Highlights of the Global Land Data Assimilation System

Rasmus Houborg[1,2], Matthew Rodell[1], Hiroko Beaudoing[1,2] and Benjamin F Zaitchik[3]

[1]*NASA Goddard Space Flight Center, Hydrological Sciences Branch, Greenbelt, MD*
[2]*Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD*
[3]*John Hopkins University, Baltimore, MD*

1. Introduction

This document provides a brief highlight of key features and recent advances of The Global Land Data Assimilation System (GLDAS). GLDAS is a high-resolution, offline (uncoupled to the atmosphere) terrestrial modeling system that integrates a large quantity of satellite- and ground-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) (Rodell et al., 2004). GLDAS and its sister project the Land Information System (LIS) have made it straightforward to execute simulations with multiple parameter and meteorological forcing datasets and several land surface models (LSM). The project has resulted in a massive archive of modeled and observed data that support hydrometeorological investigations, weather and climate prediction, and water resource applications worldwide. GLDAS can run on local, regional, continental or global domains at spatial resolutions from 1˚ down to 1 km. GLDAS typically executes at 1/4˚ and 1˚ spatial and 3-hourly to monthly temporal resolution. A primary objective of GLDAS is to allow users to run multiple LSMs without specific knowledge of the model's architecture or physics. GLDAS currently drives four LSMs namely Noah, the Common Land Model (CLM), the Variable Infiltration Capacity model (VIC), and MOSAIC. GLDAS simulations go back to 1979 and run through present for all land north of 60˚S. More detailed information on GLDAS see http://ldas.gsfc.nasa.gov/index.shtml.

2. Forcing fields

GLDAS uses base forcing from global operational weather forecast models such as NCEP's Global Data Assimilation System (GDAS) (Fig. 1a), The European Centre for Medium-Range Weather Forecasts (ECMWF), and NASA's Goddard EOS Data Assimilation System (GEOS). These model-based forcing fields are replaced with observation-based datasets, including shortwave and longwave radiation and precipitation from various sources (Fig. 1b), whenever high quality observation-based fields are available (Rodell et al ., 2004).

3. Land surface parameter inputs

A high-quality land cover classification is critical to GLDAS as the fluxes and storages of water and energy at the land surface are strongly tied to the properties of the vegetation. GLDAS currently uses a static, 1-km resolution, global vegetation dataset that was produced based on observations from the AVHRR using the University of Maryland classification scheme (Hansen et al., 2000) (Fig. 2a). GLDAS runs its land surface models using a vegetation-based tiling approach to simulate variability

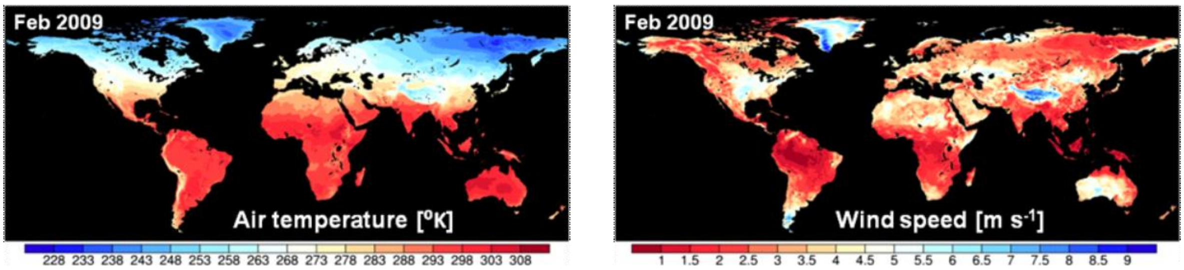

Figure 1a GDAS model reanalysis fields of air temperature and wind speed. Global fields of air humidity and surface pressure are also retrieved from global operational weather forecast models in order to force the GLDAS LSMs.

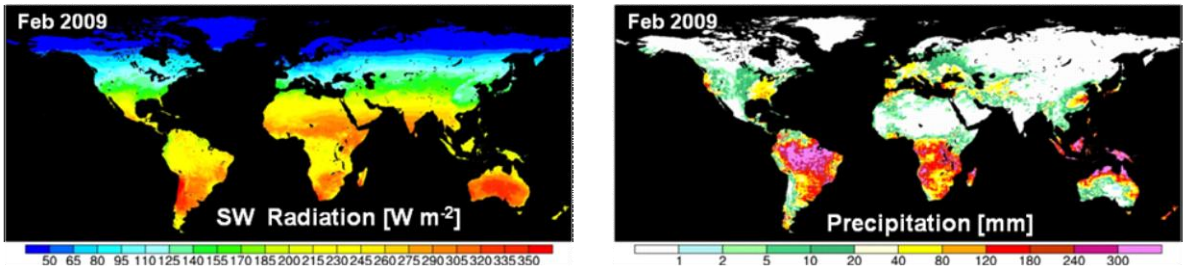

Figure 1b Incoming short-wave radiation fluxes based on the Air Force Weather Agency Agricultural Meteorology modeling system (AFWA AGRMET), and Merged Analysis of Precipitation (CMAP) fields from the Climate Prediction Center. The AGRMET global cloud analysis is produced hourly from various visible and IR satellite data sources. AGRMET also provides GLDAS with the incoming long-wave radiation component. CMAP is 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.

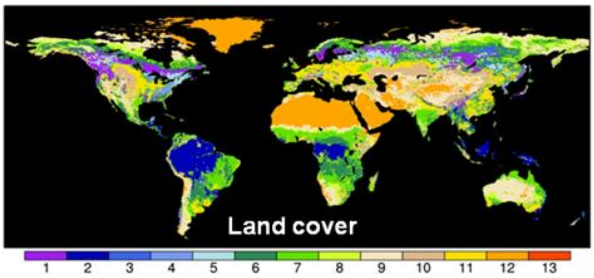

Fig. 2a GLDAS dominant vegetation type dataset (0.25 degree). The predominant vegetation type in each 0.25 grid square has been assigned based on a 1 km resolution global vegetation dataset which used the University of Maryland classification scheme (Hansen et al., 2000).

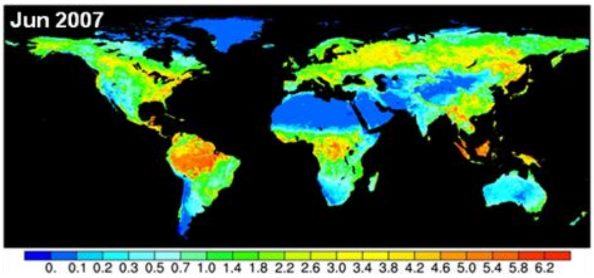

Fig. 2b MODIS based global 8-day LAI dataset. GLDAS currently uses a LAI climatology based on 20 years of AVHRR data (1982 - 2002) as default (Gottschalck et al. 2002).

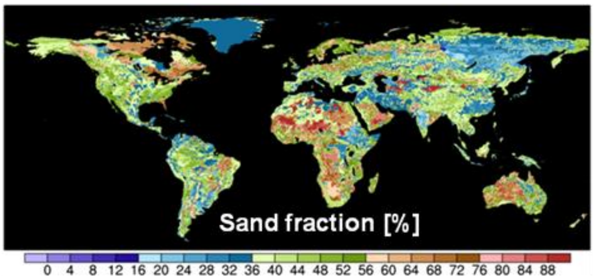

Fig. 2c The basic soil dataset used in GLDAS includes fractions of sand, silt, and clay, and porosity, among other fields, and it is based on the FAO Soil Map of the World linked to a global database of over 1300 sample soil cores (Reynolds et al. 2000).

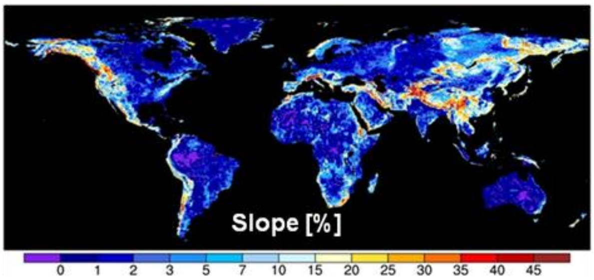

Fig. 2d The slope data was derived from the GTOPO30 global digital elevation model that has a horizontal grid spacing of 30 arc seconds (~ 1km) (Verdin and Greenlee, 1996).

below the scale of the standard operational model grid squares (1/4˚ or 1˚), and the 1 km global vegetation dataset acts as the basis for designating the tile space. GLDAS also ingests a satellite-based, 1-km resolution monthly climatology (AVHRR) (Gottschalck et al., 2002) or 8-day dynamic time series (MODIS 2002 - 2009) of leaf area index (Fig. 2b). The static soil and elevation parameters are based on high resolution global datasets (Fig. 2c and d) (see Rodell et al., 2004 for further details).

4. 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 - http://disc.gsfc.nasa.gov/hydrology/). Users can access the standard operational GLDAS model run output, namely 3-hourly and monthly 0.25 and 1.0 degree global outputs from the Noah, CLM, MOSAIC and VIC land surface models. HDISC provides data in GRIB and NetCDF format. The users can subset spatially and/or by parameter. Available output fields include water balance variables such as layered soil moisture, total canopy water storage, snow water equivalent, total evapotranspiration, rainfall and snowfall rate, and surface and subsurface runoff, in addition to energy balance variables such as net shortwave and net longwave radiation, sensible, latent and ground heat flux, and soil and surface temperature. Full documentation including detailed parameter descriptions is available on the HDISC webpage. Giovanni (http://disc.sci.gsfc.nasa.gov/giovanni) 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.

5. Incorporation of irrigation effects

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 novel algorithm (Ozdogan et al., 2009) applies irrigation based on MODIS derived intensity of irrigation, crop type, time of year, soil dryness, and common irrigation practices. Modeled annual irrigation totals were found to be consistent with data reported by the USGS (Ozdogan et al., 2009) and application of the new irrigation scheme in the Noah land surface model demonstrates that in parts of the U.S. where irrigation is intensive, it significantly affects soil moisture, evapotranspiration (Fig. 3), and sensible heat fluxes, by modulating the partitioning of water between the surface and the atmosphere.

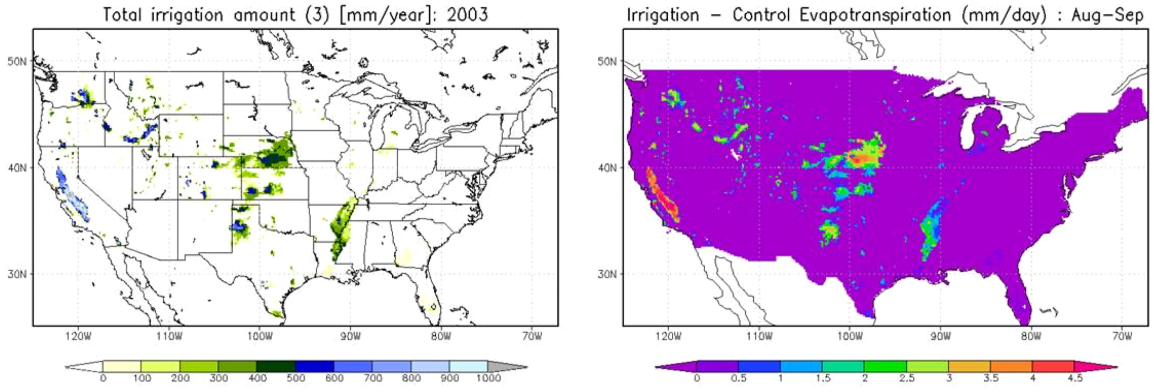

Figure 3: The irrigation was applied in the Noah land surface model and the results demonstrate that in parts of the U.S. where irrigation is intensive, it significantly affects evapotranspiration, and soil moisture and sensible heat fluxes (not shown).

6. 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. Zaitchik et al. (2009) evaluated GLDAS timeseries of river discharge using global river discharge data and a source-to-sink runoff routing scheme. GLDAS gridded runoff data is not appropriate for direct comparison with gauge observations, which integrate the combined runoff from all upstream locations, and a runoff routing scheme must be applied to the gridded runoff maps to produce more accurate estimates of discharge from the world's major rivers. In the source-to-sink scheme, 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 discharges from the Lawrence and Mississippi rivers clearly demonstrate the positive effect of applying the routing scheme to gridded runoff maps generated by GLDAS (Fig. 4); The original (un-routed) modeled discharge includes unrealistic high frequency variability whereas the routed discharge matches observations more closely.

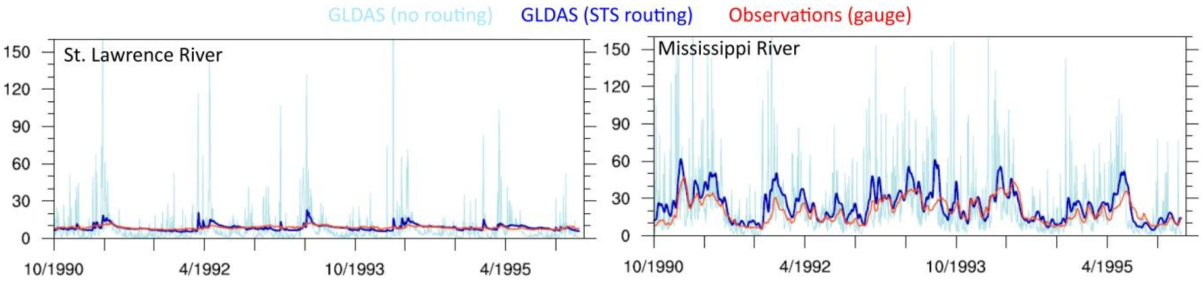

Figure 4 Modeled and observed river discharge (1000 m3/s) from the Lawrence and Mississippi rivers. The original modeled discharge includes unrealistic high frequency variability. The routed discharge matches observations more closely.

7. 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. For this reason, inaccuracies in the representation of snow-covered area within a land surface model can lead to substantial errors in both offline and coupled simulations. A new ‘pull’ snow cover assimilation technique has been developed that introduces MODIS snow cover observations to the Noah LSM in global simulations (Zaitchik and Rodell, 2009). The 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). The assimilation of MODIS snow covered area observations to the Noah LSM improved estimates of snow cover and snow water equivalent relative to open loop (control run) integrations (Fig. 5). The snow data assimilation had a significant impact on the surface radiation balance, indicating that the technique would be of value in coupled land-atmosphere simulations (Zaitchik and Rodell, 2009).

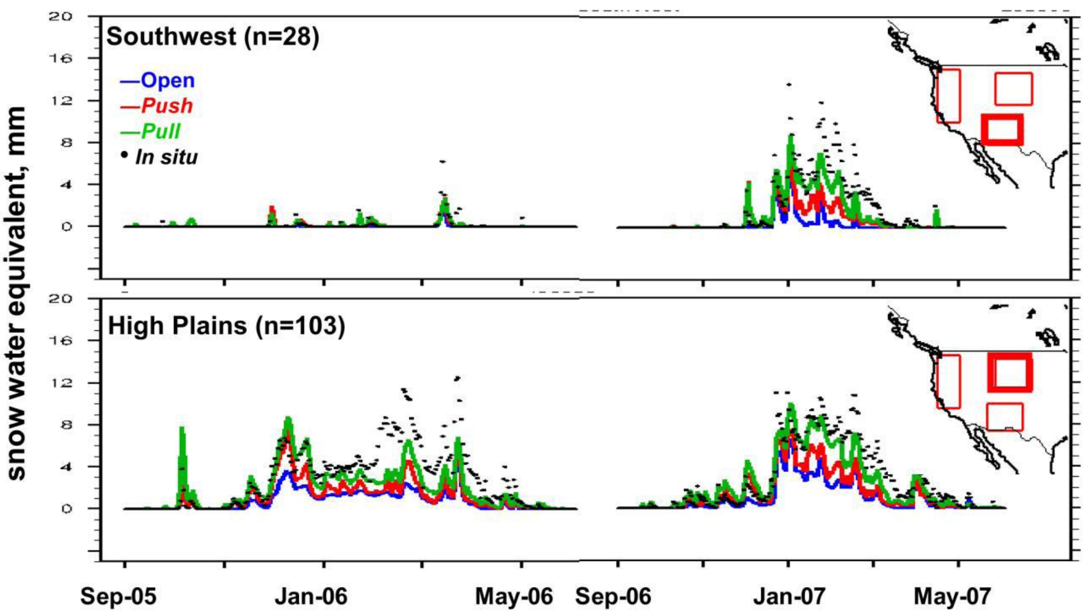

Figure 5: Regional average snow water equivalent, as predicted in Noah simulations with assimilated MODIS snow cover data and as estimated from snow-depth reports at the locations of U.S. Co-op snow observation network stations. Maps within each panel indicate the averaging region.

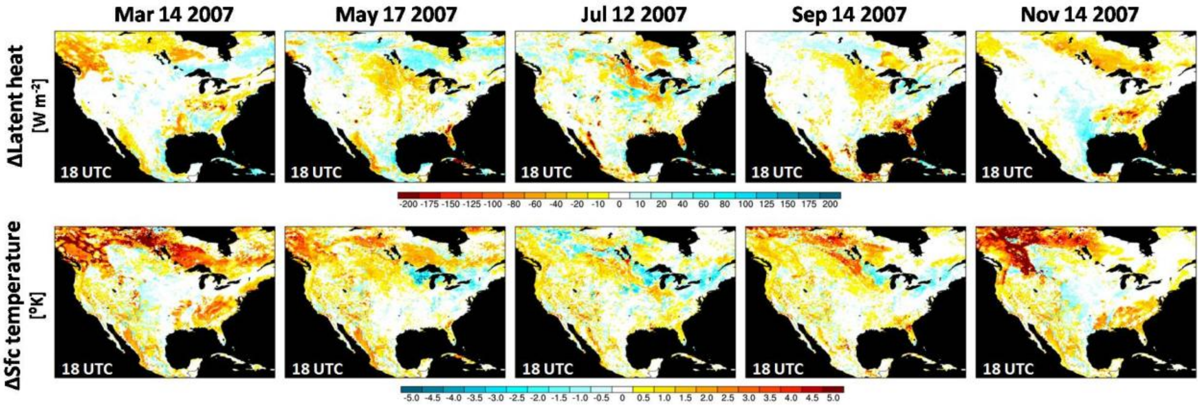

Figure 6: CLM land surface model simulations of latent heat (top) and land surface temperature (bottom) for North America illustrating the effect of using MODIS-based 8-day gap-filled LAI data in place of the existing monthly AVHRR-based LAI climatology.

8. Dynamic LAI implementation

Leaf area index (LAI) serves as a key vegetation biophysical determinant for variations in land surface energy and water fluxes, and a robust and realistic representation of temporal and spatial LAI dynamics in global land surface models is required in support of improved global water cycle predictions. The existing GLDAS LAI product is based on a 20 year monthly AVHRR climatology (Gottschalck et al., 2002). 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. Fig. 6 illustrates the effect of the revised LAI scheme on latent heat fluxes and surface temperatures simulated by the CLM LSM for the North American domain. Areas to the North and in the Southeast U.S. see particularly large changes in latent heat and surface temperature, due to large discrepancies between the 8-day dynamic and monthly climatologic LAI data. 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.

9. References

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