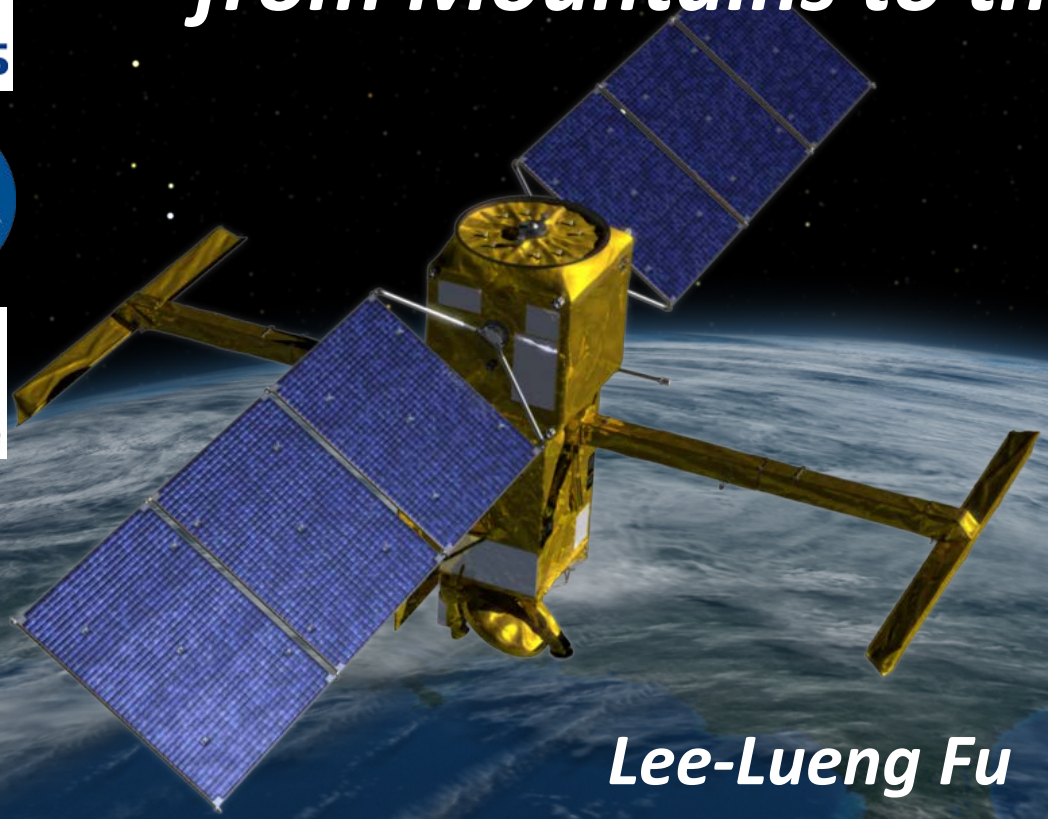
National Aeronautics and
Space Administration

SWOT: Tracking Water on Earth from Mountains to the Deep Sea



Lee-Lueng Fu
SWOT Project Scientist

Takeaway Messages

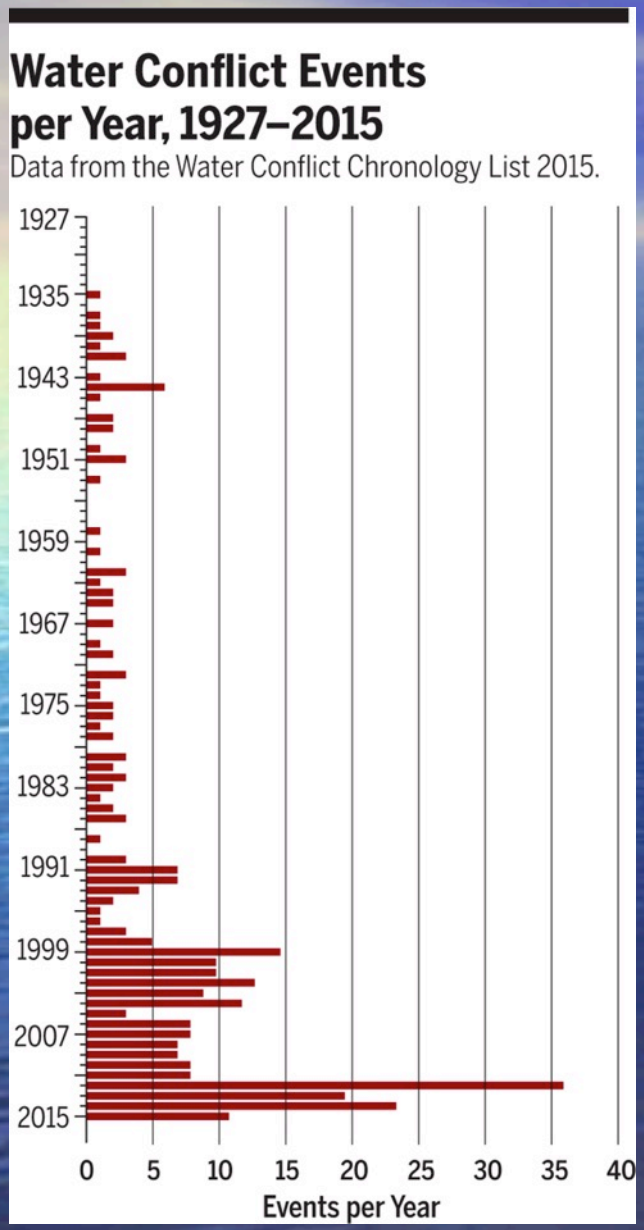
SWOT (Surface Water & Ocean Topography) will use radar interferometry for measuring the elevation of water on Earth.

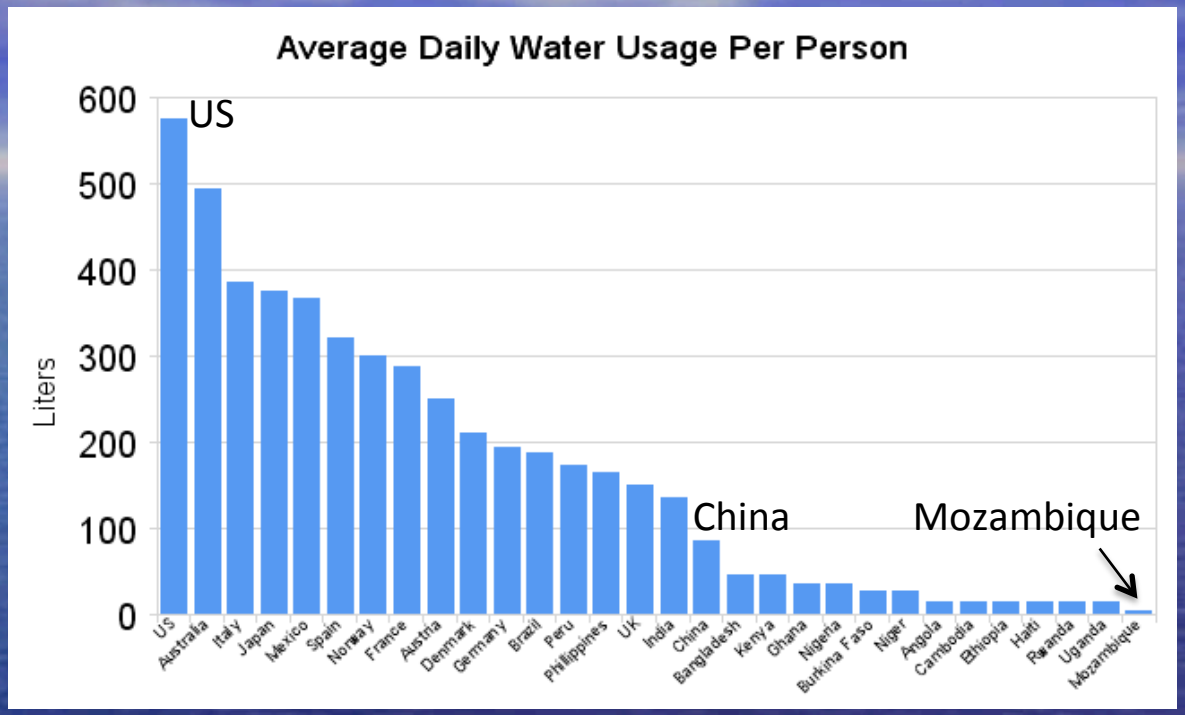
Water elevation on land provides water storage and river discharge –> water budget and cycling.

Water elevation over the ocean provides ocean current speed and direction –> oceanic flux of heat and carbon.

Resolution and coverage makes SWOT unique.

Global Water Stress



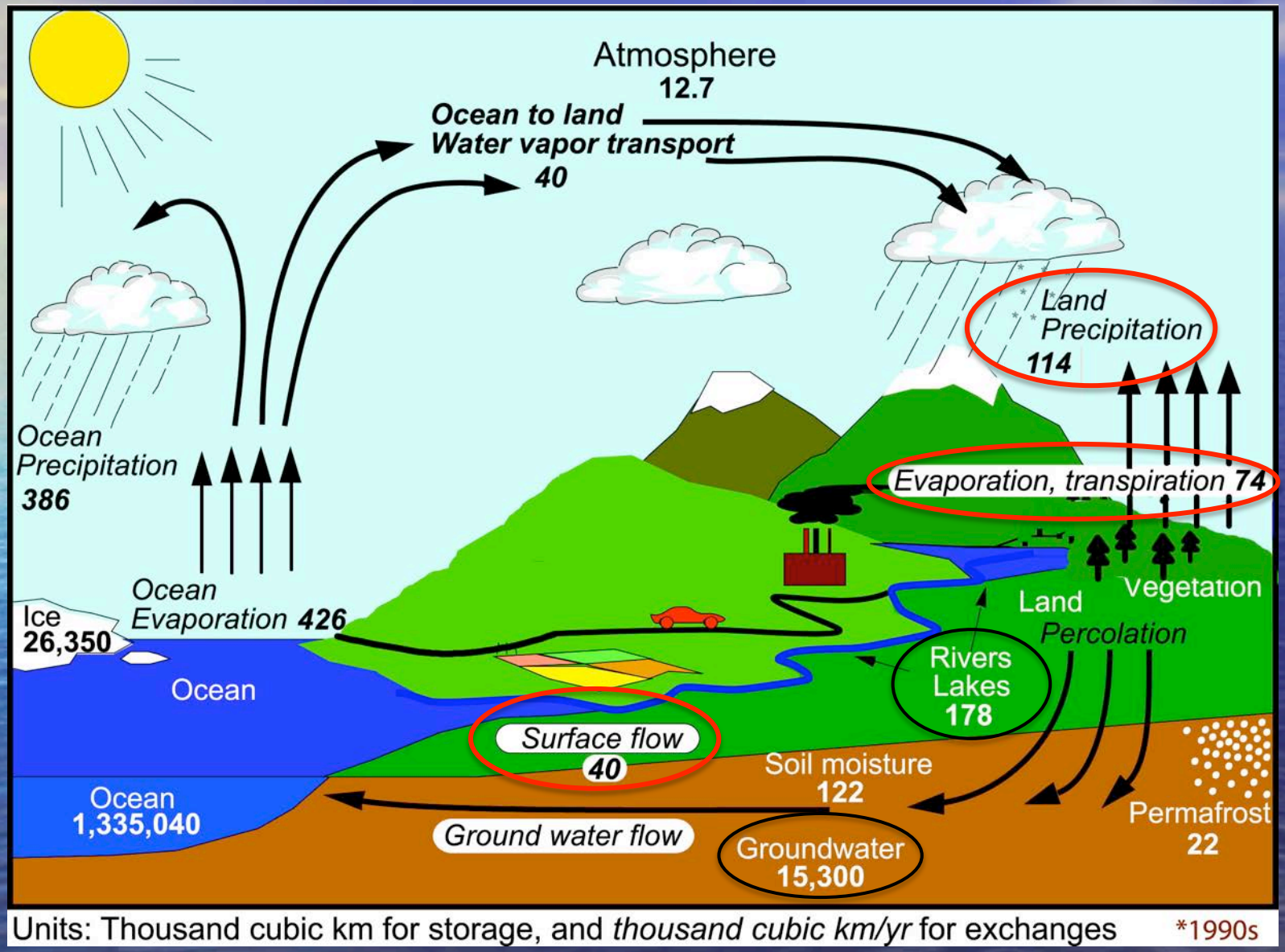


UNDP Human Development Report 2006

Population growth, climate change, political instability

Science 2016

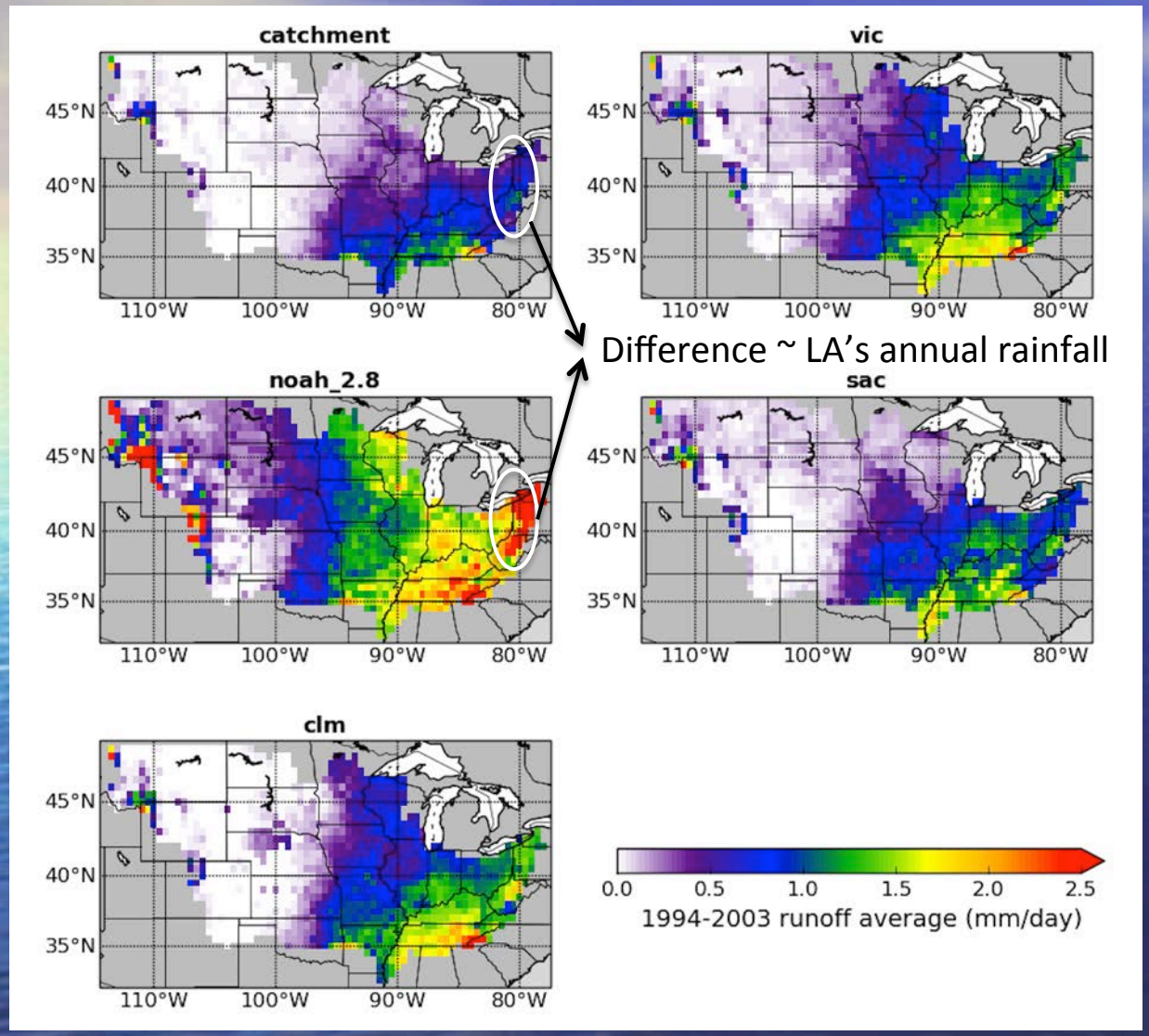
Global Water Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges *1990s

Trenberth, Fasullo, and Mackaro, 2011

Understanding the Water Cycle



Current models simulate very different patterns of runoff

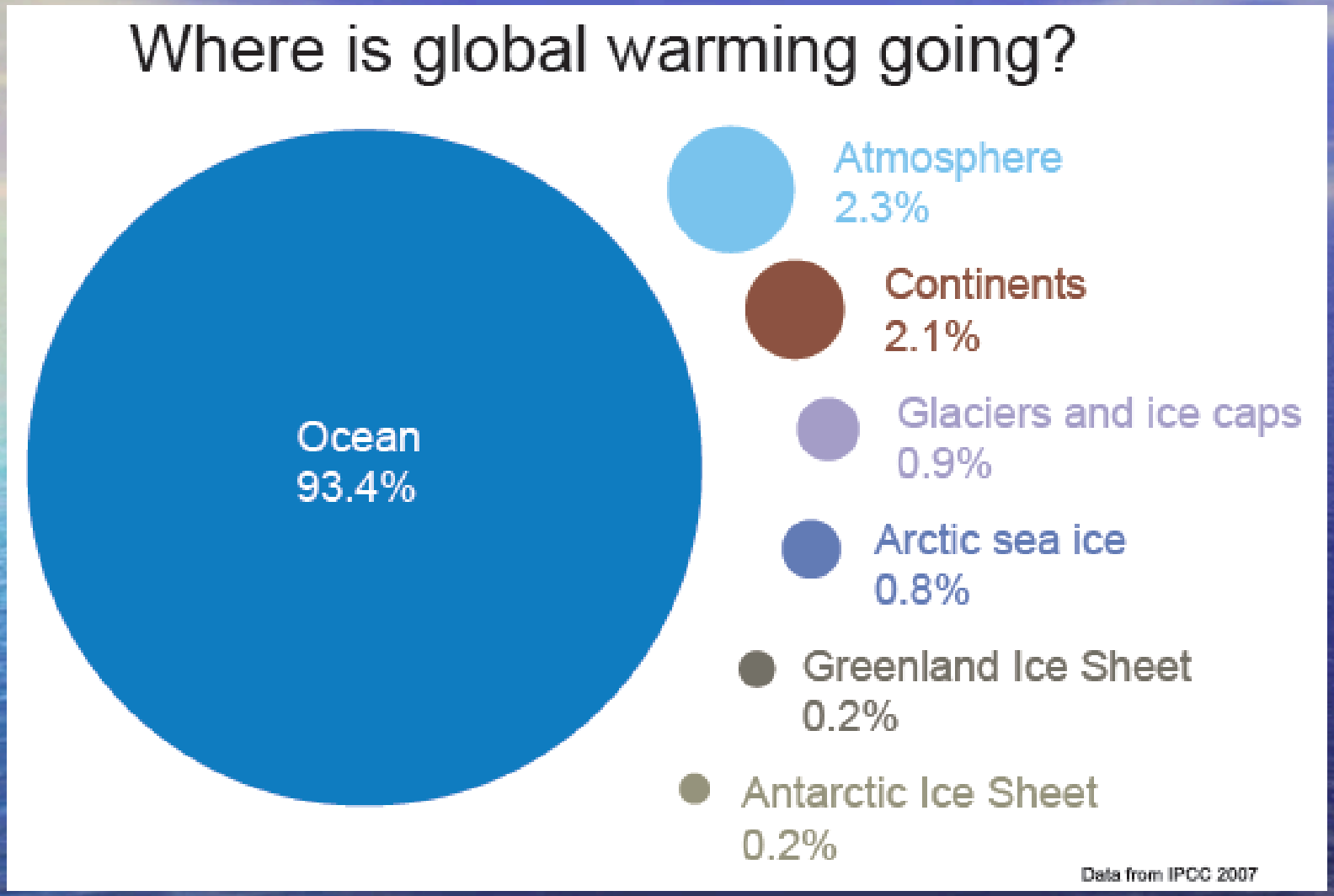
- water cycle:
  precipitation = evapotranspiration + runoff.
- Our knowledge of water balance is poor, in part because we lack global runoff data to constrain models.
- SWOT will provide runoff data at sufficiently fine spatial scales to improve the knowledge of water balance.

From D. Lettenmaier, UCLA

The Rivers of the Mississippi Watershed

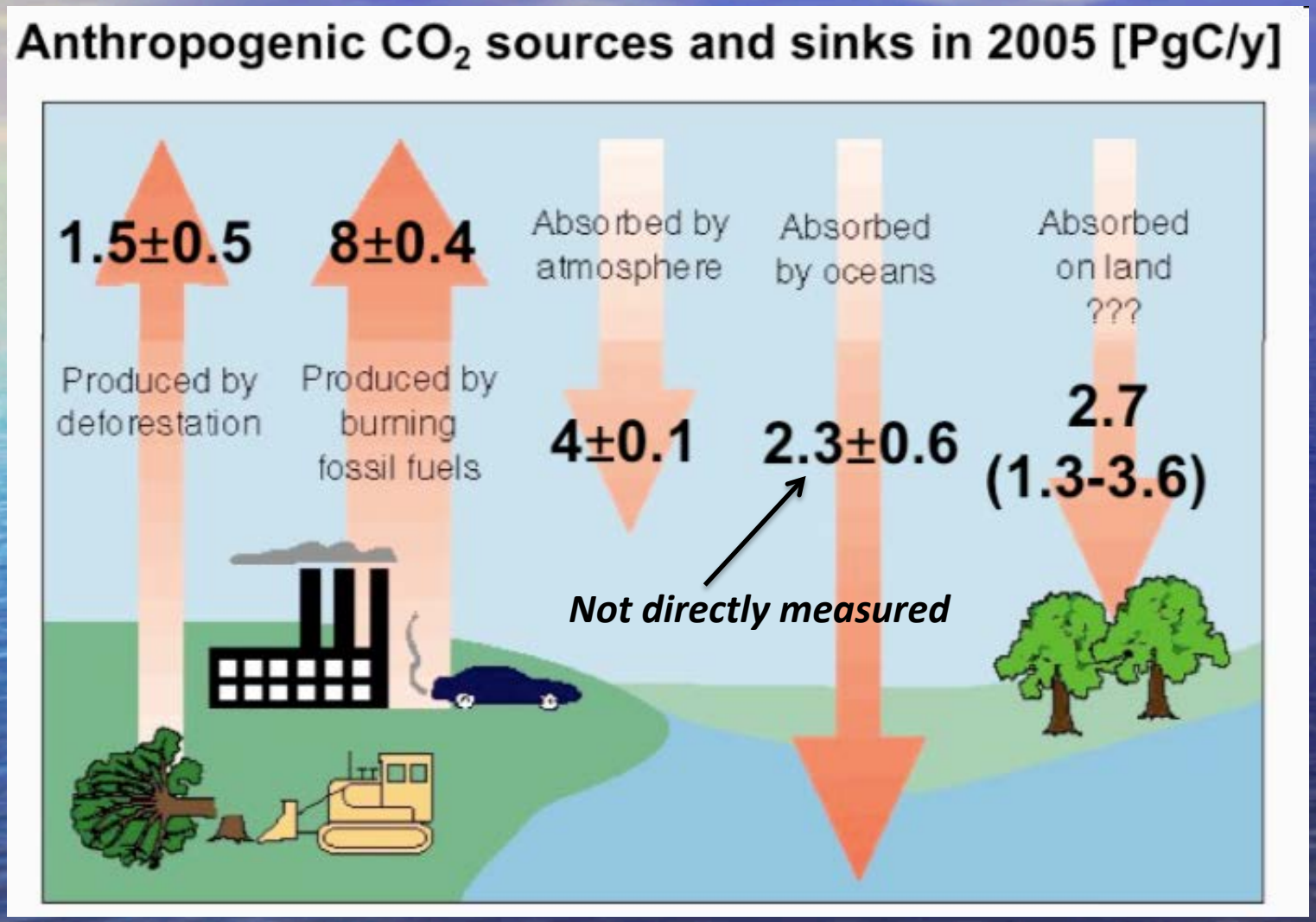
NASA's Scientific Visualization Studio
https://svs.gsfc.nasa.gov/4493

The ocean: a giant AC of the world

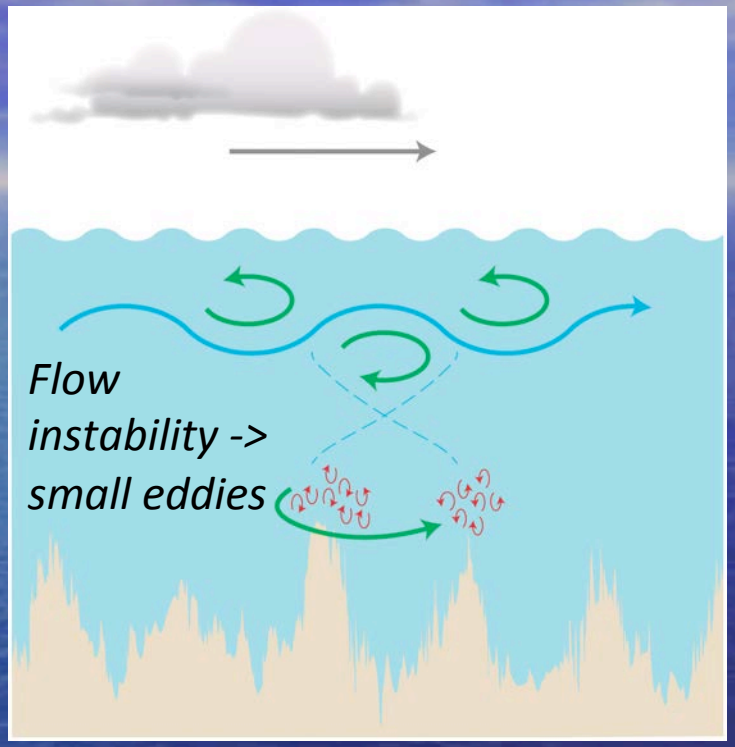


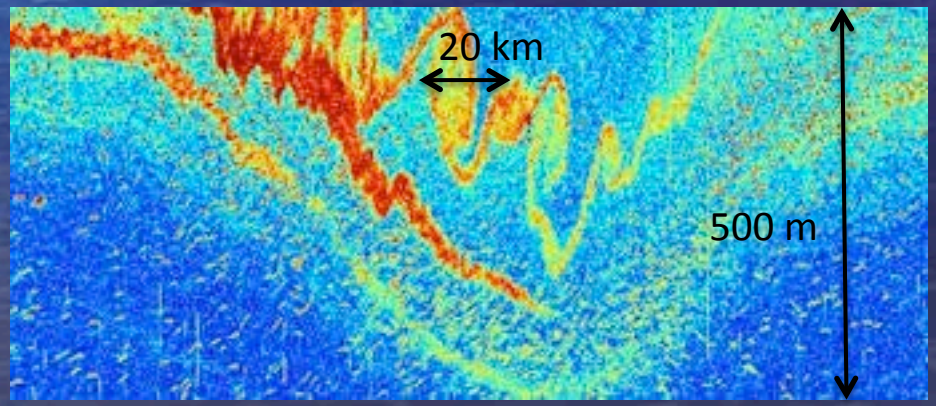
An estimate put Earth's temperature at 67° C without the ocean

Ocean absorbs ¼ of human-induced CO_2 from the atmosphere



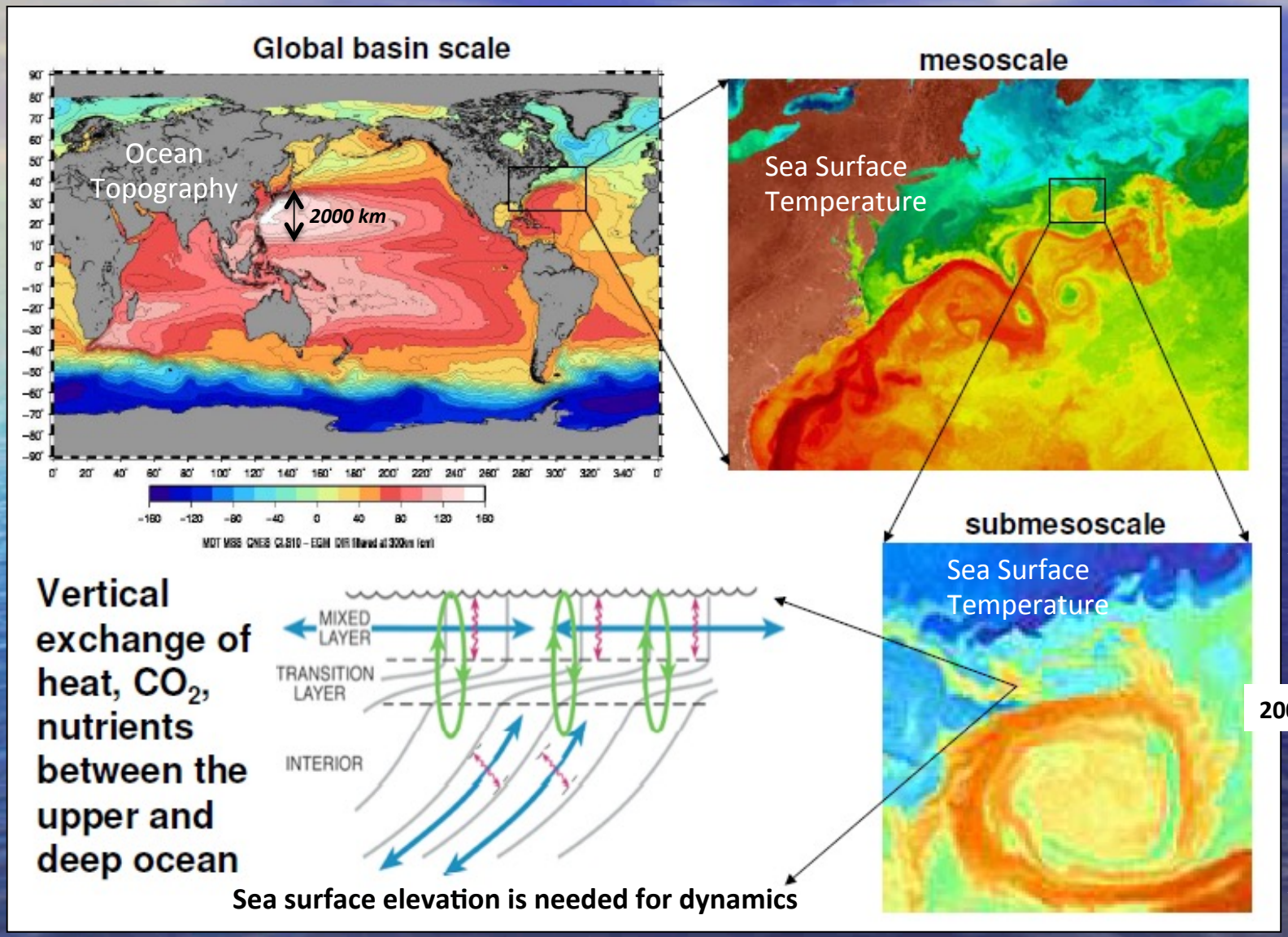
Vertical transport of heat and water properties in the ocean



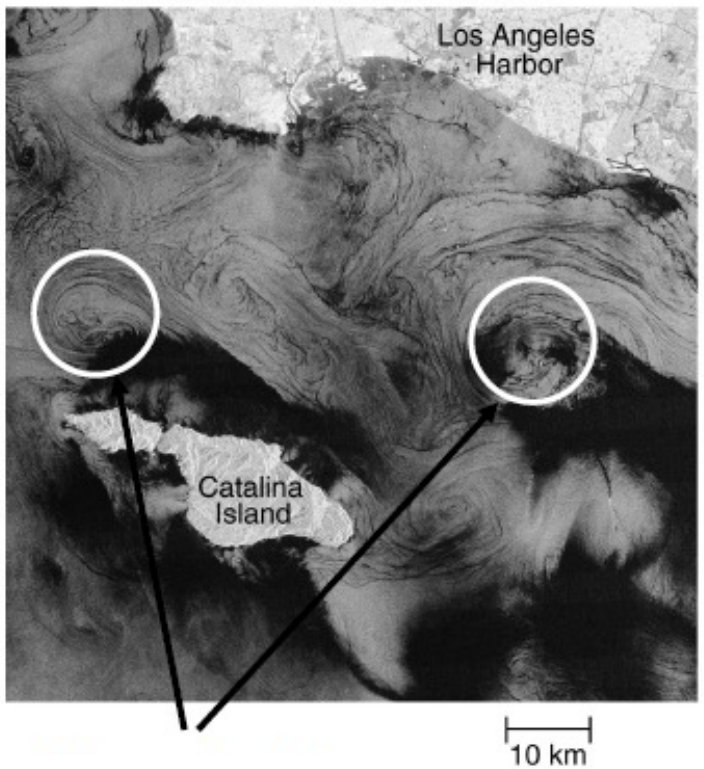


NOAA/GFDL

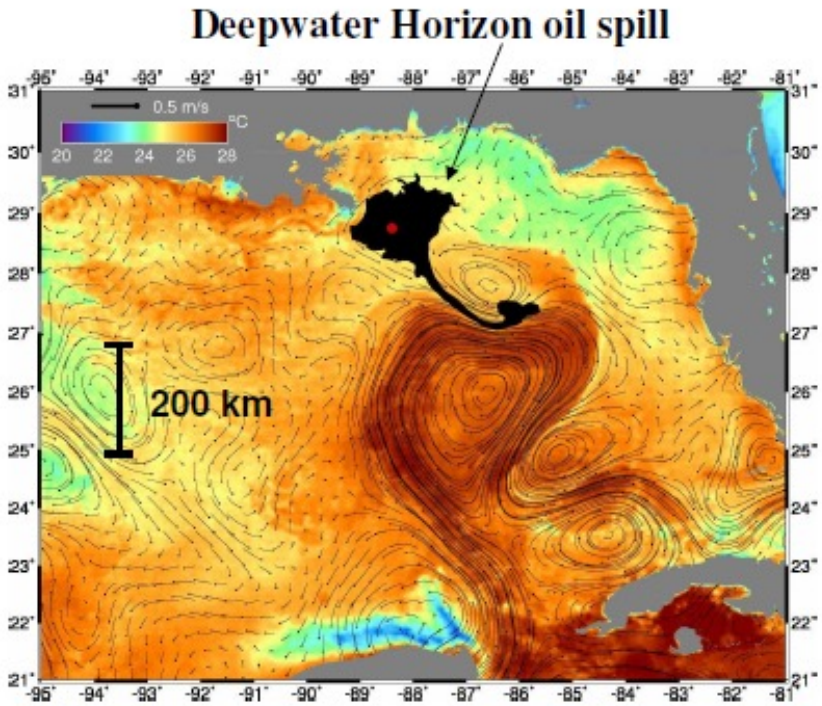
Targeting the dynamics of the smallest scales of ocean currents



Submesoscale Ocean Processes



15 km eddies

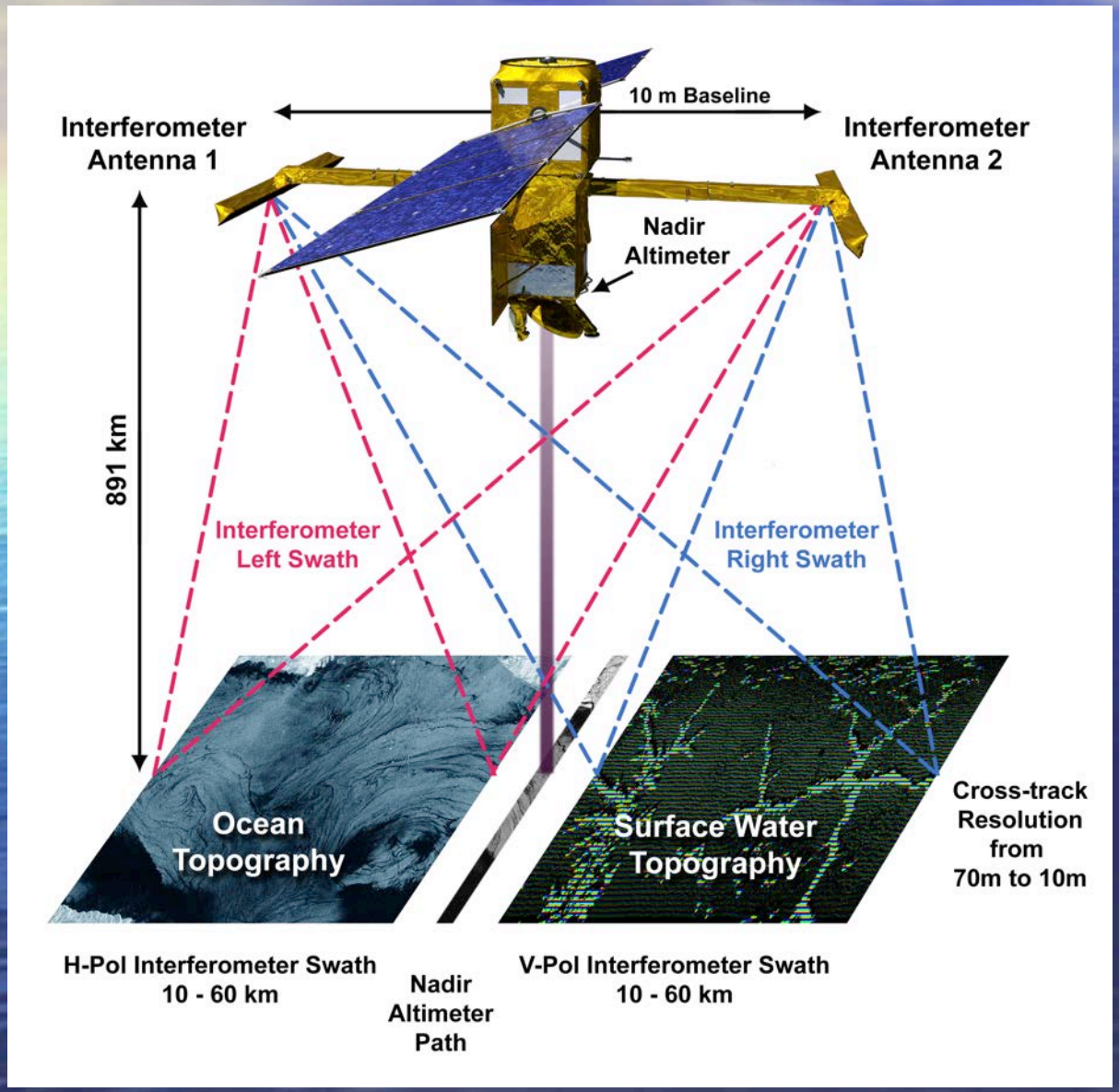


The missing information at the submesoscale is important for predicting the dispersal of pollutants in the ocean.

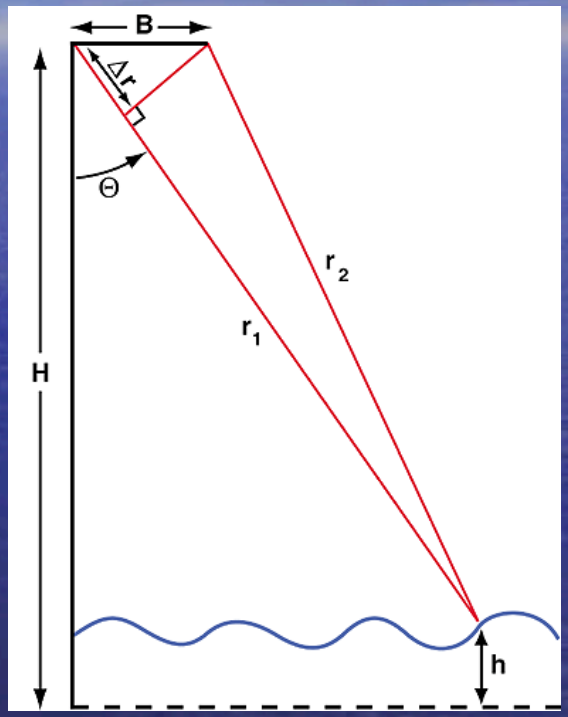
(B. Holt, 2004)

(G. Jacobs, 2010)

SWOT measurement system



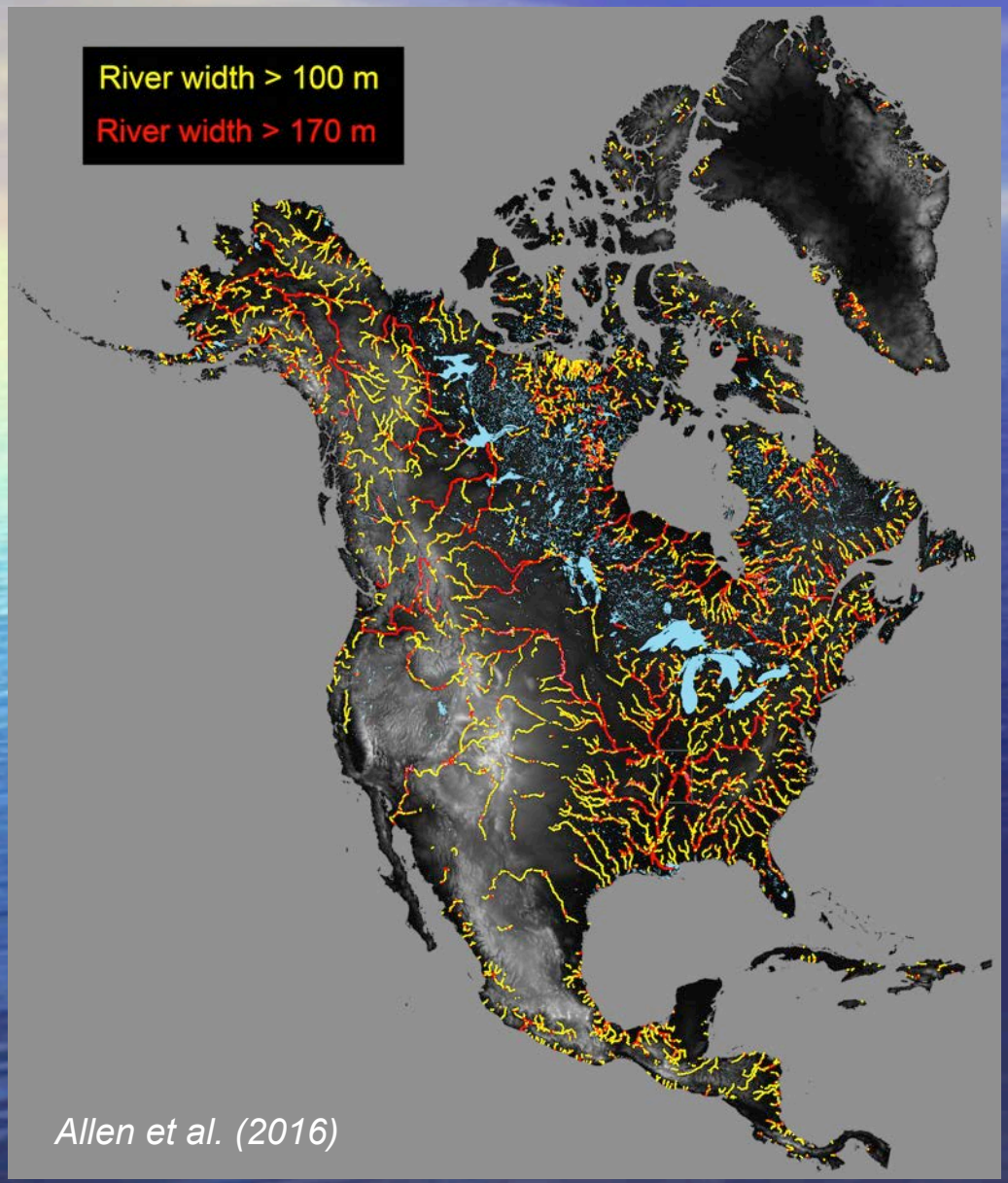
Interferometric Altimetry Measurement



SWOT Deployment in Orbit

Animation of SWOT's solar panel deployment available at
http://swot.jpl.nasa.gov/images/JPL-20160301-SWOTs-0001-Solar-Deploy.mov

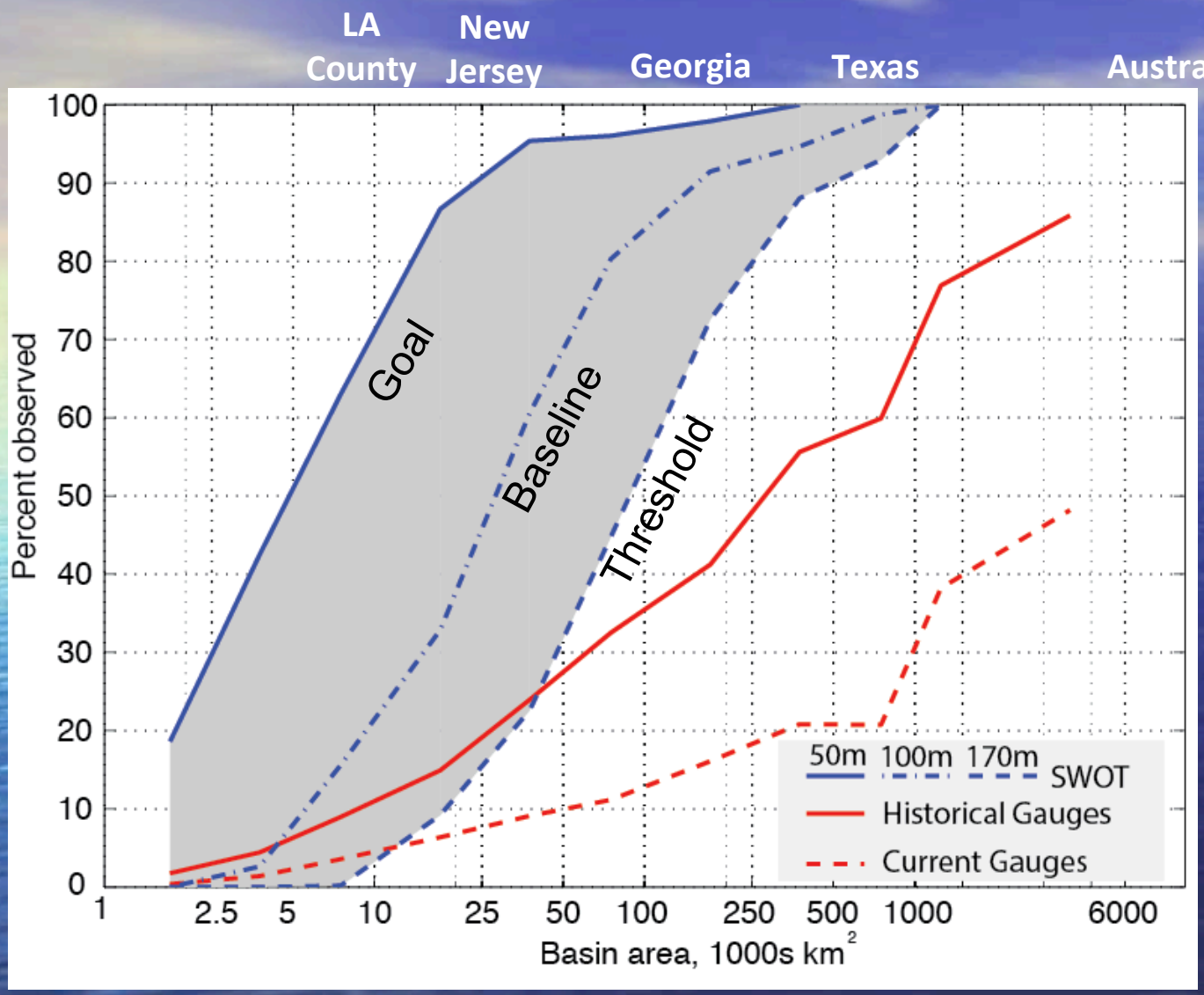
SWOT Performance Requirements: Rivers



Allen et al. (2016)

- Water detection/river width:
  - 15% error for 100-m-wide rivers over 10-km reach (baseline)
  - 15% error for 170-m-wide rivers over 10-km reach (threshold)
- Water surface elevation:
  - 10-cm error for 1-km^2 area
- Water-surface slope:
  - 17-μrad error for 100-m-wide river over 10 km (baseline)
  - 30-μrad error for 100-m-wide river over 10 km (threshold)

Global river coverage



Width-to-drainage-area translation:

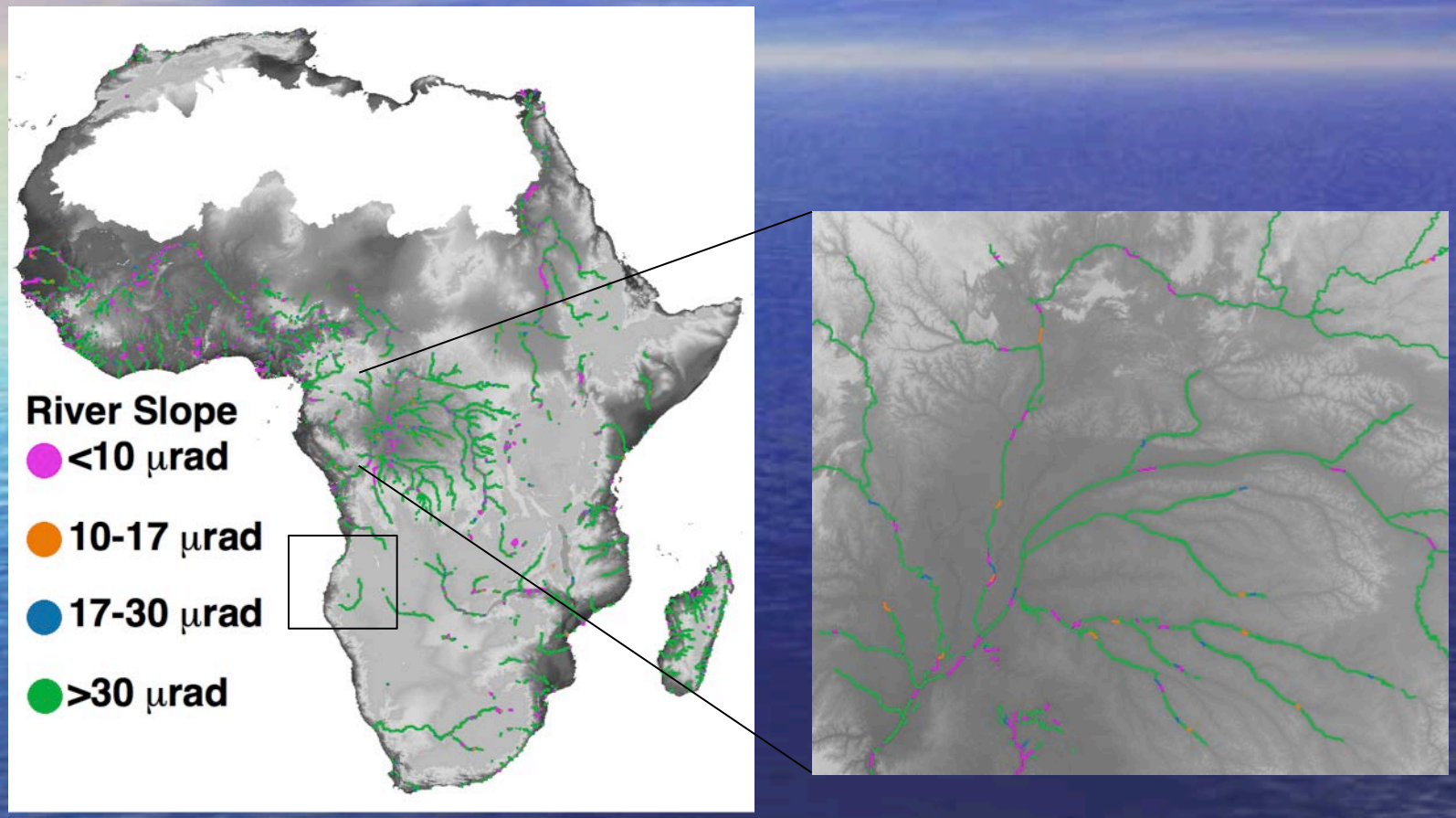
- 50 m ~10,000 km^2
  Los Angeles County
- 100 m ~50,000 km^2
  Twice New Jersey
- 170 m ~150,000 km^2
  Georgia

SWOT will give us globally consistent observations of river height and discharge at these spatial scales for the first time.

(Pavelsky et al., *J. Hydrology*, 2014)

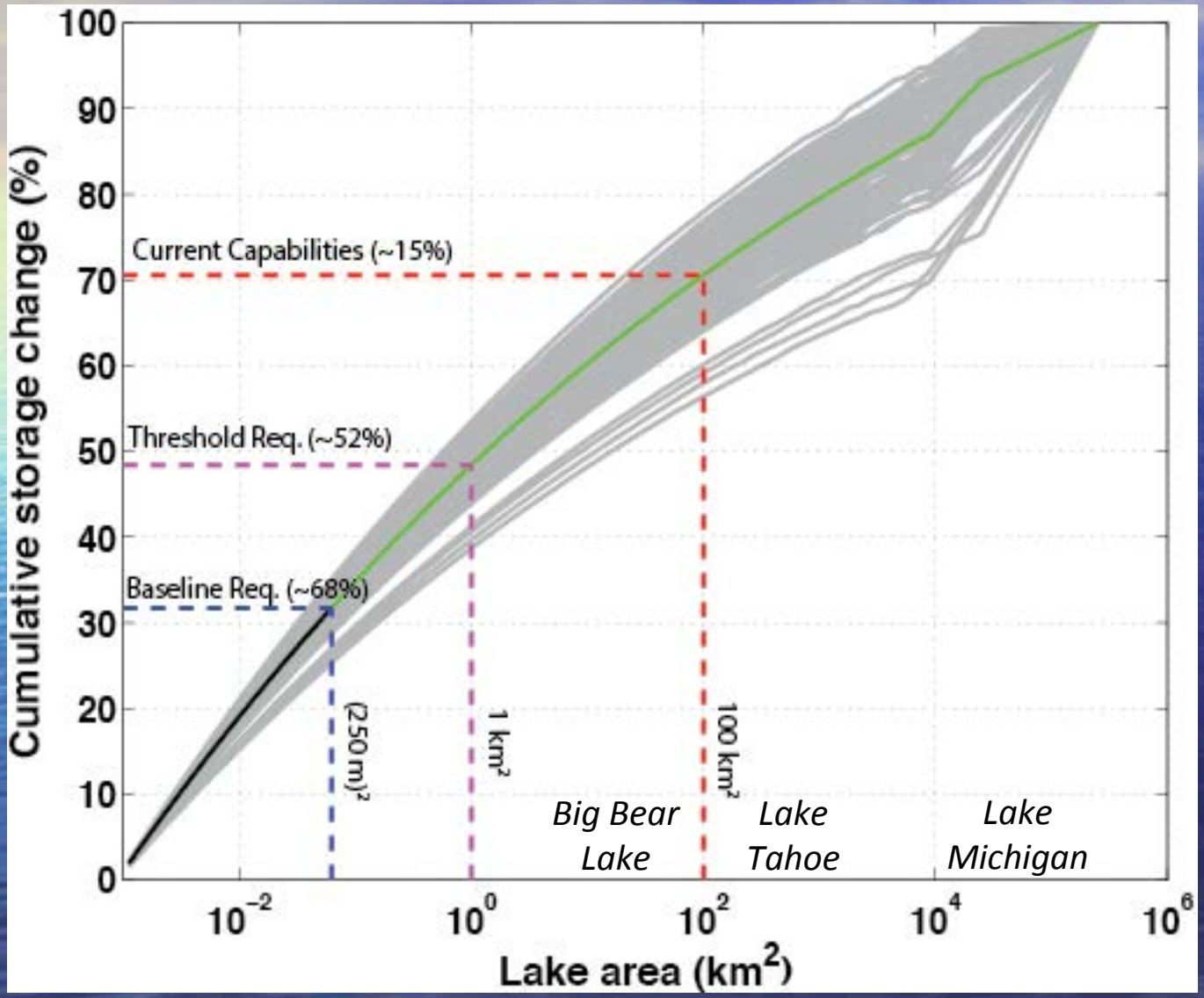
Slopes of the rivers of Africa

1 µrad = 1 cm/10 km, or 1 inch/16 miles



17 µrad: 85.2% 30 µrad: 81.1%

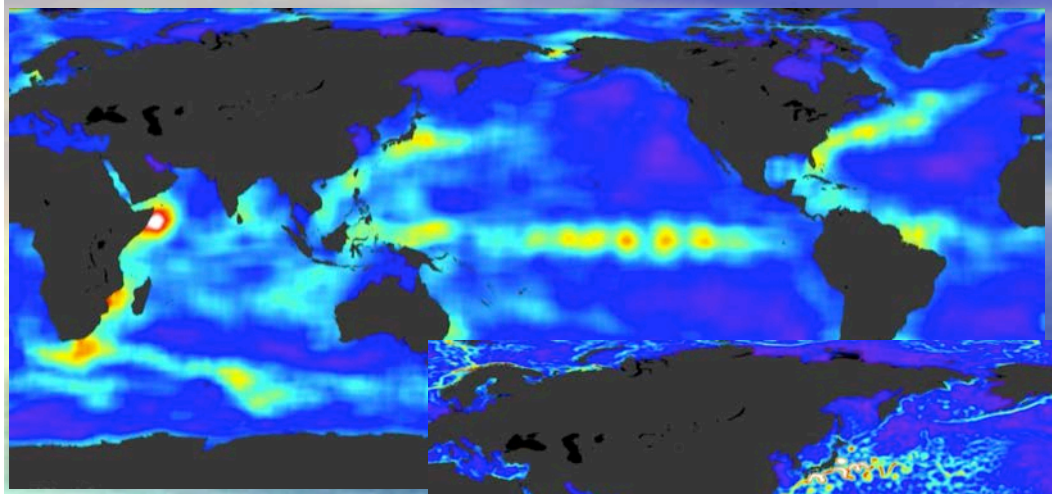
Global lake coverage



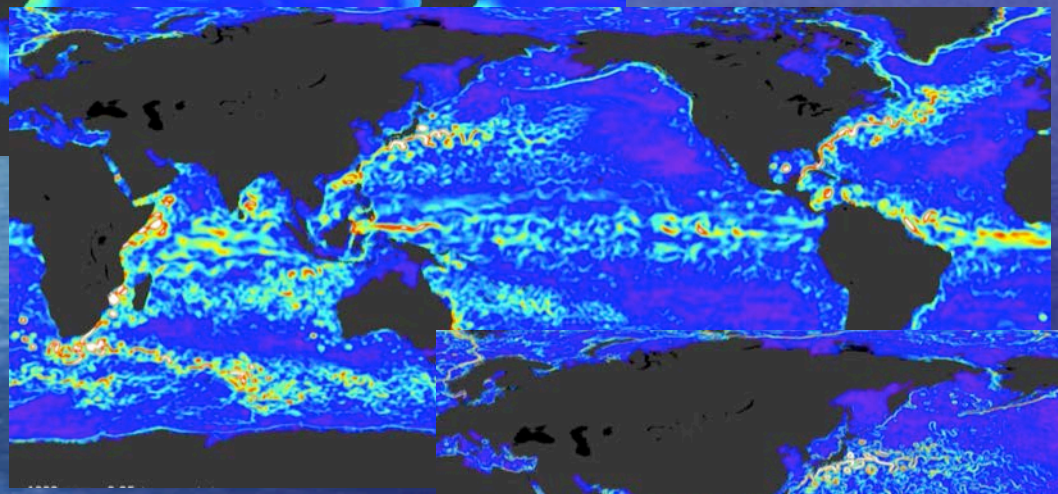
SWOT coverage will be global and will observe lakes area >(250 m)^2, thus measuring ~68% of the global lake storage change.

(Biancamaria et al. 2010)

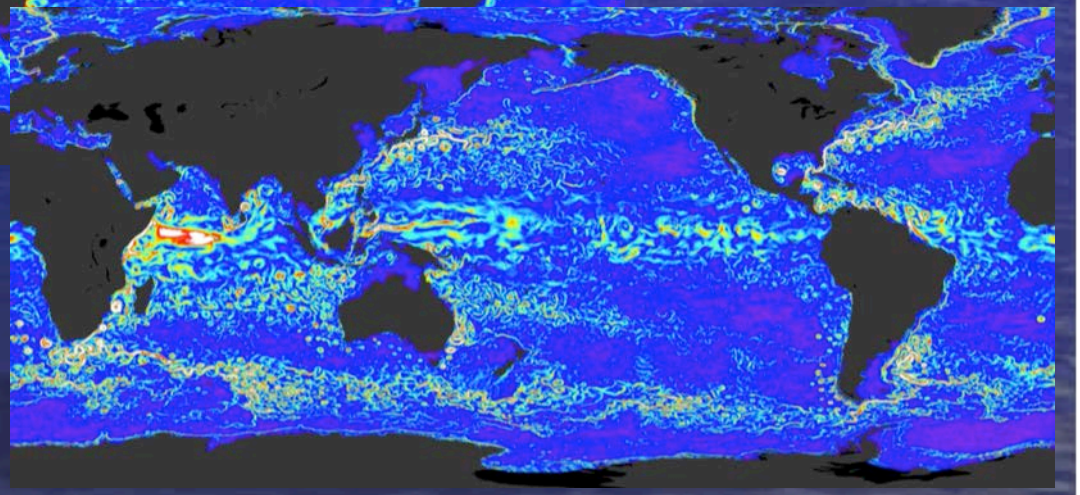
Evolution of space observations of sea surface height:
Past, present and future



1978



1992 – present
(e.g., Jason-1 & -2)

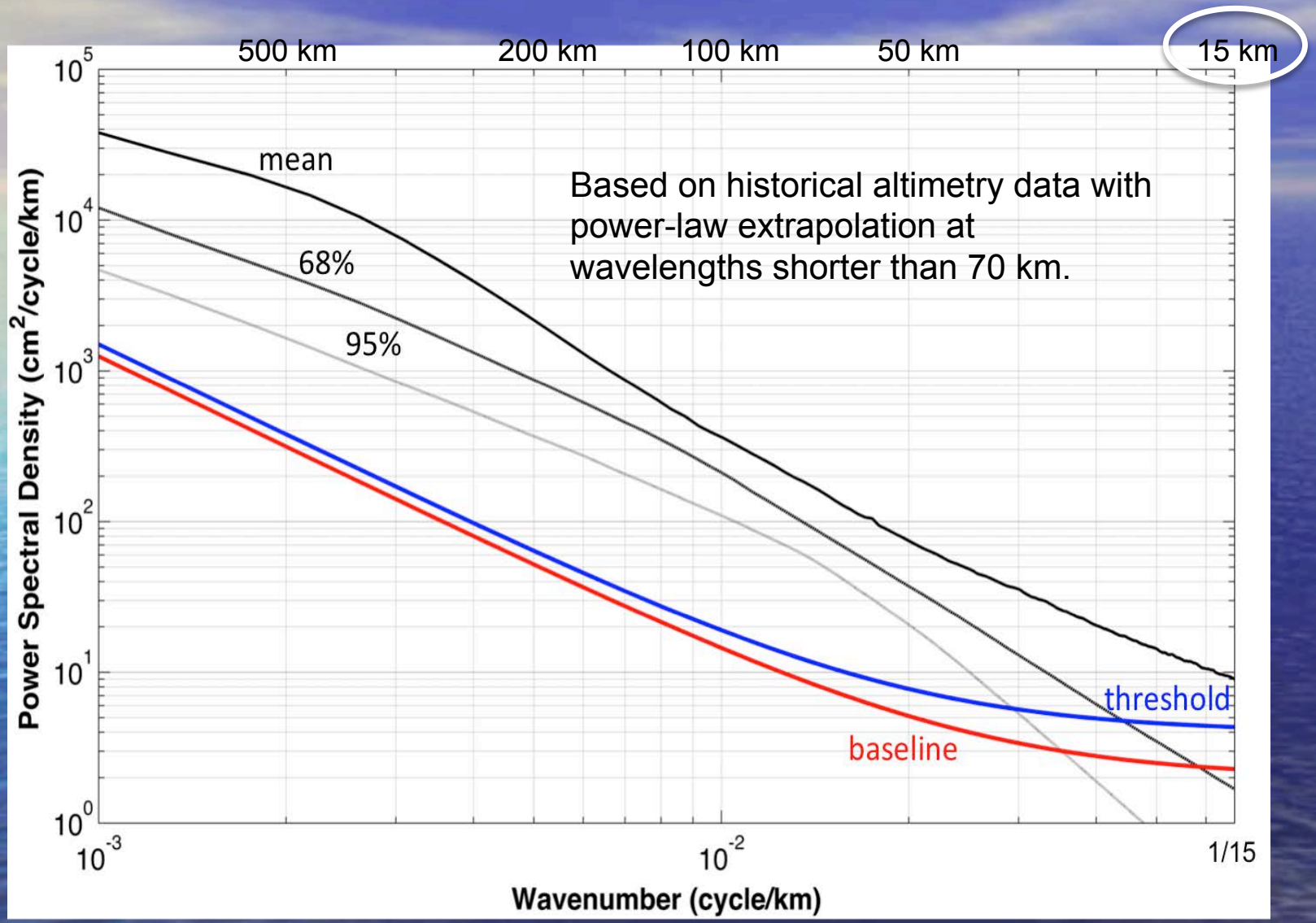


SWOT
(launch 2021)

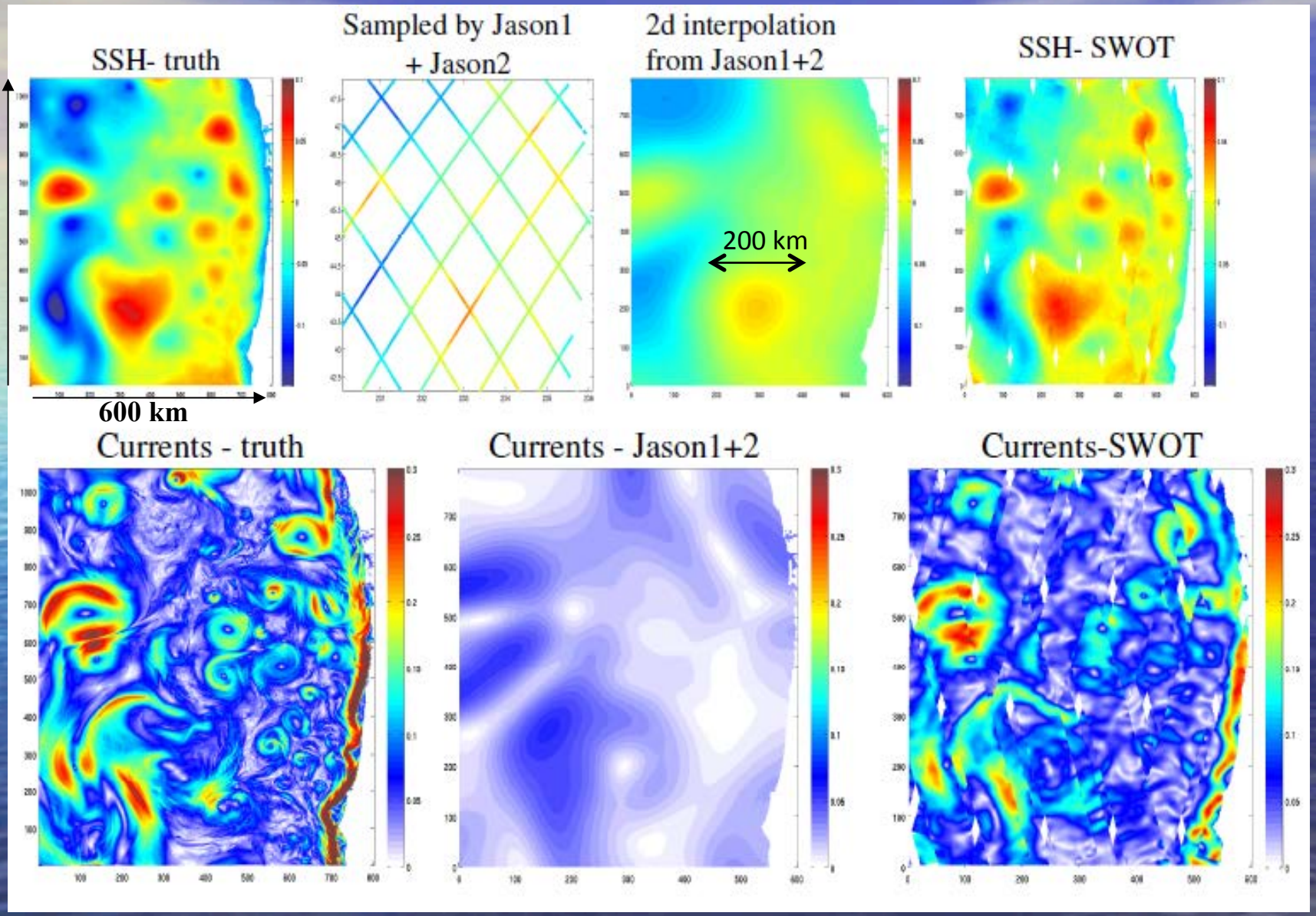
See animation at https://svs.gsfc.nasa.gov/30500

Hausman, Menemenlis, Howard

Sea Surface Height Requirement

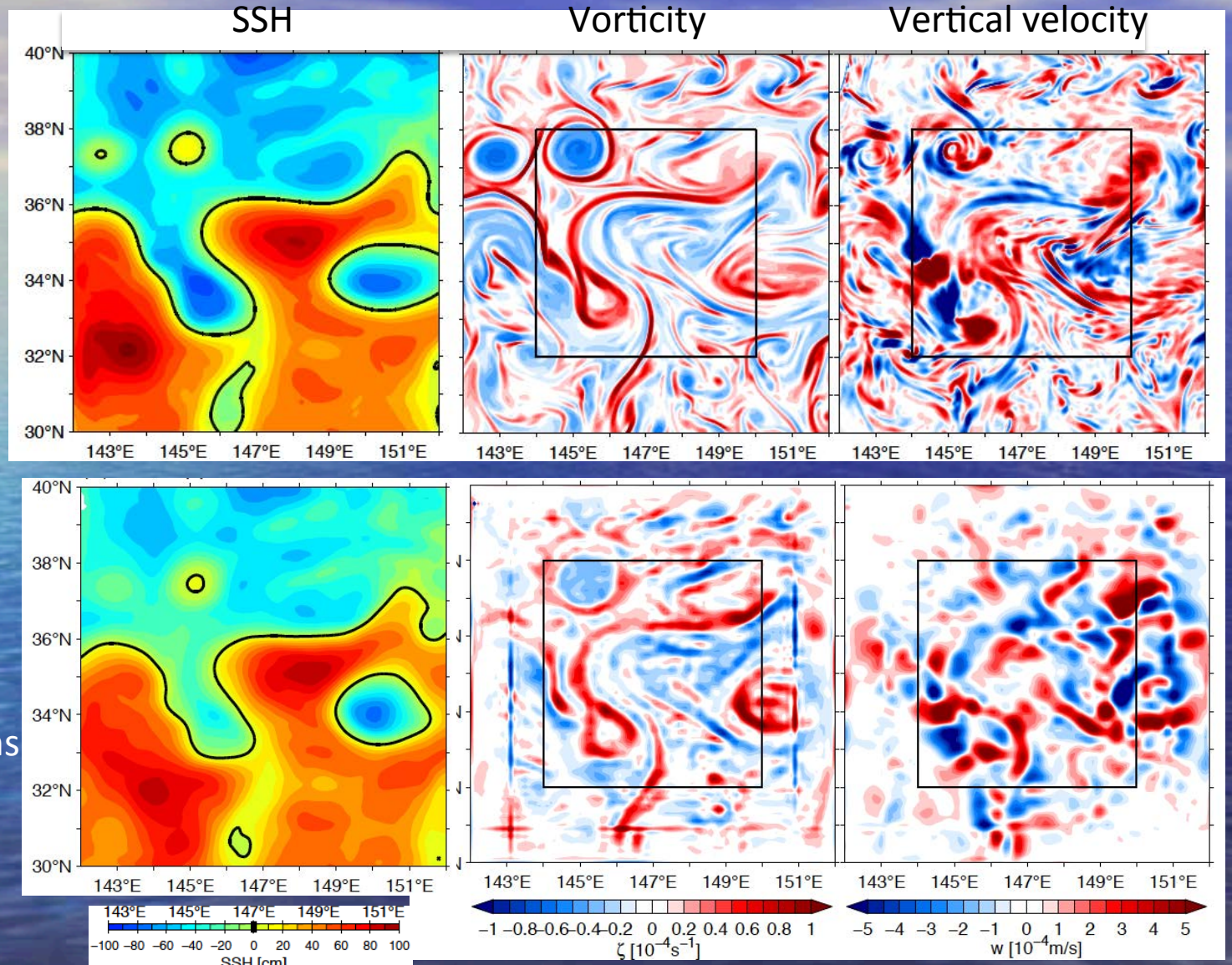


Simulated SWOT Ocean Observations



Surface Vorticty and Vertical Velocity

A Grand Challenge for Ocean Remote Sensing



(Qiu et al, 2016)

Monitoring and prediction of oceanic environment

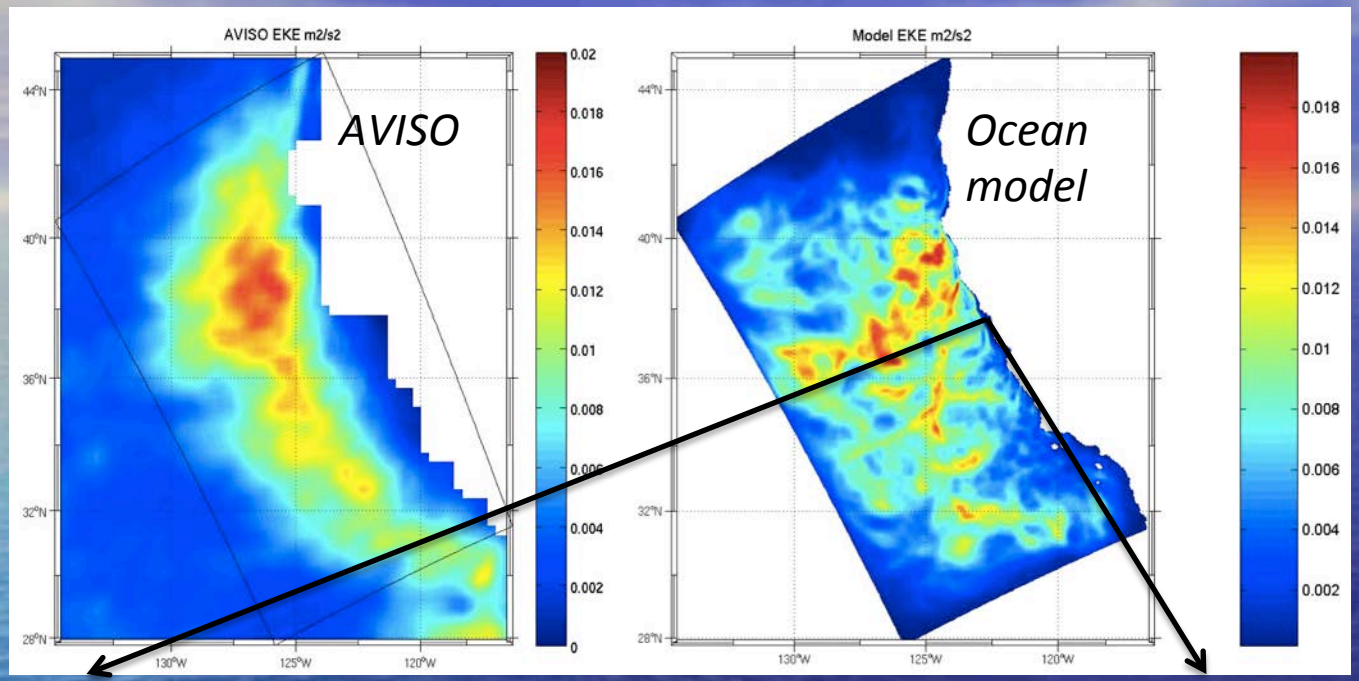
Coastal Flooding

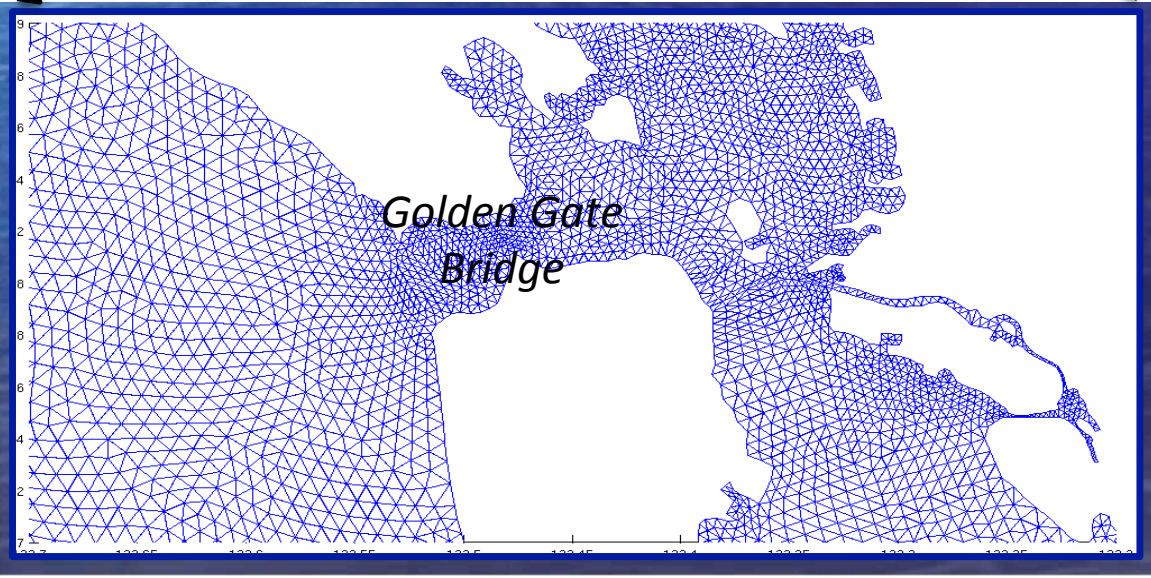
Hurricane Sandy: The last 7% of the storm surge caused 20% of the property damage.

Ocean Debris

Oil Spills

Prediction of storm surge involves small-scale interaction of ocean currents, tides, gravity, river discharge



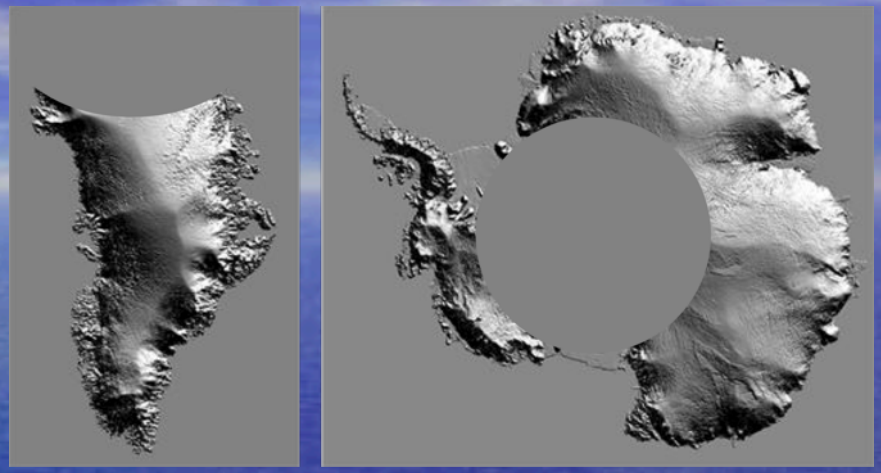


Y. Chao/RSS

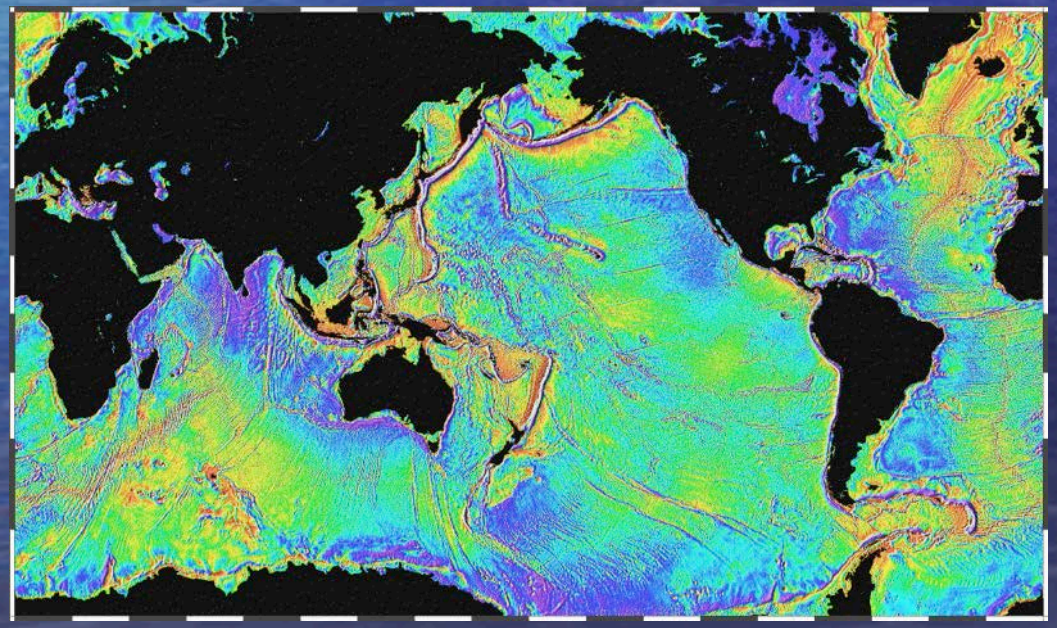
Synergistic Objectives (Not Driving Mission Design)

Sea Ice Freeboard

Ice Sheet Topography



Ocean Bathymetry



Sandwell and Smith (1997)

Final Remarks

- SWOT is a pathfinder, like Seasat, TOPEX/Poseidon, QuikSCAT, Aquarius, EOS, TRMM, Cloudsat, OCO, SMAP, etc.
- These missions are the powerhouse for meeting the challenge of observing and monitoring Earth to provide important information to sustain the modern society.
- The information is essential for achieving the goals of clean air and water, preparedness for extreme events, and adaptation to long-term environmental changes on continental scales.
- Achieving these goals is crucial to America's prosperity and security. Continuing and enhancing NASA's Earth programs should be a key element of a strong America.

Excerpts from the 2006 NASA Strategic Plan under G.W. Bush Administration

NASA pioneers new global environmental observations and research, and works with other federal agencies to improve the operational services they provide to the Nation. These services include: weather forecasting; climate prediction; natural hazard assessment, prediction, and response; and environmental management, including air quality forecasting and land use assessment.