Goddard Space Flight Center

Land Information System

NASA's Land Information System as a Testbed for JCSDA Partners and Investigators

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http://lis.gsfc.nasa.gov

Acknowledgments

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Outline

- LIS Background
- LIS Uncoupled Benchmarking
  - CEOP Sites
  - NOAA/NCEP
  - AFWA/AGRMET
- LIS/WRF/GCE Coupled Benchmarking
  - IHOP
- Data Assimilation in LIS
- LIS in GEWEX

LIS Running Modes

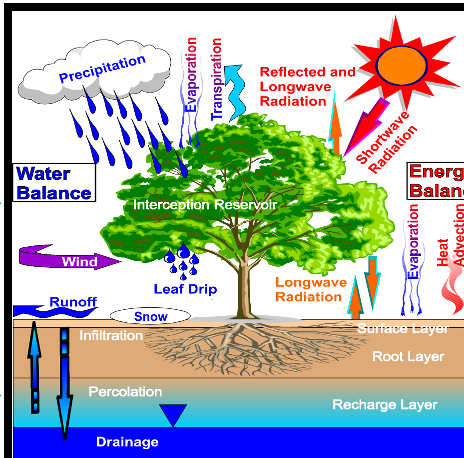
Uncoupled or Analysis Mode

Coupled or Forecast Mode

Station Data

Global, Regional Forecasts and (Re-)Analyses

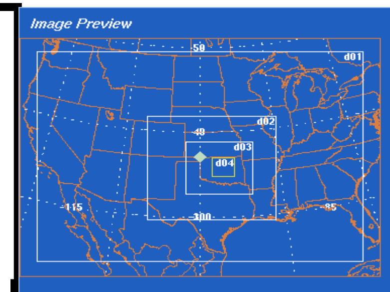
Satellite Products

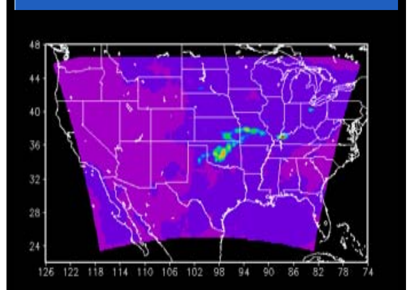


Land Sfc Model (Noah, Catchment, CLM, VIC, HYSSiB)

ESMF

WRF





LSM Initial Conditions

LIS Uncoupled/Analysis Mode

Inputs

Topography, Soils

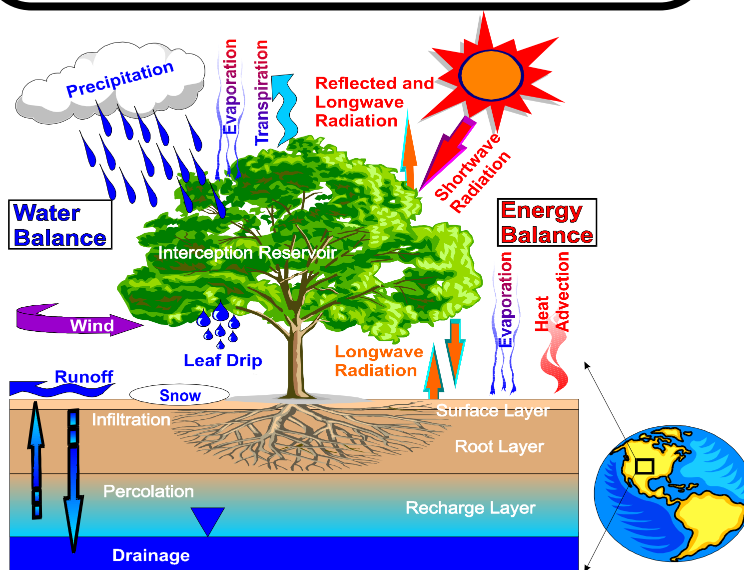
Land Cover, Vegetation Properties

Meteorological Forecasts, Analyses, and/or Observations

Snow
Soil Moisture
Temperature

Physics

Land Surface Models



Data Assimilation Modules

Outputs

Soil Moisture & Temperature

Evaporation Sensible Heat Flux

Runoff

Snowpack Properties

Applications

Weather/ Climate

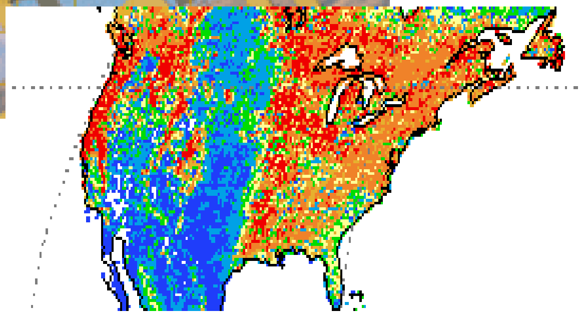
Water Resources

Homeland Security

Military Ops

Natural Hazards

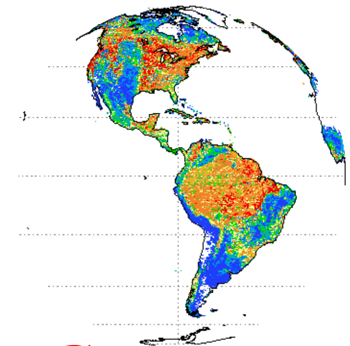
LIS Heritage: NLDAS and GLDAS



North American *LDAS*

1/8 Degree Resolution

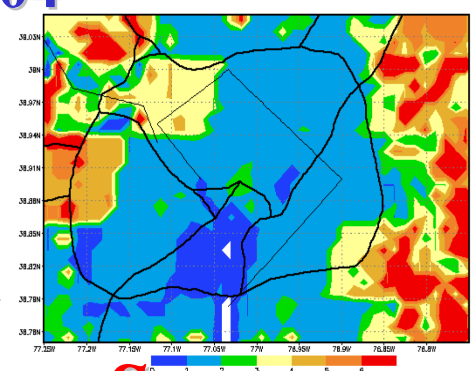
Mitchell et al., JGR, 2004



Global *LDAS*

1/4 Degree Resolution

Rodell et al., BAMS, 2004

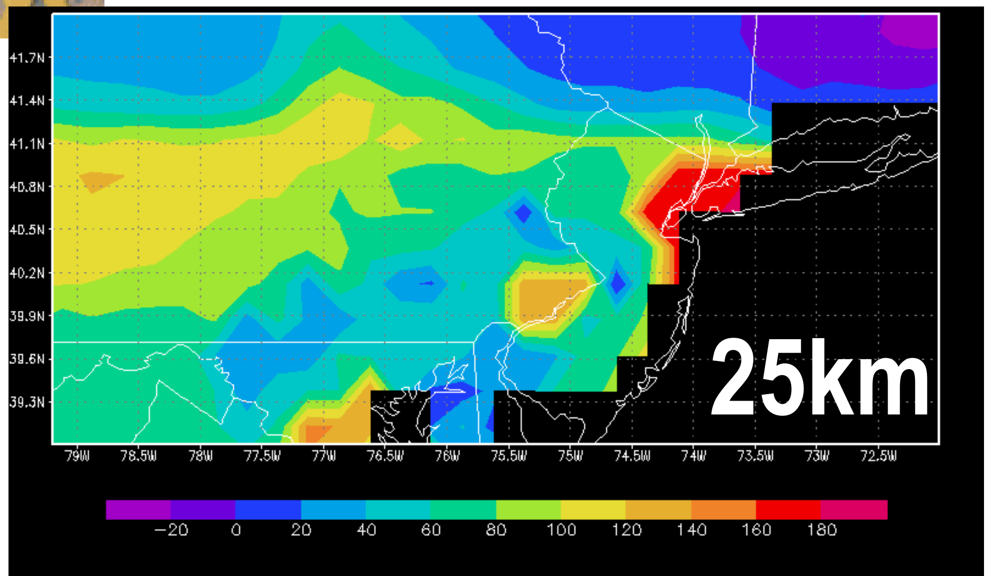


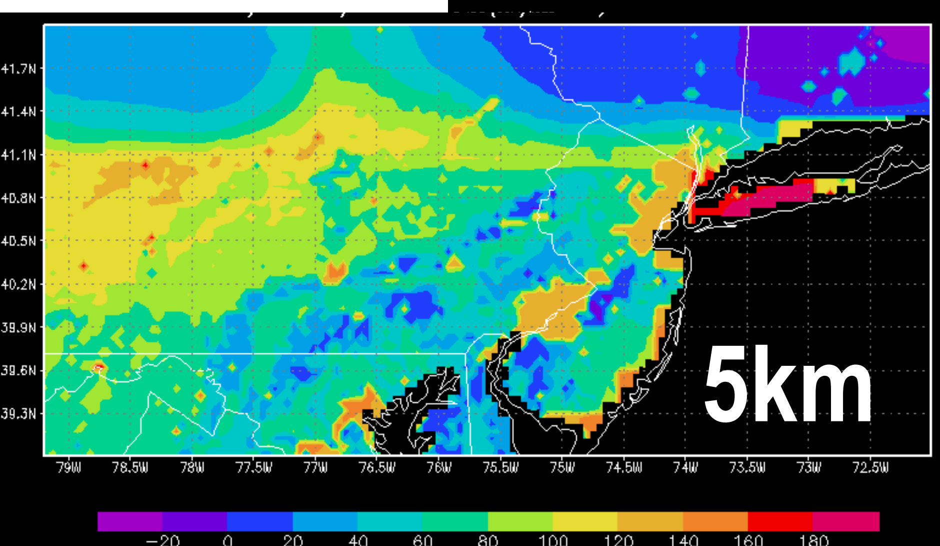
Land Information System (http://lis.gsfc.nasa.gov)

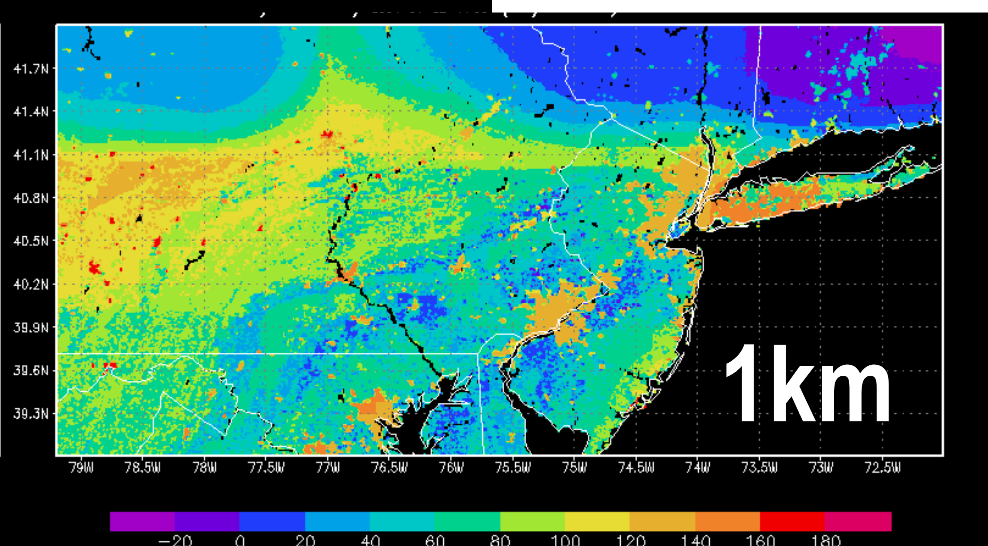
Multi-Resolution Ensemble LDAS

Kumar et al., EMS, 2006

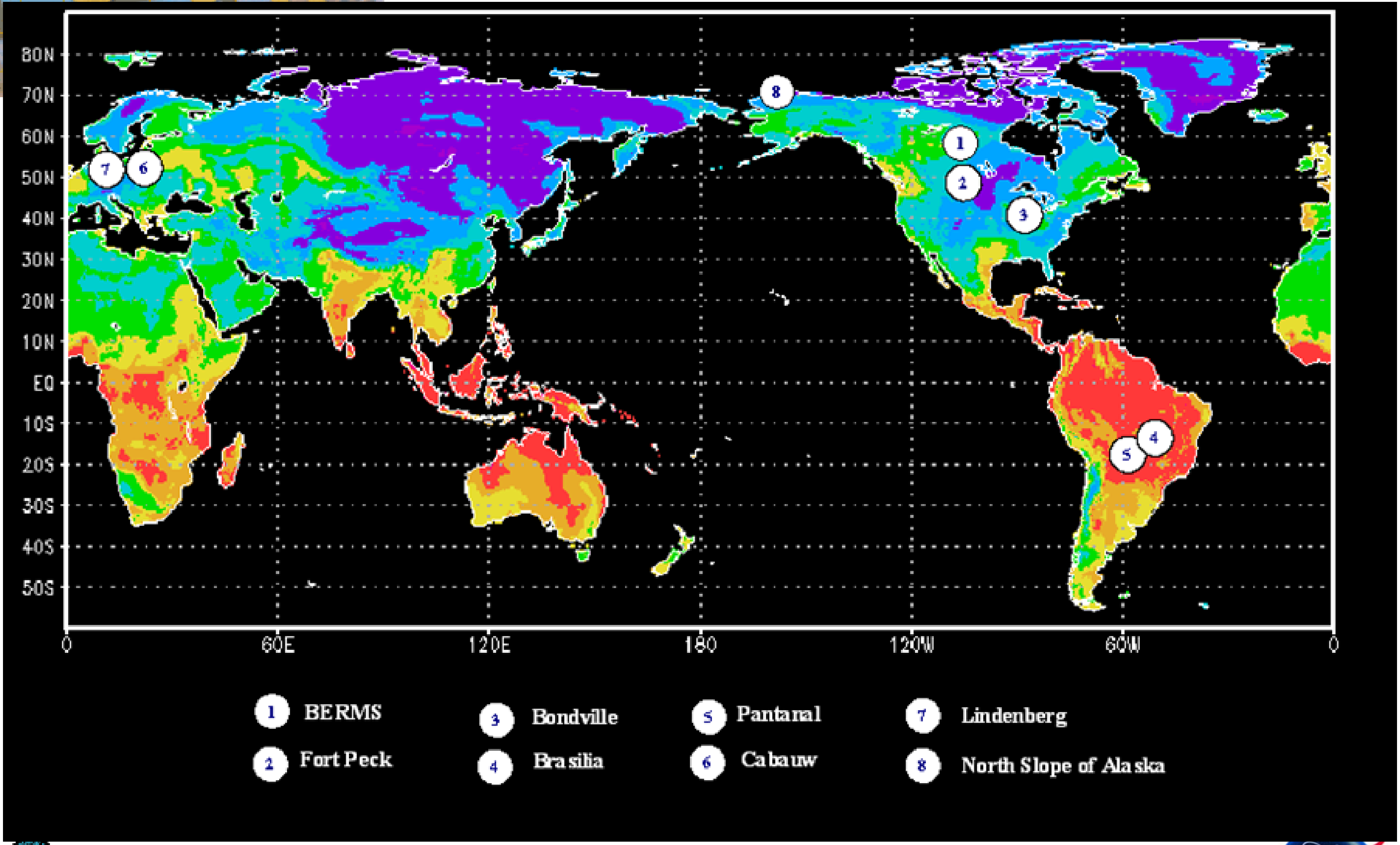
The Value of 1km Land Modeling: Exploit EOS and NPOESS





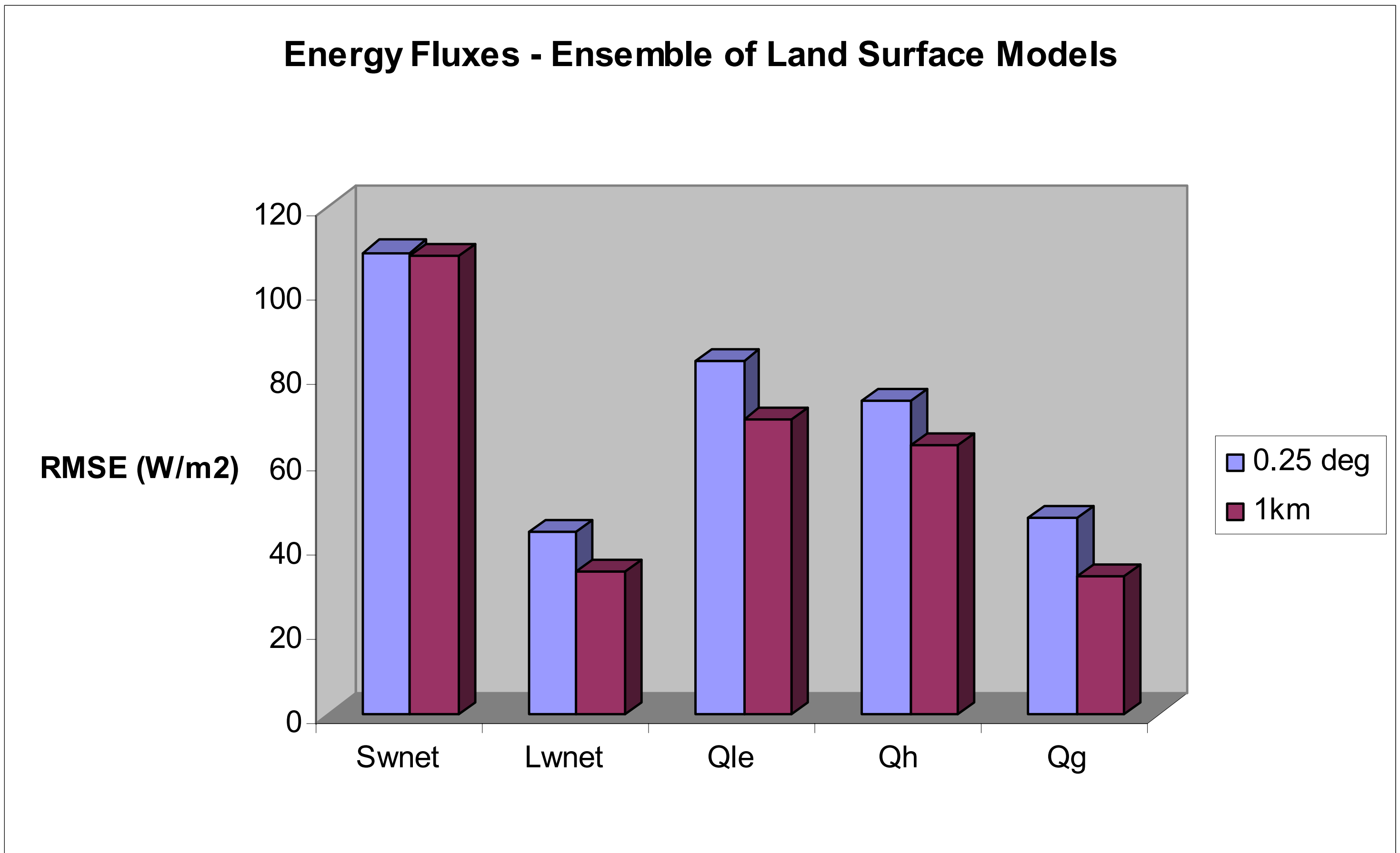


Uncoupled Benchmarking at CEOP Reference Sites

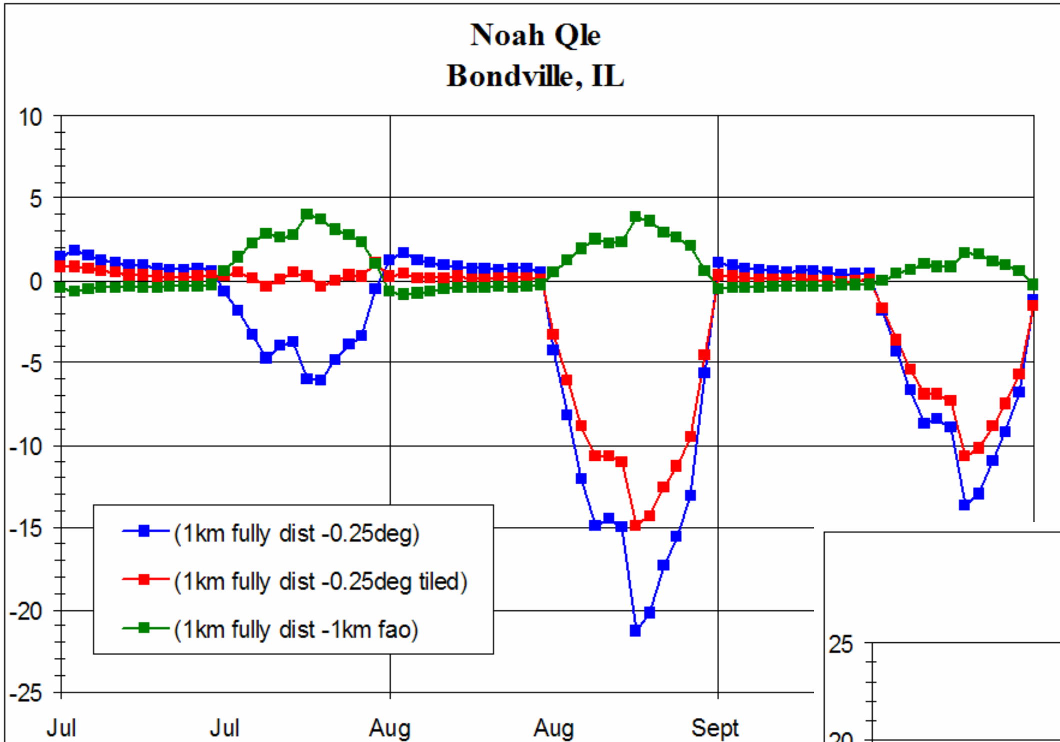


CEOP Benchmarking Summary

- **CLM/Noah/Mosaic ensemble energy fluxes**
- **All CEOP reference sites EOP-1 July 1-Sept 30, 2001**



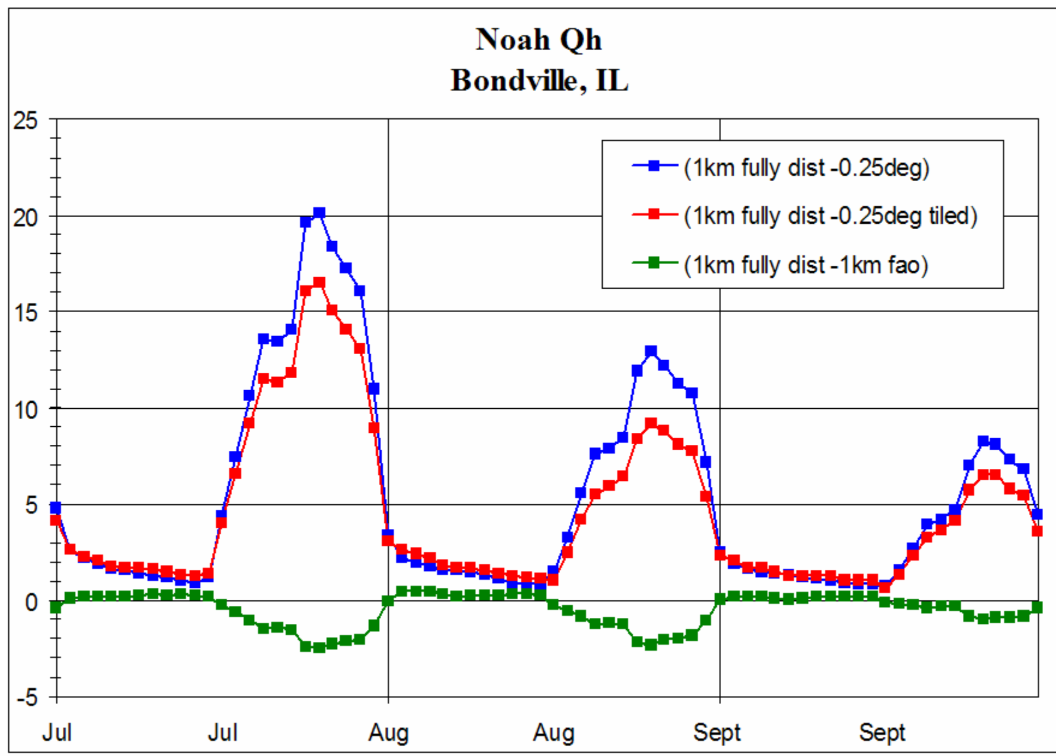
CEOP Flux aggregation: Bondville, IL



Does Heterogeneity Matter?

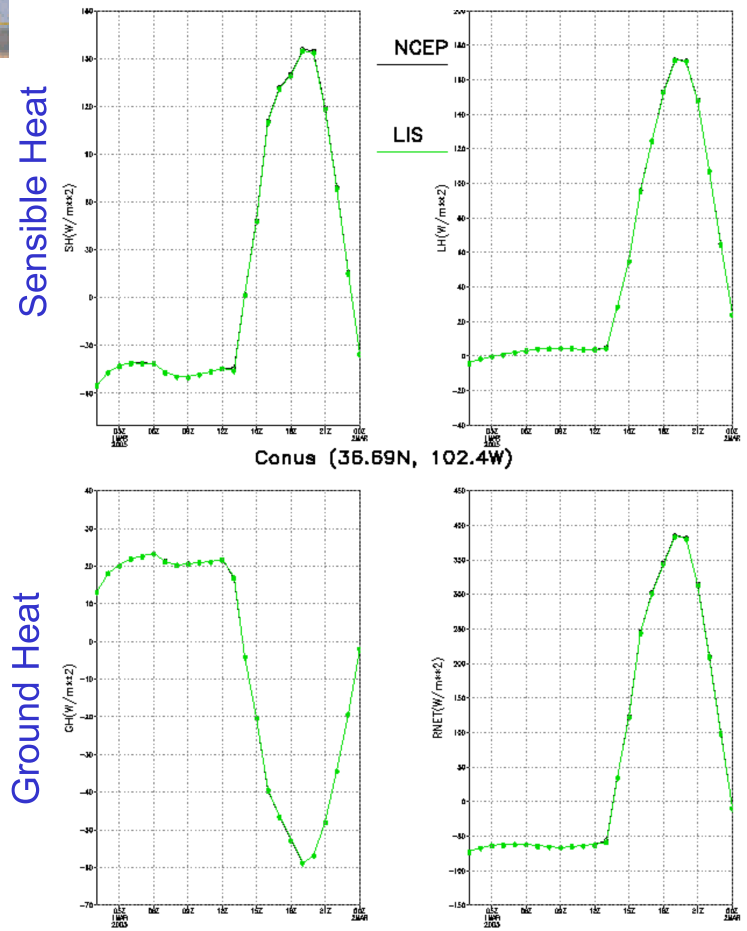
Does Landcover Tiling Help?

Does Soils Heterogeneity Matter?

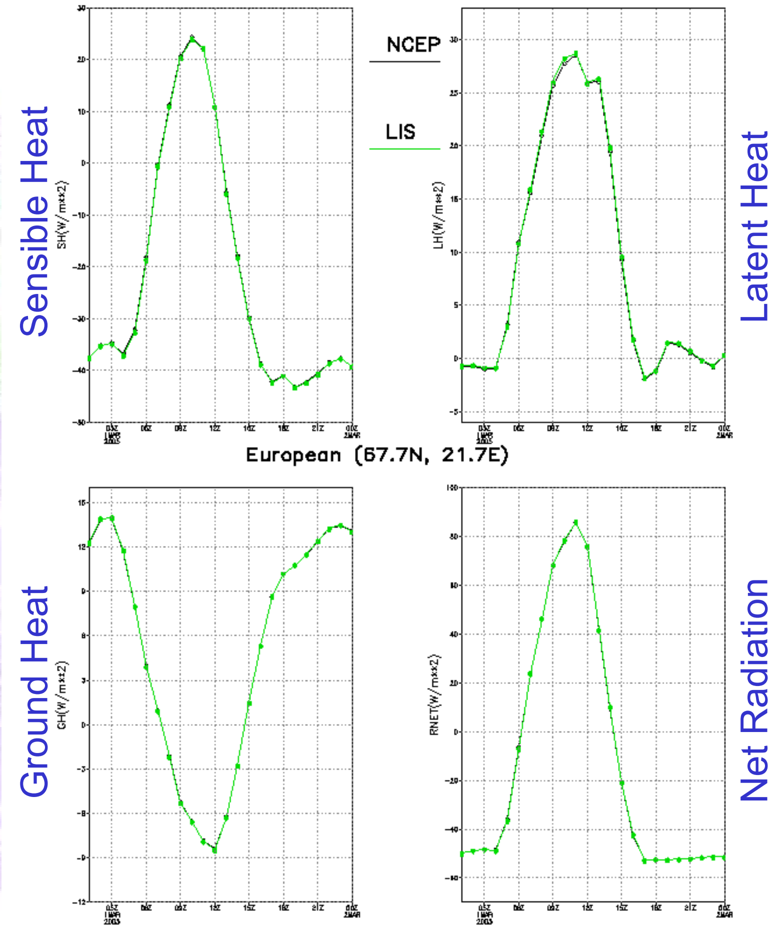


Initial Benchmarking at NCEP
Average Diurnal Cycles, March 2003

CONUS Average

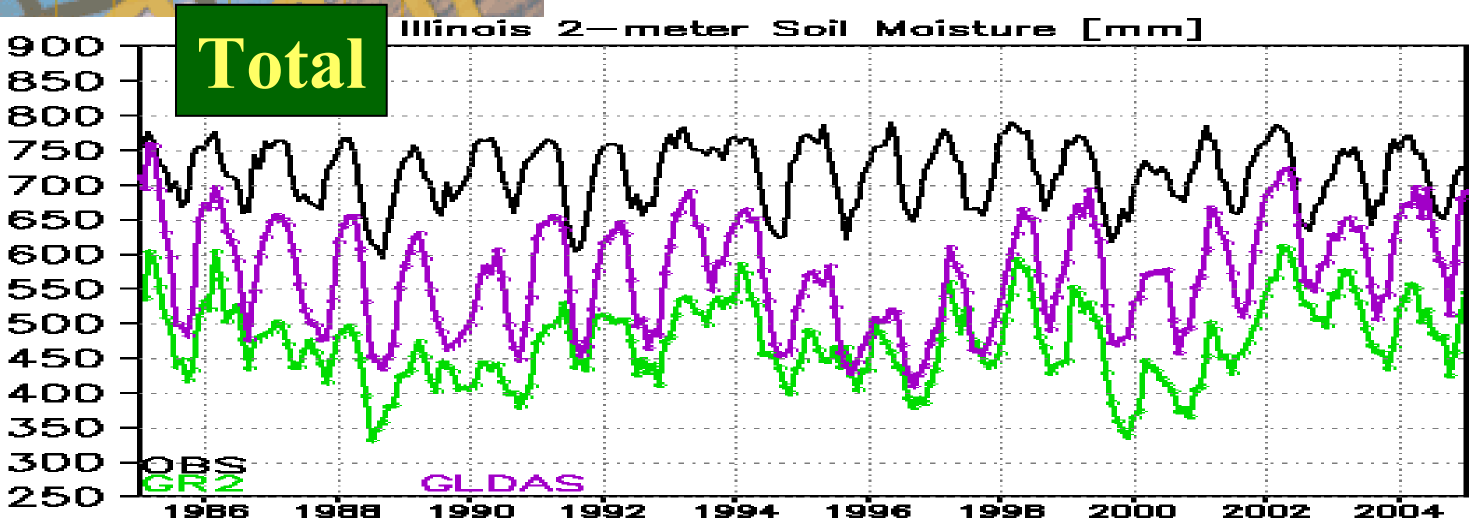


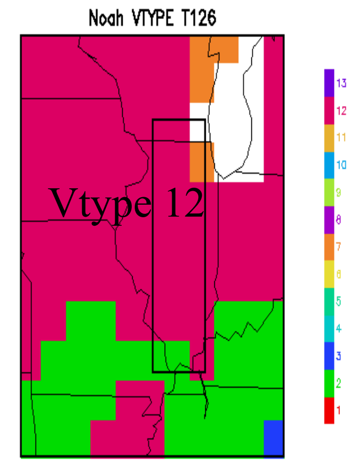
Europe Average

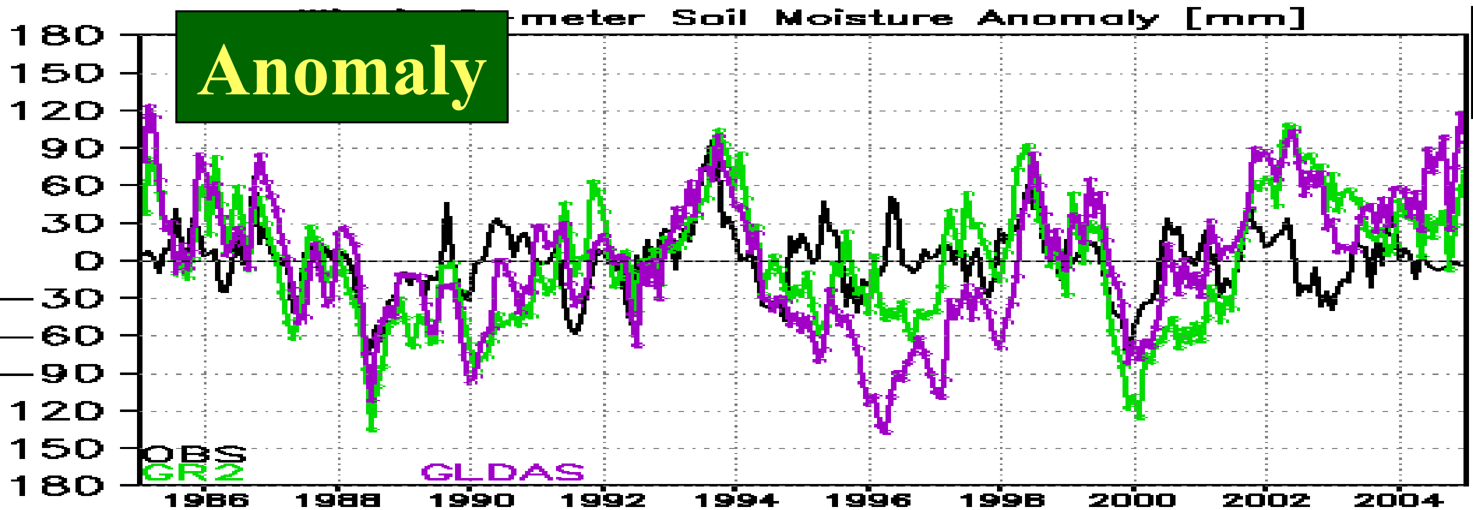


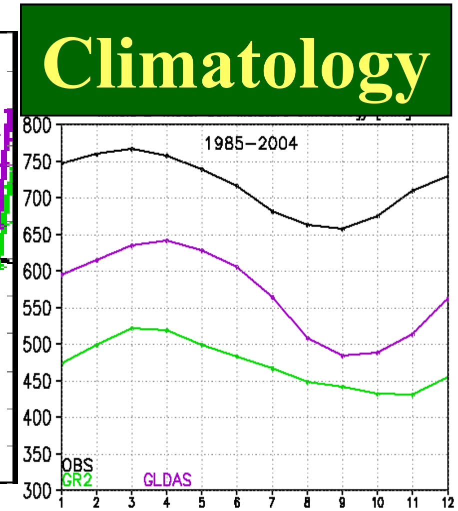
•LIS with experimental mode of GFS on the gaussian horizontal grid of T62
•Forcing: NCEP Global Reanalysis II, AGRMET radiation and CMAP precipitation.
•30% more efficient in computing time

NCEP Benchmarking with LIS: 25-year T126
Illinois 2-meter Soil Moisture [mm] 1985-2004







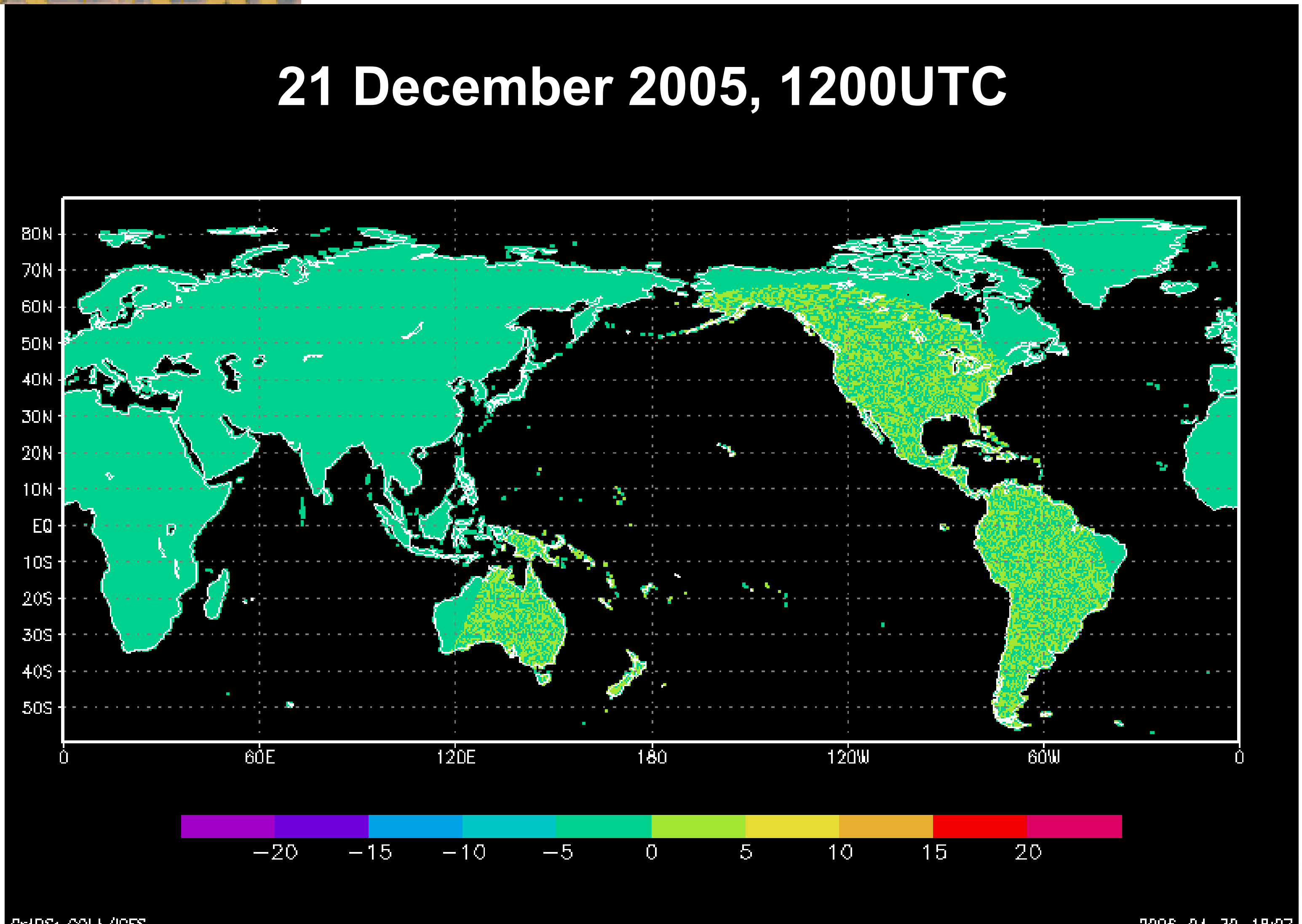


Source: Jesse Meng

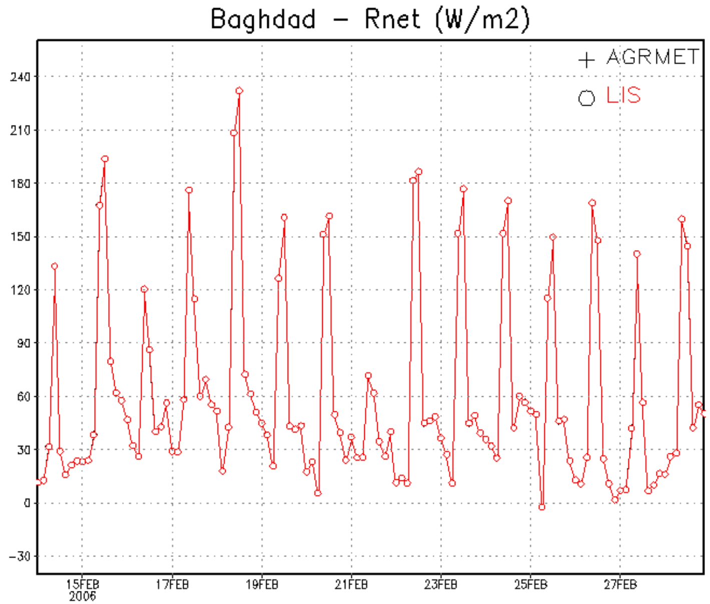
AFWA/AGRMET Benchmarking

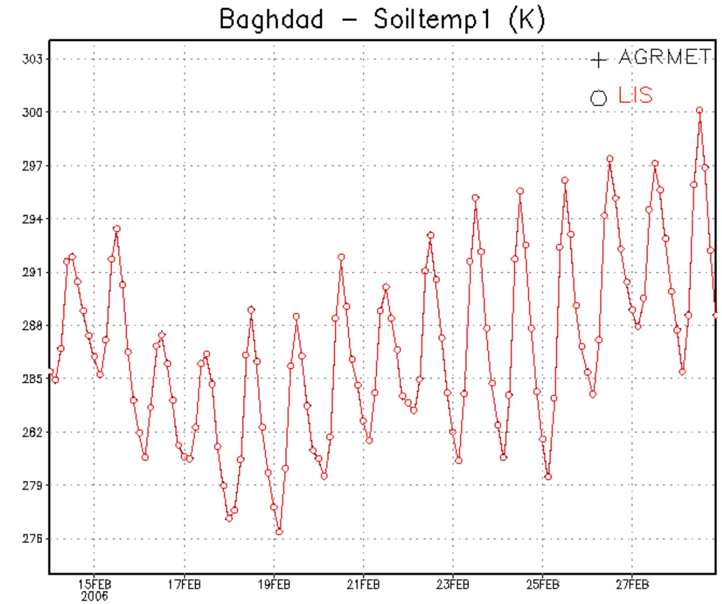
- Benchmark period: 02 December 2005- 28 February, 2006
- Global Intercomparison Dates:
    - 02 December 2005
    - 21 December 2005
    - 20 January 2006
    - 28 February 2006
- Point Intercomparisons at Sample Locations:
    - USA, Washington, DC, 38.85N 77.04W
    - Iraq, Baghdad, 33.20N, 44.30E
    - Pyongyang, North Korea, 39.03N, 125.78E
    - Zimbabwe, Harare, 17.43S, 31.02E

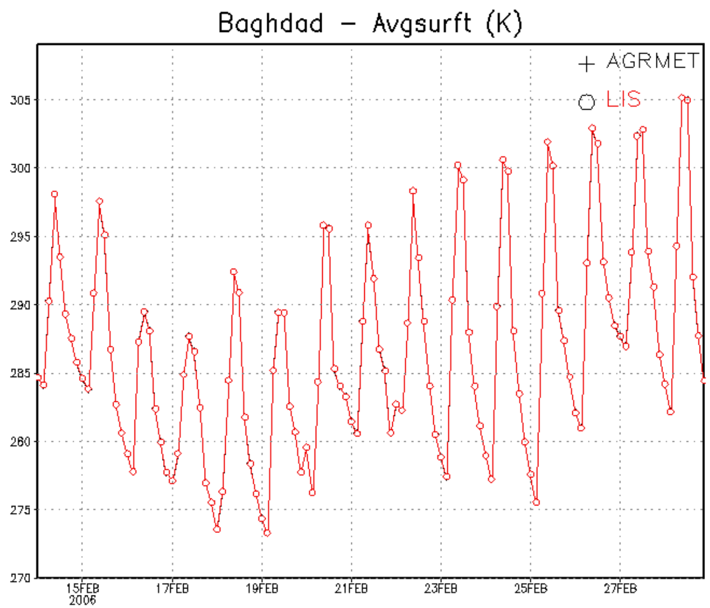
AGRMET-LIS Global Intercomparison Downward Shortwave (Wm-2)

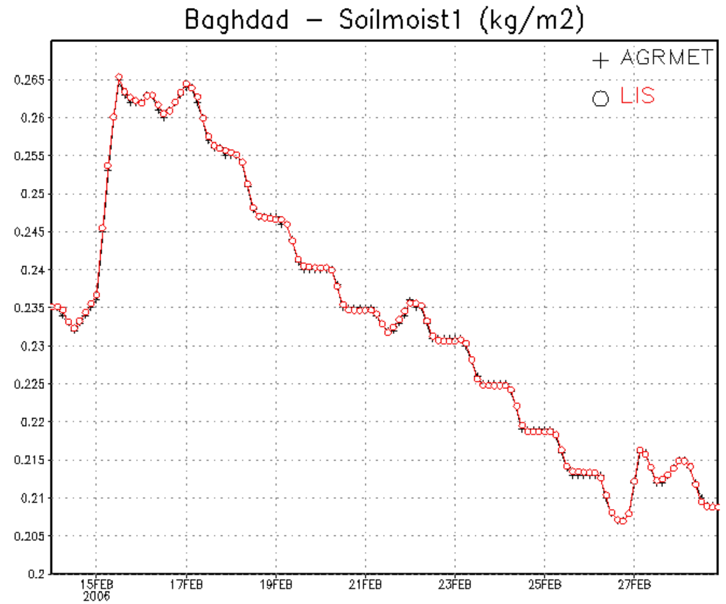


AGRMET-LIS Point Intercomparisons: Iraq, Baghdad



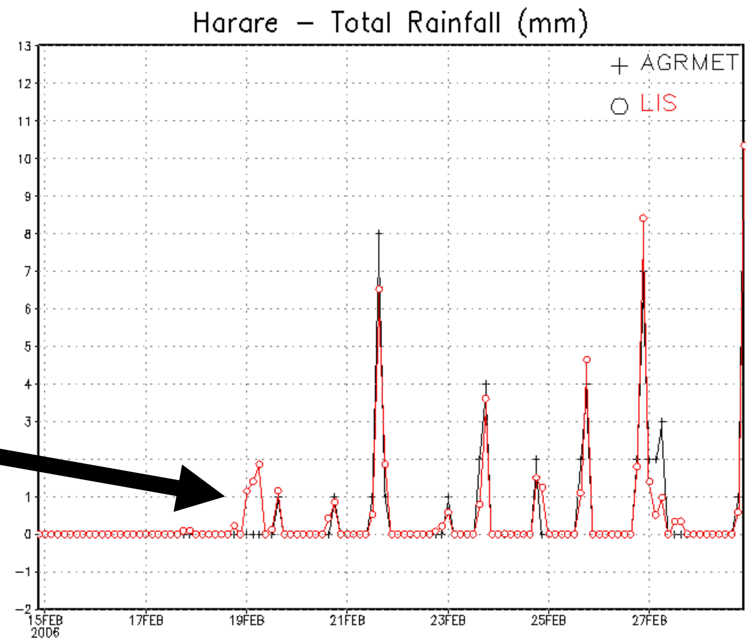




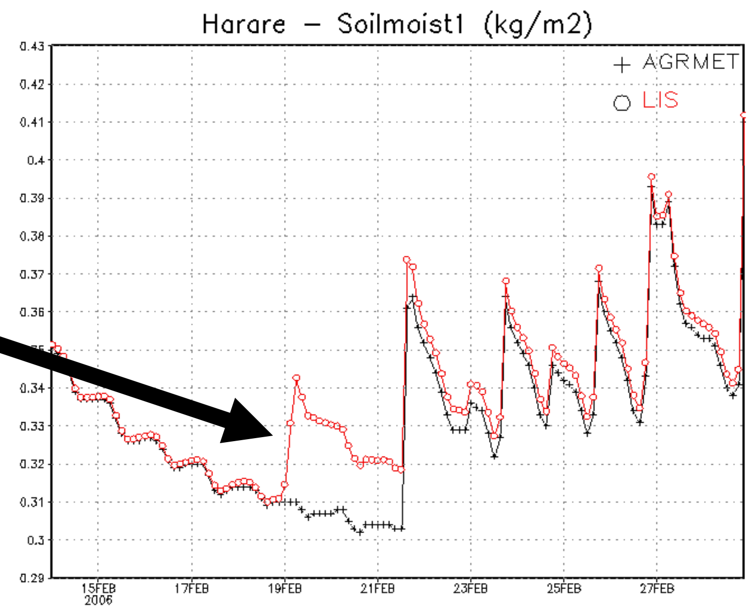


AGRMET-LIS Point Intercomparisons: Zimbabwe, Harare

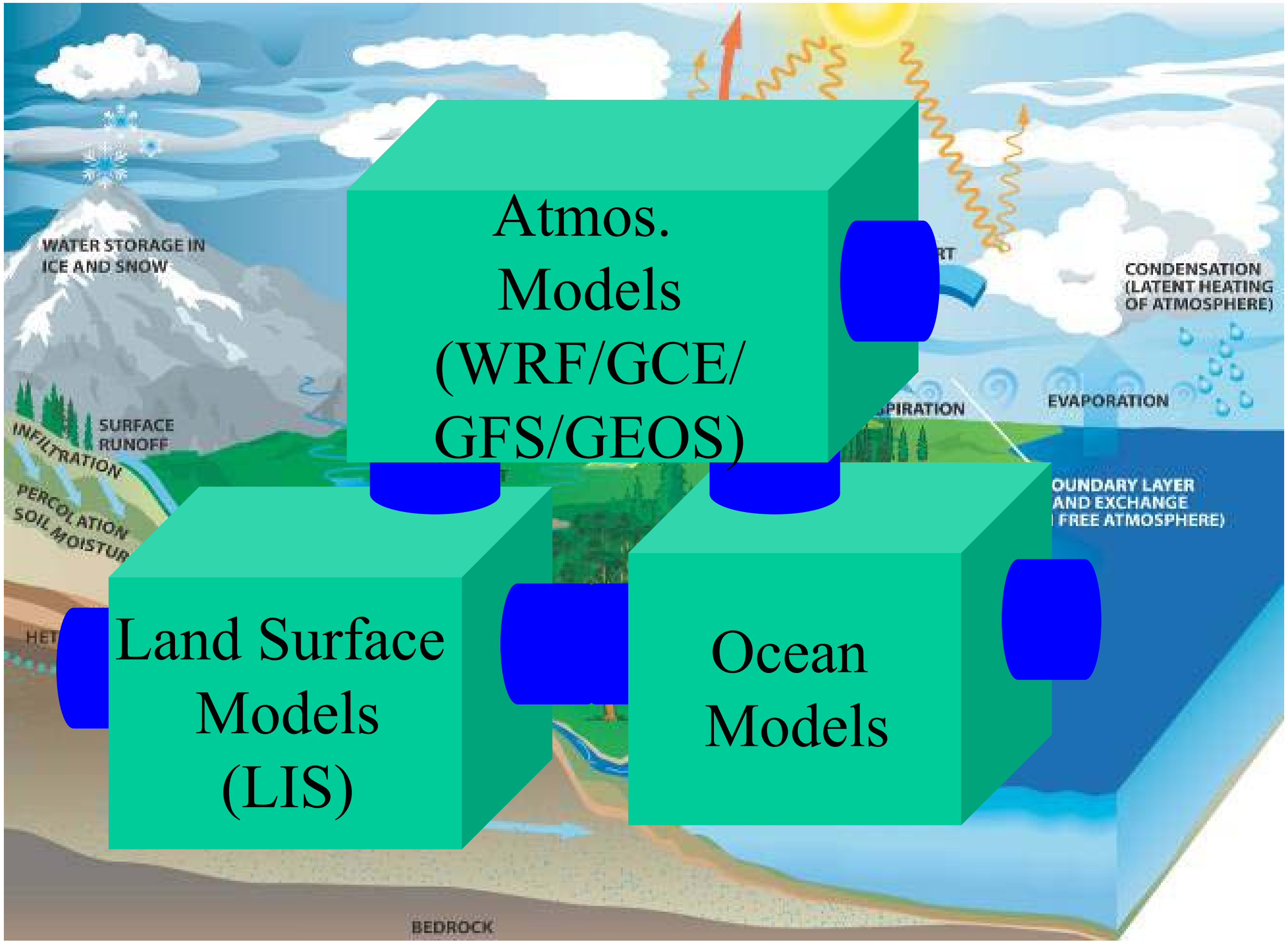
Database Update



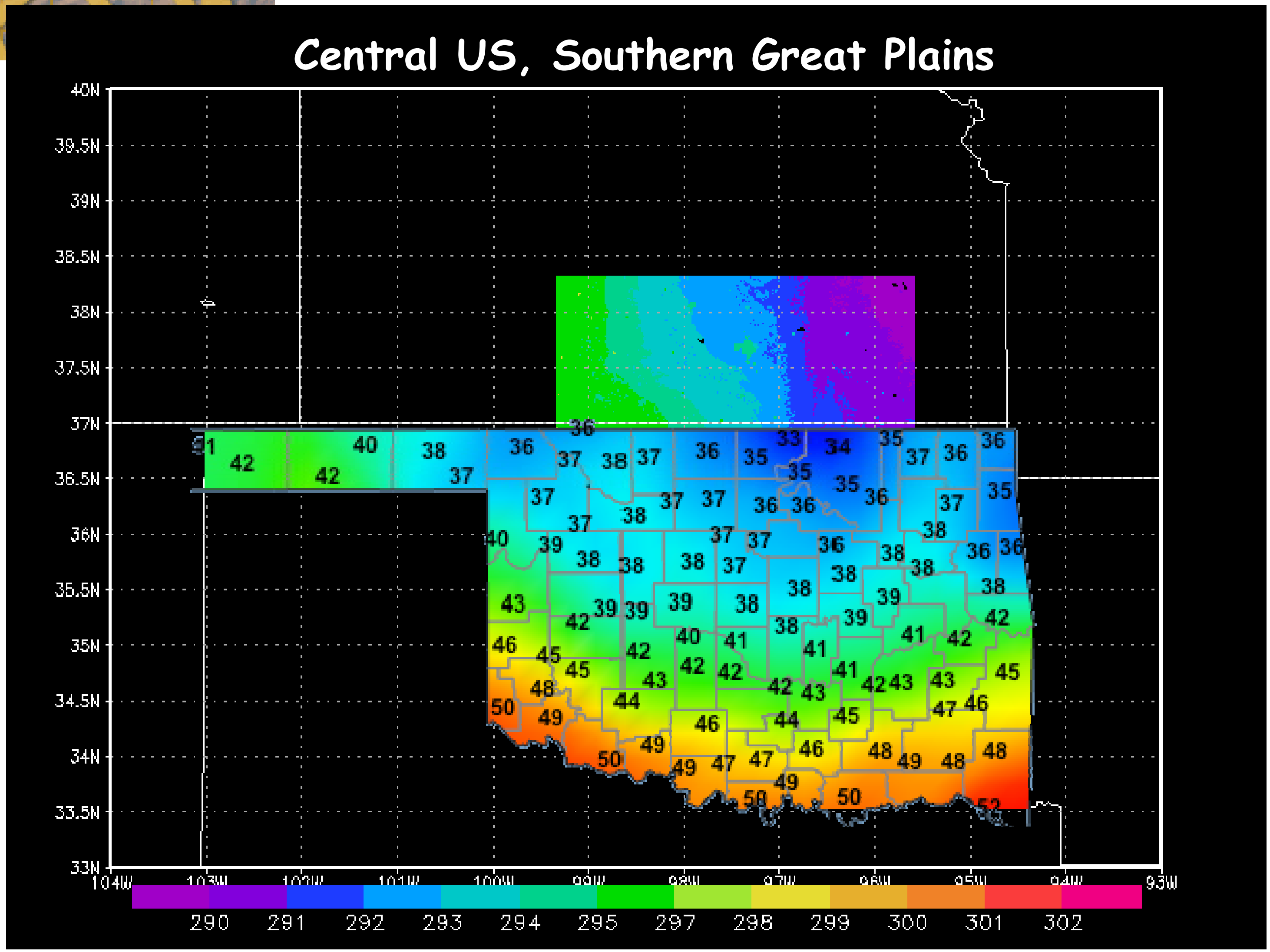
Rainfall differences persist in land analysis



Coupled: LIS as an Earth System Model Land Component



Coupled LIS/WRF Case Study: May-June 2002
International H2O Project (IHOP)



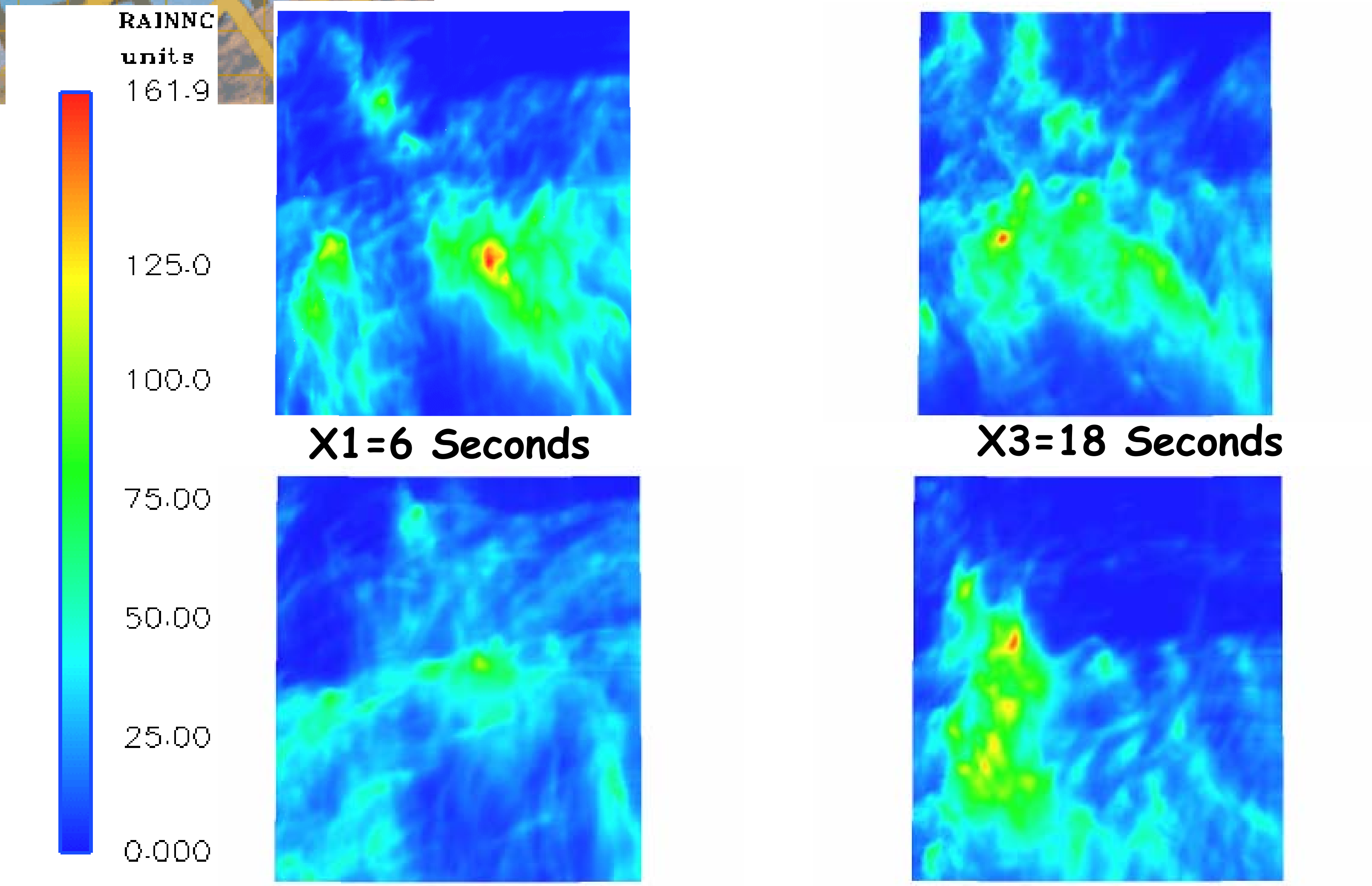
1. Radiation Coupling Experiments: June 12, 2002
2. IHOP Case Studies: June 12, 2002 and May-June 2002

WRF/ARW Model Setup

- 500x500 Horizontal Points at 1km ΔX
- 47 Vertical Levels from 10m to 18km AGL
- Lin et al microphysics (Rain, Ice, Graupel, Snow, Cloud Water)
- RRTM longwave, Dudhia Shortwave (Account for different water phases)
- NOAH LSM from the Land Information System (LIS)
- Ingested North American Regional Reanalysis (32km mesh size) into WRFSI to create initial and boundary meteorological conditions for a 24 hour integration at 3 hour intervals

WRF THE WEATHER RESEARCH & FORECASTING MODEL

WRF-LIS Precipitation vs. Radiation Coupling Time Step



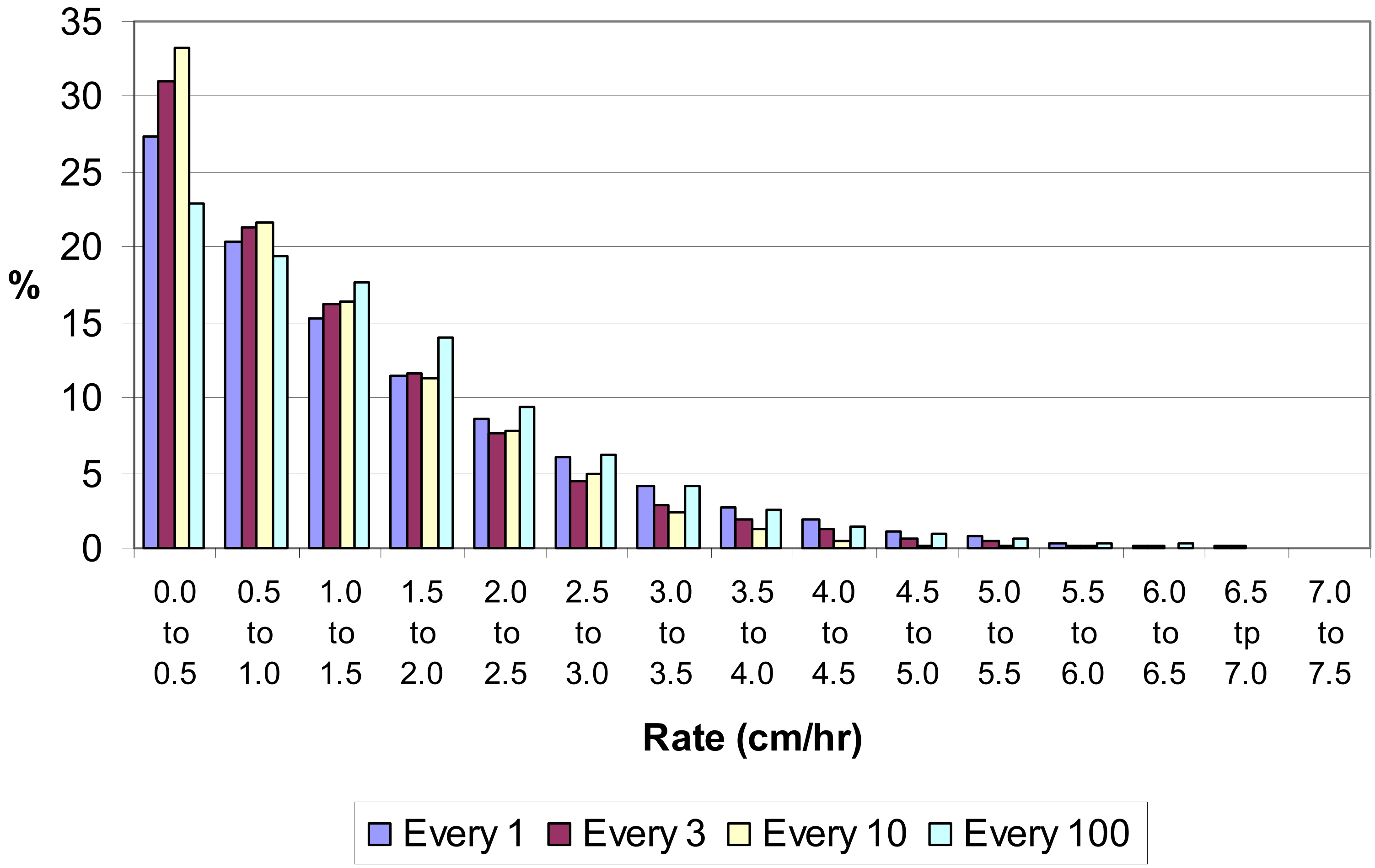
X10=60 Seconds X100=600 Seconds

Total accumulated 24-hour precipitation (mm) for update frequencies at every (6 seconds), every 3 (18 seconds), every 10 (60 seconds), and every 100 (600 seconds) time steps.

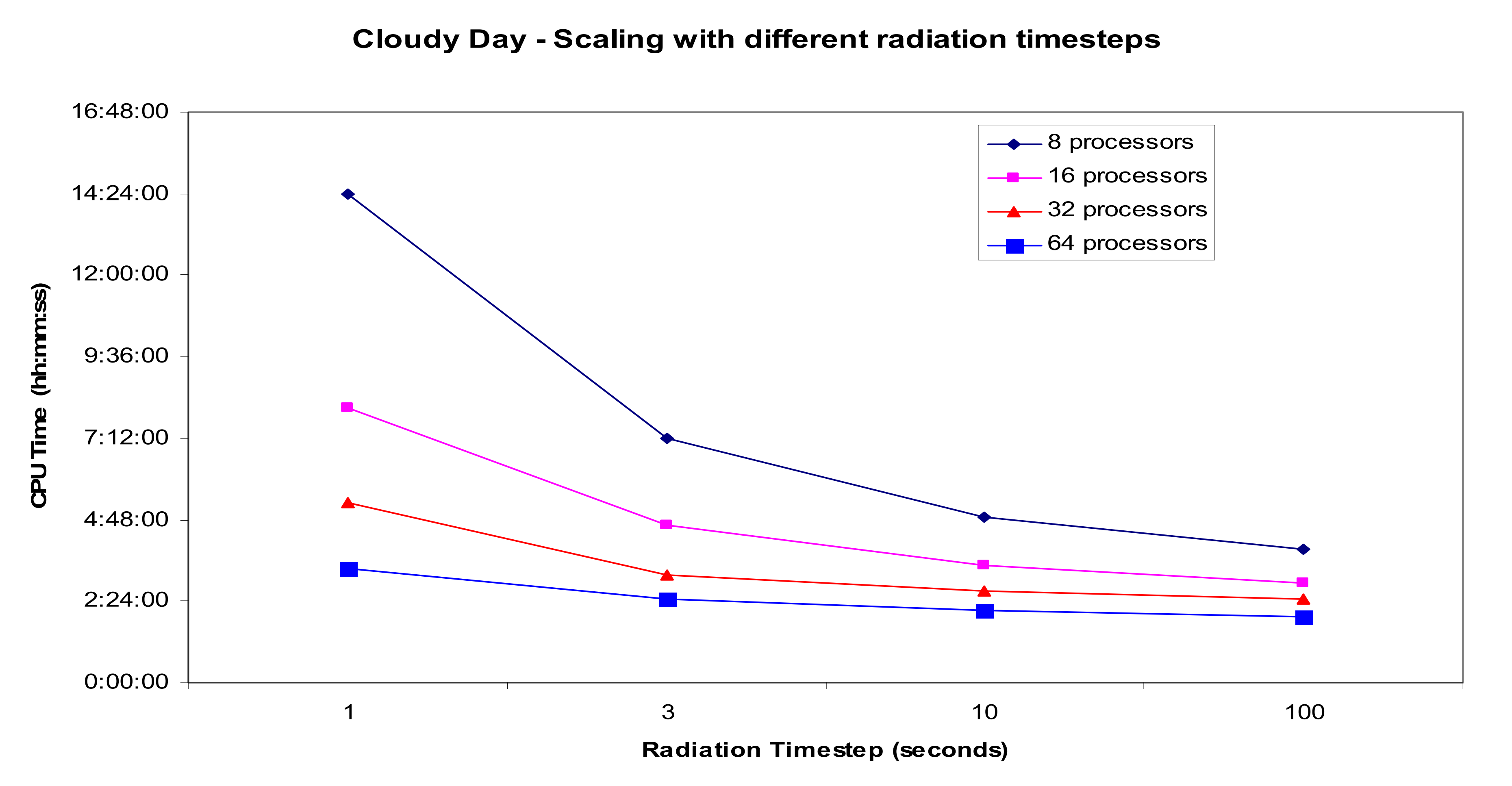
Eastman et al., GRL, 2006, submitted.

Rain Rate PDF vs. Radiation Coupling Time Step

Precipitation Probability Distribution Function (%)

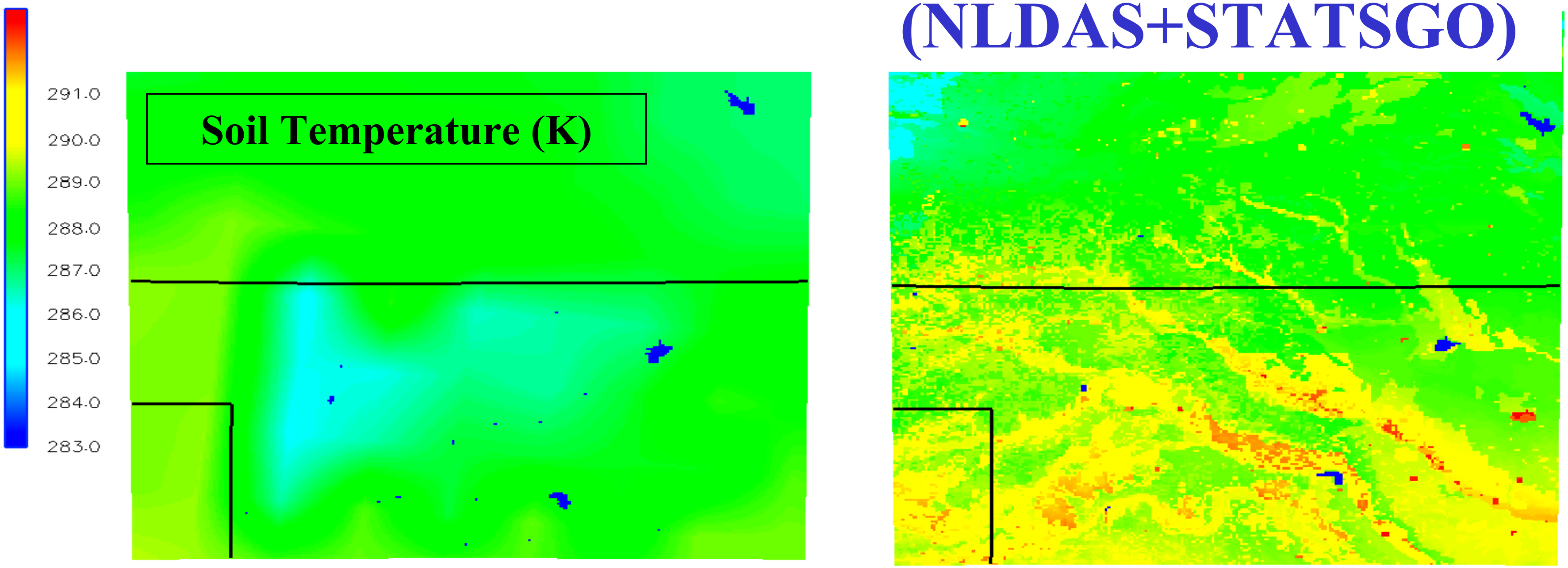


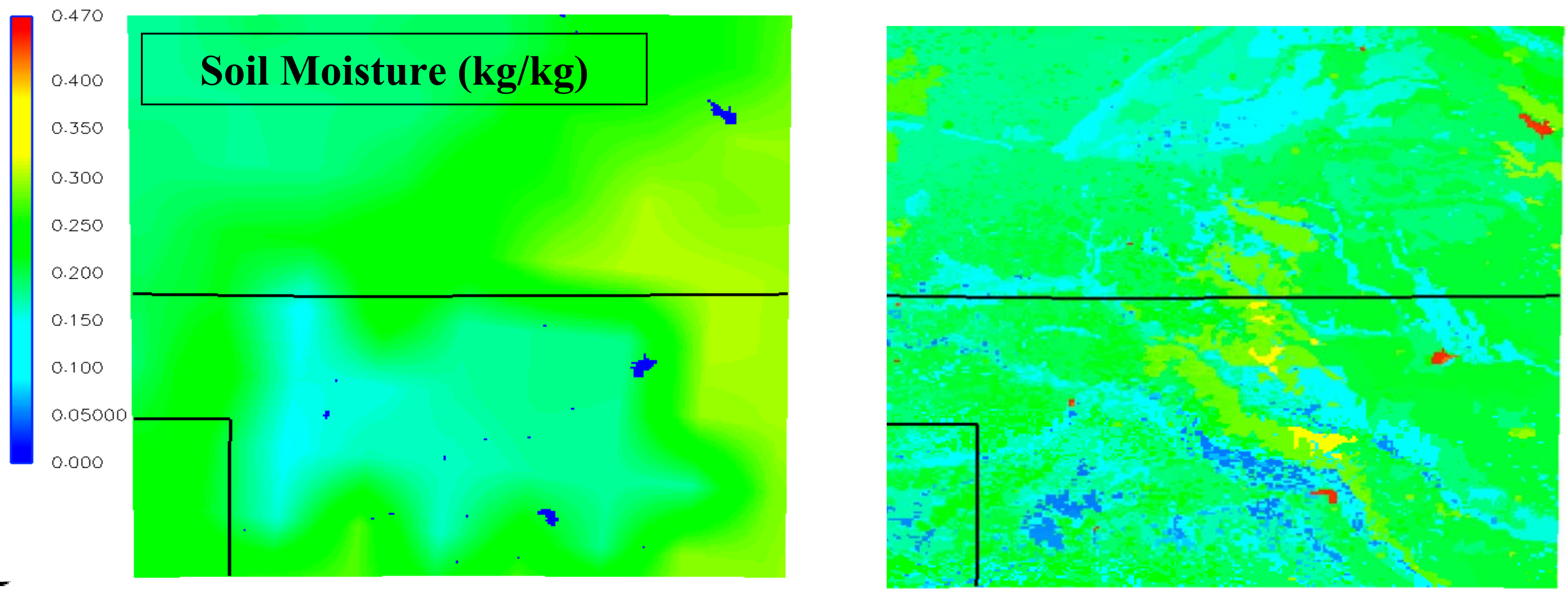
Computational Overhead of Increased Radiation Updates



WRFSI Initial Soil State

LIS Initial Soil State (NLDAS+STATSGO)

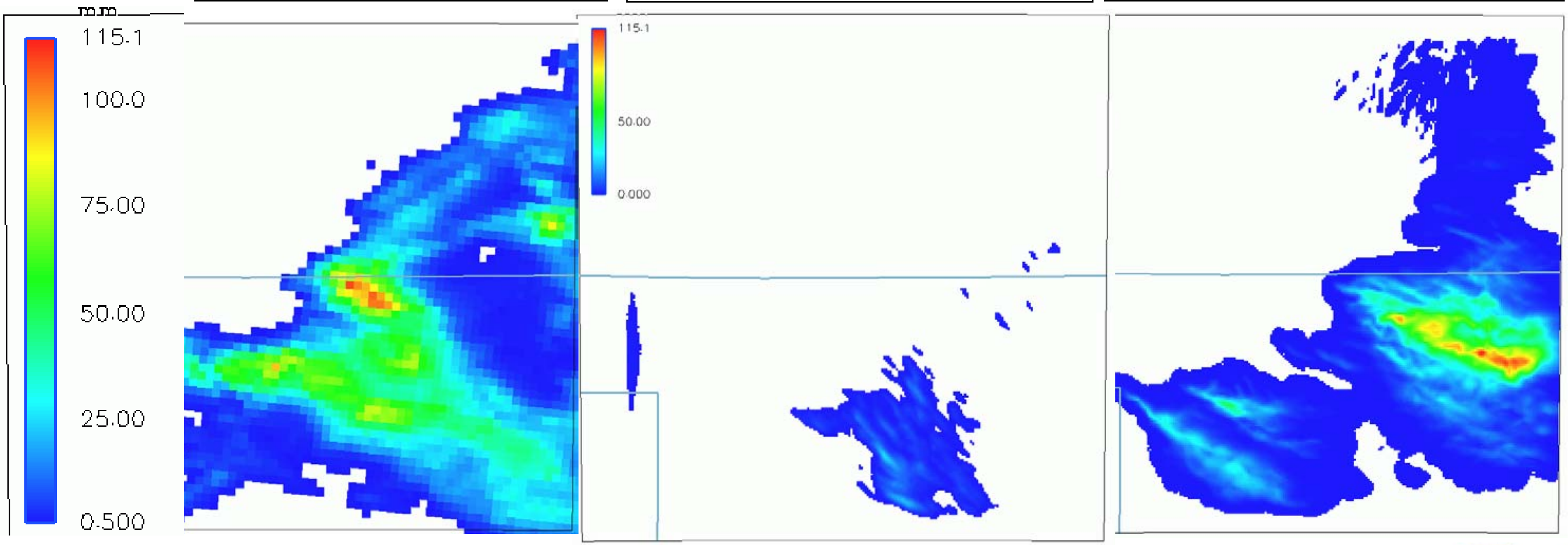




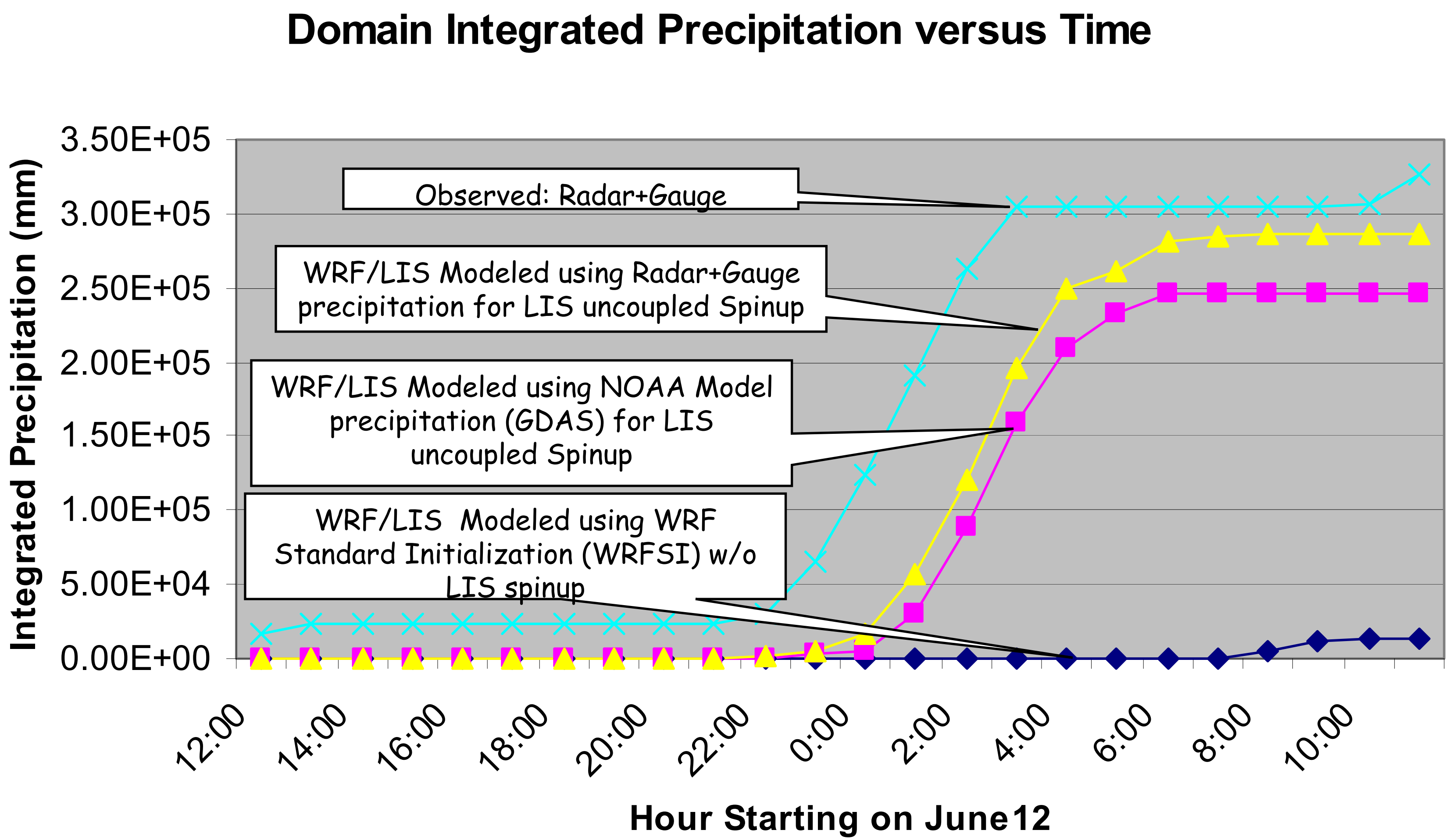
Soil Moisture Impact on Precipitation Forecast
IHOP, June 12-13, 2002

24 Hour Accumulated Precipitation (mm)

Observed NOAA/NCEP Stage II Radar+Gauge	WRF-LIS forecast Using default soil moisture initialization (WRFSI)	WRF-LIS forecast Using LIS soil moisture with 10 year uncoupled spinup using StageII precipitation inputs

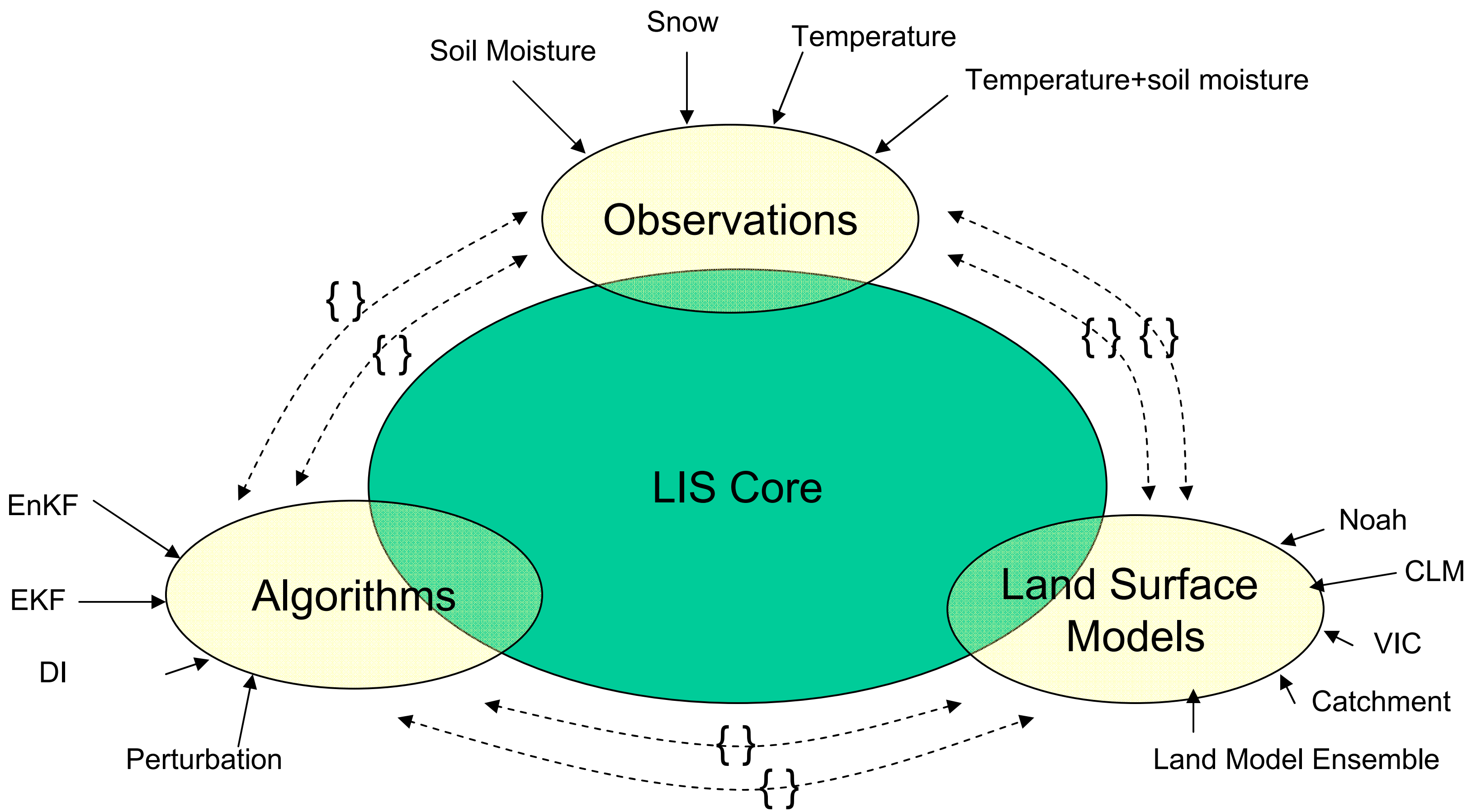


Land Impact on Precipitation Forecast IHOP, June 12-13, 2002



GDAS=Global Data Assimilation System (NOAA/National Centers for Environmental Prediction (NCEP))

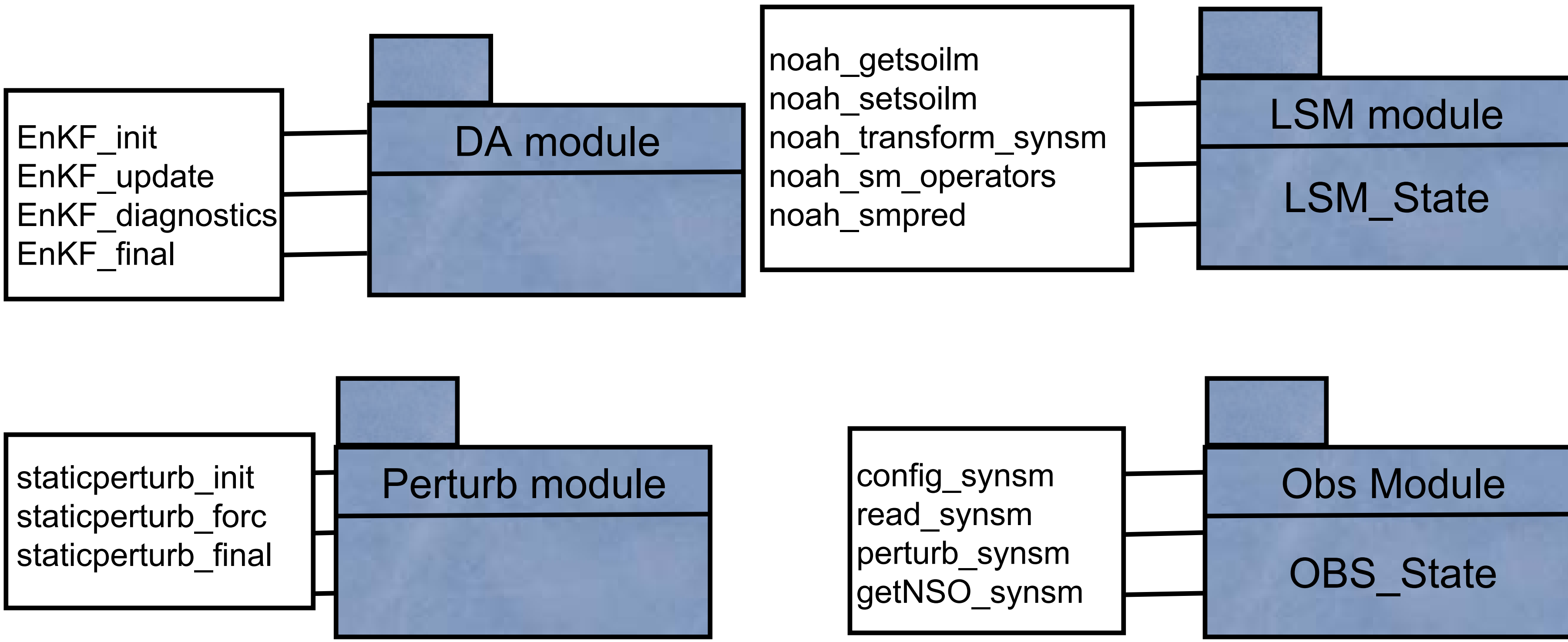
Data Assimilation Structure in LIS



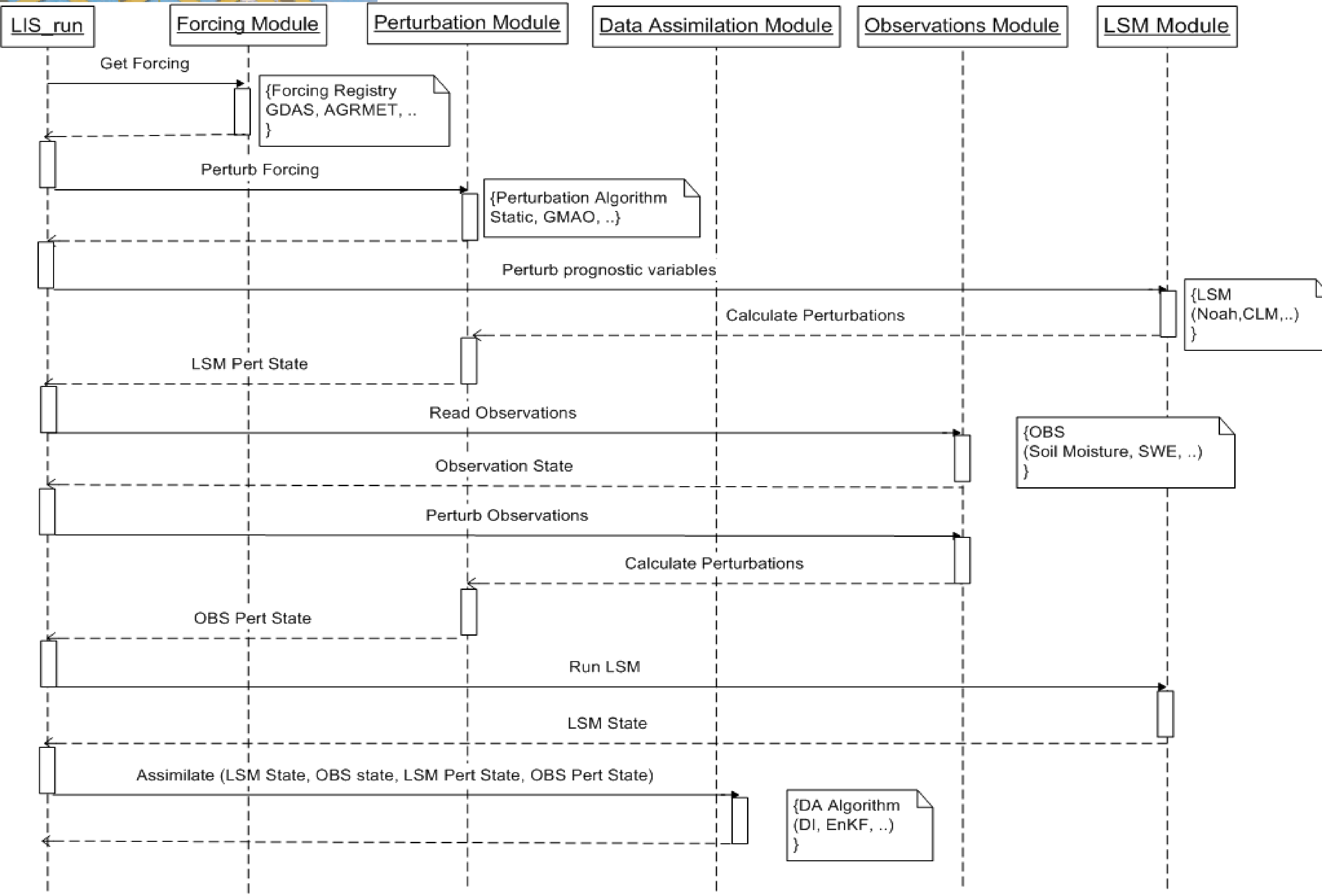
LIS Data Assimilation Design

- Support Multiple Data Assimilation Algorithms
  - Direct Insertion, Different Ensemble Kalman filter algorithms (USDA-based, GMAO-based)
- Support Multiple LSMs
- Support Perturbation algorithms for
  - Forcing
  - Observations
  - State variables
- Include options to specify perturbation frequencies
- Support assimilation of multiple observation types
- Ability to choose spatially distributed observations for each modeling grid point
- Provide Data Assimilation Diagnostics (Mean, standard deviation, spread, normalized innovations)

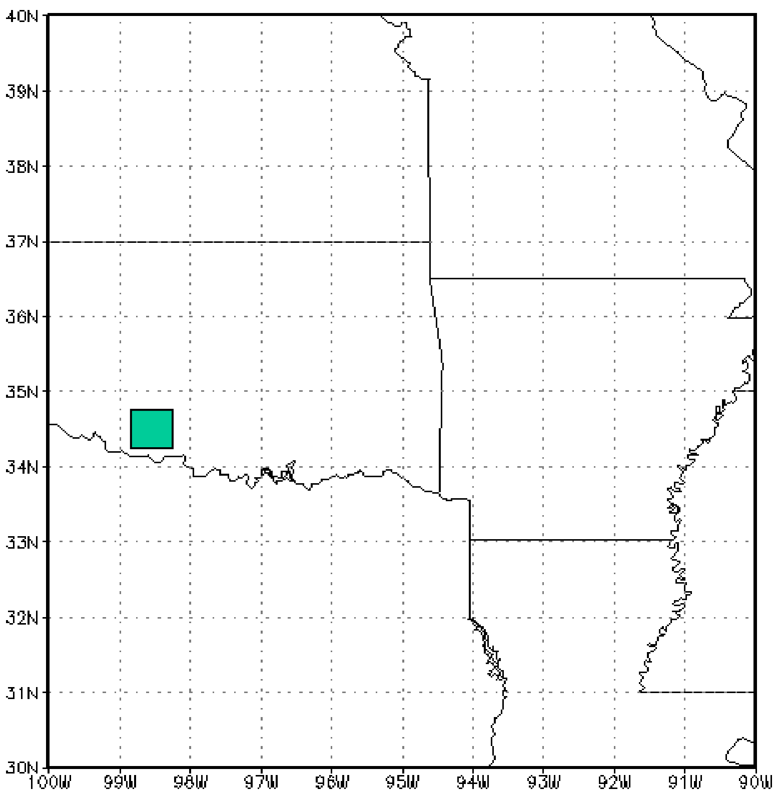
Data Assimilation Abstractions



Data Assimilation Component Interactions

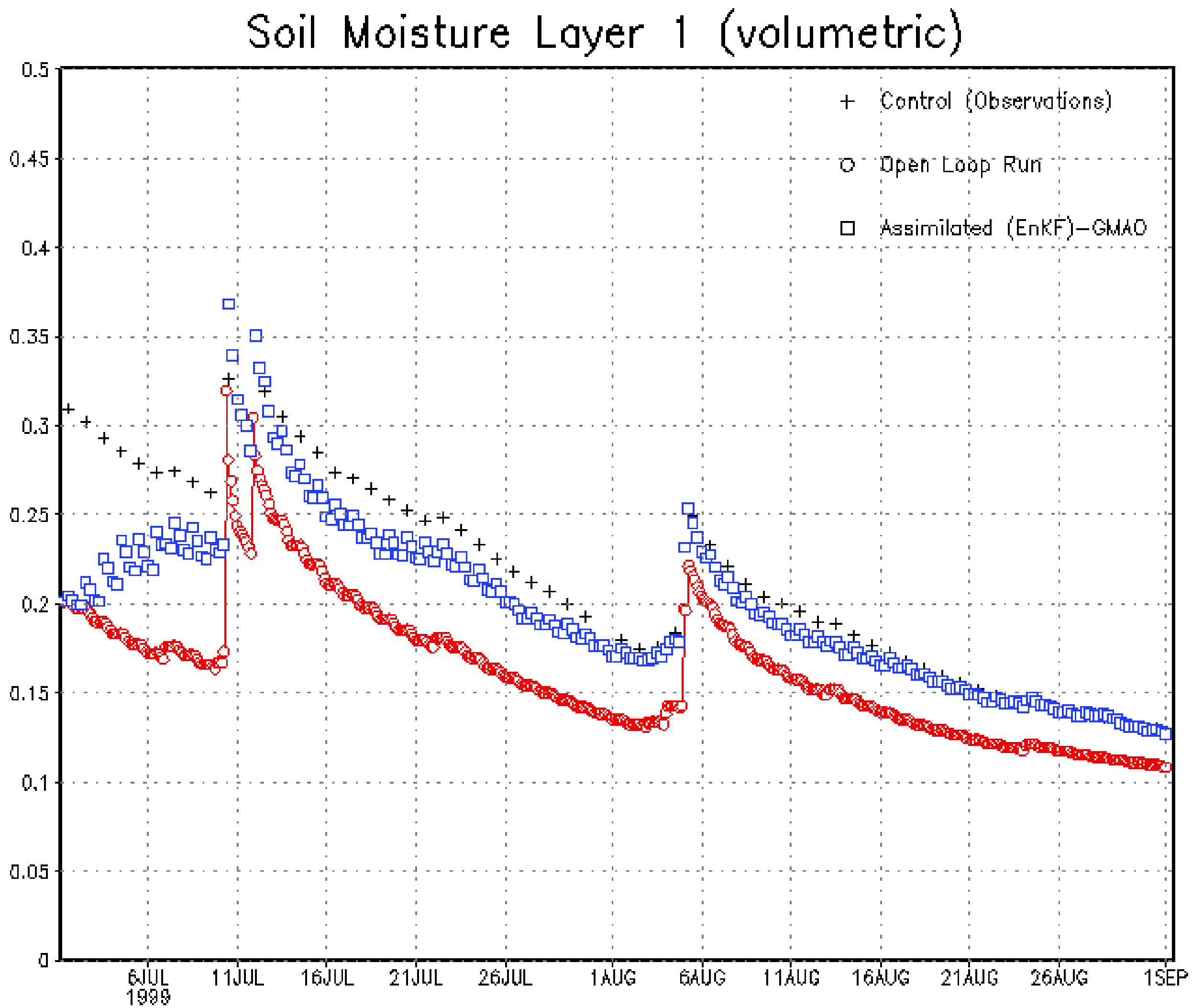


Soil Moisture Identical Twin Experiment (ITE)

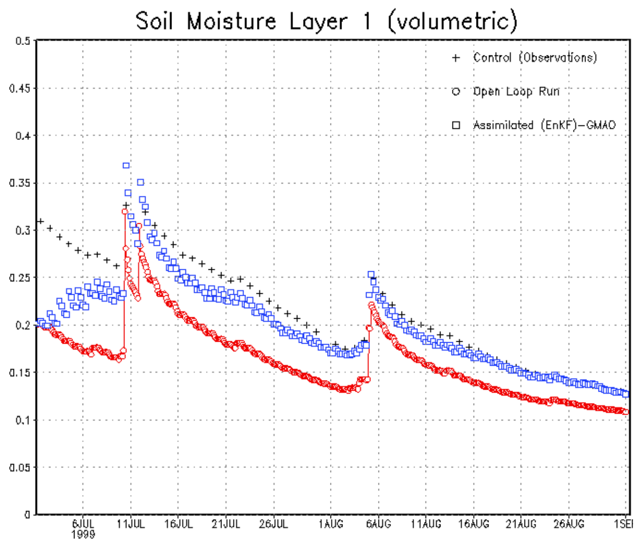


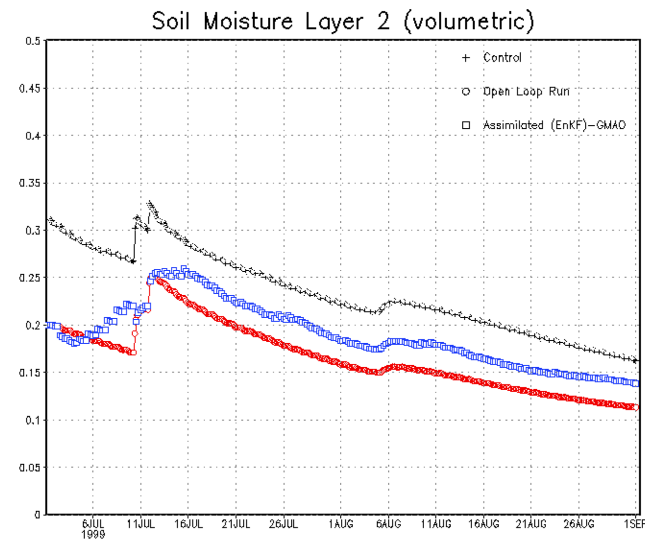
- Location :
  - Lat: 34.5 N, Lon: 98.5 W
  - Noah LSM
  - 4 soil layers (10cm, 30cm, 60cm,100cm thicknesses)
  - NLDAS forcing for atmospheric boundary conditions
- Control run
  - Two years of spinup leading up to July 1,1999
  - Two months of control simulations: 1 July 1999 to Aug 31, 1999.
- Open Loop Run
  - LSM simulations for July and August using a dry initial soil moisture
- Assimilation Runs
  - Assimilating control run 10cm soil moisture every 12Z, each day into the open loop run.
  - Simulations using Ensemble Kalman Filters, direct Insertion.

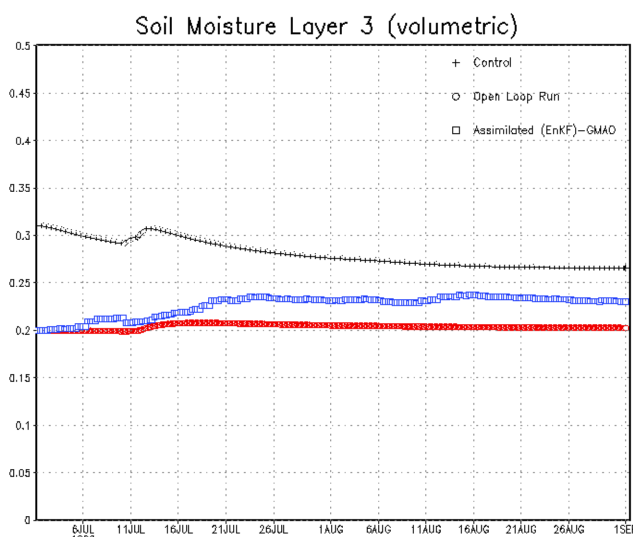
Soil Moisture Assimilation ITE
Top Layer (10cm) Update with EnKF

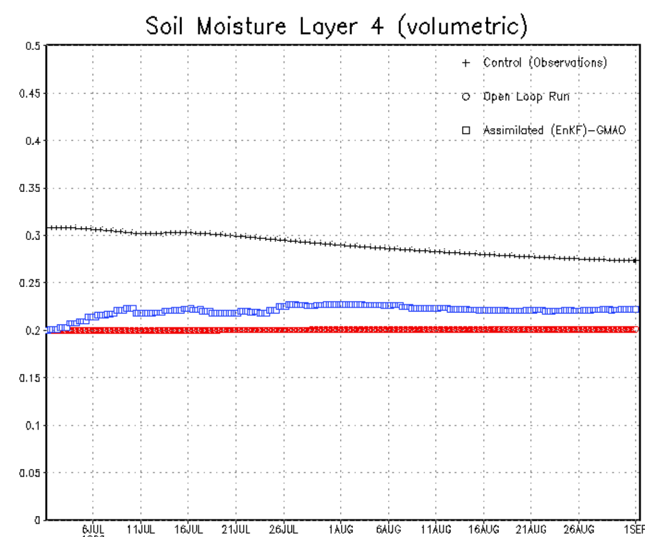


Soil Moisture Assimilation ITE
Updates for different layers with EnKF

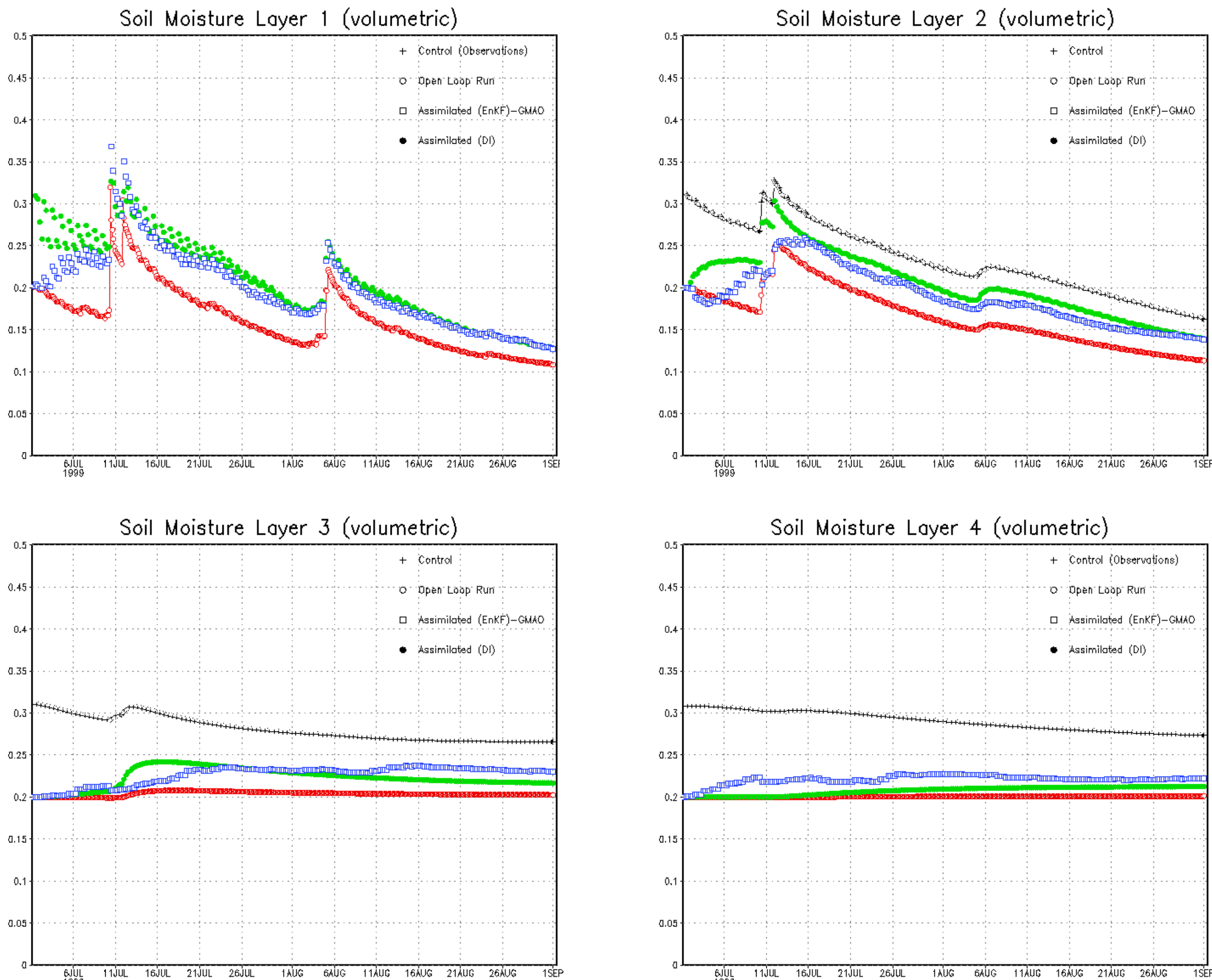




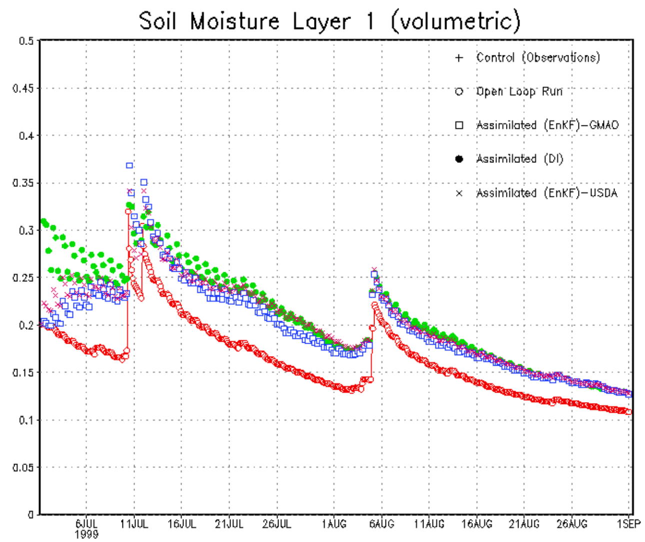


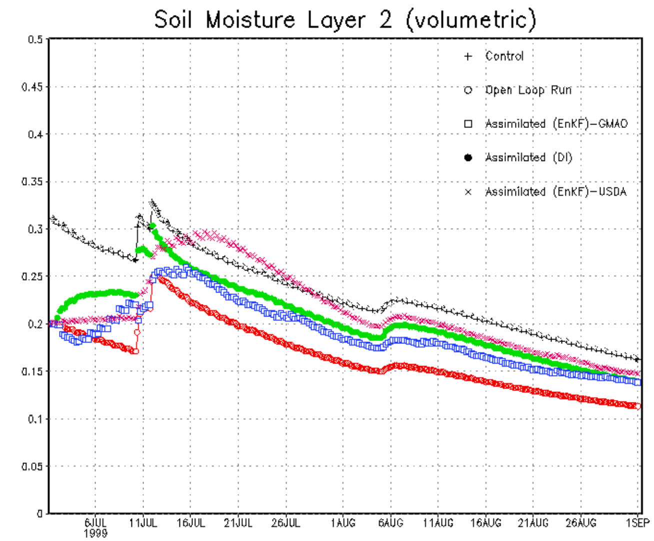


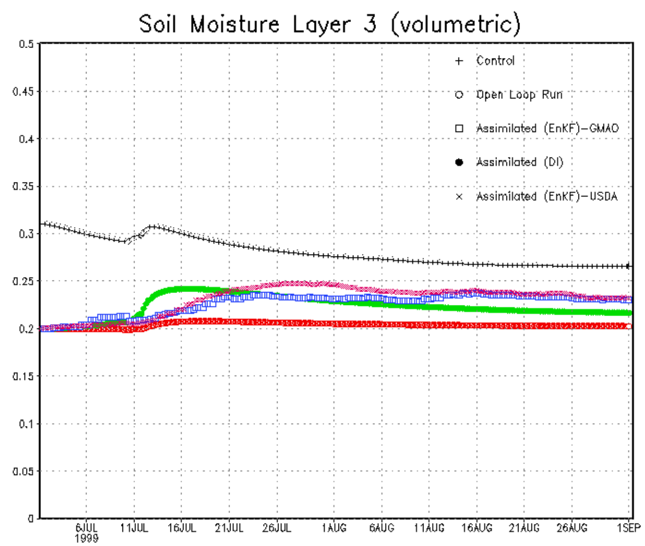
Soil Moisture Assimilation ITE Updates with EnKF, Direct Insertion

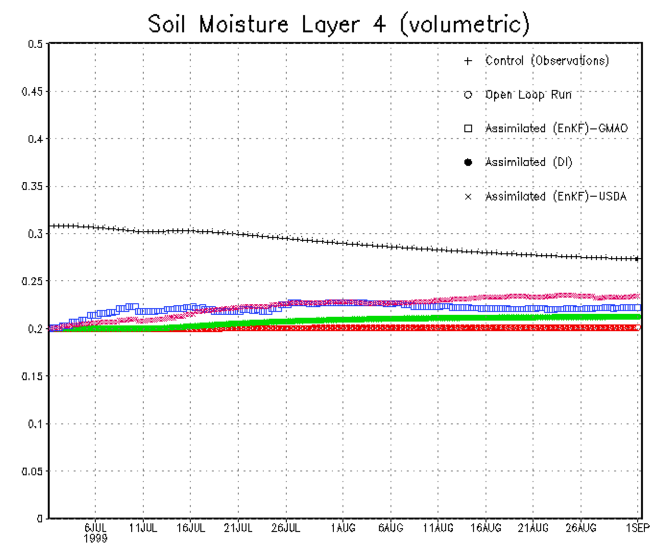


Soil Moisture Assimilation ITE Updates with multiple DA algorithms

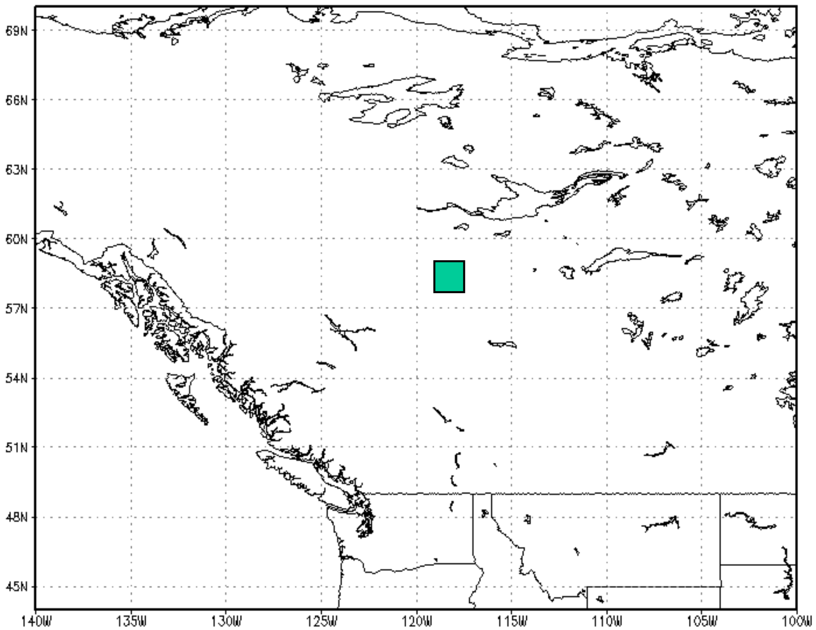






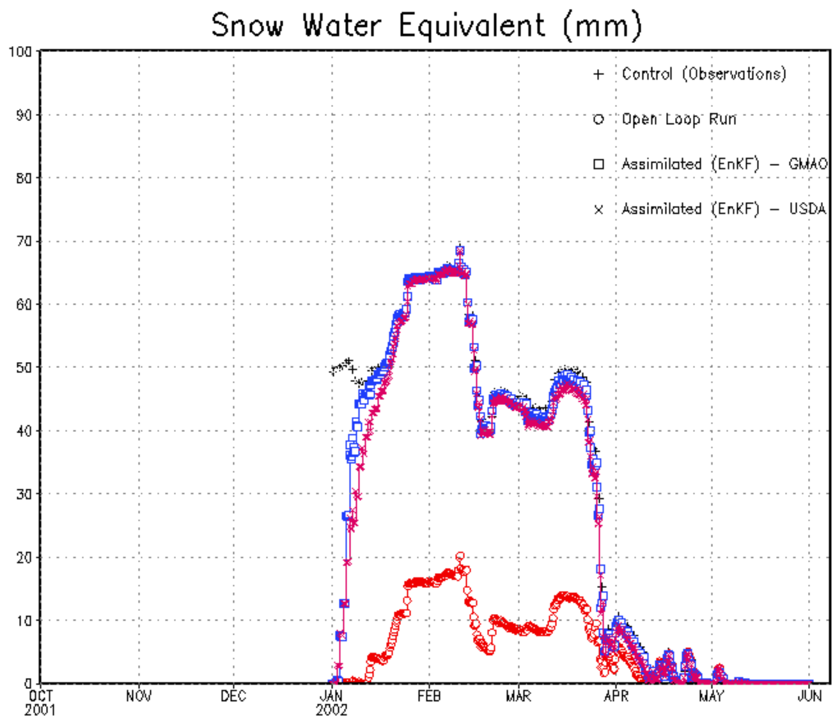


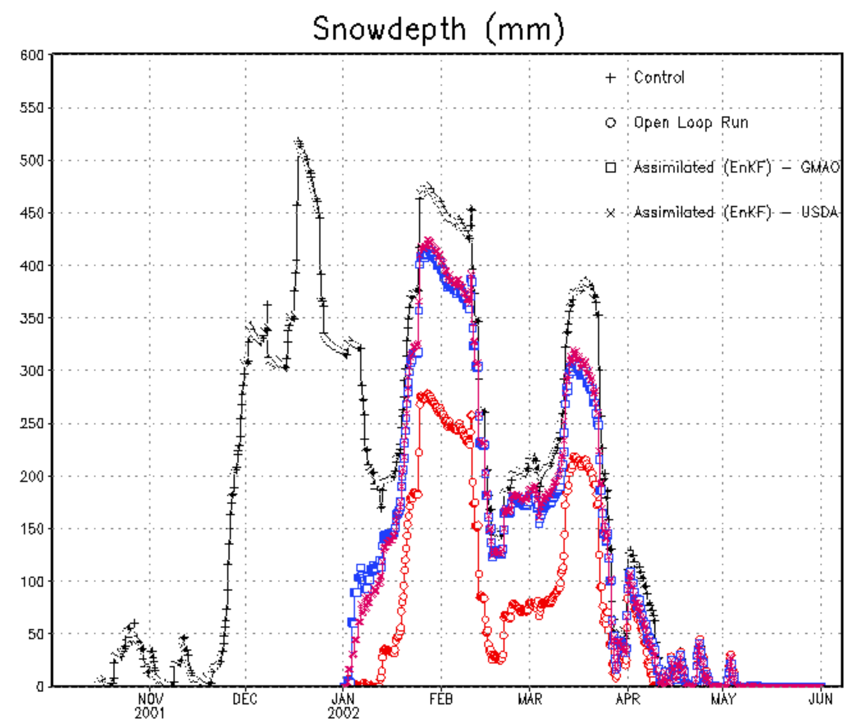
Snow Water Equivalent (SWE) ITE



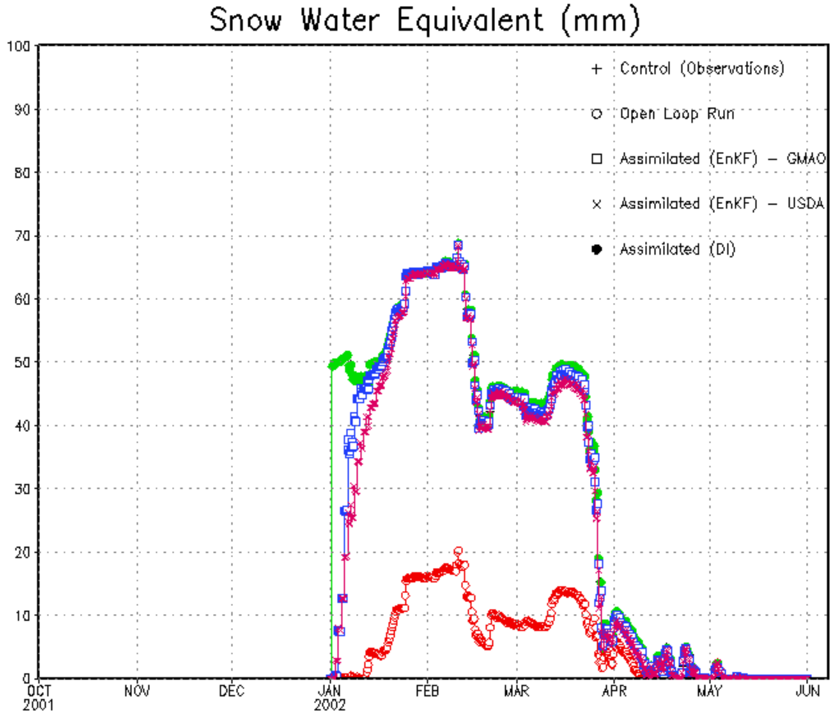
- Location
  - Lat (57-58 N), Lon (117-118W)
  - Noah LSM
  - NCEP GDAS forcing for atmospheric boundary conditions
- Control Run
  - Simulations from October 1, 2001 to June 1, 2002.
- Open Loop Run
  - Simulations from January 1, 2002 to June 30, 2002, with SWE and snowdepth initialized to zero.
- Assimilation Runs
  - LSM simulations from January 1, 2002 to June 30, 2002, assimilating the SWE values from the control run every day at 12Z into the open loop run.
  - Simulations using Ensemble Kalman Filters.
  - A direct insertion of SWE observations into the model caused the model to become unstable since the corresponding snowdepth fields was not updated automatically

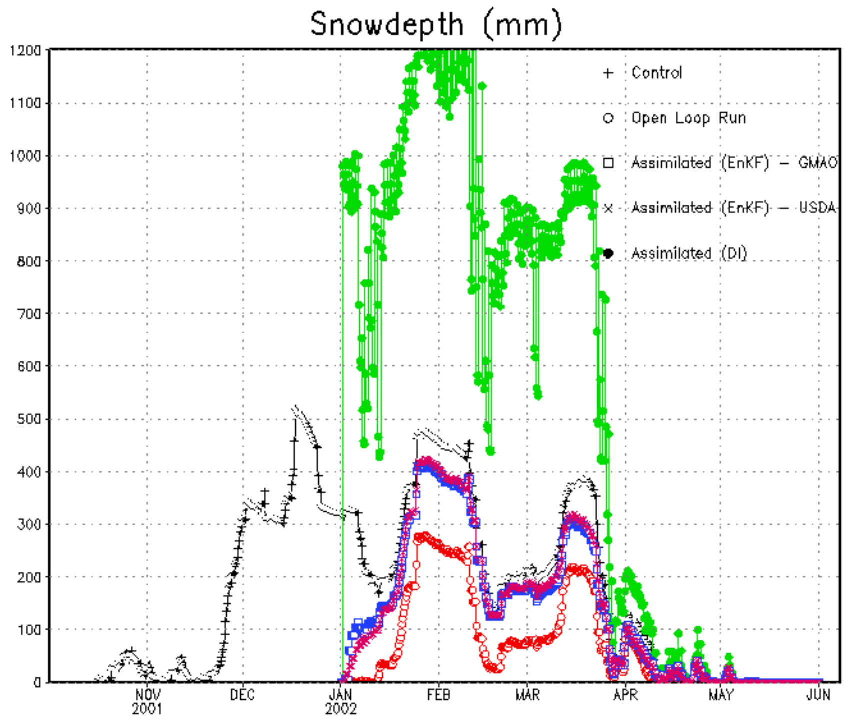
SWE Assimilation ITE
Updates for SWE/Snowdepth fields using EnKF





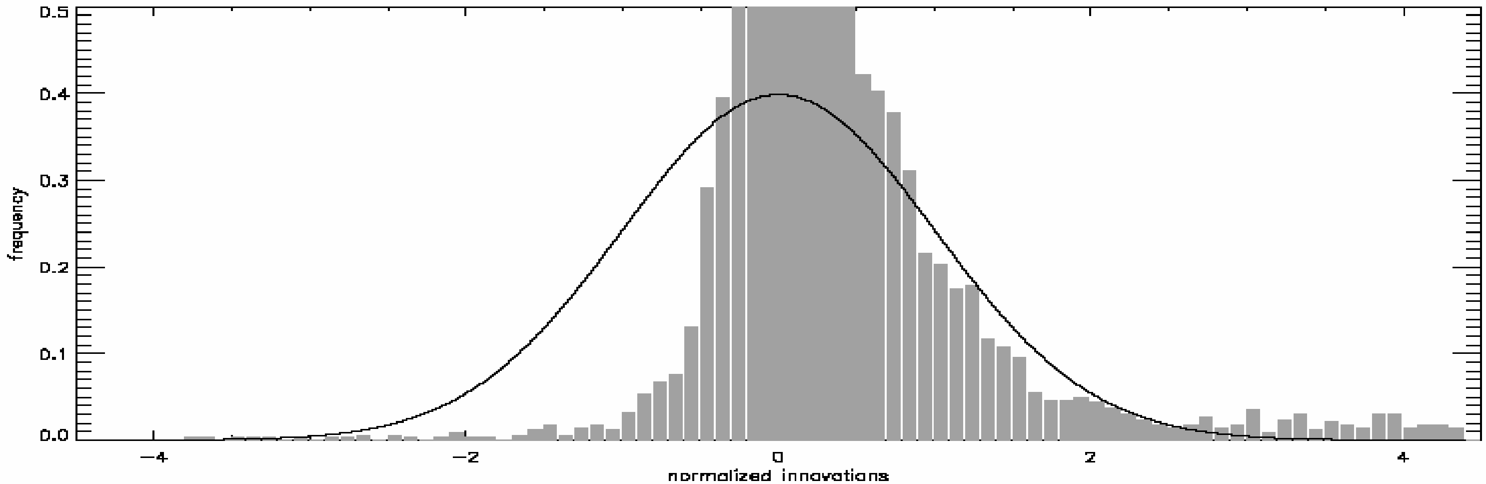
SWE Assimilation ITE Updates for SWE/Snowdepth fields using EnKF and Rule-Based DI



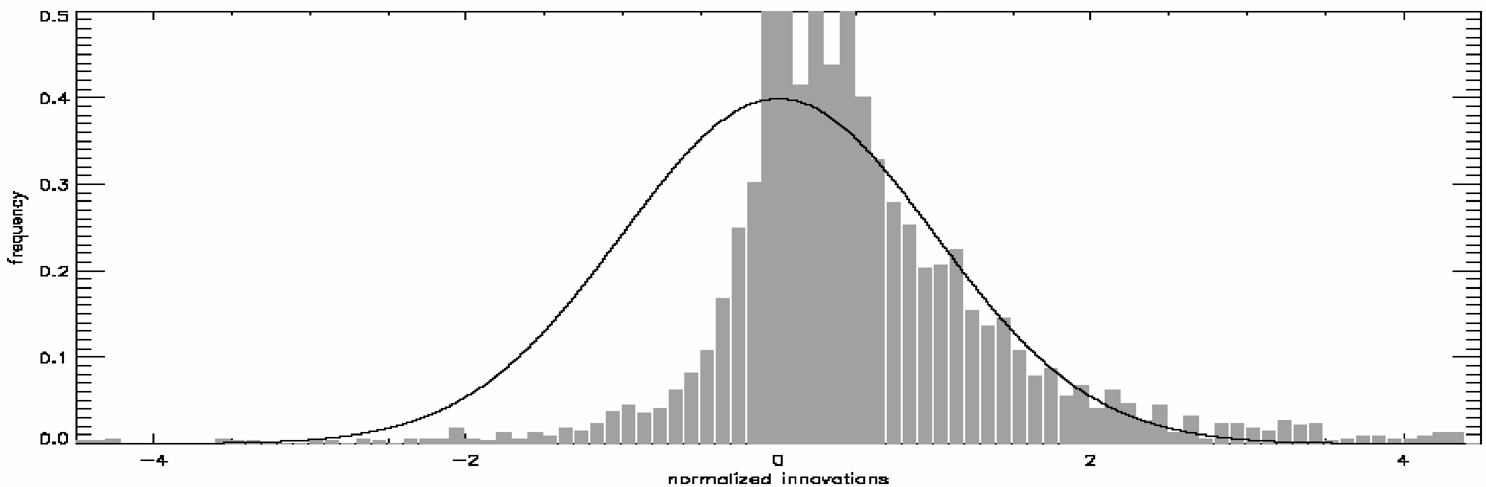


SWE Assimilation Diagnostics: Normalized Innovations

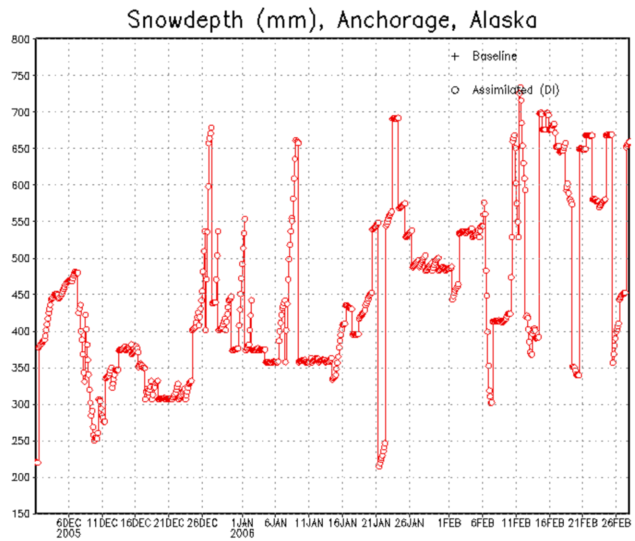
- USDA

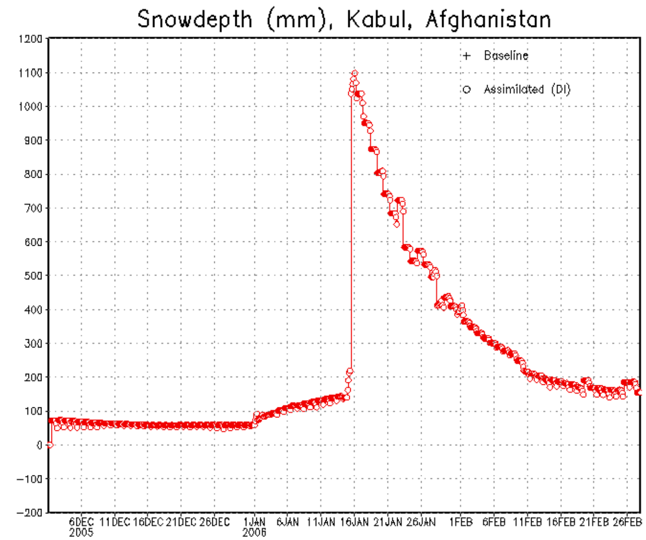


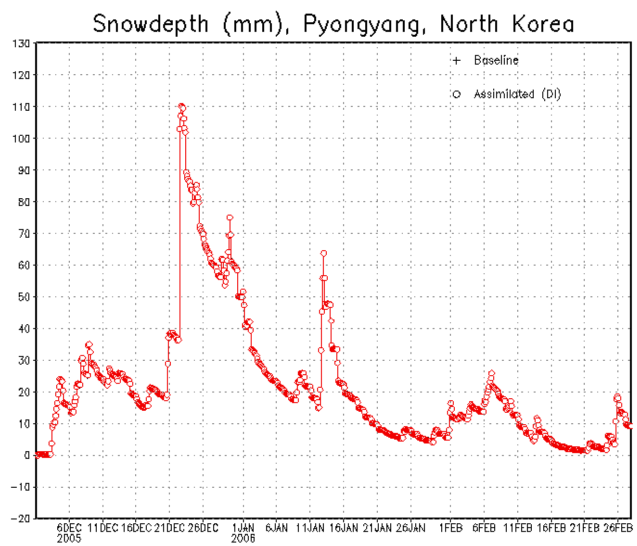
- GMAO

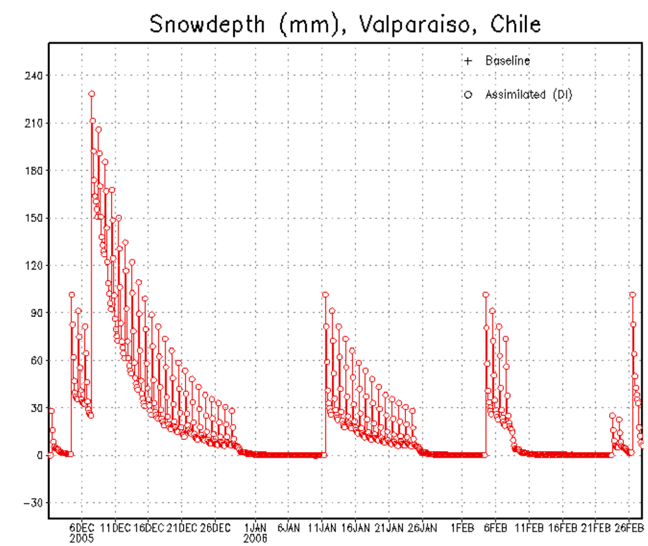


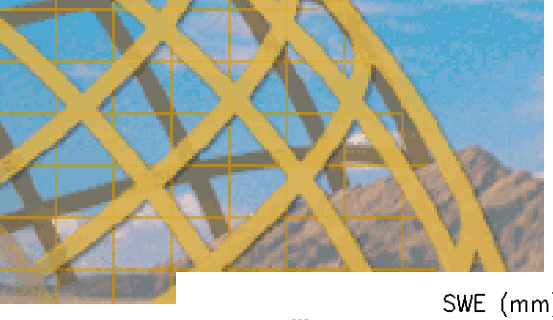
AFWA SNODEP assimilation w/LIS – Point Intercomparisons of Snow Depth



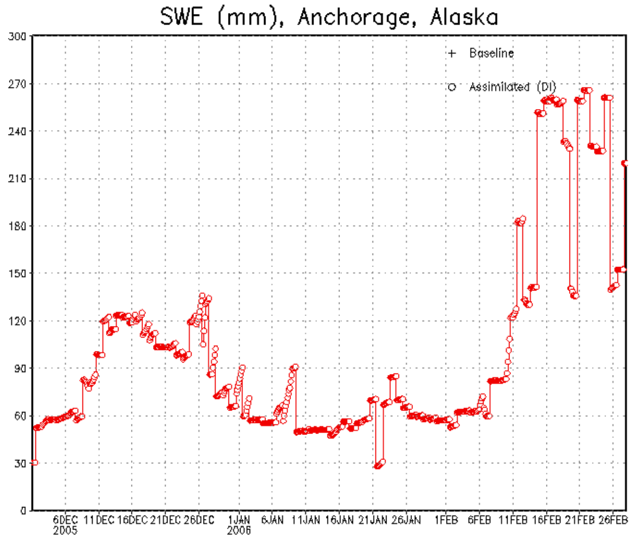


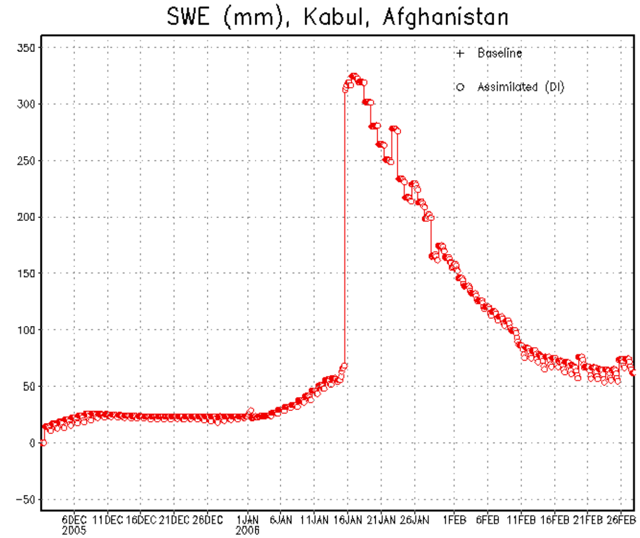


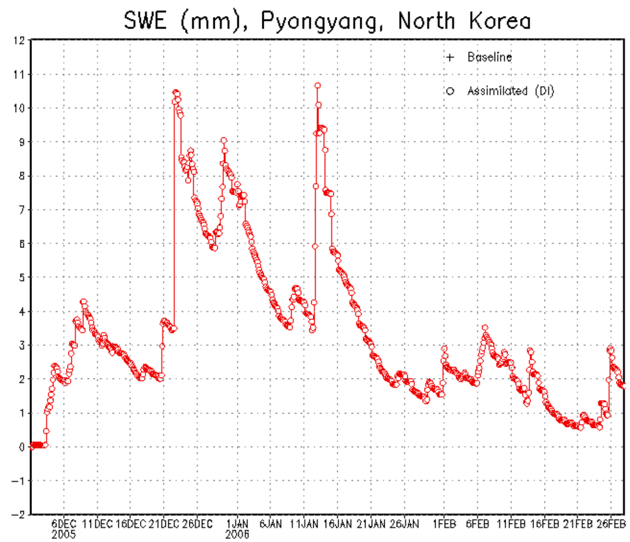


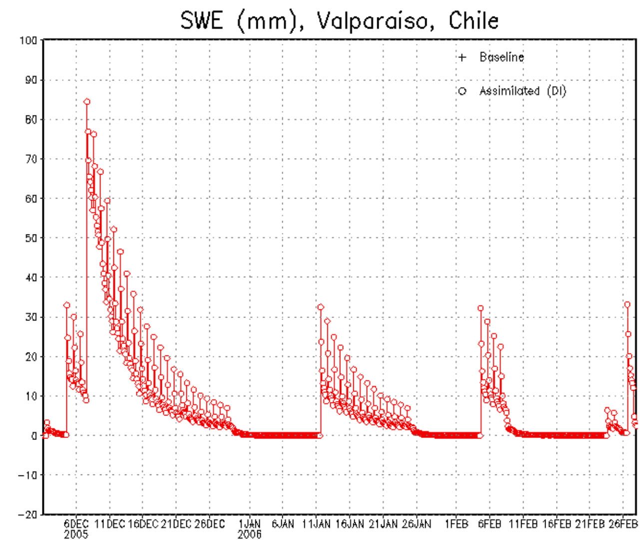


AFWA SNODEP assimilation w/LIS – Point Intercomparisons of SWE

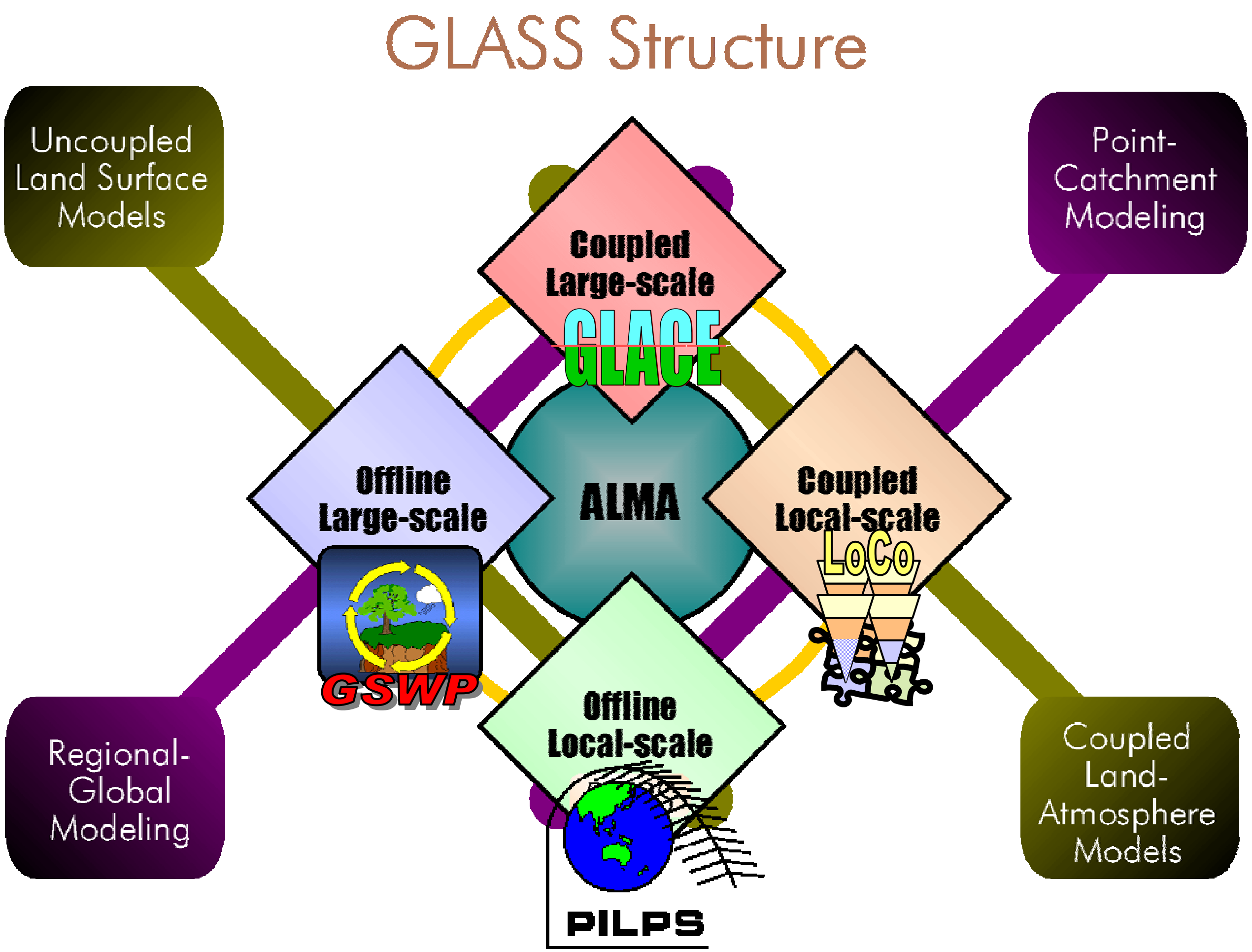




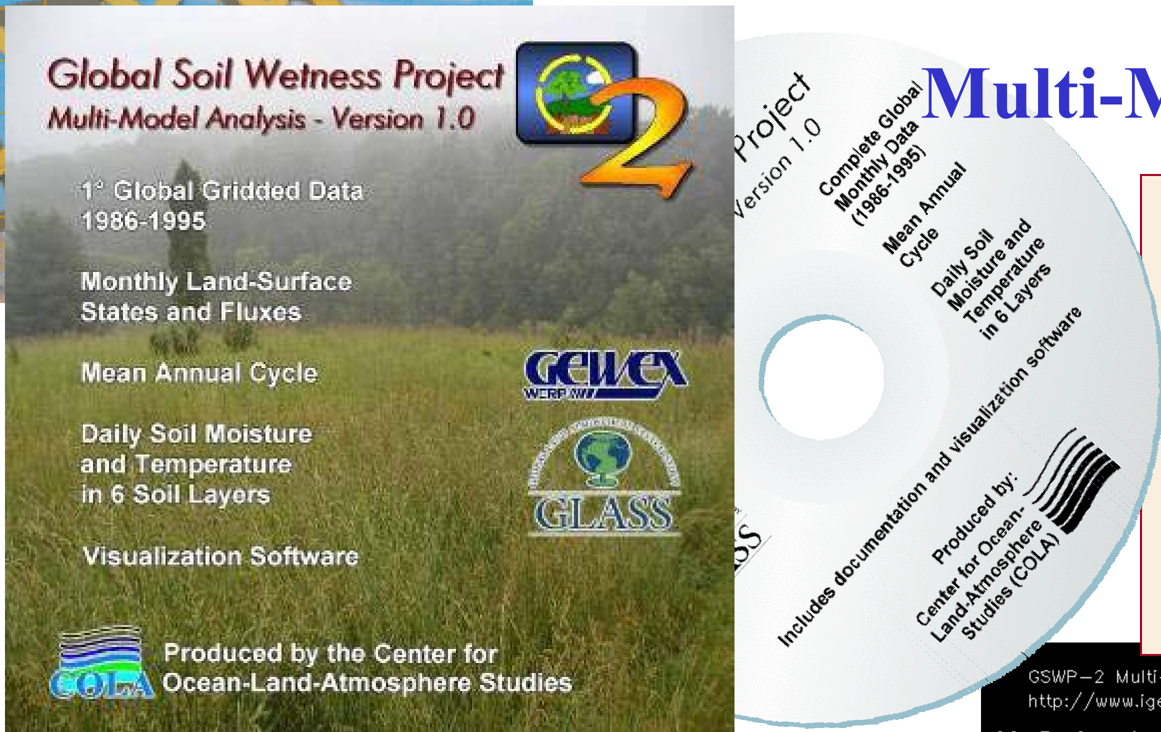




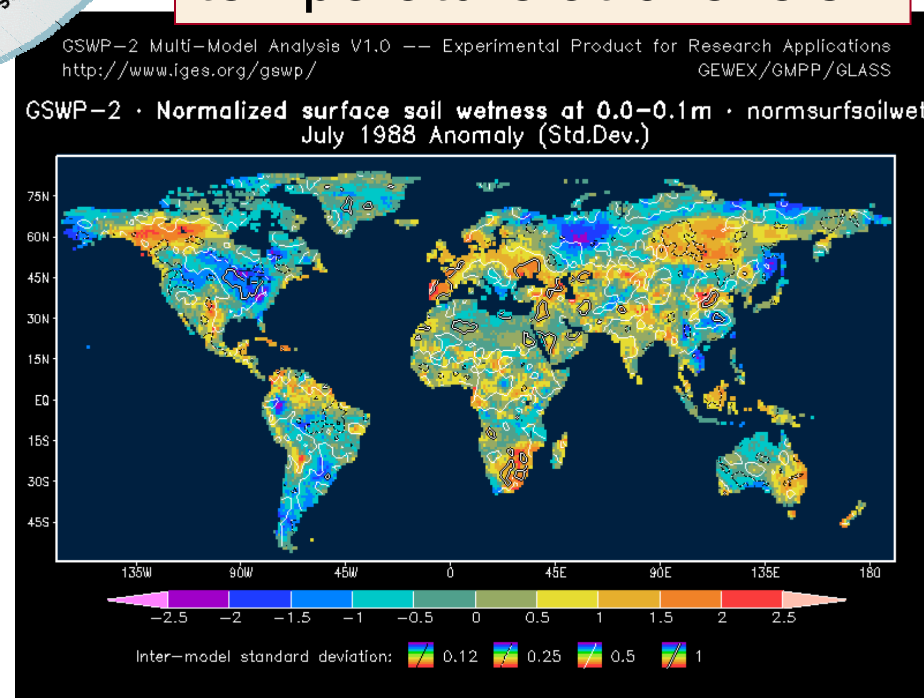
LIS in GEWEX Global Land Atmosphere System Study (GLASS)



Multi-Model Analysis



DVD with 10yr global 1° land-surface data sets for 50 different variables, including soil moisture and temperature at 6 levels.

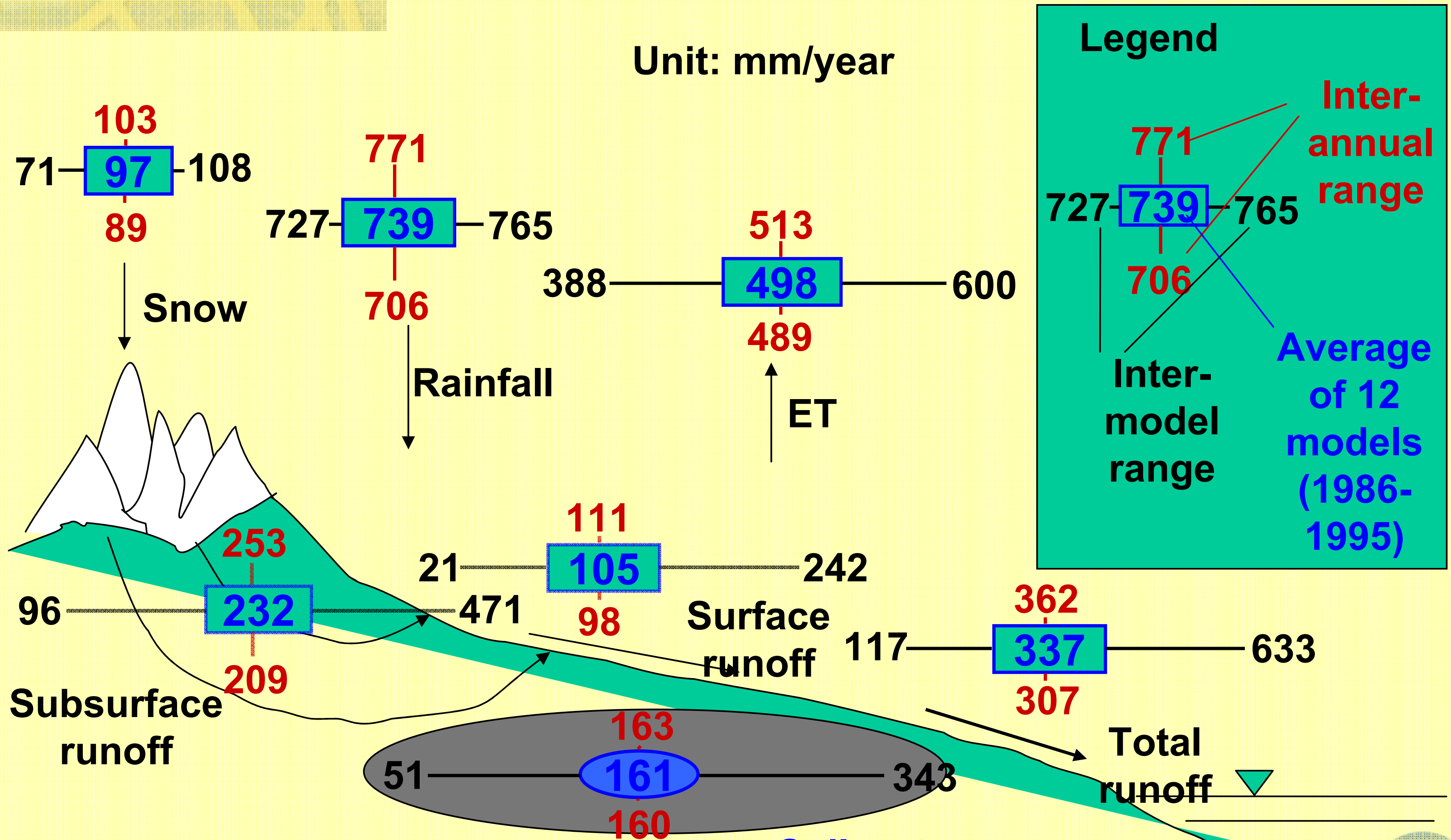


- Includes documentation, data (NetCDF monthly and climatological; daily for soil moisture and temperature only), sample images, and GrADS software.
- Monthly data include inter-model standard deviation as well as multi-model mean.
- Complete daily data online (see: www.iges.org/gswp/).

Dirmeyer et al. 2006; BAMS

GSWP-2

Global Terrestrial Water Budget



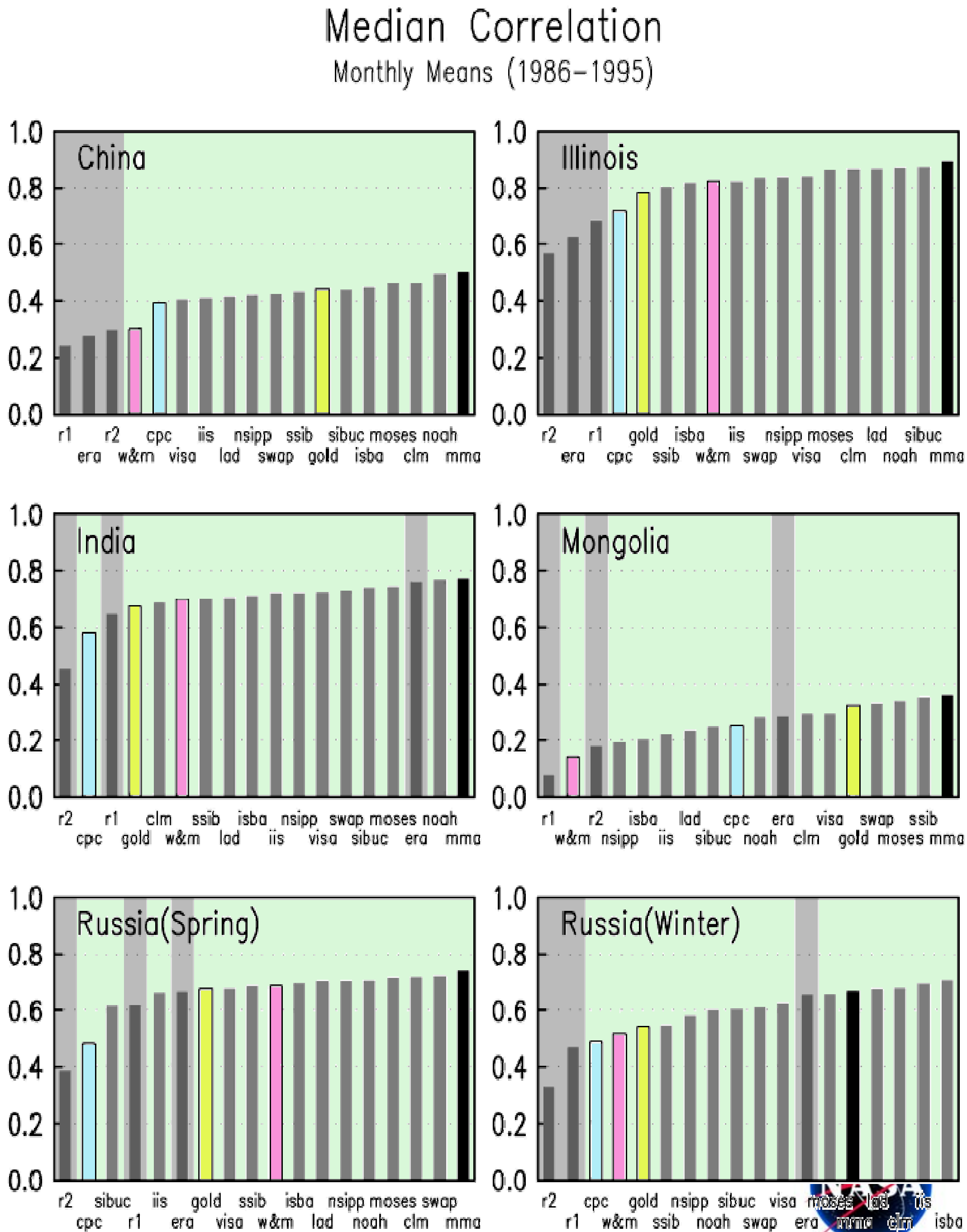
Dirmeyer et al. 2006; BAMS

GSWP-2 models outperform reanalyses

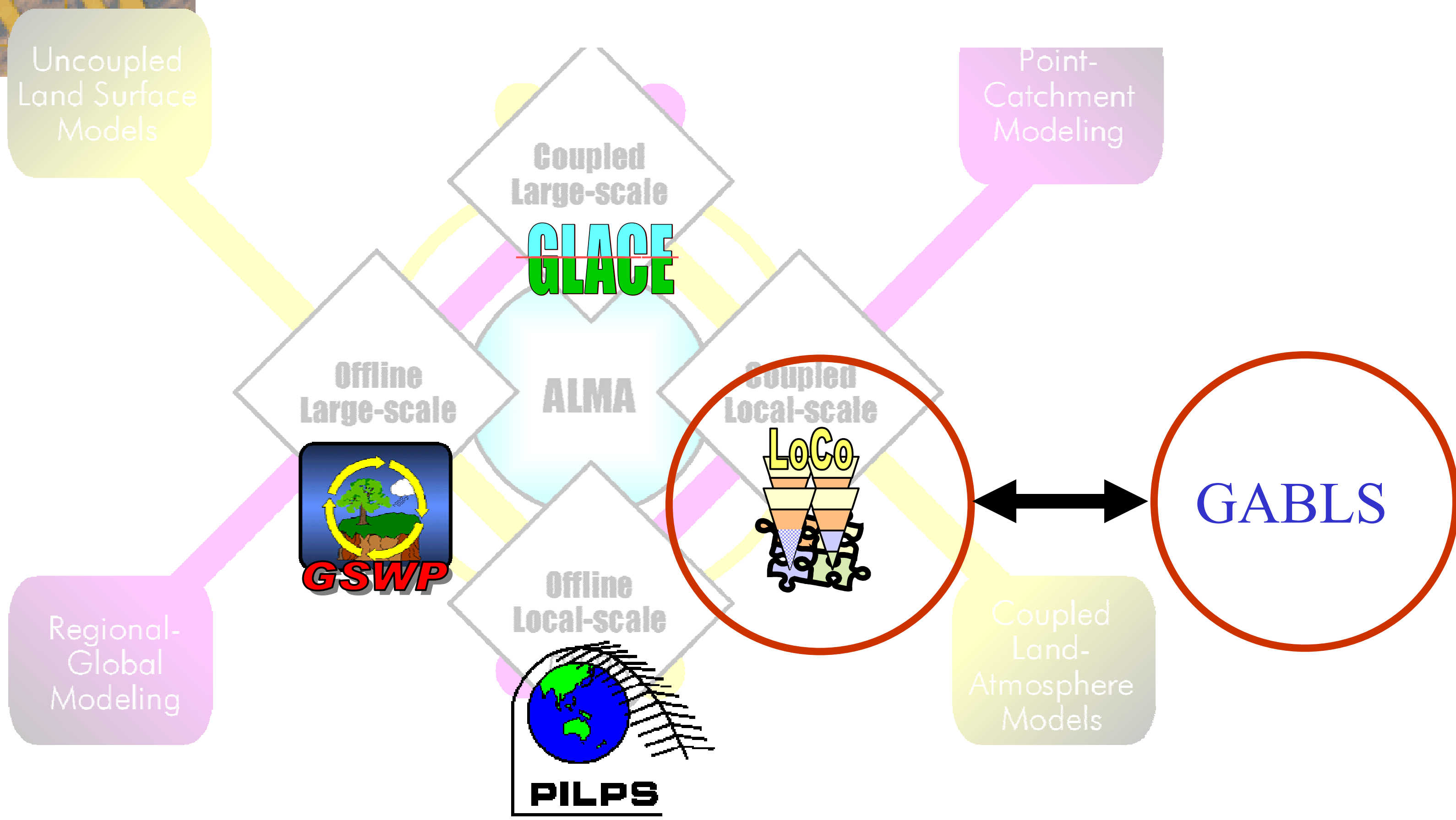
Multi-model best of all

Median temporal correlations between monthly mean simulated soil moisture and observations covering the period 1986-1995 in the five regions for both individual models and multi-model analysis (black; labeled as "mma"). The reanalysis products are indicated by a grey background and other non-GSWP2 LSSs are in color (CPC blue, Willmott pink, GOLD yellow). The products are shown in ranked order, from lowest to highest correlations, based on median values.

Guo et al. 2006: QJRMS



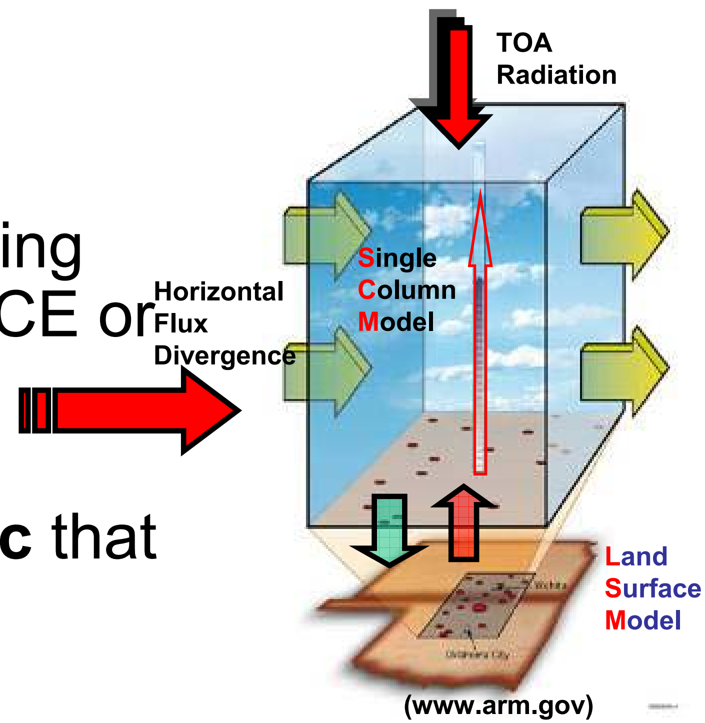
New Effort: LoCo=Local Coupling



Bart vd Hurk, Christa Peters-Lidard and Bert Holtslag

LoCo Science questions

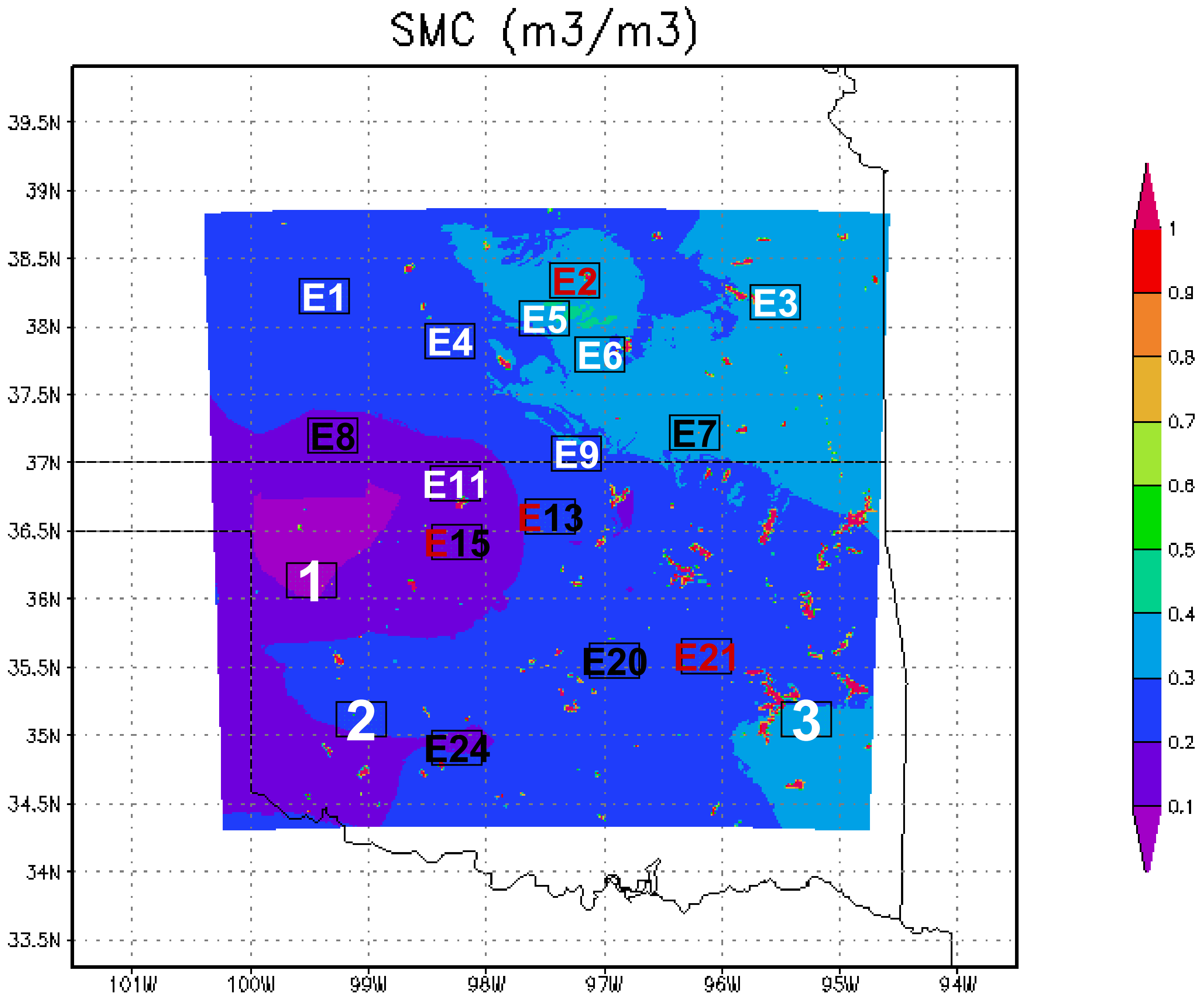
- How are the results of PILPS, GSWP, or data assimilation experiments affected by the **lack of land surface-atmosphere coupling**?
- Can we explain the **physical mechanisms** leading to the coupling strength differences found in GLACE or other coupled NWP/climate experiments?
- Is there an **observable diagnostic** that quantifies the role of local land-atmosphere coupling?



A Single Column Model

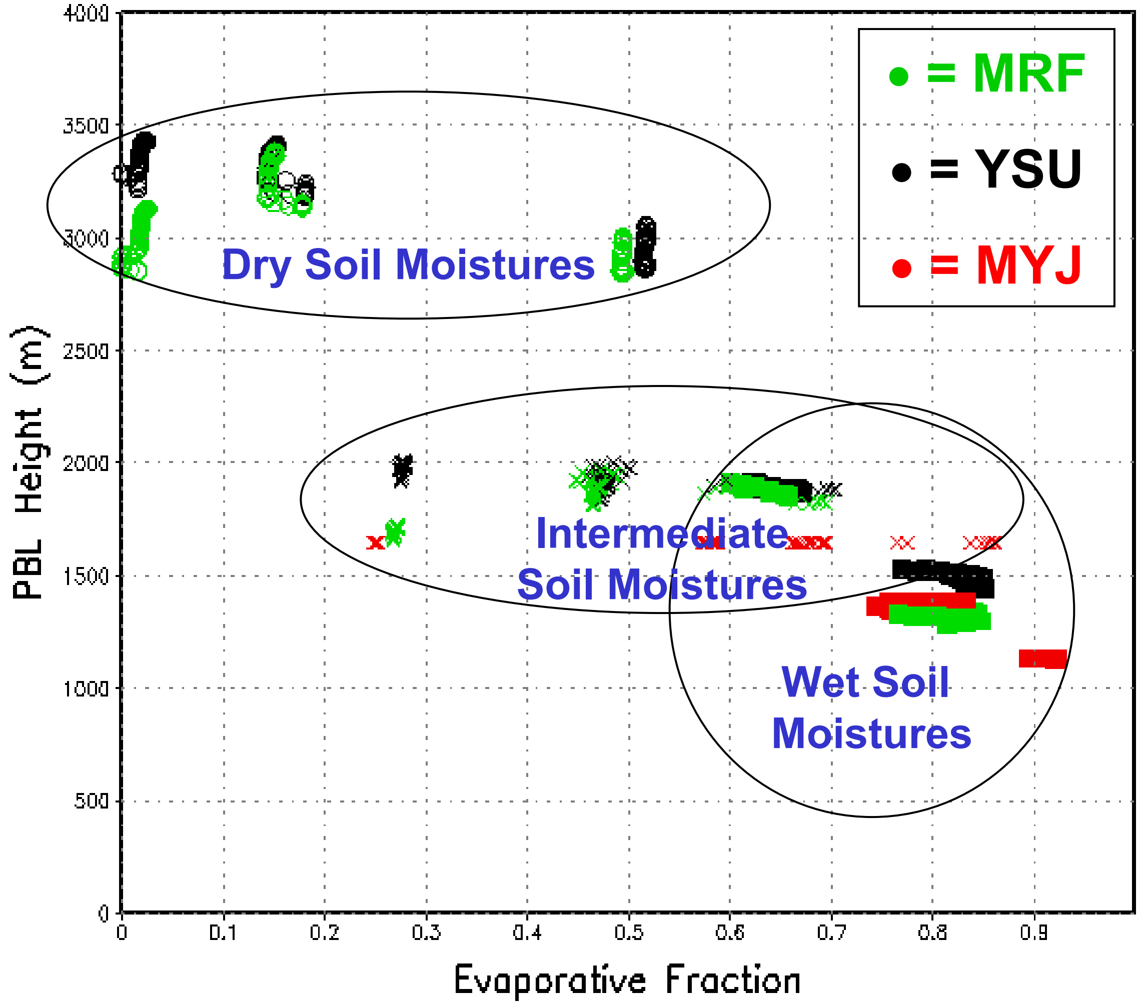
Christa Peters-Lidard and Bart vd Hurk

WRF/LIS IHOP 2002 Soil Moisture ICs, Flux, and Sounding Sites



Initial soil moisture for the WRF 1km-domain over IHOP

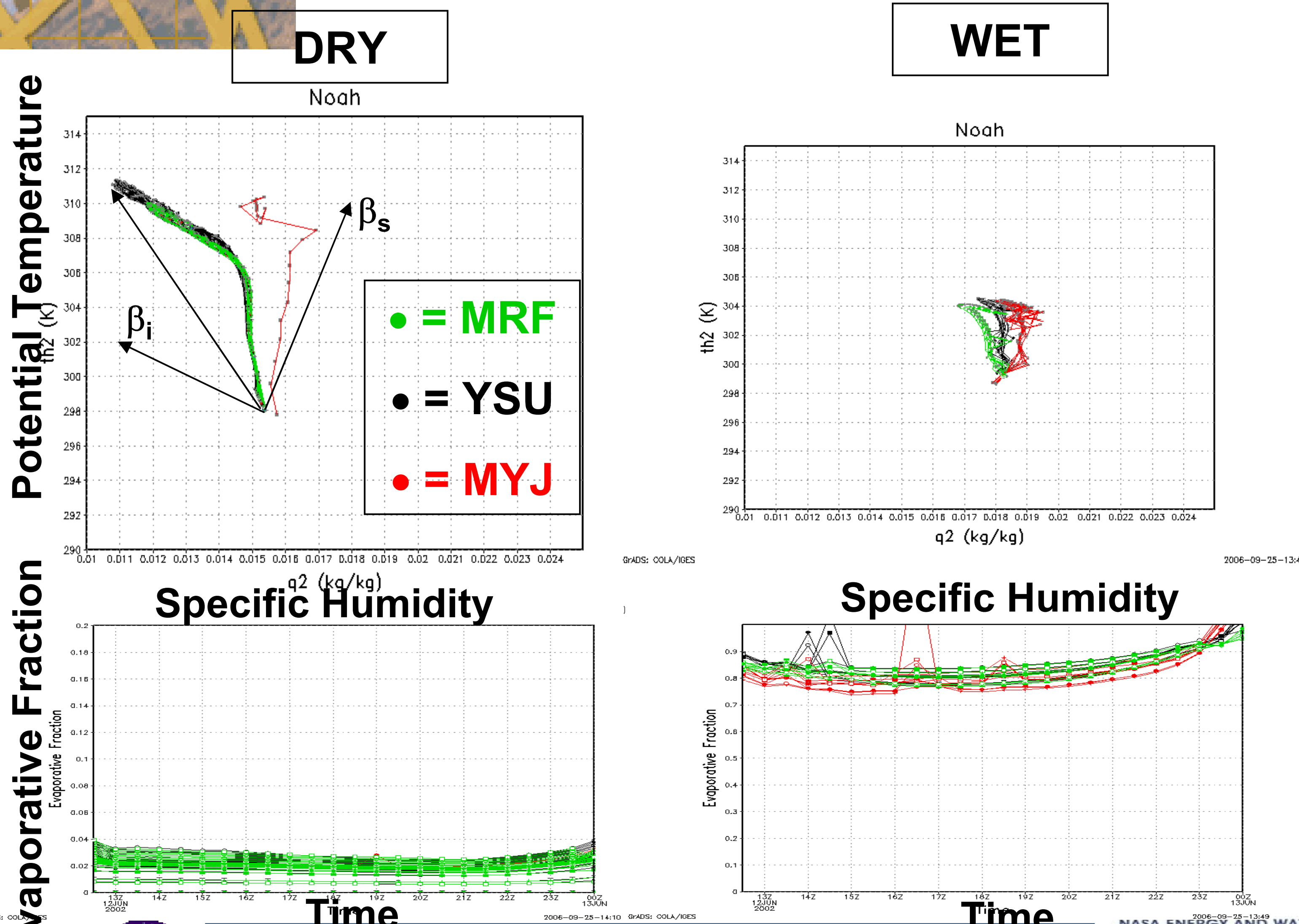
LoCo Coupling Diagnostics based on WRF/LIS IHOP 2002 Case



Christa Peters-Lidard and Joseph Santanello, Jr.

NASA ENERGY AND WATER CYCLE STUDY

LoCo Coupling Diagnostics based on WRF/LIS IHOP 2002 Case



Christa Peters-Lidard and Joseph Santanello, Jr.

NASA ENERGY AND WATER CYCLE STUDY

Ongoing Work and Future Directions

- Ongoing
  - Continued work with AFWA on EnKF Support, Precipitation enhancements, WRF Coupling (NCAR)
  - Collaboration with NCEP on NLDAS Phase 2, NLDAS-E
  - Collaboration with NOAA/OHD on SAC/Snow-17
  - Collaboration with GMAO on shared subsystems (L-ANA, CATCH)

- Future
  - Coupling CRTM and MEM
  - Coupling to GFS/CFS and GEOS-5 via ESMF
  - Provide LIS testbed to all JCSDA land partners to facilitate R2O

Recommendations for JCSDA Land DA Efforts

- **Snow Cover and SWE Assimilation with MODIS/AMSR-E with transition to VIIRS: Need a coupled benchmark**
- **Soil Moisture Assimilation with AMSR-E, preparing for Aquarius and SMOS and hopefully Hydros: Need a coupled benchmark**
- **Skin Temperature from MODIS/GOES with transition to VIIRS: Need a coupled benchmark**
- **Leaf Area Index and/or Greenness from MODIS with transition to VIIRS: Need prognostic LAI/Greenness**