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

GAPP GCIP

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

Mississippi River Climate & Hydrology Conference
15 May 2002

Improving Weather and Climate Prediction: Becominlg a Complete Earth System Endeavor

1 - ATMOSPHERE: troposphere, stratosphere
- *initial conditions require* *atmosphere data assimilation*

2 - OCEAN: deep ocean, seas, coastal ocean, sea ice
- *initial conditions require* *ocean data assimilation*

3 - **LAND**: soil, snowpack, vegetation, runoff
- ***initial conditions require*** ***land data assimilation***

GAPP

LAND DATA ASSIMILATION SYSTEMS:

- **Modern NWP & Seasonal Forecast Climate models must model and initialize the entire "Earth System"**
  - Atmosphere
  - Ocean
  - **Land → (Land Data Assimilation Systems: LDAS)**

- **Three Broad Approaches to Land Data Assimilation**
  - **1)** Coupled Land/Atmosphere 4DDA e.g. Global Reanalysis-I
    - 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) e.g. N-LDAS
    - observed precipitation/insolation used directly in land surface forcing
  - **3)** Hybrid Land 4DDA e.g. Eta/EDAS, Global Reanalysis-II
    - Coupled land/atmosphere, but observed precipitation replaces model precipitation for driving the land surface

N-LDAS Design
(The Uncoupled Approach)

1. **Force models with 4DDA surface meteorology (Eta/EDAS), 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:**

   – NOAH (NOAA/NWS/NCEP)
   – MOSAIC (NASA/GSFC)
   – VIC (Princeton U./ U. 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.**

N-LDAS Objectives: Cont'.

Determine if macroscale, physically-based, distributed SVAT-type land models can achieve skill in streamflow simulation commensurate with traditional lumped catchment models (both calibrated and uncalibrated, both research and operational).

A shared objective with the DMIP Project of NWS/OHD, but on larger scale at coarser resolution.

The GAPP/GCIP Vision:

Improving seasonal-to-interannual climate and hydrological prediction by bringing together meteorologists and hydrologists in:

(A) coupled land-atmosphere modeling

(B) uncoupled land modeling and land data 4DDA

(C) water resource applications of ensemble weather and climate forecasts

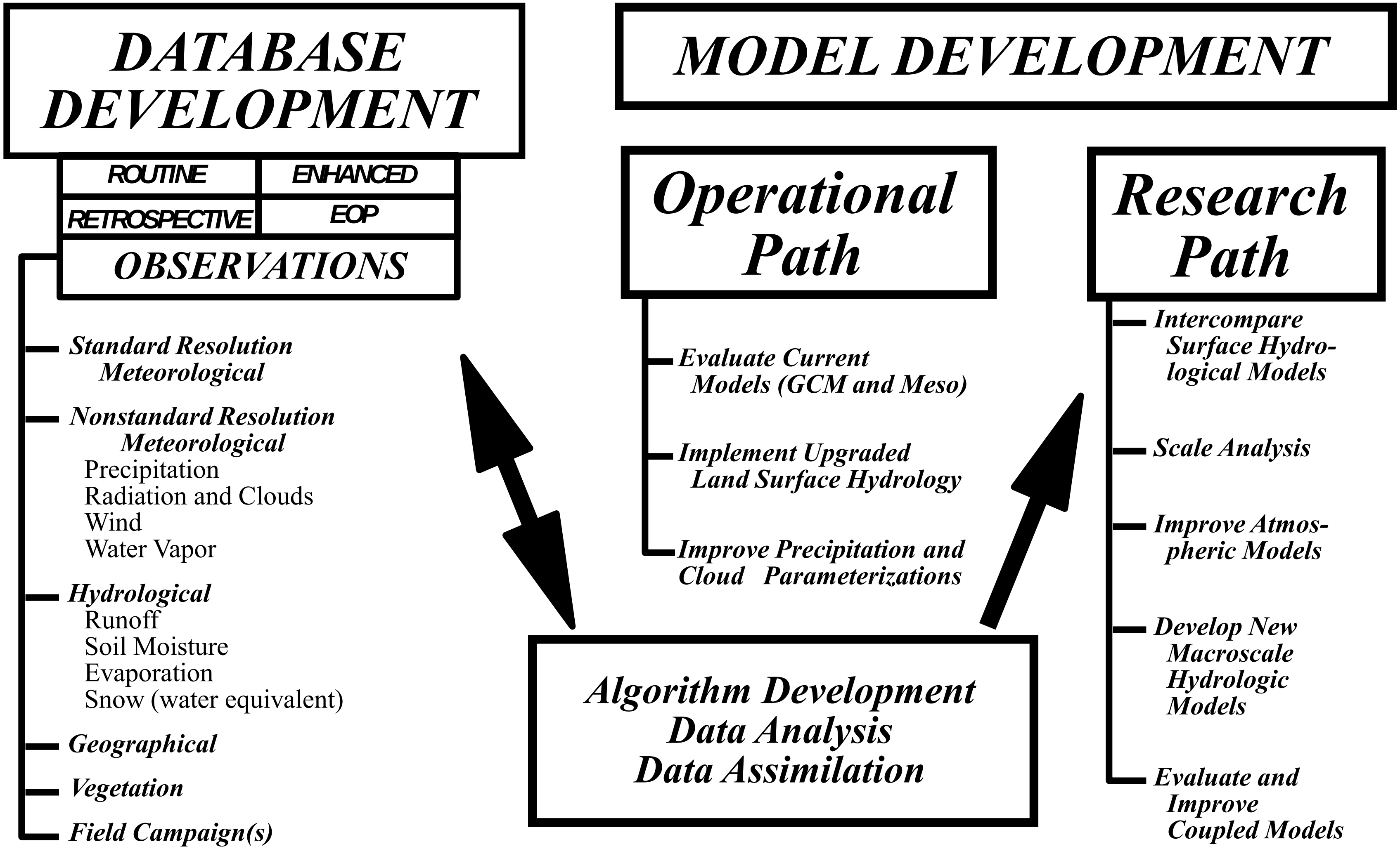


Figure 2. The GCIP implementation framework.

N-LDAS PROJECT GOAL:

Carry the distributed macro-scale legacy of the PILPS-2c and GSWP projects of GEWEX into a realtime demonstration realm, in particular at NCEP for use in NCEP seasonal climate and weather prediction suites.

N-LDAS PROJECT GOAL:

<u>Bring together</u> multi-institution (operational center, government labs, universities) GAPP-funded investigators (both research and operational), and their

A) land models
B) land-relevant satellite observations, products, databases
C) land in situ observations, products, databases
D) land validation tools and techniques, and
E) land models and modeling expertise,
F) land stakeholder applications,

into a joint, common, cohesive and ongoing **<u>realtime demonstration project</u>**, with clear **<u>follow-on operational potential</u>**, and highlighted by frequent and open infusion and sharing of methodologies, ideas, insights, and experiences.

N-LDAS Collaborators

GAPP

NCEP/EMC
Ken Mitchell
Dag Lohmann

NASA/GSFC
Paul Houser
Brian Cosgrove

NWS/OHD
John Schaake
Qingyun Duan

Rutgers Univ.
Alan Robock
Lifeng Luo

Princeton Univ.
Eric Wood
Justin Sheffield

NESDIS/ORA
Dan Tarpley
Andy Bailey

Univ. Oklahoma
Ken Crawford
Jeff Basara

Univ. Washington
Dennis Lettenmaier

NCEP/CPC
Wayne Higgins
Huug Van den Dool

NOAA/ARL
Tilden Meyers
John Augustine

Univ. Maryland
Rachel Pinker

NOAA **NASA** **Universities**

http://ldas.gsfc.nasa.gov

GAPP/GCIP Land Models, Products, Observations, and Validation Tools brought together in the N-LDAS Project:

- **Mitchell/Lohmann:** NOAH, realtime forcing & LSM output, streamflow
- **Houser/Cosgrove:** MOSAIC, retrospective forcing, LDAS web site
- **Wood/Lettenmaier:** VIC, stream connectivity, snow validation
- **Schaake/Duan:** SAC, precipitation analysis, soil properties
- **Robock/Luo:** validation of soil moisture, forcing, fluxes
- **Higgins et al:** precipitation forcing
- **Tarpley:** realtime satellite solar insolation, skin temp, snow cover
- **Pinker et al:** retrospective satellite solar insolation, skin temp
- **Crawford et al:** OU Mesonet forcing and soil moisture/temp
- **ARM/CART:** surface forcing, surface fluxes
- **Augustine/Meyers:** SURFRAD surface-based solar insolation obs
- **Lakshmi/Syed:** geo-statistical assessment of N-LDAS states/fluxes

LDAS Implementation

LSM Models: MOSAIC, VIC, NOAH, Sacramento

•1/8-degree resolution, hourly output

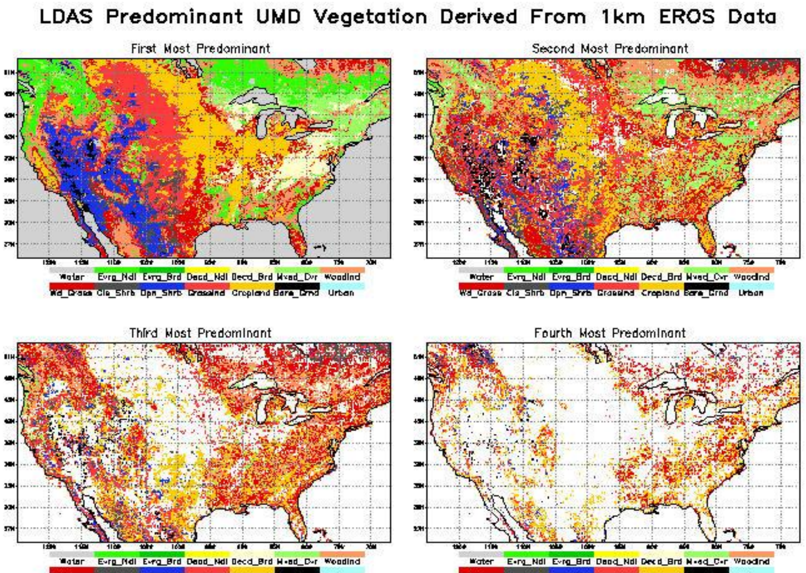
•Runoff routing: calibration, validation

Surface Characteristics:

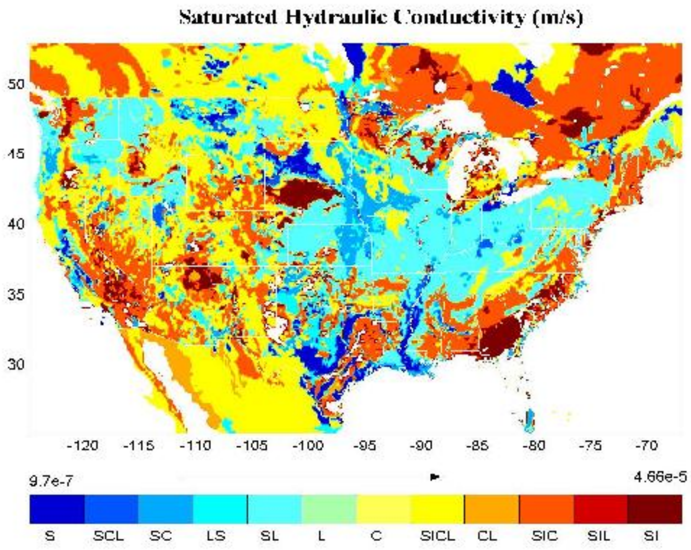
Vegetation: UMD, EROS IGBP, NESDIS greenness, EOS products

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.)

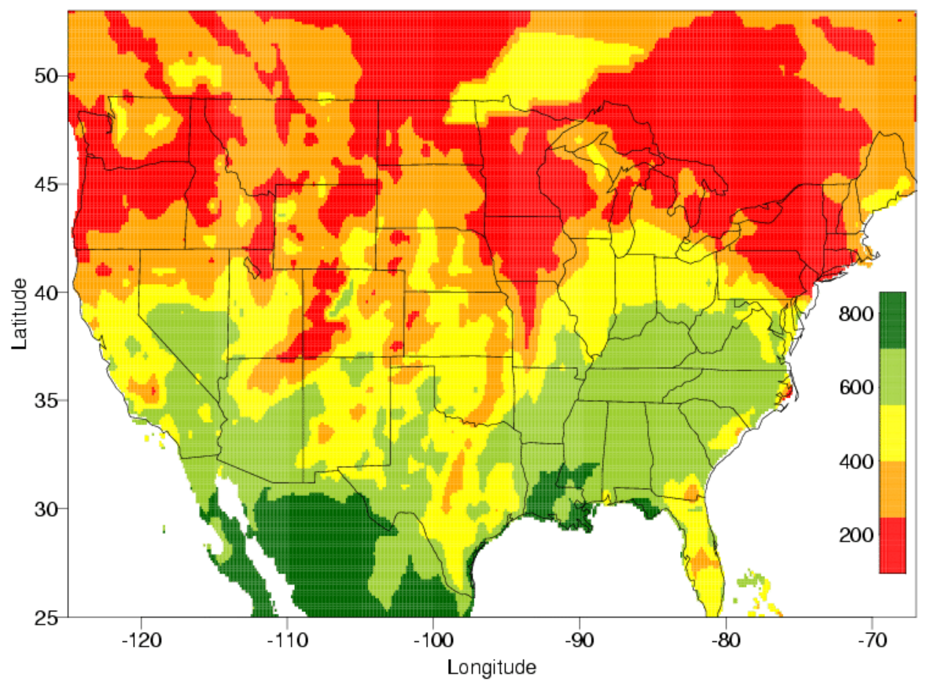
Forcing: (top two are non-model based)

Precipitation: Higgins et al daily gage anal, NCEP/OH Stage IV gage/radar

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



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**

-- Mandated largely by spin-up issues

-- NASA-assembled retrospective forcing

--- Higgins NCEP/CPC reprocessed precipitation forcing:

---- more gages obs, more QC

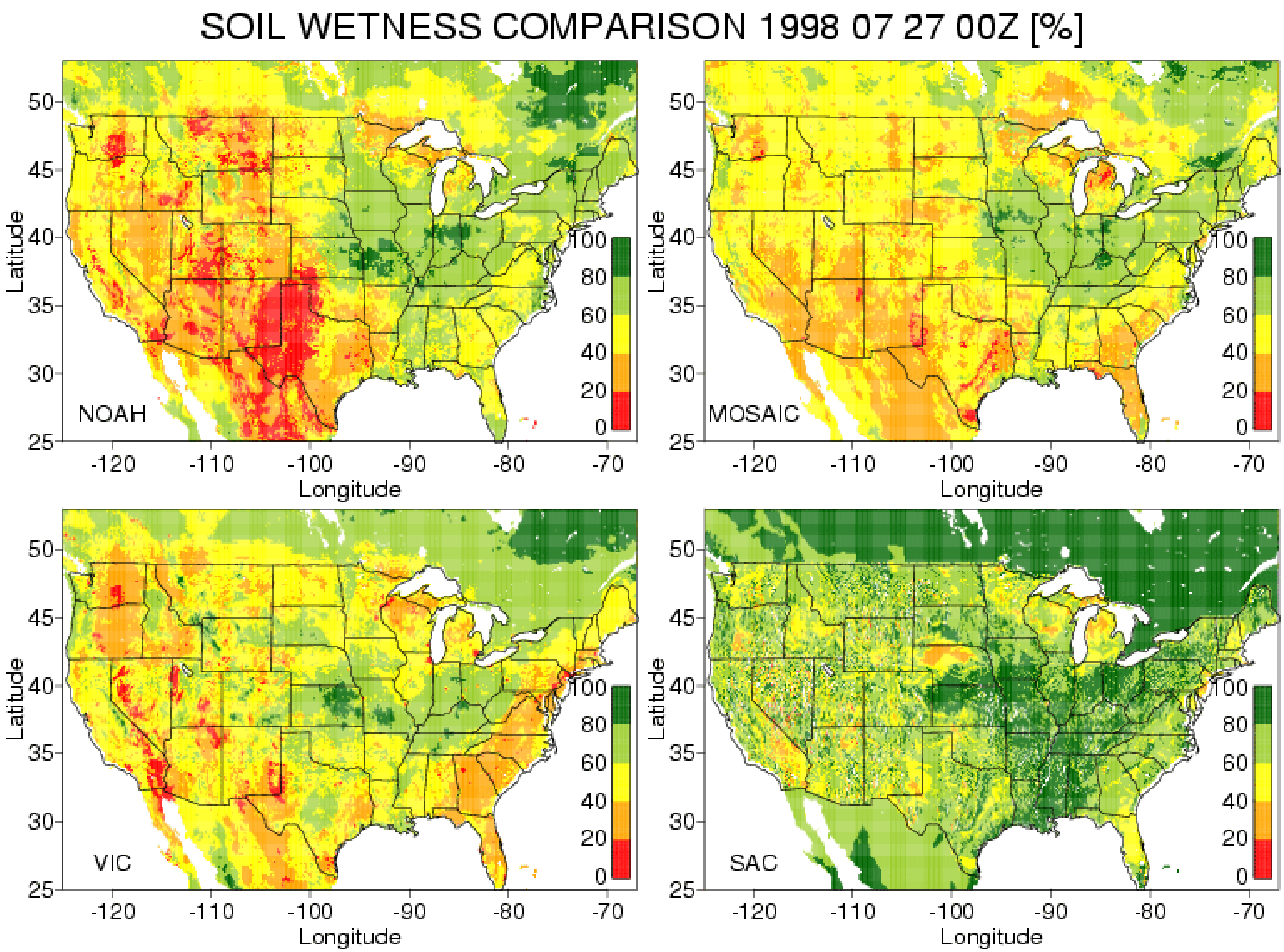
--- Pinker U.Md reprocessed solar insolation forcing

---- 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.

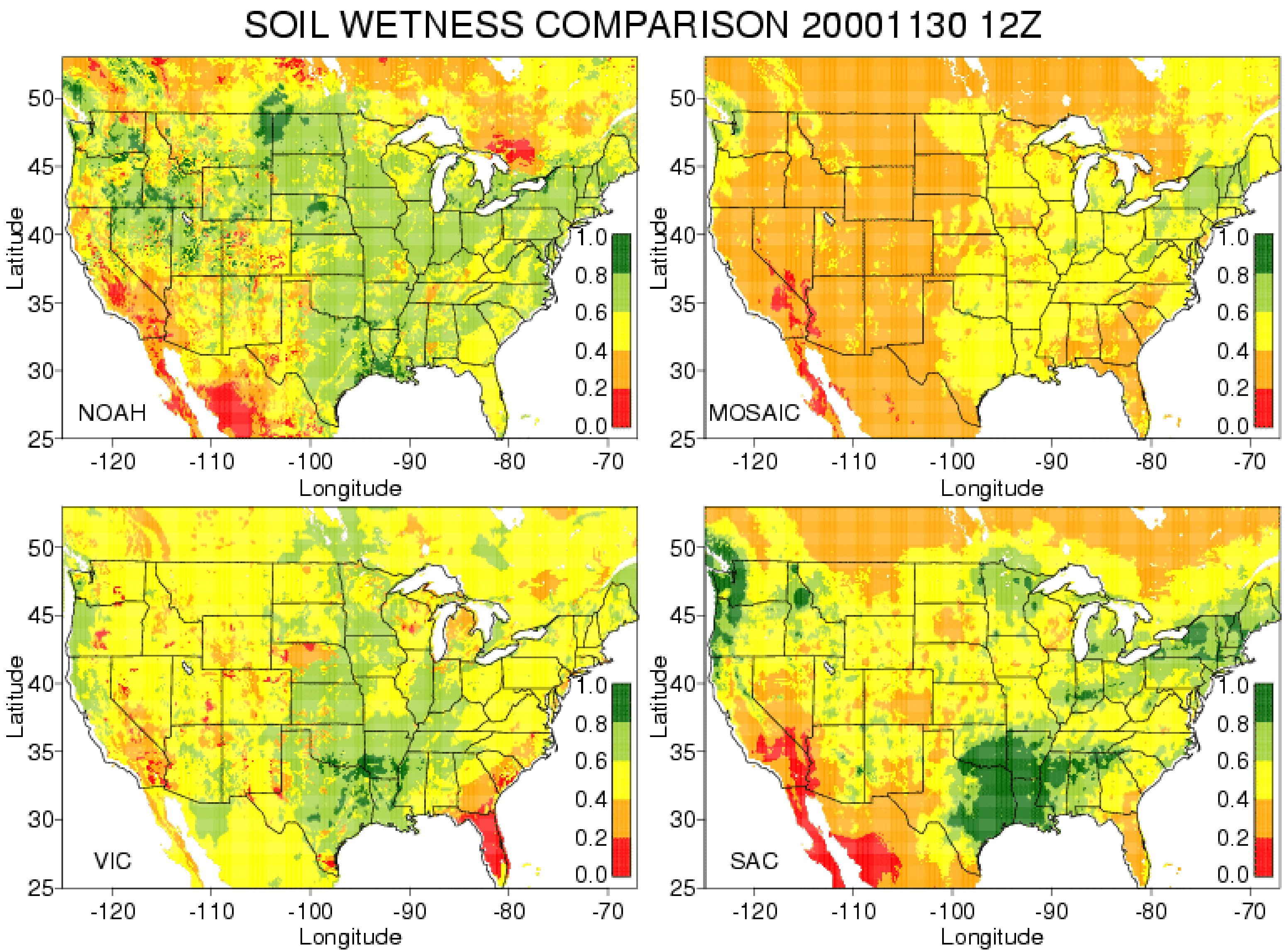
LDAS Soil Wetness Comparison

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

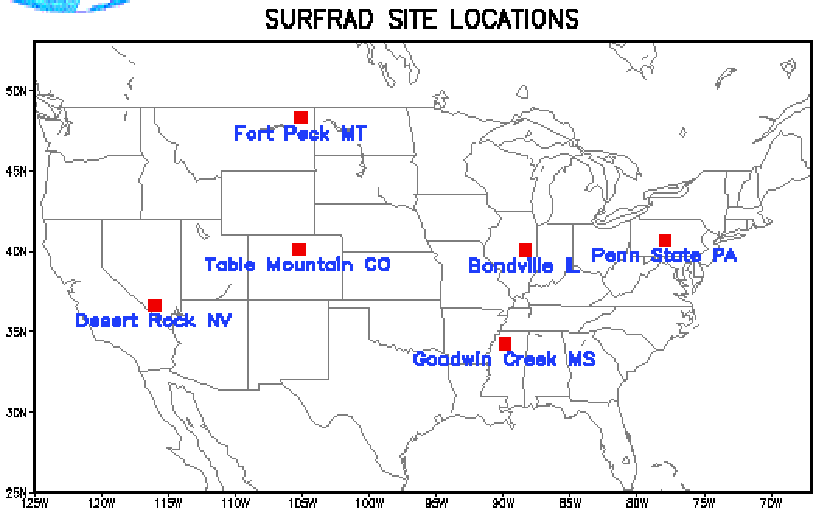


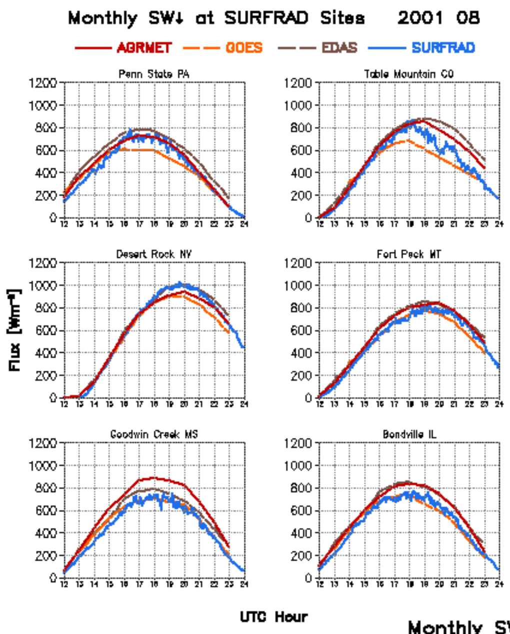
LDAS Soil Wetness Comparison

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



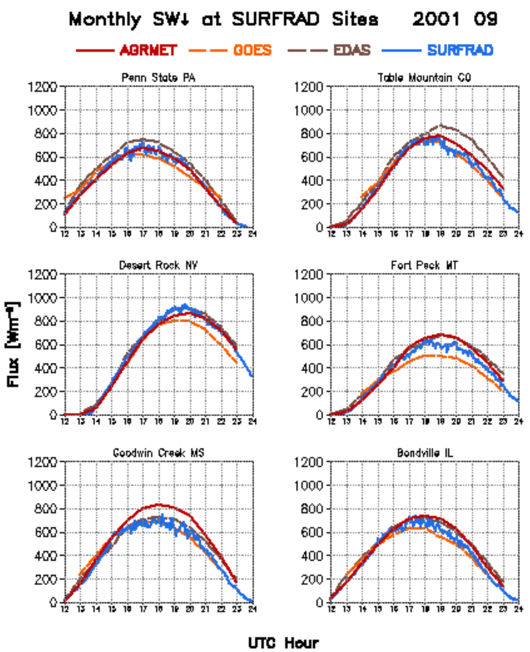
LDAS Forcing Validation 2001 08-11

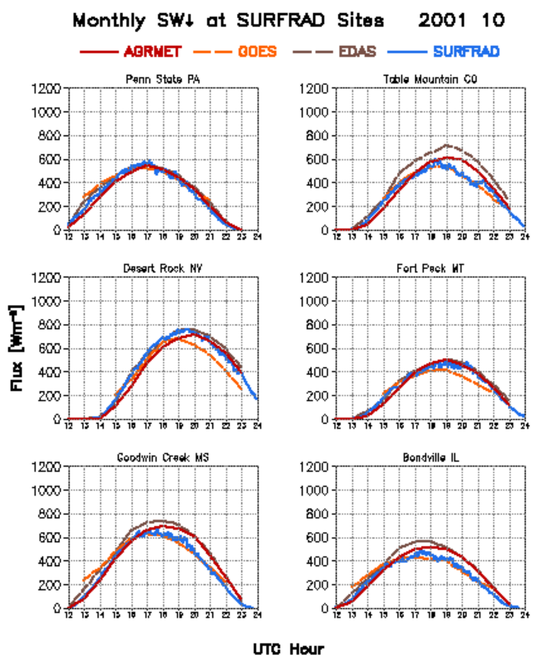


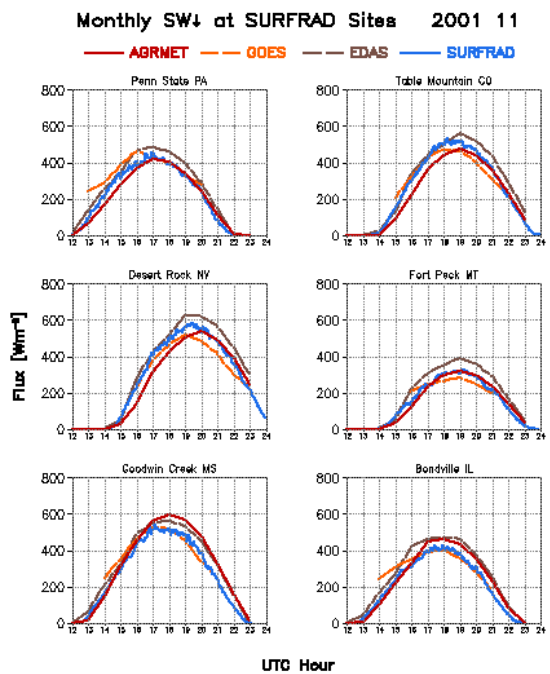


Monthly mean diurnal solar insolation intercomparison

GOES
EDAS
AGRMET
vs
SURFRAD



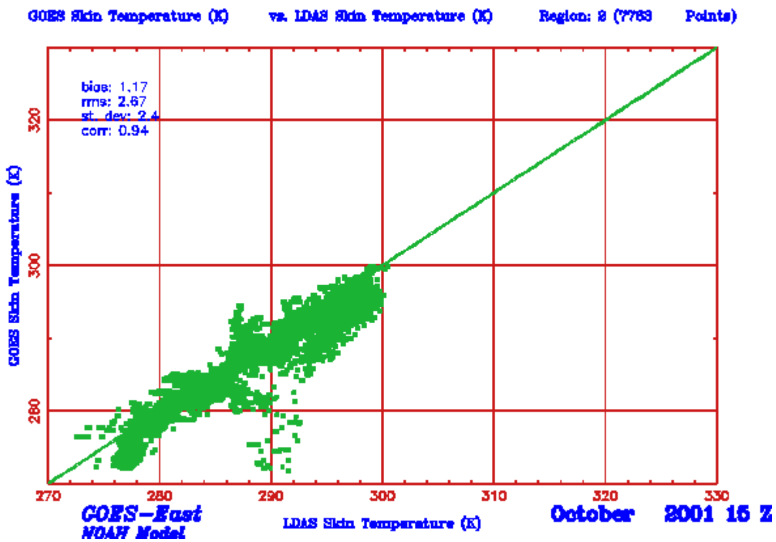


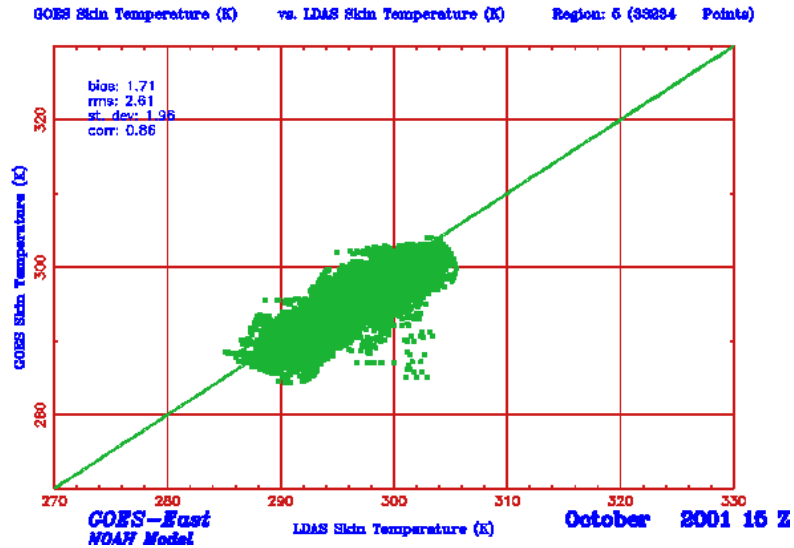


LDAS-NOAH Skin Temperature
October 2001 Validation cont.

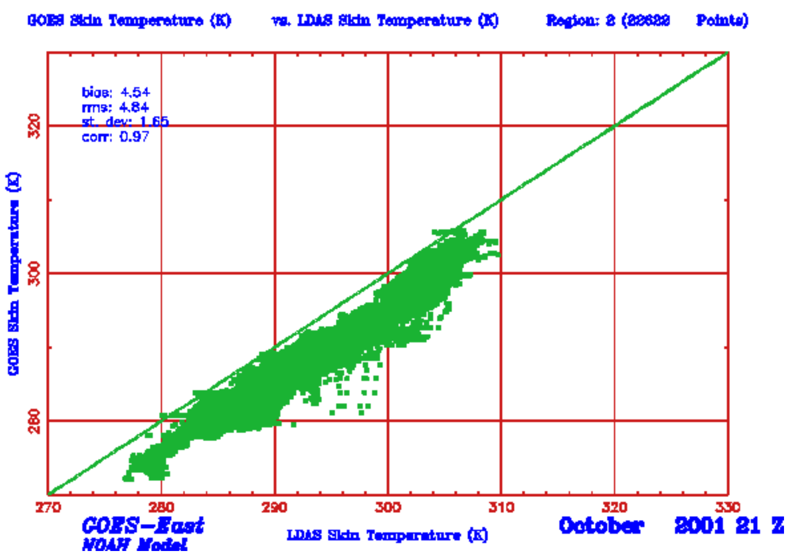
Region 2 | Region 5

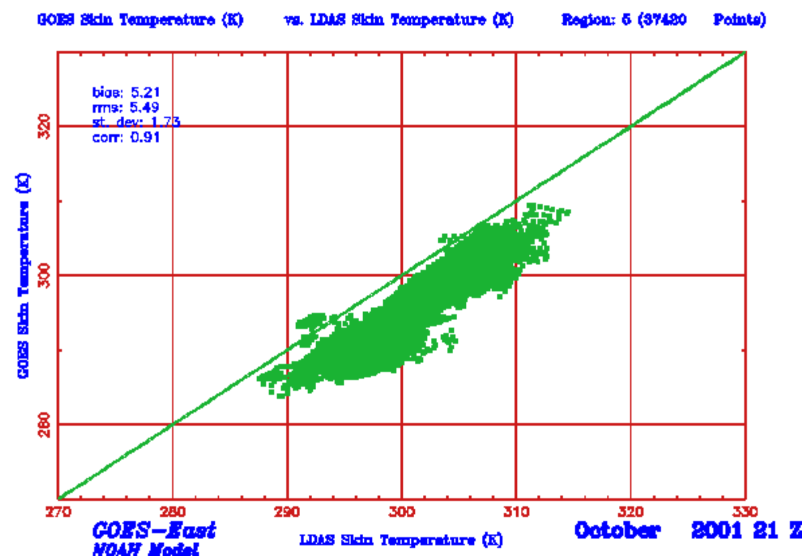
15 Z

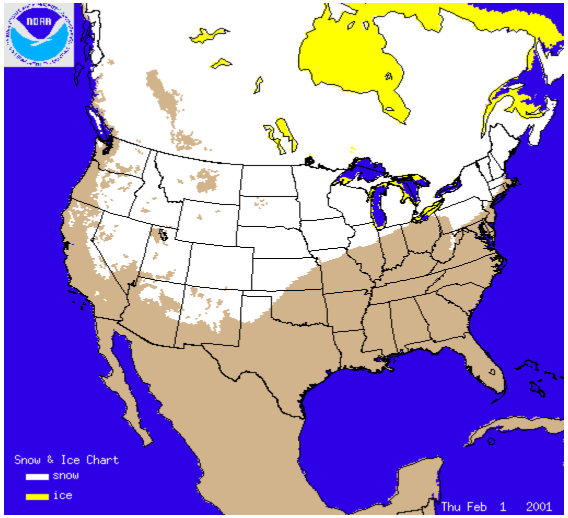




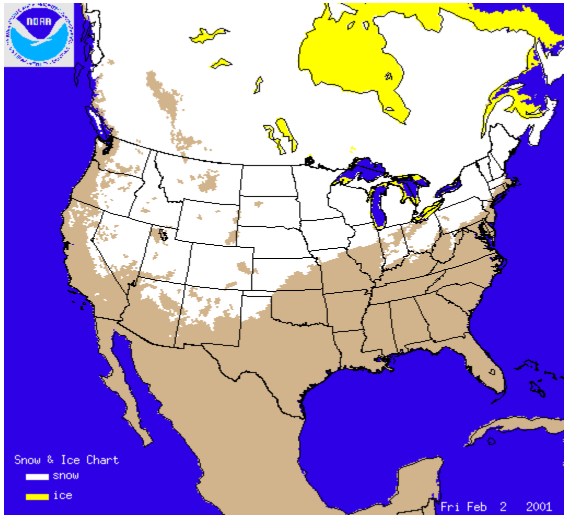
21 Z







01 Feb 2001



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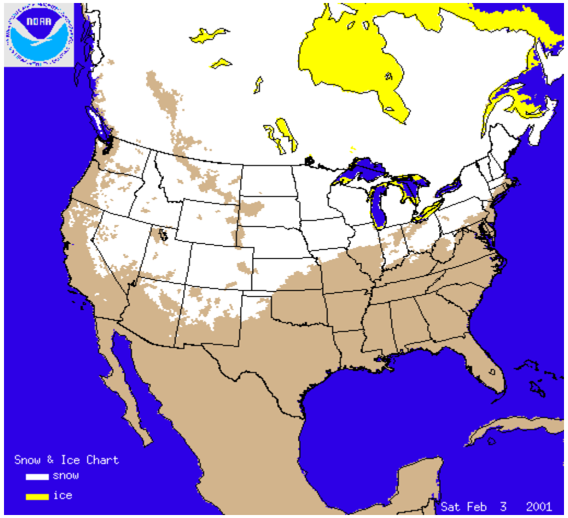
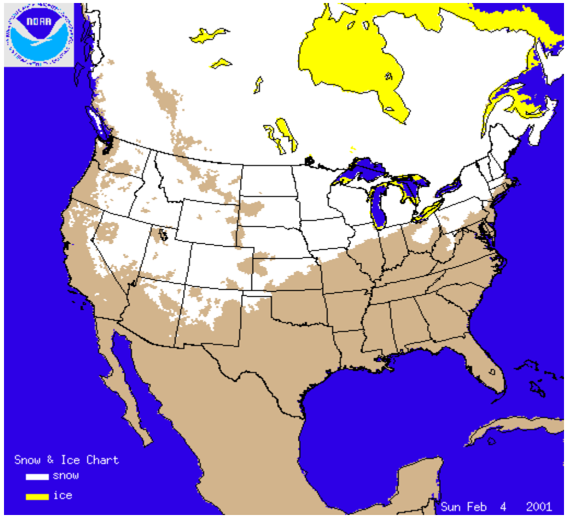
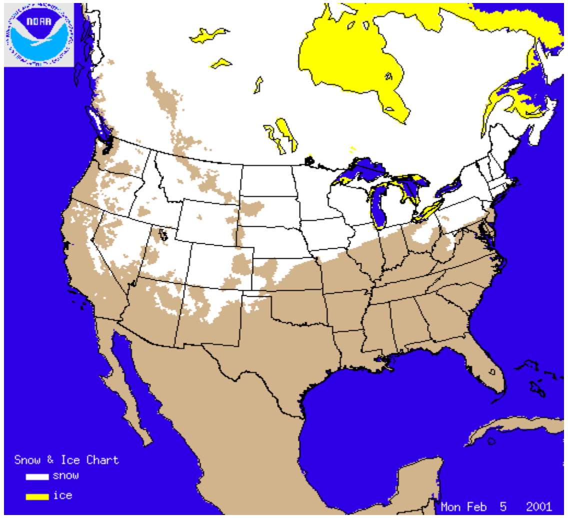


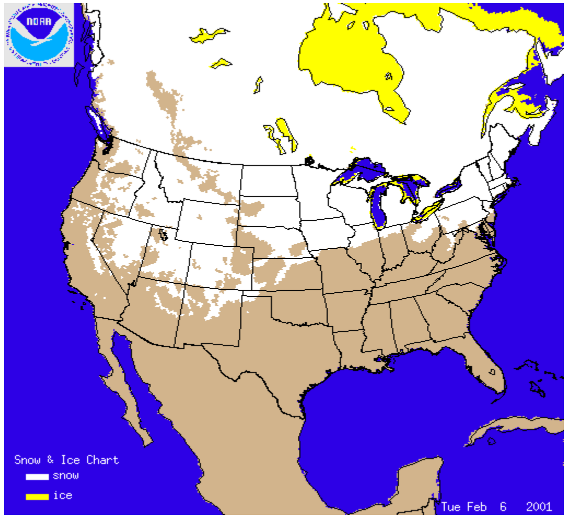
03 Feb 2001



04 Feb 2001



05 Feb 2001



06 Feb 2001

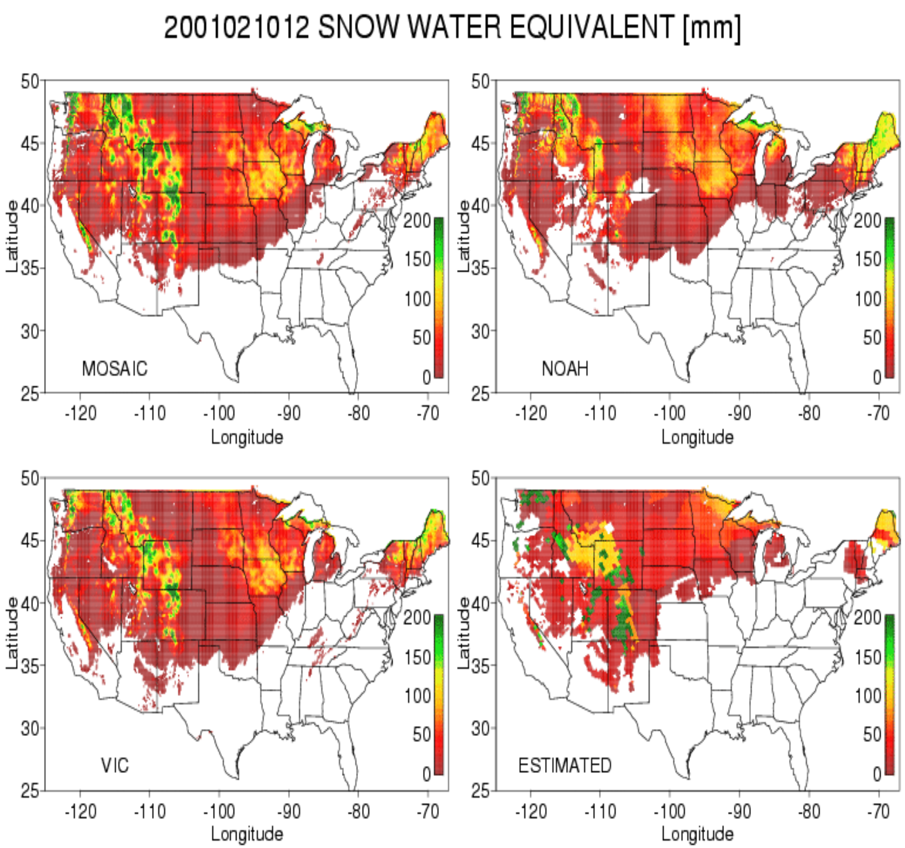
Shallow/retreating snow cover in USA northern plain states

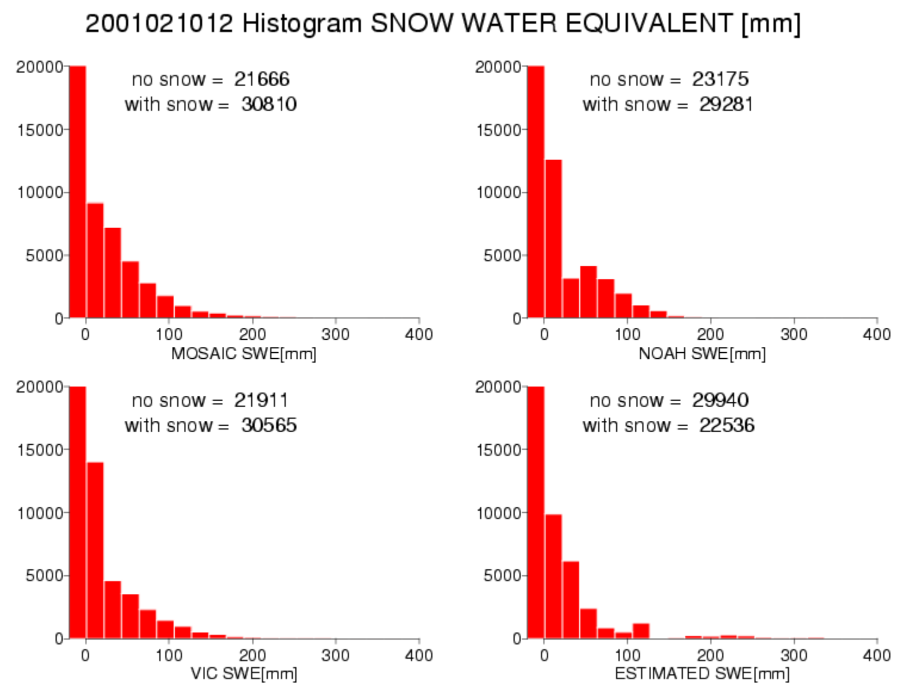
Snowpack Simulation Comparison

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

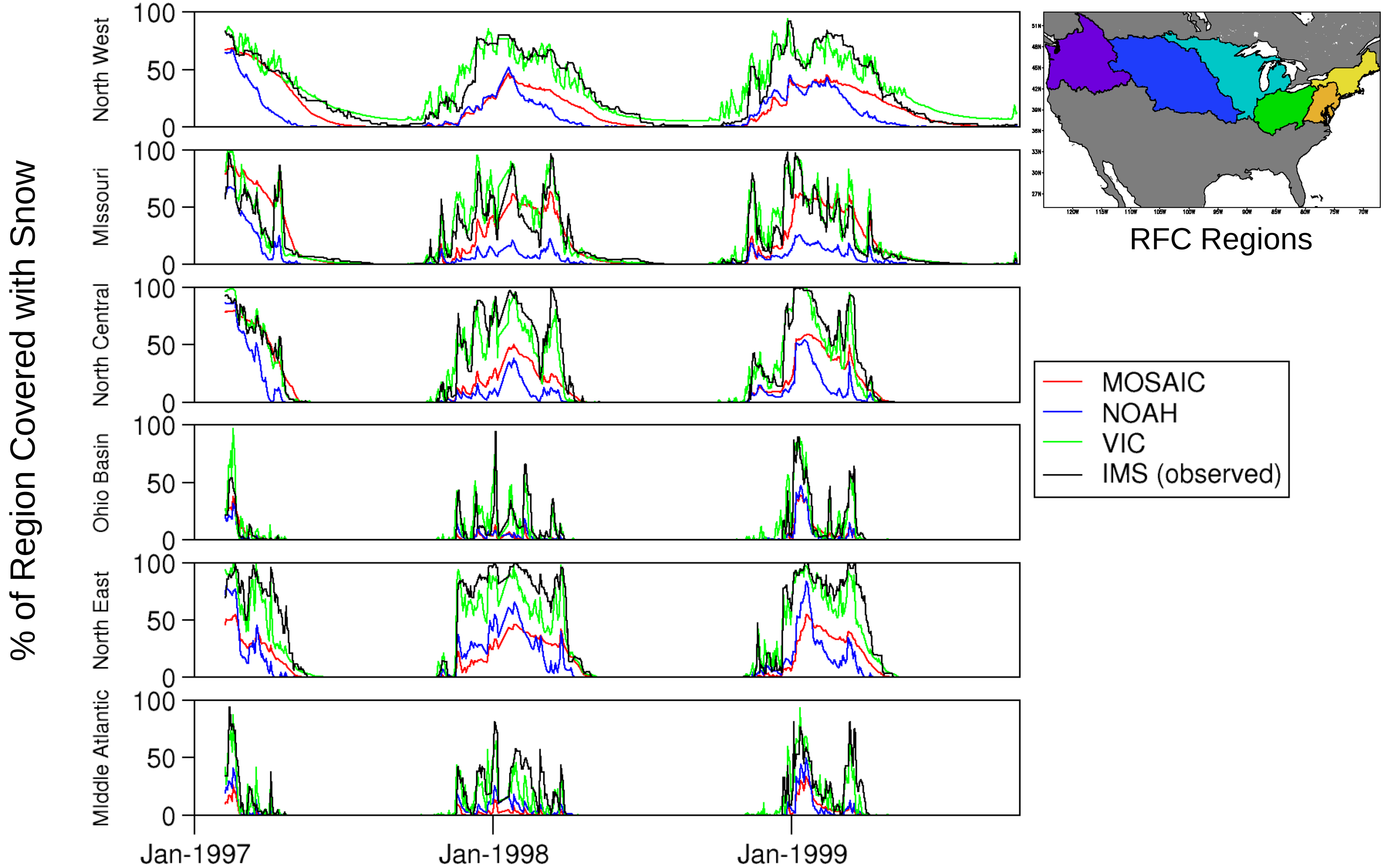
= estimated





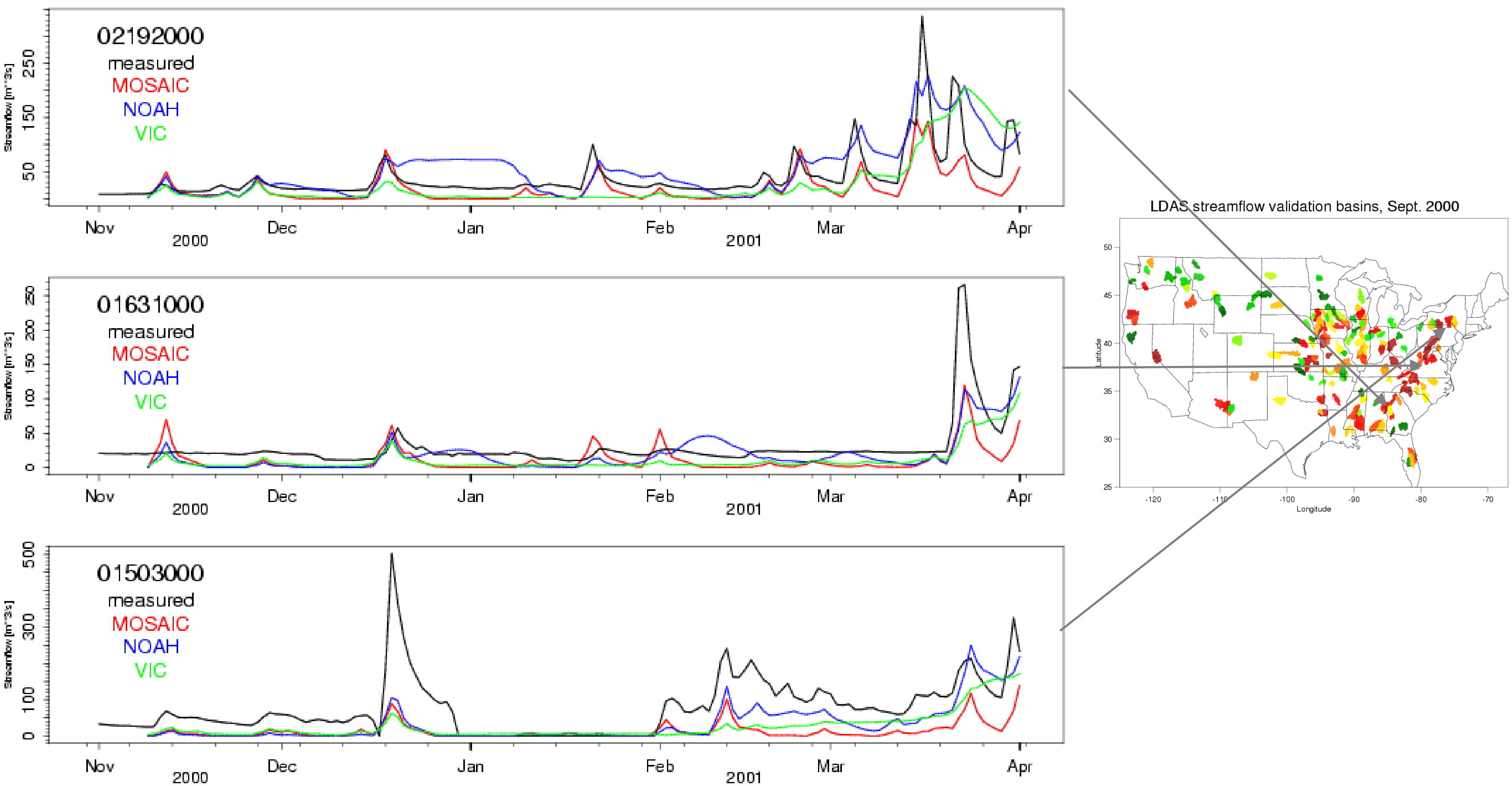
Snow Cover Validation

Comparison of Model Snow Cover with IMS (observed)



LDAS Models Streamflow

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



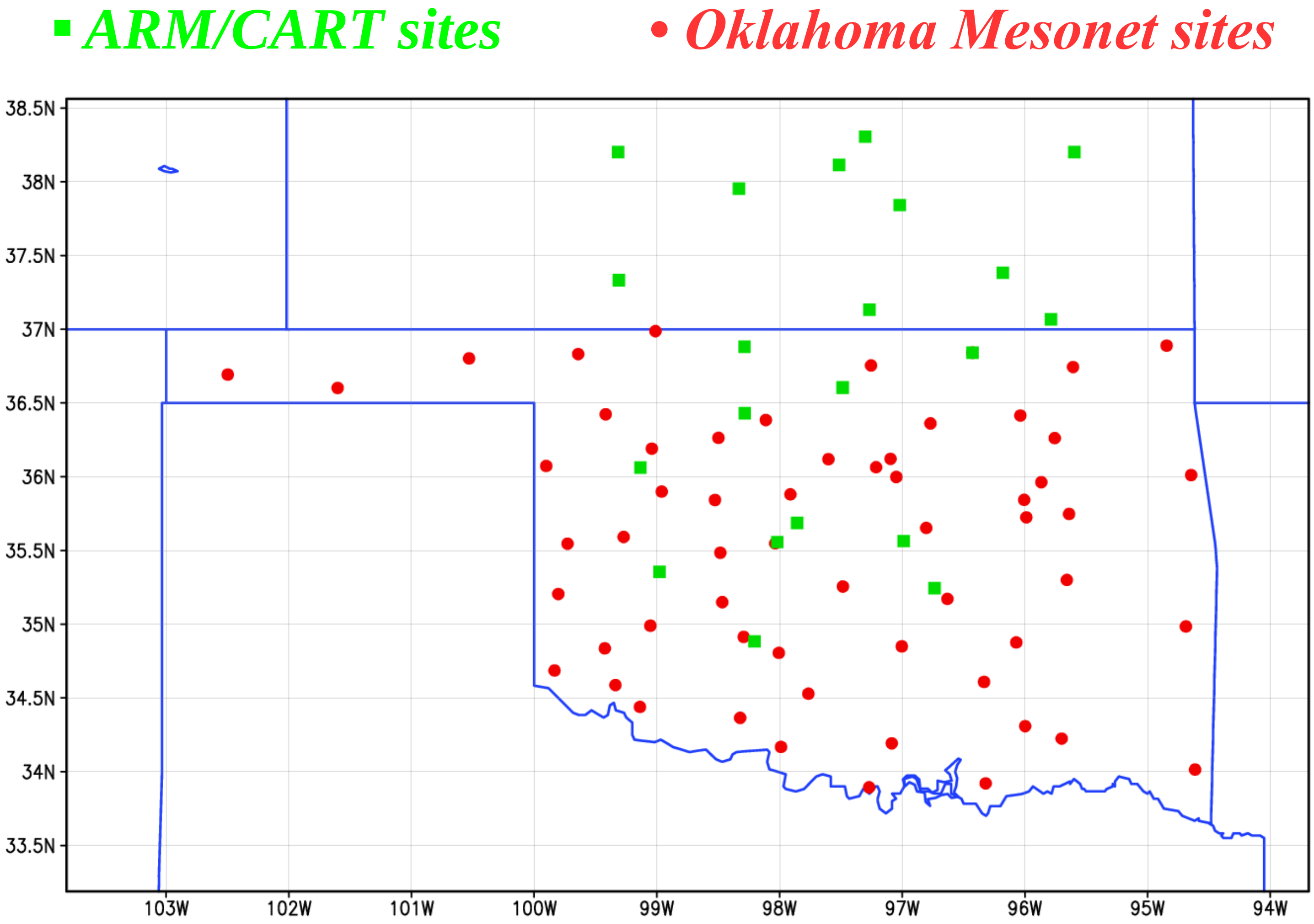
LDAS Scientific Questions

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:**

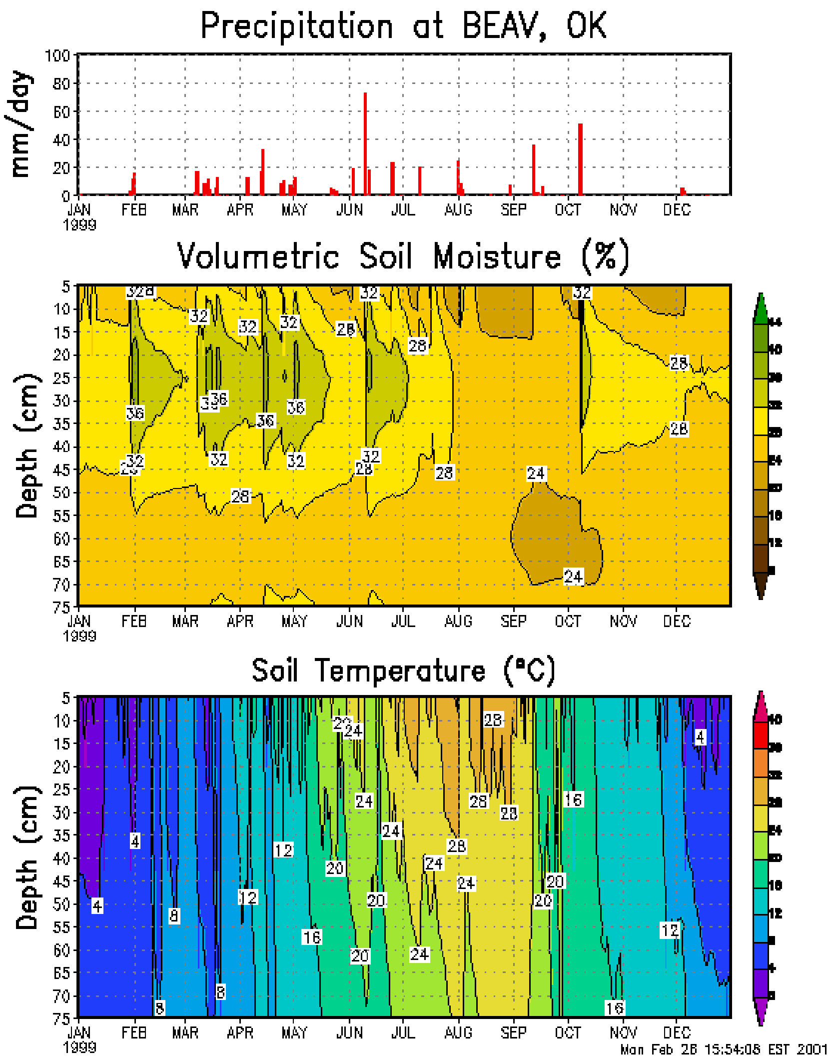
   a. **Forcing?**
   b. **Soil properties?**
   c. **Vegetation characteristics?**
   d. **Scales of representativeness?**
   e. **Vertical resolution?**
   f. **Other (e.g. tiling, variable infiltration assumptions)**

Soil Moisture/Temperature Observations



Oklahoma Mesonet

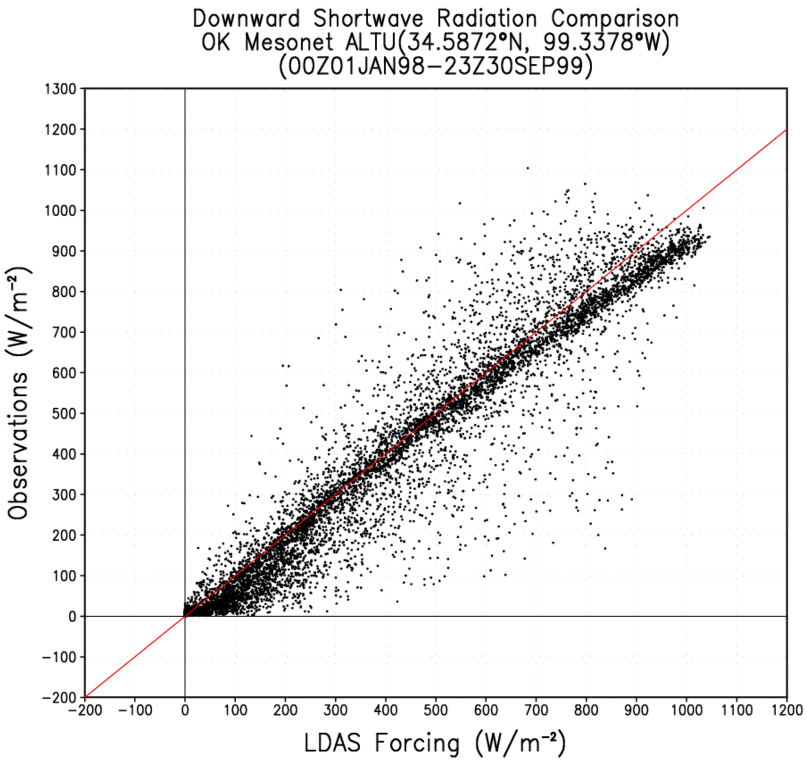
- 115 Mesonet stations covering every county of the state
- Meteorological observations are taken at 5 min intervals:
  - Relative Humidity at 1.5 m
  - Air Temperature at 1.5 m
  - Average Wind at 10 m
  - Precipitation
  - Station Pressure
  - Solar Radiation
- 72 stations have soil moisture and soil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



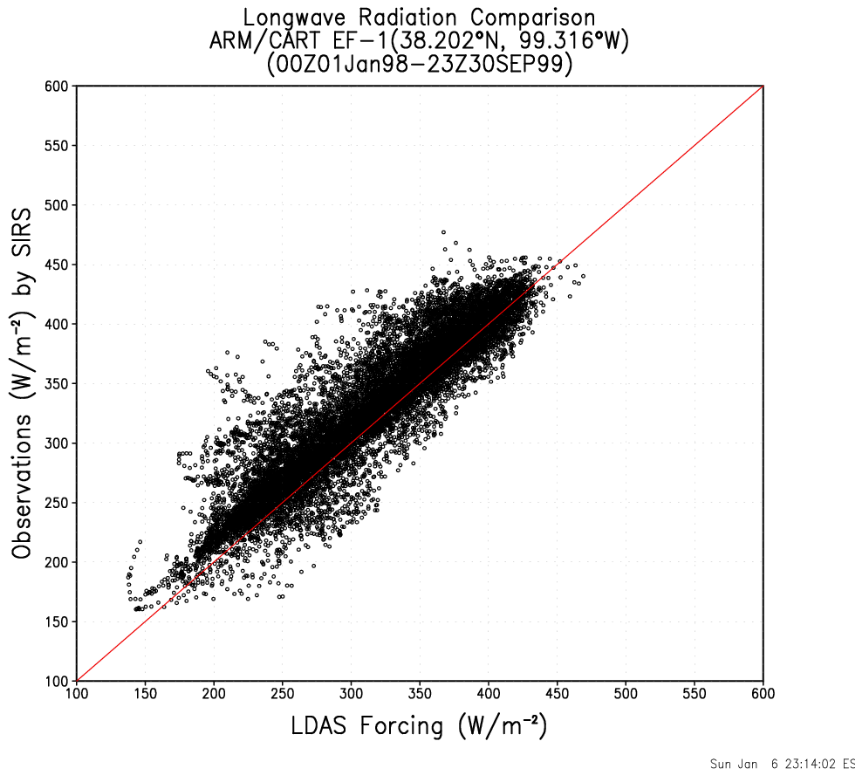
LDAS Radiation Validation: Shortwave / Longwave
(Gridded 1/8-th degree vs Pointwise Station)

Jan 98 – Sep 99

Shortwave

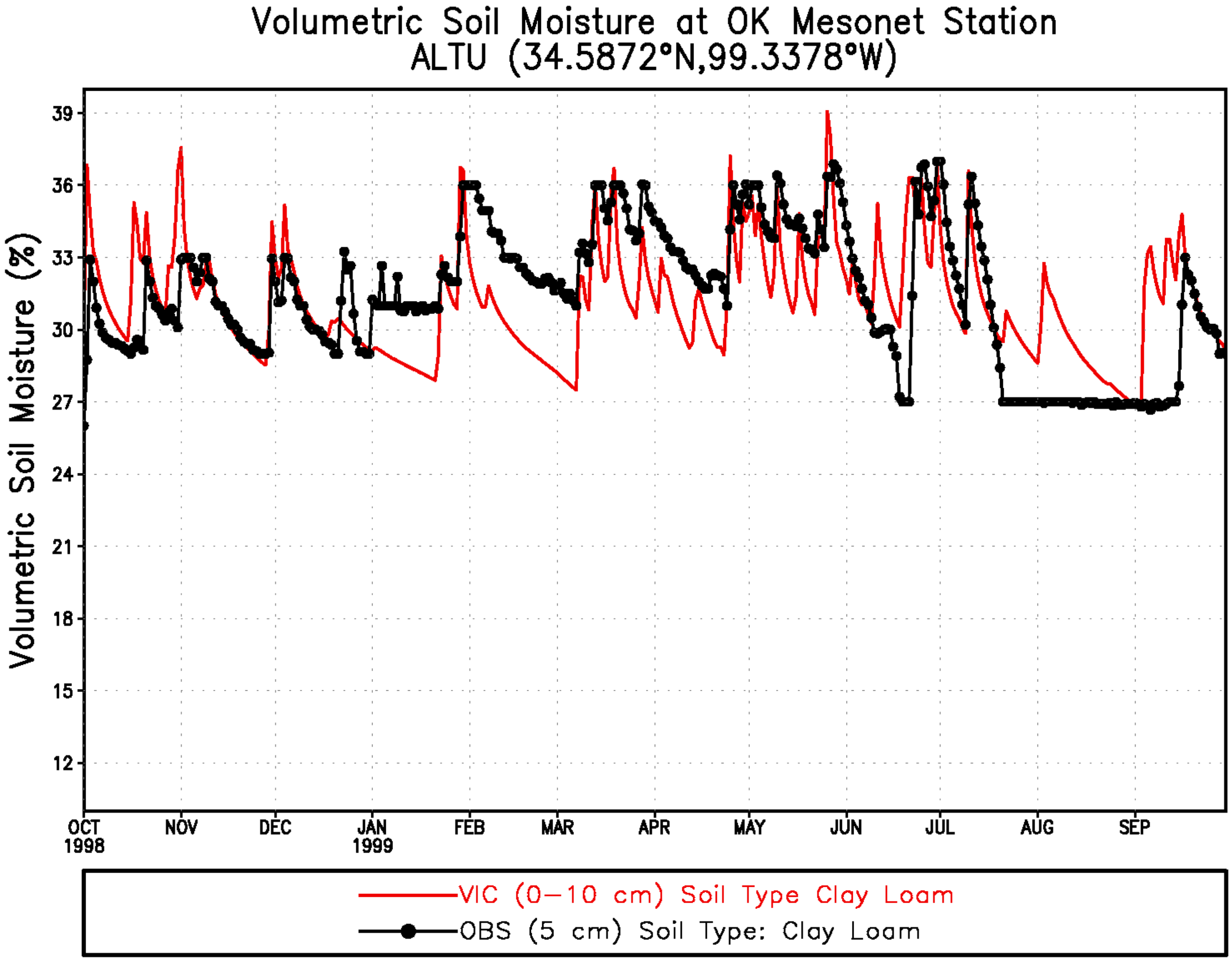


Longwave



VIC Simulation with Soil Type Matching Local Type

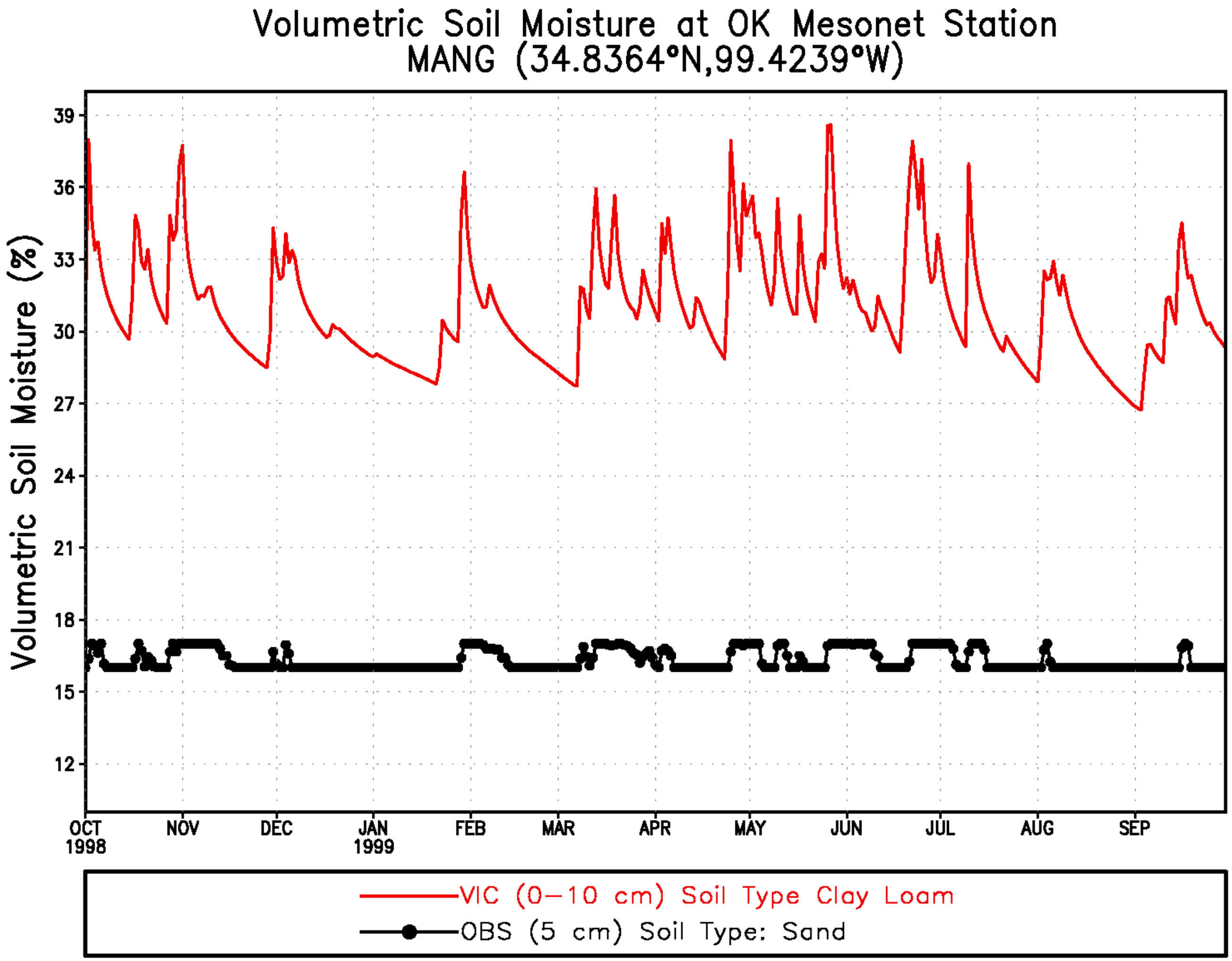
(at clay-loam site ALTU)



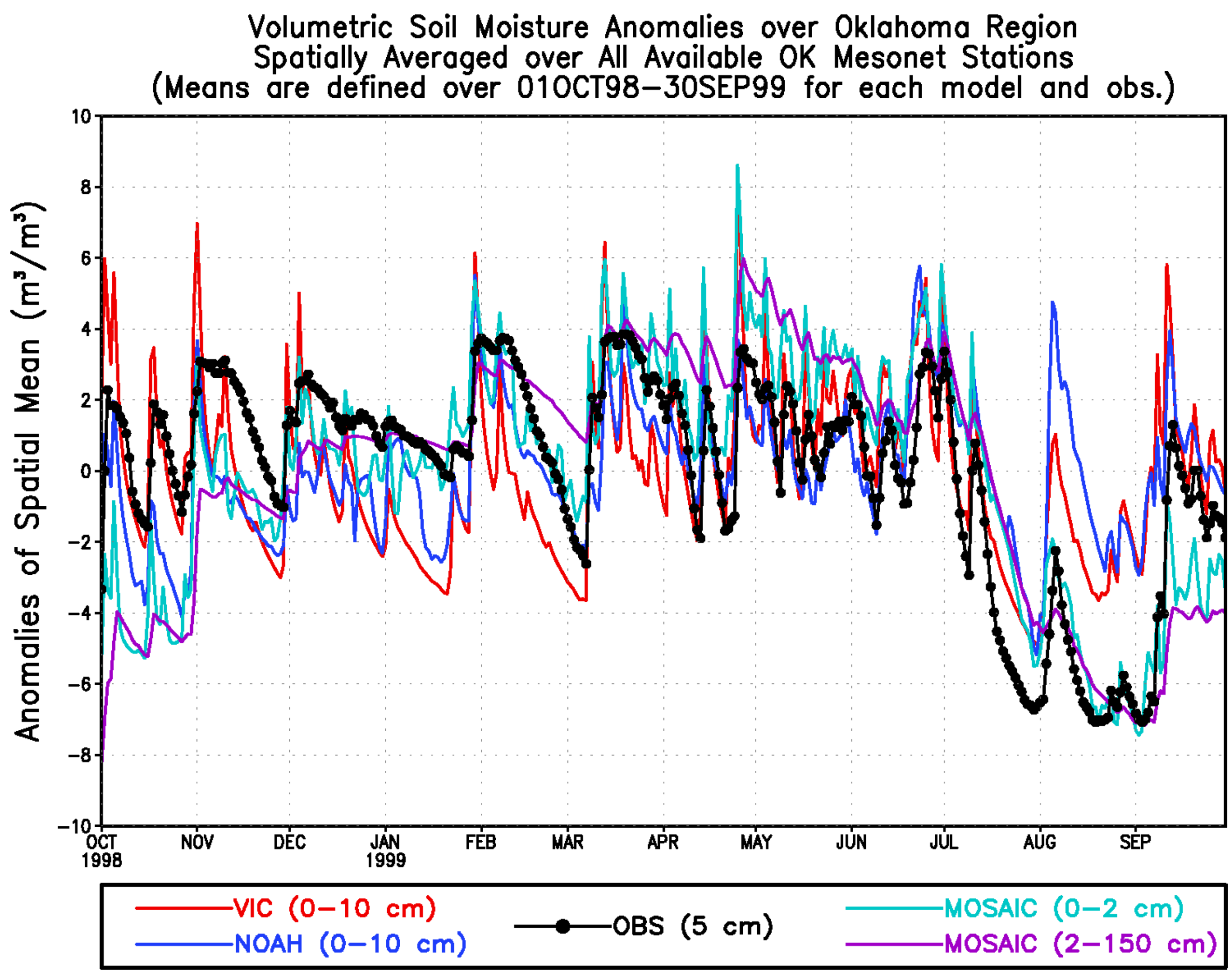
VIC Simulation with Unmatched Local Soil Type

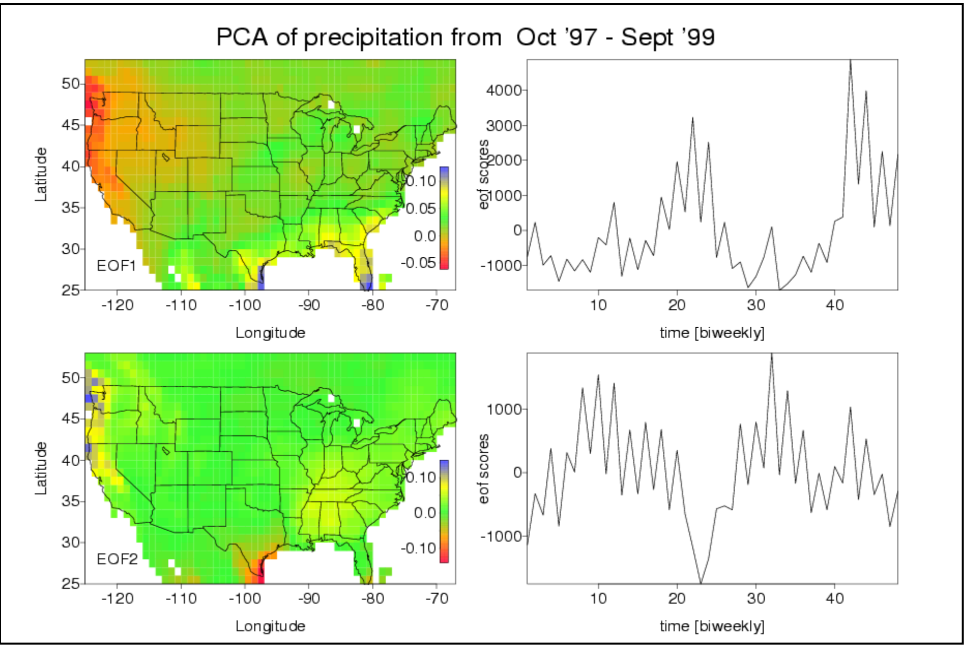
(at sand site MANG)

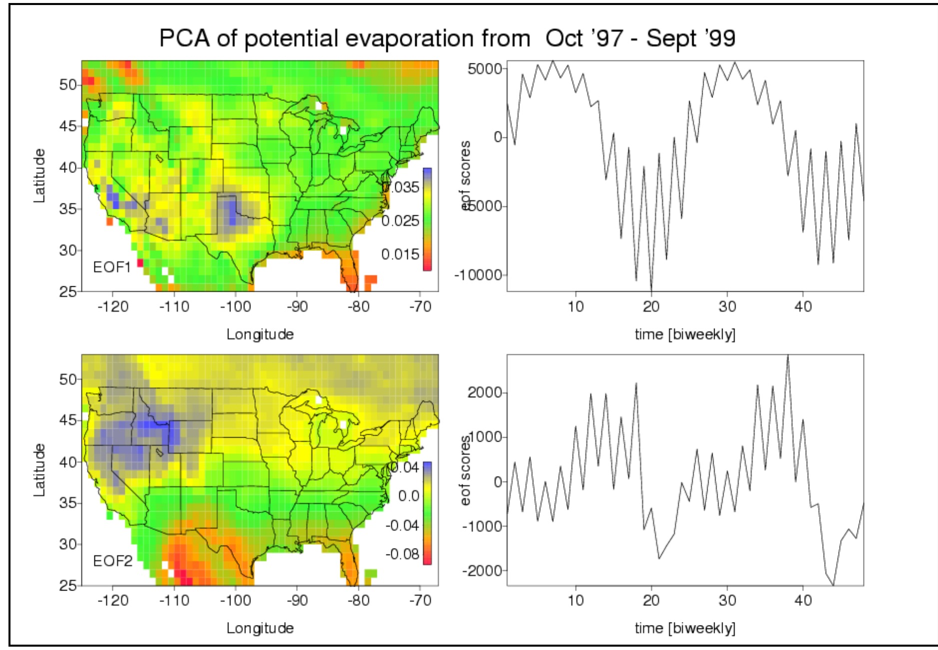
(Note: observed soil moisture somewhat suspect at all sand sites)

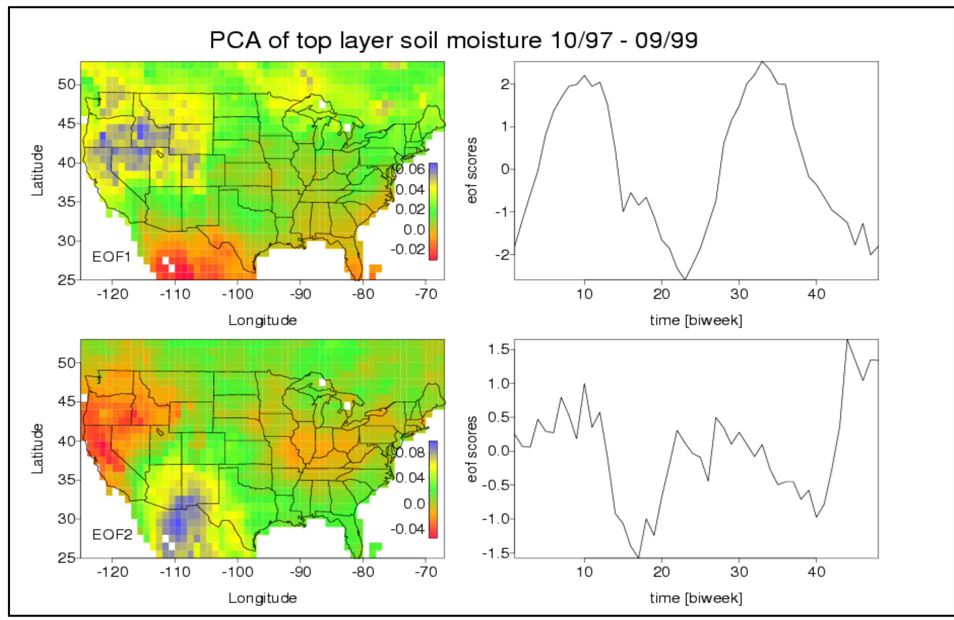


Soil Moisture Anomaly Validation









Geo-Statistical Analysis of LDAS Forcing, States, Fluxes