Recent Developments and Enhancements in the Land Information System Testbed

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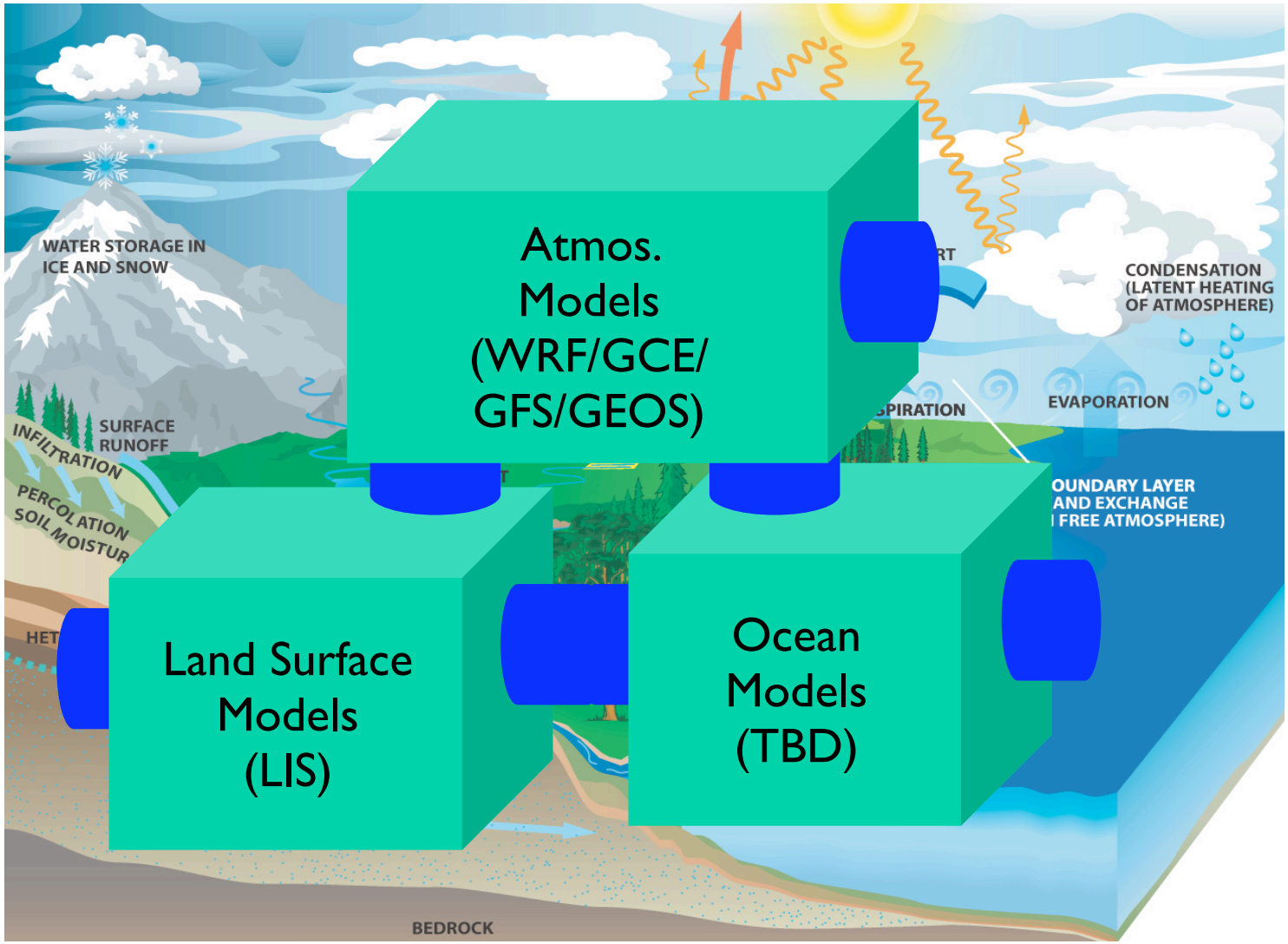
Outline

- LIS Background
- LIS Data Assimilation Capabilities (Joint with GMAO, AFWA, USDA and NESDIS)
- Ongoing Work (Not covered in this talk)
  - LIS/WRF Coupled Benchmarking (Joint with NCAR, AFWA)
  - LIS/GFS Coupling (Joint with NCEP)

LIS Background: LIS as an Earth System Model Land Component



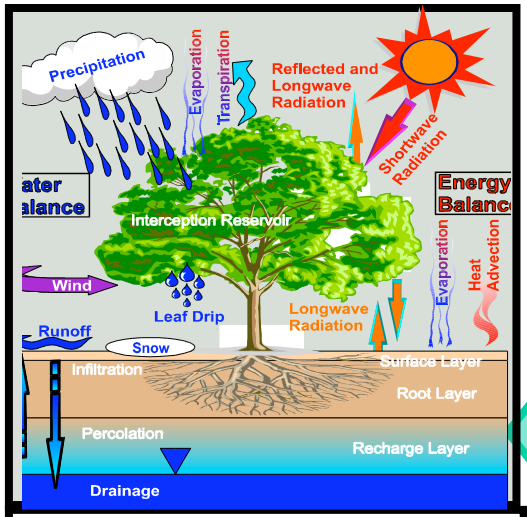
LIS Running Modes

Uncoupled or Analysis Mode

Station Data

Global, Regional Forecasts and (Re-)Analyses

Satellite Products

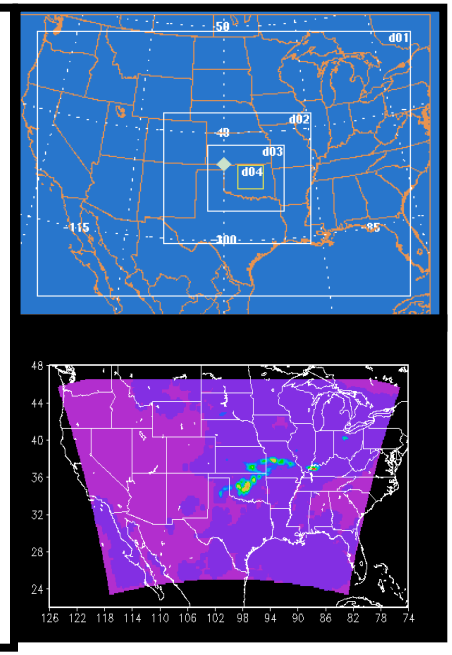


LSM Physics (Noah)

ESMF

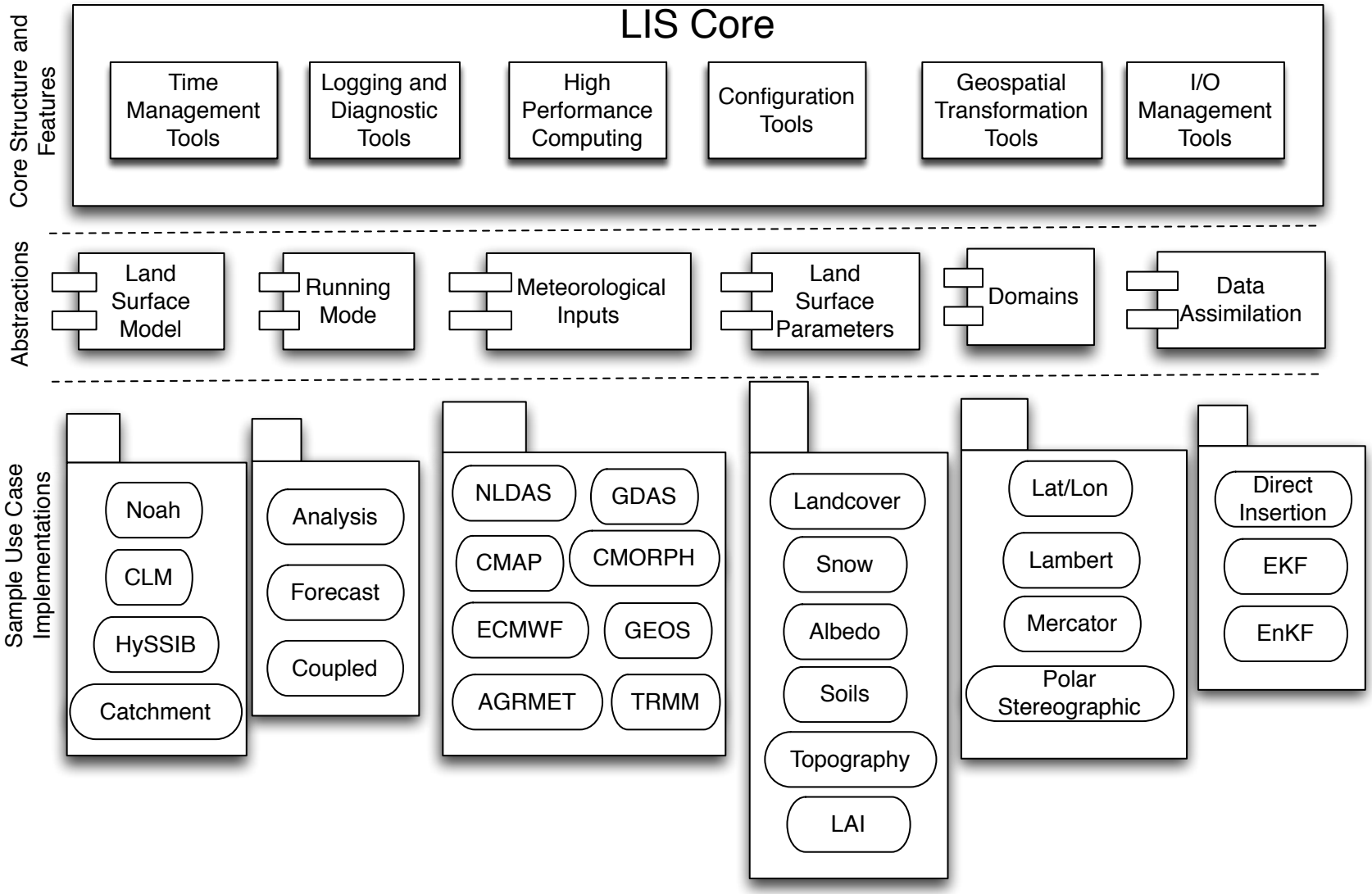
Coupled or Forecast Mode

WRF

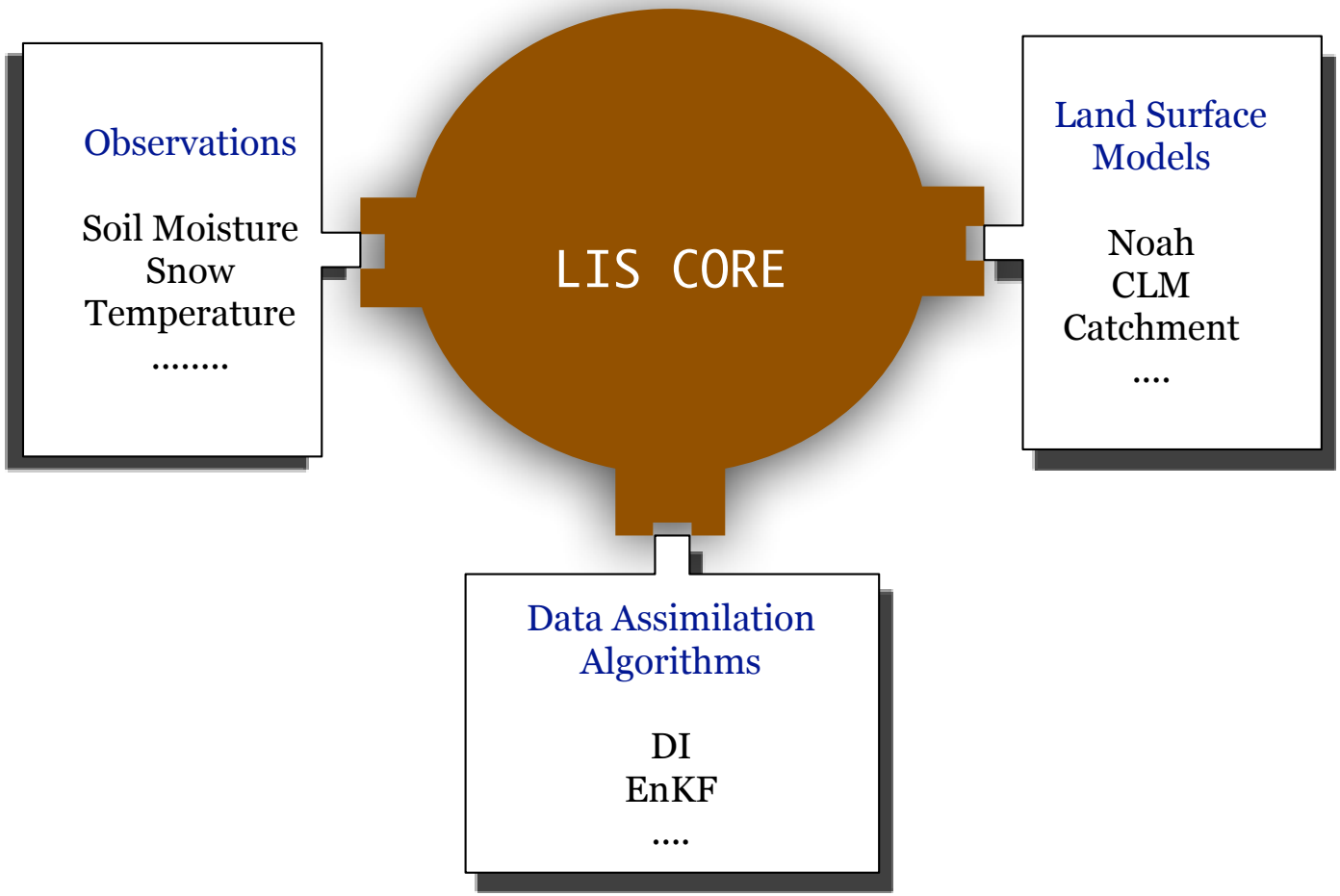


LSM Initial Conditions

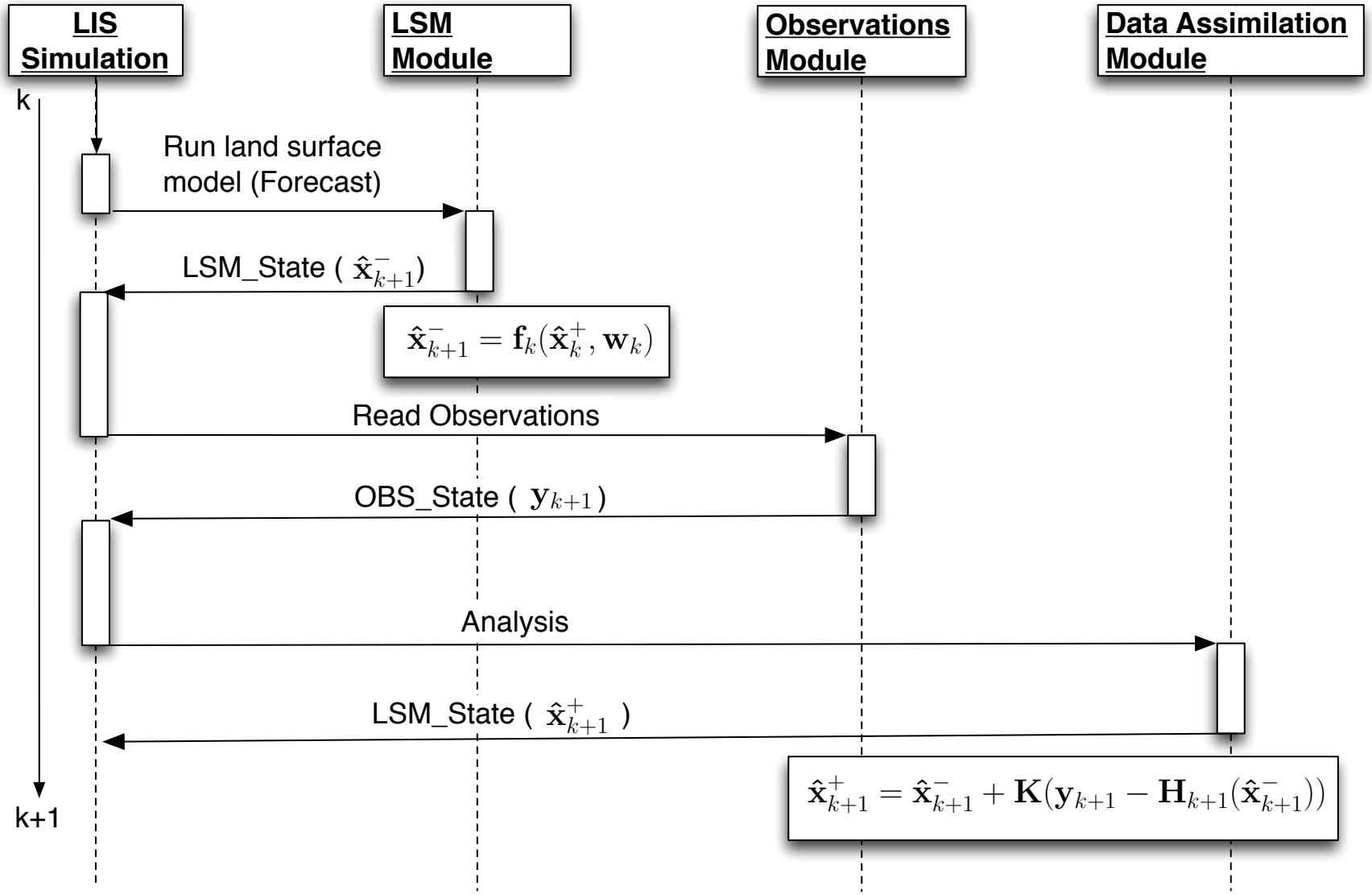
LIS Software Structure



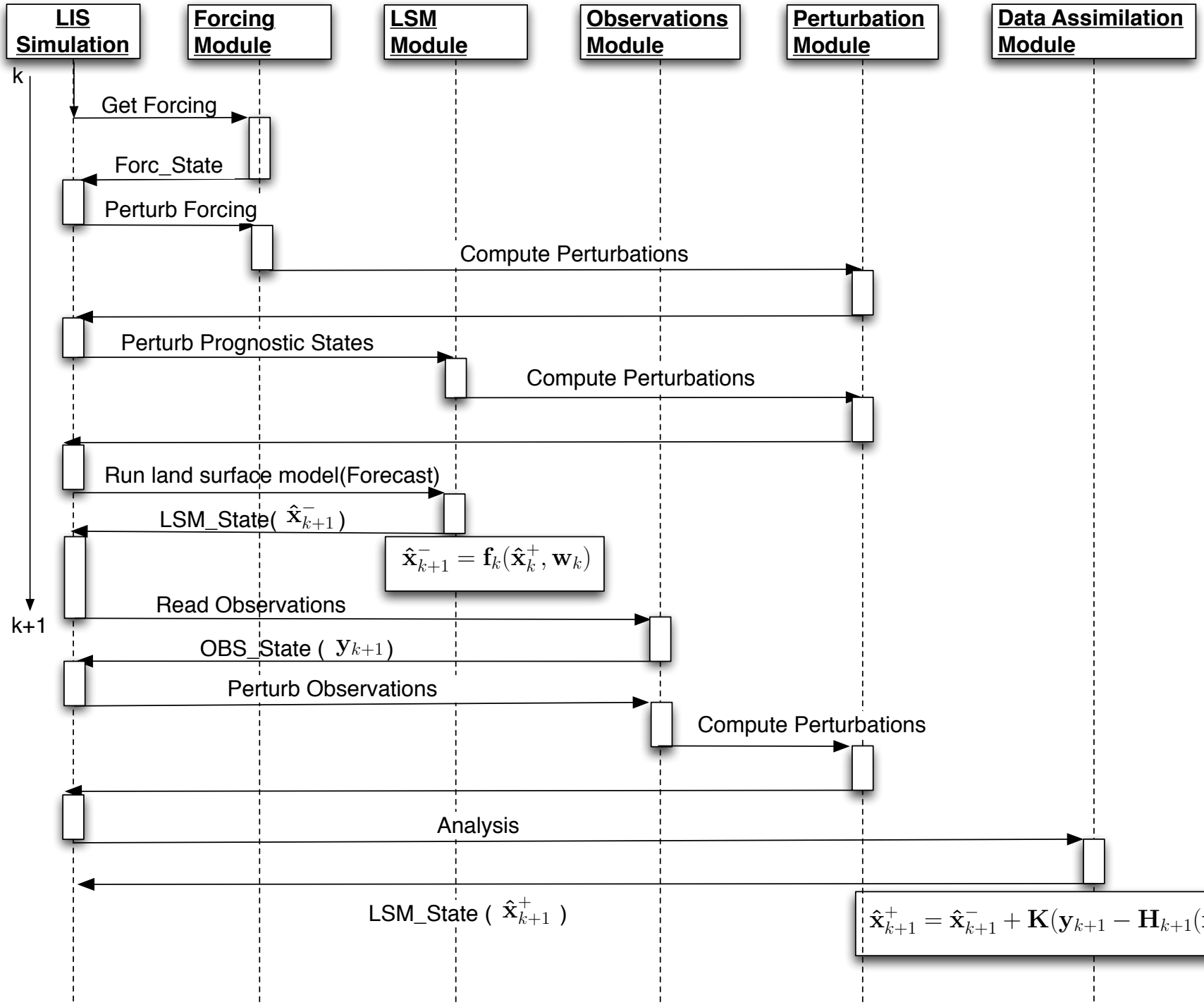
Data Assimilation Abstractions in LIS



Sequence of Component Interactions for a sequential assimilation cycle



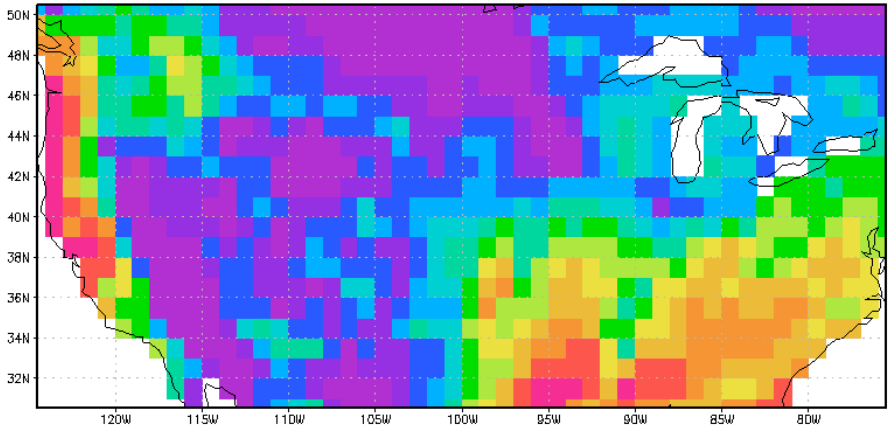
Sequence of Component Interactions for a cycle of EnKF



Data Assimilation Experiments

- To showcase the interoperable use of multiple data assimilation algorithms, land surface models and observations
- Two sets of assimilation experiments
  - Soil Moisture OSSEs - using different LSMs
  - Snow OSSEs - different types of snow observations
- OSSE setup
  - Control/Truth Run
  - Degraded/Open Loop Run
  - Generate synthetic observations
  - Assimilate synthetic observations into the open loop run

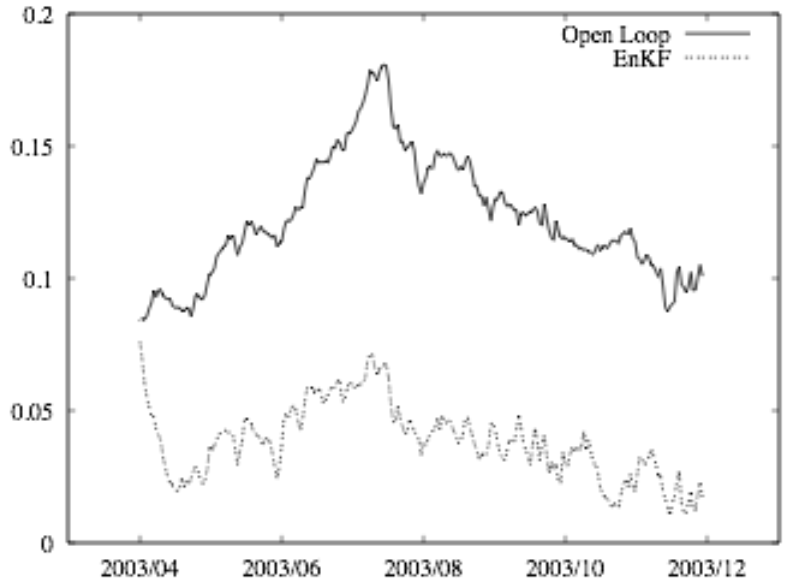
Data Assimilation Experiment Setup
Soil Moisture OSSEs

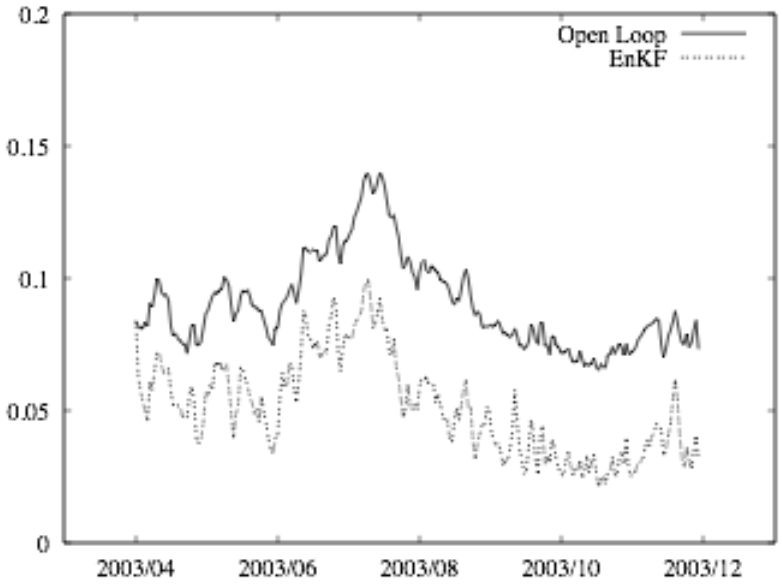


- Modeling domain: CONUS
- Catchment and Noah LSMs
- April 1,2003 to December 1, 2003.
- Control/Truth runs using GDAS forcing (spun up from January 1, 2000)
- OpenLoop runs using GEOS forcing
- Synthetic surface soil moisture observations generated from the truth runs by simulating typical retrieval errors associated with microwave sensors
  - masking of data for dense vegetation
  - data masks in the presence of rain/snow
  - random noise of 3% (volumetric) error
- Assimilation runs
  - Assimilate synthetic obs into the open loop runs, once a day at 12Z
  - Simulations using the EnKF

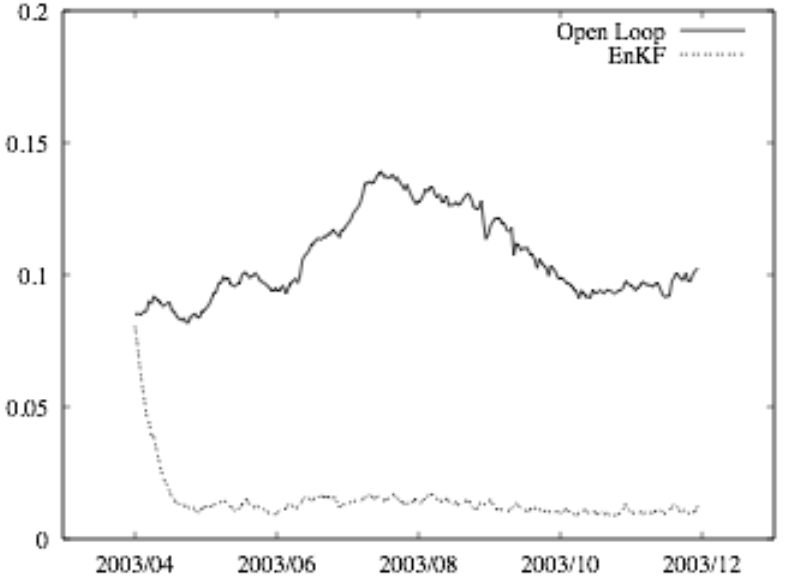
Time Series of RMSEs for Soil Moisture OSSEs

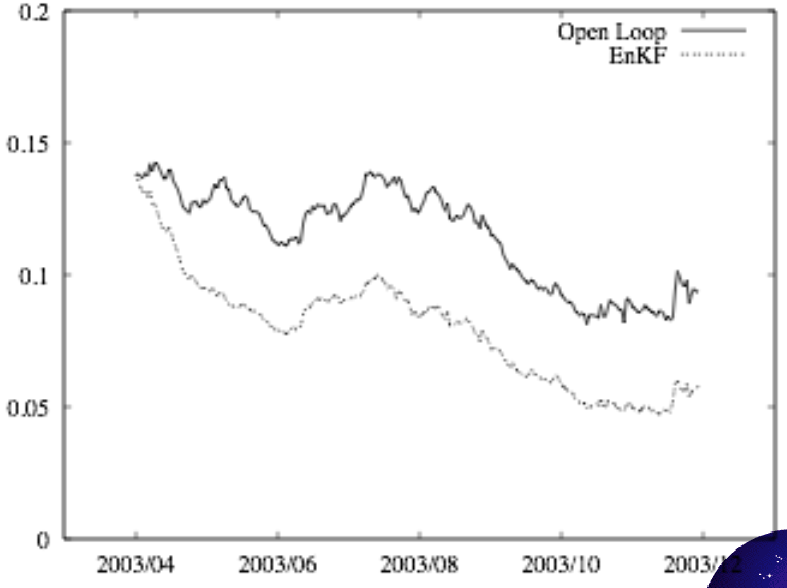
Surface Layer





Root Zone





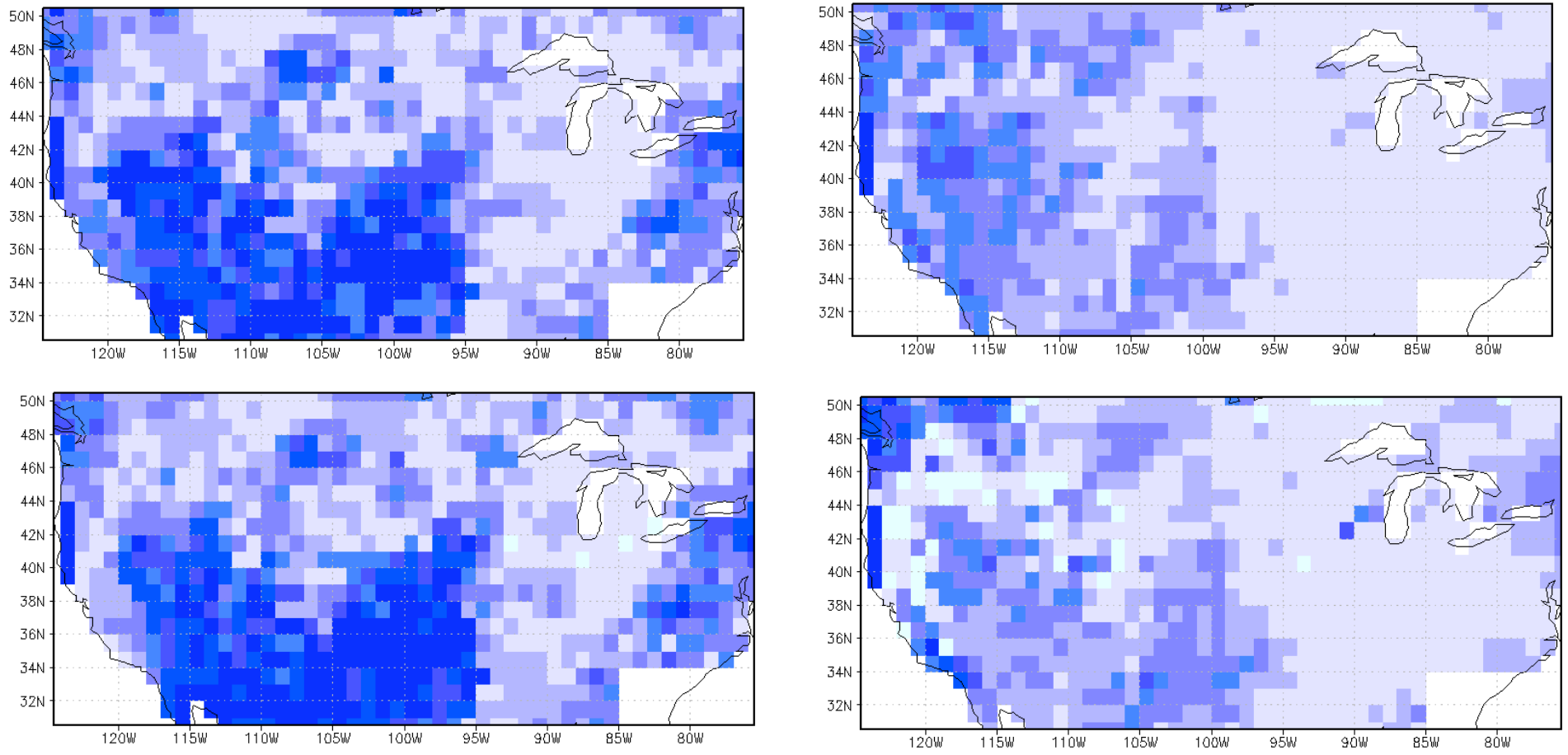
Catchment

Noah

Improvement Metric (RMSE(OpenLoop) - RMSE(EnKF)) for soil moisture OSSEs

Surface Layer

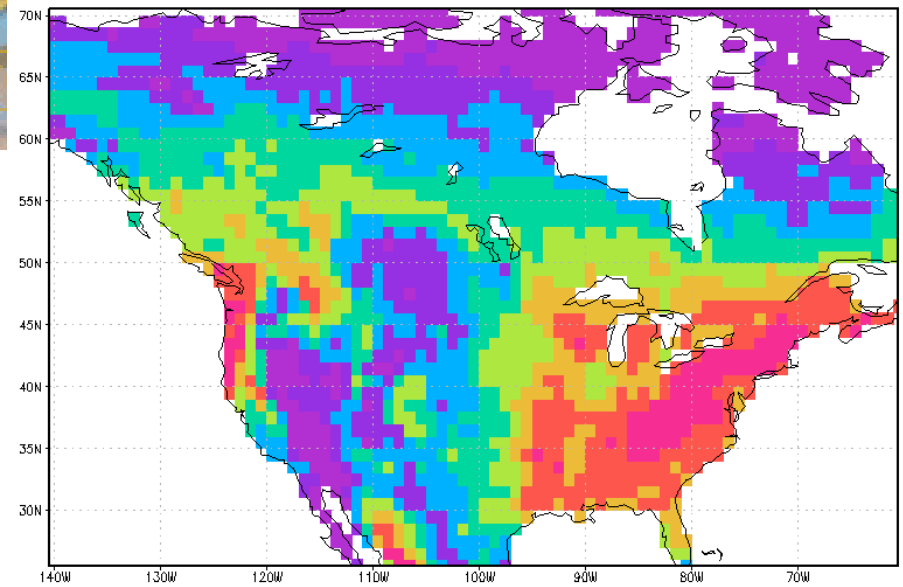
Root Zone



Catchment

Noah

Data Assimilation Experiment Setup
Snow OSSEs

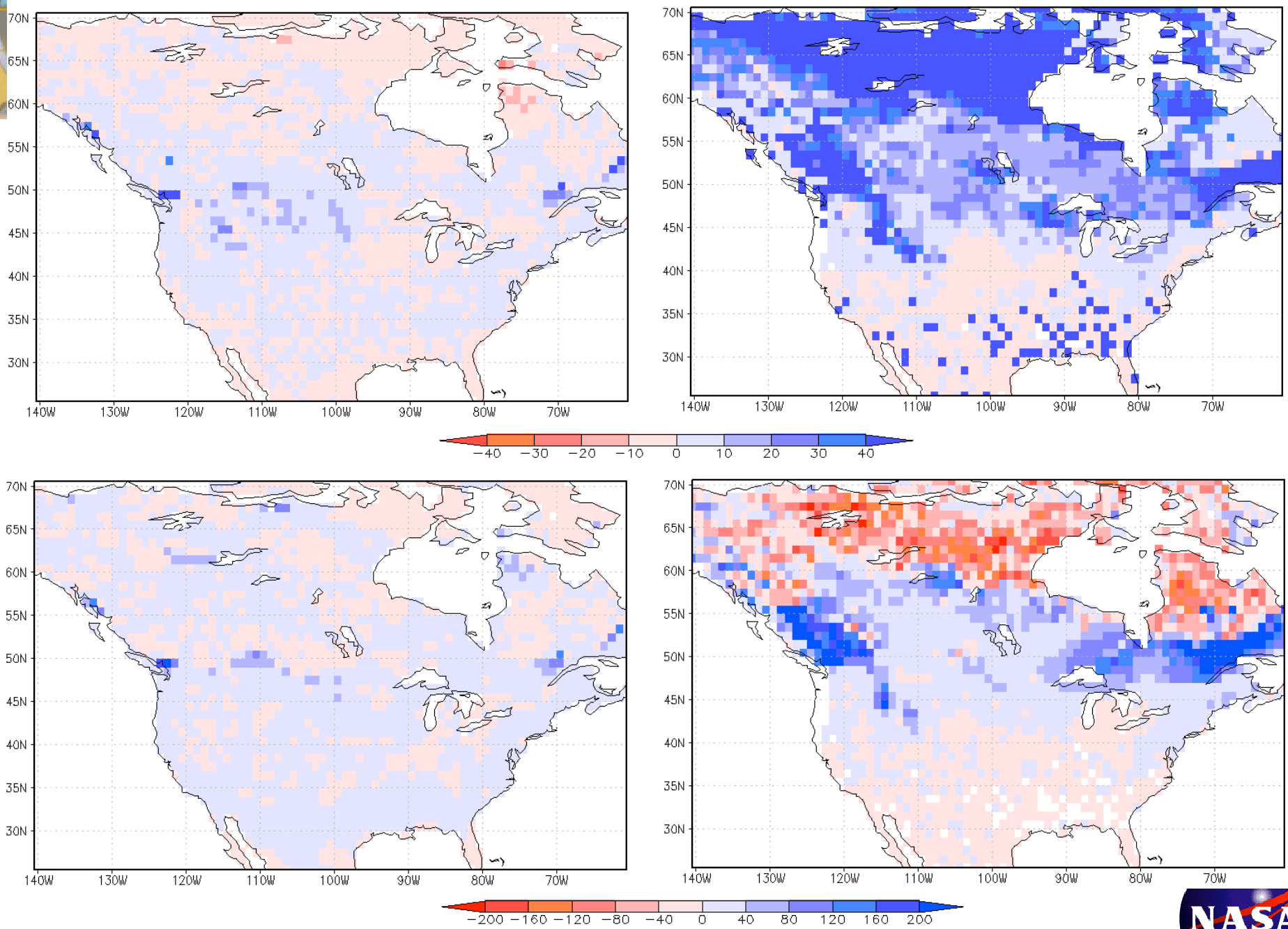


- Modeling domain: North America
- SWE Assimilation using EnKF and and SCA Assimilation using a rule based Direct Insertion (Rodell and Houser, 2004)
- October 1, 2003 to June 1, 2004
- Control/Truth runs using GDAS forcing (spun up from January 1, 2000) and Catchment LSM.
- OpenLoop runs using GEOS forcing and Noah LSM
- Synthetic SCA observations flagged using cloud cover masks from the MODIS Level 3 product (Hall et al, 2002)
- Synthetic SWE observations generated by
  - data masks for dense vegetation
  - random noise of 10mm error and 10mm minimum and 200mm maximum cutoffs
- Assimilation runs
  - SCA obs into the Open Loop run once a day at 12Z using the rule-based DI
  - SWE obs into the Open Loop run once a day at 12Z using the EnKF

Improvement Metric for snow OSSEs

SWE

Snow Depth

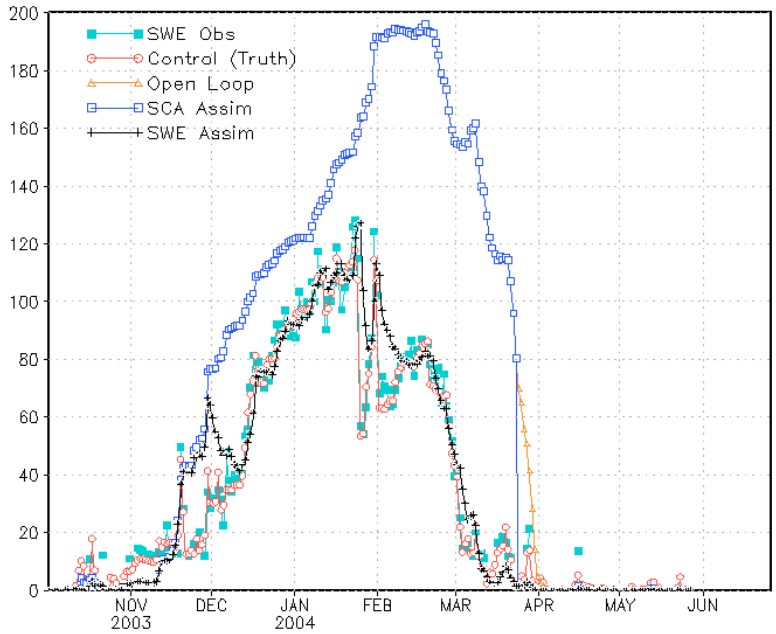


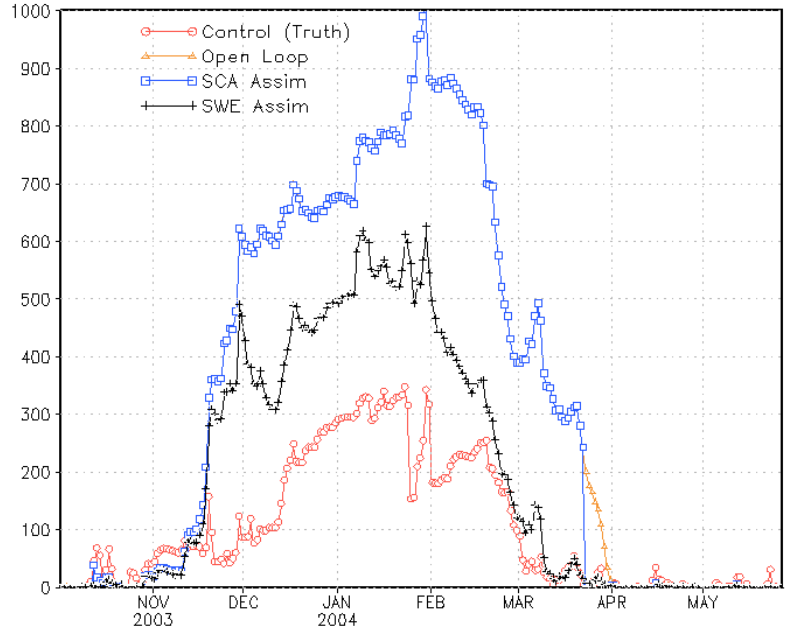
SCA Assimilation

SWE Assimilation

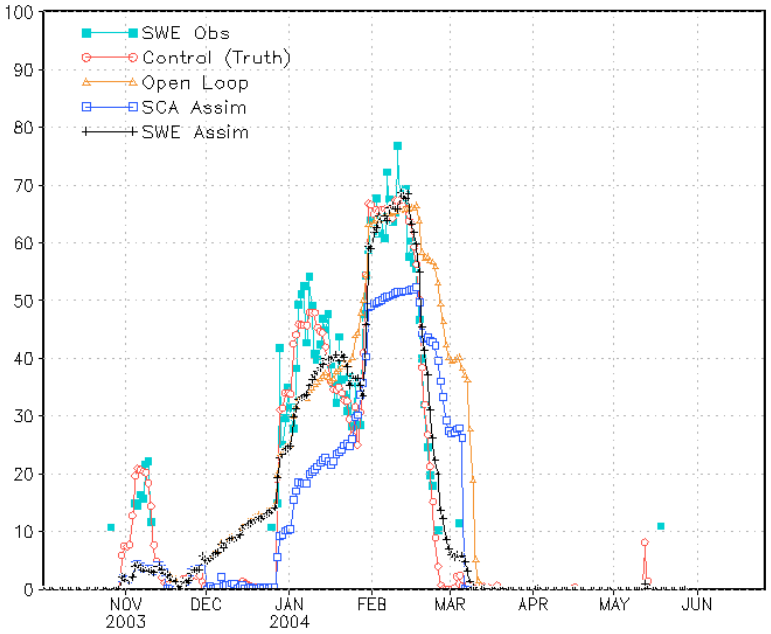
Time Series Comparisons of Snow fields

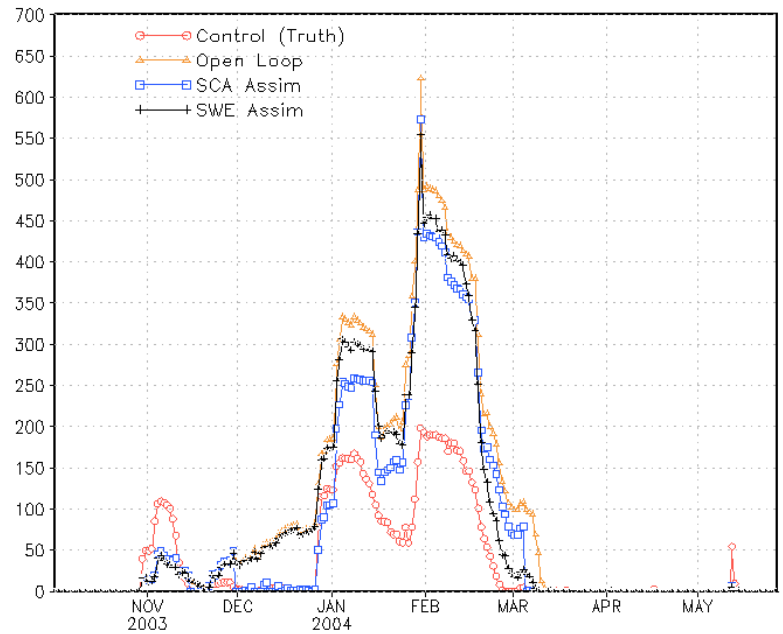
Plateau Mountain (50.2N, 116.5W)





Chinook, MT (48.6N, 109.2W)



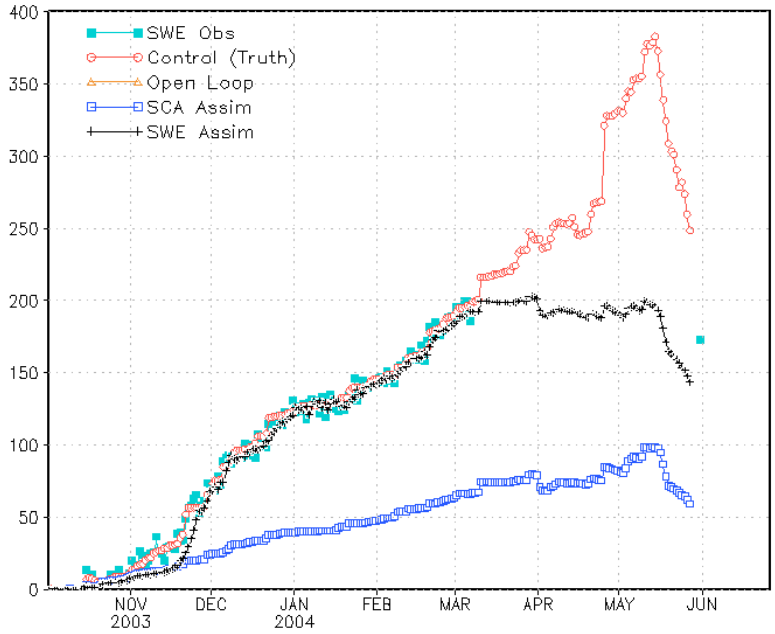


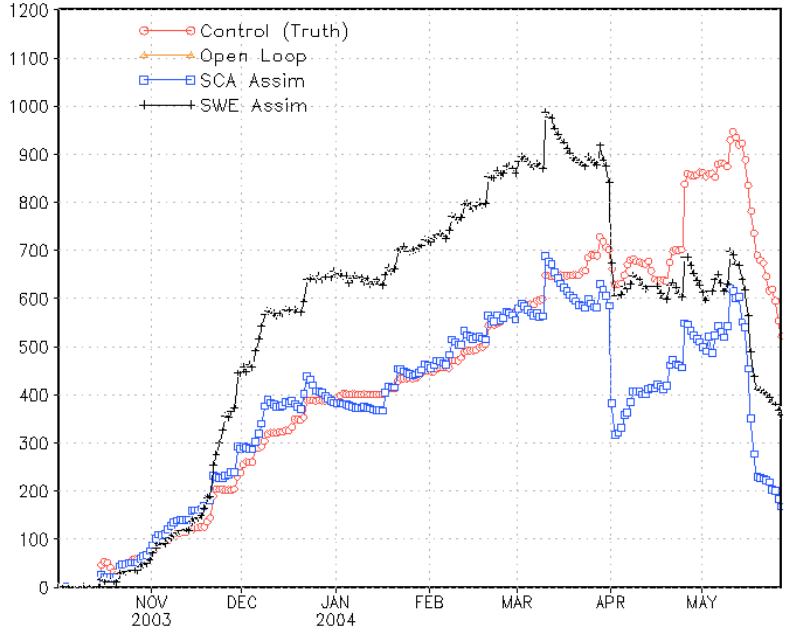
SWE

Snow Depth

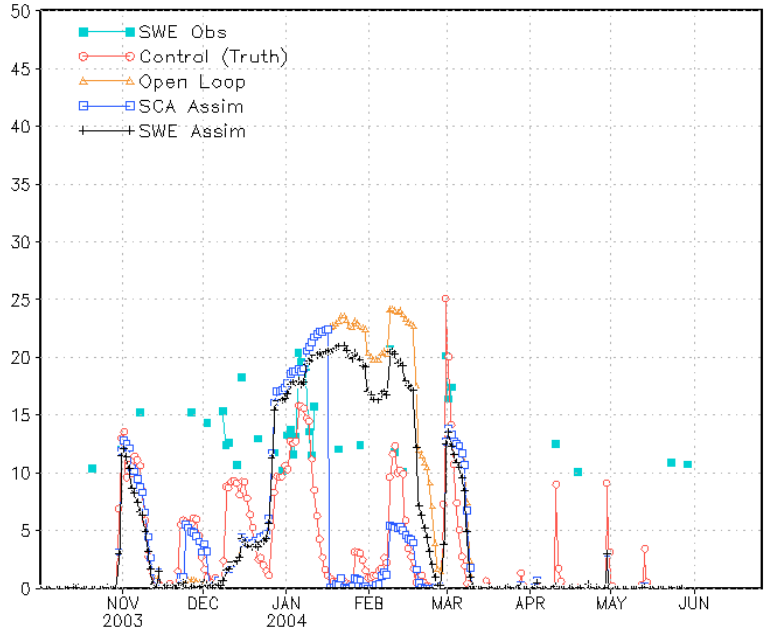
Time Series Comparisons of Snow fields

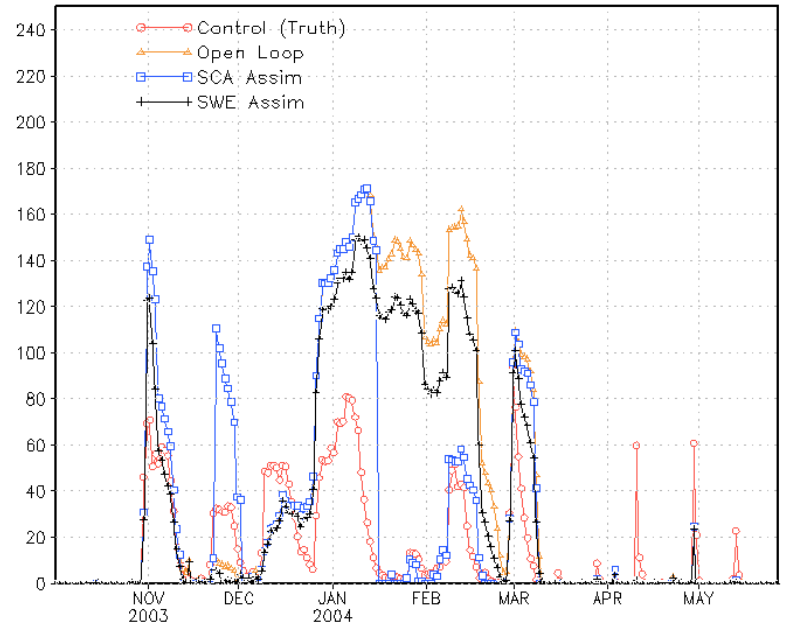
Churchill, RCT
(58.8N, 94.5W)





Riverton, WY
(43.0N, 108.4W)





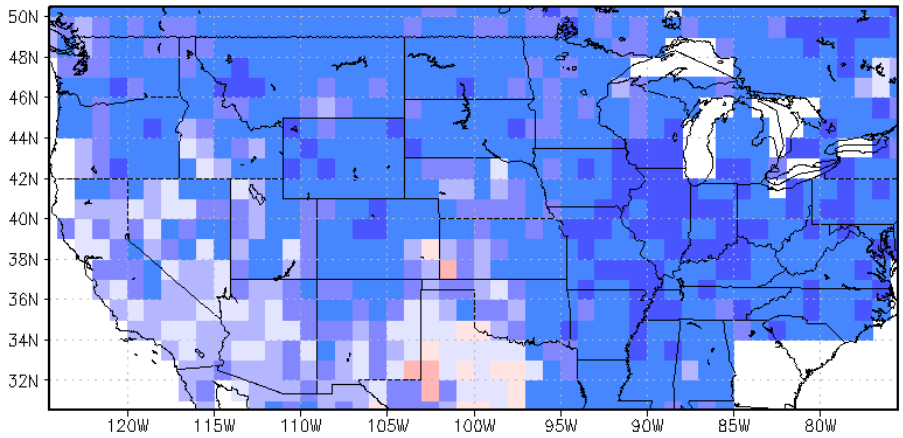
SWE

Snow Depth

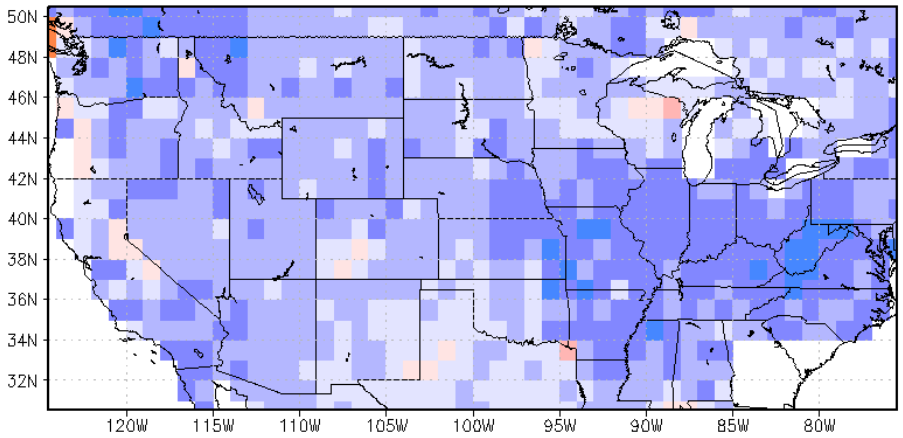
Spatially distributed variance of Normalized Innovations

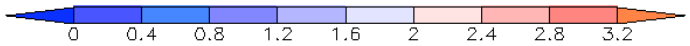
Soil Moisture OSSE

Catchment

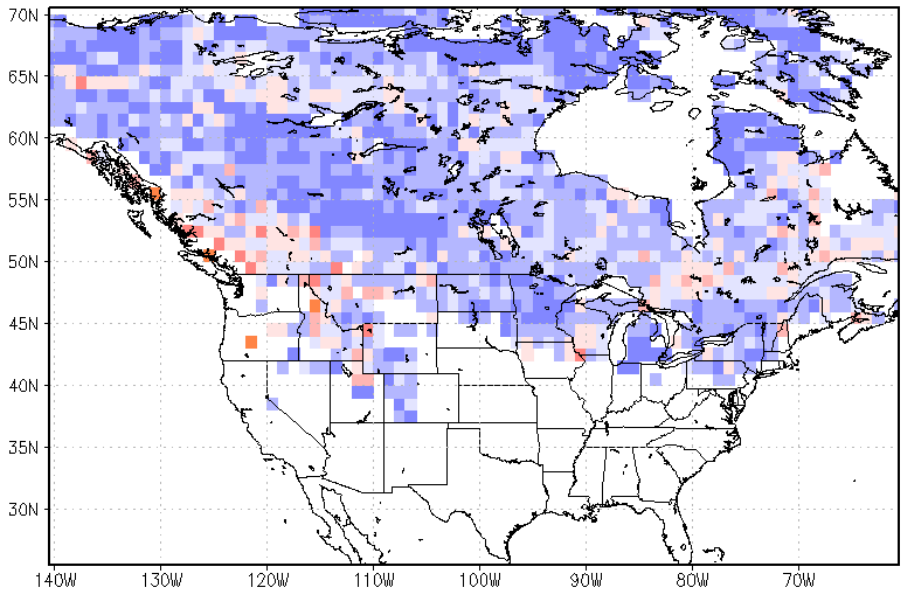


Noah

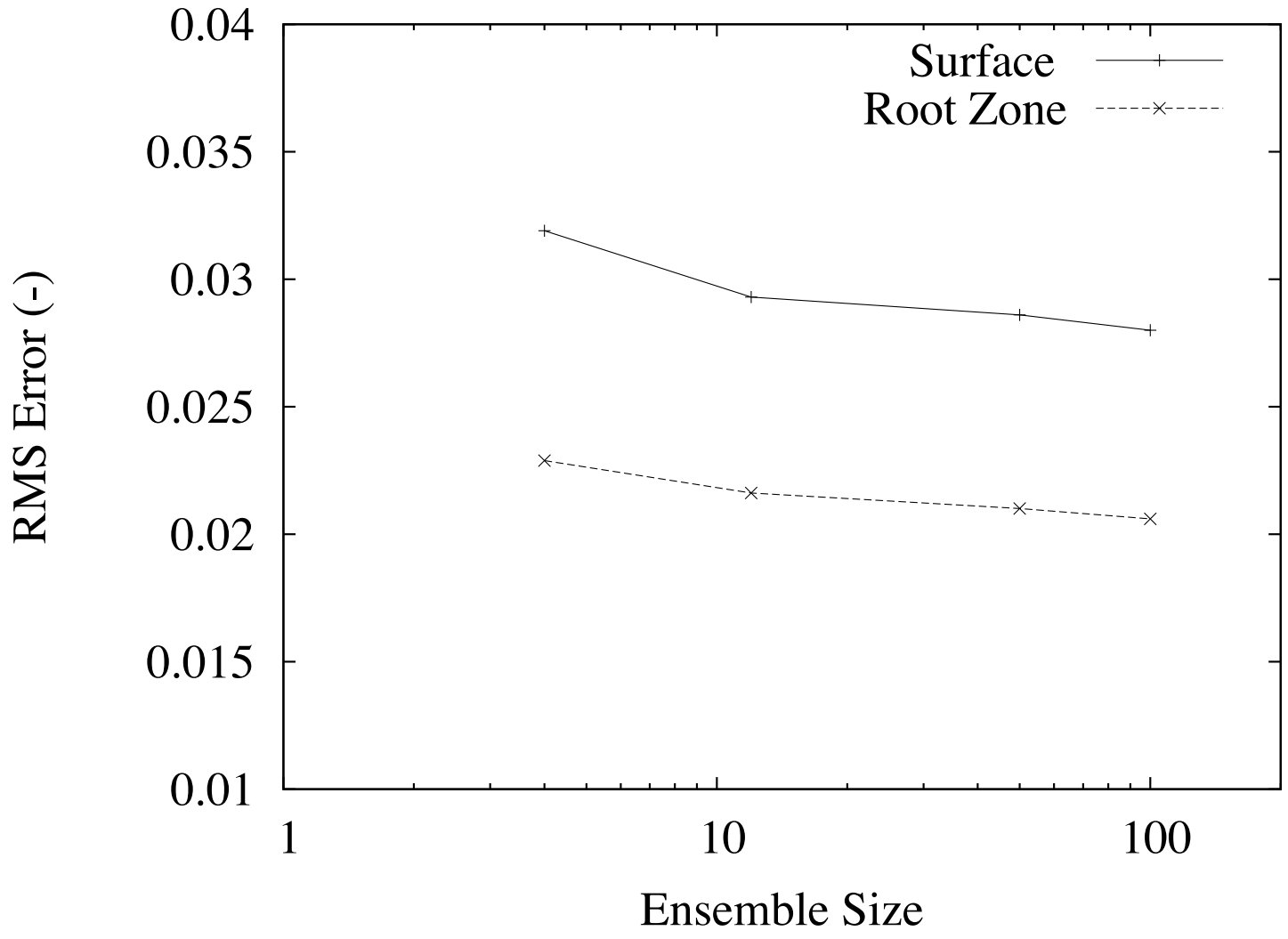




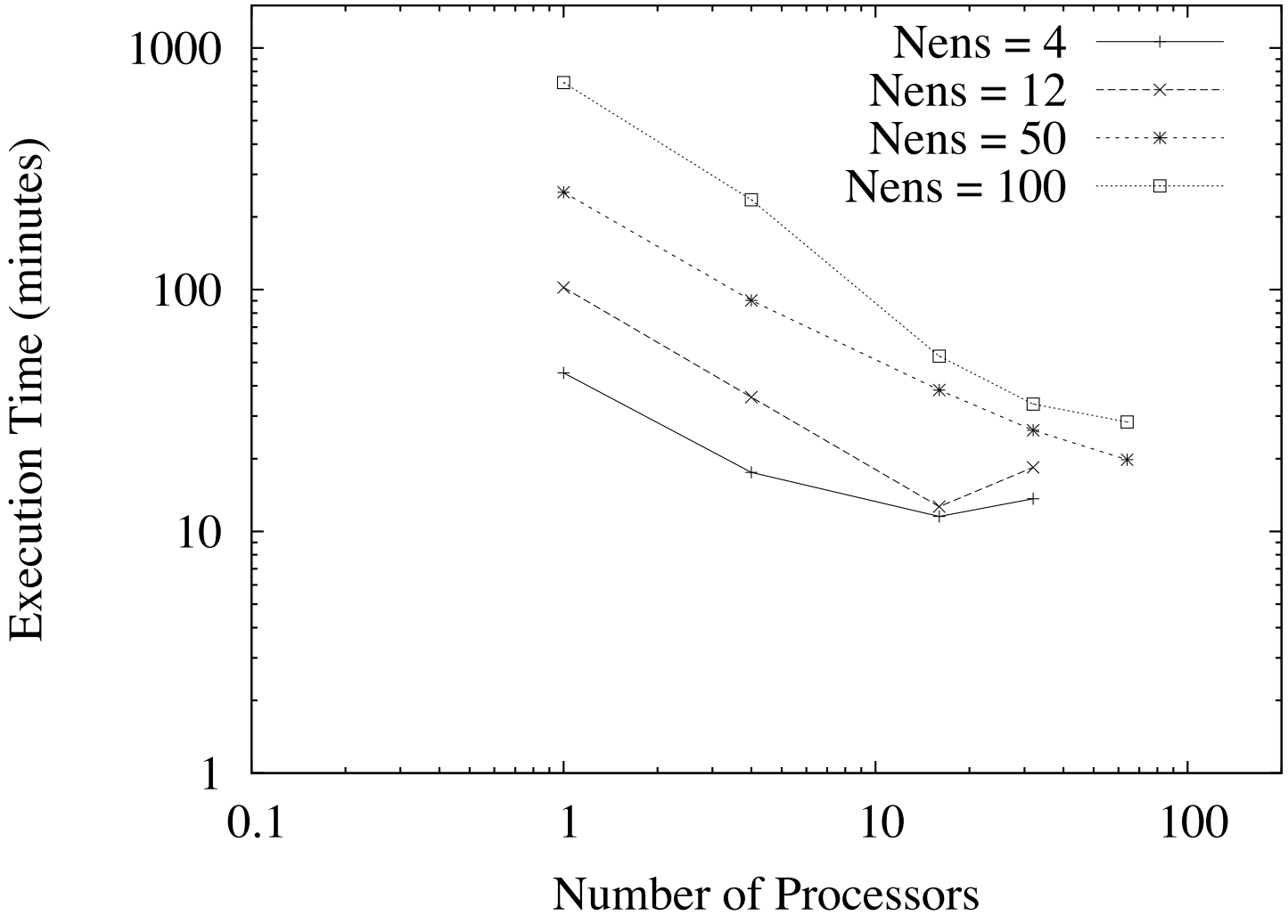
Snow OSSE

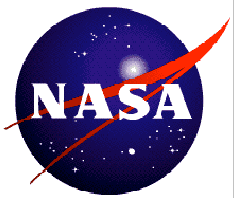


Influence of ensemble size on filter accuracy



Computational scaling with increasing ensemble





Summary

- A flexible, reusable, extensible framework for land surface data assimilation
- System supports the use of
  - multiple assimilation algorithms
  - multiple LSMs
  - multiple observation types
  - different perturbation algorithms
- Data Assimilation framework also includes a generic diagnostics component
- High Performance Infrastructure in LIS provides adequate support for computationally intensive data assimilation simulations

Future DA Enhancements

- Addition of an online bias correction component
- Assimilation of other observation types (LST), combined use of multiple observations
- Support for variational, smoothing algorithms
- Addition of a generic optimization component

Land Information System (LIS)

Objective: A global, high performance, high resolution (1km) land surface modeling and data assimilation system.

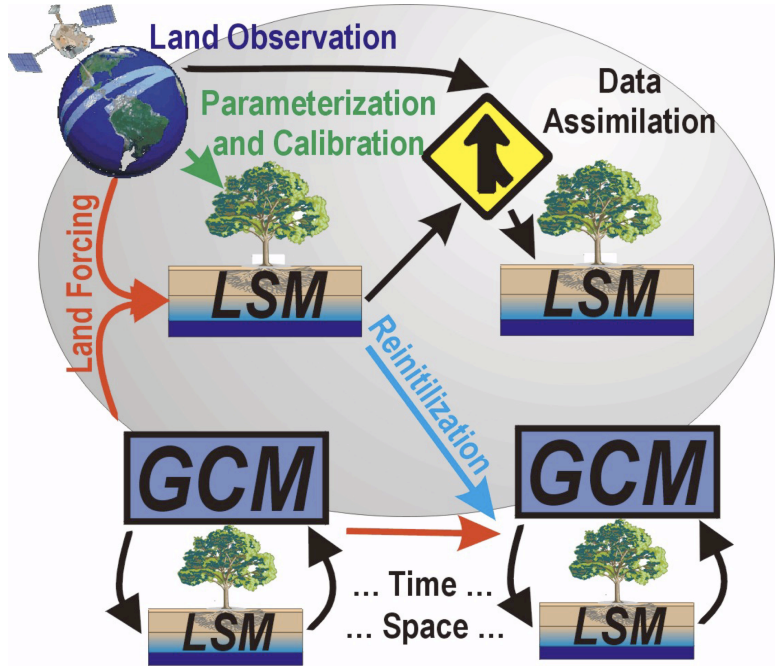
Benefits: Enable improved land-atmosphere understanding, hydrological and climate prediction, transfer research to application.

Land Modeling: Use multiple state-of-the-art water-energy-carbon land surface models (LSM's, e.g., Noah, Catchment, CLM, etc.).

Land Observation: Use best available observed forcing from surface and remote sensing platforms.

Data Assimilation: Merge a wide range of surface information to constrain and improve model trajectory.

Applications: Weather and climate model initialization and retrospective coupled modeling, Flood and water resources forecasting, Precision agriculture, Military mobility assessment, etc.



LIS Modeling Approach

Inputs

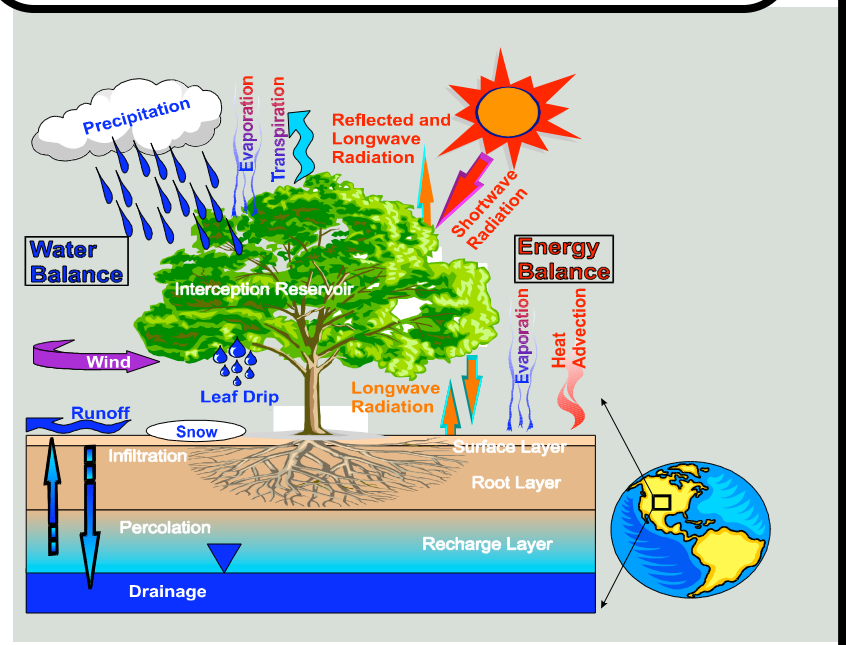
Topography, Soils (Static)

Land Cover, Leaf Area Index (Monthly)

Modeled + Observed Meteorology (Hourly-3

Physics

Land Surface Models (LSM)
(Time steps=min-hr
Spatial grid=m-deg)



Outputs

Soil Moisture & Temperature Profiles

Surface Energy Fluxes (e.g., H,LE)

Surface Water Fluxes (e.g.,Runoff)

Surface States: Snowpack LAI (some)

Applications

Mobility Models (e.g.,FCS)

Atm. Models (e.g.,WRF)

Water Resources/ Ocean Models

Carbon Models

LIS Modeling Approach

Inputs

Physics

Outputs

Applications

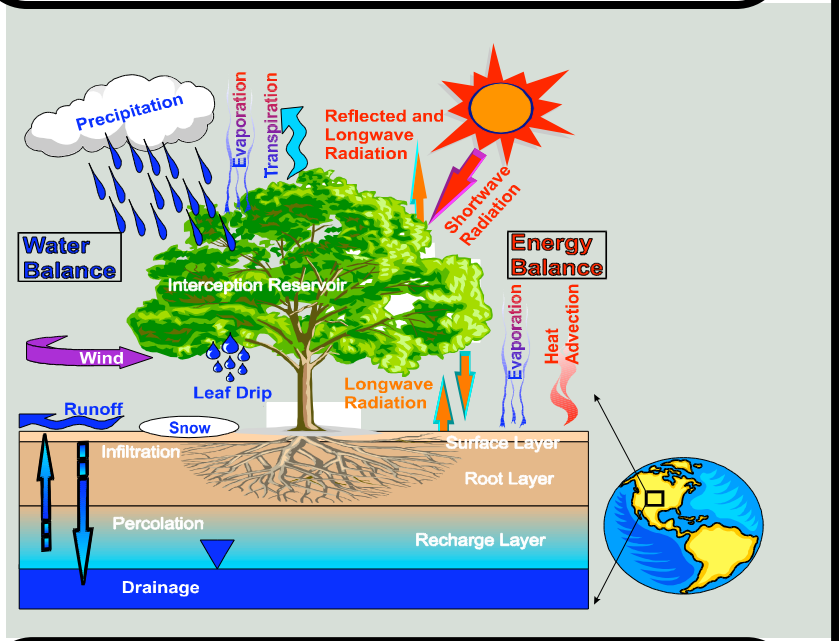
Topography, Soils (Static)

Land Cover, Leaf Area Index (Monthly)

Modeled + Observed Meteorology (Hourly-3

Observed Surface States (e.g., Snow, Soil Moisture)

Land Surface Models (LSM)
(Time steps=min-hr
Spatial grid=m-deg)



Data Assimilation Modules

Soil Moisture & Temperature Profiles

Surface Energy Fluxes (e.g., H,LE)

Surface Water Fluxes (e.g.,Runoff)

Surface States: Snowpack LAI (some)

Mobility Models (e.g.,FCS)

Atm. Models (e.g.,WRF)

Water Resources/ Ocean Models

Carbon Models

NASA