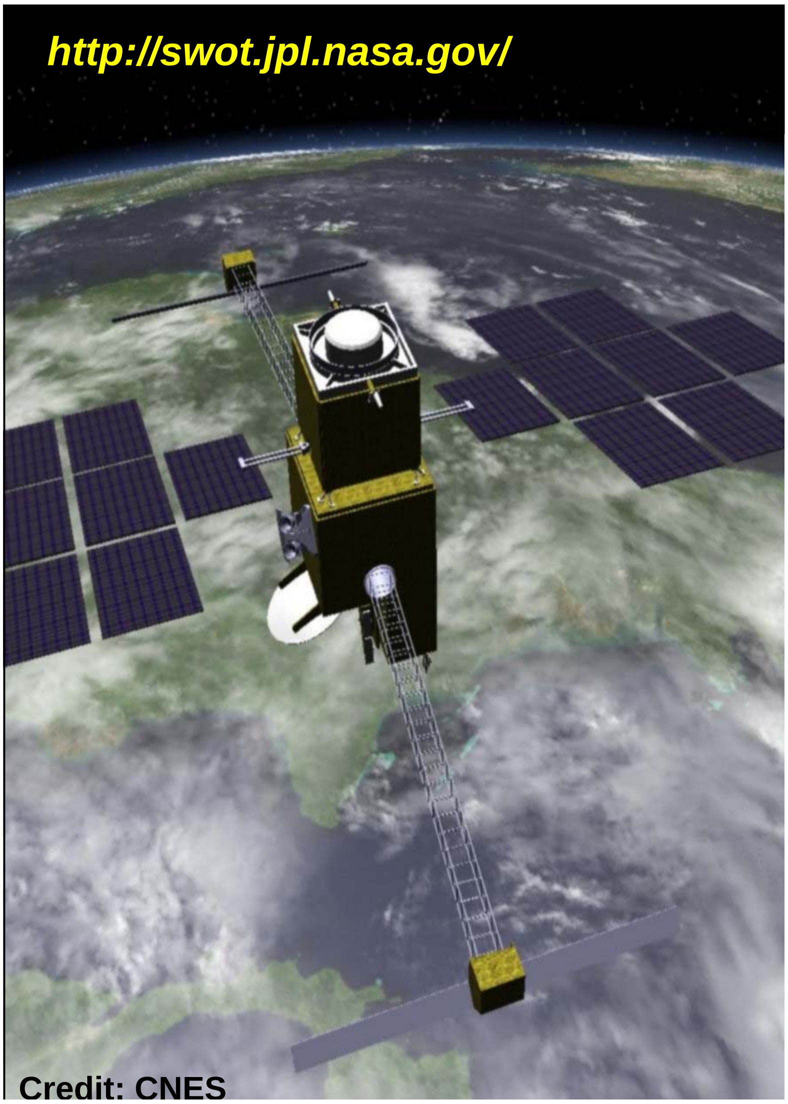

NASA's Surface Water Ocean Topography (SWOT) Mission

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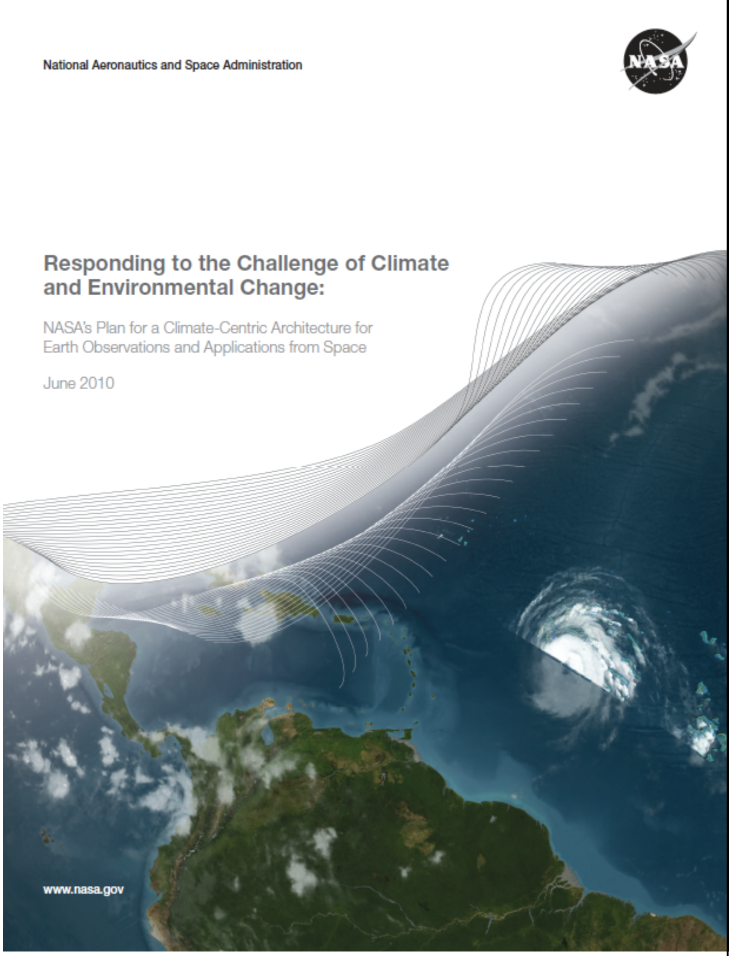
5th GTN-H Coordination Panel Meeting
University of Tokyo, Tokyo, Japan
March 12-13, 2011

SWOT is one of the key surface hydrology missions recommended in the 2007 NRC Earth Science Decadal Survey Report.

TABLE ES.2 Launch, orbit, and instrument specifications for the recommended NASA missions. Shade colors denote mission cost categories as estimated by the NRC ESAS committee. Pink, green, and blue shadings represent large ($600 million to $900), medium ($300 million to $600 million), and small (<$300 million) missions, respectively. Missions are listed in order of ascending cost within each launch timeframe. Detailed descriptions of the missions are given in Part II, and Part III provides the foundation for selection.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar radiation: spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	$700 M
Timeframe: 2013 – 2016, Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	$300 M
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	$450 M
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	$550 M
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	$800 M
Timeframe: 2016 -2020, Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	$650 M

[a] Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high accuracy SST measurement.



NRC Decadal Survey Missions Relevant for Water Storage

SMAP

SWOT

GRACE-II

SCLP

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar and Earth radiation, spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	$700 M
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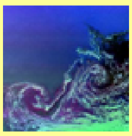
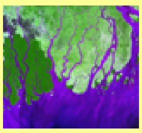
SWOT Applications from Decadal Survey

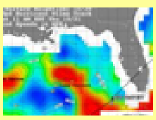
Lake, wetland, and reservoir storage



Ocean eddies and currents



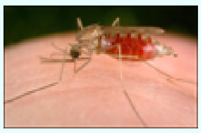
River discharge estimates



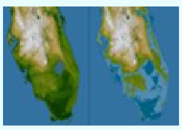
Sea level measurements extended into coastal zones

Flood forecasts

Marine forecasts



Inundation and malaria zone identification and forecasts



Prediction of changes in sea level

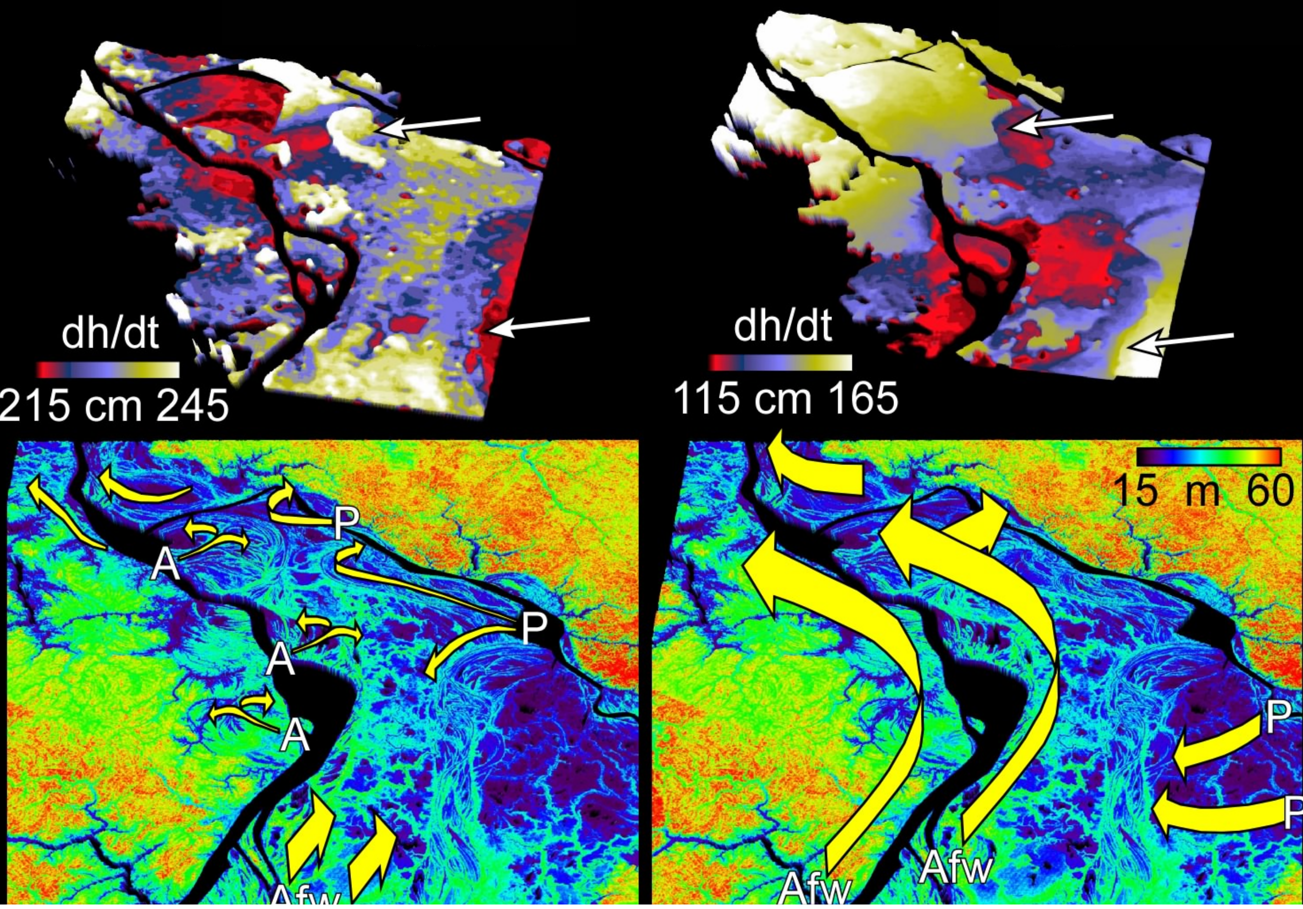
SWOT Terrestrial Hydrology

- **Water Cycle:**
  - Quantify the amount and the spatial and temporal variability in the world's terrestrial surface water storage and discharge.
  - Extend the skill of predicting the variations in surface water storage and discharge.
- **Floodplains & Wetlands:**
  - Link the quantity of water stored on floodplains to the exchange with the main channel.
  - Estimate carbon released from inundated areas.
- **Society:**
  - Quantify water stored in artificial reservoirs and its space-time dynamics.
    - What are the policy implications that freely available water storage data would have for water management?
  - Improve prediction of the propagation of disease vectors (e.g. malaria)
  - Reduce the incidence of waterborne disease through improved predictive capabilities.

SWOT Oceanography

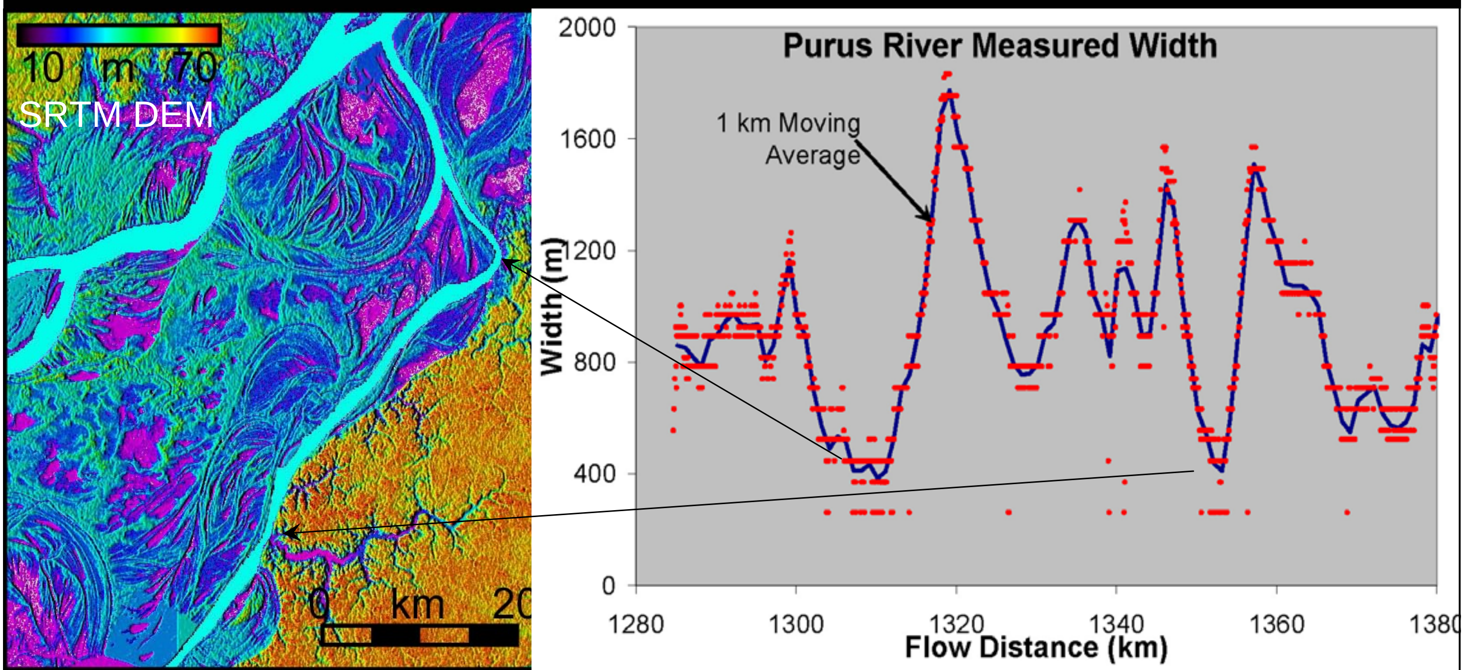
- **Ocean Currents:**
  - What is the small-scale (1-100 km) variability of ocean surface topography that determines the velocity of ocean currents?
  - How are fronts and eddies formed and evolving?
  - How is oceanic kinetic energy dissipated?
- **Coastal Currents:**
  - What is the synoptic variability of coastal currents?
  - How do the coastal currents interact with the open ocean variability?
  - What are the effects of coastal currents on marine life, ecosystems, waste disposal, and transportation?
- **Society:**
  - Map ocean currents which are needed for shipping and pollutant transport
  - Analyze the effects of ocean eddies on marine ecosystems and fisheries
  - Improved hurricane forecasts

Measurements Required: h, ∂h/∂x, ∂h/∂t, and area, globally, on a ~weekly basis



What we know: Discharge

River channel width can be automatically measured in any satellite based image.



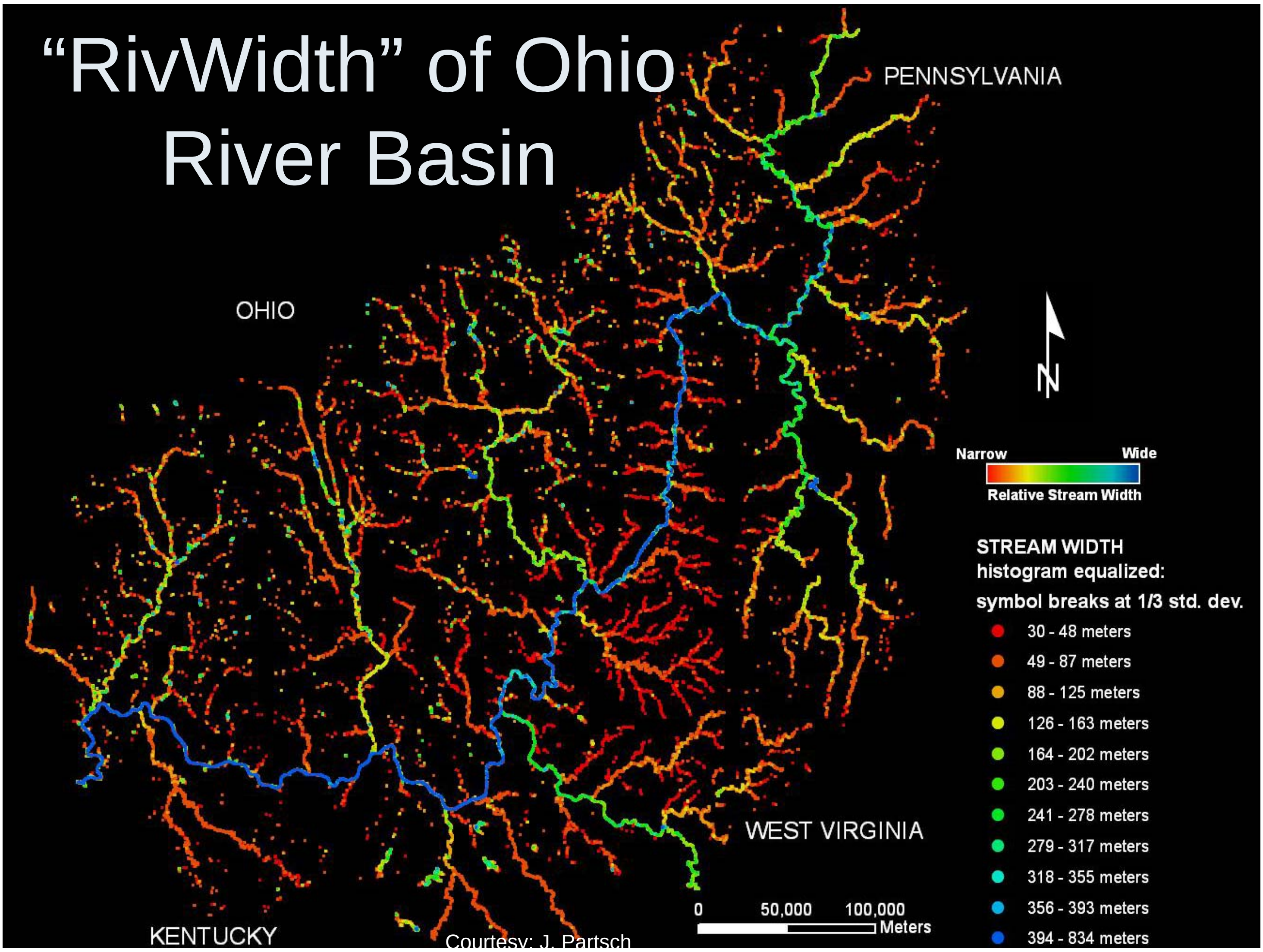
$$Q = \frac{w}{n} Z^{5/3} \left(\frac{\partial h}{\partial x}\right)^{1/2}$$

Large Width to Depth Rivers

Simple equation of water flow demonstrates need to measure width (w), depth (z), slope (dh/dx), and friction coefficient (n). Z and n will come from data assimilation.

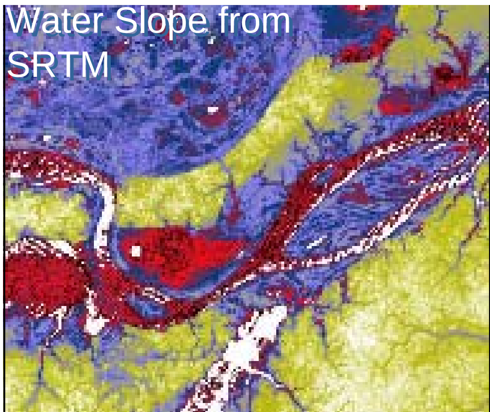
Pavelsky & Smith, RivWidth, *IEEE GRSL*, 2008

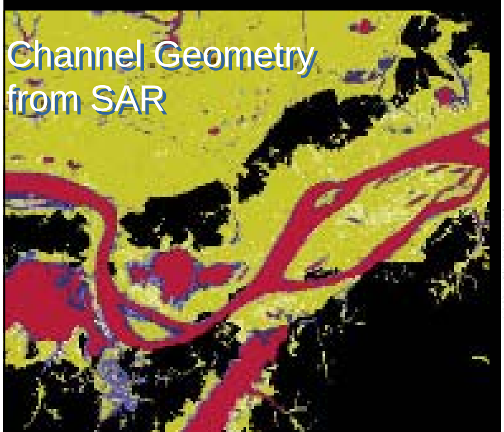
"RivWidth" of Ohio River Basin

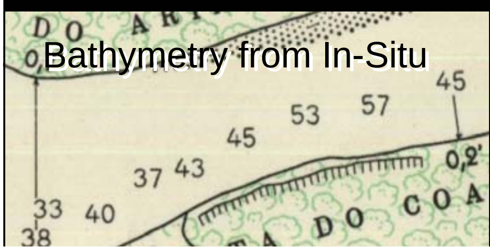


Courtesy: J. Partsch

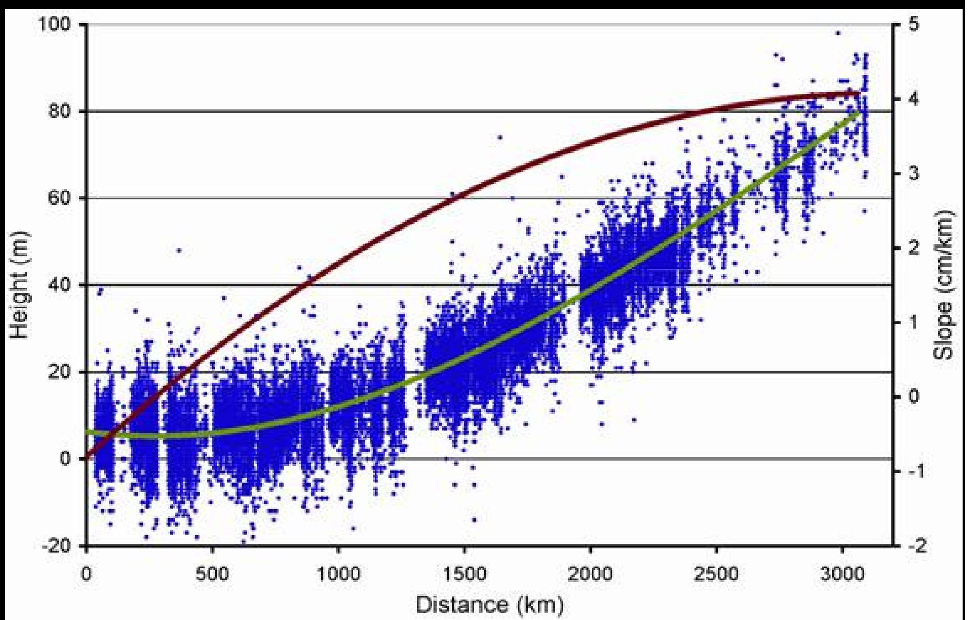
Channel Slope and Amazon Q from SRTM





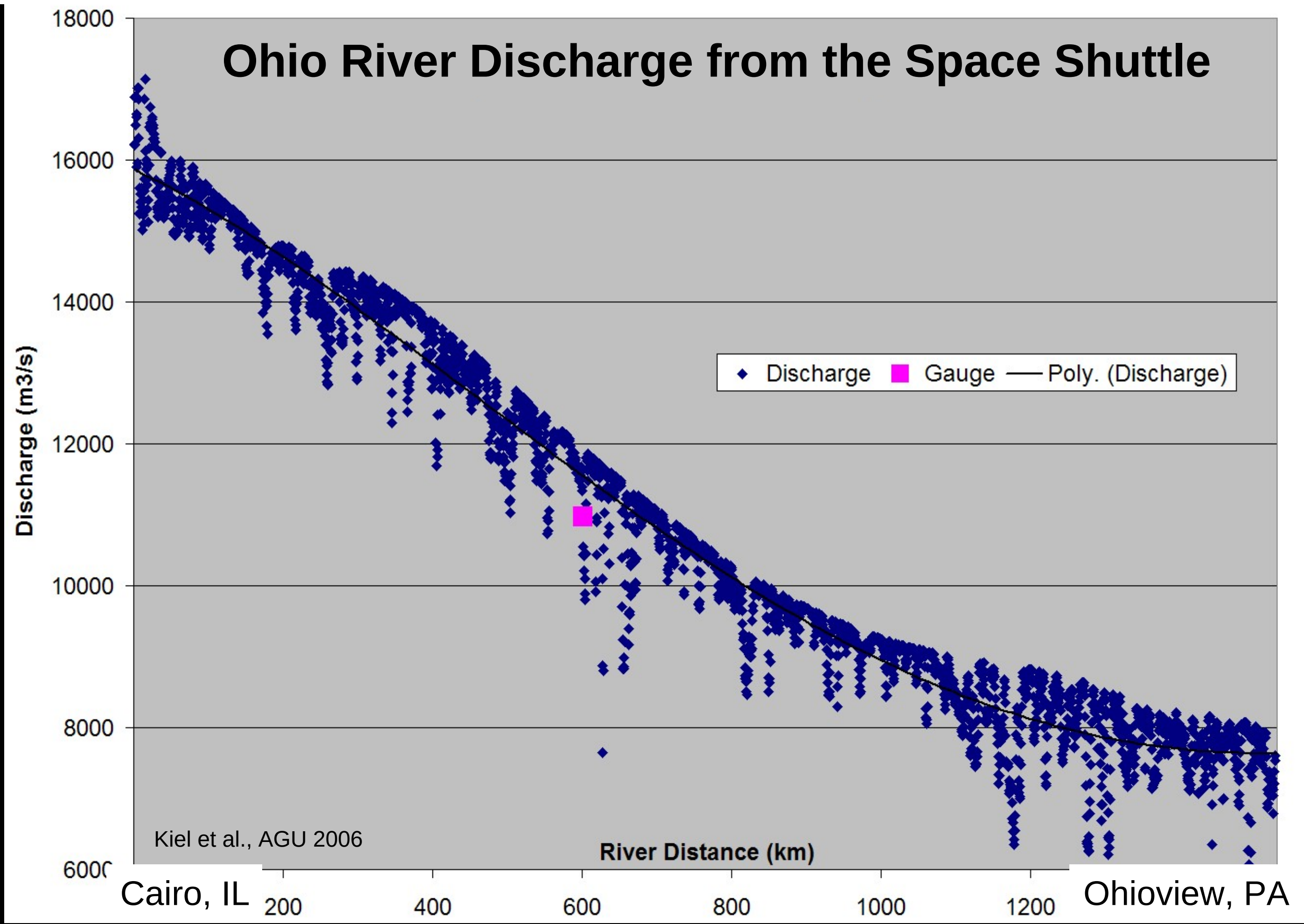


Q m^3/s	Observed	SRTM	Error
Tupe	63100	62900	-0.3%
Itapeua	74200	79800	7.6%
Manacapuru	90500	84900	-6.2%



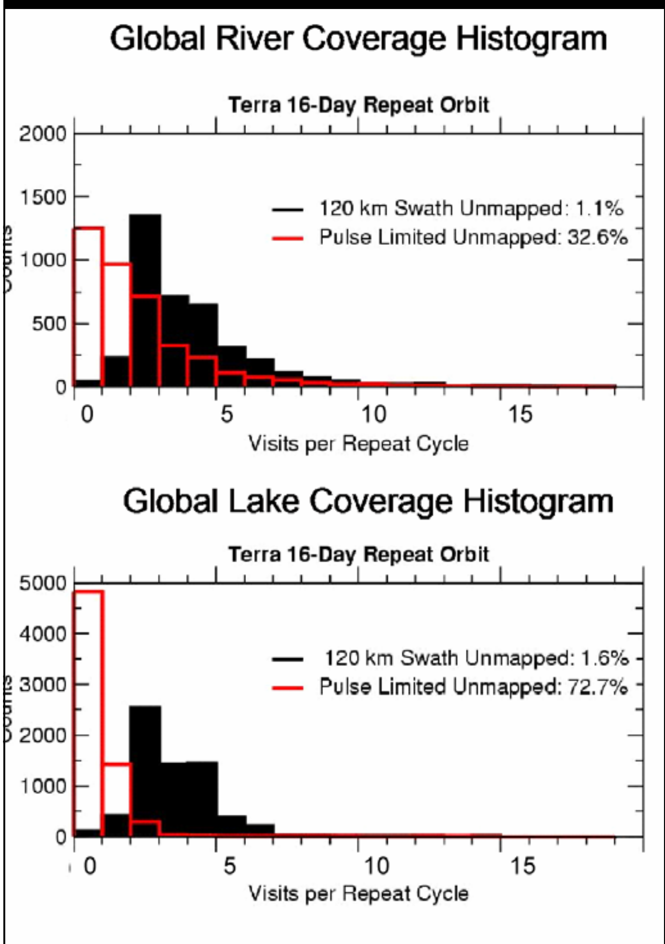
Manning's n method

LeFavour and Alsdorf, GRL, 2005



SRTM Elevations of water surfaces can be converted to river flow using Manning's equation which relates water slope to flow velocity.

What we know: Global Perspective



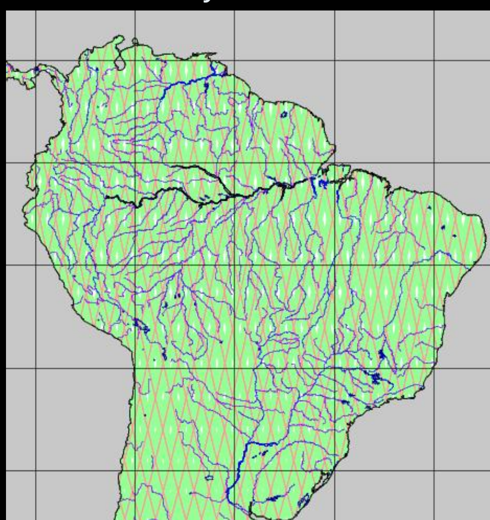
Present measurements do not provide needed global coverage, but a swath altimeter blankets the globe.

Profiling Altimeter: (16-day repeat)

- About half of world's rivers sampled only once or not at all, no slope thus no river discharge.

Swath Interferometer: (16-day repeat)

- Swath provides h, ∂h/∂x, ∂h/∂t, and area in one overpass, thus ability to estimate discharge.



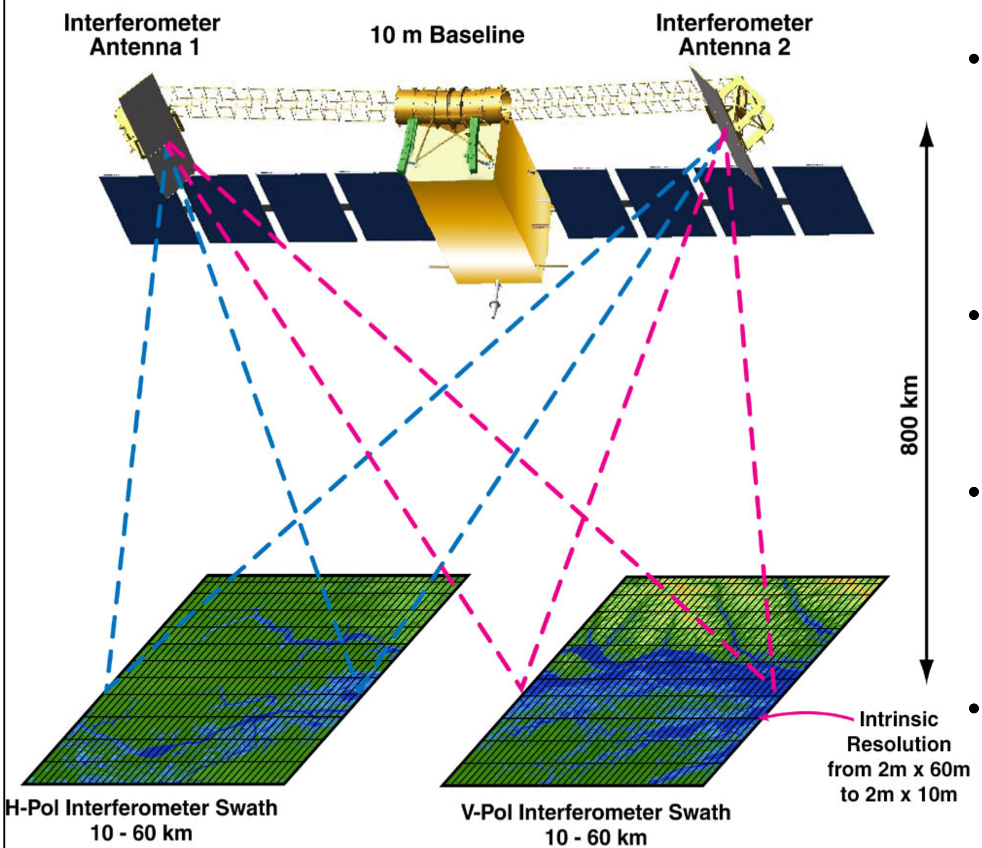
Alsdorf, D., E. Rodriguez, and D. Lettenmaier, Measuring surface water from space, *Reviews of Geophysics*, 2007

SWOT Surface Water Measurement Requirements

- **5-10 cm height accuracy** (need height change for storage change, not absolute height)
  - River discharge, wetland/lake storage change
- **Map rivers > 100m width**
  - Would like to go to smaller rivers
- **River slope accuracy: 10 mrad (1cm/1km)**
  - River discharge
- **Revisit time**:
  - Ideal: 3 days in the Arctic, 7 days in the tropics
  - Acceptable: 7 days in the arctic, 21 days in the tropics
- **Imager with resolution better than 100 m**
  - River width, wetland/lake extent
  - Should distinguish vegetated/non-vegetated
- **Global coverage, sampling all major contributors to surface water, is not affected by clouds**
  - Wetlands, rivers, lakes in tropics, Arctic thaw

Alsdorf & Lettenmaier, Science, 2003

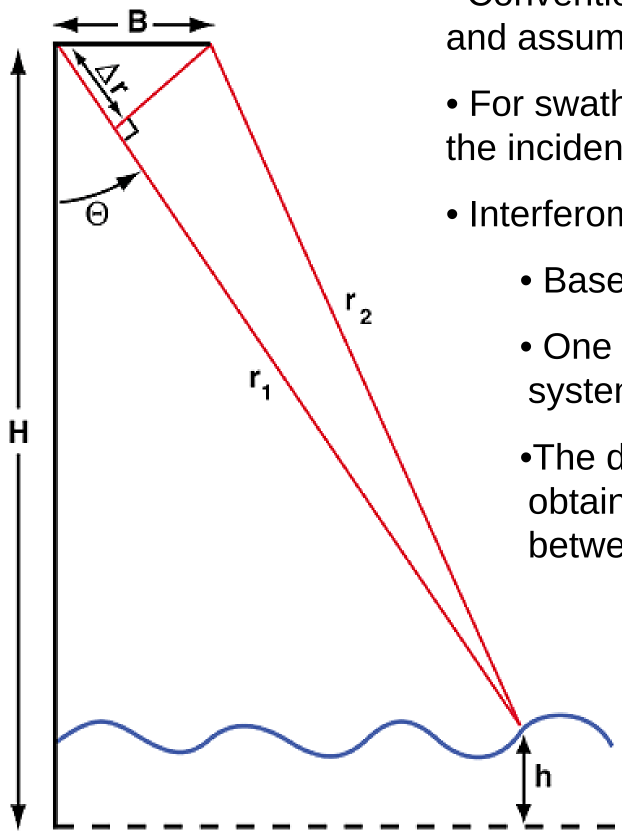
SWOT Surface Water Interferometer Concept



- **Ka-band SAR interferometric system with 2 swaths, 10km-60km on each side of the nadir track**
- **Produces heights and co-registered all-weather imagery**
- **200 MHz bandwidth (0.75 cm range resolution) for higher resolution imaging**
- **Uses near-nadir returns for SAR altimetry to fill in nadir swath**

SWOT

Interferometric Measurement Concept



- Conventional altimetry measures a single range and assumes the return is from the nadir point
- For swath coverage, additional information about the incidence angle is required to geolocate
- Interferometry is basically triangulation
  - Baseline B forms base (mechanically stable)
  - One side, the range, is determined by the system timing accuracy
  - The difference between two sides (Δr) is obtained from the phase difference (Φ) between the two radar channels.

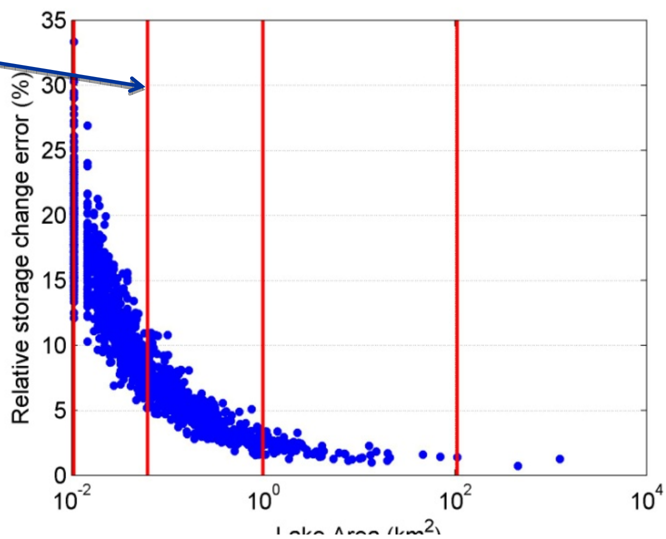
$$\Phi = 2\pi \, \Delta r/\lambda = 2\pi B \sin \Theta/\lambda$$

$$h = H - r \cos \Theta$$

SWOT Storage Change

- Arctic lakes are disappearing as permafrost melts
- SWOT will measure ΔS to better than 10% for lakes 250m by 250m in size.
- SWOT will measure ΔS in ~30 million lakes, globally; accounting for as much as 80% of the world's changing surface water volume.

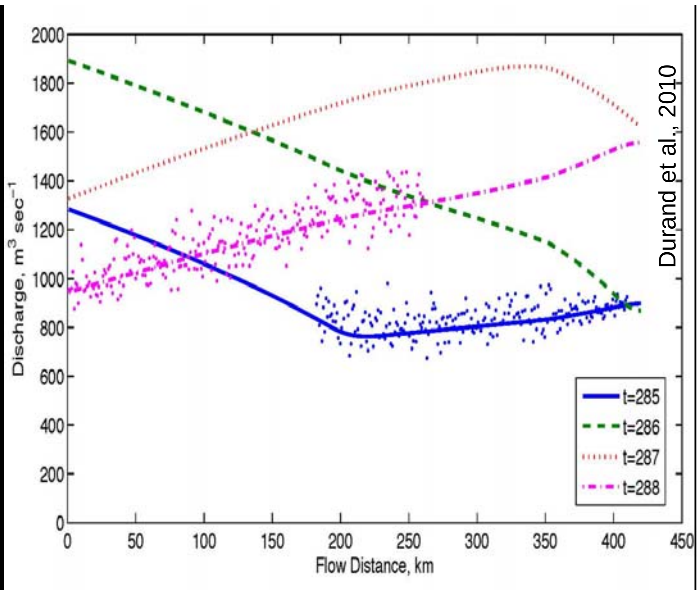
Smith et al., 2005

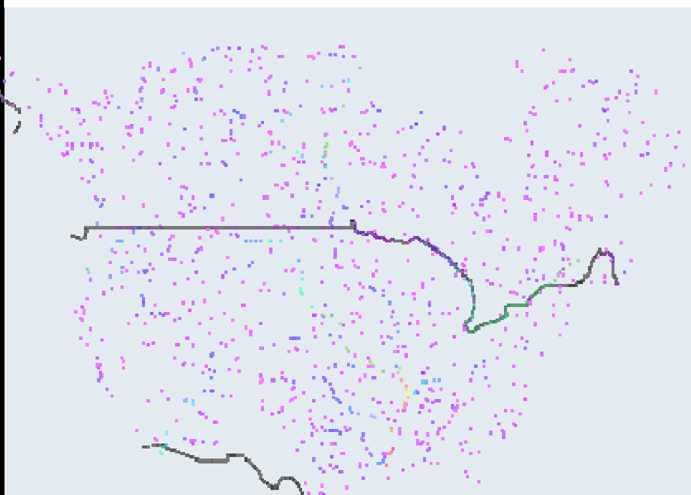


Lee et al., 2010

SWOT Discharge

- Floods are poorly measured whereas flow information from rivers crossing international boundaries is rarely shared.
- SWOT will measure h, dh/dx, dh/dt, and water area; these hydraulics are used to estimate river discharge.
- SWOT will measure floodwaves and estimate discharge along entire networks of rivers, globally.





Expected SWOT Sampling in North America

SWOT

Summary

- SWOT will help determine:
    - How much surface water we have at any place on Earth and at any time during the mission, thus a significantly improved understanding of the global water cycle.
    - How floods work, i.e., the hydrodynamics of floods
    - River flow across international boundaries
    - Energy dissipation, ocean circulation, and climate change implications from ocean currents (e.g., Gulf Stream)
    - Coastal upwelling and cross-shelf transport, and thus implications on marine life, ecosystems, waste disposal, transportation, and spill mapping
    - Ocean bathymetry, sea ice thickness, floodplain topography
- SWOT will provide a revolutionary set of hydrodynamic and sea surface height measurements, globally (e.g., h, dh/dt, dh/dx, and area).
- This mission is for everybody, please join us via the mission web page: **http://swot.jpl.nasa.gov/**