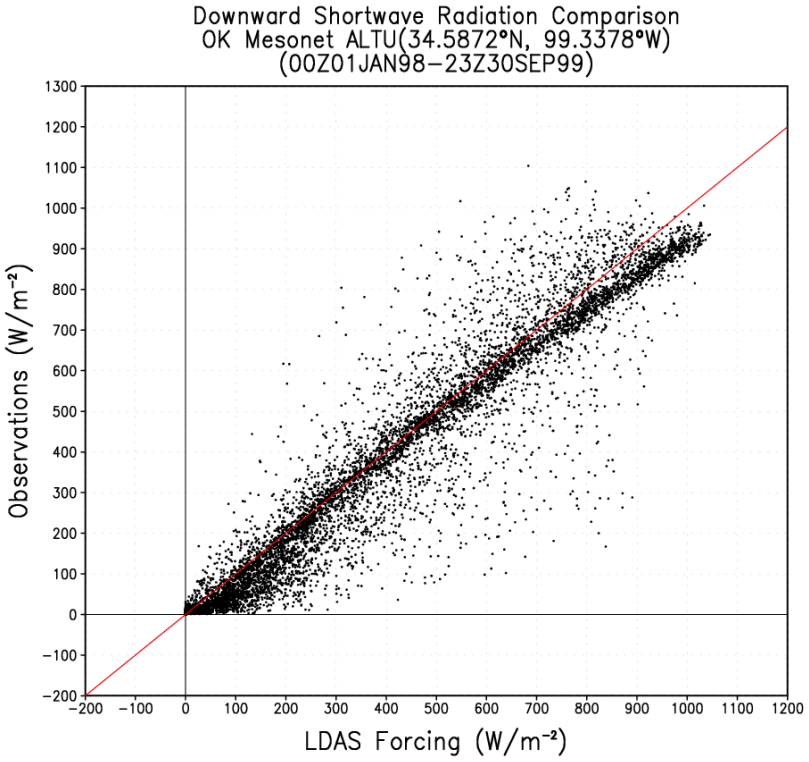
Mon Jan 7 16:09:56 EST 2002

LDAS Radiation Validation: Shortwave / Longwave

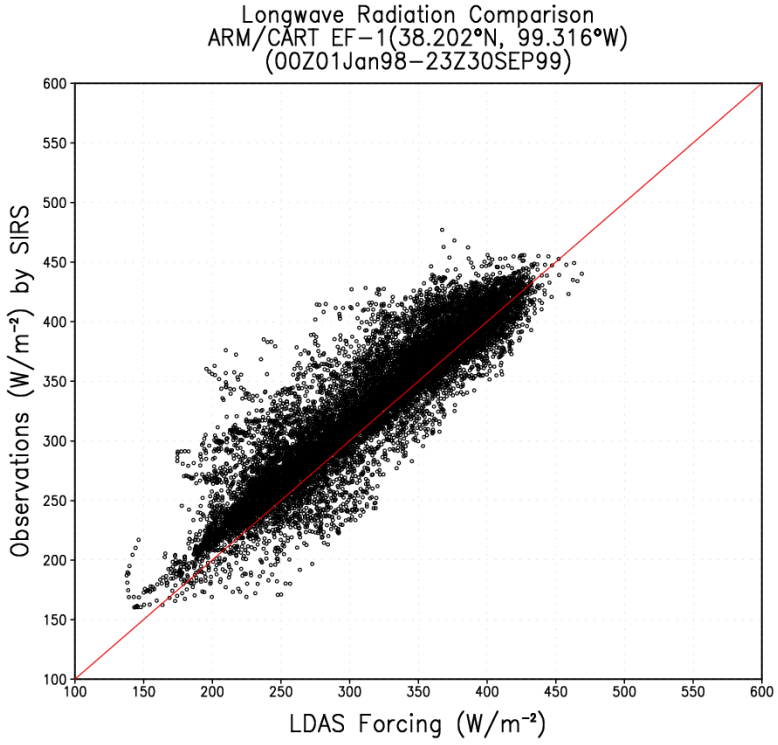
(Gridded 1/8-th degree vs Pointwise Station)

Jan 98 – Sep 99

Shortwave

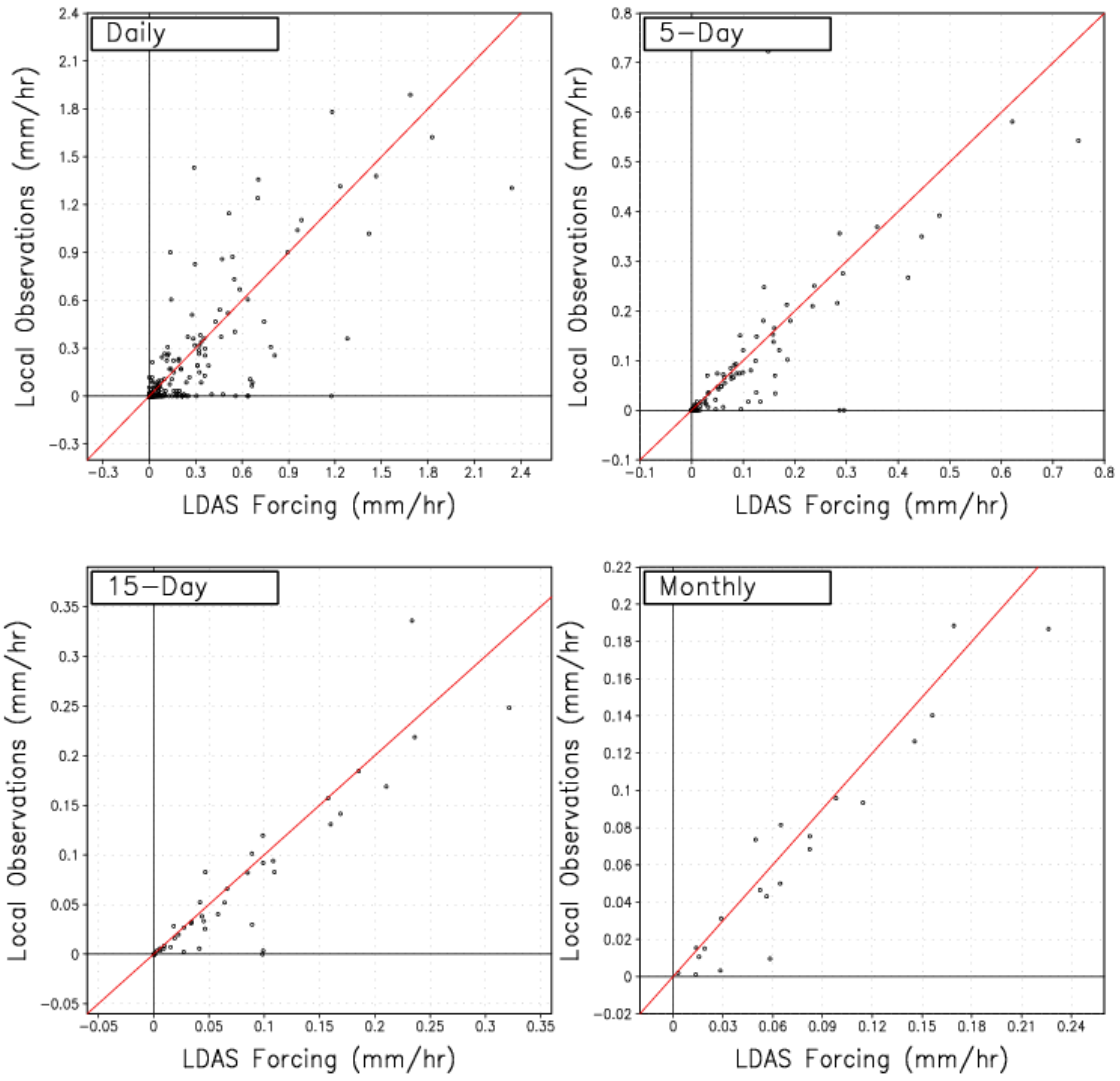


Longwave



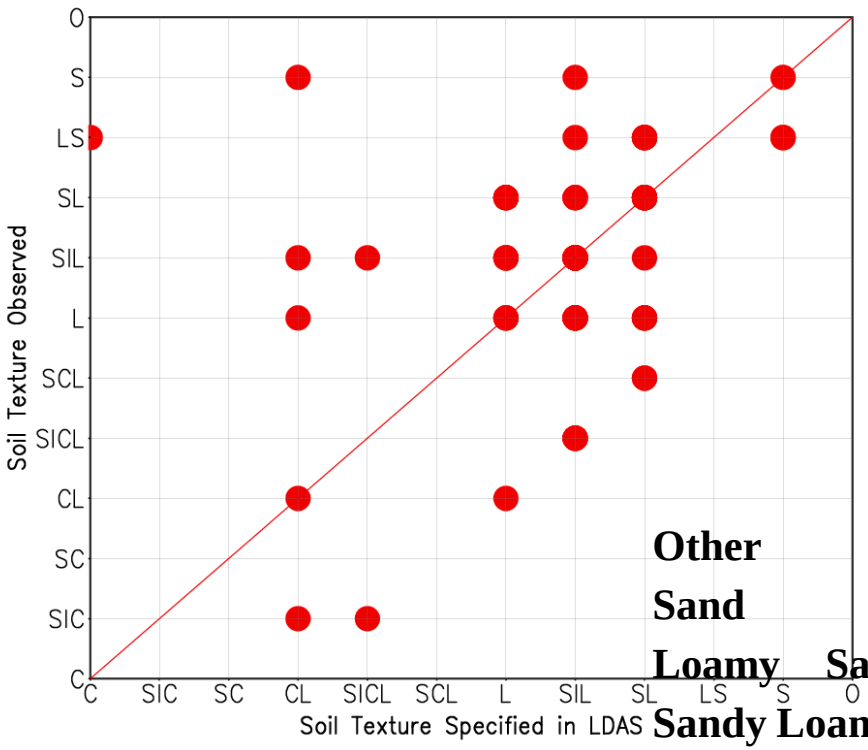
Sun Jan 6 23:14:02 ES

Forcing Validation: Precipitation



Soil Texture Comparison

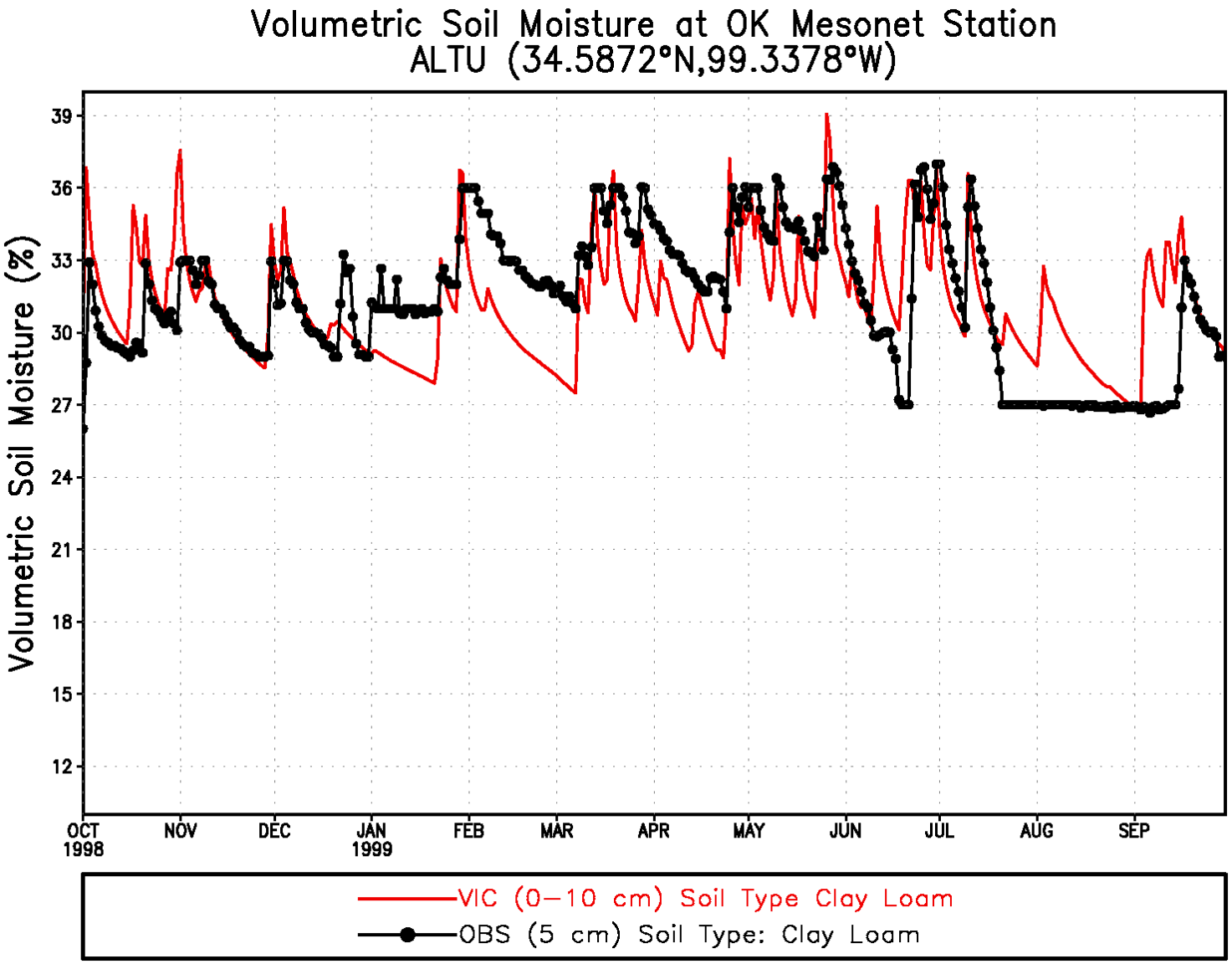
- Soil texture is as important as vegetation in the land surface model simulations.
- Soil texture data set used by LDAS is based on 1-km Penn State STATSGO and 5-min ARS FAO data.
- At Oklahoma Mesonet and ARM/CART stations, soil texture information is also available.
- The actual point-wise station soil type typically does not agree well with those specified for the LDAS models.



Other
Sand
Loamy Sand
Sandy Loam
Silty Loam
Loam
Sandy Clay
Silty Clay
Clay Loam
Sandy Clay
Silty Clay
Clay

VIC Simulation with Soil Type Matching Local Type

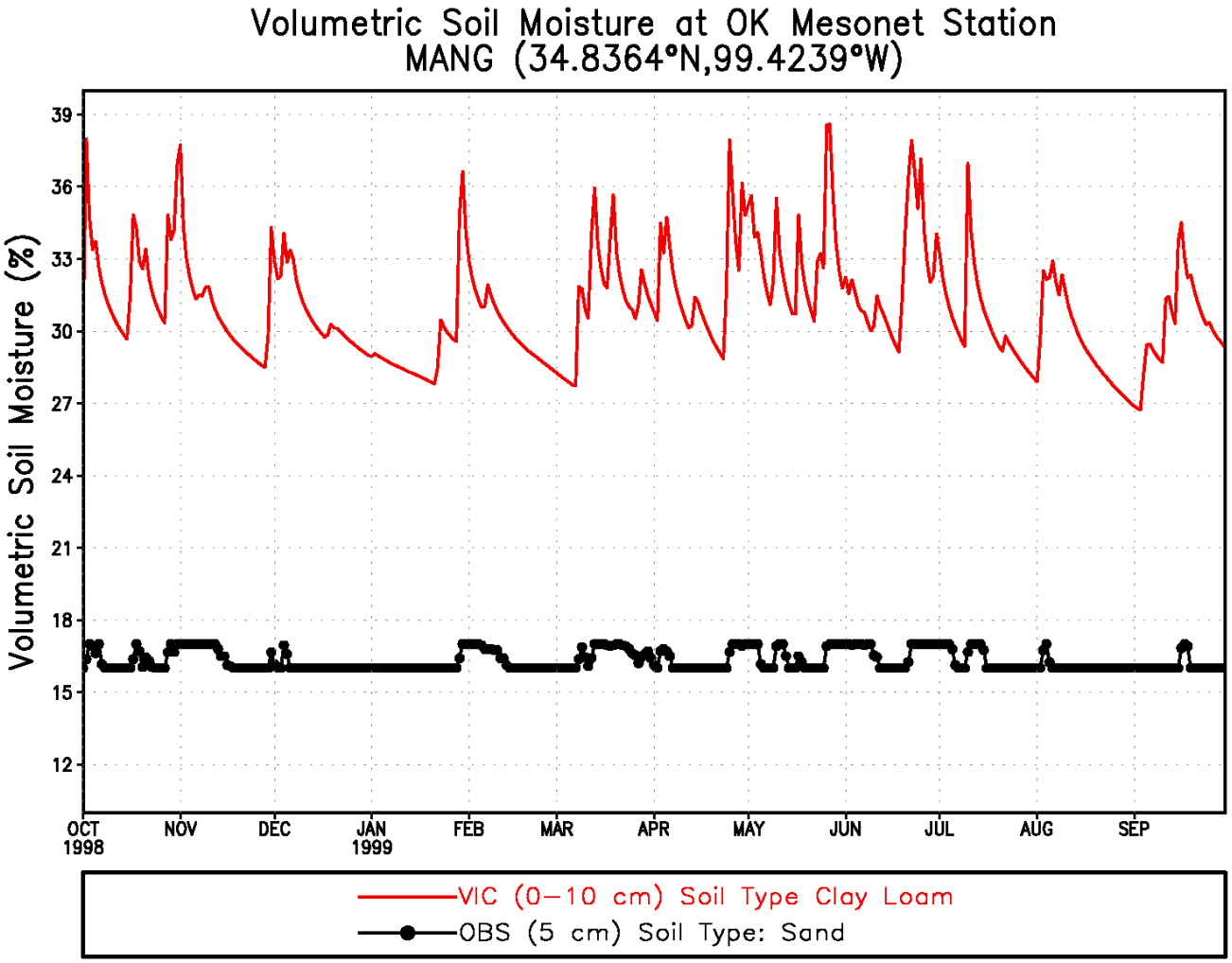
(at clay-loam site ALTU)



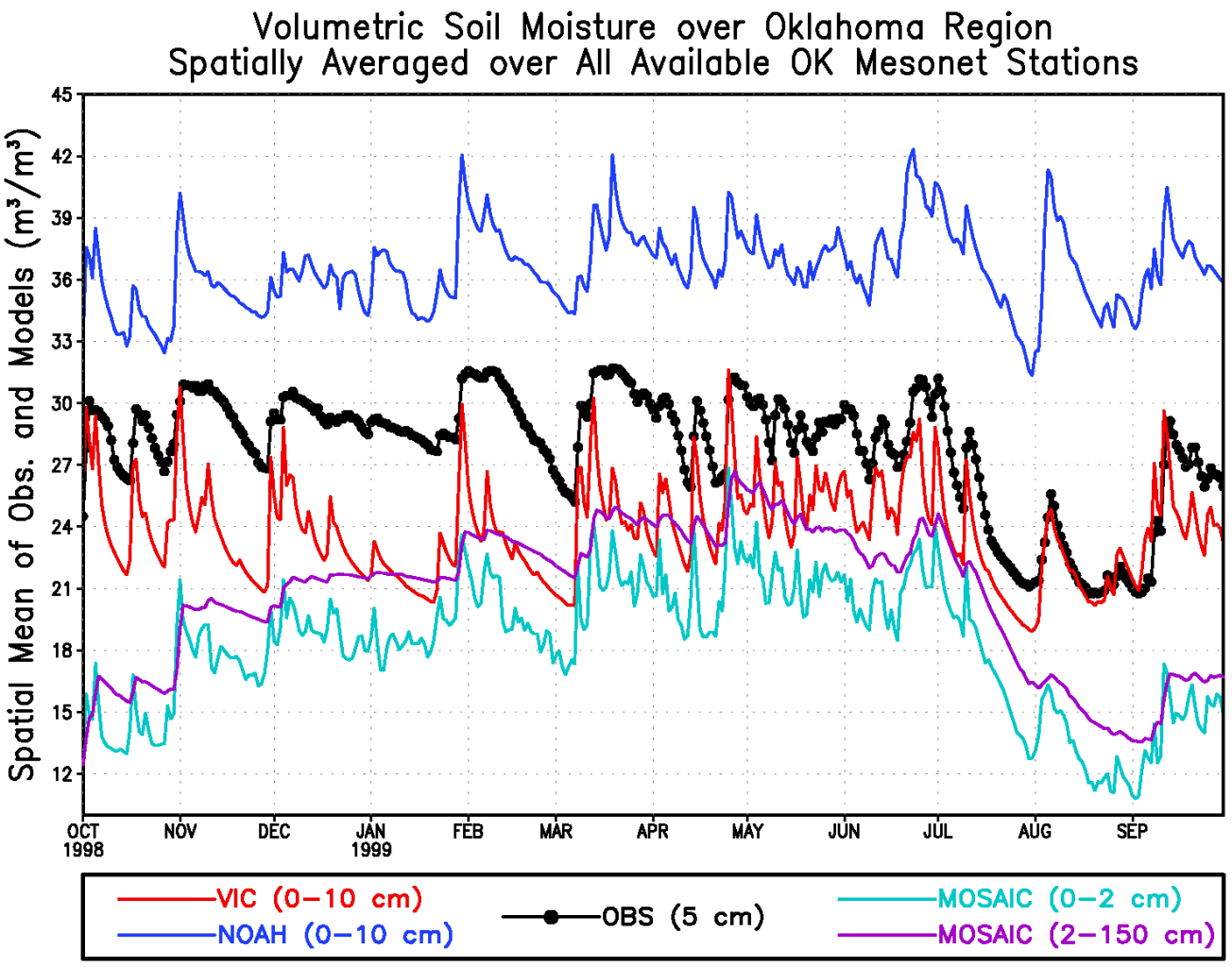
VIC Simulation with Unmatched Local Soil Type

(at sand site MANG)

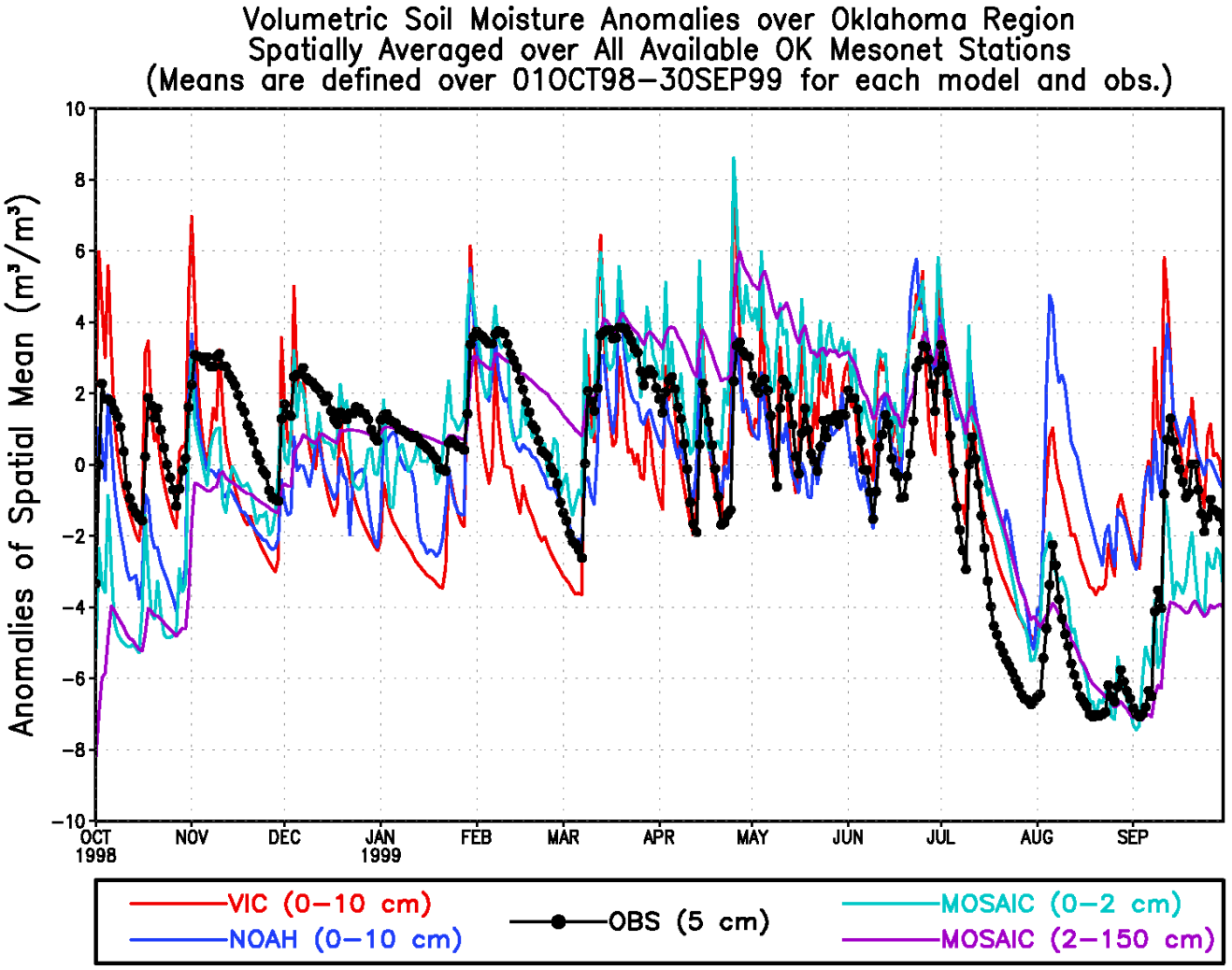
(Note: observed soil moisture somewhat suspect at all sand sites)



Soil Moisture Validation

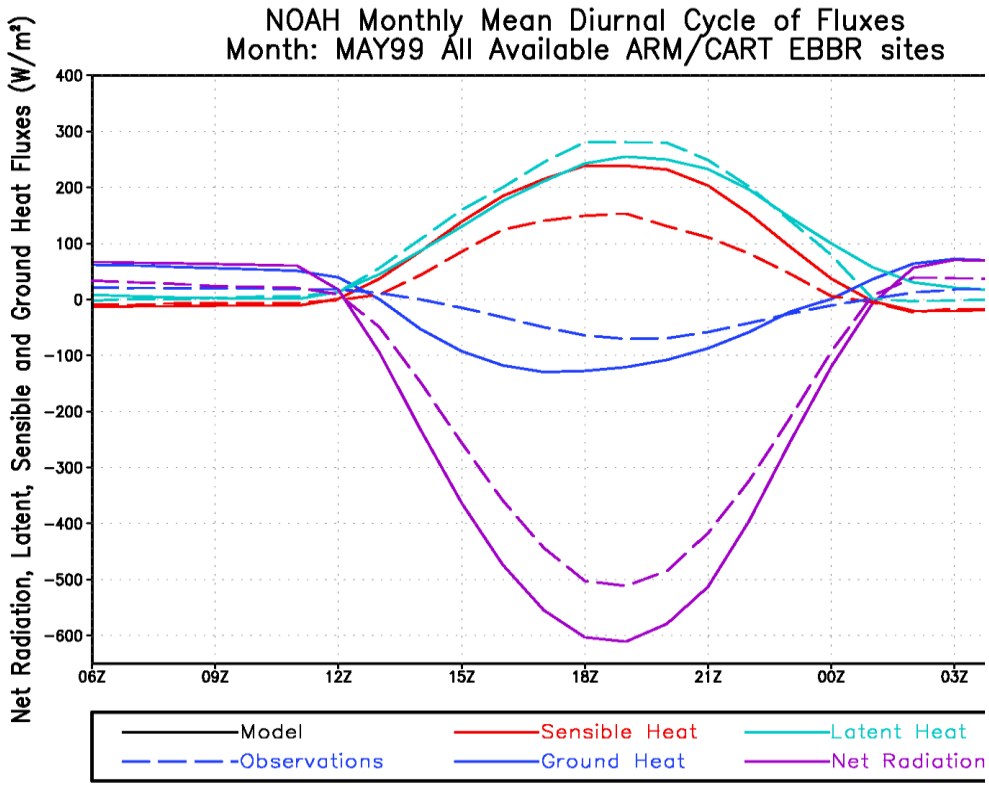


Soil Moisture Anomaly Validation

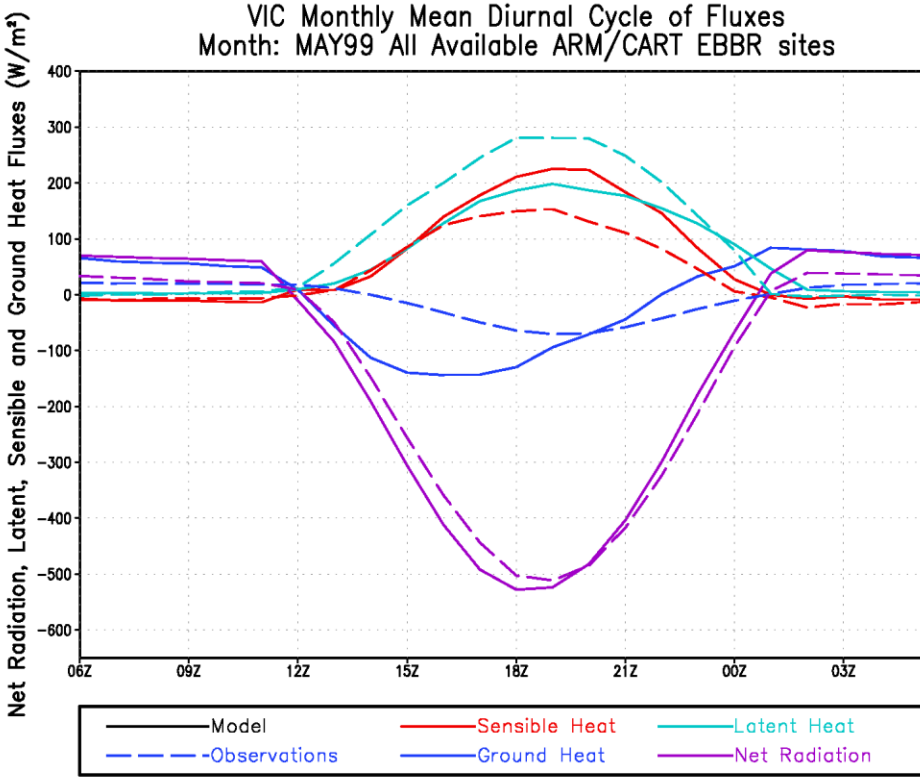


Surface Flux Validation
All ARM Sites: May 99

NOAH

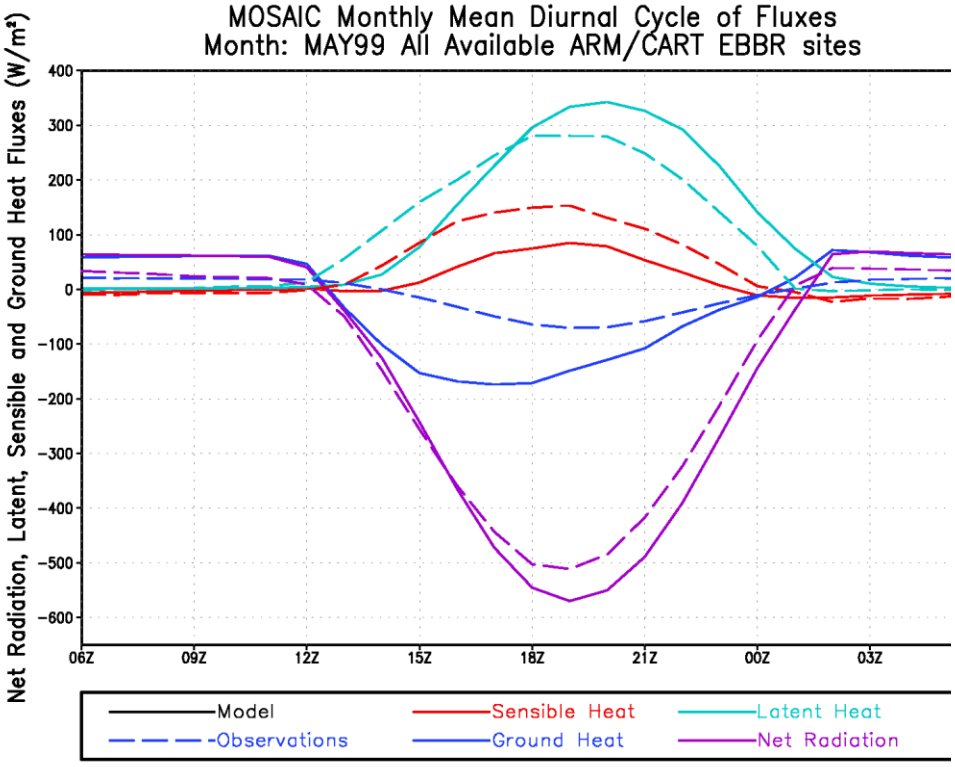


VIC

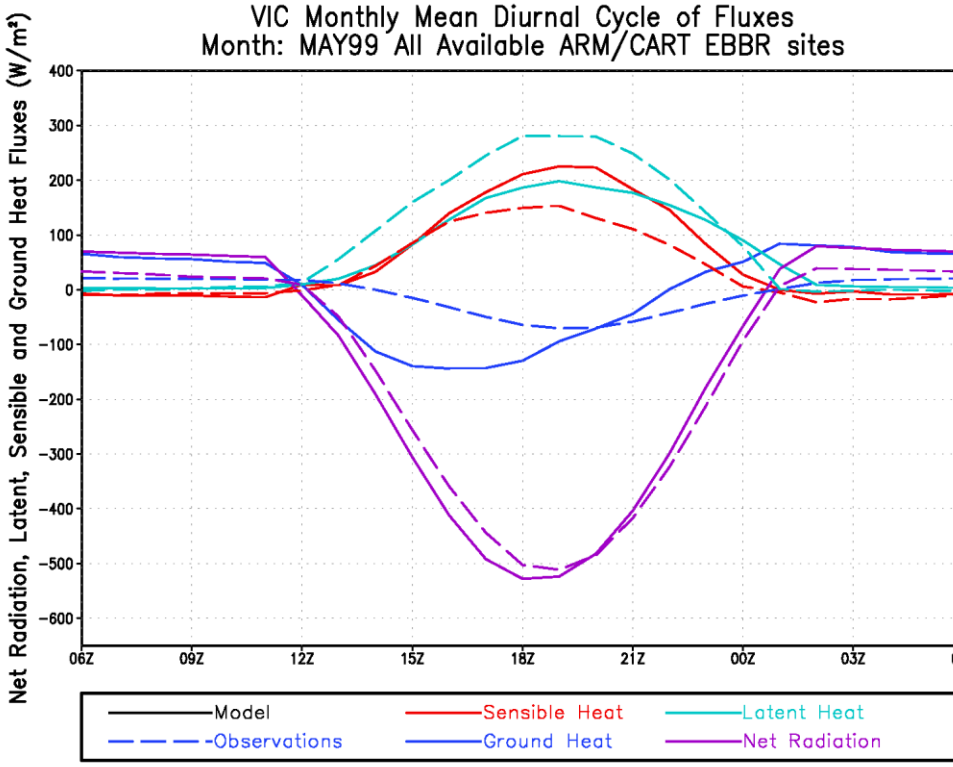


Surface Flux Validation
All ARM Sites: May 99

MOSAIC



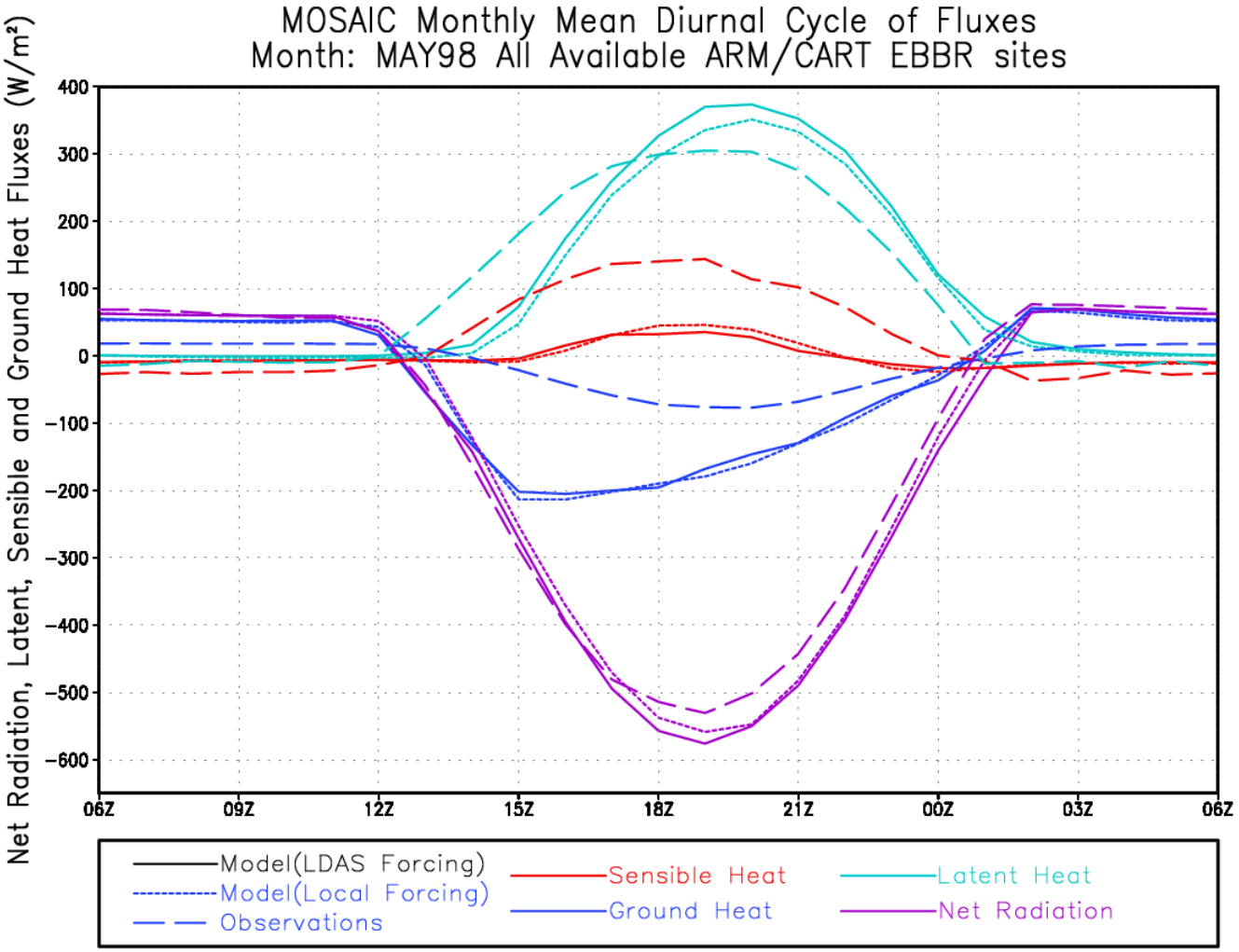
VIC



Impact of Local Forcing vs Gridded LDAS Forcing on Sfc Fluxes

(small impact compared to earlier impact of unmatched local vs gridded soil type)

Similar impact in VIC and NOAH as shown here for MOSAIC



Answers: LDAS Scientific Questions

1. **Can land surface models forced with observed meteorology and radiation accurately calculate soil moisture?** **Yes**

2. **What are the relative contributions to the differences between models and observations of errors in the soil moisture observations or of differences in the following between model and observed:**

   a. **Forcing?** **No**
   b. **Soil properties?** **Yes**
   c. **Vegetation?** **Probably**
   d. **Scales?** **No, if using spatial average**
   e. **Vertical resolution?** **Apparently not, thus far**
   f. **Tiling assumptions?** **?**

Conclusions

1. A preliminary look at the LDAS simulations of soil moisture shows reasonable simulations of soil moisture and temperature and fluxes compared to Oklahoma observations.

2. Differences between model output and observations are not due to differences between actual and LDAS-specified forcing or random observational errors, but are likely due to soil type or vegetation type differences and model assigned parameters.

3. Conducting these experiments is very difficult, given the task of assembling and quality controlling the complex combination of disparate forcings and the validation observations, the massive amounts of output generated, and typical computer and disk storage problems problems, but coordination between the LDAS team members has worked extremely smoothly.