SWOT: The Surface Water & Ocean Topography Satellite Mission

Doug Alsdorf
Byrd Polar Research Center
School of Earth Sciences
The Ohio State University

Funded By:
with many thanks to:

http://swot.jpl.nasa.gov/
Outline

Some Water Problems

Can Today’s Satellites Answer these Problems?

The Surface Water & Ocean Topography Satellite
Trans-Boundary Issues: ex: Tigris & Euphrates Disputes

- **Water Usage:**
  - 98.5% water in Euphrates from Turkey; Syria totally dependent; Iraq heavily dependent

- **Upsetting the Status Quo:**
  - 1977 Turkey launched Southeastern Anatolia Project (GAP): 22 dams 19 hydroelectric power plants
  - Irrigation will use 27% of total flow (25 km$^3$)
  - Tensions raised by unilateral development of basins

- **Project effectively controls both rivers**

- **Remote measurements of surface water volumes and fluxes creates free information for all, removing questions regarding who has how much.**

Slide courtesy Frank Schwartz
What is the role of wetland, lake, and river water storage as a regulator of biogeochemical cycles, such as carbon and nutrients? e.g., Rivers outgas as well as transport Carbon. Ignoring water borne C fluxes, favoring land-atmosphere only, yields overestimates of terrestrial C accumulation.

Results: 470 Tg C/yr all Basin; 13 x more C by outgassing than by discharge. But what are seasonal and global variations? If extrapolate Amazon case to global wetlands, = 0.9 Gt C/yr, 3x larger than previous global estimates; Tropics are in balance, not a C Sink?
Even the current northern lake/wetland extent is poorly known (let alone storage!):

West Siberia

(Frey and Smith, Glob. Biogeochem. Cycles, 2008)
Disappearing Arctic Lakes

Photo: Larry Smith
Arctic lakes are losing storage, despite a slight increase in precipitation. The spatial pattern of lake loss strongly suggests that the melting of permafrost is driving the process (rather than evaporation). At first, permafrost melting increases lake storage, but continued melting breaches the underlying frozen ground allowing the lake to drain into the subsurface.

Smith et al., “Disappearing Arctic Lakes,” Science, 2005
Although altimetry data have significantly advanced the study of the dynamics of oceanic variability, we have not resolved the critical scales that contain most of the kinetic energy of the ocean. For example, the cross-stream scale of the Gulf Stream is 100 km, which is not fully resolved in two dimensions by the best altimeter data set one can put together. A large fraction of the mesoscale eddy field kinetic energy appears to reside at scales close to the deformation radius which is shorter than 100 km in most of the ocean. In addition, recent work suggests that there is a rich spectrum of processes at scales shorter than 100 km that hold the key to understanding the evolution of oceanic kinetic energy and its implications for biogeochemistry.

L. Fu and R. Ferrari
Outline

Some Water Problems

Can Today’s Satellites Answer these Problems?

The Surface Water & Ocean Topography Satellite
Basic Water Balance

\( \Delta S = P - E - Q \)

- \( \Delta S \): Storage change summed from soil moisture, snow water content, surface water storage, vegetation water content, ground water, and glaciers
- \( P \): Precipitation
- \( E \): Evaporation and Evapotranspiration
- \( Q \): River discharge and Groundwater flux across basin boundary
What Can Be Measured from Space

1. **Precipitation**: measure the rainfall at a coarse spatial resolution.

2. **Surface Water**: measure the water surface elevation but not the bottom of the rivers and lakes.

3. **Soil Moisture**: measure the surficial few centimeters of moist soils and frozen ground state but not the depths below.

4. **Groundwater**: can not “see it” but can be measured along with all other mass changes.

5. **Snow**: measures radar interactions with snow grains and models the snow-water equivalent.

6. **Evaporation**: Active area of research with rich potential.

7. **Topography and vegetation**: Well proven, with decades of data.
That was a very coarse resolution, what about high resolution?

How does water flow through this floodplain? Which channels convey the most water? Where does water reside the longest?
Conventional Idea of Floodplain Inundation

Gauge Based

Amazon R.

Purus R.

\( \Delta h/44 \text{d} \)

210 cm 270

0 km 50
Measurements of Floodplain Inundation

Mid-Rising

Localized, complex patterns of $\frac{dh}{dt}$
Sharp $\frac{dh}{dt}$ aligned with many channels
Purus flood wave is apparent
Localized, complex patterns of $dh/dt$ with sharp $dh/dt$ aligned with many channels indicates flow to floodplain arriving via channels and emptying to one side. Purus flood wave supplies water.
Mud Markings

These methods do not measure the temporal changes in flood water elevations and thus are a static view of a highly dynamic process. These are also point-based approaches, yet flood waters change significantly in the lateral spatial dimension. Accuracy can be problematic: Neal et al report “... observed water mark heights vary over a 1 m vertical range within 100 m ...”
River and wetland stage in the Amazon (bottom) and Congo (top) are significantly different. Stages are similar in the Amazon thus indicating two-way fluvial-wetland exchange. Congo wetland stage is always higher than river stage, thus only one-way flow from wetlands to rivers. SWOT will enable detailed mapping of water levels and hence an understanding water, nutrient, and carbon exchange.

Lee et al., 2011
Outline

Some Water Problems

Can Today’s Satellites Answer these Problems?

The Surface Water & Ocean Topography Satellite
• SWOT continues the two-decades of CNES-NASA partnership made upon spaceborne ocean altimetry.

• CNES is a major partner, involved in SWOT technology and science; involved in hydrology and oceanography.

• CNES partnership is THE key to the success of SWOT.

• A workshare agreement between CNES and NASA is now in place, as of September 16, 2010.

• SWOT is budgeted at $951,000,000 with $269M or 28% from CNES, $682M or 72% from NASA.
KaRIN: Ka-Band Radar Interferometer

- Ka-band SAR interferometric system with 2 swaths, each 60 km wide
- WSOA and SRTM heritage
- Produces heights and co-registered all-weather imagery \textit{required by both communities}
- No land data compression onboard (+/-50 cm height accuracy per pixel)
- Onboard data compression over the ocean (1km resolution)
- Because looking near nadir, height accuracy improved by more than an order of magnitude over SRTM.
- Noise is uncorrelated, thus averaging further improves height accuracy by $\sqrt{n}$.

Graphics: Karen Wiedman

Lee et al., 2010
• Analysis based on global lake frequency-area distribution by Downing et al., 2006.

• Nadir altimeters miss more than 60% of lakes and can see area > 100 km² -> see only 15% of the global lake storage change.

• SWOT = global coverage and see area > 250 m x 250 m -> see 65% of the global lake storage change.

Biancamaria et al., 2009
SWOT capability to observe water height

Ohio River SRTM Water elevation measurements

In Situ observations from Carlston, 1969; originally by Army Corps of Engineers

Courtesy: Michael Durand, OSU
SWOT Simulated Discharge Along the Kanawha River

Durand et al., 2010

Day 1
Day 2
Day 3
Day 4

Floodwave moving downstream

Discharge, m³ sec⁻¹
Flow Distance, km
Upstream
Downstream

Ohio
Pennsylvania
West Virginia
KY
Virginia
SWOT capability to estimate discharge

Ohio River accuracy estimate based on:

1) Expected SWOT height observation accuracy
2) Temporal sampling errors
3) River width

Legend
- Width < 50 m
- Width < 100 m
- Discharge at least 20% accurate
- Discharge less than 20% accurate

Courtesy: Elizabeth Clark, UW