Terrestrial Hydrological Data from NASA's Hydrology Data and Information Services Center (HDISC): Products, Services, and Applications

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ABSTRACT

Terrestrial hydrological variables are important in global hydrology, climate, and carbon cycle studies. The North American and Global Land Data Assimilation Systems (NLDAS and GLDAS, respectively) have been generating a series of land surface states (soil moisture, snow, and temperature) and fluxes (evapotranspiration, radiation, and heat flux) variables. These data, hosted at and available from NASA's Hydrology Data and Information Services Center (HDISC), include the NLDAS hourly 1/8 degree products and the GLDAS 3-hourly 0.25 and 1.0 degree products. HDISC provides easy access and visualization and analysis capabilities for these products, thus reducing the time and resources spent by scientists on data management and facilitating hydrological research. Users can perform spatial and parameter subsetting, data format transformation, and data analysis operations without needing to first download the data. HDISC is continually being developed as a data and services portal that supports weather and climate forecasts, and water and energy cycle research.

INTRODUCTION

Land surface states (soil moisture, snow, and temperature) and fluxes (evapotranspiration, radiation, and heat flux) are important variables in global climate, weather forecast, and carbon cycle studies. These variables are obtained through field observations, remote sensing retrievals, or hydrological model simulations. However, it is often difficult to access, explore, merge, analyze, and inter-compare these data products in a coherent manner due to issues of data resolution, format, and structure. The overall goals of NASA's Hydrology Data and Information Services Center (HDISC) are to provide easy access and visualization and analysis capabilities for these products, thus reducing the time and resources spent by scientists on data management and facilitating hydrological research, and to develop HDISC as a data and services portal that supports weather and climate forecasts, and water and energy cycle research.

The current focus of HDISC is on developing the North American and Global Land Data Assimilation Systems (NLDAS and GLDAS, respectively) data and services portal. Hydrological products currently accessible from HDISC include outputs from a number of land surface models: hourly 1/8th degree products for North America (NLDAS) and 3-hourly 0.25 and 1.0 degree products globally (GLDAS). Planned for future inclusion in HDISC are satellite retrievals of land surface parameters (e.g., temperature, soil moisture, precipitation). HDISC provides advanced data search and downloading services, as well as simple and intuitive ways to visualize and analyze vast amounts of data. Users can perform spatial and parameter subsetting, data format transformation, and data analysis operations without needing to first download the data.

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LAND DATA ASSIMILATION SYSTEMS

NLDAS and GLDAS integrate data from multiple space- and ground-based Earth observing systems, using advanced land surface modeling and assimilation techniques. These products support weather and climate forecast experiments, water resources applications, and water and energy cycle research. Table 1 lists some basic characteristics of these products.

NLDAS integrates a large quantity of observation-based and model reanalysis data to drive offline (not coupled to the atmosphere) land-surface models, and executes at 1/8th-degree grid spacing over central North America, enabled by the Land Information System (LIS) (Mitchell et al., 2004; Kumar et al., 2006). NLDAS forcing drives four land-surface models: NASA's Mosaic, NOAA's Noah, NWS's SAC, and Princeton's implementation of VIC. The temporal resolution for NLDAS products is hourly. Monthly products will be generated by temporal averaging of the hourly products. Phase 2 of NLDAS (hereafter, NLDAS-2) comprises data from Jan 1979 to present. The first phase of NLDAS (NLDAS-1) covers data from Oct 1, 1996 to Dec 31, 2007.

GLDAS drives multiple offline land surface models, integrates a huge quantity of observation-based data, and executes globally at 2.5° to 1 km resolutions, enabled by LIS (Rodell et al., 2004). Currently, GLDAS drives four land surface models: Mosaic, Noah, CLM, and VIC. The temporal resolution for GLDAS products is 3-hourly. Monthly products are generated by temporal averaging of the 3-hourly products.

Table 1. Basic characteristics of the NLDAS and GLDAS products.

	NLDAS	GLDAS
Content	Water and energy budget data, forcing data	
Spatial extent	Conterminous U.S., parts of southern Canada and northern Mexico	All land north of 60 degree south
Spatial resolution	0.125 degree	1.0 degree and 0.25 degree
Time period	Jan 1, 1979 to present for NLDAS-2 Oct 1, 1996 to Dec 31, 2007 for NLDAS-1	Jan 1, 1979 to present for the 1.0° data Feb 24, 2000 to present for the 0.25° data
Temporal resolution	Hourly and monthly	3-hourly and monthly
Forcing	Multiple data sets derived from satellite measurements, radar estimation, precipitation gauges, and atmospheric analyses[a]	Multiple data sets derived from satellite measurements and atmospheric analyses [b]
Land surface models	Mosaic, Noah, SAC, and VIC	CLM, Mosaic, Noah, and VIC
Output format	GRIdded Binary (GRIB), netCDF	
Elevation definition	GTOPO 30	
Vegetation definition	University of Maryland, 1 km[c]	

[a]http://ldas.gsfc.nasa.gov/LDAS8th/forcing/forcing_narr.shtml
[b]http://ldas.gsfc.nasa.gov/GLDAS/DATA/data_forc.shtml
[c]http://ldas.gsfc.nasa.gov/LDAS8th/EROSveg2/LDASvegetation2.shtml

DATA PARAMETERS AND FORMAT

Data Content

Both NLDAS and GLDAS products are created using the GRIdded Binary (GRIB) format with pre-defined parameter tables. Tables 2 and 3 list the NLDAS-2 forcing and Mosaic output parameters, respectively. Table 4 lists the GLDAS parameters. In addition to the parameter names, these tables also show the corresponding GRIB Product Definition Section (PDS) ID and units.

Table 2. NLDAS-2 primary and secondary forcing data.

Primary forcing data			Secondary forcing data		
PDS IDs	Full Name	Unit	PDS IDs	Full Name	Unit
61	Precipitation hourly total	kg/m^2	179	Aerodynamic conductance	m/s
157	180-0 mb above ground convective available potential energy	J/kg	63	Convective precipitation hourly total	kg/m^2
153	Fraction of total precipitation that is convective	unitless	61	Precipitation hourly total	kg/m^2
205	LW radiation flux downwards (surface)	W/m^2	204	SW radiation flux downwards (surface)	W/m^2
204	SW radiation flux downwards (surface)	W/m^2	7	NARR hybrid level geopotential height	gpm
228	Potential evaporation	kg/m^2	1	NARR hybrid level pressure	Pa
1	Surface pressure	Pa	51	NARR hybrid level specific humidity	kg/kg
51	2-m above ground specific humidity	kg/kg	11	NARR hybrid level temperature	K
11	2-m above ground temperature	K	33	NARR hybrid level zonal wind speed	m/s
33	10-m above ground zonal wind speed	m/s	34	NARR hybrid level meridional wind speed	m/s
34	10-m above ground meridional wind speed	m/s			

Table 3. Geophysical parameters generated from the Mosaic model of NLDAS-2.

PDS IDs	Full Name	Unit	PDS IDs	Full Name	Unit
179	Aerodynamic conductance	m/s	111	SW radiation flux net (surface)	W/m^2
84	Albedo	%	198	Sublimation (evaporation from snow)	W/m^2
162	Rainfall (unfrozen precipitation)	kg/m^2	122	Sensible heat flux	W/m^2
161	Snowfall (frozen precipitation)	kg/m^2	66	Snow depth	m
148	Average surface skin temperature	K	229	Snow phase-change heat flux	W/m^2
234	Subsurface runoff (baseflow)	kg/m^2	99	Snow melt	kg/m^2
181	Canopy conductance	m/s	238	Snow cover	%
223	Plant canopy surface water	kg/m^2	86	0-10 cm layer 1 soil moisture content	kg/m^2
205	LW radiation flux downwards (surface)	W/m^2	86	0-40 cm root zone soil moisture content	kg/m^2
204	SW radiation flux downwards (surface)	W/m^2	86	0-100 cm top 1 meter soil moisture content	kg/m^2
199	Direct evaporation from bare soil	W/m^2	86	0-200 cm total column soil moisture content	kg/m^2
200	Canopy water evaporation	W/m^2	86	10-40 cm layer 2 soil moisture	kg/m^2

				content	
57	Evaporation	kg/m^2	86	40-200 cm layer 3 soil moisture content	kg/m^2
155	Ground heat flux	W/m^2	235	Surface runoff (non-infiltrating)	kg/m^2
182	Leaf Area Index (0-9)	unitless	210	Transpiration	W/m^2
121	Latent heat flux	W/m^2	85	Deep soil temperature	K
207	0-40 cm root zone moisture availability	%	87	Vegetation	%
207	0-200 cm total column moisture availability	%	65	Accumulated snow water-equivalent	kg/m^2
112	LW radiation flux net (surface)	W/m^2			

Table 4. Geophysical parameters generated from GLDAS.

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

Data Handling

To handle the 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/). GRIB files label their contents (e.g., soil moisture, temperature) with parameter numbers. These numbers are linked to their respective parameter names in a parameter table. Users need to set the specific parameter table before using any GRIB reader.

HDISC DATA ACCESS AND SERVICES

The HDISC maintains archives of NLDAS and GLDAS data products, which can be accessed via anonymous http and ftp data downloading (Figure 1). In addition, HDISC provides two advanced data search and downloading services, Mirador and GrADS Data Server (GDS).

:
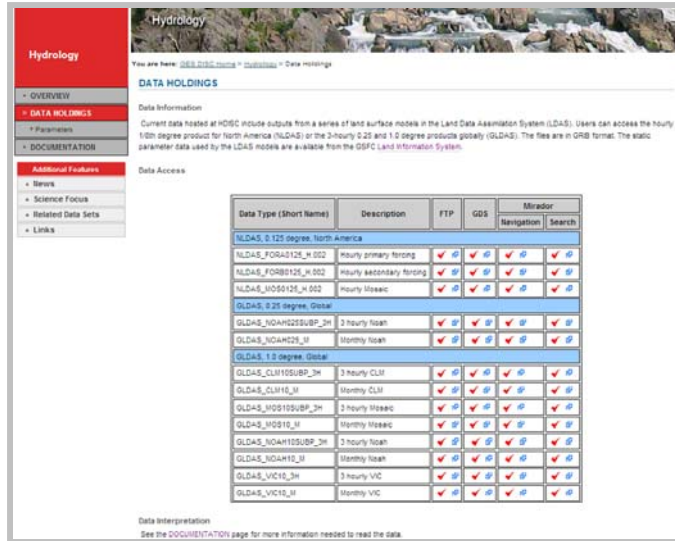
Figure 1. HDISC data holding and ftp downloading page.

Mirador

Search and Access. Mirador (Spanish for window offering an extensive view) is a Google-based keywords search tool for Earth sciences data at the NASA GES DISC. NLDAS and GLDAS products can be searched by specifying a keyword (e.g., Noah) and a time span (Figure 2a). Data products listed in the search results can then be downloaded. Mirador was recently enhanced with semantic web technology and offers multiple views of project, instrument, and earth science parameter (with an applications view to come). Users can quickly navigate down the hierarchical path to find data of interest (Figure 2b). The key semantic technology behind these tree structures is an ontology based on the Global Change Master Directory (GCMD) Directory Interchange Format (DIF). Mirador's semantic infrastructure enables interoperability with other semantically-based hydrological data discovery and service frameworks.
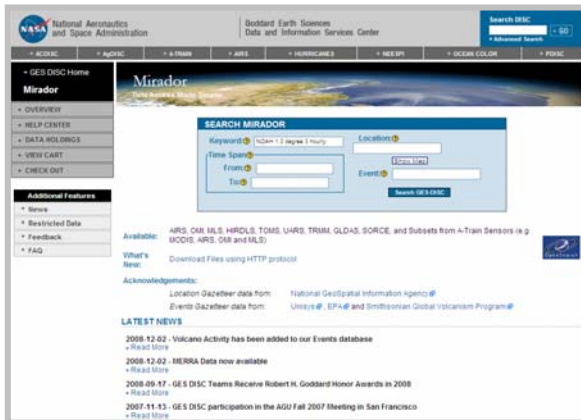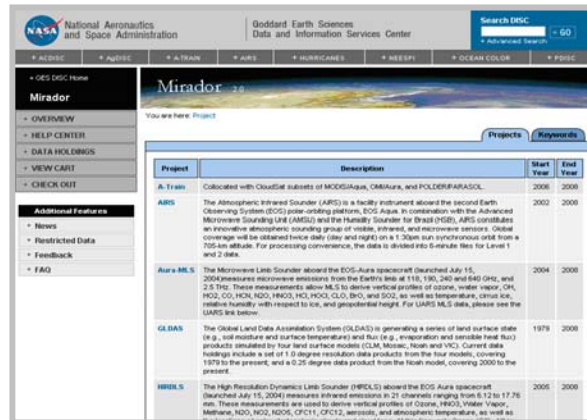
| (a) | (b) |

Figure 2. Search and access GES DISC products (including NLDAS and GLDAS) by either (a) Mirador keyword search or (b) hierarchical navigation search.

On-The-Fly Spatial and Parameter Subsetting. HDISC has developed on-the-fly spatial and parameter subset services for the GLDAS products and will provide such services for the NLDAS products in future releases. Users can specify their parameters and spatial region of interest, before downloading from Mirador. For example, a user selects three GLDAS data products from Mirador (Figure 3a) and selects the parameter(s) and spatial region of

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interest to subset (Figure 3b). The user then runs the subset services and downloads the subsetted data on the fly. The subsetted data are in the GRIB format, same as that of the original GLDAS products.

(a)   (b)
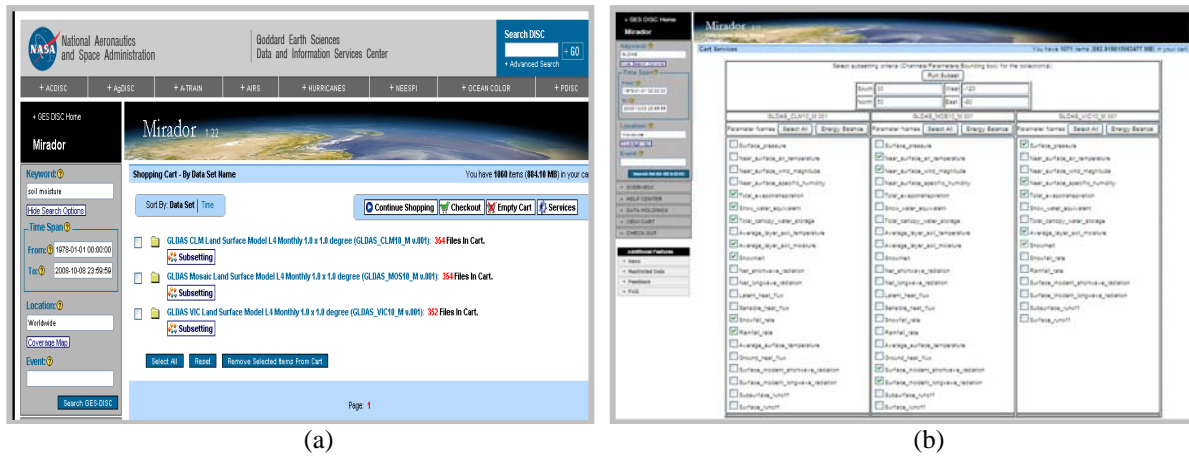
Figure 3. Example of a user selecting (a) GLDAS data products and (b) the spatial region and parameters of interest for subsetting on-the-fly.

On-The-Fly Conversion to NetCDF. NetCDF (network Common Data Form) is a self-describing, machine-independent format for representing scientific data. This format is widely used in the Earth sciences community. To serve netCDF users, HDISC has developed an on-the-fly GRIB-to-netCDF conversion service. Figure 4 shows examples of the netCDF conversion function, at the data product and granule (individual file) levels. Conversion is performed on downloading.

(a)   (b)
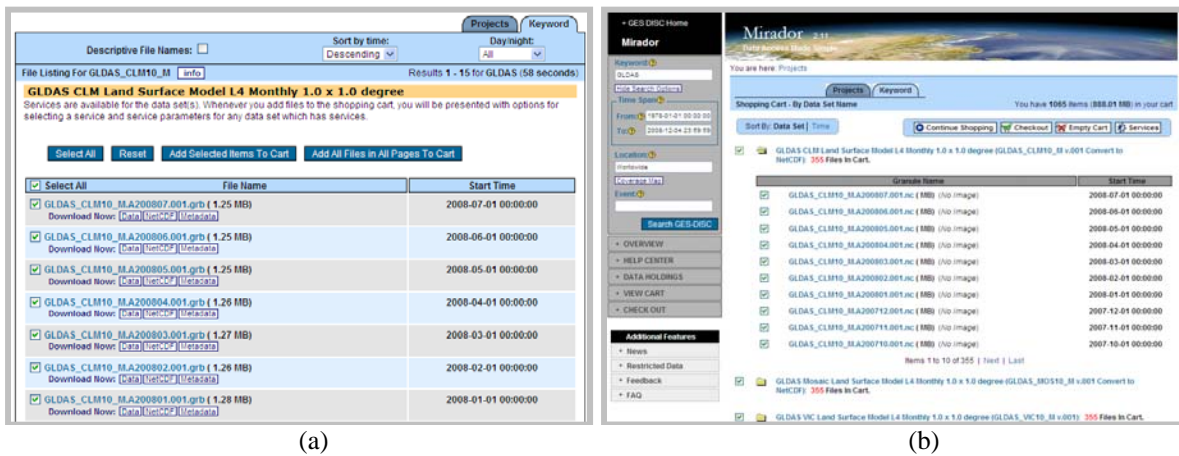
Figure 4. (a) The convert–to-netCDF service is available for GLDAS data products; and (b) from the shopping cart interface, users can run the conversion and download netCDF files.

GrADS Data Server (GDS)

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. Both NLDAS and GLDAS products are available to GDS users. Figure 5 shows the HDISC GDS pages, which have links to various NLDAS and GLDAS products. 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 products on the server. GDS supports any operation that can be expressed in a single GrADS expression, including basic math functions, averages, smoothing, differencing, correlation, and regression.
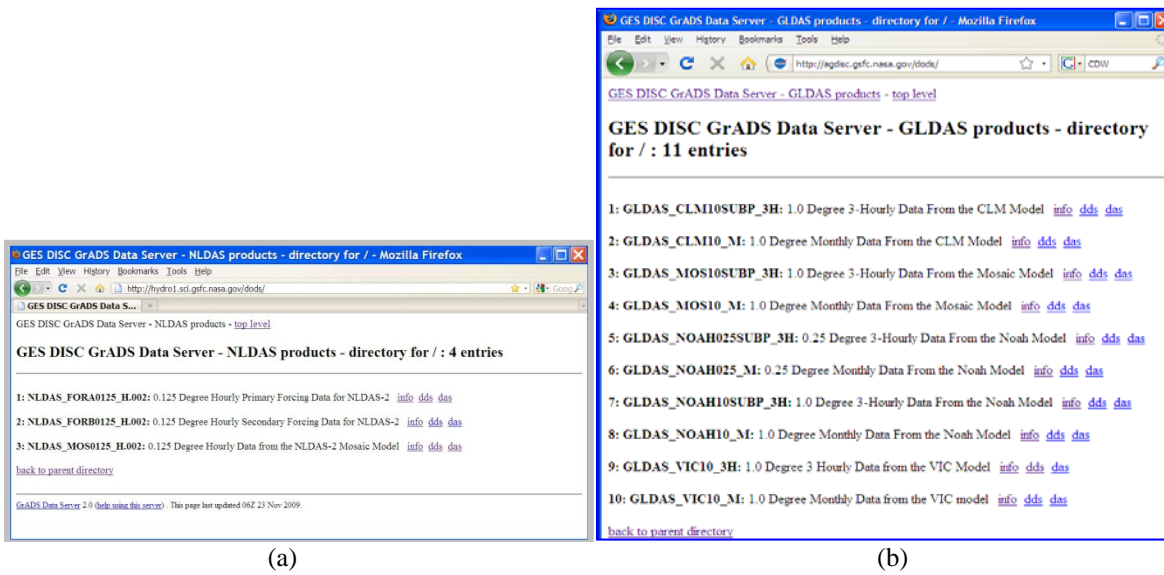
Figure 5. The HDISC GrADS Data Server (GDS) interfaces for (a) NLDAS and (b) GLDAS products.

ONLINE VISUALIZATION AND ANALYSIS WITH GIOVANNI

Giovanni is an online application developed by the GES DISC that allows researchers to rapidly explore data, so that spatial-temporal variability, anomalous conditions, and patterns of interest can be directly and easily analyzed online before optionally downloading higher resolution data (http://disc.sci.gsfc.nasa.gov/techlab/giovanni/). It is user friendly and no previous experience with visualization tools or software installations is required. All 1.0° monthly GLDAS products from the four land surface models are available from the GLDAS instance of Giovanni. A screen capture of the instance interface page is shown in Figure 6.

Giovanni-GLDAS users simply select one or more of the data parameters, spatial and temporal ranges, and the desired visualization. Seven visualization options are available in the current GLDAS instance: animation; lat-lon map (time-averaged); correlation map; lat-lon map (time-averaged differences); scatter plot; scatter plot (time-averaged); and time-series. More advanced visualization capabilities will be added in the future. Figure 6 shows the lat-lon map (time-averaged differences) being selected, along with the Average layer 1 soil moisture data layer. As an example of Giovanni's useful feature for quick comparisons, maps of evapotranspiration fields from each of the four models are plotted in Figure 7, for the Amazon for December 2009, using common color scale and color bars.

Figure 6. Online visualization and analysis of GLDAS products in Giovanni.
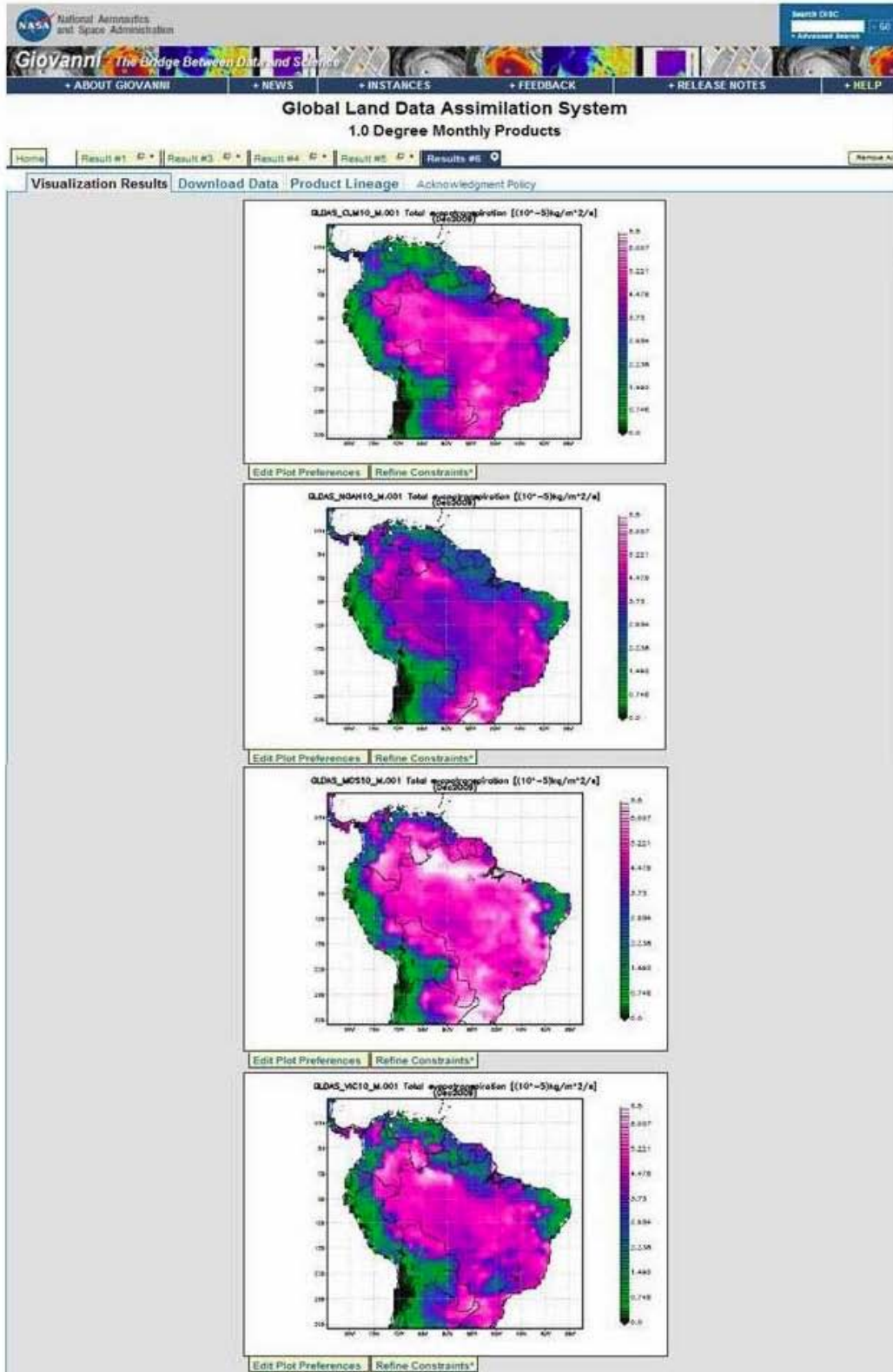
Figure 7. Monthly mean evapotranspiration maps of the Amazon for December 2009 from CLM, Noah, Mosaic, and VIC (top to bottom), plotted by Giovanni.

Outputs from Giovanni visualization are available in several formats: HDF, netCDF, ASCII, and KMZ. The KMZ file option allows researchers to view the GLDAS data in Google Earth by downloading the KMZ files under the "Download Data" tab. Figure 8 is an example of Average layer 1 soil moisture data, estimated from the VIC model, as visualized in Google Earth.
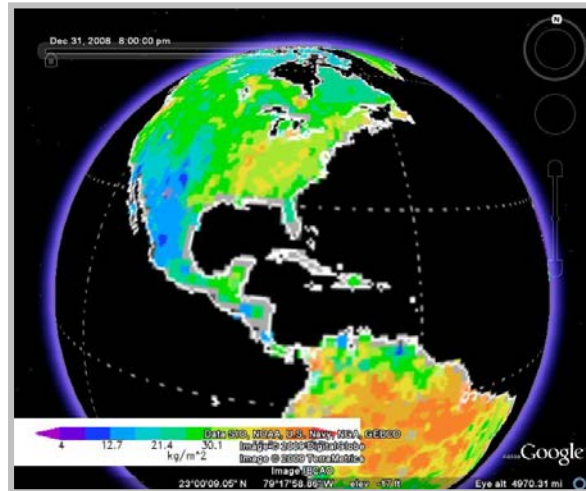

Figure 8. The KMZ file option allows users to view the GLDAS data in Google Earth.

APPLICATIONS OF TERRESTRIAL HYDROLOGICAL PRODUCTS

The NLDAS and GLDAS products have been used in seasonal numerical weather prediction, monitoring water storage, and other hydrometeorological studies. NLDAS drought monitoring products are applied in support of the National Integrated Drought Information System (NIDIS).

Drought Monitoring With NLDAS Data

In an ongoing study, the NLDAS-2 data are used in various combinations to generate different drought indices. The three main types of droughts investigated were (a) meteorological (primarily from precipitation deficit); (b) hydrological (primarily from streamflow/runoff deficit); and (c) agricultural (primarily from soil moisture deficit). Figure 9 shows an example of the precipitation deciles drought index calculated from the NLDAS forcing data. The NLDAS drought monitor also includes real-time monitoring that examines current soil moisture anomalies and percentiles as compared to the 30 years of retrospective NLDAS data.
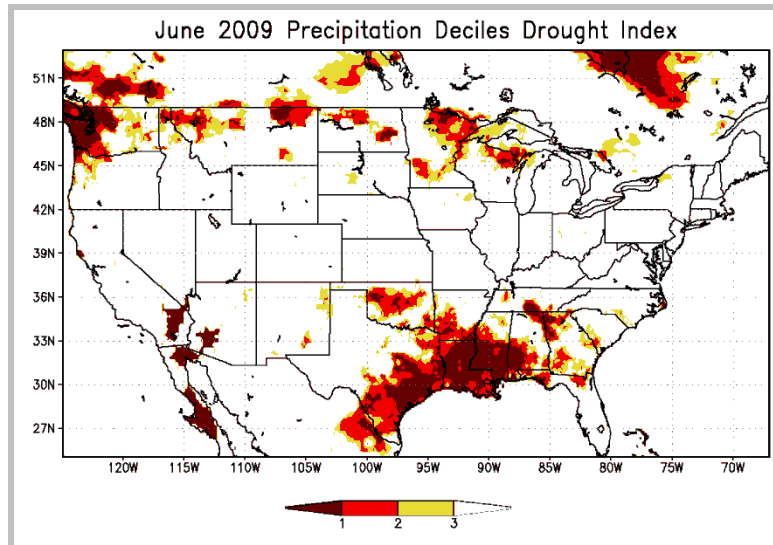
Figure 9. Precipitation deciles drought index from the NLDAS forcing data.

FUTURE HDISC DIRECTIONS

Several enhancements to HDISC are being planned: (1) a new version of reprocessed GLDAS data with more climatologically consistent data set, (2) addition of the 3-hourly products to the Giovanni-GLDAS instance, (3) release of the monthly NLDAS products, and (4) inclusion of the monthly NLDAS data in Giovanni. HDISC has the potential to support more hydrology data products and provide more advanced data access and visualization tools. Users can access the HDISC website for the latest NLDAS and GLDAS data and HDISC news (http://disc.gsfc.nasa.gov/hydrology/).

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