Demonstrating Land Information System (LIS) Decision Support Solutions

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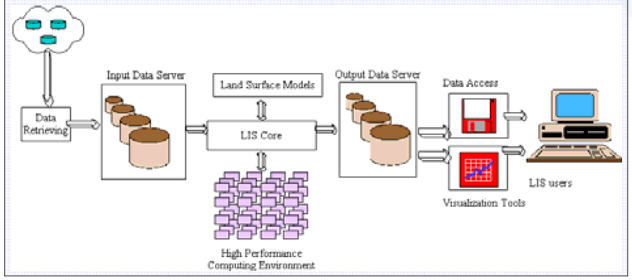
Overview

The focus of this crosscutting integrated systems solutions project is to develop, demonstrate, and enable the use of land surface research results to address multiple national application solutions. Knowledge of terrestrial water, energy, and carbon conditions are of critical importance to real-world applications such as agricultural production, water resource management, flood, weather and climate prediction, hazard mitigation and mobility assessment. A huge volume of land surface states and fluxes are being observed on the ground or from space, including surface temperatures, vegetation conditions, snow states, albedo, longwave and solar radiation, precipitation, surface moisture, freeze/thaw state, runoff, total water storage and elevation, among others. The need to interpret and transition these NASA land surface research results into decision support solutions has motivated the development of the Land Information System (LIS). LIS incorporates the following functionality to enable this transition: a high-resolution capable land data assimilation system, involving several independent community land surface models, land surface data assimilation technologies, and integrated database operations for observation and prediction data management; a web-based user interface that accesses data mining, numerical modeling, and visualization tools. ***LIS has been recognized by many partner agencies as a valuable tool for translating and interpreting NASA's vast Earth observation resources into information useful for decision support***. Therefore, this work is being conducted in response to requests by these partner agencies to prototype LIS solutions, demonstrate them in the partner's operational environment, and characterize LIS performance. In addition, the data assimilation capability provided within LIS enables the optimization of NASA Earth science research results in partner decision support tools using Observing System Simulation Experiments (OSSEs).

Methods

The Global Land Data Assimilation System (GLDAS) is internationally recognized as a key NASA resource for the global assessment of terrestrial water and energy conditions and fluxes. It is being used extensively by the research community for studies ranging from climate and weather forecast initialization to the improvement of hydrologic decision support systems. The goal of the GLDAS is to ingest satellite- and ground-based observational data products, using advanced land surface modeling and data assimilation techniques, in order to generate optimal fields of land surface states and fluxes (Rodell et al., 2004). The GLDAS software, which has been streamlined and parallelized by the Land Information System, drives multiple, offline (not coupled to the atmosphere) land surface models, integrates a huge quantity of observation based data, executes on a global domain at high spatial resolutions (2.5° to 1 km), and is capable of producing results in near-real time. The LIS infrastructure (Peters-Lidard et al., 2004) unifies and extends the capabilities of GLDAS in a common software framework capable of ensemble land surface modeling on points, regions or the globe at spatial resolutions from 2x2.5 degrees down to 1km and finer. The 1km and finer resolution capability of LIS allows it to take advantage of the latest EOS-era observations, such as MODIS leaf area index and surface temperature, at their full resolution. The hallmark of LIS is its object-oriented software engineering design and integrated high performance computing and communications technologies that enable high-resolution ensemble land surface modeling. LIS has also adopted other Earth system modeling standards and conventions, such as the Earth System Modeling Framework (ESMF; Hill et al. 2004) and Assistance for Land Modeling Activities (ALMA; Polcher et al. 1998).



Users and Tools

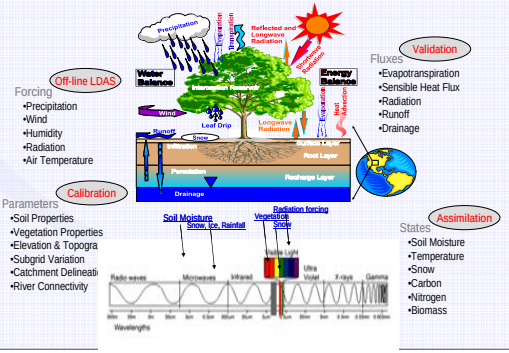
First, we identify the current and future observational systems (table 1) that may guide the development of improved parameters, forcing, validation, and data assimilation constraints for end-use solutions (Table 2). A huge volume of land surface observations may be operationally sensed from space, including surface temperatures, vegetation conditions, snow, albedo, longwave and solar radiation, precipitation, surface moisture, freeze/thaw state, runoff, total water storage, and elevation, among others.

Table 1. List of the primary data products generated from NASA's terrestrial satellite observations

Class	Observation	Technique	Example Platform	Temporal	Spatial
Land Parameters	Leaf area and greenness	optical/IR	AVHRR, MODIS, NPOESS	weekly	1km
	Albedo	optical/IR	MODIS, NPOESS	weekly	1km
	Emissivity	optical/IR	MODIS, NPOESS	weekly	1km
	Vegetation structure	lidar	ICESAT, ESSP lidar mission	weekly-monthly	100m
	Topography	in-situ survey, radar	GTOPO30, SRTM	episodic	30m–1km
Land Forcings	Wind profile	radar			
	Air Humidity and temperature	IR, MW	TOVS, GOES, AVHRR, MODIS, AMSR	hourly-weekly	5 km
	Near- surface radiation	optical/IR	GOES, MODIS, CERES, ERBS, etc.	hourly-weekly	1km
	Precipitation	microwave/IR	TRMM, GPM, SSMI, GEO-IR, etc.	hourly-monthly	10km
Land States	Temperature	IR, in-situ	IR-GEO, MODIS, AVHRR, TOVS	hourly-monthly	10m-4km
	Thermal anomalies	IR, NIR, optical	AVHRR, MODIS, TRMM	daily-weekly	250m–1km
	Snow cover and water	optical, microwave	SSMI, TM, MODIS, AMSR, AVHRR, etc.	weekly-monthly	1km
	Freeze/thaw	radar	Quickscat, HYDROS, IceSAT, CryoSAT	weekly	3km
	Total water storage	gravity	GRACE	monthly	1000km
	Soil moisture	active/passive microwave	SSMI, AMSR, HYDROS, SMOS, etc.	3-30 day	10-100 km
Land Fluxes	Evapotranspiration	optical/IR, in-situ	MODIS, GOES	hourly-weekly	10m-4km
	Solar radiation	optical, IR	MODIS, GOES, CERES, ERBS	hourly-monthly	
	Longwave radiation	optical, IR	MODIS, GOES	hourly-monthly	10m-4km
	Sensible heat flux	IR	MODIS, ASTER, GOES	hourly-monthly	10m-4km

Table 2: Example LIS relevance to crosscutting national priority applications.

Potential Partner Agencies and DSTs	Relevant National Application Areas	LIS Relevance and Applicability	Potential Value and Benefits to Citizens and Society
USDA Natural Resources Conservation Service (NRCS), Soil Climate Analysis Network (SCAN), National Integrated Drought Information System (NIDIS)	Agricultural Efficiency Disaster Management Ecological Forecasting Public Health	Water availability and weather/climate prediction (LIS fields: precipitation, runoff, evaporation and transpiration, and soil moisture)	Assessment of water availability and shifts in wetlands; prediction of weather/climate, mitigation of drought; estimation of cropping system sustainability and crop irrigation requirements, production and seasonal yield.
US Bureau of Reclamation, Agriculture Water Resources Decisions (AWARDS) Evapotranspiration (ET) Toolbox	Agricultural Efficiency Disaster Management Water Management	Water availability and weather/climate prediction (LIS fields: solar radiation, precipitation, runoff, snow states, evaporation and transpiration, and soil moisture)	Assessment and forecasting of water availability; irrigation agriculture efficiency; optimization of hydropower production; reduction of greenhouse gas emissions.
US Bureau of Reclamation and University of Nevada—Reno, RiverWare	Agricultural Efficiency Disaster Management Water Management	Water availability and weather/climate prediction (LIS fields: precipitation, runoff, soil moisture, snow states, and evapotranspiration)	Reservoir regulation; water supply for irrigation, hydroelectric power and recreation; endangered species; flood reduction; mitigation of drought.
US Army Corps of Engineers (USACE), Corps Water Management System (CWMS)	Coastal Management Disaster Management Energy Management Water Management	Water availability and weather/climate prediction (LIS fields: solar radiation, precipitation, runoff, snow states, evaporation and transpiration, and soil moisture)	Port and inland harbor operations; inland waterway navigation; water supply regulation; hydropower production; flood control and emergency response; environmental restoration; recreation.
US Army Engineering Research and Development Center (ERDC), Combat Terrain Information System (CTIS) and Army Remote Moisture System (ARMS)	Homeland Security	Military mobility (LIS fields: precipitation, runoff, and soil moisture)	Terrain trafficability for military vehicle mobility and logistics.
NOAA National Weather Service, River Forecast System (NWSRFS)	Agricultural Efficiency Coastal Management Water Management	Drought, wildfire, and flooding hazards (LIS fields: precipitation, runoff, soil moisture, and snow states)	Rapid production of timely forecasts and warnings on local and regional scales.
US Environmental Protection Agency (EPA), Better Assessment Science Integrating Point and Nonpoint Sources (BASINS)	Ecological Forecasting Water Management	Nonpoint source pollution, environmental conditions, and surface and subsurface water quality (LIS fields: precipitation, runoff, soil moisture, and evapotranspiration)	Prediction of land-use impacts; assessment of ecosystem changes; management of protected areas; forecasting for marine fisheries.
US Environmental Protection Agency (EPA), Community Multiscale Air Quality (CMAQ) Model	Air Quality Homeland Security Public Health Water Management	Weather/climate prediction, environmental conditions, surface deposition of pollutants, and surface and subsurface water quality (LIS fields: precip, runoff, and soil moisture)	Management of air quality for multiple pollutants; understanding of physical and chemical reactions in the atmosphere and land surface.
USDA Agricultural Research Service, Automated Geospatial Watershed Assessment (AGWA) and Soil & Water Assessment Tool (SWAT)	Agricultural Efficiency Ecological Forecasting Water Management	Water availability and weather/climate prediction (LIS fields: solar radiation, precipitation, runoff, snow states, evaporation and transpiration, and soil moisture)	Assessment of water availability and shifts in wetlands; prediction of weather/climate; estimation of and crop irrigation requirements.
(UK) Risk Management Solutions, River Flood Model and RiskLink	Disaster Management	Weather/climate prediction (LIS fields: precipitation, runoff, snow states, soil moisture)	Flood inundation modeling, insurance coverage determination, disaster-oriented financial losses.
US Federal Emergency Management Agency (FEMA), Hazards-US (HAZUS)	Disaster Management	Weather/climate prediction (LIS fields: precipitation, runoff, snow states, soil moisture)	Flood inundation modeling, insurance coverage determination, disaster-oriented financial losses.
US Geological Survey, Vector-borne Disease Projects	Public Health	Atmospheric transport and dispersion of pollution and pathogens, water quality, and environmental health (LIS fields: precipitation, runoff and soil moisture)	Outbreak assessment and investigation; increased warning time; reduced likelihood of pesticide resistance.
Global Energy and Water Cycle Experiment (GEWEX), World Climate Research Program (WCRP), Coordinated Enhanced Observation Program (CEOP)	Agricultural Efficiency Carbon Management Disaster Management Water Management	Atmospheric pollution, water availability, and weather/climate prediction (LIS fields: solar radiation, precipitation, runoff, snow states, evaporation and transpiration, and soil moisture)	Prediction of weather/climate; mitigation of atmospheric pollution; mitigation of drought water and food shortages.
NOAA National Weather Service, National Centers for Environmental Prediction (NCEP)	Agricultural Efficiency Disaster Management Ecological Forecasting Water Management	Water availability and weather/climate prediction (LIS fields: solar radiation, precipitation, runoff, snow states, evaporation and transpiration, and soil moisture)	Assessment and forecasting of water availability; irrigation agriculture efficiency; optimization of hydropower production; mitigation of drought water and food shortages.



Progress

NCEP Forecast Initialization: LIS was used to generate land surface states to initialize NCEP's Eta model, which should lead to improved meteorological forecasts (Cosgrove and Alonge, 2005). Forecasts of surface and upper air meteorological fields, as well as precipitation, were validated against observations using NCEP's Forecast Verification System (FVS), with the following conclusions:

Surface Forecasts
- Improved relative humidity and temperature.
- Mixed impact on wind speed forecasts.
- MODIS snow cover data improved forecasts

Upper Air Meteorology
- Mixed results
- 300mb temperature consistently improved.

Daily Precipitation
- Impact generally mixed & small.
- Improvements in placement.

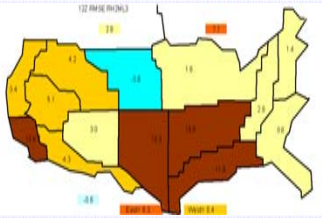


Figure 1. Percent improvement in 2m relative humidity RMSE versus control run. Results are from LIS3 12Z cycle. Warm colors indicate improvements, while cool colors indicate degradations.

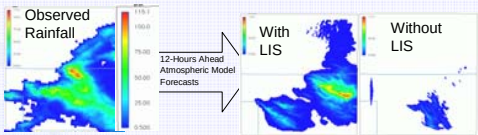
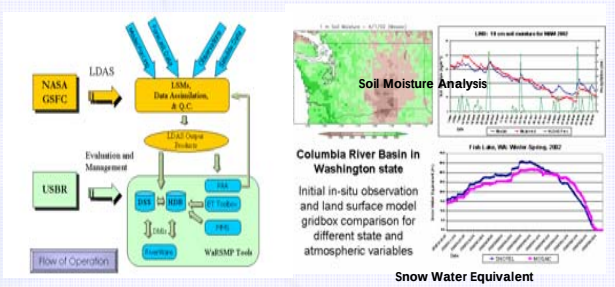


Figure 2. Coupled model precipitation forecast improvement using LIS.

US Bureau of Reclamation: Integration of LIS land products into USBR river forecasting systems (such as land cover, snow, evapotranspiration, streamflow, soil moisture, etc.) is being used to improve water resource and Hydro-energy management.



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More information

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