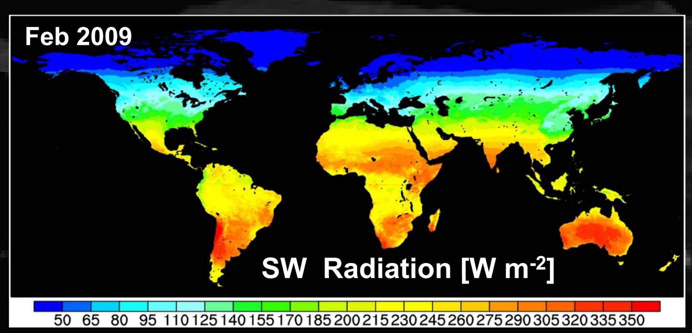
The Global Land Data Assimilation System

Rasmus Houborg, Matthew Rodell, Hiroko Beaudoing, Ben Zaitchik

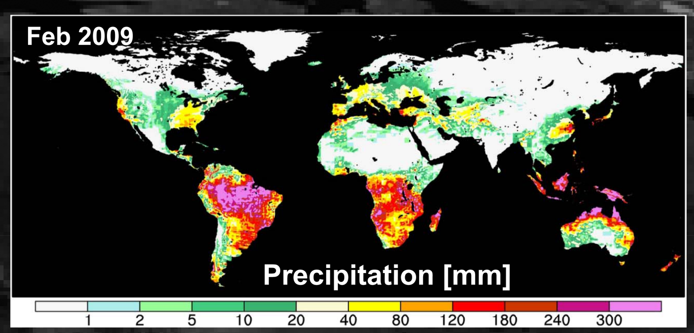
Hydrological Sciences Branch, NASA Goddard Space Flight Center, Greenbelt, MD

FORCING FIELDS

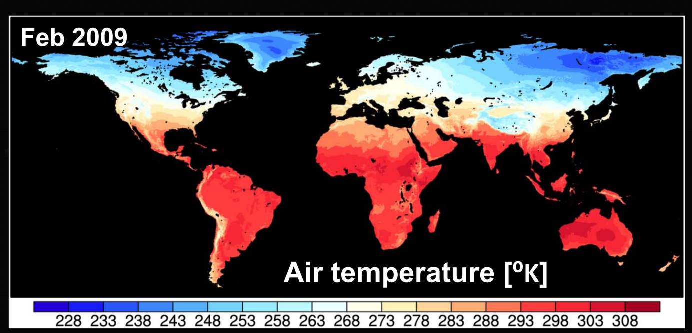
GLDAS uses base forcing from global operational weather forecast models such as NCEP's Global Data Assimilation System (GDAS), The European Center for Medium-Range Weather Forecasts (ECMWF), and NASA's Goddard EOS Data Assimilation System (GEOS). The model forcing is combined with optional observation-based datasets of radiation and precipitation from various sources

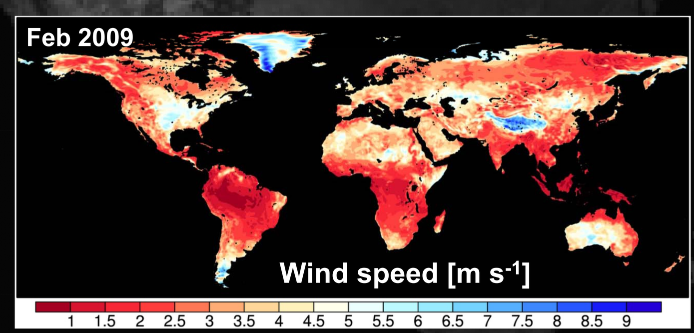


1/4 Deg incoming short-wave radiation fluxes based on the Air Force Weather Agency Agricultural Meteorology modeling system (AFWA AGRMET). A global cloud analysis is produced hourly from various visible and IR satellite data sources. AGRMET also provides GLDAS with the incoming long-wave radiation component.



The Merged Analysis of Precipitation (CMAP) fields from the Climate Prediction Center are used as the primary precipitation source in GLDAS. CMAP merges gauge observations with precipitation estimates from several satellite-based algorithms. TRMM and PERSIANN are other available satellite-based precipitation sources.





GDAS model reanalysis fields of air temperature and wind speed. Global fields of air humidity and surface pressure are also retrieved from global operational weather forecast models in order to force the GLDAS land surface models.

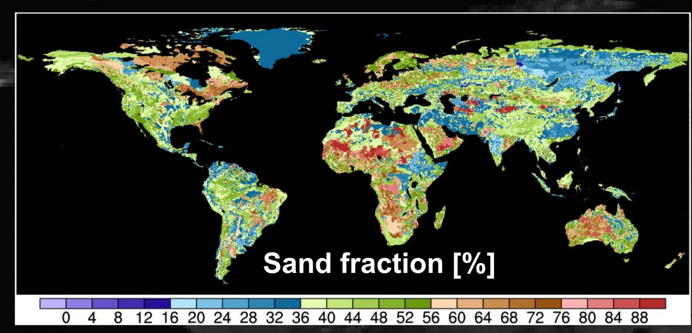
GLDAS

The Global Land Data Assimilation System (GLDAS) integrates a large quantity of observation-based and model (re)analysis data by using it to parameterize, force, and constrain sophisticated numerical land surface models towards the goal of producing physically consistent, high resolution fields of land surface states (e.g. snow, land surface temperature, soil moisture) and fluxes (e.g. evapotranspiration, runoff) . GLDAS typically executes at 1/4° and 1° spatial and 3h – monthly temporal resolution, enabled by the Land Information System (LIS). GLDAS currently drives four land surface models: Common Land Model (CLM), MOSAIC, Noah, and Variable Infiltration Capacity (VIC) model.

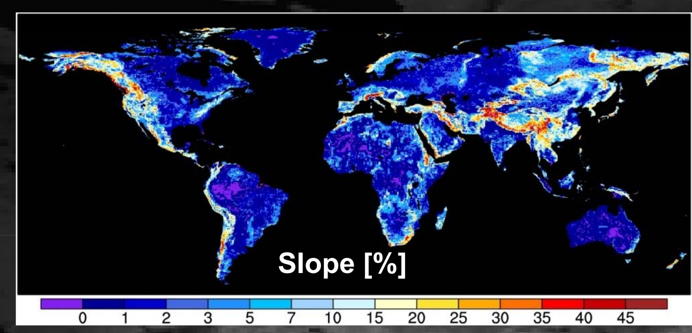
Spatial extent:	All land north of 60°S
Spatial resolution:	1 km – 1°
Time period:	1979 - present
Temporal resolution:	3-hourly output fields
Homepages:	http://ldas.gsfc.nasa.gov/index.shtml http://lis.gsfc.nasa.gov/

PARAMETER INPUTS

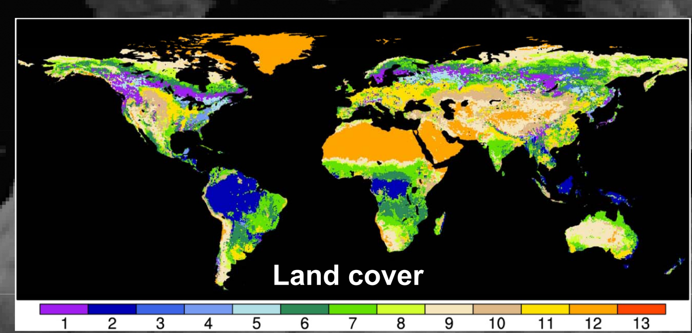
GLDAS runs its land surface models using a vegetation-based tiling approach to simulate variability below the scale of the model grid squares (1/4° or 1°). A 1 km global vegetation dataset which currently uses the UMD classification scheme is the basis for designating tile space. The static soil and elevation parameters are based on high resolution global datasets.



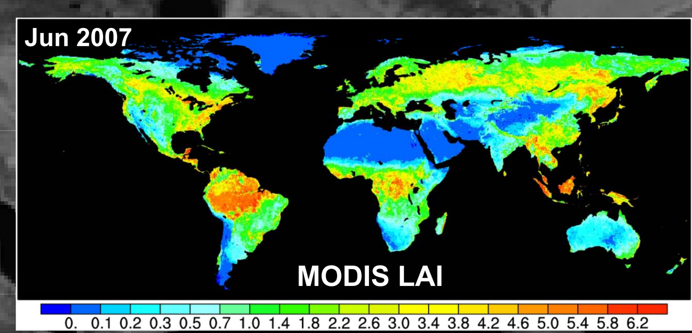
The basic soil dataset used in GLDAS includes fractions of sand, silt, and clay, and porosity, among other fields, and it is based on the FAO Soil Map of the World linked to a global database of over 1300 sample soil cores (Reynolds et al. 2000).



The slope data was derived from the GTOPO30 global digital elevation model that has a horizontal grid spacing of 30 arc seconds (~ 1km) (Verdin and Greenlee, 1996).



GLDAS dominant vegetation type dataset (0.25 degree). The predominant vegetation type in each 0.25 grid square has been assigned based on a 1 km resolution global vegetation dataset which used the University of Maryland classification scheme (Hansen et al., 2000).



MODIS based global 8-day LAI dataset. GLDAS currently uses a LAI climatology based on 20 years of AVHRR data (1982 - 2002) as default (Gottschalck et al. 2002).

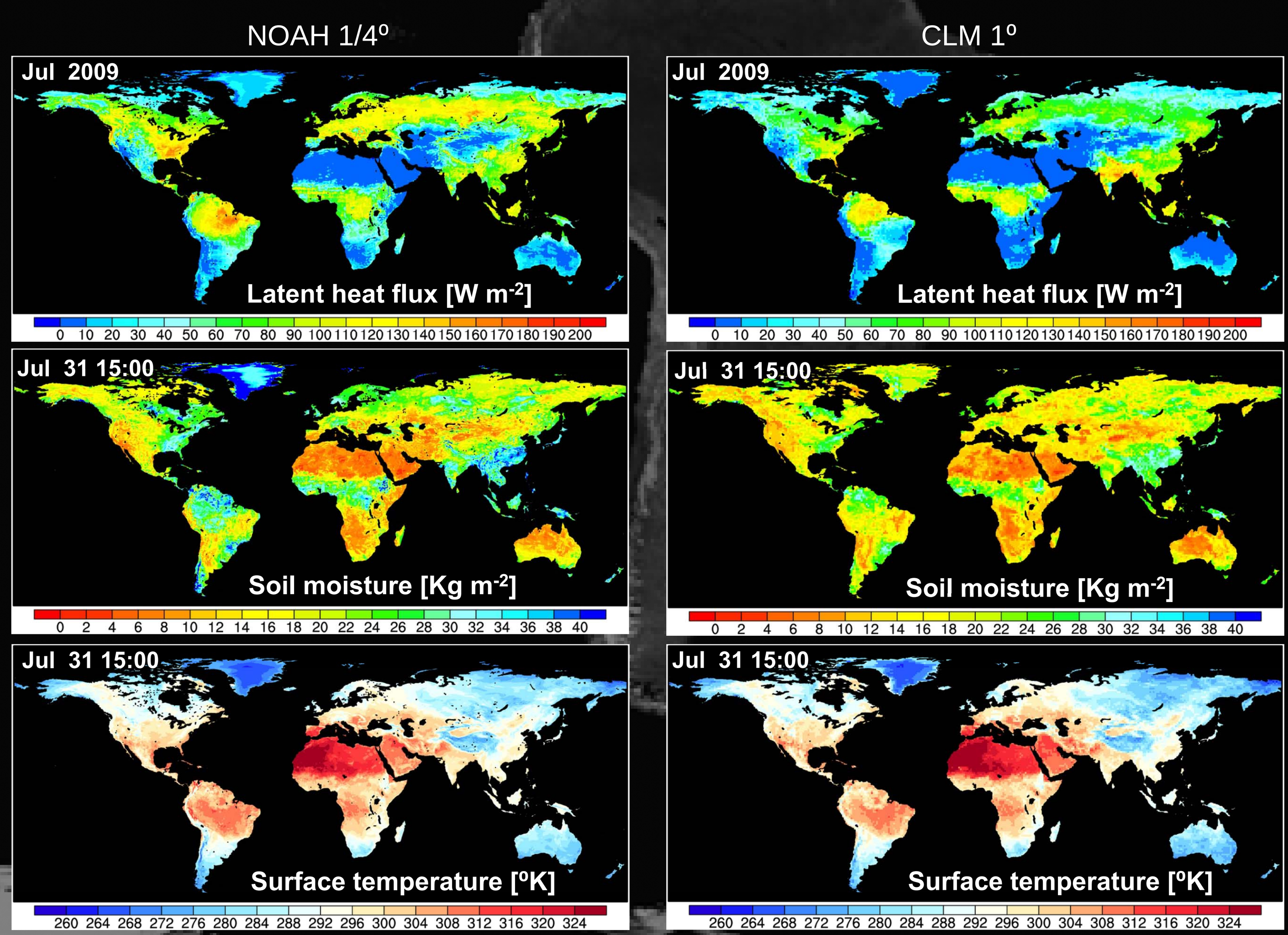
DATA AVAILABILITY AND VISUALIZATION

To support scientific research and water resources applications worldwide, GLDAS datasets are made available for download from the Hydrology Data and Information Services Center (HDISC). Users can access 3-hourly and monthly 0.25 and 1.0 degree global outputs from the Noah, CLM, MOSAIC and VIC land surface models.

HDISC → http://disc.gsfc.nasa.gov/hydrology/

Data Type (Short Name)	Description	FTP	GDS	Mirador Navigation	Mirador Search
NLDAS, 0.125 degree, North America					
NLDAS_FORA0125_H.002	Hourly primary forcing	✔	✔	✔	✔
NLDAS_FORB0125_H.002	Hourly secondary forcing	✔	✔	✔	✔
NLDAS_MOS0125_H.002	Hourly Mosaic	✔	✔	✔	✔
GLDAS, 0.25 degree, Global					
GLDAS_NOAH025SUBP_3H	3 hourly Noah	✔	✔	✔	✔
GLDAS_NOAH025_M	Monthly Noah	✔	✔	✔	✔
GLDAS, 1.0 degree, Global					
GLDAS_CLM10SUBP_3H	3 hourly CLM	✔	✔	✔	✔
GLDAS_CLM10_M	Monthly CLM	✔	✔	✔	✔
GLDAS_MOS10SUBP_3H	3 hourly Mosaic	✔	✔	✔	✔
GLDAS_MOS10_M	Monthly Mosaic	✔	✔	✔	✔
GLDAS_NOAH10SUBP_3H	3 hourly Noah	✔	✔	✔	✔
GLDAS_NOAH10_M	Monthly Noah	✔	✔	✔	✔
GLDAS_VIC10_3H	3 hourly VIC	✔	✔	✔	✔
GLDAS_VIC10_M	Monthly VIC	✔	✔	✔	✔

HDISC provides data in GRIB and NetCDF format. The users can subset spatially and/or by parameter. Full documentation including detailed parameter descriptions is available



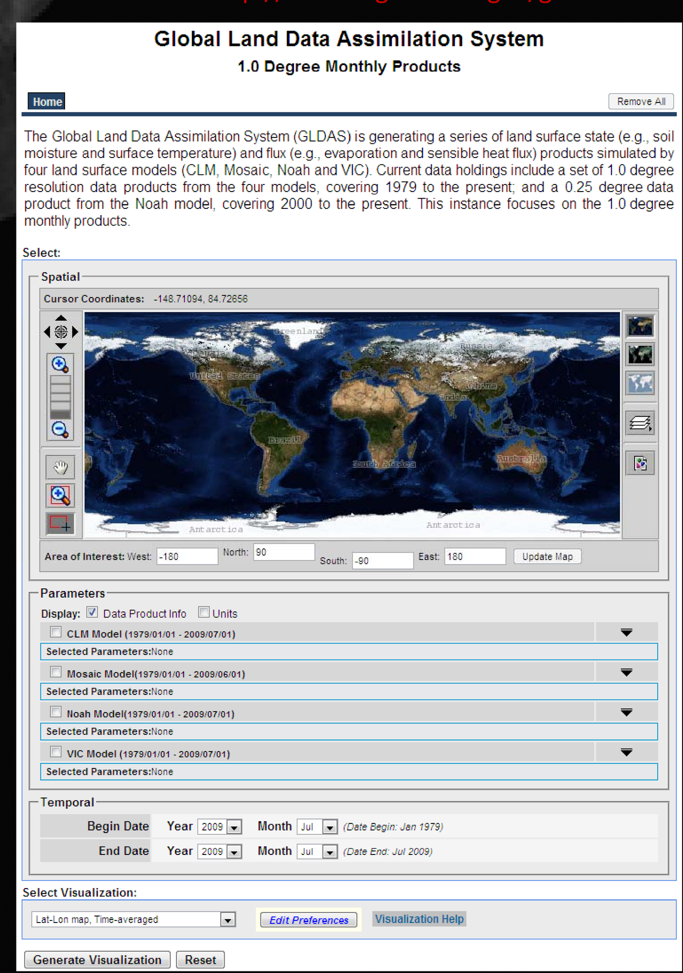
Giovanni is an application that provides a simple interface to visualize, analyze, and access vast amounts of GLDAS data without having to download the data. Current data holdings include 1.0 degree monthly products from the four land surface models, covering 1979 to the present. Giovanni is a useful tool for intercomparing model output from the suite of GLDAS land surface models for any user-specified spatial domain and time-period.

Summary of output fields

Water balance	Energy balance
Soil moisture (layer)	Net shortwave radiation
Total canopy water storage	Net longwave radiation
Snow water equivalent	Sensible heat flux
Total evapotranspiration	Latent heat flux
Rainfall rate	Ground heat flux
Snowfall rate	Surface temperature
Surface runoff	Soil temperature (layer)
Subsurface runoff	

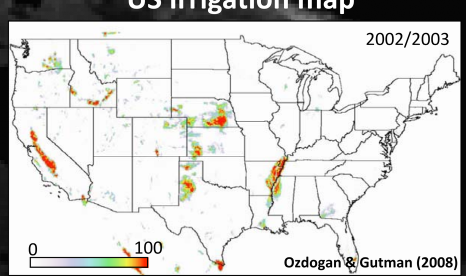
Intercomparative Noah 0.25 degree and CLM2 1.0 degree output fields of monthly averaged latent heat flux, and 3-hourly surface soil moisture and surface temperature (at 15:00 UTC). Data downloaded from HDISC

Giovanni → http://disc.sci.gsfc.nasa.gov/giovanni



INCORPORATING IRRIGATION EFFECTS

US Irrigation map

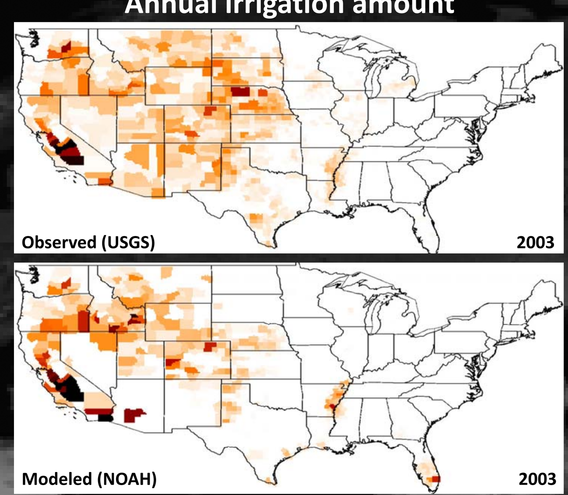


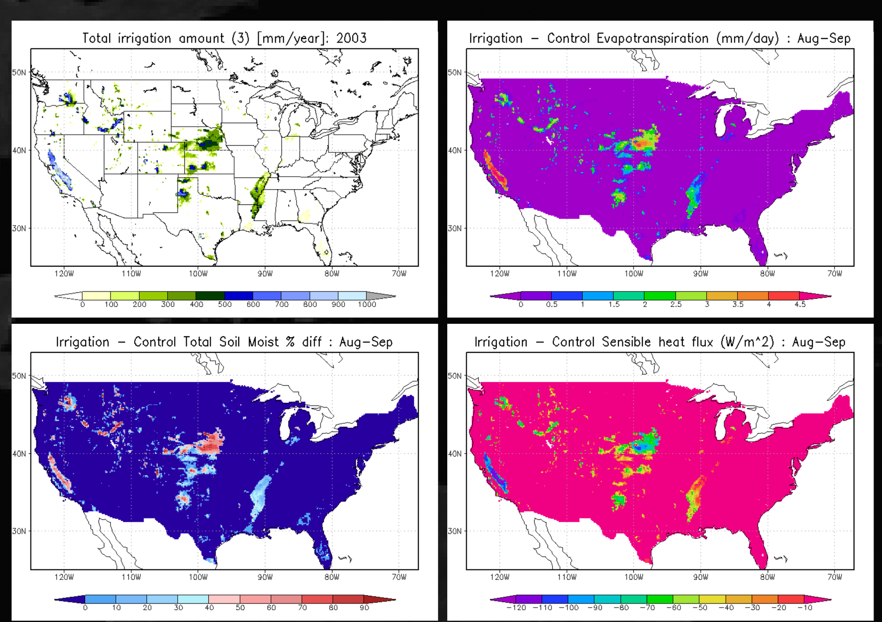
Intensity of Irrigation map for the U.S. developed at 500 m resolution based on MODIS imagery

Irrigation can have a significant effect on land surface states (soil moisture and surface temperature) and energy fluxes but is rarely incorporated into land surface models. A recently developed innovative algorithm applies irrigation based on MODIS derived intensity of irrigation (left), crop type, time of year, soil dryness, and common irrigation practices.

The modeled annual irrigation totals (km³) for 2003 are consistent with data reported by the USGS (right).

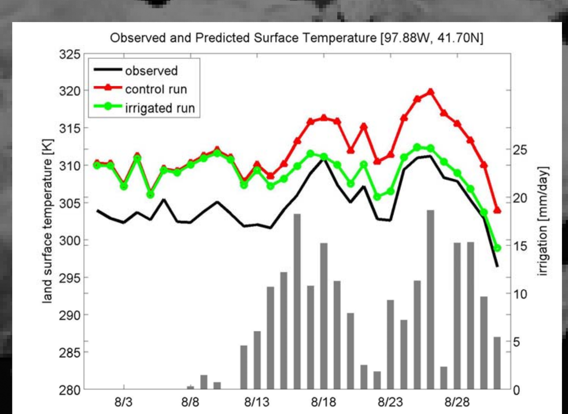
Annual irrigation amount





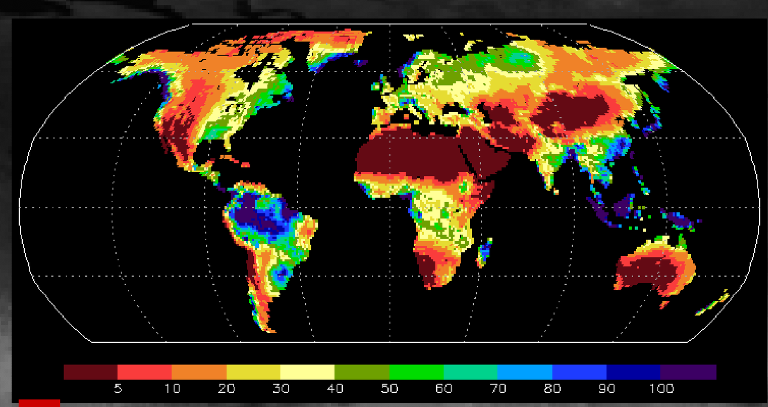
The irrigation was applied in the Noah land surface model and the results demonstrate that in parts of the U.S. where irrigation is intensive, it significantly affects soil moisture, evapotranspiration, and sensible heat fluxes (left).

Incorporation of irrigation leads to improved surface temperature predictions (right)



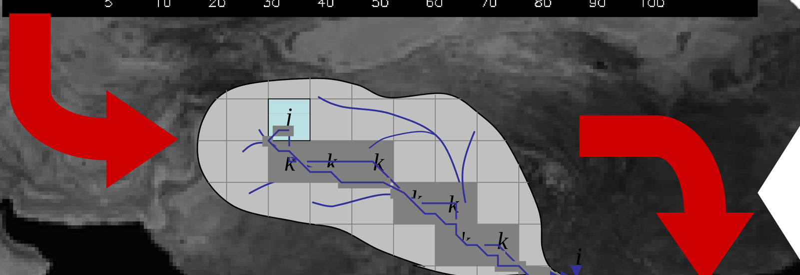
Ozdogan, Rodell, Beaudoing, Toll (2009). *J. Hydrometeor.*, DOI: 10.1175/2009JHM1116.1

RUNOFF ROUTING SCHEME

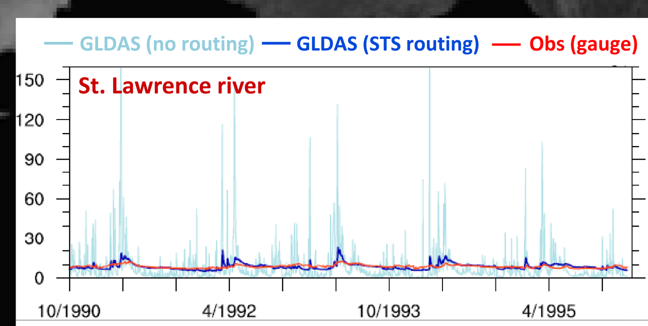


River discharge is a quantity that integrates all upstream water cycle processes making it an important indicator of the hydrologic and climatic conditions of a river basin, as well as a useful tool for evaluating hydrologic models. By applying a source-to-sink runoff routing scheme to gridded runoff maps generated by a global hydrologic model, we can produce more accurate estimates of discharge from the world's major rivers.

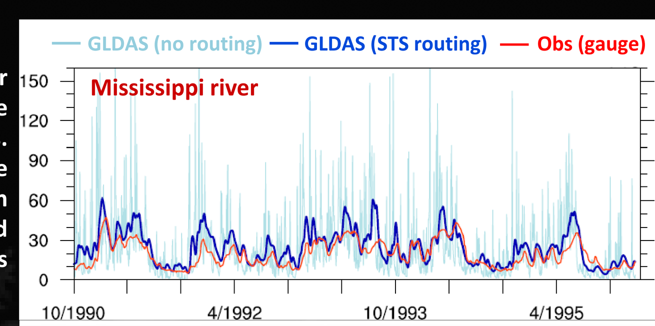
GLDAS gridded mean annual runoff as equivalent height of water in units of cm/yr. This output is not appropriate for direct comparison with gauge observations, which integrate the combined runoff from all upstream locations



This schematic represents the runoff routing algorithm that we apply to GLDAS gridded runoff. It is a source-to-sink (STS) scheme, which means that streamflow parameters have been estimated *a priori*, and the algorithm can be applied to modeled runoff as a post process to produce a time series of discharge for each predetermined outflow location.



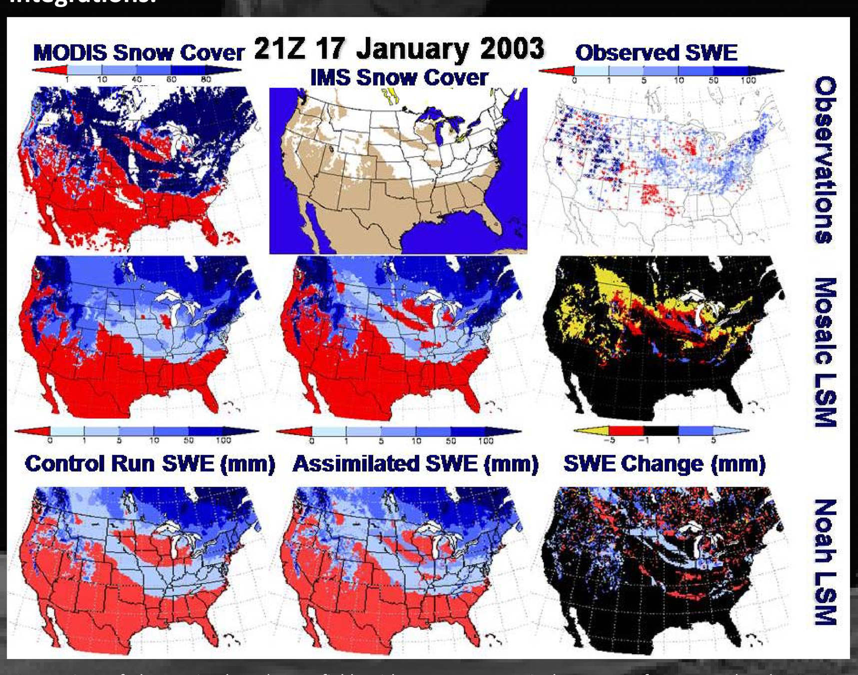
Modeled and observed river discharge (1000 m3/s) from the Lawrence and Mississippi rivers. The original modeled discharge includes unrealistic high frequency variability. The routed discharge matches observations more closely.



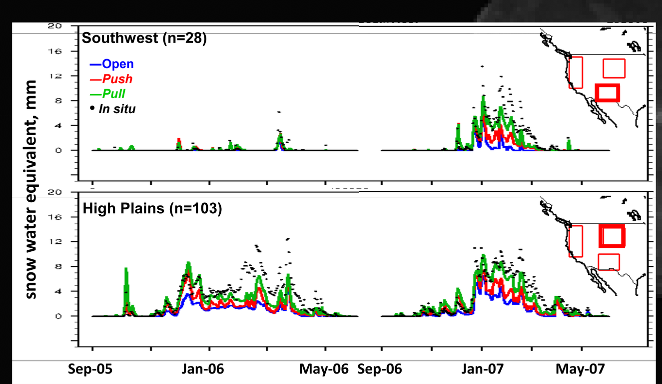
Zaitchik, Rodell, Olivera (2009). *Water Resour. Res.* (in review)

SNOW COVER ASSIMILATION

Snow cover over land has a significant impact on the surface radiation budget, turbulent energy fluxes to the atmosphere, and local hydrological fluxes. A new "pull" snow cover assimilation technique has been developed that introduces MODIS snow cover observations to the Noah LSM in global simulations. The assimilation algorithm provided improved simulation of snow covered area and snow water equivalent relative to open loop (control run) integrations.



Comparison of observation based snow fields with snow water equivalent output from control and MODIS snow cover assimilation runs of the MOSAIC and NOAH land surface models, driven by GLDAS. Assimilated output agrees more closely with IMS snow cover and ground observations.



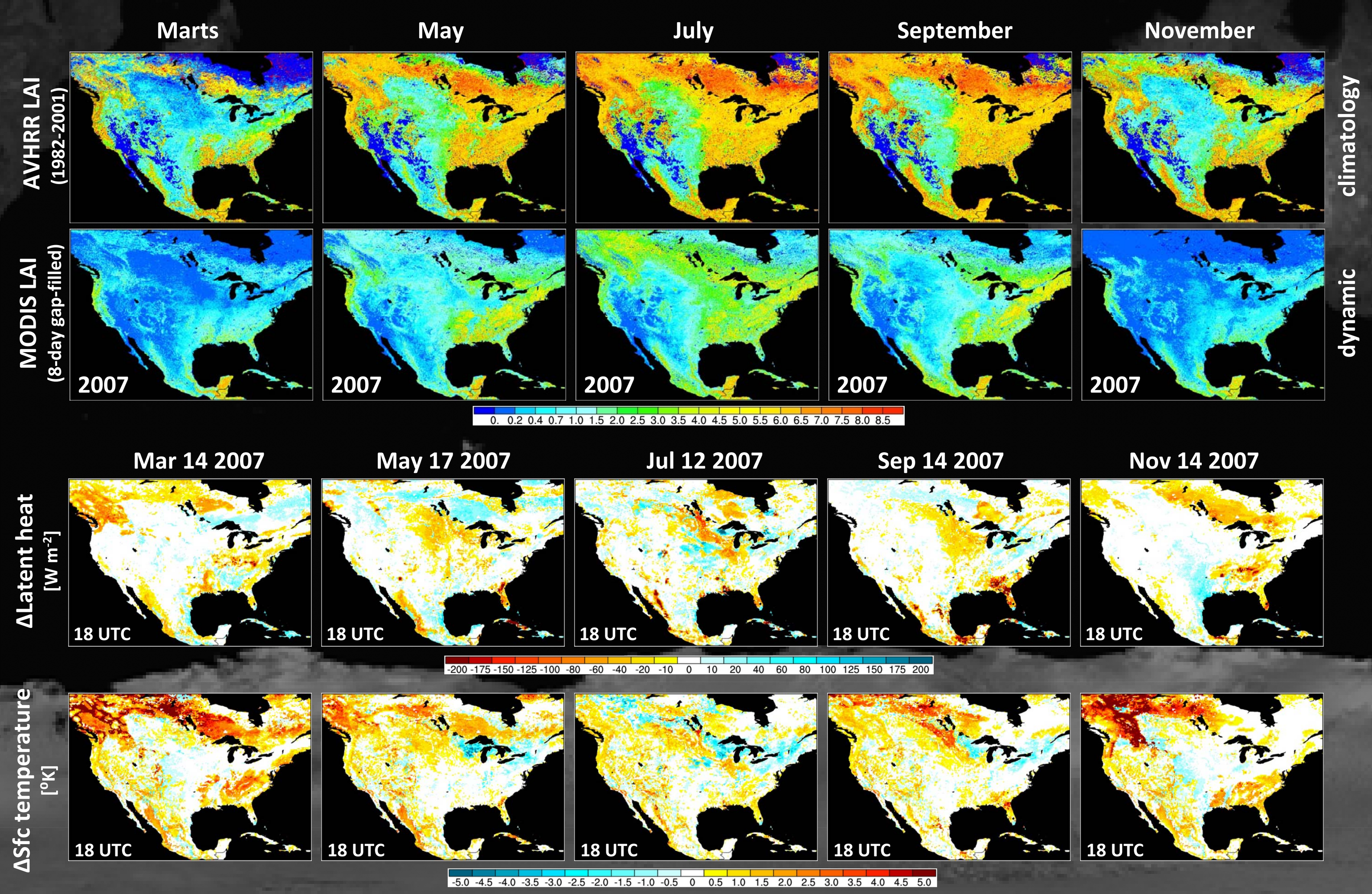
Regional average snow water equivalent, as predicted in Noah simulations and as estimated from snow-depth reports at the locations of U.S. Co-op snow observation network stations. Maps within each panel indicate the averaging region

The "pull" algorithm uses observations from up to 72 h ahead of the model simulation to correct against emerging errors in the simulation of snow cover while preserving the local hydrologic balance. This is accomplished by using future snow observations to adjust air temperature and, when necessary, precipitation within the LSM.

In contrast to the MODIS observations (daily snow cover), the assimilated output is continuous in space and time and contains more information (e.g. snow water equivalent, snow depth and albedo at hourly intervals).

Zaitchik and Rodell (2009). *J. Hydrometeor.*, 10 (1), 130-148

DYNAMIC LAI IMPLEMENTATION



The existing GLDAS LAI product is based on a 20 year AVHRR climatology. A new dynamic LAI dataset (1 km) has been derived from the combined Terra and Aqua MODIS 8-day resolution LAI product (2002-2009). Temporally and spatially continuous LAI fields were produced by adopting a hybrid of temporal and spatial gap-filling techniques. Significant discrepancies are observed due to interannual variability and differences in retrieval algorithm.

Application of the MODIS LAI in the CLM land surface model generally causes a decrease in latent heat flux and increase in surface temperature for forested areas in Canada. Areas in the US Southeast see a large increase in surface temperature due to overestimated AVHRR LAI values. Evidently, the effect of LAI misrepresentation can be significant. Due to internal model calibration, PDF matching may be required to adjust the MODIS LAI values to the AVHRR range before implementing them in GLDAS.