

An Integrated System for Sequential Hydrologic Data Assimilation using the Land Information System

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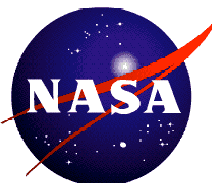
^bNASA Goddard Space Flight Center, Greenbelt, MD

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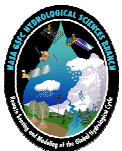
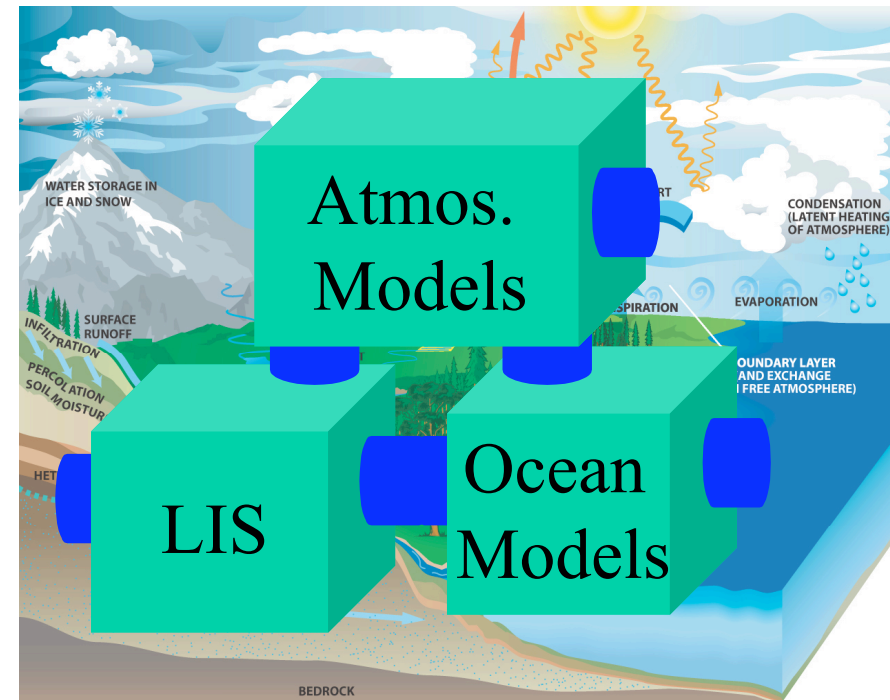
^eAir Force Weather Agency, Offutt AFB, NE

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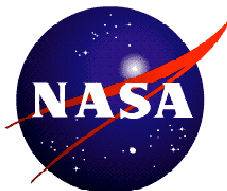


Land Information System (LIS)

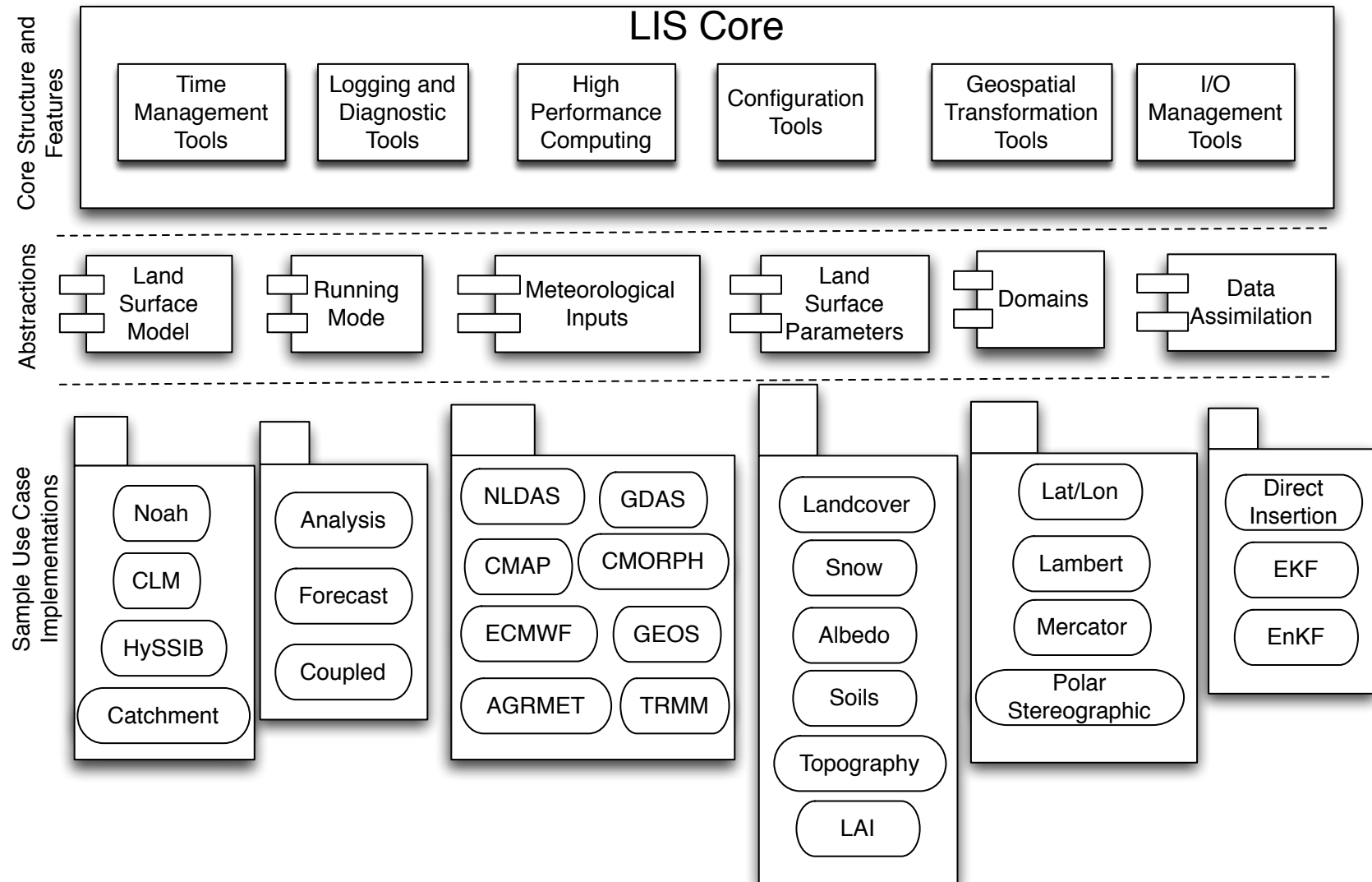
- A global, high performance, high resolution land surface modeling and data assimilation system.
- Use multiple state-of-the-art water-energy-carbon land surface models (LSM's, e.g., Noah, Catchment, CLM).
- Use best available observations from surface and remote sensing platforms, to force and constrain LSMs
- Weather and climate model initialization and retrospective coupled modeling, Flood and water resources forecasting, Precision agriculture, Military mobility assessment, etc.



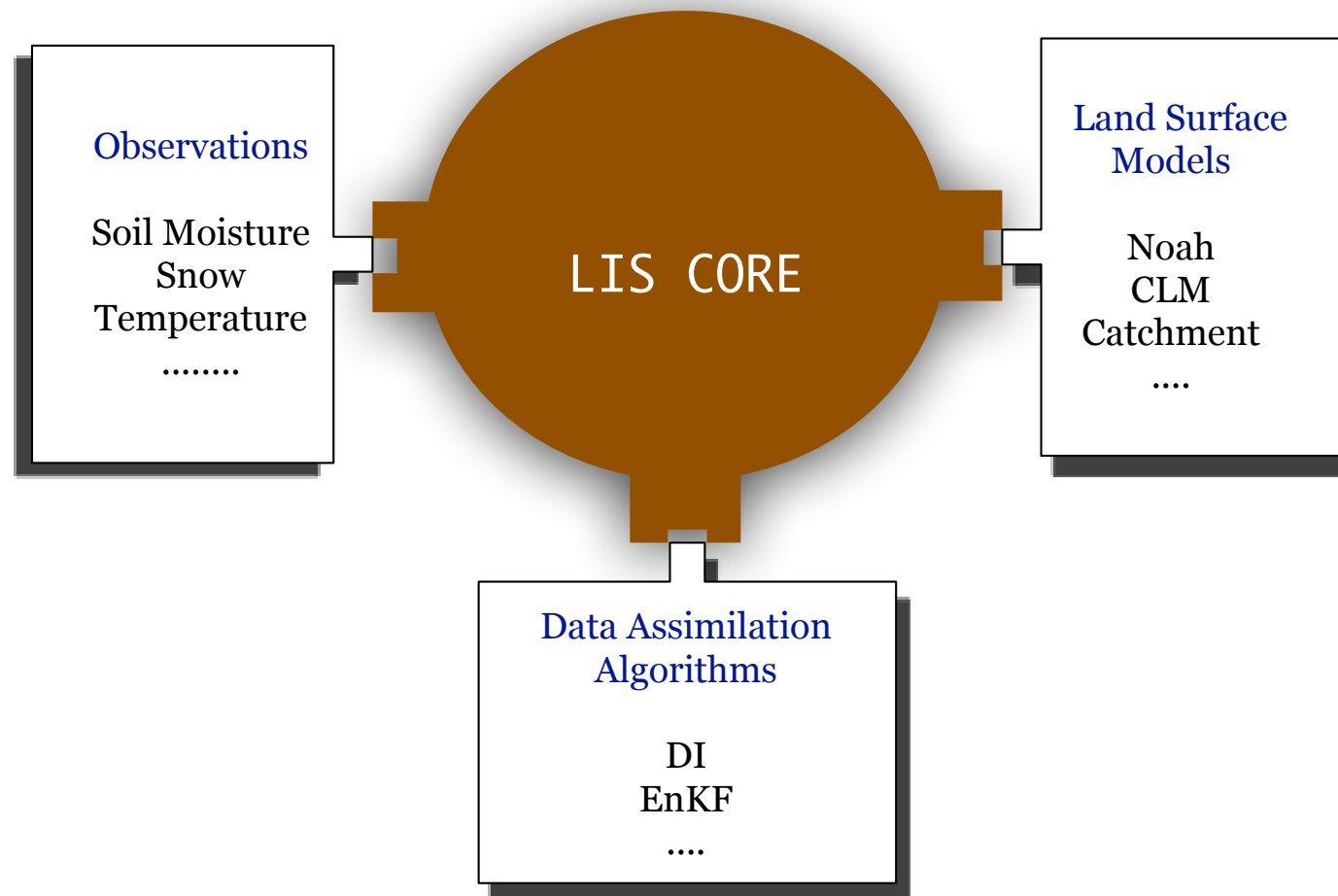
Kumar et al. (2006): Land Information System: An interoperable Framework for High Resolution Land Surface Modeling, Environmental Modeling and Software, Vol 21, pp 1402-1415.



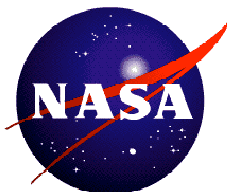
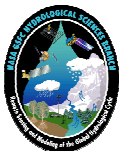
LIS Software Structure



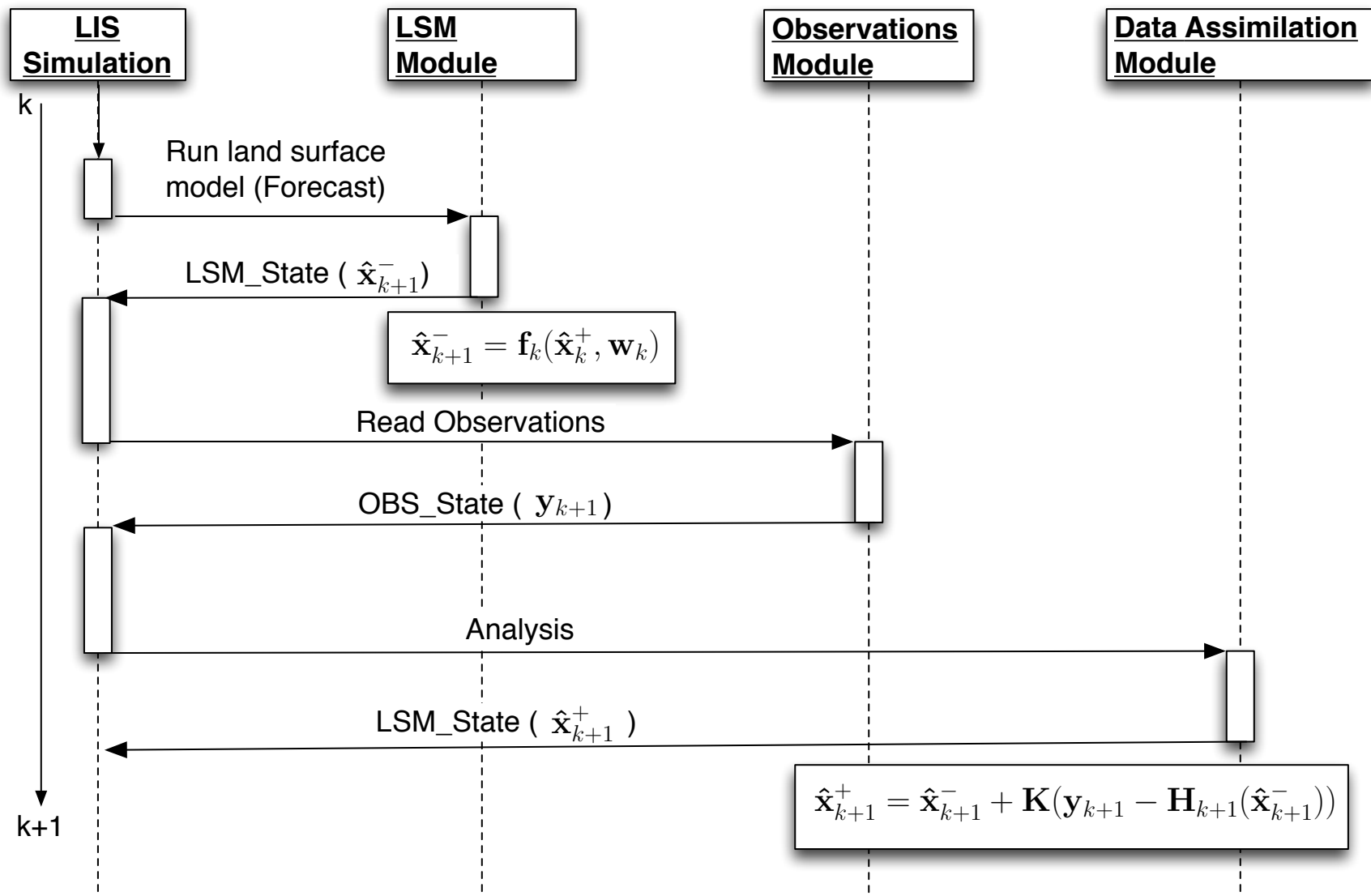
Data Assimilation Abstractions in LIS

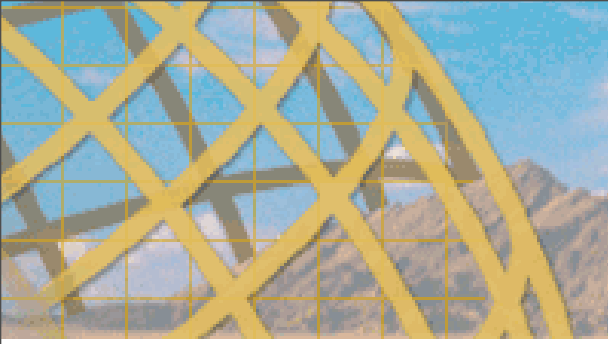


Kumar et al. (2007): A Land Surface Data Assimilation Framework using the Land Information System: Description and Applications, submitted to Special Issue on Hydrologic Remote Sensing, Advances in Water Resources



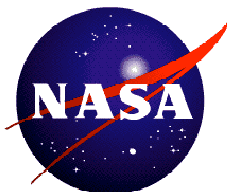
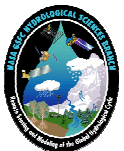
Sequence of Component Interactions for a sequential assimilation cycle





Data Assimilation Experiments

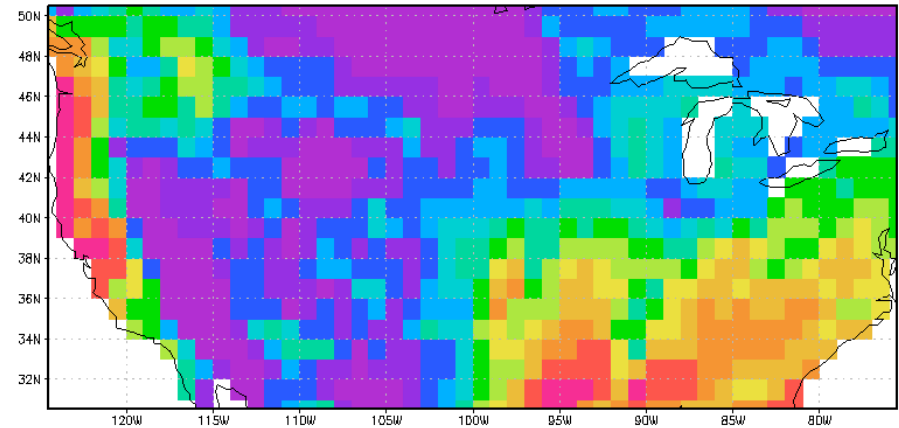
- To showcase the interoperable use of multiple data assimilation algorithms, land surface models and observations
- Two sets of assimilation experiments
 - Soil Moisture OSSEs - using different LSMs
 - Snow OSSEs - different types of snow observations
- OSSE setup
 - Control/Truth Run
 - Degraded/Open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



Data Assimilation Experiment Setup

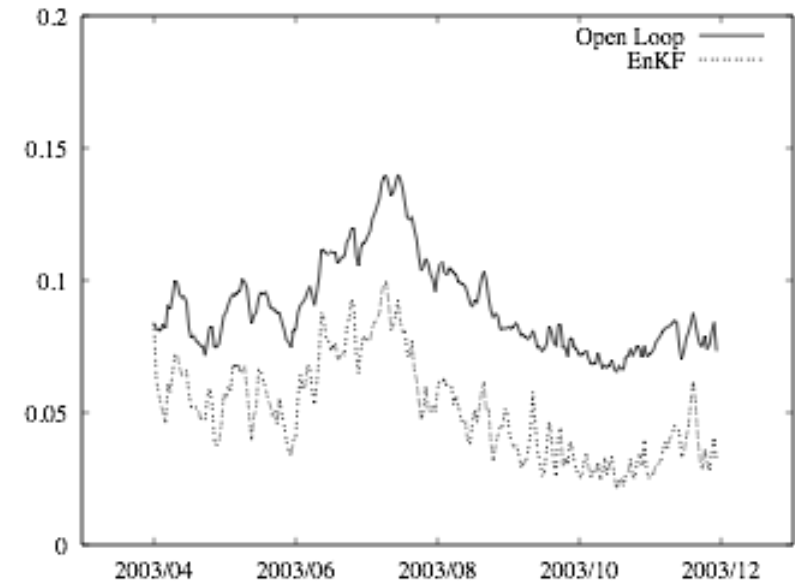
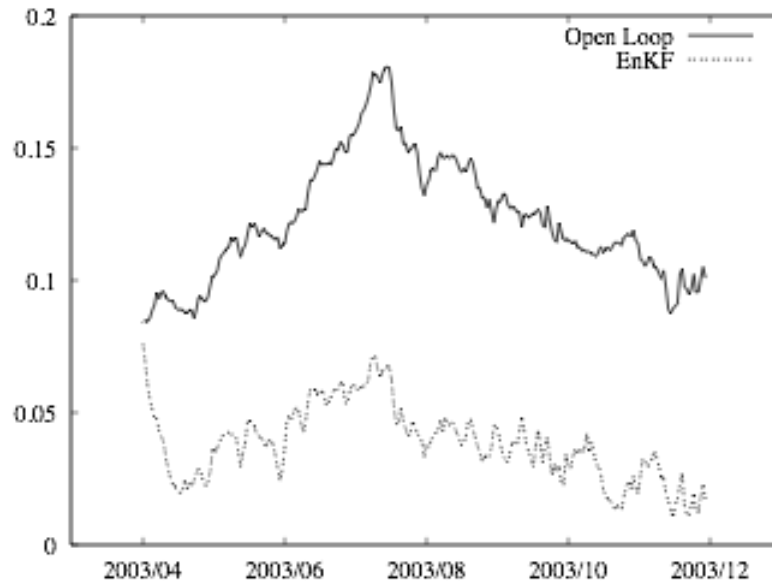
Soil Moisture OSSEs

- 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

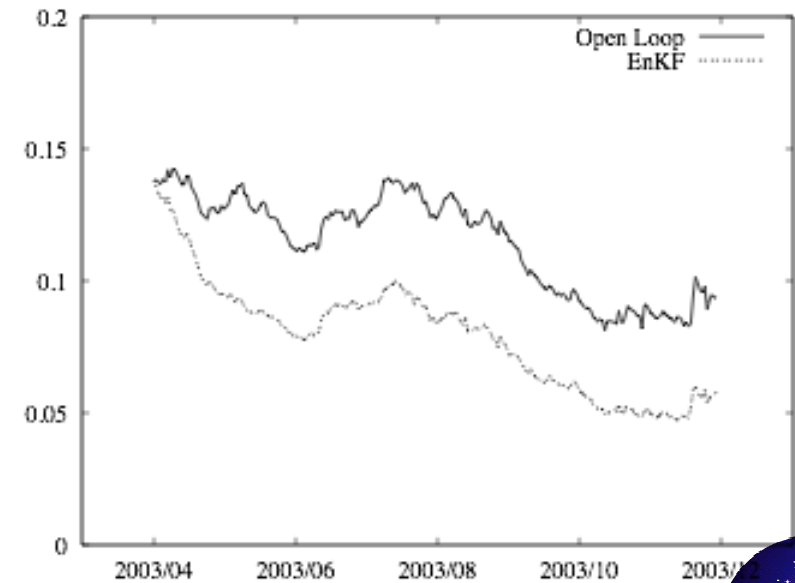
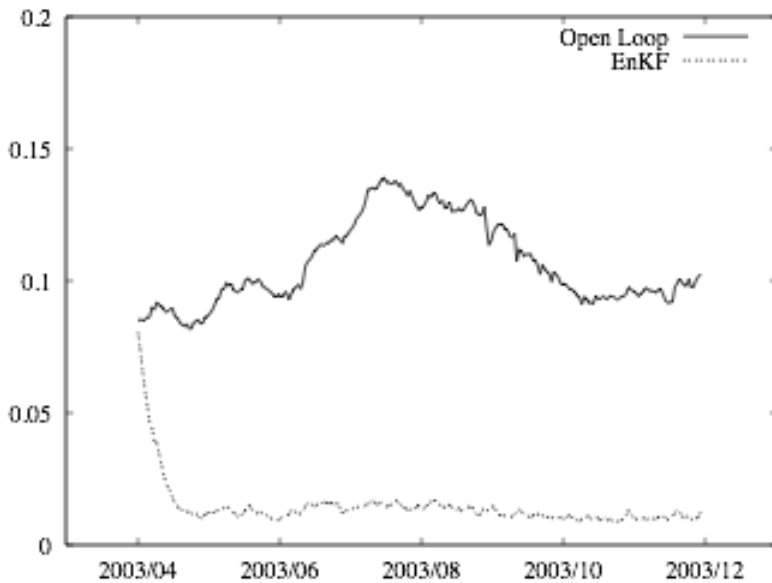


Time Series of RMSEs for Soil Moisture OSSEs

Surface Layer

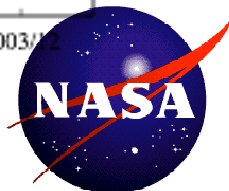
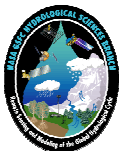


Root Zone



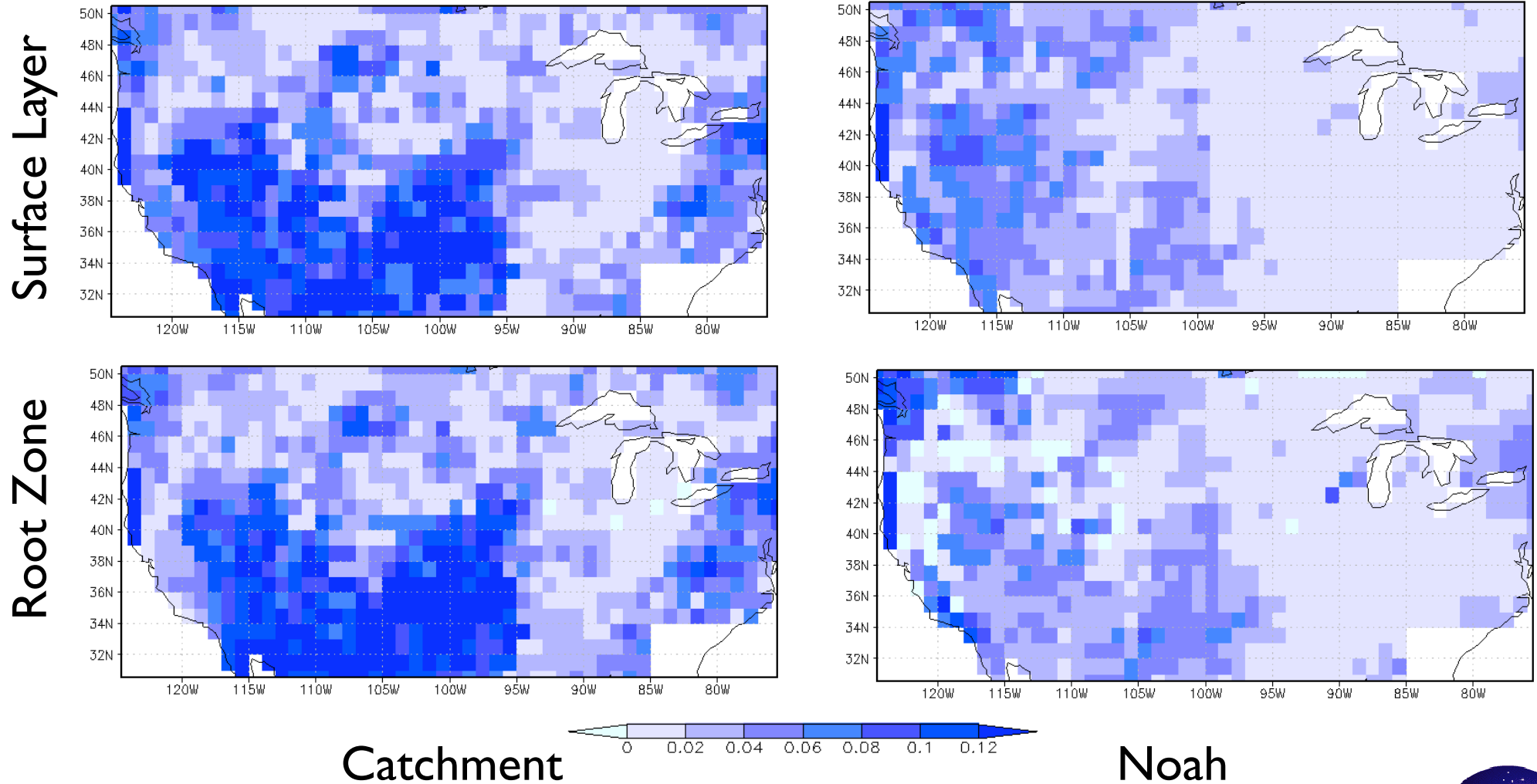
Catchment

Noah



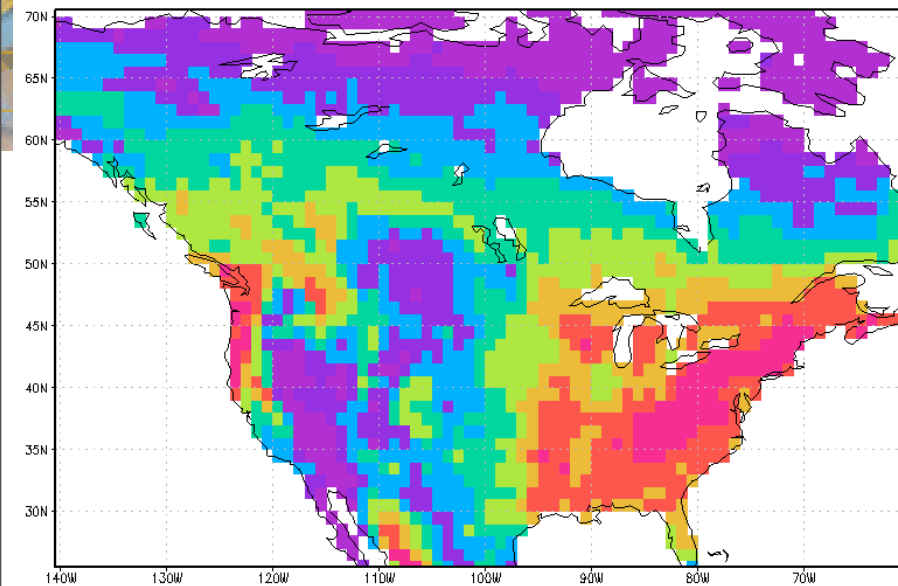


Improvement Metric (RMSE(OpenLoop) - RMSE(EnKF)) for soil moisture OSSEs

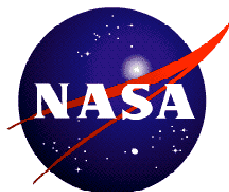
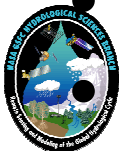


Data Assimilation Experiment Setup

Snow OSSEs

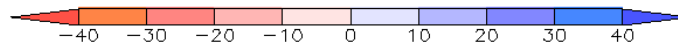
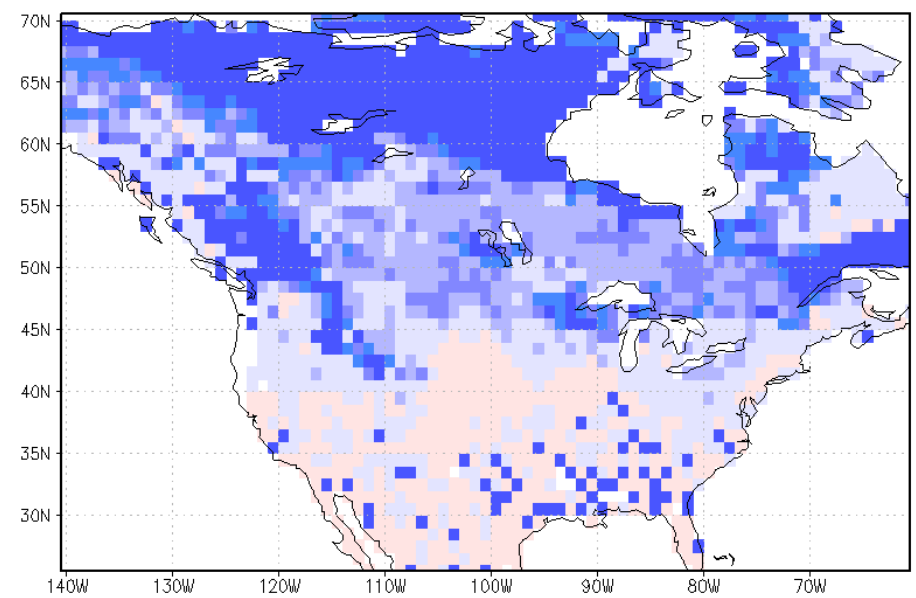
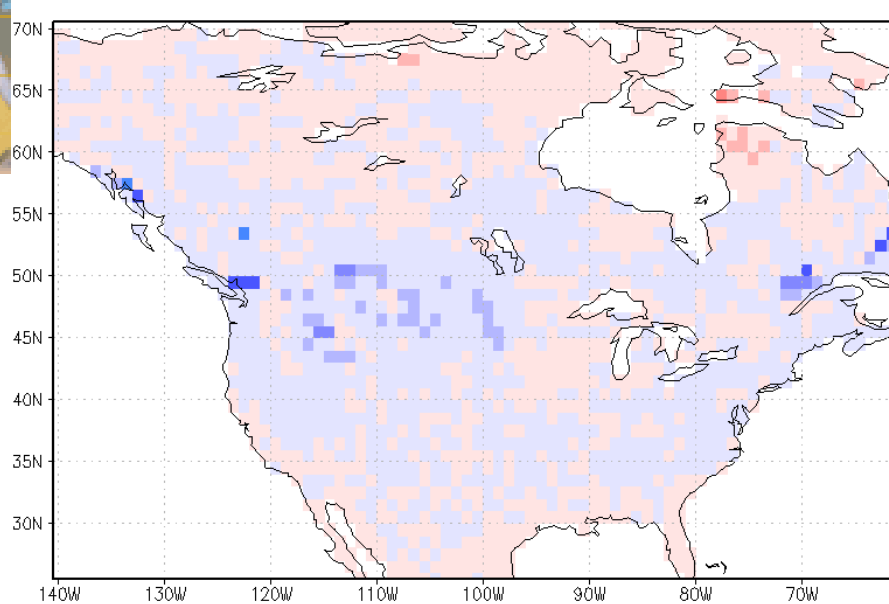


- Modeling domain: North America
- SWE Assimilation using EnKF and SCA
Assimilation using a rule based Direct Insertion (Rodell and Houser, 2004)
- October 1, 2003 to June 1, 2004
- Control/Truth runs using GDAS forcing (spun up from January 1, 2000) and Catchment LSM.
- OpenLoop runs using GEOS forcing 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

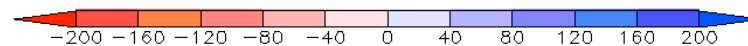
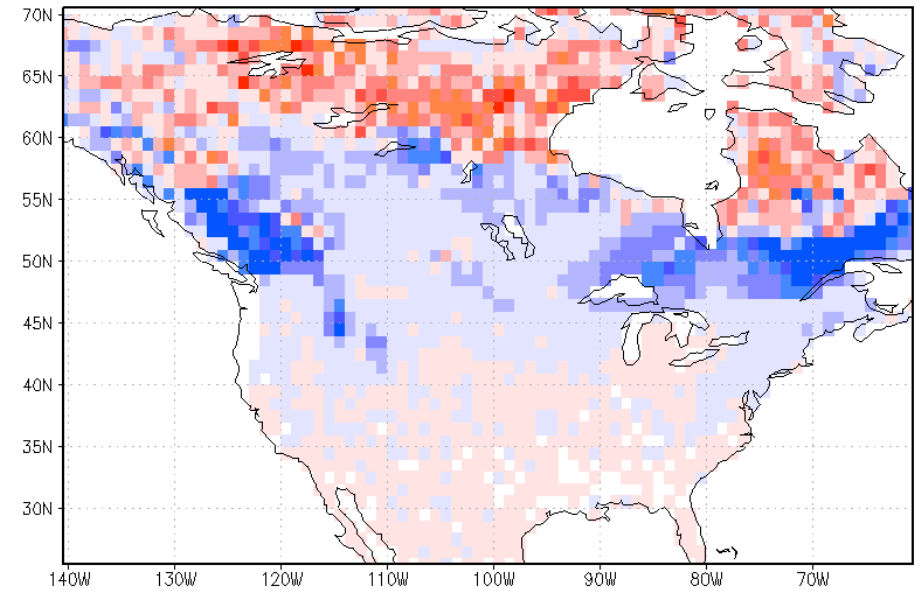
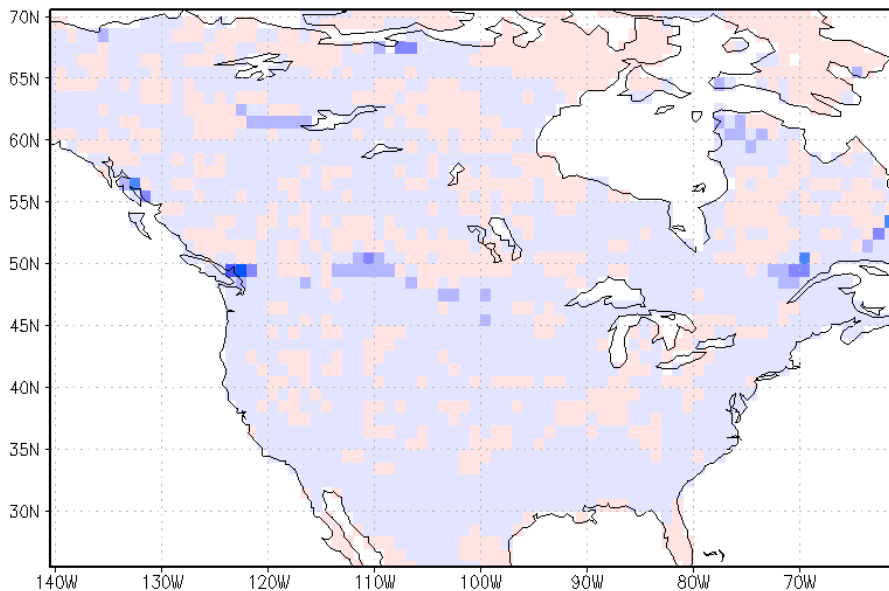


Improvement Metric for snow OSSEs

SWE

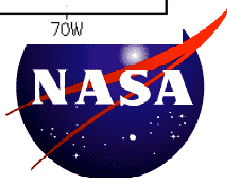
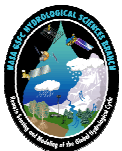


Snow Depth



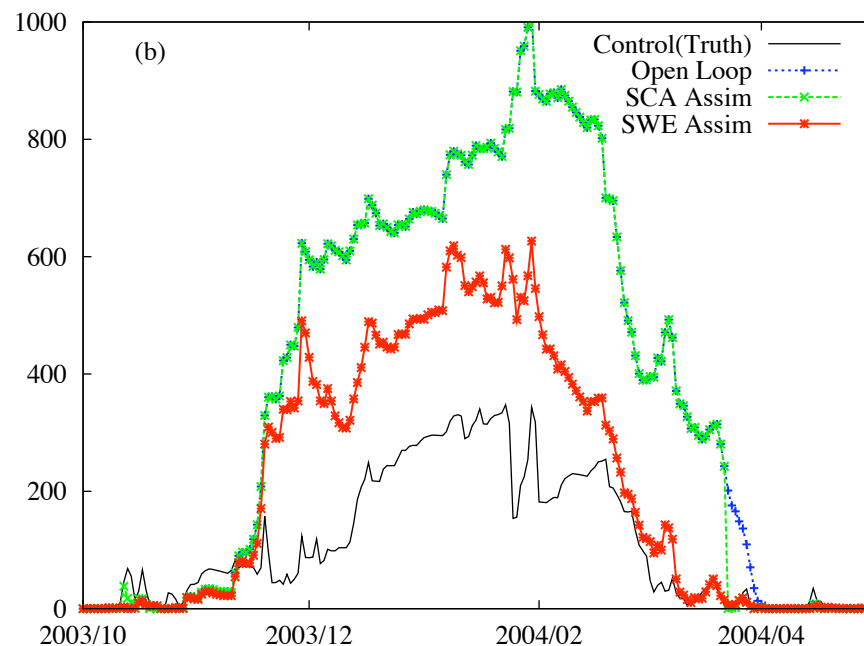
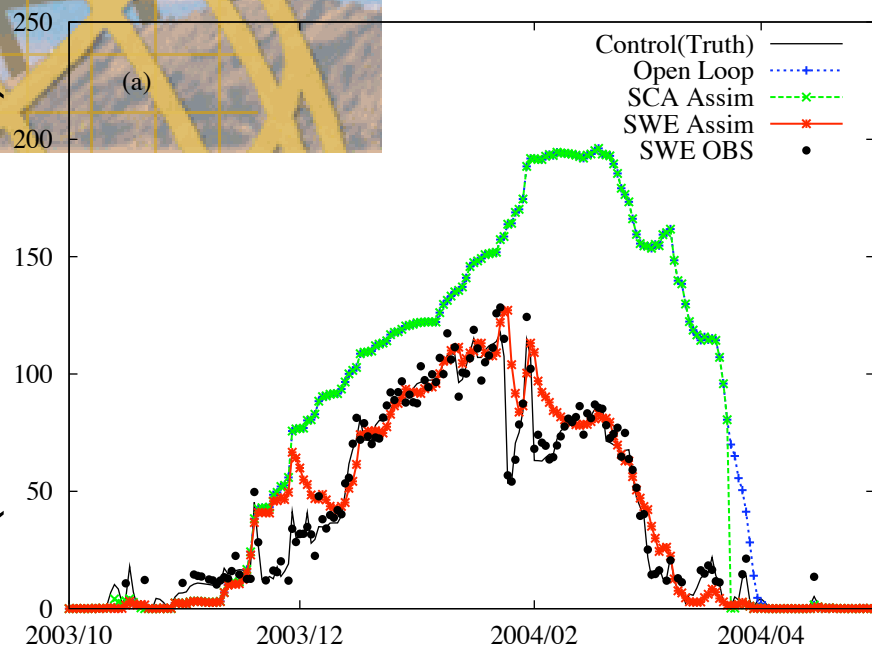
SCA Assimilation

SWE Assimilation

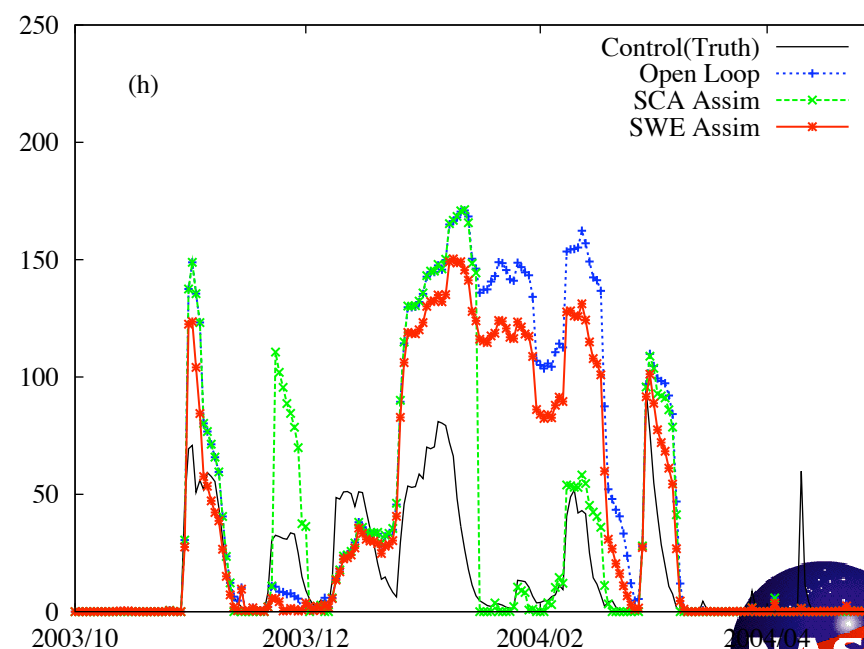
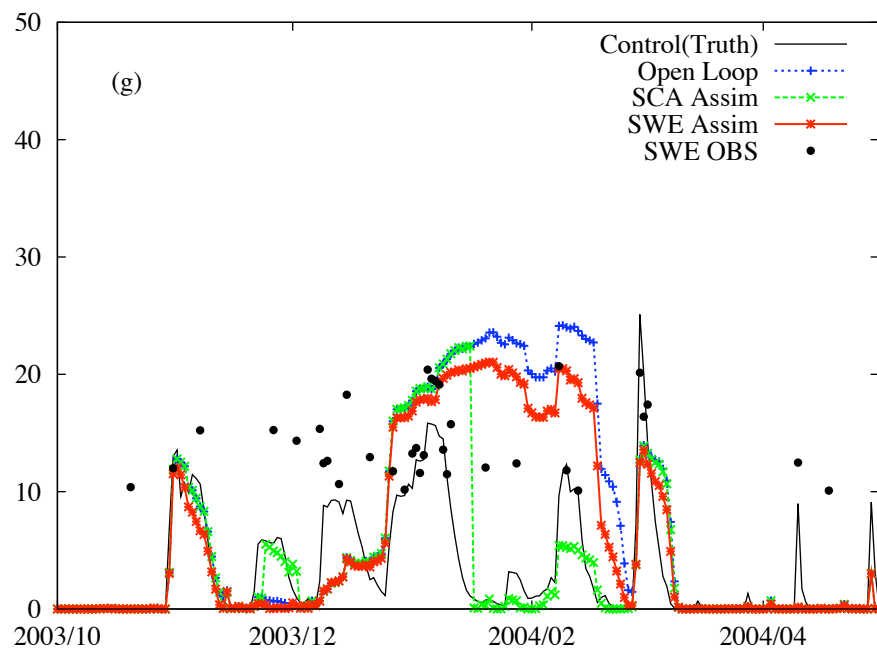


Time Series Comparisons of Snow fields

Plateau Mountain
(50.2N, 116.5W)

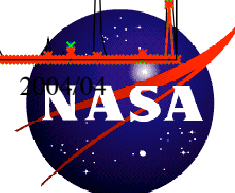
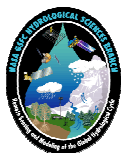


Riverton, WY
(43.0N, 108.4W)



SWE

Snow Depth

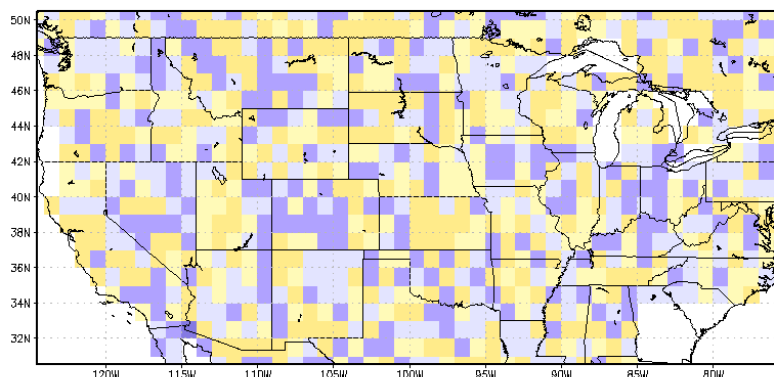




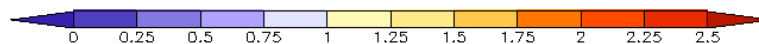
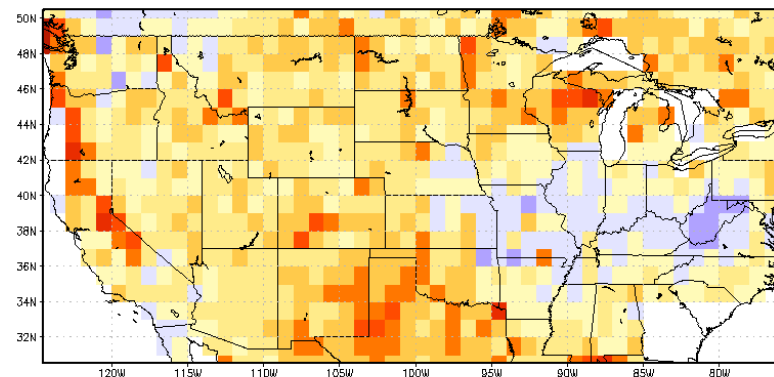
Spatially distributed variance of Normalized Innovations

Soil Moisture OSSE

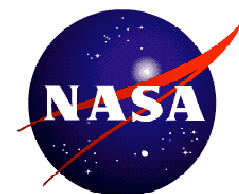
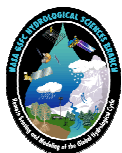
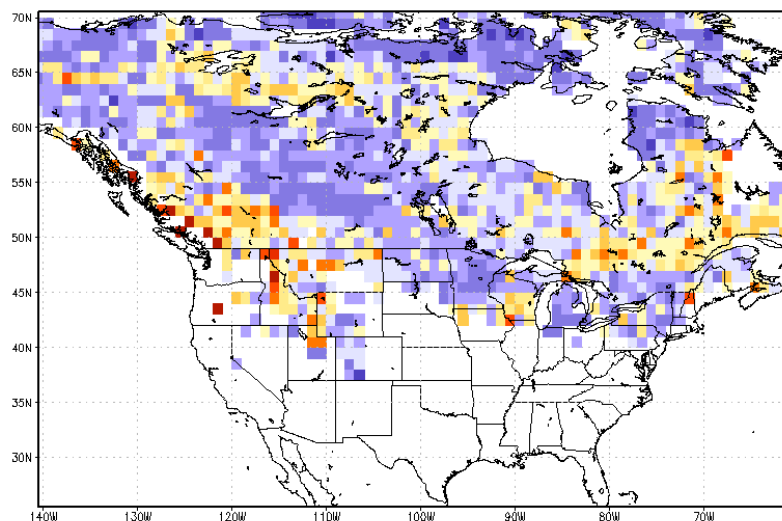
Catchment



Noah

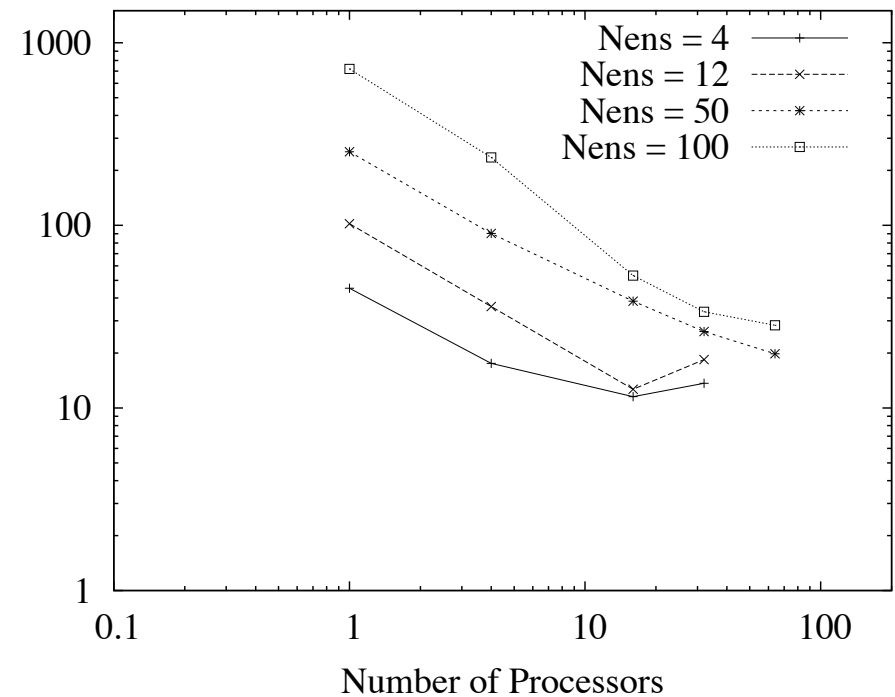
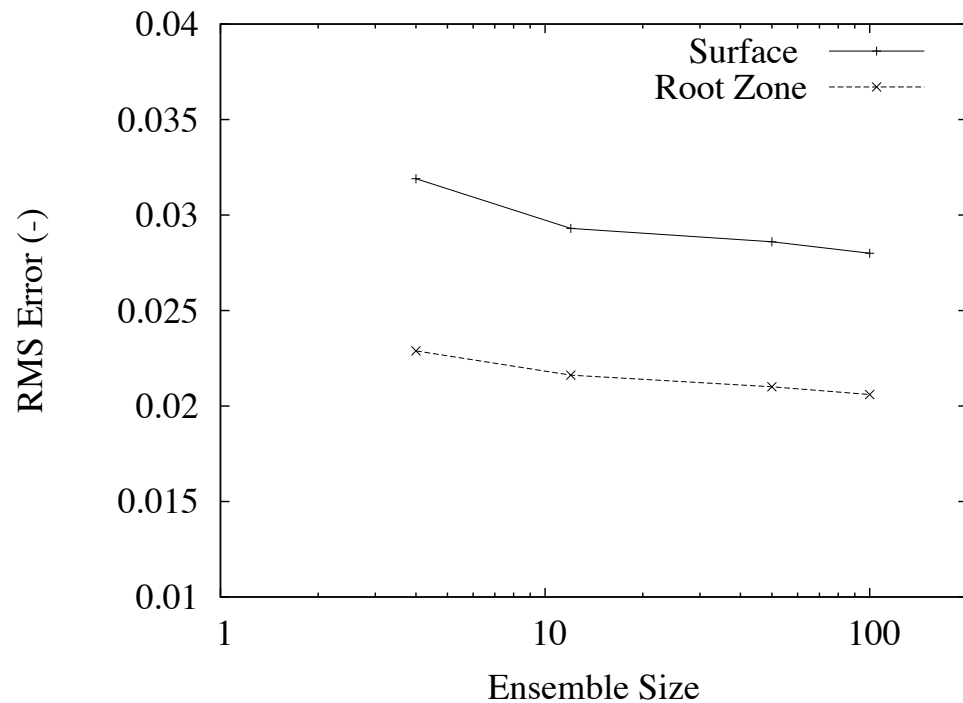


Snow OSSE





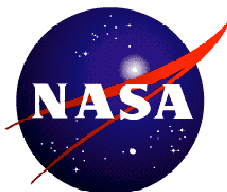
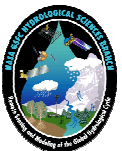
Impact of ensemble size





Summary

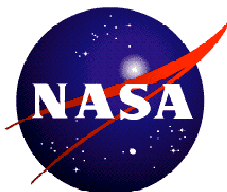
- A flexible, reusable, extensible framework for land surface data assimilation
- System supports the use of
 - multiple assimilation algorithms
 - multiple LSMs
 - multiple observation types
 - different perturbation algorithms
- Data Assimilation framework also includes a generic diagnostics component
- 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



LIS Modeling Approach

Inputs

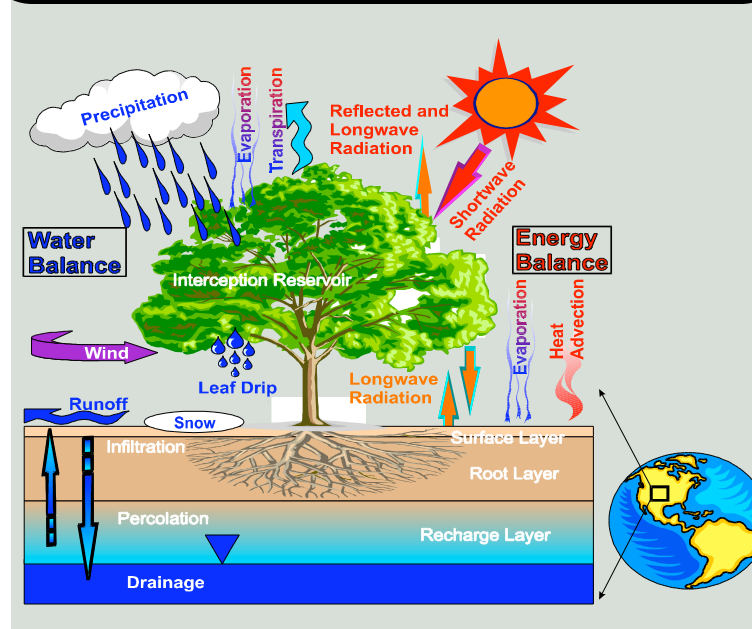
Topography,
Soils
(Static)

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

Surface
Water
Fluxes
(e.g., Runoff)

Surface
States:
Snowpack
LAI (some)

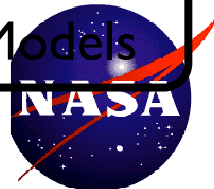
Applications

Mobility
Models
(e.g., FCS)

Atm.
Models
(e.g., WRF)

Water
Resources/
Ocean
Models

Carbon
Models



LIS Modeling Approach

Inputs

Physics

Outputs

Applications

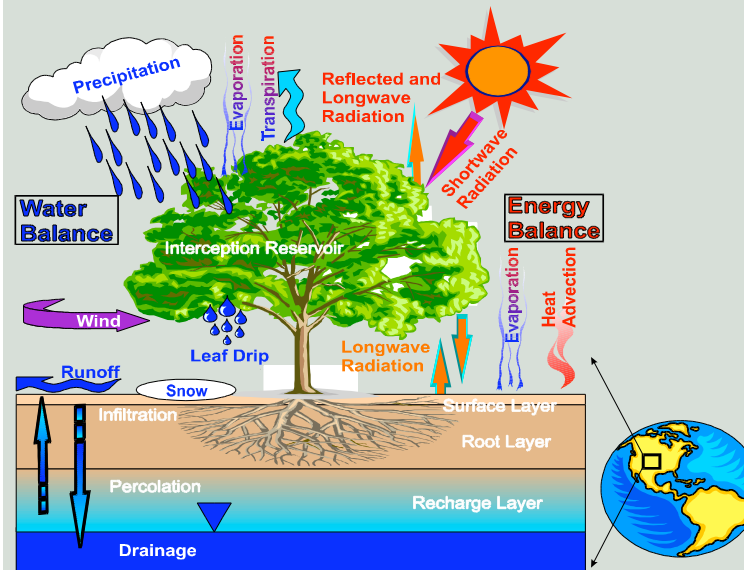
Topography,
Soils
(Static)

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

Surface
Water
Fluxes
(e.g., Runoff)

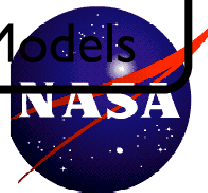
Surface
States:
Snowpack
LAI (some)

Mobility
Models
(e.g., FCS)

Atm.
Models
(e.g., WRF)

Water
Resources/
Ocean
Models

Carbon
Models



Sequence of Component Interactions for a cycle of EnKF

