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Making an informed decision on freshwater resource management by integrating remote sensing data with traditional data

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Abstract: The US National Research Council (NRC) recommended that: "The U.S. government, working in concert with the private sector, academe, the public, and its international partners, should renew its investment in Earth-observing systems and restore its leadership in Earth science and applications." in response to the NASA Earth Science Division's request to prioritize research areas, observations, and notional missions to make those objectives. [NRC, 2007] In this presentation, we will discuss our approach to connect remote sensing science to decision support applications by establishing a framework to integrate direct measurements, earth system models, inventories, and other information to accurately estimate fresh water resources in global, regional, and local scales. We will discuss our demonstration projects and lessons learned from the experience. Deploying a monitoring system that offers sustained, accurate, transparent and relevant information represents a challenge and opportunity to a broad community spanning earth science, water resource accounting and public policy. An introduction to some of the scientific and technical infrastructure issues associated with monitoring systems is offered here to encourage future treatment of these topics by other contributors as a concluding remark.

Keywords: *Climate, Water resource management, Remote Sensing, Decision support framework*

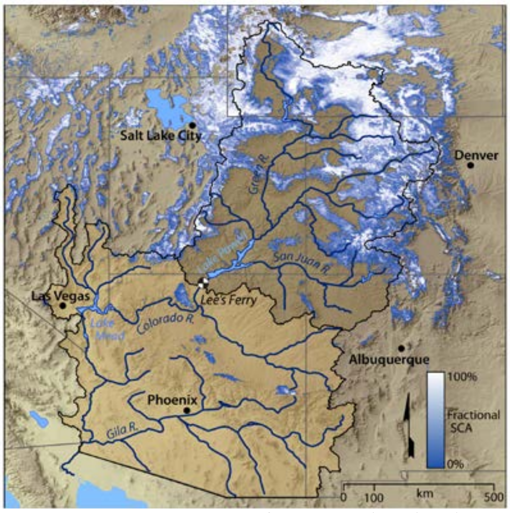
1. INTRODUCTION

NASA with a partnership with international space agencies has flown satellites to understand hydrological cycle since 1980's; they consist of SeaSAT, QuikSCAT, Jason-1, GRACE, OSTM, EOS (Aura and Aqua), TRIMM, CloudSat, and Aquarius to provide measurements of sea level, ice in land and ocean, salinity, sea surface winds, sea surface temperature, sub surface water, rain, and clouds. In coming years, more satellite and airborne instruments will be deployed to provide measurements of soil moisture, water level in rivers and lakes, snow covers, and water vapour. In developing capability to connect remote sensing measurements to decision support applications such as green house gas monitoring [Duren, 2011] and fresh water resource management, we have established a framework to integrate heterogeneous sources of information in order to establish a validated information source which estimates water resource in a statistically robust fashion with quantified uncertainties.

Adaptation to and mitigation of climate change impacts in the western United States are becoming increasingly important considerations for planning and policy development. However, an integrated, multi-disciplinary framework that enables trust-worthy, scientifically informed decisions is lacking. In conceptualizing this framework, we have studied current practices by decision makers and identified key gaps. One of the key gaps is reconciling between 'top-down' estimates of water resources in the earth atmosphere, land, and ocean, and 'bottom-up' estimates of water inventories in an iterative synthesis assessment of the amount, location, and trends from in situ statistics and analysis.[Duren, 2011] Another key component of the effort is to build on established relationships with local, regional and state level water managers to develop and refine requirements for information products and the IT infrastructure. Here are three key objectives in establishing the goal:

- **Understand stakeholder information needs** by **building** on relationships with local, regional and state agencies (LADWP, MWD, DOI/USGS) to provide decision relevant information products through active engagement of the end users.
- **Integrate multi-disciplinary science and technology to enable informed decisions** through **synthesis** of Earth science mission and *in situ* observations to create relevant information products and services. Specifically:
  - —Range-scale Snow Water Equivalent products derived from integrated MODIS, airborne instruments, and USDA SNOTEL observations with emphasis on effects of dust on snow [Painter, 2010].
  - —Near real-time flood inundation information products for the Sacramento and San Joaquin Valleys derived from multiple microwave sensors and integrated with USGS river gauge measurements.
  - —Multi-scale surface water and vegetated wetlands GIS based maps for the Sacramento-San Joaquin Delta derived from AMSR-E, MODIS, QuikSCAT, Palsar and Landsat.
- **Facilitate the flow of information to managers and stakeholders** by **developing** the IT infrastructure to provide integrated information products that will improve monitoring and data collection.

According to the Colorado river basin forecast system [Werner, 2012], models validated by observed data are critical in estimating water resources. Climate change and dust deposition from disturbed lands have already begun the encroachment on this precious resource. As a proof concept for a forecast system, JPL is establishing an airborne snow observatory (ASO) to provide snow water equivalence in the Sierra Nevada and the mountains of the Upper Colorado River Basin. For ASO, data sources of dust accumulation and snow water equivalence are the airborne instrument suite of radar, radiometer, hyperspectral imager, and lidar. (Fig. 1 & 2) [Painter 2010] The key role for remote sensing data is to provide timely coverage of snow and to validate models used in the river forecast system, which consists of weather and climate forecasts, hydrologic model analysis, observed data, and calibration. JPL also hosted a workshop to address key observed data requirements in estimating water resource in this changing climate; they included measurements of precipitation, snow, evapotranspiration, soil moisture, ground water, surface water and runoff, and integration and modeling. [Fisher, 2012] The biggest unknown identified in the workshop was a quantification of evapotranspiration. Additionally, fusion of complex heterogeneous data sources in a timely manner will require GIS based infrastructure to handle multiple data formats and quality of service that a decision support system requires.



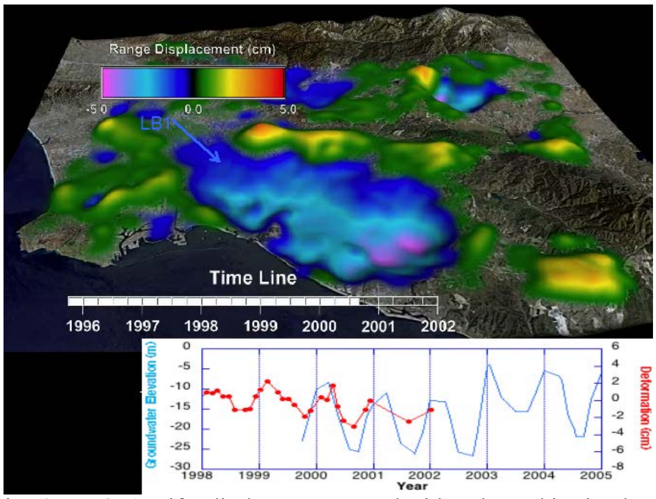


Figure 1. Snow Cover map of Upper Colorado River Basin **Figure 2.** Aquifer discharge compared with radar and in situ data

4. CONCLUSIONS

The challenges are to connect global and regional scale models and data product to local scale. Furthermore, there is growing recognition of the potential of applying improved top-down methods in synthesis with bottom-up methods to the challenge of monitoring and forecasting water resources across the coupled earth system. Independent of supporting verification efforts or enabling improvements in accuracy, a system like ASO would offer relevant information in order to quantitatively assess the ultimate effects of mitigation actions on policy-relevant space–time scales and provide rigorous guidance for future policy formulation. The best approach might be to prototype systems to build a capability one step at a time and understand the impact to decision process. Remote sensing plays an important role; however, it is only relevant if the existing forecasting systems incorporate these new data and clearly understand caveats associated with these data.

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