SWOT Integration with In-Situ Measurement Networks and the Combined Utility for Water Cycle Modeling

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Overview

• The need for integrated water cycle modeling
  – What is it?
  – Why do we need it?
• How can SWOT and in-situ measurement networks help?
  - Examples
    Model calibration/validation
    Groundwater storage monitoring
    Global freshwater discharge
The Need for Integrated Water Cycle Modeling

Integrated Water Cycle Modeling

• Modeling all the major stocks and fluxes of the terrestrial water cycle in a comprehensive and interactive manner.
  – Snow, surface water, soil moisture, groundwater
  – Evapotranspiration, runoff, streamflow, floodplain hydrodynamics, energy fluxes, interfacial water fluxes
• Links to in situ and remotely-sensed data, hydrologic information systems, etc.
  – Streamflow, soil moisture, well levels
  – SWOT, SMAP, GRACE, AMSR-E, MODIS, etc.
• Ideally, water management, consumptive use and urban areas should be included
  – Irrigation, reservoir storage, withdrawal rates
• Links to water quality, biogeochemical, ecological and climate models
• Models should be available to the community
  – Community Hydrologic Modeling Platform (CHyMP)
Recommendations:

• *Near-term development of CHyMP* from existing model components and software packages

• Longer-term commitment to exploring the role of multiphysics modeling as key component of a CHyMP

• An important use case of the CHyMP should be a *framework for national water cycle modeling* that can serve as a critical focal point for the CHyMP and hydrologic communities.
## CHyMP Scoping Workshop

**26-27 March, 2008, Washington, DC**

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**Modeling Platform**
An Integrated Water Cycle Model

The need for SWOT and other sensors

Goteti et al., 2008
Potential Applications of Integrated Water Cycle Modeling

What questions can we address with such models?

• How is fresh water distributed over and through the land surface, and how will this change over the next century?

• How can water management best adapt to changes in global hydrology, and what are the local- to global-scale feedbacks?

• What are the full Earth system implications for large-scale biofuel production?

• Is enhanced terrestrial water storage a viable strategy to mitigate sea level rise while relieving potential water availability in drought-prone regions?

**Grand challenge: modeling the storage, movement and quality of water at every point on the landscape**

*There is simply no way to accomplish this without assimilation of in situ and remotely sensed data*
How can SWOT and in-situ measurement networks help?

Example using GRACE, streamflow measurements and CHARMS

- Calibration/validation of CHARMS model (Goteti et al, 2008)
- In situ data from Illinois Soil Water Survey and USGS stream gauges
- Remotely-sensed total water storage from GRACE
- Joint use of GRACE and baseflow calibration (Lo et al. 2008a) gives better water table depth simulation than either baseflow or GRACE alone (Lo et al. 2008b)
How can SWOT and in-situ measurement networks help?

Example using GRACE, soil moisture and groundwater measurements and an empirical model

- Remote sensing of groundwater using GRACE, Oklahoma mesonet data, and an empirical model for the unsaturated zone
- Fit unsat model using mesonet soil moisture data and removed snow, surface and soil water mass from the GRACE signal to estimate groundwater storage changes
- Compares well (bottom panel) to observed groundwater storage changes from well levels

Swenson et al. 2008
Decomposition of GRACE into Surface and Subsurface Water Components

Rio Negro Basin

Fractional Inundation Extent
Papa et al.

Water Storage Anomalies
Frappart et al., 2008

Variation in total from GRACE
Variation in surface waters from altimetry
Variation in soil moisture and groundwater from difference
How can SWOT and in-situ measurement networks help? Example using Jason and the Argonauts to compute monthly global freshwater discharge (1994-2007) into the ocean

\[ R = \Delta M + E - P \]

* \( R \): Global freshwater discharge
* \( \Delta M \): Global ocean mass change from T/P & Jason-1 mean sea level variations (from Steve Nerem).
* We compared GRACE \( \Delta M \) with that computed using ARGO floats, and to Ishii (2006) and Ingleby and Huddleston (2007). Comparisons were favorable so we used both Ishii and IH to compute global discharge
* \( E \): Global ocean evaporation (from OAFlux, HOAPS, SSM/I)
* \( P \): Global ocean precipitation (from CMAP and GPCP)

*Syed, Famiglietti, Chambers, Willis, Hilburn, in preparation*
Summary

• Integrated water cycle models can be used to address a range of hydrological and related issues of national and international significance
• Efforts in the U.S. are being launched to accelerate their development, distribution and support at community tools
• In order to address the most pressing hydrologic issues, the models must fully utilize SWOT, other remote and in situ observations
• Follow the Jason example – what are our floats and which agencies will deploy them?
• USGS, other global databases (GTN-H, GTN-R, GRDC, US and Russian lakes data) and international partnerships
Potential Applications of a Community Hydrologic Modeling Platform

What would it look like?

• A platform of swappable components
  River transport, floodplain and wetland dynamics, snow, unsaturated zone, groundwater, etc.

• Implemented at the global scale at a spatial resolution consistent with advancing hydrology in climate models

• Watershed- rather than grid-based

• Capabilities should also include water quality, water management and urban hydrology

• Clear links to biogeochemistry and ecology

• Assimilation friendly

• Run off-line and coupled

• Prototypes are NCAR CLM and NASA LIS

• Maintaining and distributing such a platform is very likely beyond what an individual PI can accomplish
How does GRACE provide hydrological information?

How do we know the GRACE data are right?

ΔS_{LAND} compared with observed ΔS_{TOTAL} (from observed ΔS_{SNOW} + ΔS_{SW} + ΔS_{SM} + ΔS_{GW})

Illinois

Yeh et al., 2006

Saskatchewan

Swenson and Berg, 2007