Land Data Assimilation at NCEP:

Strategic Lessons Learned from the North American Land Data Assimilation System (NLDAS)

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Collaborators:

NOAA, NASA, Princeton Univ., Rutgers Univ., Univ. Washington, Univ. Maryland

(ECMWF, Reading 2004)

Objective 1

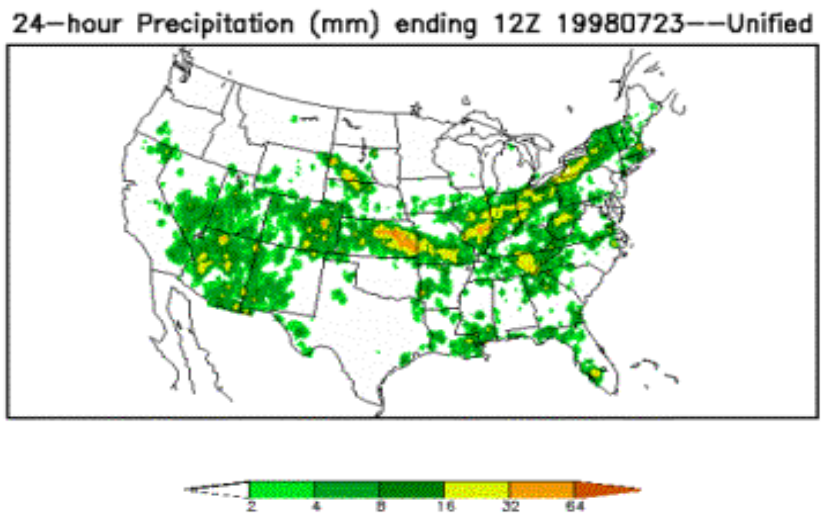
Provide initial land state conditions for regional and global weather and climate prediction models in realtime that are superior *(to be demonstrated)* to current methodologies

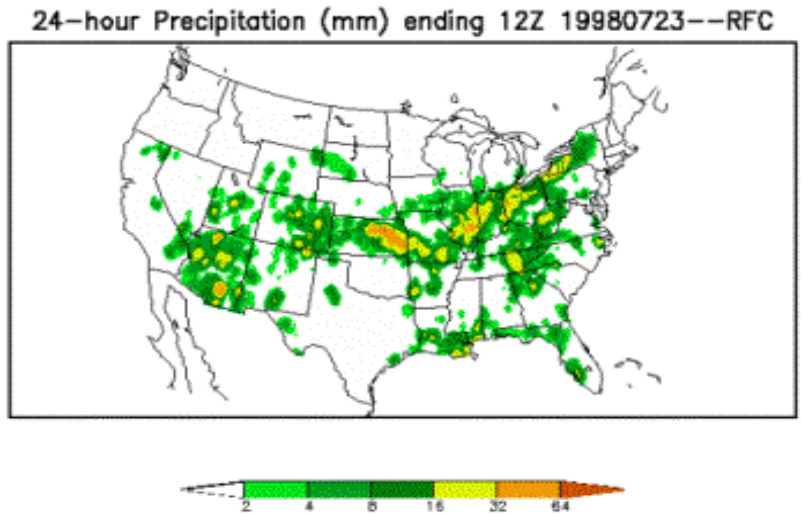
Method

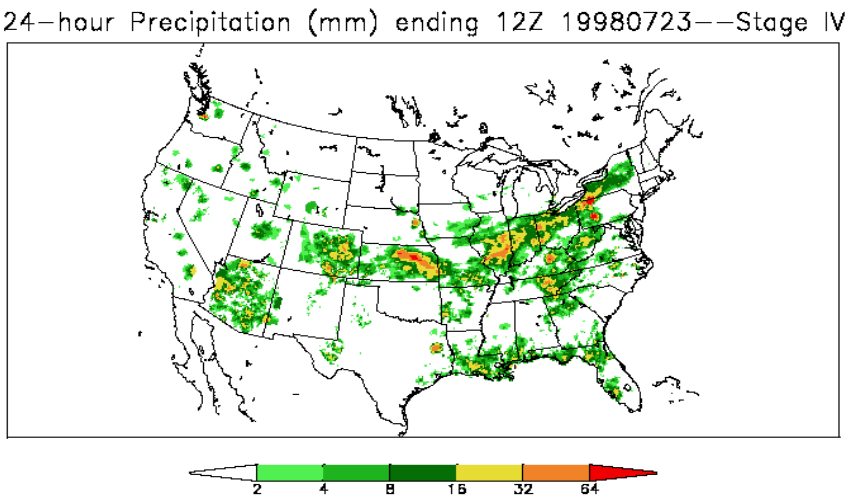
Eliminate biases and errors in precipitation and short wave radiation by replacing predicted model precipitation with measured (gauge / radar) precipitation and satellite-based (GOES) short wave radiation

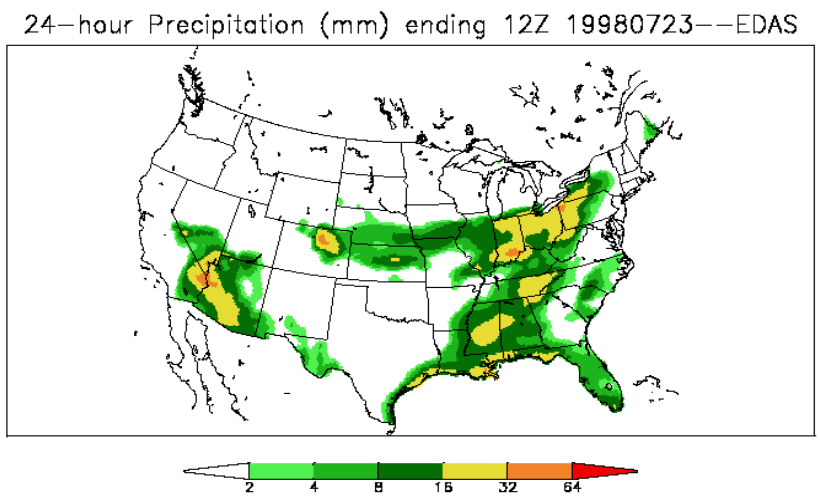
Derive improved land surface states by using the observed forcings in LMS. Assimilate these into the coupled forecast models

NLDAS Precipitation Input Data Sources / Errors



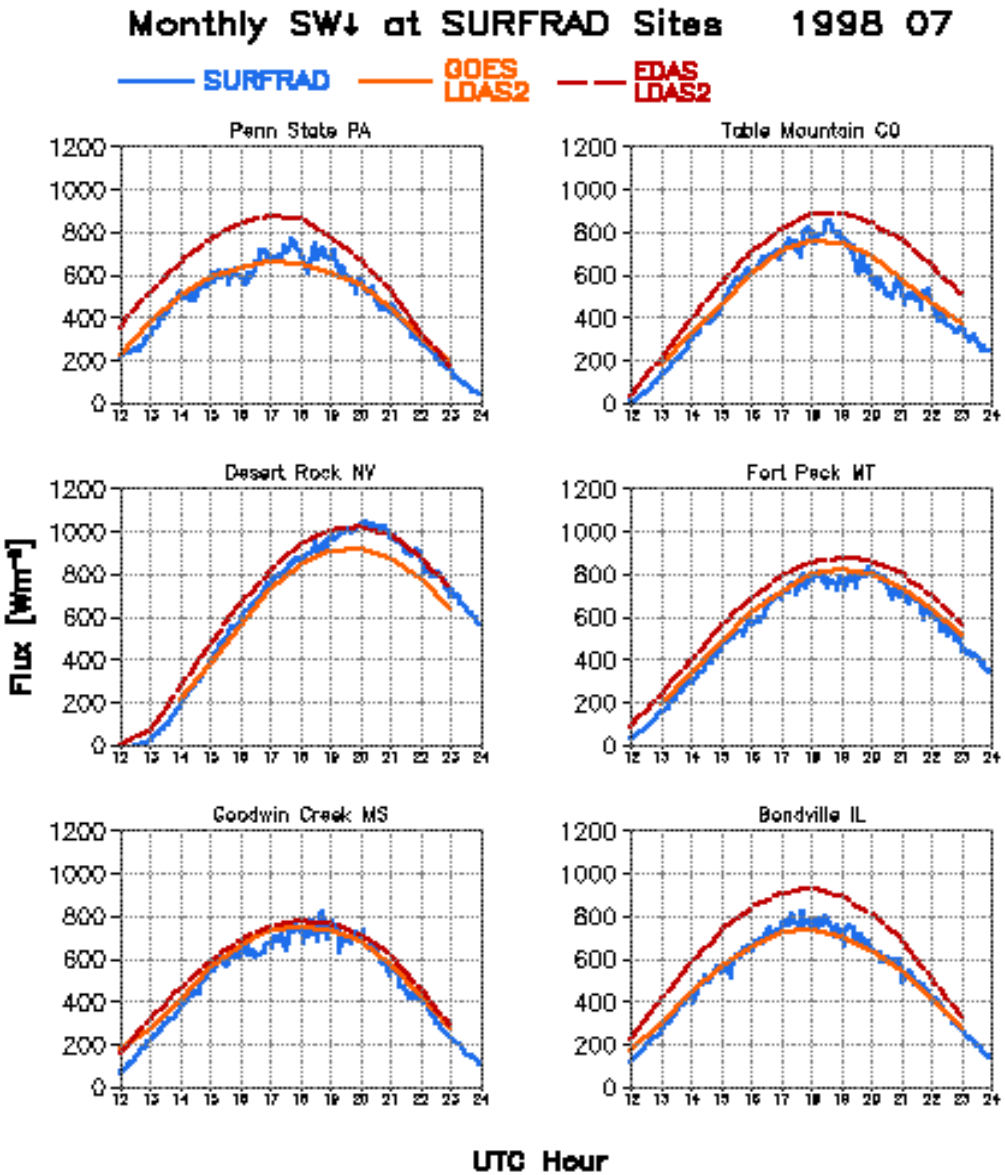






Daily precipitation (mm) analysis based on retrospective gage reports (upper left), realtime gage reports (upper right), Stage IV radar estimates (lower left) and EDAS (lower right).

NLDAS Shortwave Radiation Input Data Sources / Errors



Monthly mean daily cycle for July 1998

Surfrad

EDAS

GOES

EDAS shows a high bias

GOES is much closer for 5 out of 6 stations to point measurements (Surfrad)

Objective 2

Provide framework to

1. Spin-up land states to realtime whenever land model is changed / updated
2. Develop improved land surface model/parameterizations

Background

Future upgrades of land surface models will introduce new state variables (e.g. groundwater, urban, lake, chemical model) that need sufficient spin-up (months to years)

Changes in land surface model parameters, model physics, model geometry, and model numerics impact the resulting model climatologies

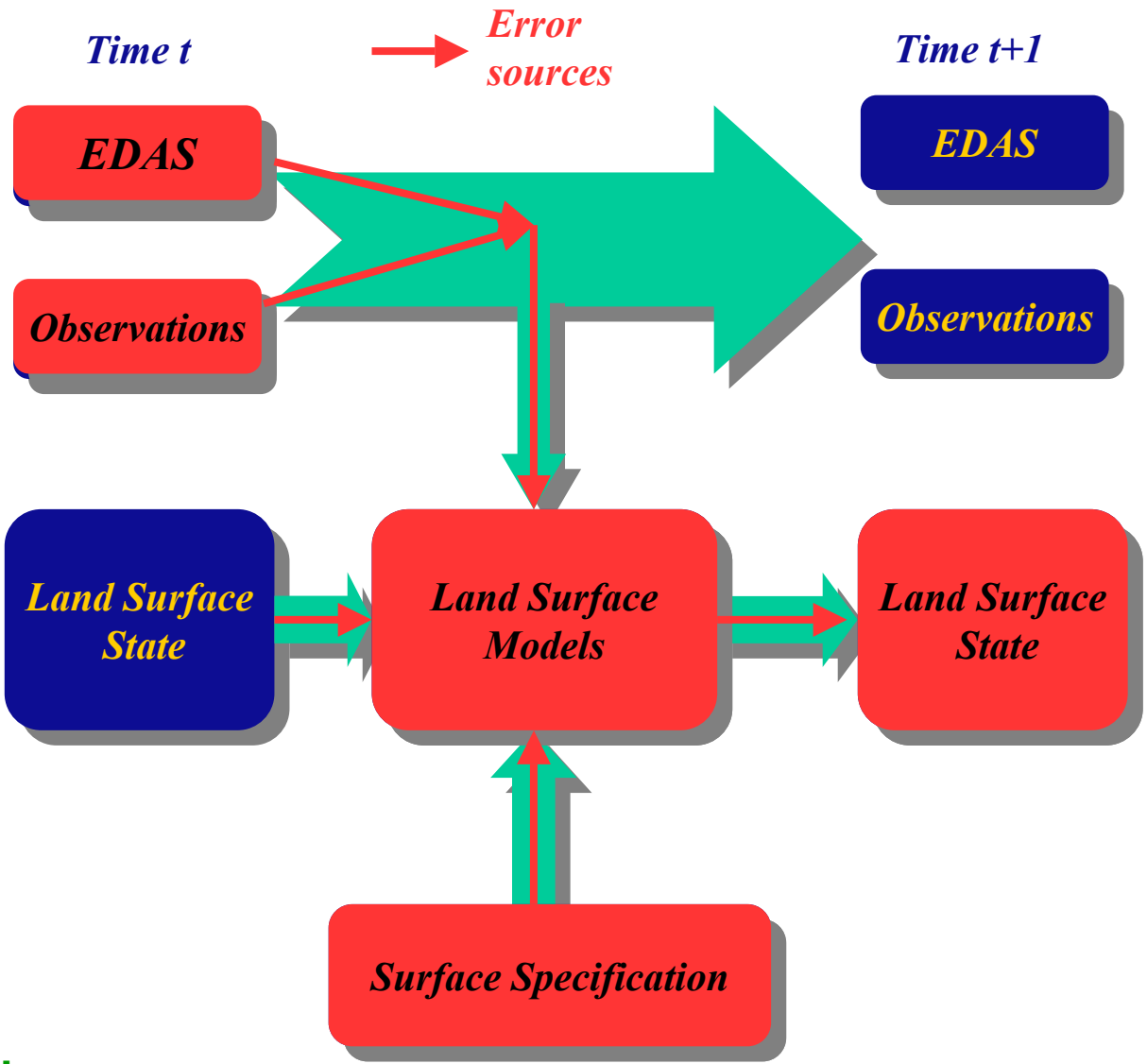
Background continued

A change in the horizontal resolution of the atmospheric model also changes the resolution and underlying topography of the land surface model. There's no scientifically based theory of how to transfer land surface information from one scale to another – especially when grid cells have different elevations and snow and frozen ground processes become more important

Method

Run land model offline on the same grid and topography as the atmospheric model for sufficient spin-up period prior to using land model states in coupled atmospheric – hydrological model, validate Model output

NLDAS Data Flow



Current Additions: assimilate satellite-derived and in-situ soil moisture and skin temperature (http://ldas.gsfc.nasa.gov)

NLDAS Data Sources

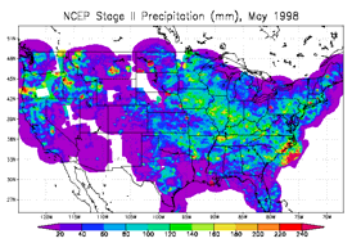
NLDAS LSMs common forcing

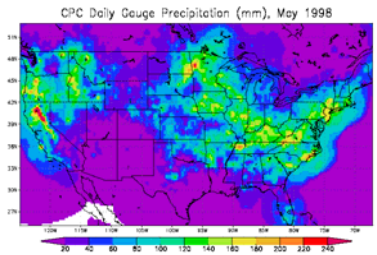
Model Based	Observation Based
2 Meter temperature	Downward shortwave radiation
2 Meter specific humidity	Doppler/gauge/model based precipitation
Surface Pressure	
U wind component	
V wind component	
Downward longwave radiation	
Convective Precipitation	

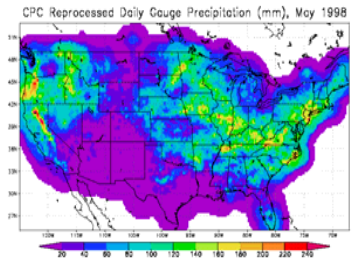
Secondary fields

Model Based
Downward shortwave radiation
Total precipitation
Convective available potential energy (CAPE)
Observation Based
Skin temperature
PAR
Doppler radar total precip

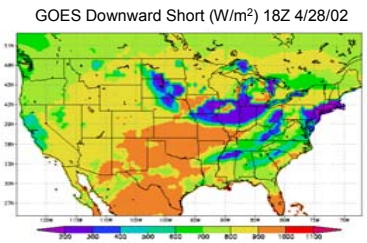
Make use of ETA / EDAS, Stage II and CPC data to form best available product—a temporally disaggregated hourly CPC value Interpolated to 1/8th degree

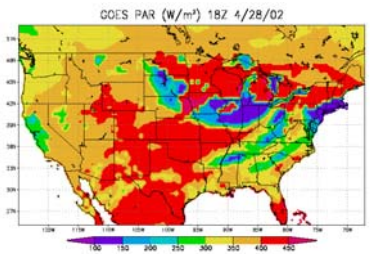


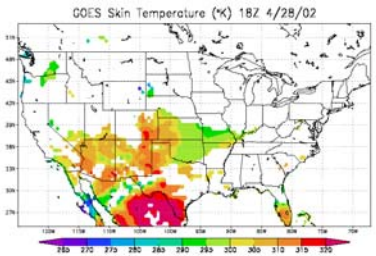




GOES data processed to create ½ degree, hourly, instantaneous surface downward shortwave radiation, PAR and skin temperature fields, interpolated to 1/8th degree

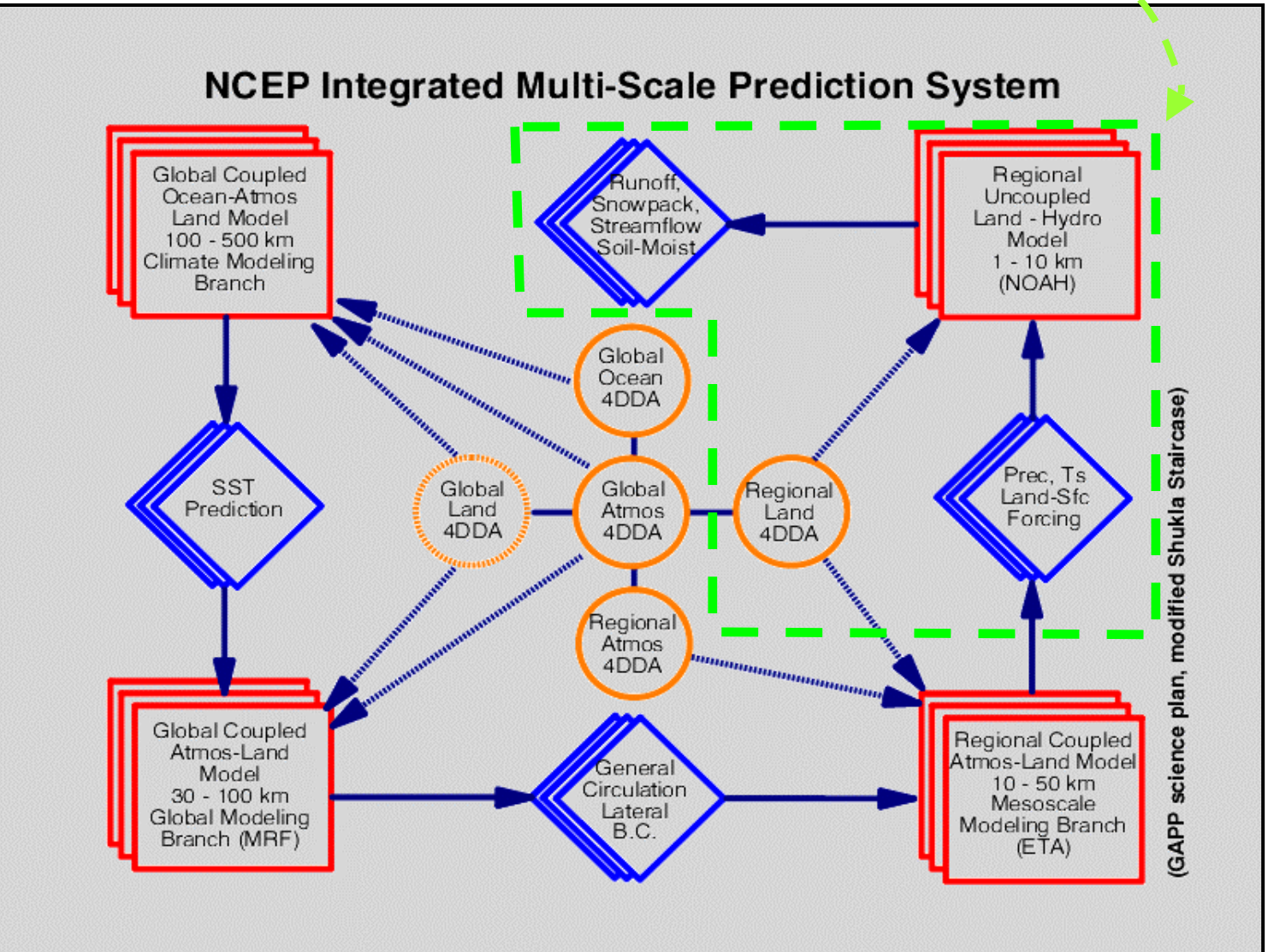






Where is NLDAS on the Shukla Staircase?

The basic concept of NLDAS is also applied to different scales



Ensemble

Data Assimilation

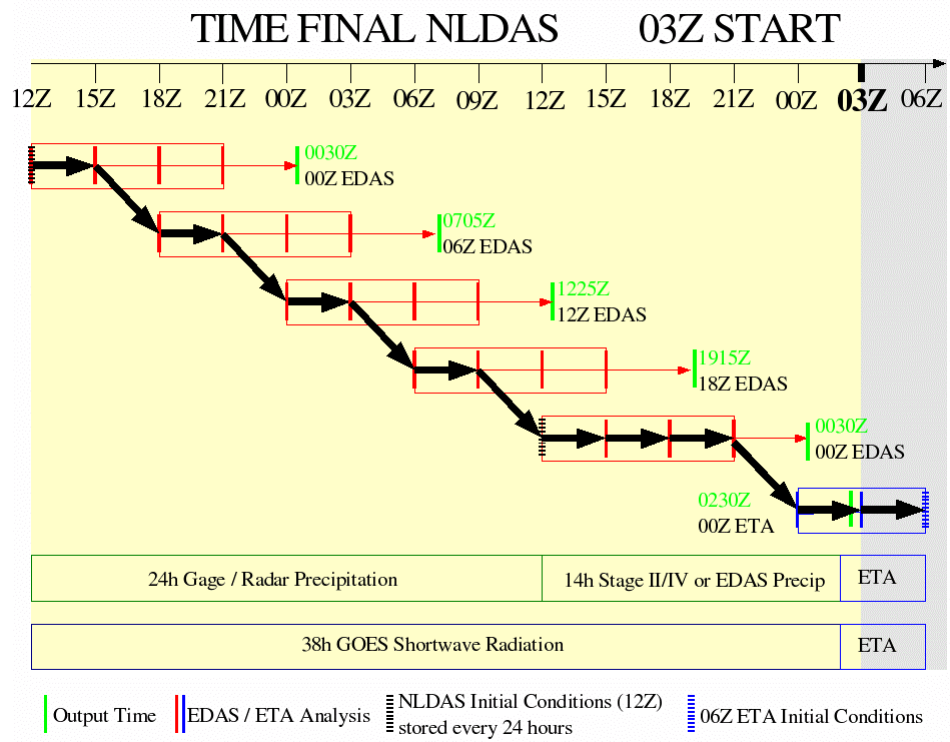
Boundary Conditions

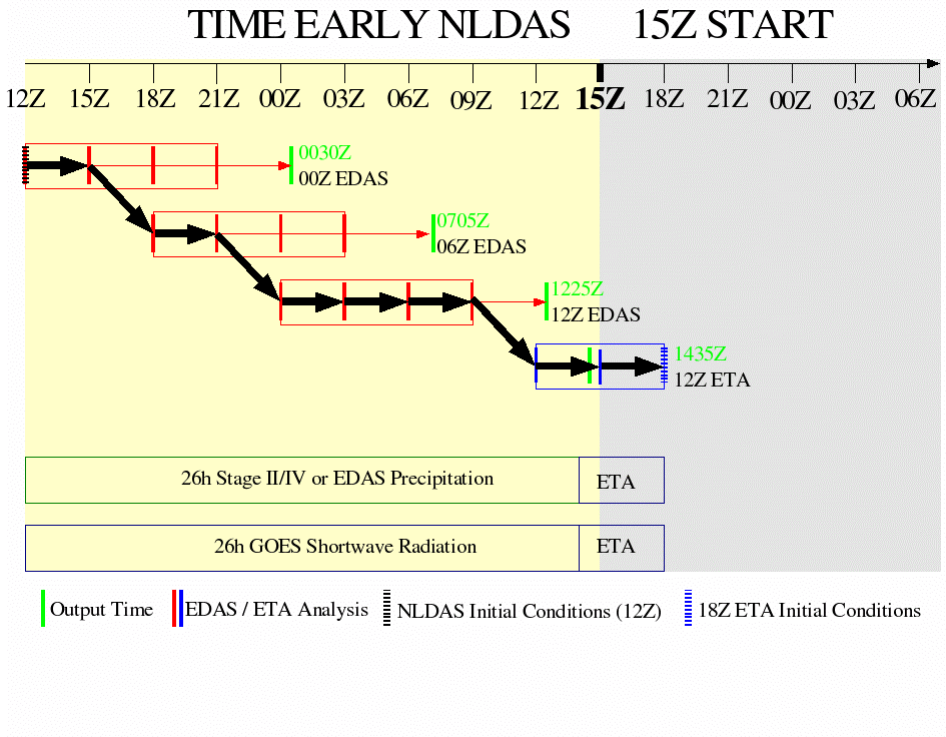
Implement Realtime NLDAS Runs

Run land surface model twice daily to initialize ETA runs

a) Final NLDAS run for 06Z ETA (starts when gauge precipitation product becomes available from previous 24h period)

b) Early NLDAS run for 18Z ETA

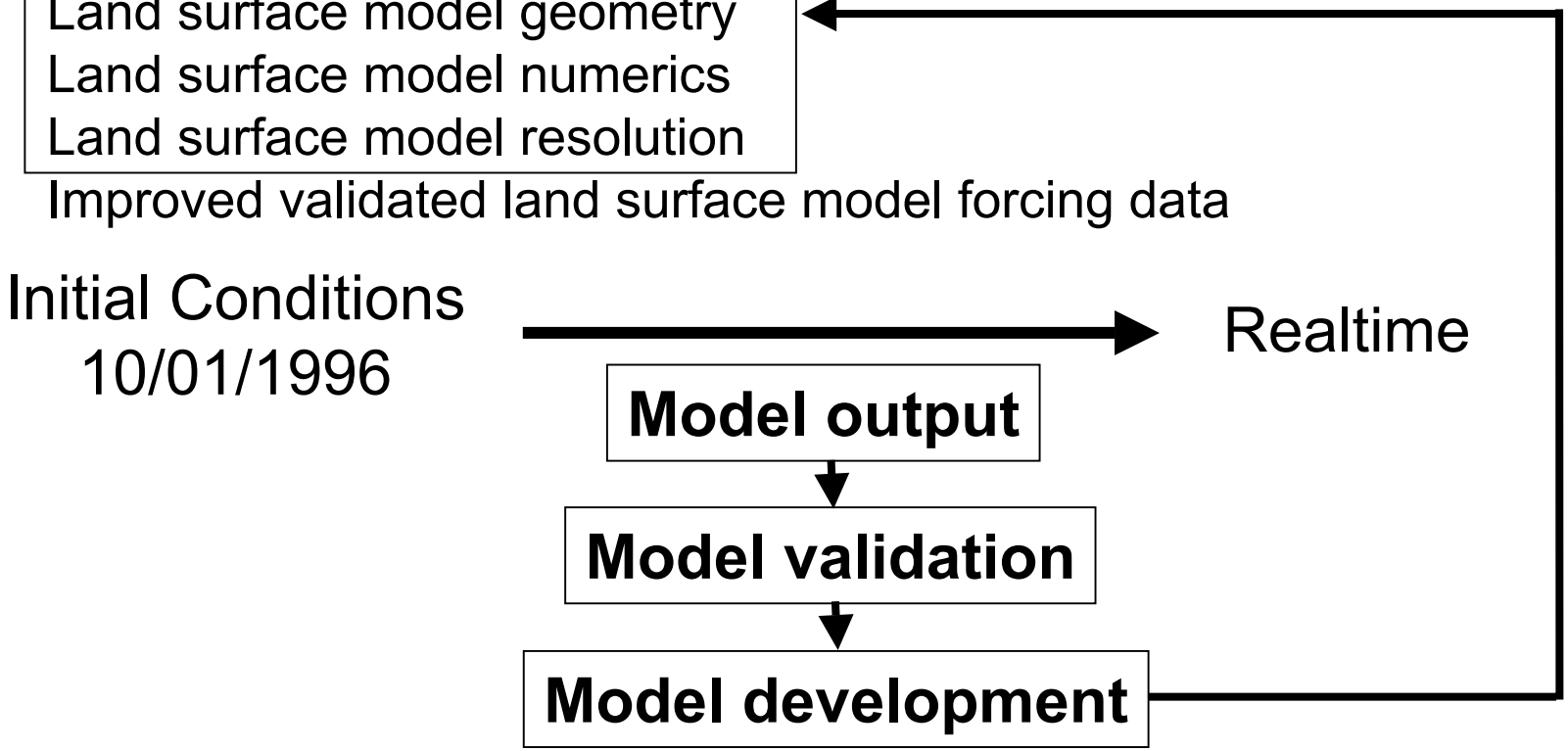




Implement Retrospective NLDAS Runs

Run land surface model whenever there are changes to

- Land surface model parameters
- Land surface model physics
- Land surface model geometry
- Land surface model numerics
- Land surface model resolution
- Improved validated land surface model forcing data



Utilize multi-scale data sources, parameter estimation routines

Validation work in NLDAS Multi-Scale / Multi-Source

for retrospective period 10/96 to 09/99

10 NLDAS Papers in JGR GCIP III Special Edition

(Overview Paper by Mitchell et al., 2004)

- Forcing data (surface meteorology, radiation, precipitation): Rutgers University, Princeton University, NASA, NOAA/NCEP/EMC
- Surface energy and water fluxes at flux stations: Rutgers University
- Runoff / streamflow NOAA/NCEP/EMC, NWS-OHD, University of Washington
- Snow cover and Snow water equivalent: Princeton University
- Soil moisture Rutgers University, NWS-OHD
- Surface temperature NOAA/NCEP/EMC, Rutgers University

LDAS Validation Across Scales

Measured, Estimated		Residual	Resolution
$R_N - G - H - \lambda E$	=	0	Δt = minutes - hours
$P - E - dS/dt$	=	R	Δx = 1–100m (flux tower)
R_N	=	$G - H - \lambda E$	Δt = hours - days
$P - R$	=	$dS/dt + E$	Δx = 10km (catchment)
R_N(**Tskin**)	=	$(G - H - \lambda E)$(**Tskin**)	Δt = days – months
$P - R$	=	$dS/dt + E$	Δx = 1000km (continent)
$dW/dt + \nabla^* \underline{Q} + P$	=	E	(atmosphere)

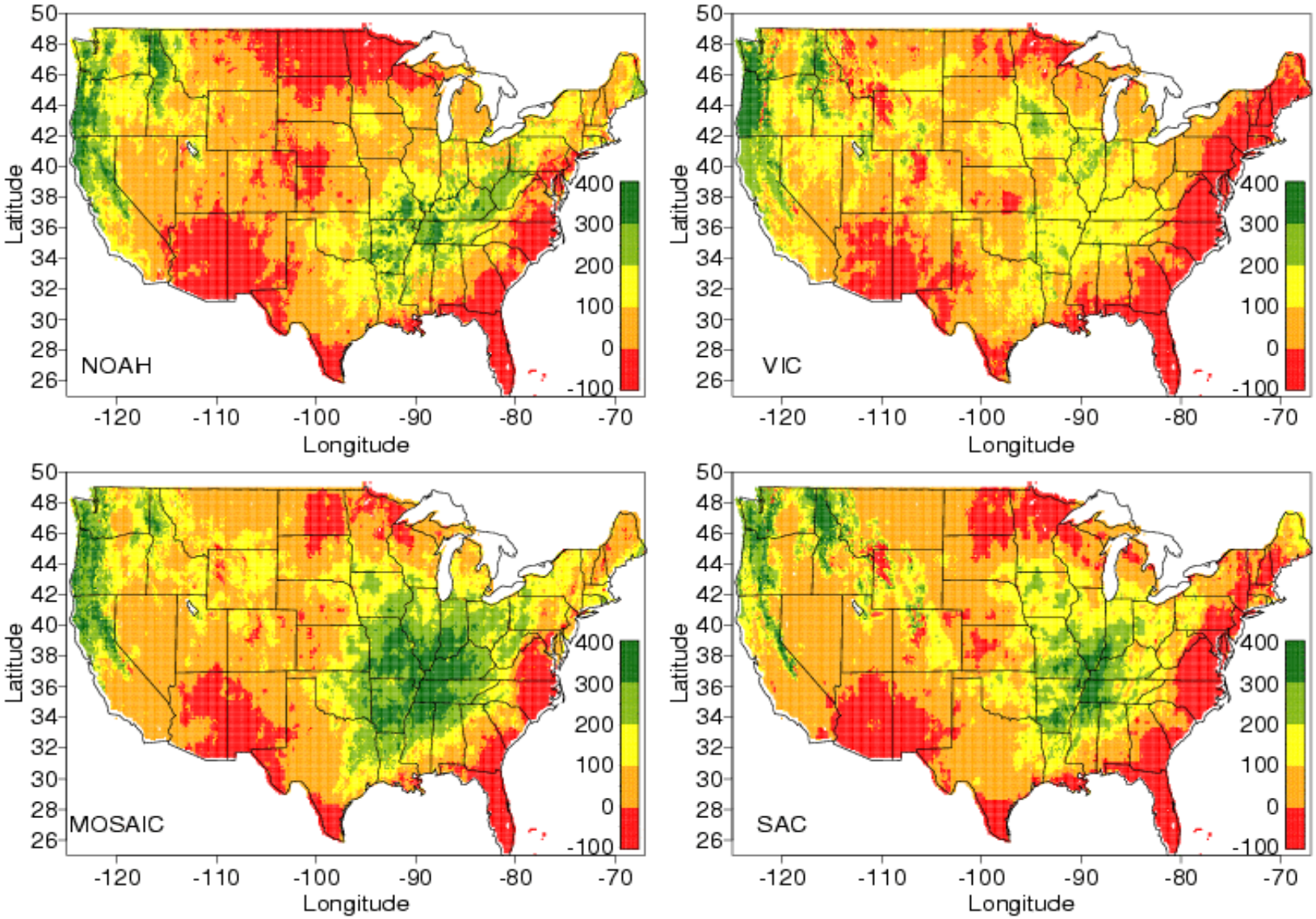
instantaneous: GOES, remote sensing
Mesonet&Surfrad, ARM/CART

daily: Streamflow, Snow Water Eq.

Coupled Terrestrial – Atmospheric Water Budget

$$dS/dt + R = -dW/dt - \nabla^* \underline{Q}$$

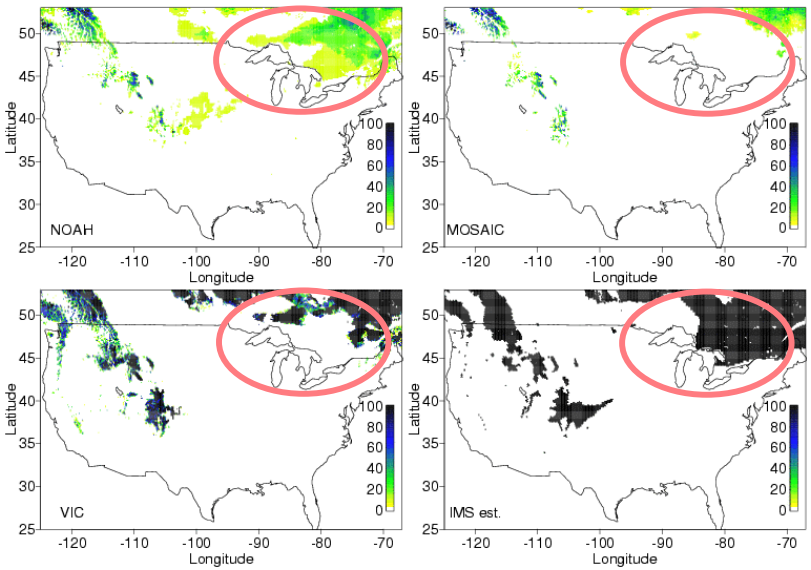
Seasonal Change of Total Column Soil Moisture [mm]
30 Apr. minus 30 Sep., 99, at 23Z



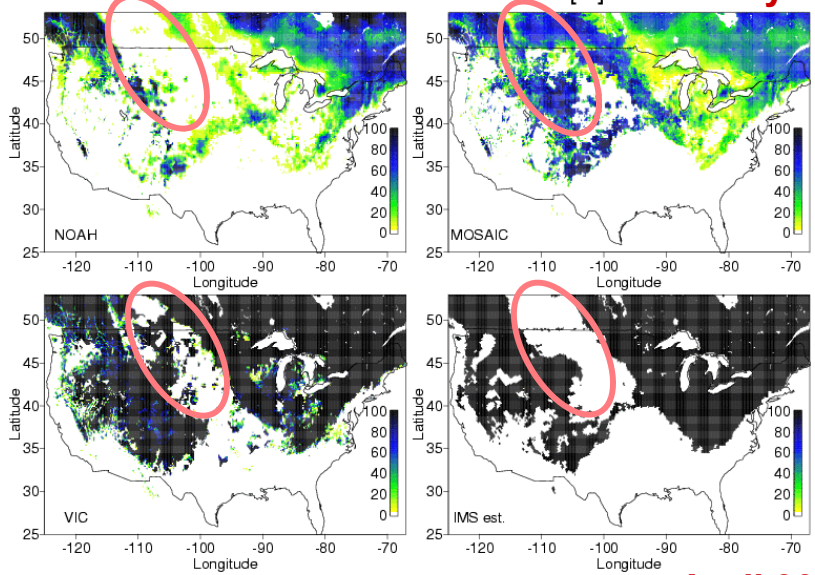
Snowpack Simulation Comparison

Snow cover product from NESDIS daily IMS: 1/16 degree N.Hemisphere grid, flag

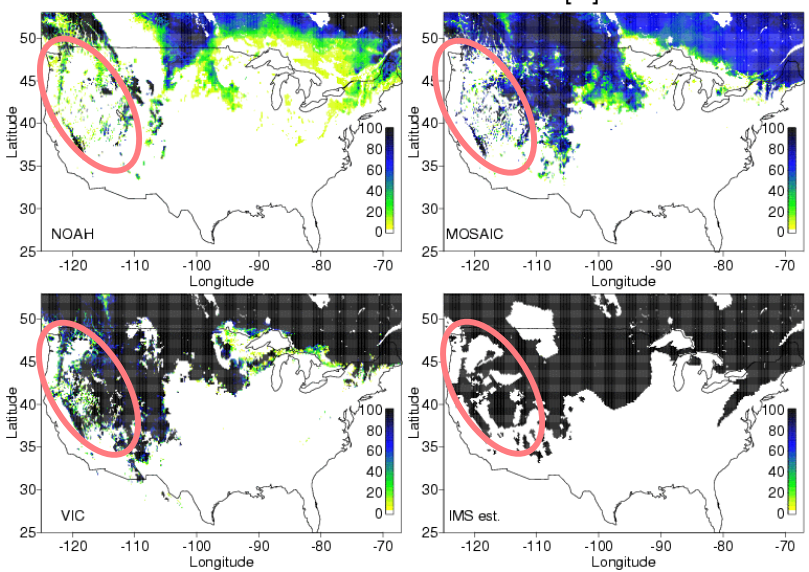
November 1st



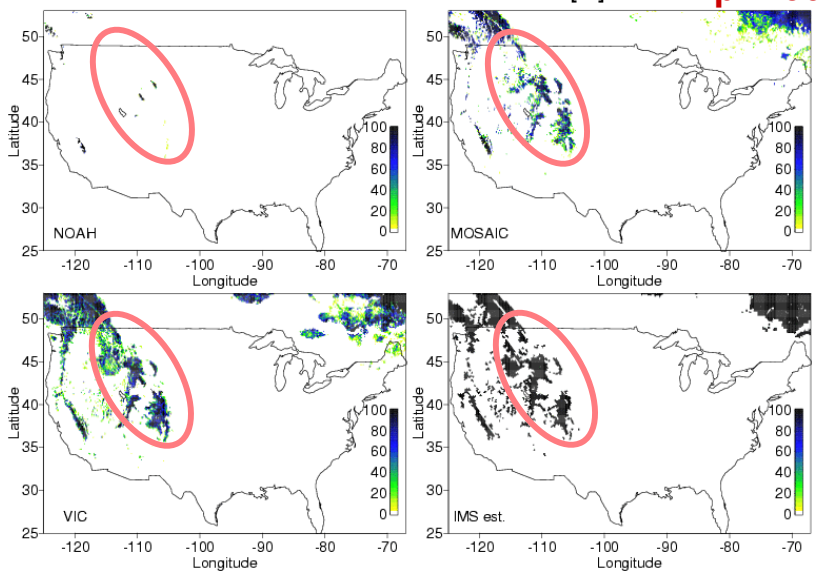
January 1st



March 1st

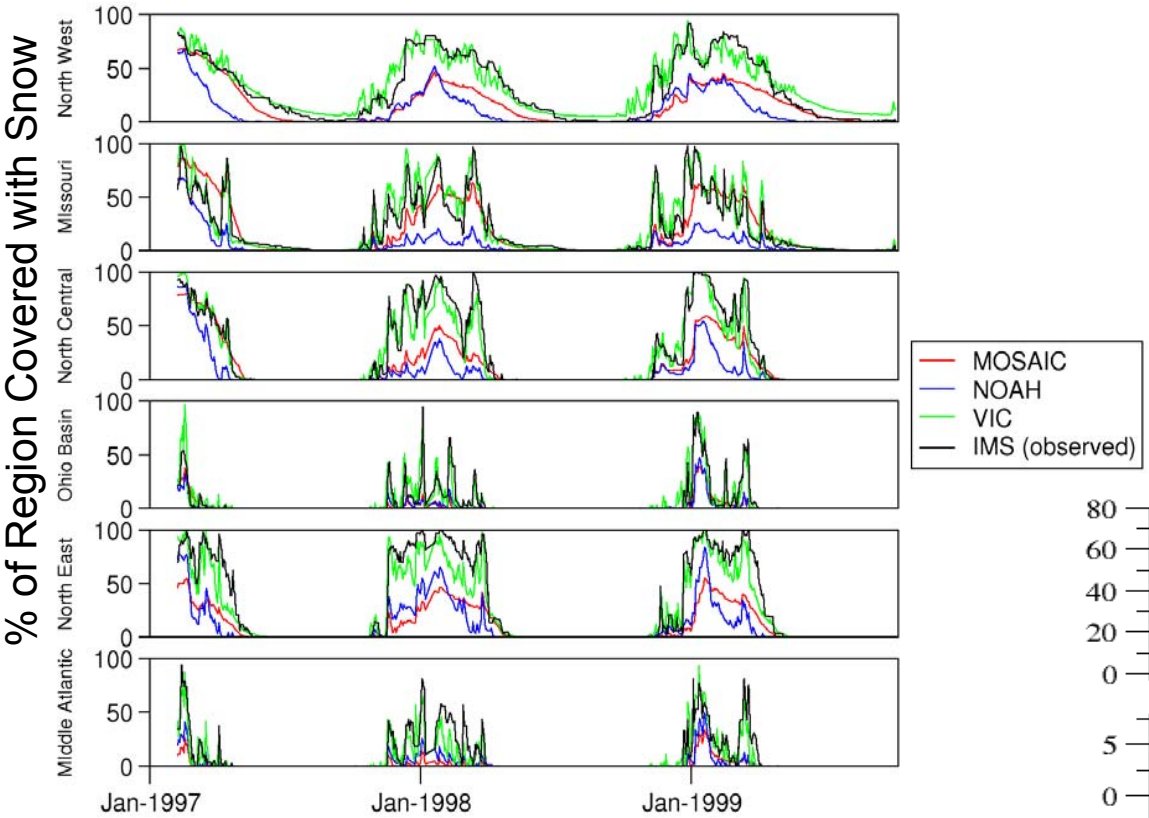


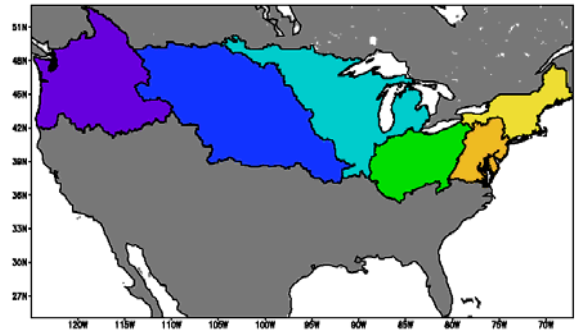
April 30st



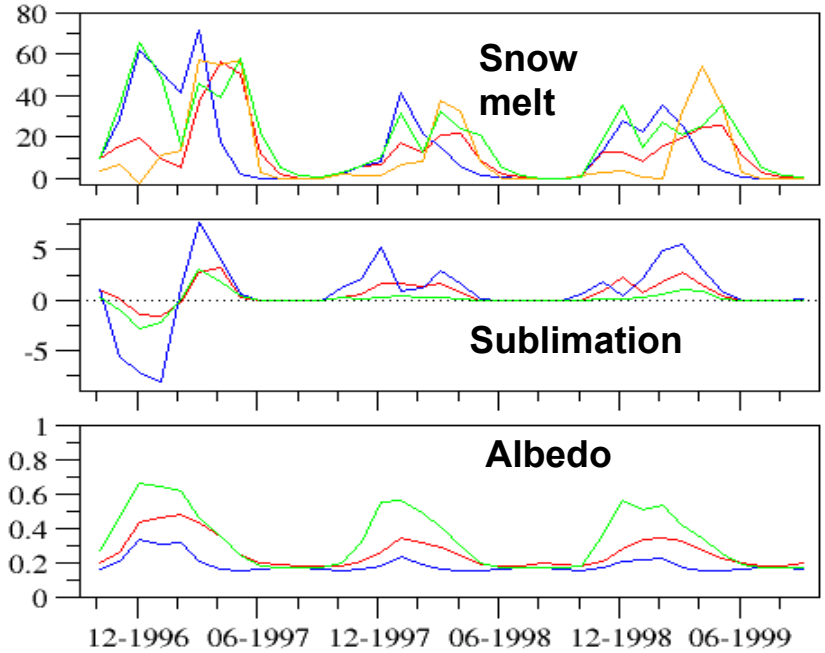
Snow Validation continued

Snow cover product from NESDIS daily IMS: 1/16 degree N.Hemisphere grid, flag

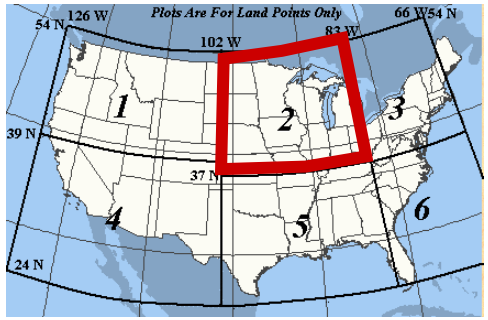




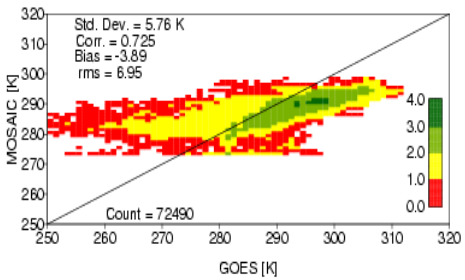
RFC Regions

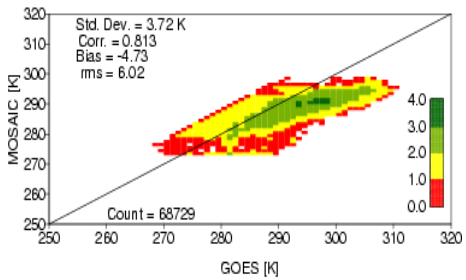


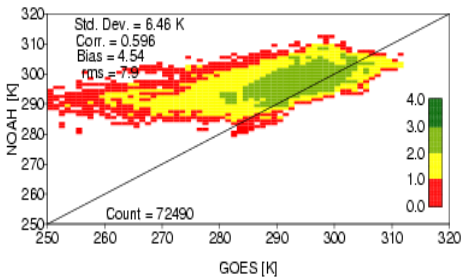
NLDAS Surface Temperature Validation for GOES-East 18Z, Area 2 with and without screening

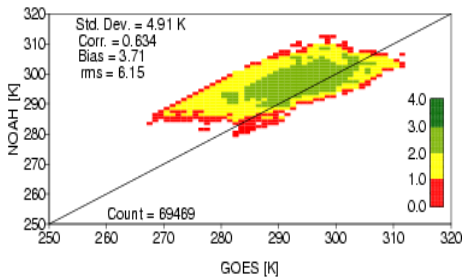


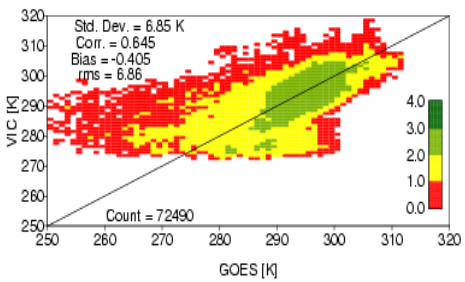
April 1999

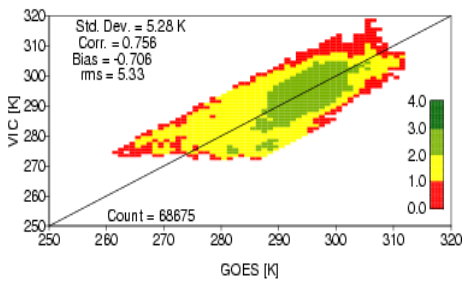




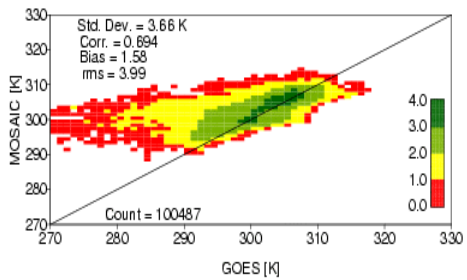


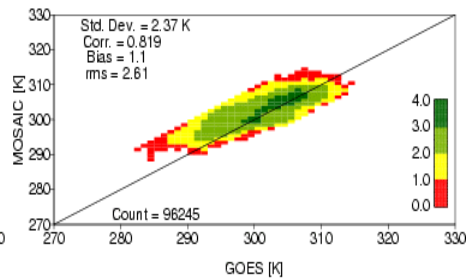


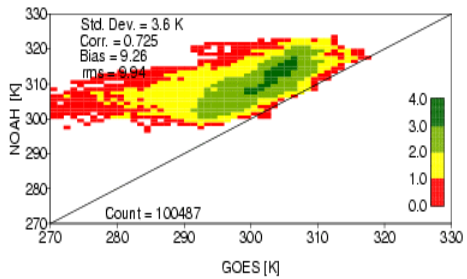


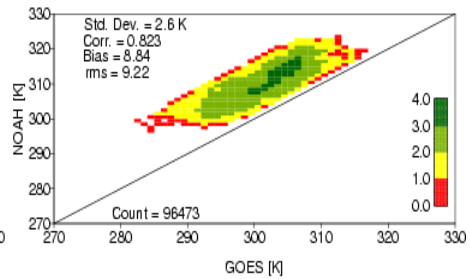


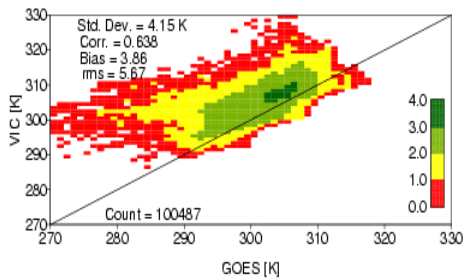
July 1999

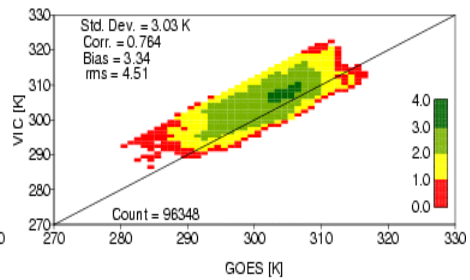




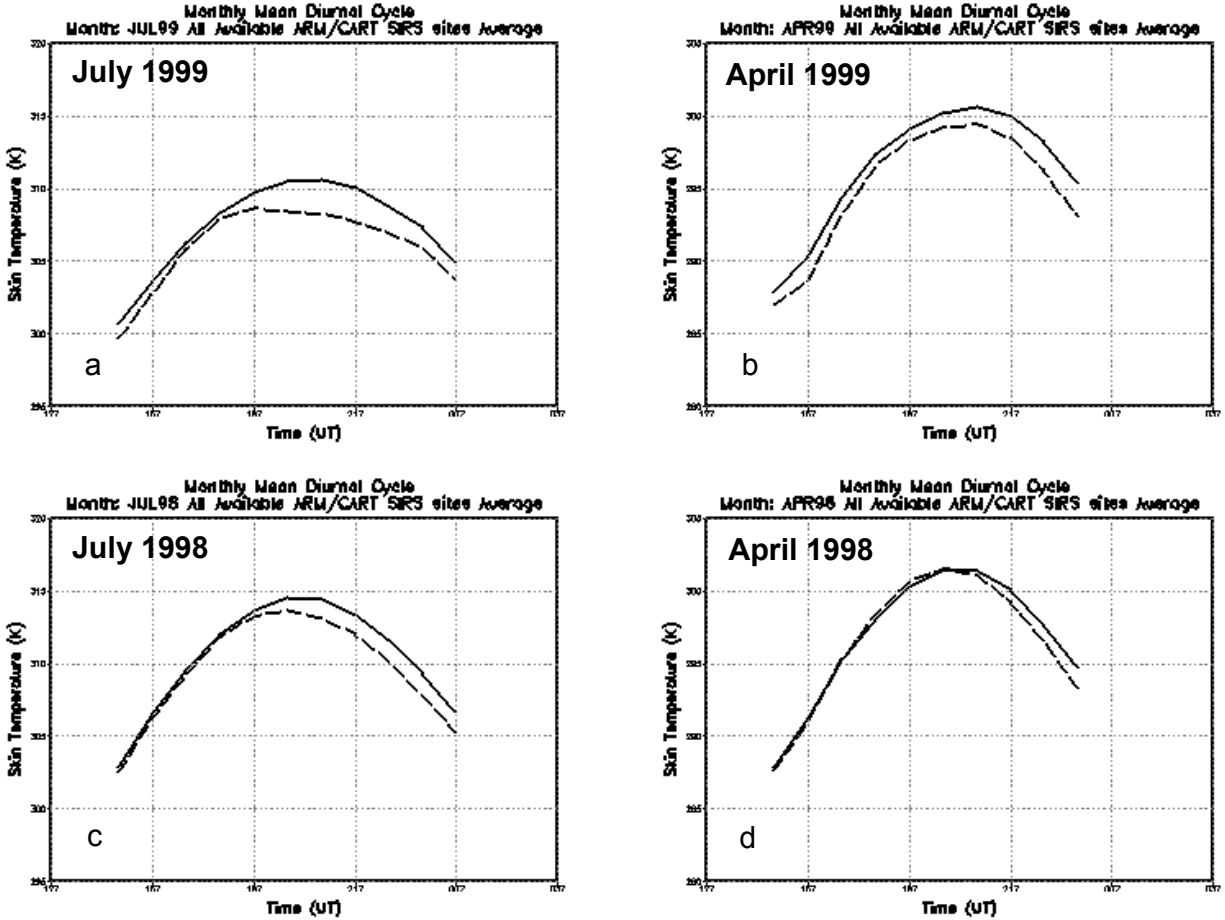








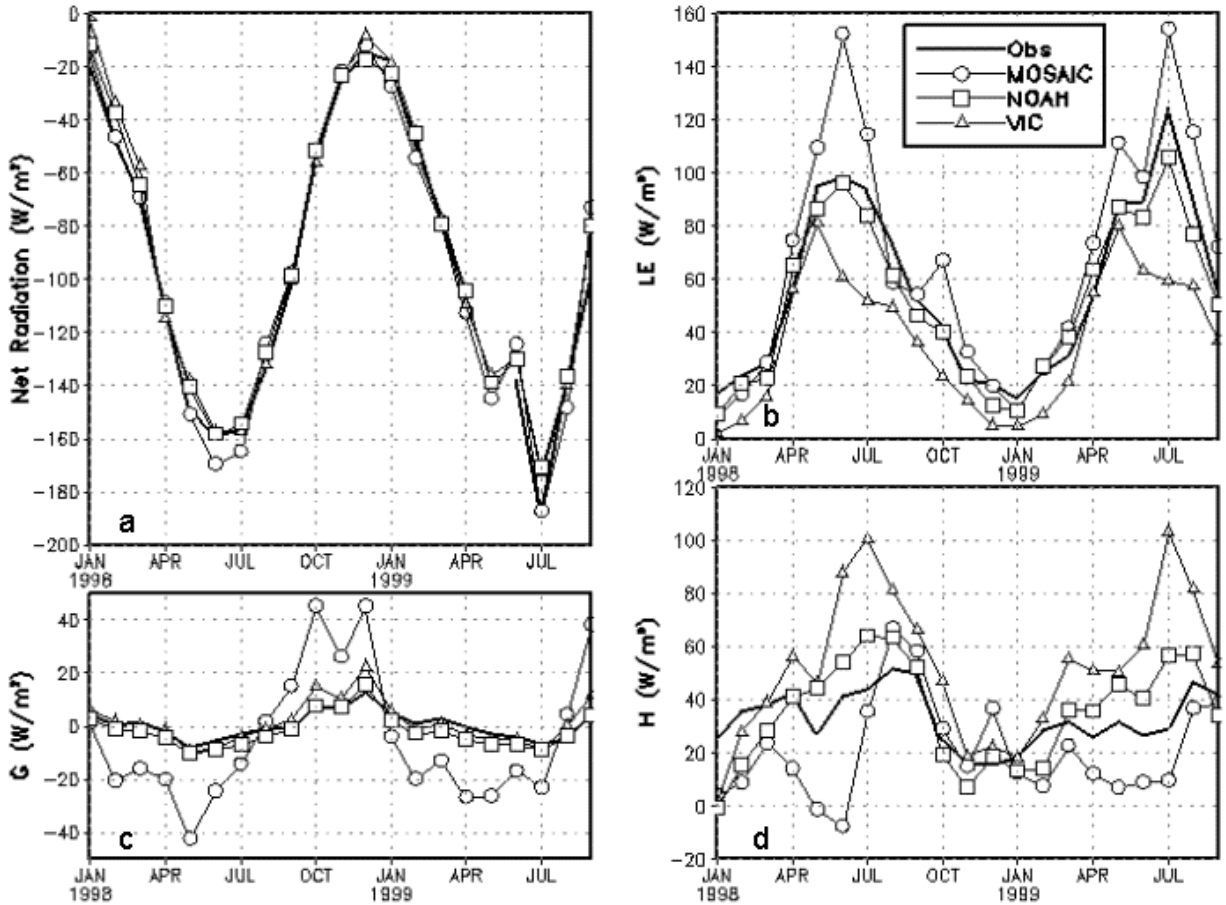
GOES Skin Temperature Validation



Monthly mean diurnal cycle of LST (K) averaged over all ARM/CART SIRS sites for July (left) and April (right) during 1999 (top) and 1998 (bottom) from SIRS observations (solid) and GOES-East retrieval (dashed).

In progress: Assimilation of GOES skin temperature with Noah Adjoint Noah model

Surface Flux Validation



Similar to previous PILPS results:
-Models have a wide spread in modeled energy fluxes despite identical forcing

Monthly mean surface energy fluxes (Wm^2) of (a) net radiation R, (b) latent heat LE, (c) ground heat G and (d) sensible heat H averaged over the ARM/CART sites during January 1998 to September 1999

Conclusions NLDAS

- NLDAS project is an effective tool to determine, operationally, land surface states, and to understand integrated validation (remote sensing and in-situ) across all scales.
- Model results, using default parameters, have a wide spread for some states and fluxes. Every model is doing something better than other models in some parts of the country
- IMS is high-quality data for understanding large scale snow cover and its time evolution – new version of Noah model addresses snow modeling shortcomings
- Ongoing validation is documented in a series of 10 papers of the GCIP / GAPP JGR special issue (2003 / 2004)
- Data assimilation is in progress

Data available for Oct. 1996 to realtime

Multi-agency + Universities research project

Strategic Issues

1. Land Surface Models

   A framework that allows for objective and accountable model development including calibration and validation, data at a variety of space/time scales, and long-term data.

2. Implementing LDAS system

   Multi-models are needed, need to address multi-year spin-up, need a framework for evaluating the value of LDAS systems in prediction.

Near Future NLDAS NCEP Activities

1. Model Modifications
   - Include NLDAS surface microwave emission model
   - Include new land surface types (lakes/reserviors, urban, irrigation), and groundwater.
   - Set-up NLDAS on Eta grid
   - Expand domain to cover Mexico
2. Forcing Modifications
   - Use 12km EDAS forcing instead of 40km output
   - Use 1/8-degree GOES product
   - Use realtime weekly 0.144 degree greenness from NESDIS
3. LDAS forecast activities
   - Include forecast component (1-3 days, 1-15 days, 1-45 days, 1-6 months) with ensembles
   - Implement large scale data assimilation / parameter estimation routines
   - Use output from and integrate NLDAS with ensemble forecasts