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NASA Land Information System (LIS) Water Availability to Support Reclamation ET Estimation

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ABSTRACT

The U.S. Bureau of Reclamation identified the remote sensing of evapotranspiration (ET) as an important water flux for study and designated a test site in the Lower Colorado River basin. A consortium of groups will work together with the goal to develop more accurate and cost effective techniques using the enhanced spatial and temporal coverage afforded by remote sensing. ET is a critical water loss flux where improved estimation should lead to better management of Reclamation responsibilities. There are several areas where NASA satellite and modeling data may be useful to meet Reclamation's objectives for improved ET estimation. In this paper we outline one possible contribution to use NASA's data integration capability of the Land Information System (LIS) to provide a merger of observational (*in situ* and satellite) with physical process models to provide estimates of ET and other water availability outputs (e.g., runoff, soil moisture) retrospectively, in near real-time, and also providing short-term predictions.

INTRODUCTION

Evapotranspiration (ET) or the water flux from the surface to the atmosphere is a crucial water availability loss that is measured in the western US by the Bureau of Reclamation (Reclamation) in a few selected locations. The amount of ET imparted to the atmosphere can account for 60% or more of surface water loss (e.g., Hartzell *et al.,* 2000) of the western US and can critically affect local economies tied to agriculture, recreation, and hydroelectric power. The development of more accurate ET estimates could save Reclamation millions of dollars. Typically, Reclamation estimates ET from land cover classifications and weather station data using field based "transfer coefficients". Reclamation entered a partnership with Alliance Universities, NASA, USDA, USGS and other groups to study more accurate and cost effective methods to estimate ET. The initial test sites will be in the high water loss corridor of the Lower Colorado River basin characterized by irrigated agriculture and riparian vegetation such as the invasive species salt cedar.

NASA CONTRIBUTIONS TO RECLAMATION ET

Overall Contributions

NASA Earth science satellite and modeling data may provide significant inputs to Reclamation's evapotranspiration and water supply and demand program. There are various satellite data such as afforded by NASA and other agencies that could benefit USBR evapotranspiration and water availability related models (Table 1). In addition to the long heritage of Landsat data, the MODerate resolution Imaging Spectroradiometer (MODIS) on the Aqua and Terra satellites provides global land, water and atmospheric data at a 1km resolution (2 bands at 250 m for land products) and up to four times per day. In addition, MODIS data are archived and processed as specific products (Table 2) for the user community. NASA with the University of Princeton is currently developing a MODIS based ET product for possible Reclamation use. Other higher resolution data sets may be useful, for example, including the Landsat Enhanced Thematic Mapper (ETM+), the EO-1 Advanced Land Imager (ALI), and the Terra ASTER.

Land Information System for Reclamation ET

We propose through the NASA Land Information System (LIS) (http://lis.gsfc.nasa.gov) (Peters-Lidard et al. 2004) to use modeling and satellite data in conjunction with ancillary Earth science data, including Reclamation data, to provide spatially distributed (e.g., 100m-1km) evapotranspiration estimates at hourly time steps for selected test cases in the Lower Colorado. Table 3 summarizes the typical output products available from LIS. LIS will be used to integrate and assimilate various data sets using a suite of land surface models within a data integration framework. LIS provides water resources applications building on the heritage of the Global Land Data Assimilation System (GLDAS; Rodell et al. 2004) the North American Land Data Assimilation System (NLDAS; Mitchell et al. 2004) developed primarily for weather and climate model initializations and predictions (http://ldas.gsfc.nasa.gov).

LIS features a high-performance and flexible design, providing infrastructure for data integration and assimilation, and operates primarily on an ensemble of land surface models (e.g. CLM2, Noah, VIC) for execution over user-specified regions and time-frames (retrospective, real-time and predictive) throughout the global land surface. Meteorological forcing is provided by satellite-, radar- and gauge-based observations of precipitation (e.g. CPC, CMAP, CMORPH, TRMM MPA) and by satellite-based observations of radiation (e.g. GOES, AGRMET), while MODIS is used to supply many surface input parameters (land cover, albedo, temperature, LAI, vegetation indexes). In addition, Reclamation site specific meteorological data (e.g., Agrimet) may also be used to provide more accurate LIS forcing data. Higher resolution data such as from the Landsat ETM+ will be used for finer resolution estimates for land cover and leaf area index. Depending on data availability, LIS may be run retrospectively, in near real-time, and also provide short-term forecasts.

Data Assimilation A key advantage to LIS is the data assimilation capability which combines land surface modeling with satellite and observational data to produce optimal ET estimates. LIS includes data assimilation methods such as the extended Kalman, ensemble Kalman and optimal insertion to merge observational and model data. This capability will enable spatially and temporally consistent fields of evapotranspiration from land surface models assimilated with surface ET measurements (e.g., eddy covariance, scintillometer, Bowen-ratio derived ET estimates).

Prediction System The physical process modeling framework of LIS coupled with its data integration capability provides an excellent opportunity to provide forecasts of evapotranspiration and other water availability parameters such as soil moisture, snow water equivalent, and runoff. For example, short-term predictions may be derived from inputting NOAA weather prediction forcings (e.g., precipitation, radiation, wind, humidity) to drive LIS for several days in to the future (e.g., 1-14 days).

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Table1. Satellite based products for input and/or assimilation in to LIS.

Class	Observation	Technique	Example Platform	Temporal	Spatial
Land Parameters	Land cover/change	optical/IR	AVHRR, MODIS, NPOESS	monthly	1km
	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	Precipitation	microwave/IR	TRMM, GPM, SSMI, GPCP, GEO-IR, AVHRR, MODIS, NPOESS	hourly-monthly	10km
	Wind profile	Radar			
	Air Humidity and temperature profiles	IR, MW	TOVS, AIRS, GOES, AVHRR, MODIS, AMSR	hourly-weekly	5 km
	Near- surface solar radiation	optical/IR	GOES, MODIS, CERES, ERBS	hourly-weekly	1km
	Near-surface LW radiation	IR	GOES, MODIS, CERES, ERBS	hourly-weekly	1km
Land States	Soil moisture	active/passive microwave, IR change	SSMI, AMSR, HYDROS, SMOS, NPOESS, TRMM	3-30 day	10-100 km
	Temperature	IR, in-situ	IR-GEO, MODIS, AVHRR, TOVS	hourly-monthly	10m-4km
	Thermal anomalies	IR, MIR, optical	AVHRR, MODIS, TRMM	daily-weekly	250 m -
	Snow cover or water equivalent	optical, microwave	SSMI, TM, MODIS, AMSR, AVHRR, NPOESS, GEO-IR, SMMR, future ESSP	weekly-monthly	1km
	Freeze/thaw	Radar	Quickscat, HYDROS, IceSAT, CryoSAT	weekly	3km
	Ice cover	radar, lidar	IceSAT, GLIMS	weekly-monthly	
	Inundation	optical/microwave	MODIS, ESSP Surface Water Mission	weekly-monthly	100m
	Total water storage	Gravity	GRACE	monthly	1000km
	Cloud water	Radar	CLOUDSAT	hourly-weekly	
	Cloud type	IR, optical, MW	TRMM, GPM	hourly-weekly	
Land Fluxes	Evapotranspiration	optical/IR, in-situ	MODIS, GOES	hourly-weekly	10m-4km
	Streamflow	microwave, laser	ERS2, TOPEX/POSEIDON, future ESSP, GRDC	weekly-monthly	100m-1km
	Carbon flux				
	Solar radiation	optical, IR	MODIS, GOES, CERES, ERBS	hourly-monthly	10m-4km
	Longwave radiation	optical, IR	MODIS, GOES	hourly-monthly	10m-4km
	Sensible heat flux	IR	MODIS, ASTER, GOES	hourly-monthly	10m-km

Table 2. Summary of MODIS available products.

Land	**Cryosphere**
•MOD 09 - Surface Reflectance	•MOD 10 - Snow Cover
•MOD 11 - Land Surface Temperature & Emissivity	•MOD 29 - Sea Ice Cover
•MOD 12 - Land Cover/Land Cover Change	
•MOD 13 - Gridded Vegetation Indices (Max NDVI & Integrated MVI)	**Atmosphere**
•MOD 14 - Thermal Anomalies, Fires & Biomass Burning	•MOD 04 - Aerosol Product
•MOD 15 - Leaf Area Index & FPAR	•MOD 05 - Total Precipitable Water (Water Vapor)
•MOD 16 - ***Evapotranspiration (Under development)***	•MOD 06 - Cloud Product
•MOD 17 - Net Photosynthesis and Primary Productivity	•MOD 07 - Atmospheric Profiles
•MOD 43 - Surface Reflectance	•MOD 08 - Gridded Atmospheric Product
•MOD 44 - Vegetation Cover Conversion	•MOD 35 - Cloud Mask

Table 3. Typical LIS forcing and output products.

ATMOSPHERIC	LAND SURFACE AND SUBSURFACE	
Net Shortwave Radiation (W/m^2)	Snowpack Water Equivalent (kg/m^2)	Top 1 m Soil Moisture (kg/m^2)
Net Longwave Radiation (W/m^2)	Snow Depth (m)	Layer 2 Soil Moisture (kg/m^2)
Downward Solar Radiation Flux (W/m^2)	Snow Cover (%)	Layer 3 Soil Moisture (kg/m^2)
Downward Longwave Radiation Flux (W/m^2)	Snowmelt (kg/m^2)	Total Soil Column Wetness (%)
Snowfall, Frozen Precipitation (kg/m^2)	Surface Runoff (kg/m^2)	Root Zone Wetness (%)
Rainfall, Unfrozen (kg/m^2)	Subsurface Runoff (kg/m^2)	Root Zone Soil Moisture (kg/m^2)
Surface Pressure (Pa)	Average Sfc Temperature (K)	Total Column Soil Moisture (kg/m^2)
Air Temperature, 2m (K)	Surface Albedo (%)	Plant Canopy Surface Water Storage (kg/m^2)
Specific Humidity, 2m (kg/kg)	Canopy Surface Water	Canopy Transpiration (W/m^2)
U Wind Component (m/s)	Vegetation Greenness (%)	Aerodynamic Conductance (m/s)
V Wind Component (m/s)	Leaf Area Index	Canopy conductance (m/s)
Convective Precipitation (kg/m^2)	Evaporation (W/m^2)	Sensible Heat Flux (W/m^2)
	Deep Soil Temperature (K)	Latent Heat Flux (W/m^2)
	Canopy Temperature (K)	Ground Heat Flux (W/m^2)

Figure 1. Flow diagram showing data integration of the Land Information System to provide evapotranspiration and other water availability parameters.