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GLOBAL LAND DATA ASSIMILATION SYSTEM (GLDAS) PRODUCTS FROM NASA HYDROLOGY DATA AND INFORMATION SERVICES CENTER (HDISC)

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ABSTRACT

The Global Land Data Assimilation System (GLDAS) is generating a series of land surface state (e.g., soil moisture and surface temperature) and flux (e.g., evaporation and sensible heat flux) products simulated by four land surface models (CLM, Mosaic, Noah and VIC). These products are now accessible at the Hydrology Data and Information Services Center (HDISC), a component of the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC). Current data holdings include a set of 1.0 degree resolution data products from the four models, covering 1979 to the present; and a 0.25 degree data product from the Noah model, covering 2000 to the present. The products are in Gridded Binary (GRIB) format and can be accessed through a number of interfaces. New data formats (e.g., netCDF), temporal averaging and spatial subsetting will be available in the future. The HDISC has the capability to support more hydrology data products and more advanced analysis tools. The goal is to develop HDISC as a data and services portal that supports weather and climate forecast, and water and energy cycle research.

INTRODUCTION

Global hydrological data such as soil moisture and evaporation are crucial for understanding the land surface process and the atmospheric general circulation modeling for climate simulation and weather forecasting. The Hydrologic Sciences Branch (HSB) at NASA's Goddard Space Flight Center (GSFC) has collected a series of surface hydrological data sets in order to enable a better understanding of the global hydrospheric cycle. These data sets include field measurements, parameters simulated from land surface models, and products derived from many satellite instruments.

NASA is mandated by Congress to make its data and products available to the broader user community. The Hydrology Data and Information Services Center (HDISC) was developed as part of the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) to archive and support data products generated by the GSFC HSB.

HDISC is a portal to a hydrology-specific, on-line, easy-access archive and distribution system, employing data analysis and visualization, data subsetting, and other user-requested techniques for better science data usage. HDISC provides convenient access to hydrology data and information from various land surface models. The first products hosted are outputs from the Global Land Data Assimilation System (GLDAS) (Rodell et al., 2004). The HDISC has the capability to support more hydrology data products and more advanced analysis tools. The goal is to develop HDISC as a data and services portal that supports weather and climate forecast, and water and energy cycle research. The following sections will introduce the GLDAS project and the data set, and the means to access the data set through HDISC.

BACKGROUND ABOUT THE GLDAS

GLDAS drives multiple offline (not coupled to the atmosphere) land surface models, integrates a huge quantity of observation based data, and executes globally at 2.5° to 1 km resolutions, enabled by the Land Information System (LIS) (Kumar et al., 2006). Currently, GLDAS drives four land surface models: Mosaic, Noah, the Community Land Model (CLM), and the Variable Infiltration Capacity (VIC). GLDAS products include land surface state (e.g., soil moisture and surface temperature) and flux (e.g., evaporation and sensible heat flux) parameters. The temporal resolution for the GLDAS products is 3-hourly. Monthly products are also generated through temporal averaging of the 3-hourly products. For example, the total evapotranspiration for April 1979 is the average 3-hour mean rate of evapotranspiration over all the 3-hour intervals in April 1979. Output files from these four models are briefly described here. Table 1 lists some basic characteristics of the GLDAS data.

Table 1. Basic characteristics of the GLDAS data.

Contents	Water and energy budget components, forcing data
Latitude extent	-60° to 90°N
Longitude extent	-180° to 180°E
Spatial resolution	0.25°, 1.0°
Temporal resolution	3-hourly or monthly
Temporal coverage	January 1, 1979 to present for the 1.0° data February 24, 2000 to present for the 0.25° data
Dimension	360 (lon) x 150 (lat) for the 1.0° data 1440 (lon) x 600 (lat) for the 0.25° data
Origin (1st grid center)	(179.5W, 59.5S) for the 1.0° data (179.875W, 59.875S) for the 0.25° data
Land surface models	CLM 2.0 (1.0°) MOSAIC (1.0°) NOAH 2.7.1 (1.0°) VIC water balance (1.0°) NOAH 2.7.1 (0.25°)

The data used by LIS include parameter data and forcing data. All simulations were initialized on model date January 1, 1979 using soil moisture and other state fields from the respective LSM climatology for that day of the year. The 1.0 degree resolution data range from 1979 to present for the four models. The 0.25 degree data cover 2000 to present from the NOAH model. The forcing data set combines multiple data sets for the period of January 1, 1979 to present:

1979-1993: bias-corrected ECMWF Reanalysis data (Berg et al., 2003)
1994-1999: bias-corrected NCAR Reanalysis data (Berg et al., 2003)
2000: NOAA/GDAS atmospheric analysis fields
2001-2007: a combination of NOAA/GDAS atmospheric analysis fields, spatially and temporally disaggregated NOAA Climate Prediction Center Merged Analysis of Precipitation (CMAP) fields, and observation based downward shortwave and longwave radiation fields derived using the method of the Air Force Weather Agency's AGRicultural METeorological modeling system (AGRMET)

In NOAH (0.25°), snow cover data derived from the MODIS sensor aboard NASA's Terra satellite were assimilated in order to constrain the modeled snow water equivalent (SWE), using the updating technique described by Rodell and Houser (2004). SWE was adjusted when and where there was a discrepancy between the modeled SWE state (snow or no snow) and the MODIS snow cover state. A quantity of 10 mm SWE was added to pixels where the model did not have snow but the fractional MODIS snow cover was greater than 40%. Snow was removed from model pixels where MODIS indicated fractional snow cover was less than 10%.

GLDAS DATA SET IN HDISC

Current GLDAS data hosted at HDISC include a set of 1.0° data products, covering 1979 to the present, from the four models and a 0.25° data product, covering 2000 to the present, from the Noah model. Table 2 shows the number of files and data volume from each model.

Table 2. Data volume from each land surface model hosted at HDISC

Model	Resolution	3-Hourly		Monthly	
		Files/day	GB/year	Files/year	GB/year
CLM	1.0° × 1.0°	8	3.8	12	12.1
Mosaic	1.0° × 1.0°	8	2.3	12	9.0
Noah	1.0° × 1.0°	8	2.6	12	9.6
Noah	0.25° × 0.25°	8	42	12	153.6
VIC	1.0° × 1.0°	8	2.1	12	7.6

The GLDAS LSM data were created using the GRIdded Binary (GRIB) format. GLDAS applies user-defined parameter tables for the GRIB files. Table 3 shows a list of parameters provided in the GRIB files. This table shows the GRIB Product Definition Section (PDS) ID and the corresponding parameter name.

Table 3. Geophysical parameters generated from the GLDAS project.

PDS IDs	Full Name	Unit
001	Surface pressure	Pa
011	Near surface air temperature	K
032	Near surface wind magnitude	m/s
051	Near surface specific humidity	kg/kg
057	Total evapotranspiration	kg/m^2
065	Snow water equivalent	kg/m^2
071	Total canopy water storage	kg/m^2
085	Average layer soil temperature	K
086	Average layer soil moisture	kg/m^2
099	Snowmelt	kg/m^2/s
111	Net shortwave radiation	W/m^2
112	Net longwave radiation	W/m^2
121	Latent heat flux	W/m^2
122	Sensible heat flux	W/m^2
131	Snowfall rate	kg/m^2/s
132	Rainfall rate	kg/m^2/s
138	Average surface temperature	K
155	Ground heat flux	W/m^2
204	Surface incident shortwave radiation	W/m^2
205	Surface incident longwave radiation	W/m^2
234	Subsurface runoff	kg/m^2
235	Surface runoff	kg/m^2

DATA READING AND INTERPRETATION

To handle the GLDAS GRIB data, WGRIB, GrADS, or other GRIB readers are required. WGRIB is a program to manipulate, inventory, and decode GRIB files (http://www.cpc.ncep.noaa.gov/products/wesley/wgrib.html). WGRIB version 1.7.X is recommended to avoid any possible discrepancies caused by different WGRIB versions. The Grid Analysis and Display System (GrADS) is an interactive desktop tool for easy access, manipulation, and visualization of earth science data (http://grads.iges.org/grads/). Examples of using the GrADS to read the GLDAS data are shown in Figures 1 and 2, respectively. Figure 1 shows the 0.25 degree 3-hourly top layer soil moisture (0-

10 cm) simulated from the Noah model at 00Z, May 1, 2007. Figure 2 shows the 1.0 degree monthly top layer soil moisture (0-2 cm) simulated from the Mosaic model in May, 2007.

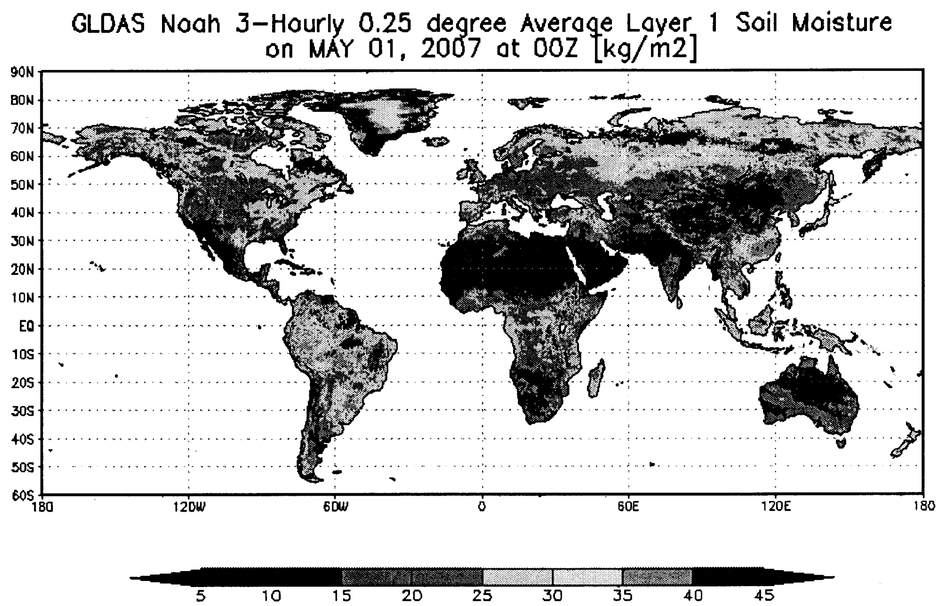


Figure 1. The 0.25 degree 3-hourly top layer soil moisture (0-10 cm) simulated from the Noah model at 00Z, May 1, 2007.

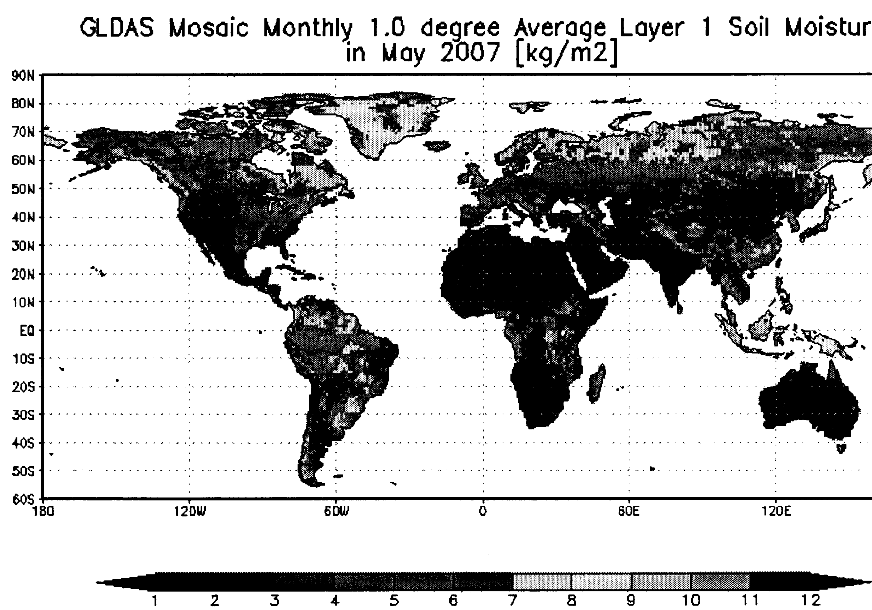


Figure 2. The 1.0 degree monthly top layer soil moisture (0-2 cm) simulated from the Mosaic model in May, 2007.

GRIB files identify the contents (e.g., soil moisture, temperature) by parameter numbers. These numbers are linked to their respective parameter names in a parameter table. The GLDAS data set applies a user-specific parameter table for each model to indicate the content and parameter number. An example of the parameter table for the Mosaic model is shown in Table 4. This table shows the PDS ID, the abbreviated and full variable names and their units. Users need to set the specific parameter table before using any GRIB reader.

Table 4. The GRIB parameter table (GRIBTAB) for the MOSAIC output

```
-1:-1:-1:-1
111:SWnet:Net Shortwave Radiation        W/m^2
112:LWnet:Net Longwave Radiation         W/m^2
121:Qle:Latent Heat Flux                 W/m^2
122:Qh:Sensible Heat Flux                W/m^2
155:Qg:Ground Heat Flux                  W/m^2
131:Snowf:Snowfall rate                  kg/m^2/s
132:Rainf:Rainfall rate                  kg/m^2/s
057:Evap:Total Evapotranspiration        kg/m^2/s
235:Qs:Surface Runoff                    kg/m^2/s
234:Qsb:Subsurface Runoff                kg/m^2/s
099:Qsm:Snowmelt                         kg/m^2/s
068:DelSoilMoist:Change in soil moisture          kg/m^2
078:DelSWE:Change in snow water equivalent  kg/m^2
138:AvgSurfT:Average Surface Temperature     K
085:SoT:Deep Soil Temperature            K
084:Albedo:Surface Albedo, All Wavelengths  -
065:SWE:Snow Water Equivalent            kg/m^2
086:SoilM1:Average layer 1 soil moisture    kg/m^2
086:SoilM2:Average layer 2 soil moisture    kg/m^2
086:SoilM3:Average layer 3 soil moisture    kg/m^2
207:SoilWet:Total Soil Wetness           -
200:ECanop:Interception evaporation      kg/m^2/s
210:TVeg:Vegetation transpiration        kg/m^2/s
199:ESoil:Bare soil evaporation          kg/m^2/s
070:RootMoist:Root zone soil moisture       kg/m^2
071:Canopint:Total canopy water storage   kg/m^2
174:ACond:Aerodynamic conductance        m/s
032:Wind:Near surface wind magnitude     m/s
059:Rainfforc:Rainfall rate              kg/m^2/s
064:Snowfforc:Snowfall rate              kg/m^2/s
011:Tair:Near surface air temperature    K
051:Qair:Near surface specific humidity   kg/kg
001:PSurf:Surface pressure               Pa
204:SWdown:Surface incident shortwave radiation  W/m^2
205:LWdown:Surface incident longwave radiation W/m^2
```

The number of vertical levels for soil moisture (SoilM) is model specific. The generic GRIB table defines the different soil layers as SoilM1, …, SoilM*N*, respectively, where *N* is the number of soil layers. Table 5 lists the depths of soil layers used in different land surface models. Terrestrial water storage is the sum of soil moisture in all layers, accumulated snow, and plant canopy surface water. Total precipitation is the sum of rainfall and snowfall and the total runoff is the sum of subsurface runoff and surface runoff.

Table 5. The depth of soil layers used in different land surface models.

CLM 2.0 (10 layers)	
Depths	0-0.018, 0.018-0.045, 0.045-0.091, 0.091-0.166, 0.166-0.289, 0.289-0.493, 0.493-0.829, 0.829-1.383, 1.383-2.296, and 2.296-3.433 m.
MOS (3 layers)	
Depths	0-0.02,0.02-1.50, and 1.5-3.50 m.
NOAH (4 layers)	
Depths	0-0.1, 0.1-0.4, 0.4-1.0, and 1.0-2.0 m.
VIC (3 layers)	
Depths	0-0.1, 0.1-1.6, and 1.6-1.9 m.

ACCESS HDISC DATA

The HDISC maintains archives of all GLDAS data products. The data are publicly available. The archived data can be accessed via anonymous ftp network transfer. The GLDAS data holding and ftp downloading interface is shown in Figure 3. The 3-hourly GLDAS data can be downloaded directly via the GES DISC anonymous ftp: ftp://agdisc.gsfc.nasa.gov/data/s4pa/GLDAS_SUBP/. The monthly GLDAS data can be downloaded from ftp://agdisc.gsfc.nasa.gov/data/s4pa/GLDAS/

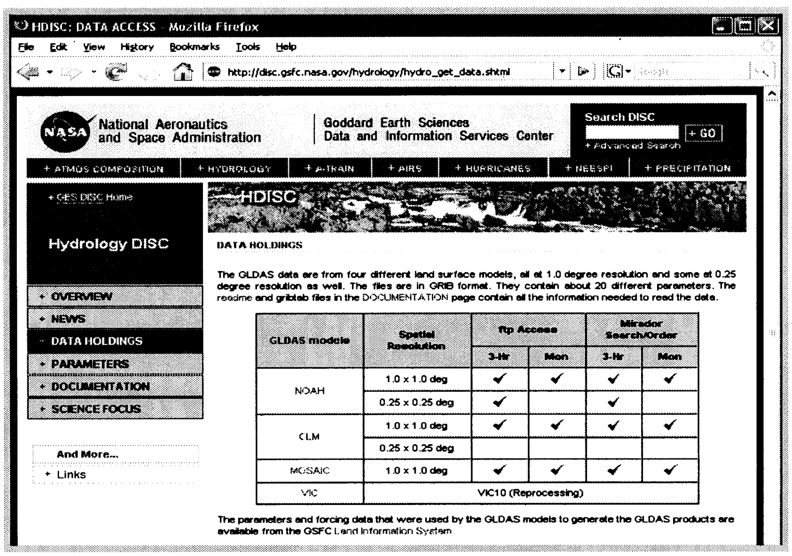
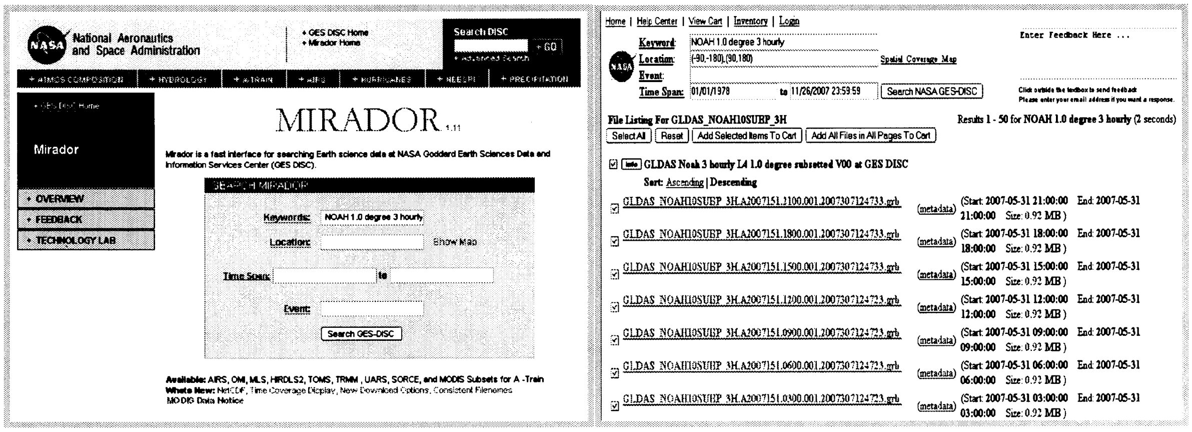


Figure 3. HDISC data holding and ftp downloading page

Search and Access System

In addition to the basic anonymous data downloading, HDISC provides several advanced data search and downloading services, such as Mirador (Figure 4). Mirador, a Spanish word for a window offering an extensive view, is a Google-based search tool that provides keywords searching of Earth science data at the NASA GES DISC. In the Mirador interface, GLDAS data can be searched through a keyword (e.g., Noah) and the time span (Figure 4a). Once the list of data products is shown in the interface, users can download GLDAS data in batch mode (Figure 4b).



(a) (b)

Figure 4. Search GLDAS in Mirador (a) and the output page (b)

Access GLDAS products through the GrADS Data Server (GDS)

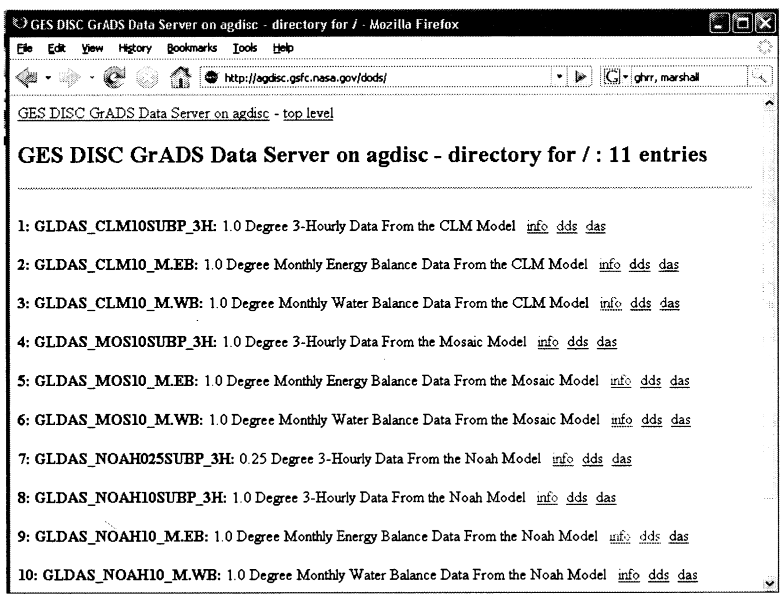


Figure 5. The HDISC GrADS Data Server (GDS) interface for the GLDAS products

The GrADS Data Server (GDS) is a stable, secure data server that provides subsetting and analysis services across the internet. The core of the GDS is OPeNDAP (formerly DODS), a software framework used for data networking that makes local data accessible to remote locations. The GLDAS products are provided to the GDS users via http://agdisc.gsfc.nasa.gov/dods/. Figure 5 shows the HDISC GDS page, which has links to various GLDAS products. GDS users can perform subsetting and analysis operations without first downloading data. The GDS subsetting capability allows users to retrieve a specified temporal and/or spatial subdomain from a large data set. The GDS analysis capability allows users to retrieve the results of an operation applied to one or more data sets on the server. The GDS supports any operation that can be expressed in a single GrADS expression, including basic math functions, averages, smoothing, differencing, correlation, and regression.

Future HDISC direction

HDISC will provide daily GLDAS products through time-averaging of the current 3-hourly data set. New data format, such as the NetCDF will be supported in the next phase. More advanced tools will be provided in later releases, such as on-the-fly spatial and parameter subsetting and temporal aggregation in Mirador, and an online visualization and analysis tool (Giovanni). Giovanni is a Web-based application developed by the GES DISC that provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data (http://disc.sci.gsfc.nasa.gov/techlab/giovanni/). Users can access the HDISC website (http://disc.gsfc.nasa.gov/hydrology/) for the latest GLDAS data and HDISC news.

Acknowledgement

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