Land Data Assimilation Systems

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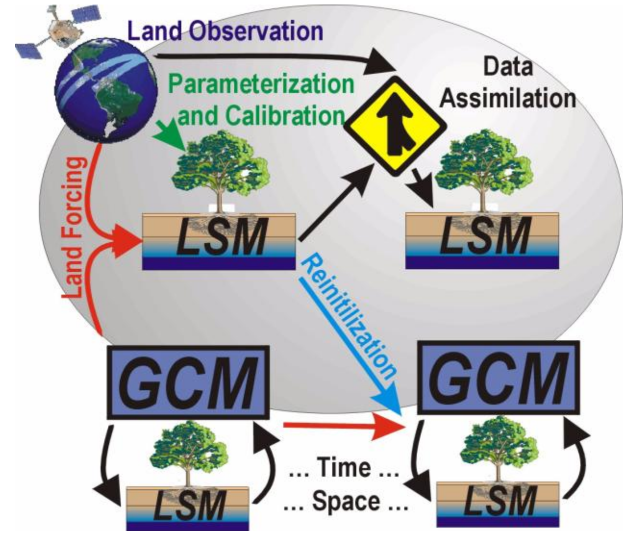
Land Data Assimilation Systems: Motivation



Quantification and prediction of hydrologic variability

- Critical for initialization and improvement of weather/climate forecasts
- Critical for applications such as floods, agriculture, military operations, etc.

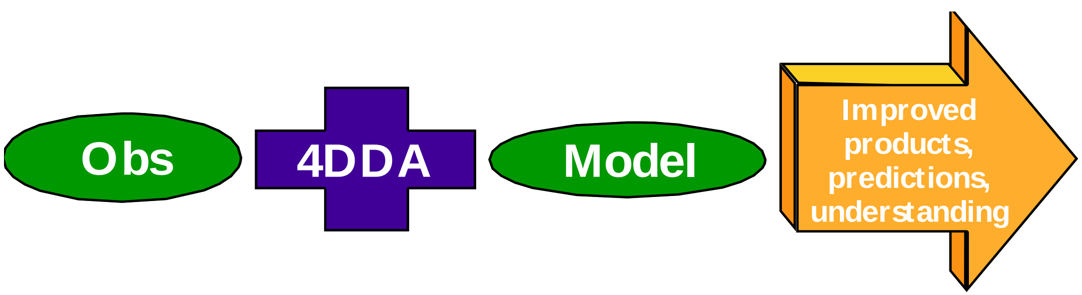
Maturing of hydrologic observation and prediction tools:

- Observation: Forcing, storages(states), fluxes, and parameters.
- Simulation: Land process models (Hydrology, Biogeochemistry, etc.).
- Assimilation: Short-term state constraints.

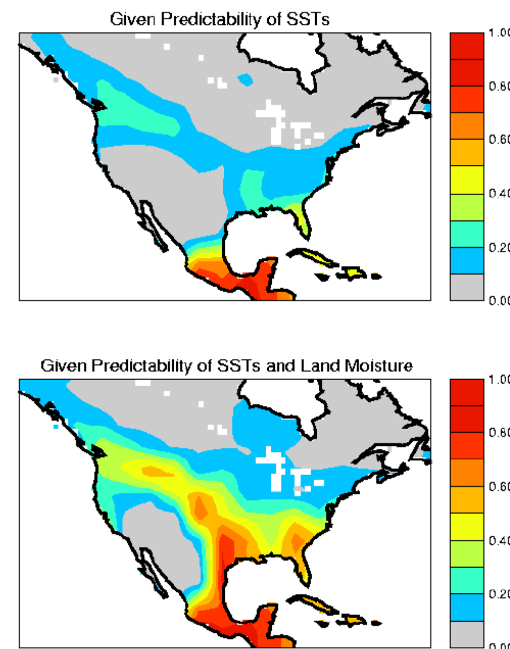
"LDAS" concept:

Bring state-of-the-art tools together to *operationally* obtain high quality land surface conditions and fluxes.

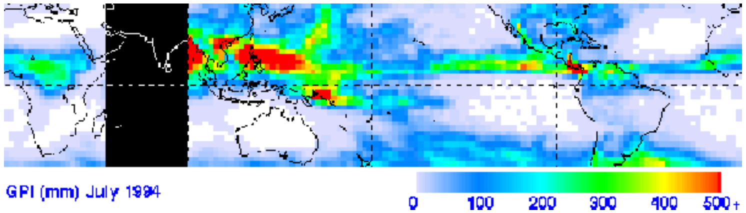
- Optimal integration of land surface observations and predictions.
- Continuous in time&space; multiple scales; retrospective, realtime, forecast

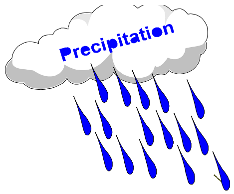


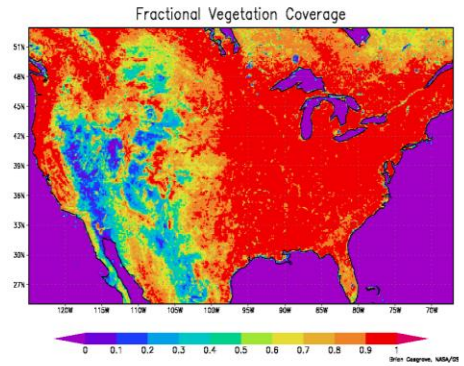
Index of Precipitation Predictability (JJA):

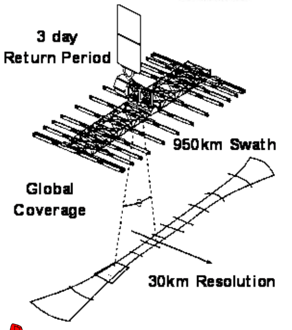


Background: Land Surface Observations









Precipitation: ***Remote-Sensing:*** SSM/I, TRMM, AMSR, GOES, AVHRR

In-Situ: Surface Gages and Doppler Radar

Radiation: ***Remote-Sensing:*** MODIS, GOES, AVHRR

In-Situ: DOE-ARM, Mesonets, USDA-ARS

Surface Temperature: ***Remote-Sensing:*** AVHRR, MODIS, SSM/I, GOES

In-Situ: DOE-ARM, Mesonets, NWS-ASOS, USDA-ARS

Soil Moisture: ***Remote-Sensing:*** TRMM, SSM/I, AMSR, **HYDROS**, ESTAR, NOHRSC, SMOS

In-Situ: DOE-ARM, Mesonets, Global Soil Moisture Data Bank, USDA-ARS

Groundwater: ***Remote-Sensing:*** GRACE

In-Situ: Well Observations

Snow Cover, Depth & Water: ***Remote-Sensing:*** AVHRR, MODIS, SSM/I, AMSR, GOES, NWCC, NOHRSC

In-Situ: SNOTEL

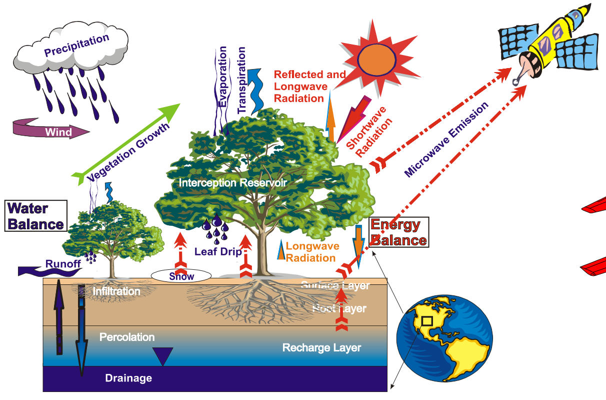
Streamflow: ***Remote-Sensing:*** Laser/Radar Altimiter

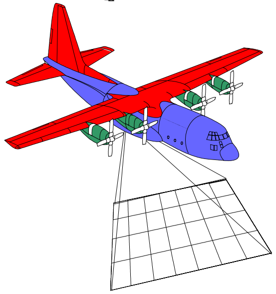
In-Situ: Real-Time USGS, USDA-ARS

Vegetation: ***Remote-Sensing:*** AVHRR, TM, VCL, MODIS, GOES

In-Situ: Field Experiments

Others: Soils, Latent & Sensible heat fluxes, etc.





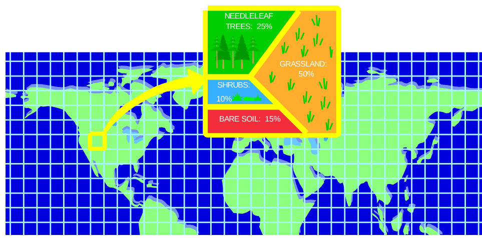
Background: Land Surface Modeling

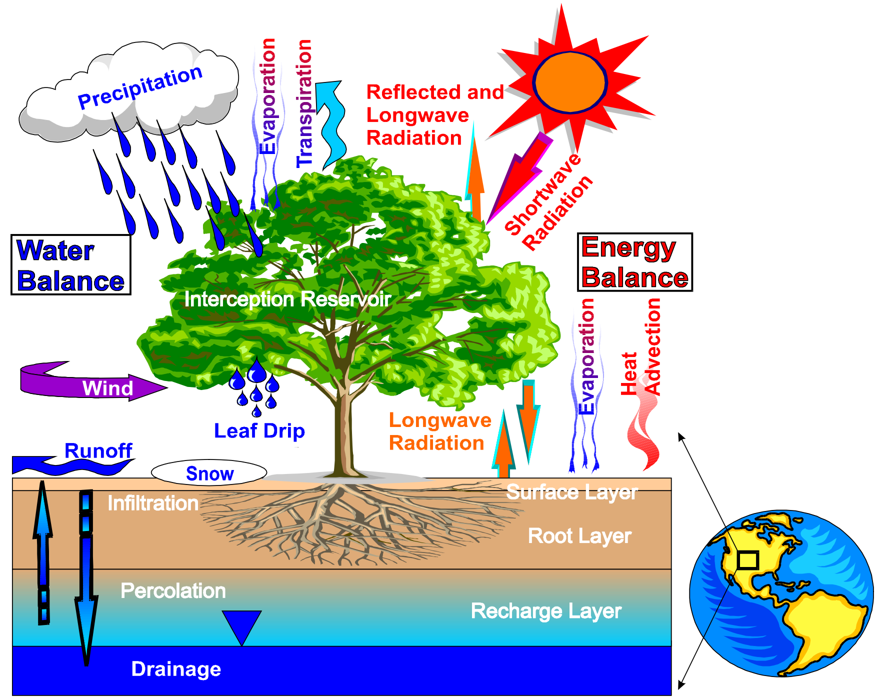
Land Surface Prediction: Accurate land model prediction is essential to enable data assimilation methods to propagate or extend scarce observations in time and space. Based on ***water and energy balance***.

Input - Output = Storage Change

$$P + G_{in} - (Q + ET + G_{out}) = \Delta S$$

$$R_n - G = L_e + H$$



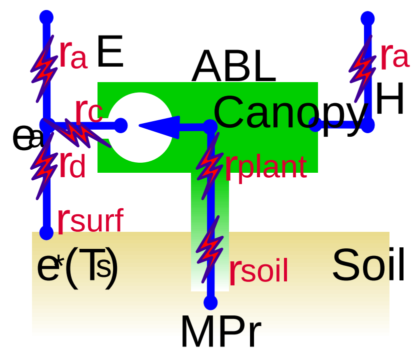


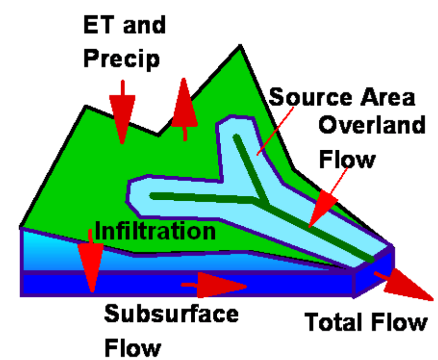
Mosaic (Koster, 1996):
- Based on simple SiB physics.
- Subgrid scale "mosaic"

CLM (Community Land Model, ~2001):
- Community developed “open-source” model.
- 10 soil layers, 5 layer snow scheme.

Catchment Model (Koster et al., 2000):
- Models in catchment space rather than on grids.
- Uses Topmodel concepts to model groundwater

NOAA-NCEP-NOAH Model (NCEP, ~2001):
- Operational Land Surface model.



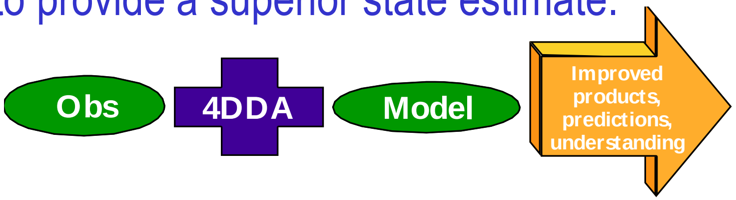


Also: vic, bucket, SiB, etc.

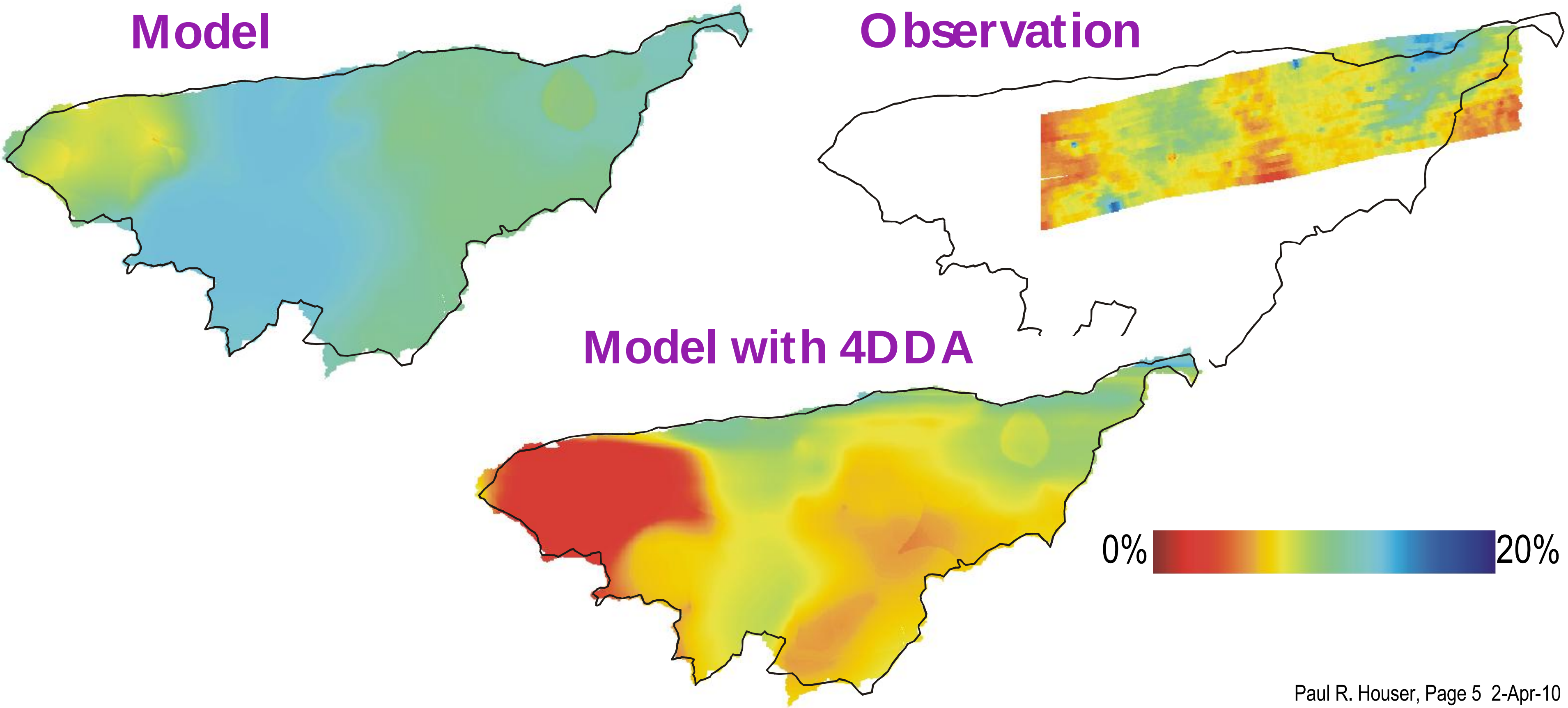
Land Data Assimilation

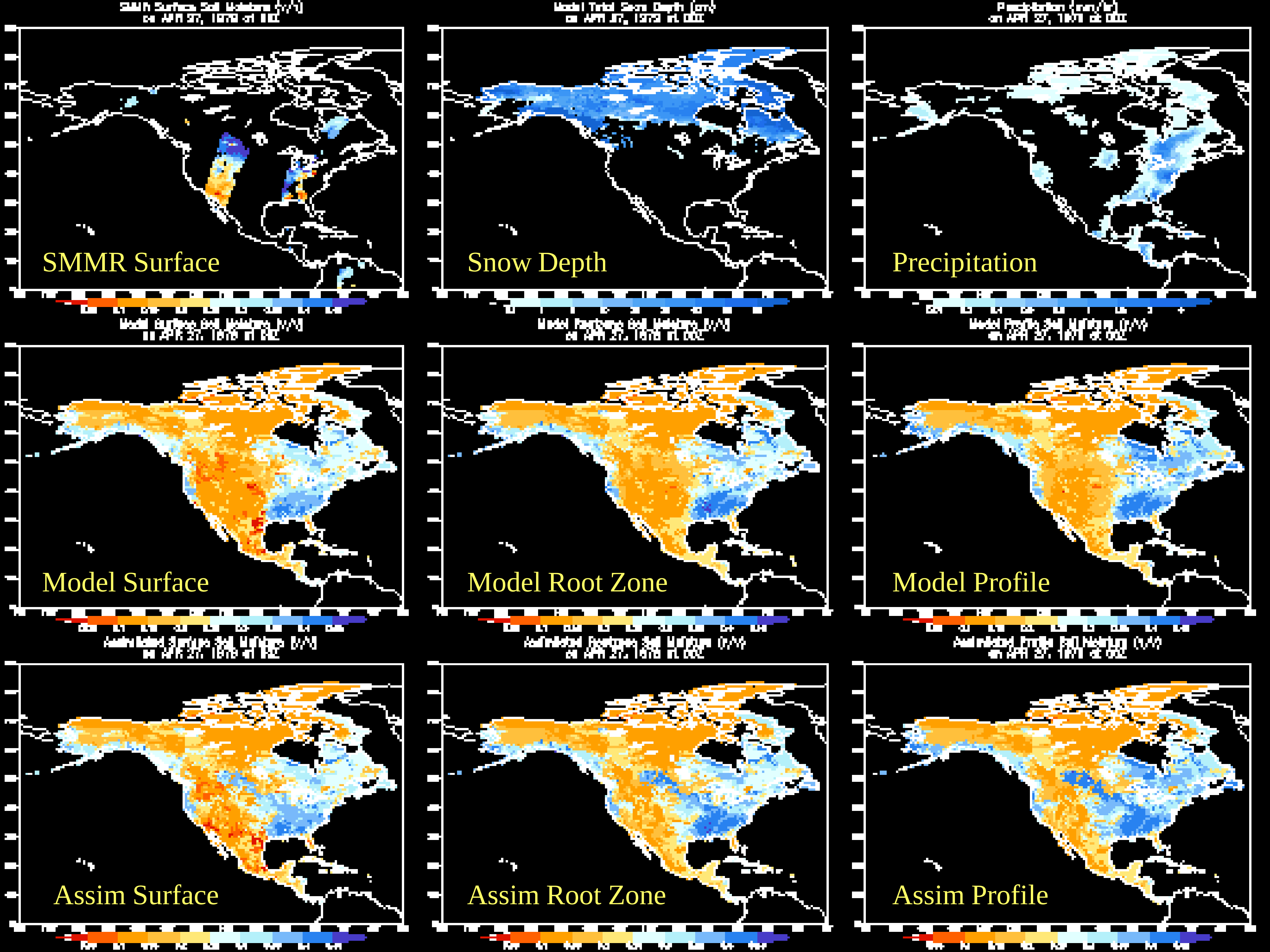
Data Assimilation merges observations & model predictions to provide a superior state estimate.

$$\partial x / \partial t = dynamics + physics + \Delta x$$

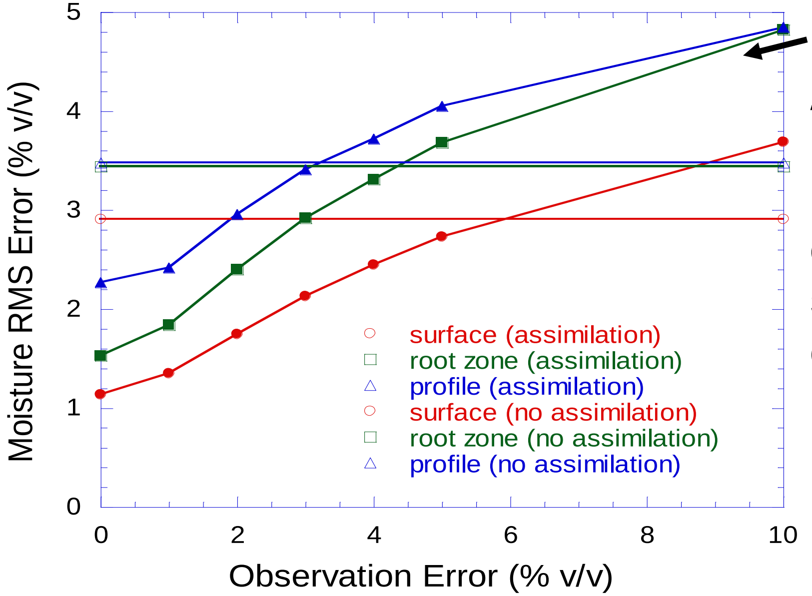


Remotely-sensed hydrologic **state** or storage observations (**temperature, snow, soil moisture**) are integrated into a hydrologic model to improve prediction, produce research-quality data sets, and to enhance understanding of complex hydrologic phenomenon.

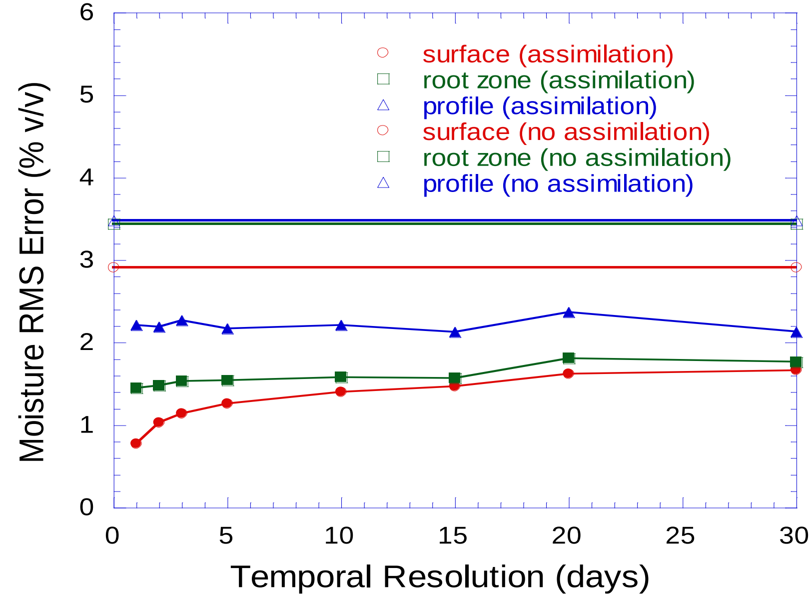


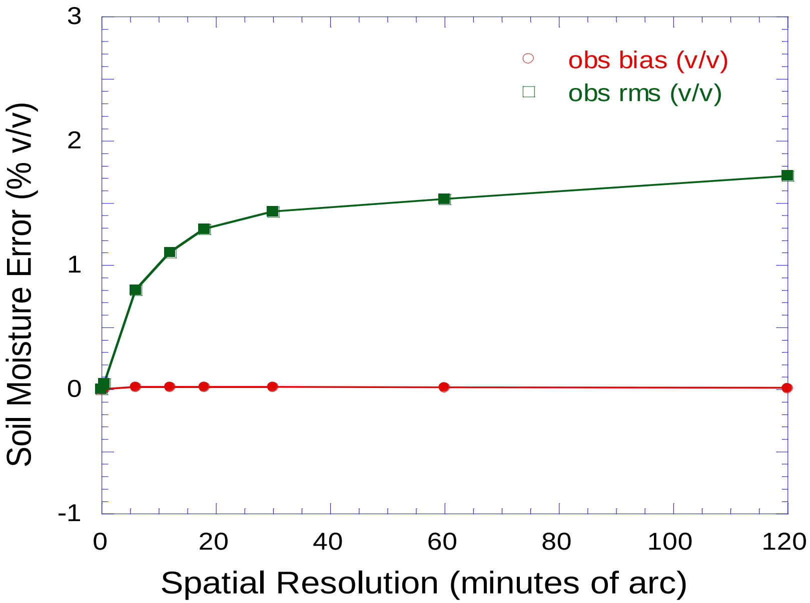

SMMR Surface
Snow Depth
Precipitation
Model Surface
Model Root Zone
Model Profile
Assim Surface
Assim Root Zone
Assim Profile

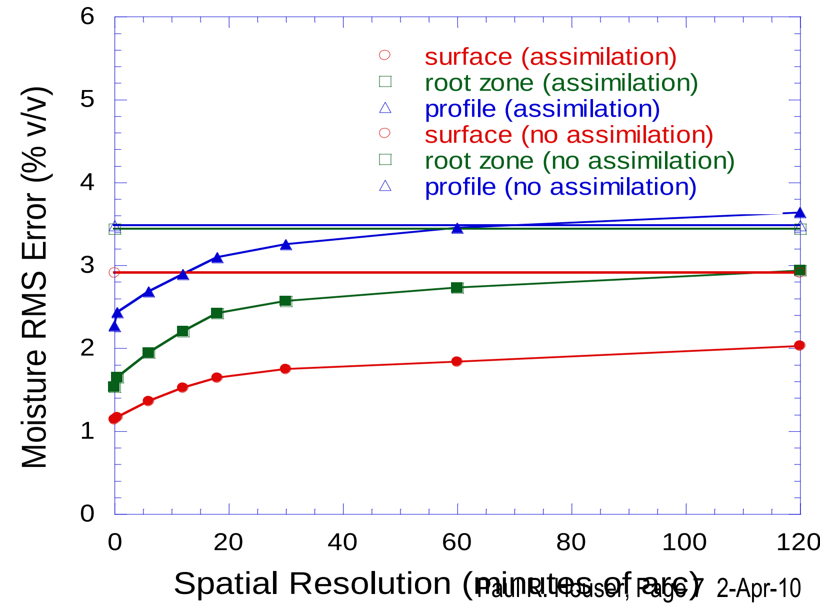
Soil Moisture Observation Error and Resolution Sensitivity:



NOTE:
Assimilation of near-surface soil moisture can degrade profile soil moisture if errors are not known perfectly

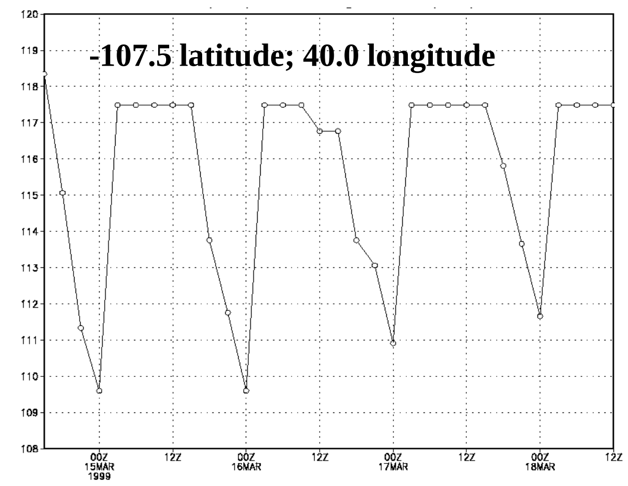






Data Assimilation: Importance of Snow

- In the northern hemisphere the snow cover ranges from 7% to 40% during the annual cycle.
- The high albedo, low thermal conductivity and large spatial/temporal variability impact both the energy and water budgets.
- Snow adjacent to bare soil causes mesoscale wind circulations.
- Direct replacement does not account for model bias.



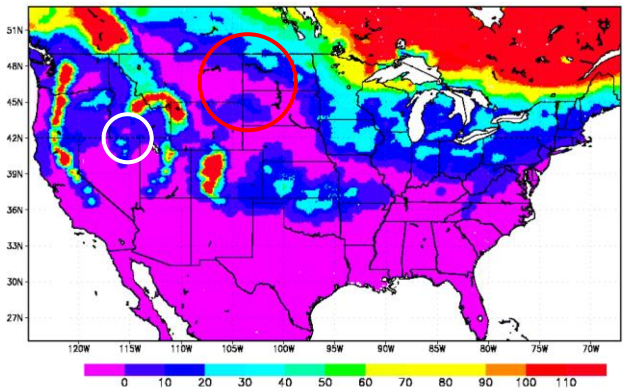
NCEP-Eta Snow Updating

Update Time

Melt

Update Time

3Z 3/15/99



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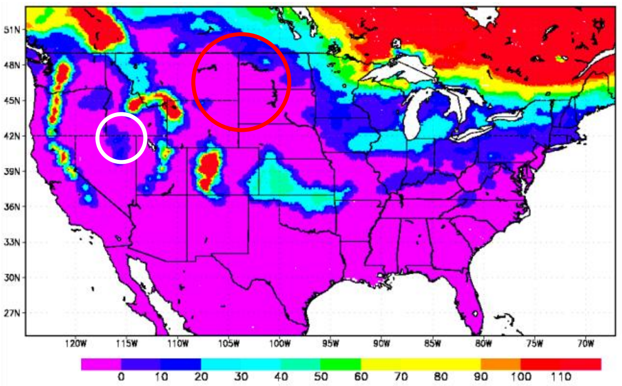
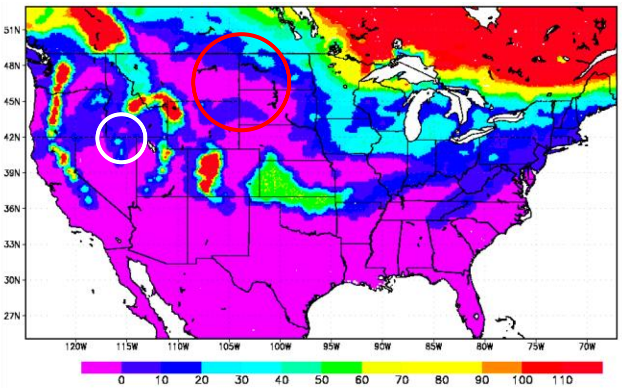


3Z 3/16/99

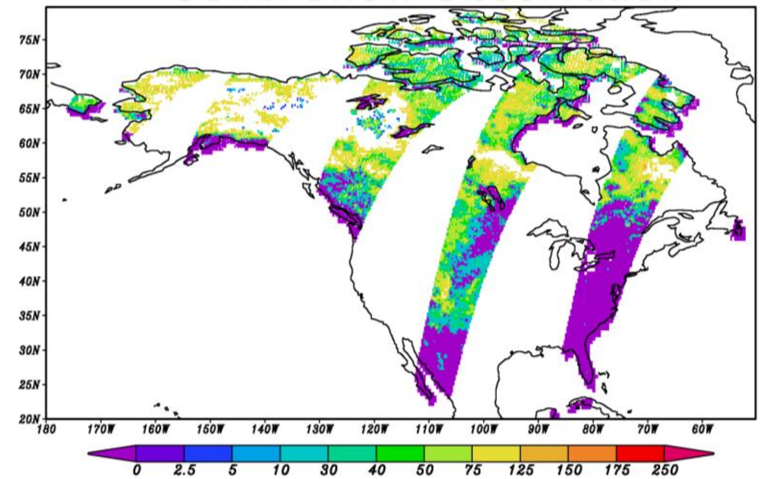


Snow Data Assimilation

Goals

- Develop a Kalman filter snow assimilation to overcome current limitations with assimilation of snow water equivalent, snow depth, and snow cover.
- Investigate novel snow observation products such as snow melt signature and fractional snow cover.
- Provide a basis for global implementation.

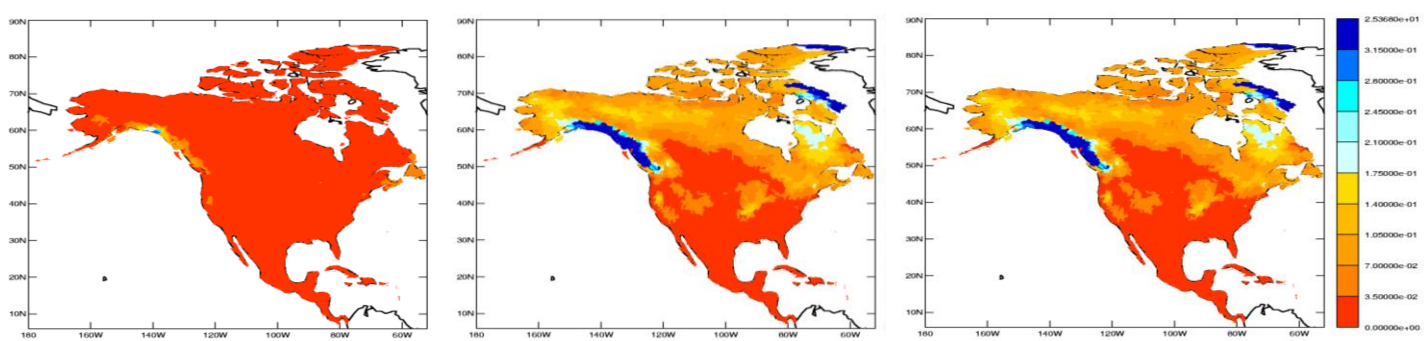
SSM/I Snow Observation



Unique Snow Data Assimilation Considerations:

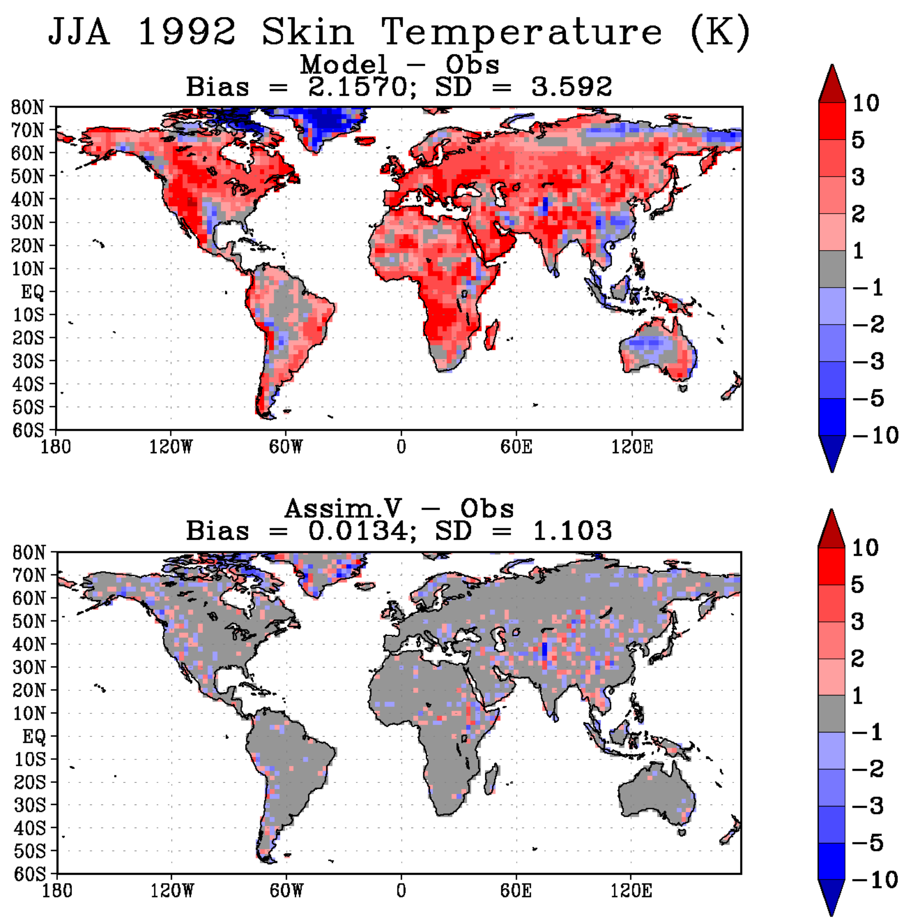
- "Dissappearing" layers and states
- Arbitrary redistribution of mass between layers
- Lack of information in SWE about snow density or depth
- Lack of information in snow cover about snow mass & depth
- Biased forcing causing divergence between analysis steps

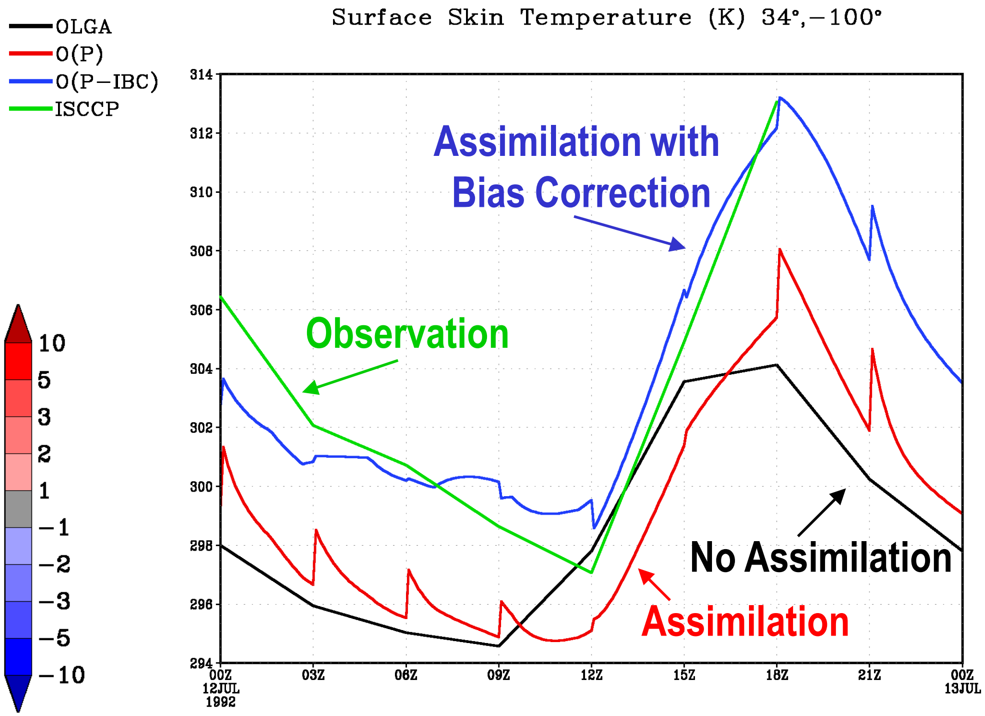
Open Loop Truth Assimilation



Surface skin temperature data assimilation

DAO-PSAS **Assimilation** of **ISCCP (IR based) Surface Skin Temperature** into a global 2 degree uncoupled land model.

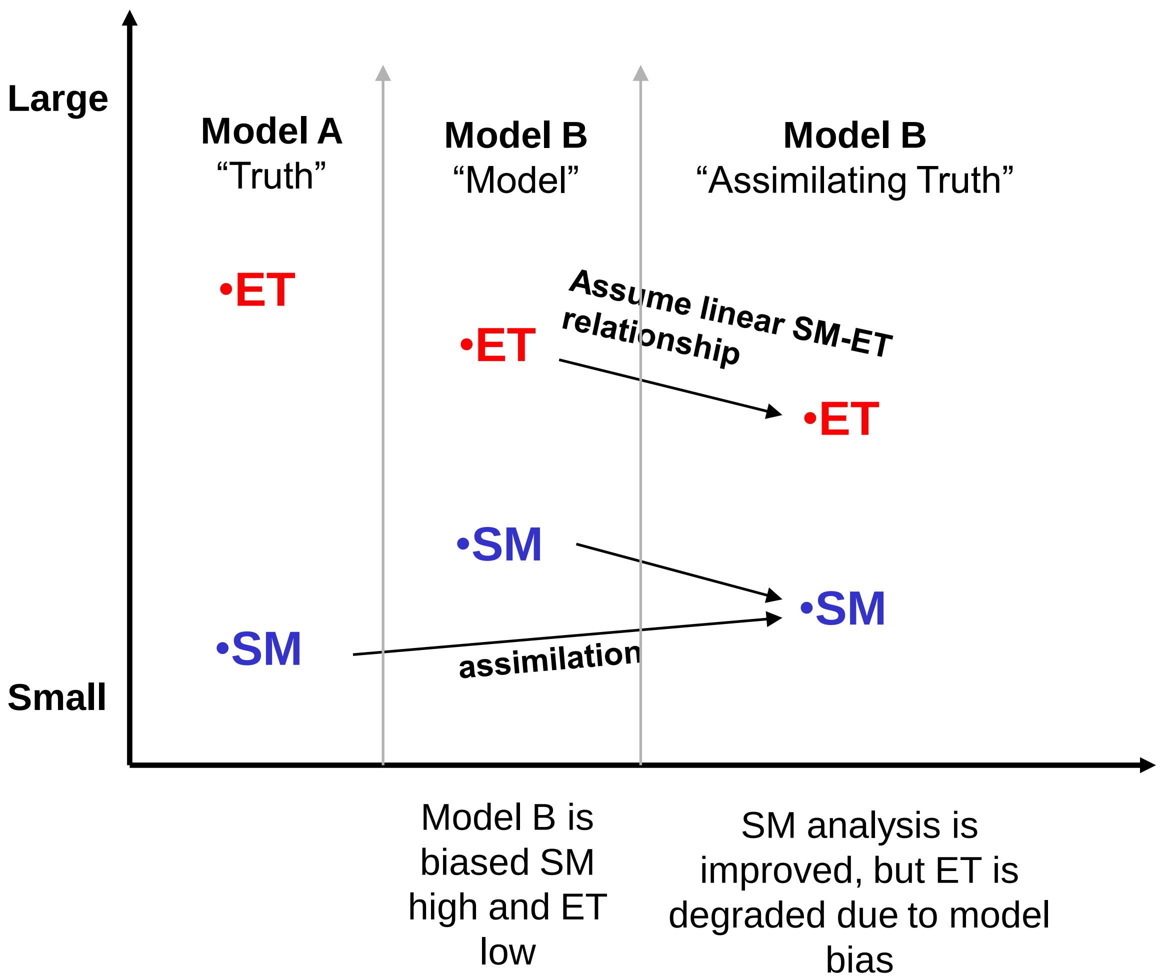




Surface temperature has **very little memory** or inertia, so without a continuous correction, it tends drift toward the control case very quickly.

Fraternal Twin Studies

•"Truth" from one model is assimilated into a second model with a biased parameterization
•The "truth" twin can be treated as a perfect observation to help illustrate conceptual problems beyond the assimilation procedure.



We must not only worry about obtaining an optimal model constraint, but also <u>understand the implications</u> of that constraint.

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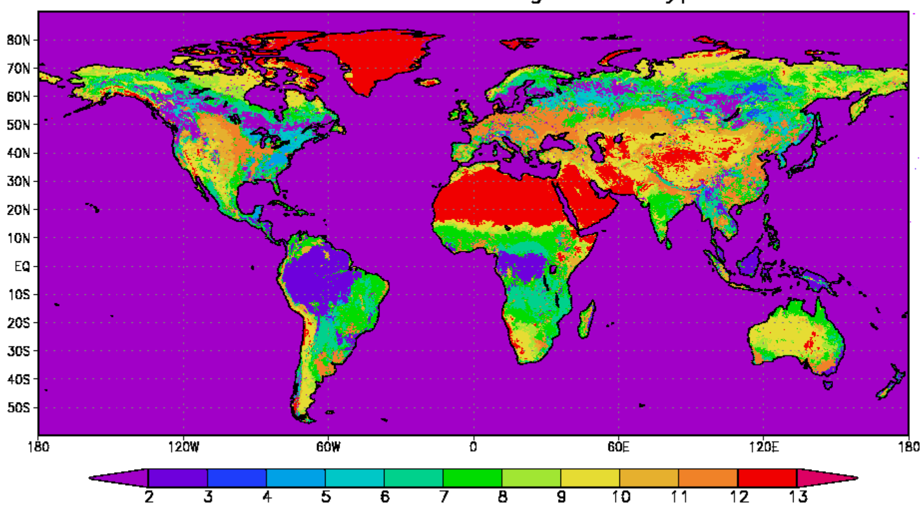
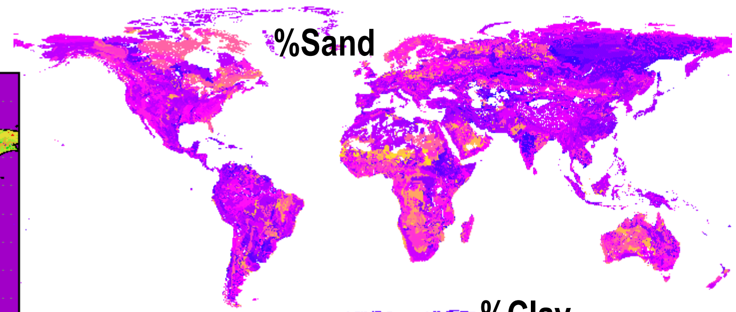
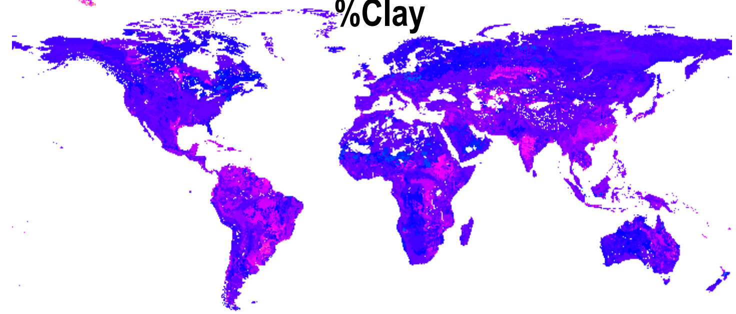
Global Land Data Assimilation System

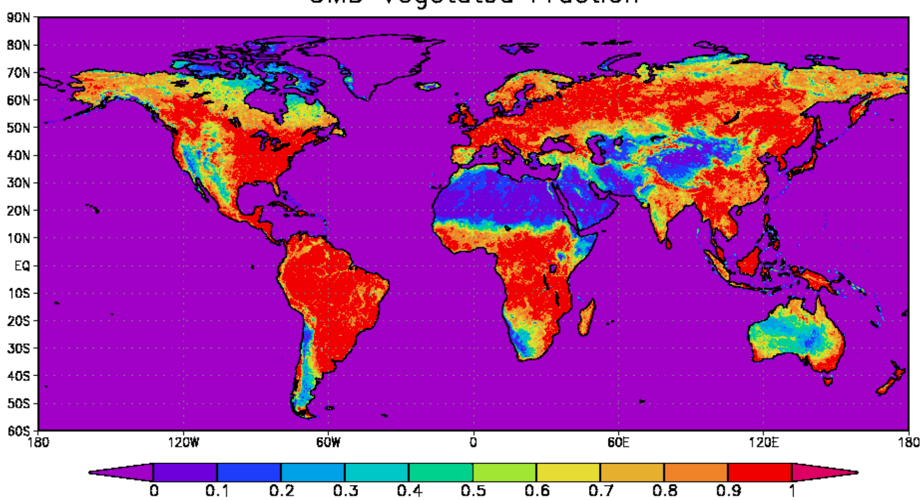
UMD Predominant Vegetation Type



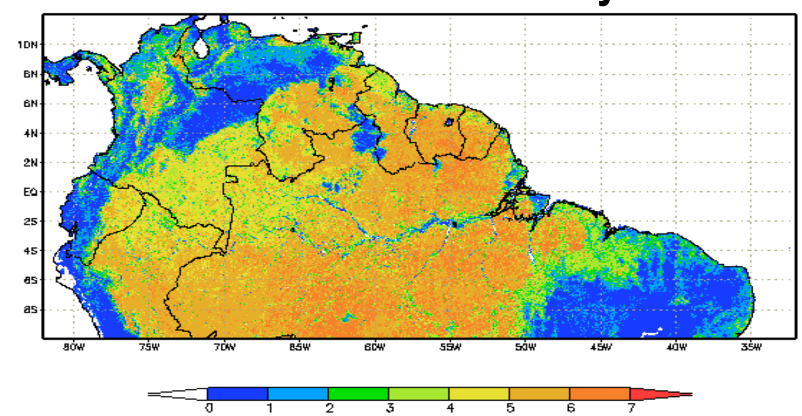




UMD Vegetated Fraction



AVHRR/MODIS 1 km LAI -- July



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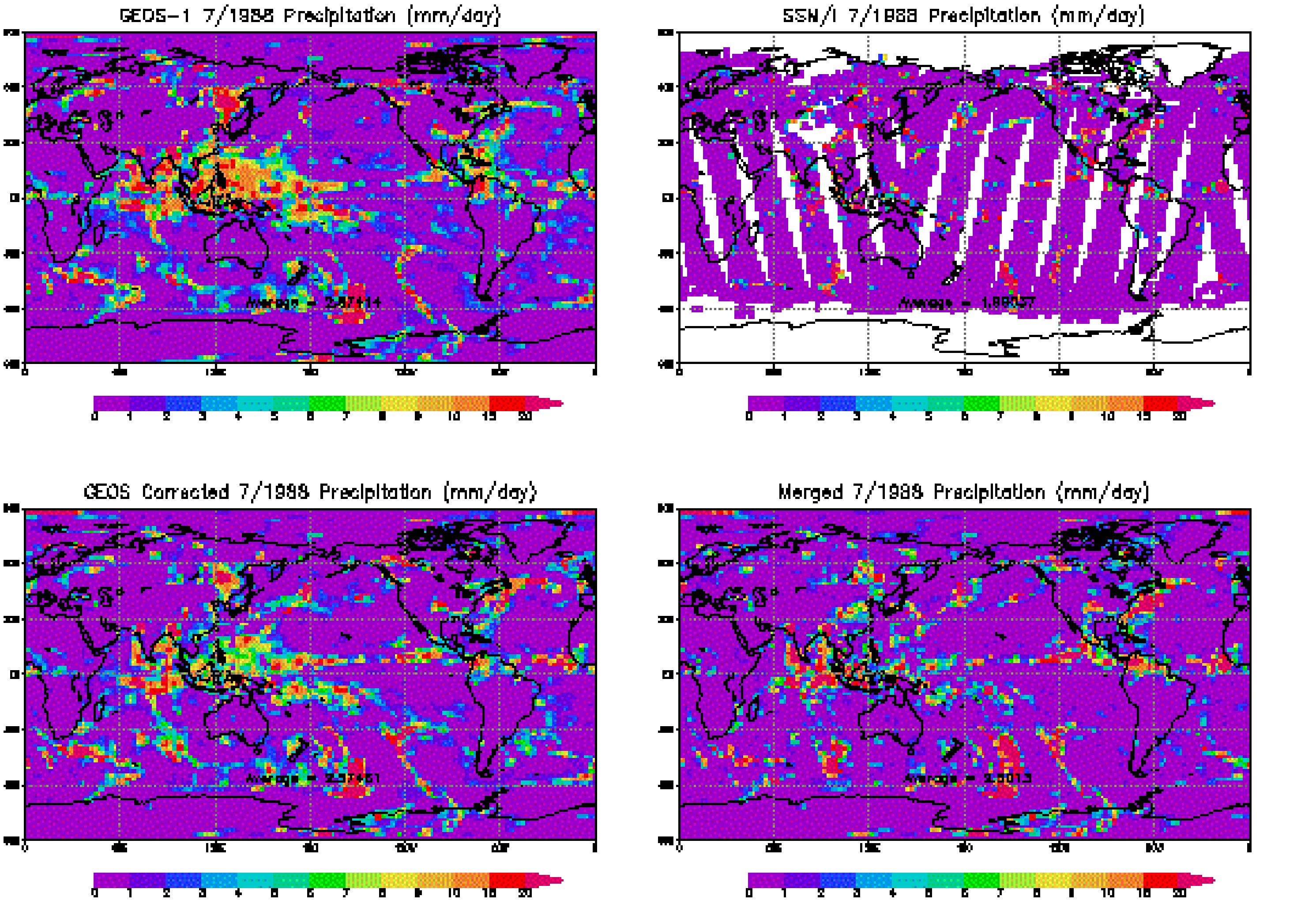
Global Land Data Assimilation System

Example 3hr Merged Precipitation Field:

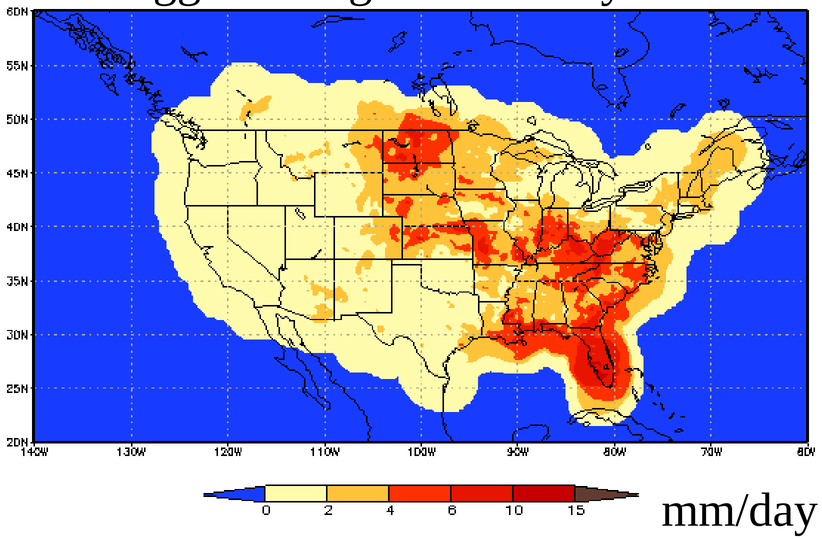
GEOS1 model and SSMI observed precipitation corrected to GPCP and merged using PSAS.

Day 1.25

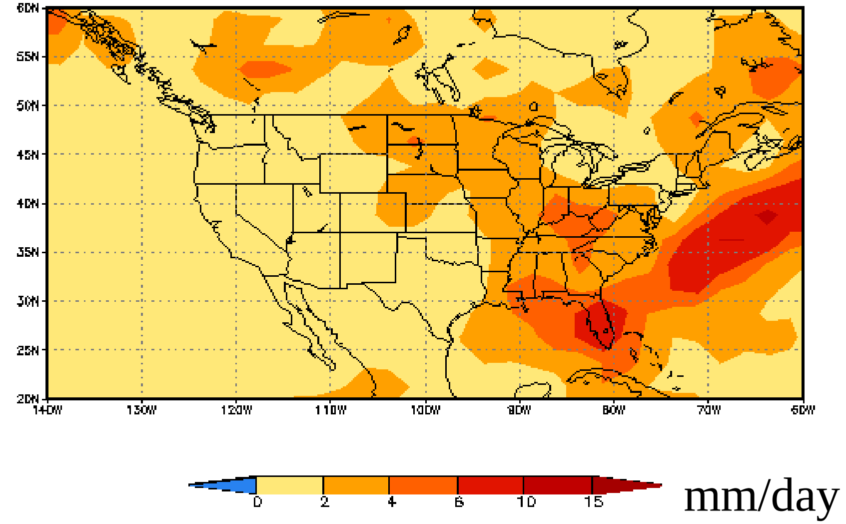


Precipitation evaluation; July 2001

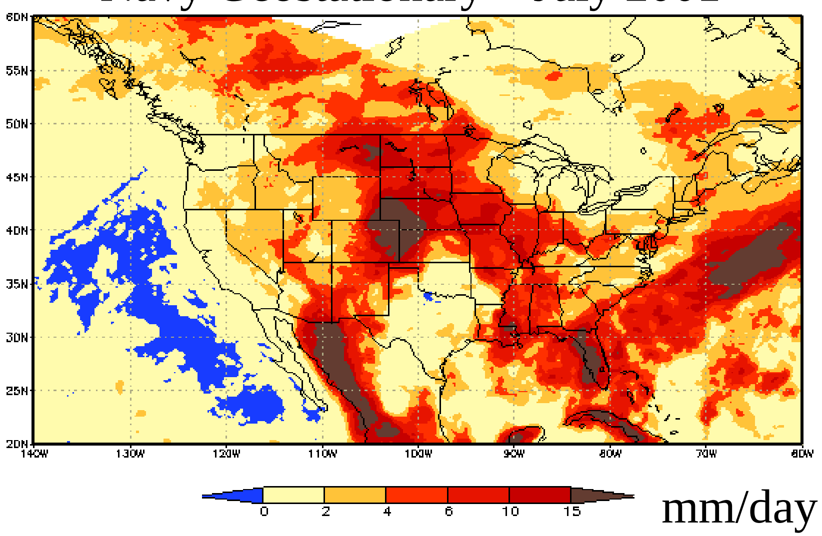
Higgins Gauge Data – July 2001



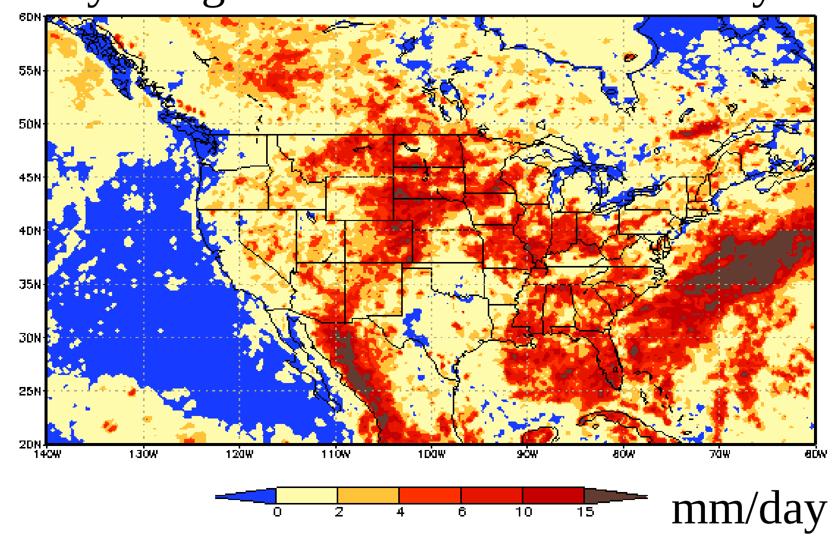
CPC Pentad – 6/30-7/29



Navy Geostationary – July 2001

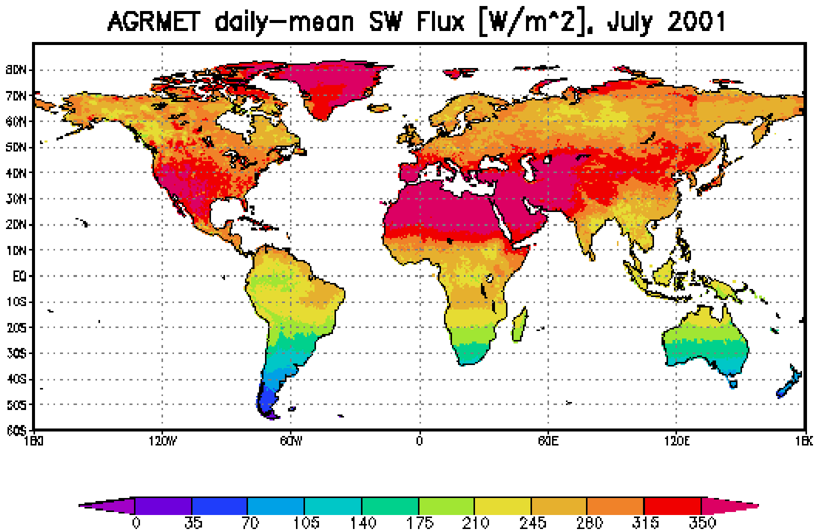


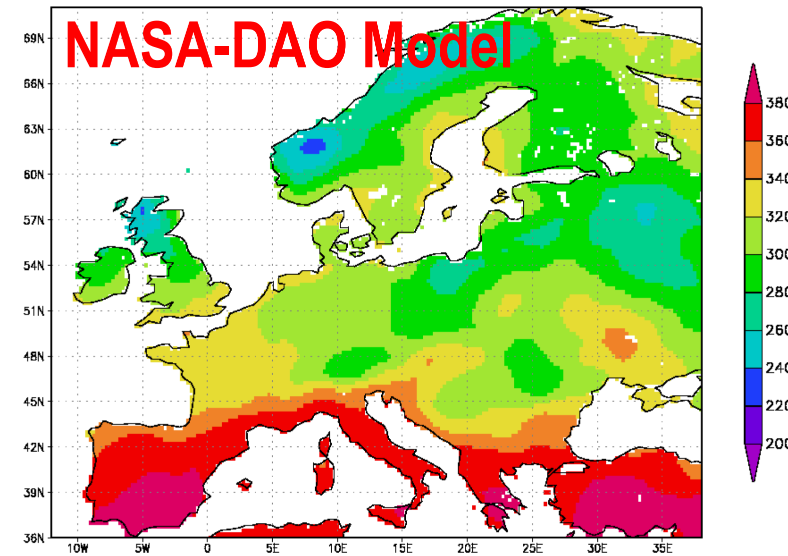
Navy Merged TRMM and SSM/I – July 2001

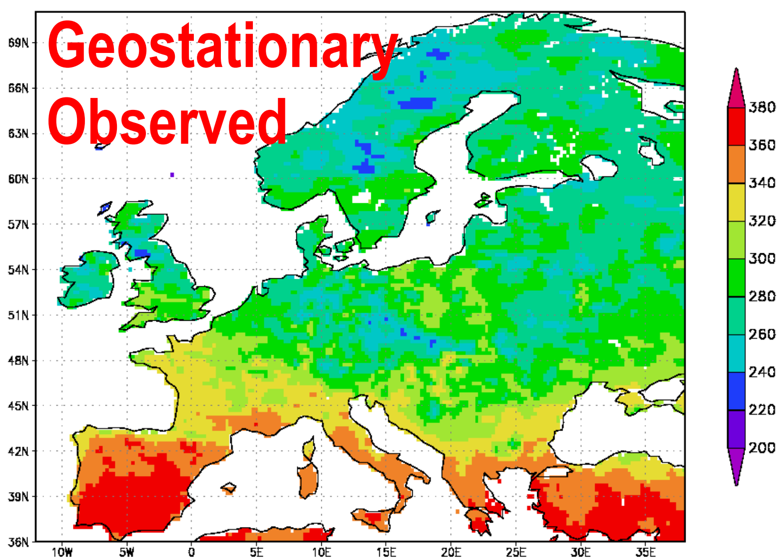


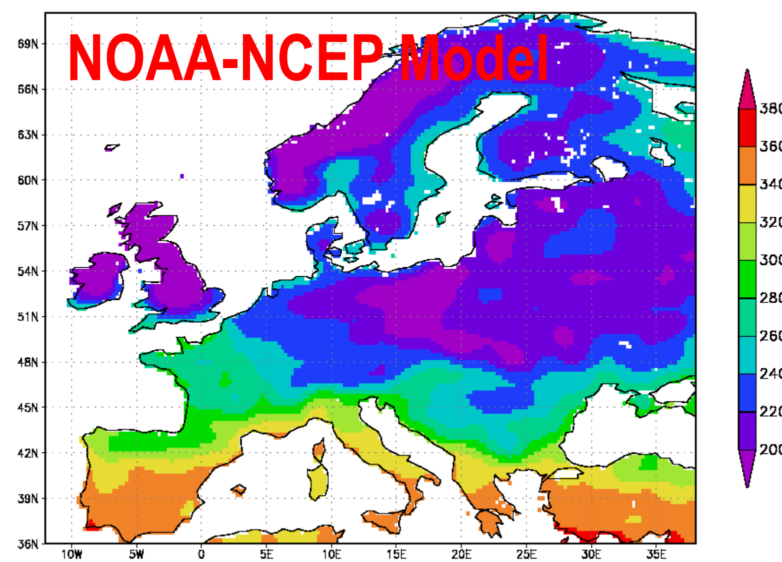
Surface SWdown flux evaluation; June 2001

Geostationary Observed



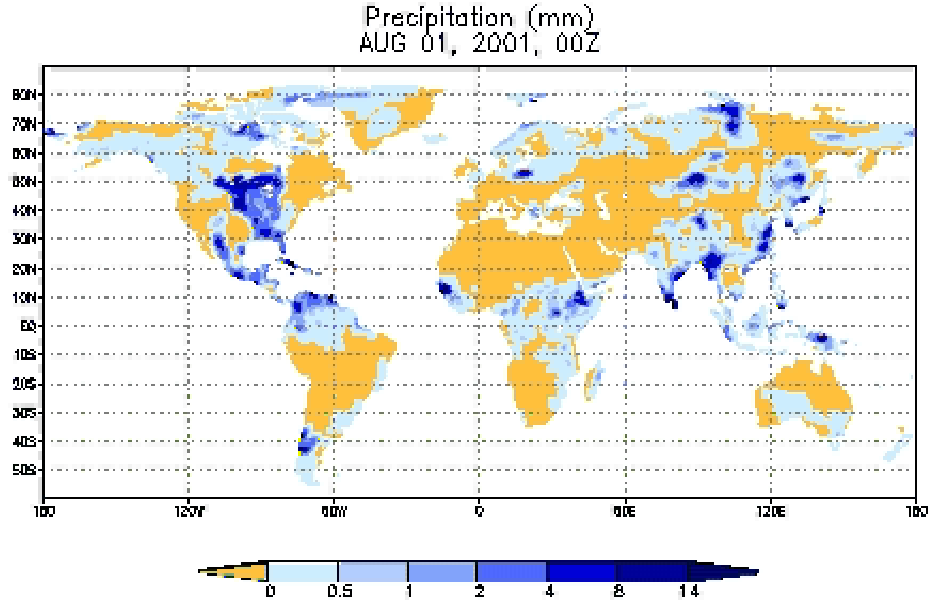


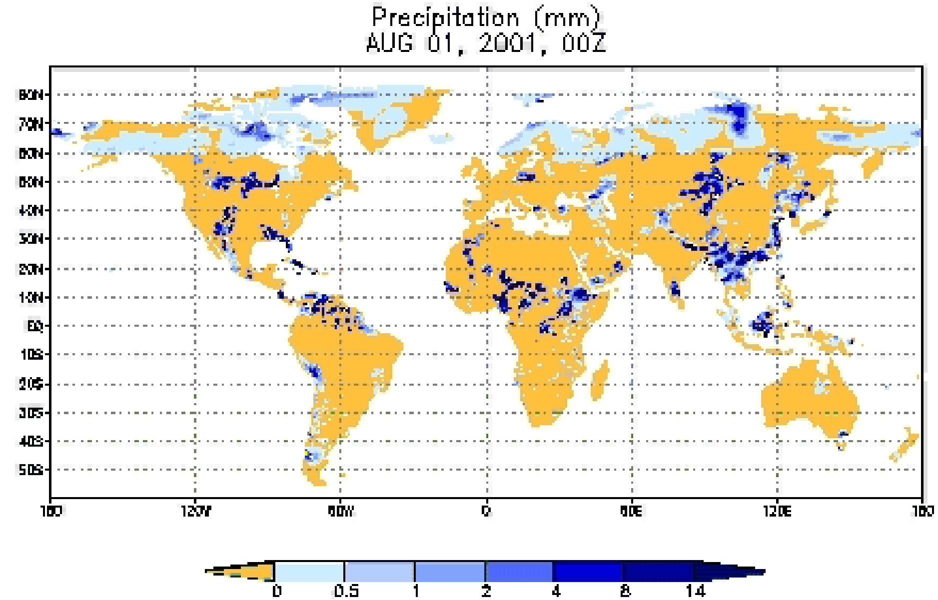


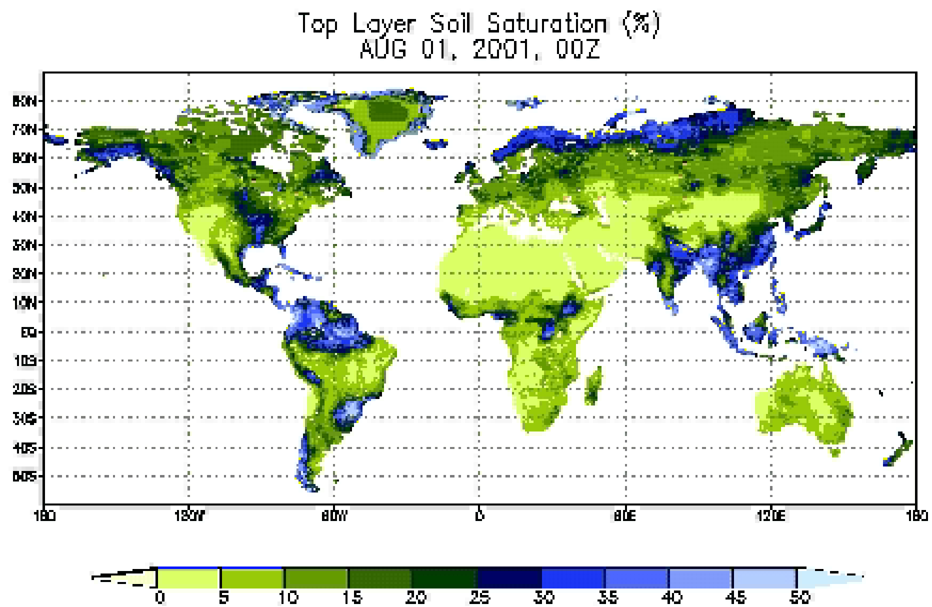


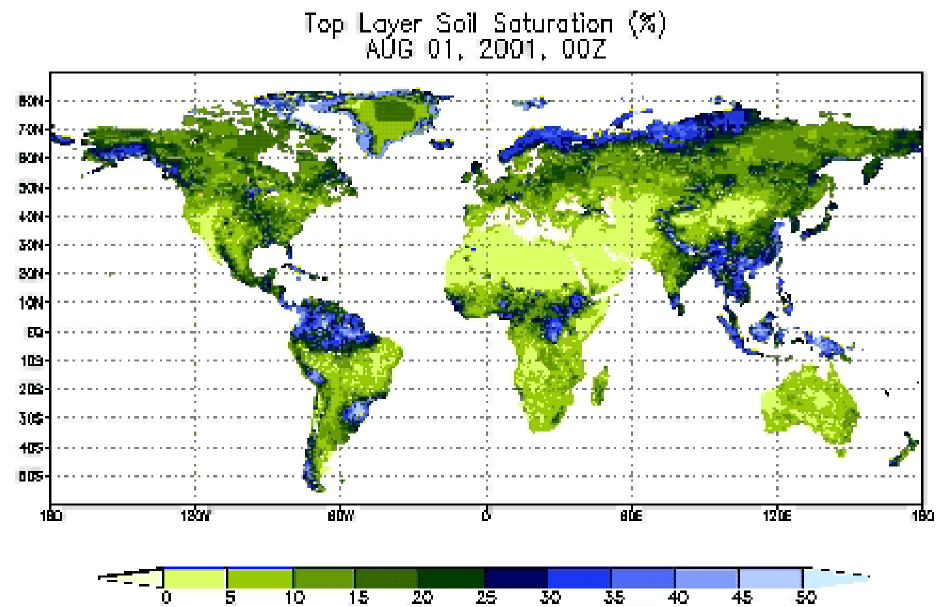
GEOS Model Forcing

Satellite-derived Precipitation Option









Land Data Assimilation: Selected Future Challenges

Data Assimilation Algorithm Development: *Link calibration and assimilation* in a logical and mutually beneficial way and move towards *multivariate assimilation* of data with complementary information

Land Observation Systems: Regular provision of *snow, soil moisture*, and *surface temperature* with knowledge of *observation errors*

Land Modeling: Better *correlation* of land model states with observations, and knowledge of *prediction errors* and Advanced processes: *River runoff/routing*, *vegetation and carbon dynamics, groundwater interaction*

Assimilate new types of data: Streamflow, vegetation dynamics, groundwater/total water storage (Gravity), evapotranspiration

Coupled feedbacks: Understand the impact of land assimilation feedbacks on coupled system predictions.