SWOT and Wide Swath Altimetry in the past, present, and future

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Jet Propulsion Laboratory, California Institute of Technology
SWOT Science Team meeting, 2024-06-17

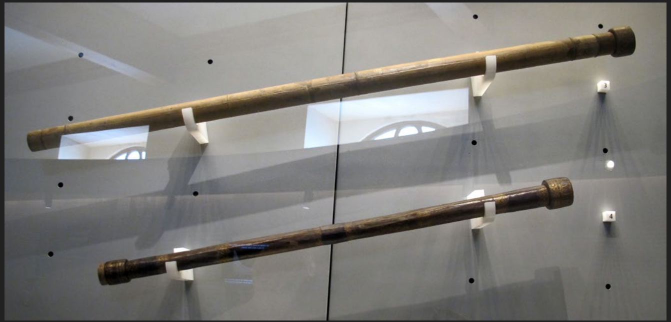
Jet Propulsion Laboratory
California Institute of Technology

SWOT

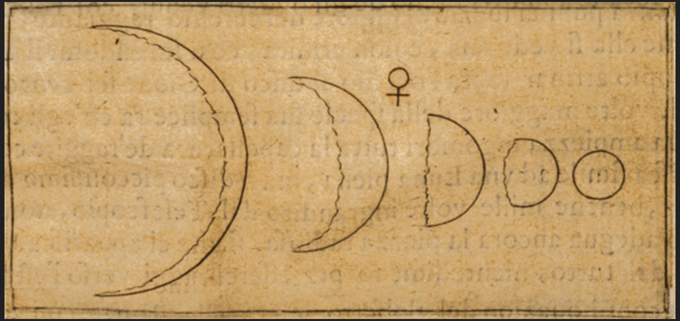
In praise of exploratory science

To see what no one has seen before…

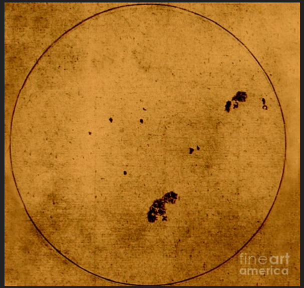
Galileo Galilei



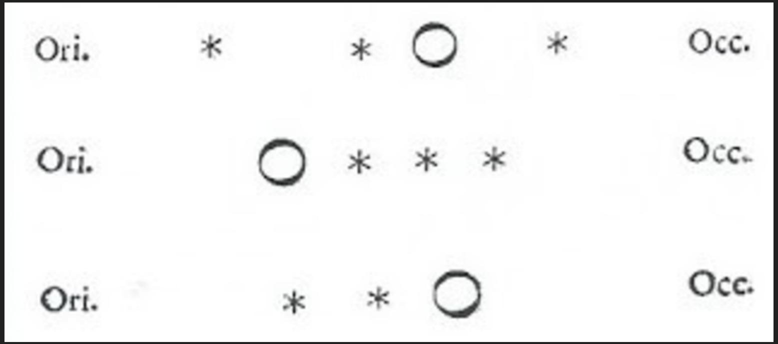
Galileo's telescopes



Phases of Venus: our twin planet



Sunspots



Moons of Jupiter: a mini solar system

The Moon has mountains, like the Earth

Wide-Swath Ocean Altimetry (dob:1998-99)

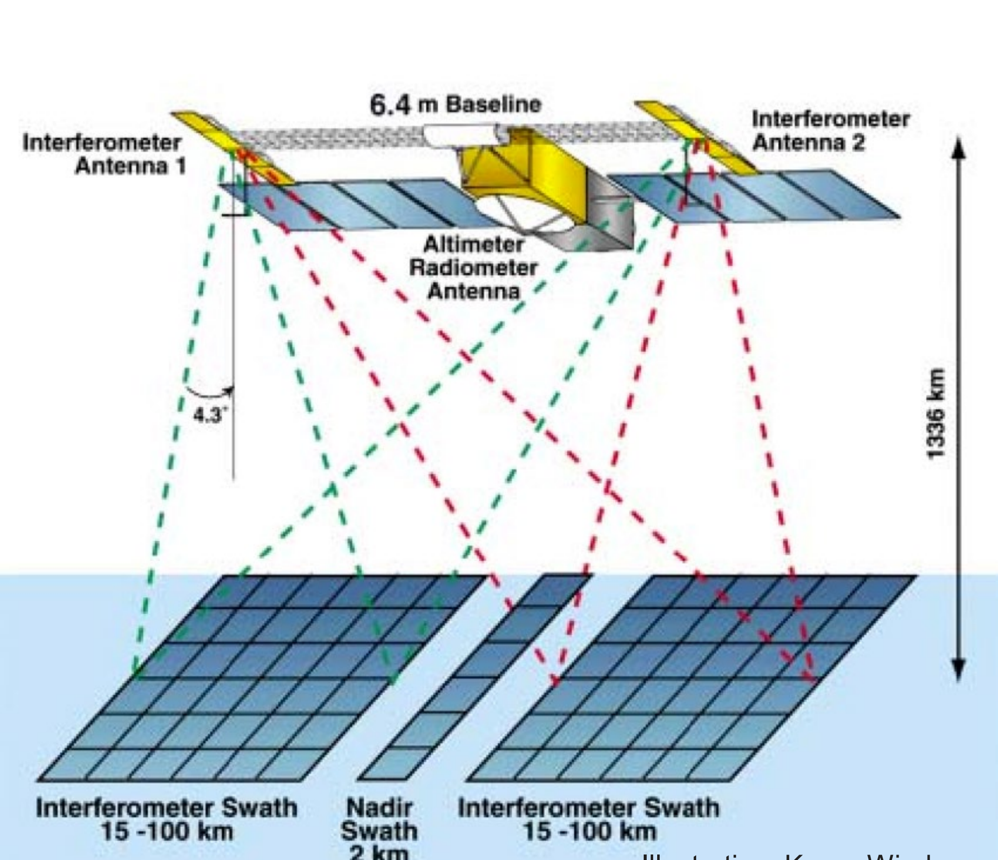


Illustration: Karen Wiedman

New concepts:

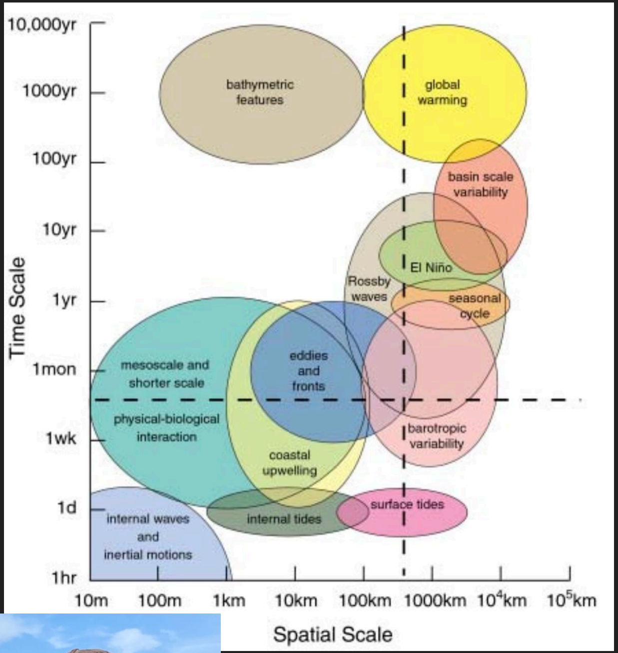
Extend radar interferometry to near-nadir, achieving altimeter-like precision

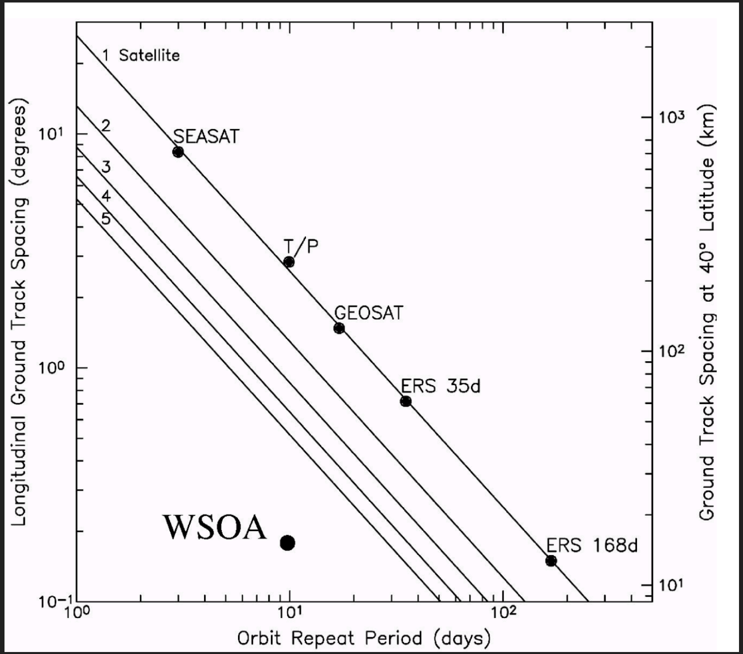
Wide swath coverage by mapping on both sides of nadir track

Use nadir altimeter/radiometer for calibration and validation

Go to higher frequencies (Ku-band) for a compact instrument and higher precision

HOTSWG Meeting at OSU (2000)





Ocean shoot-out between:

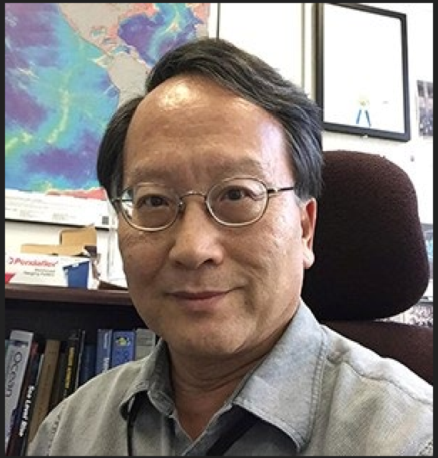
- near-nadir interferometry
- Multi satellite altimetry
- GNSS heights

Near-nadir interferometry won

Chelton, D. B. (2001). Report of the High-Resolution Ocean Topography Science Working Group Meeting. *College of Oceanic and Atmospheric Sciences Oregon State University*.

WSOA: NASA/CNES start wide-swath journey

Yves Menard



Lee Fu

Mission descoped by NASA near final reviews due to lack of funds

Next Step: SAR wide-swath

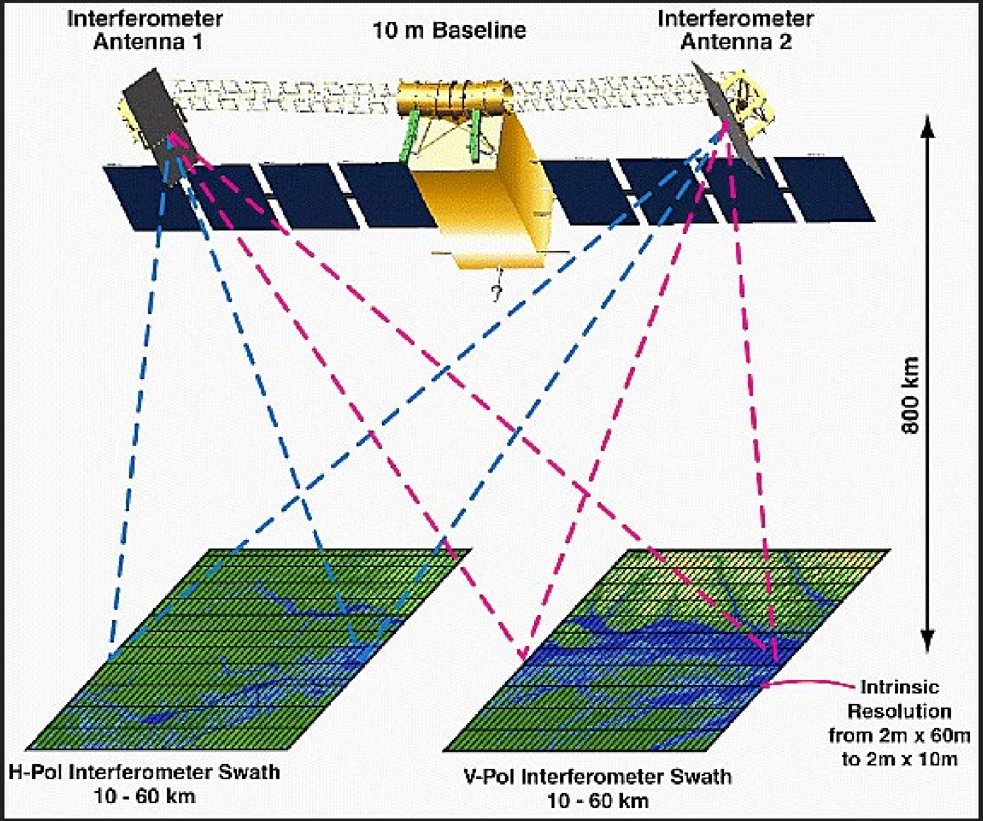


Illustration: Karen Wiedman

New concepts:

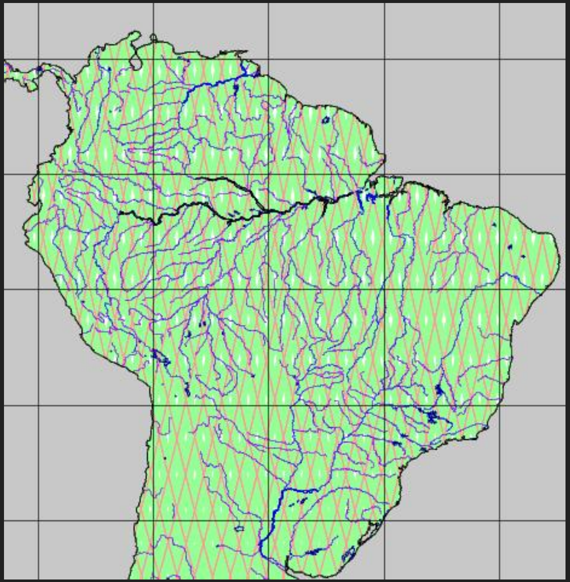
Enlarge user community to hydrology!

Use SAR to achieve spatial resolutions to O(10m)

Increase frequency to Ka-band to achieve better precision at high spatial resolution

Rely on roll corrections using cross-overs only

Shoot-out in Irvine (2004)



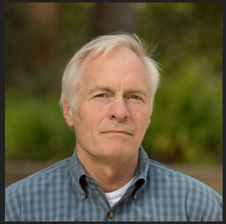
120 km Swath

Pulse Limited Swath

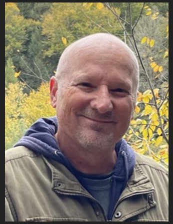
4 competing concepts for hydro evaluated at UC Irvine community meeting:

- SAR near-nadir interferometry
- Conventional altimetry
- Lidar altimetry
- GNSS height estimation

SAR near-nadir interferometry won



D. Lettenmaier



D. Alsdorf

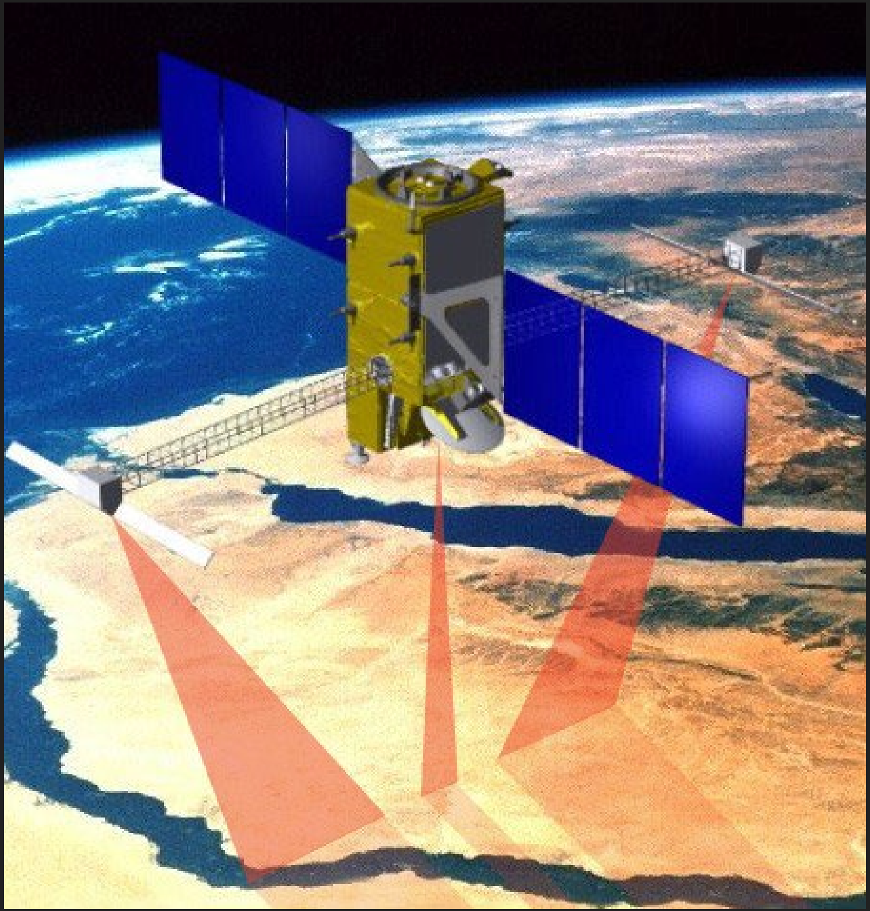
L. Smith

P. Bates

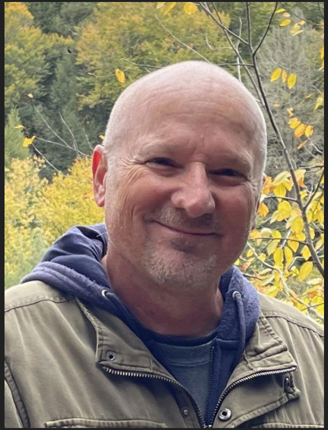
T. Pavelsky

A. Cazenave

WATER Mission to ESA (2005)



Nelly Mognard



Doug Alsdorf

Proposal not selected because critical components were coming from the US

ESA 2nd thoughts: S3NG

Resurrection: 2007 Decadal Survey

TABLE 2.1 Missions Recommended for NASA (or Joint with NOAA) in ESAS 2007

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost (FY 2006 $ Million)
2010-2013				
CLARREO (NASA portion)	Solar and Earth radiation, spectrally resolved forcing, and response of the climate system	LEO, Precessing	Absolute, spectrally resolved interferometer	200
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	300
ICESat-2	Ice-sheet height changes for climate change diagnosis	LEO, non-SSO	Laser altimeter	300
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
2013-2016				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	300
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	400
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ku- or Ka-band radar Ku-band altimeter Microwave radiometer	450
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High-spatial-resolution hyperspectral spectrometer Low-spatial-resolution imaging spectrometer IR correlation radiometer	550
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

Two coordinated concept papers submitted:

Fu & Rodriguez for ocean

Alsdorf & Rodriguez for hydro

SWOT (coined by D. Lettenmaier & Kathy Kelly) recommended as a 2nd tier mission.

Nicolas Sarkozy had a big hand in making it a 1st tier mission: the “big loan” investment in 2011 was instrumental in advance SWOT

SWOT is born

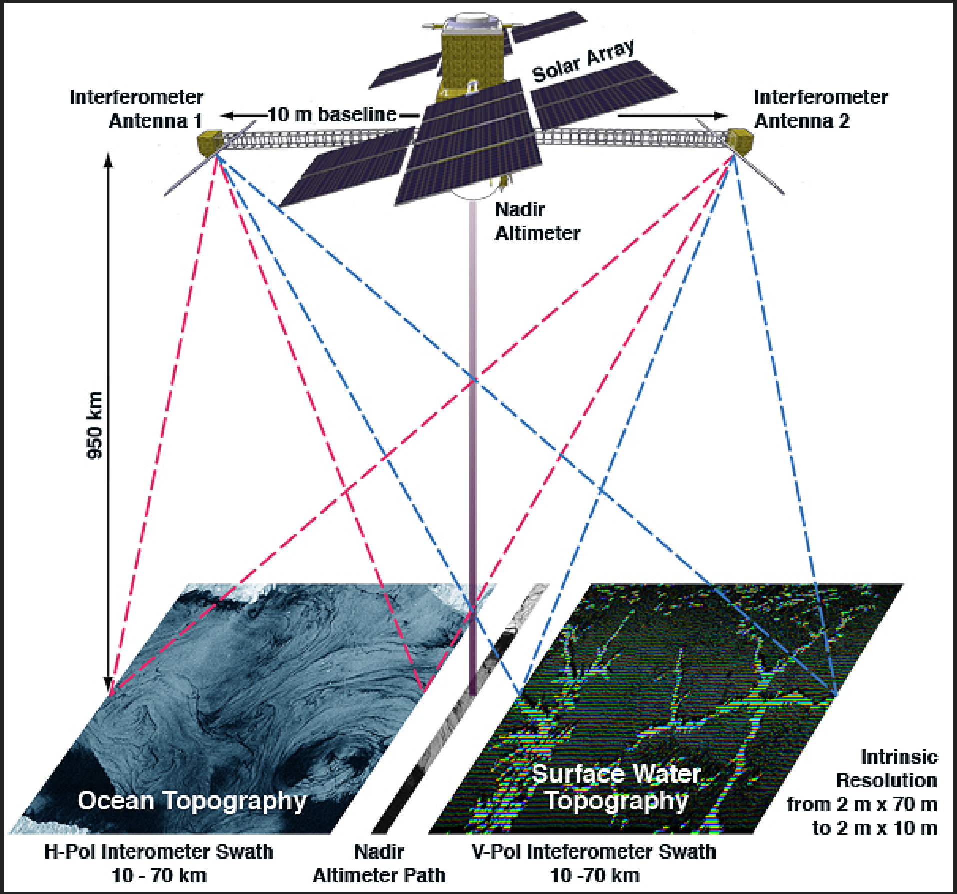


Illustration: Karen Wiedman

New concepts:

Non sun-sync orbit to avoid tidal aliasing

Solid interferometric mast to avoid vibrations and distortions

Onboard processing of ocean data to 250m resolution

Hydro data capable of achieving ~6m azimuth resolution

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AirSWOT: pre-launch experiments

SWOT

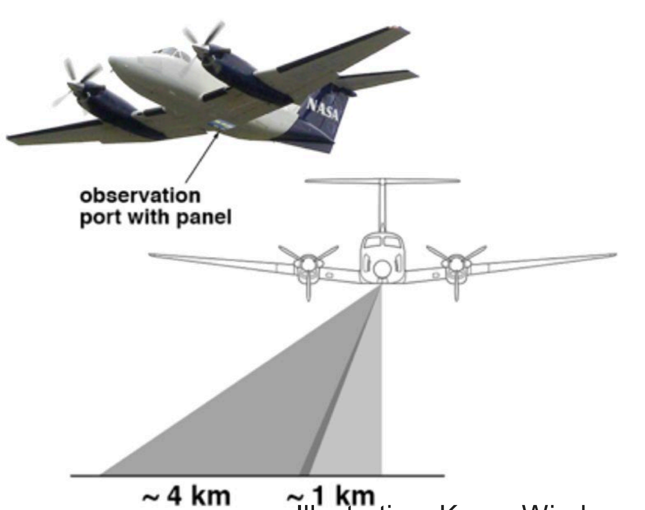
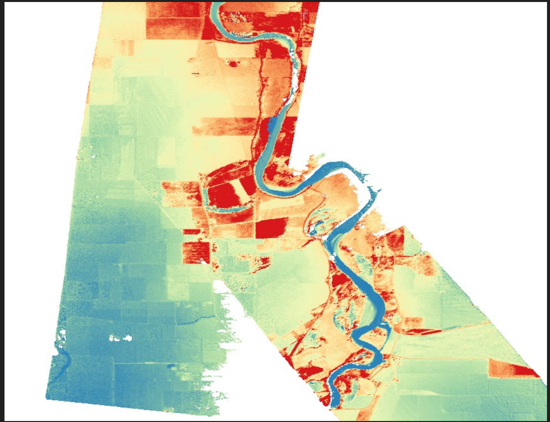


Illustration: Karen Wiedman

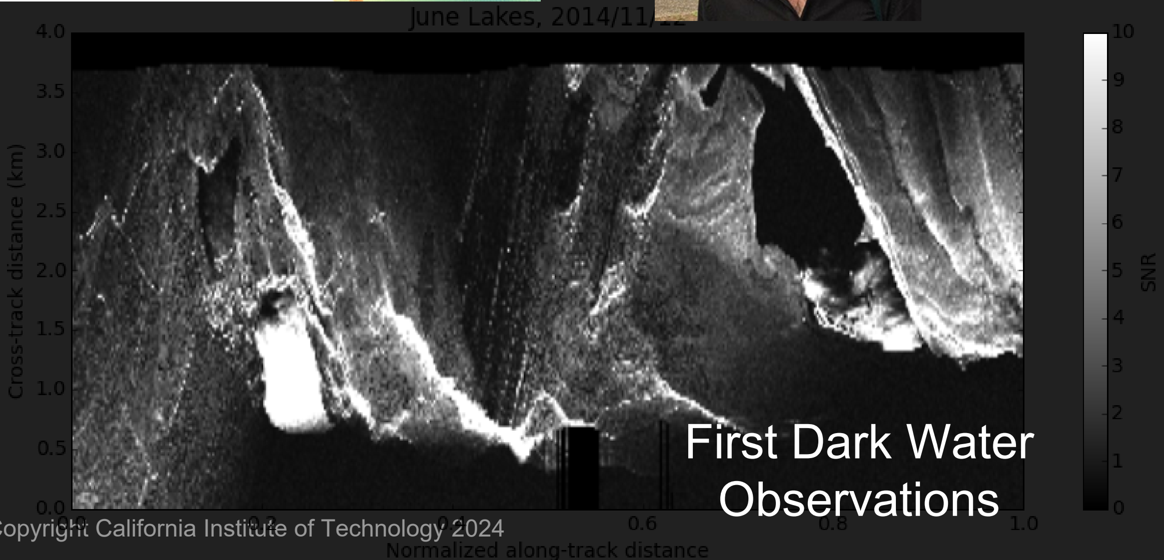


Sacramento River Topography

Jean-François Crétaux

Delwyn Moller

Dragana Perkovic-Martin



First Dark Water Observations

The birth of McFLI & the DaWG

20 IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 3, NO. 1, MARCH 2010

Estimating River Depth From Remote Sensing Swath Interferometry Measurements of River Height, Slope, and Width

Michael Durand, Ernesto Rodríguez, Douglas E. Alsdorf, and Mark Trigg

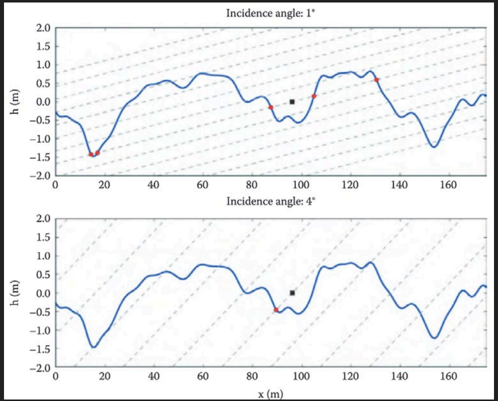
Mike Durand

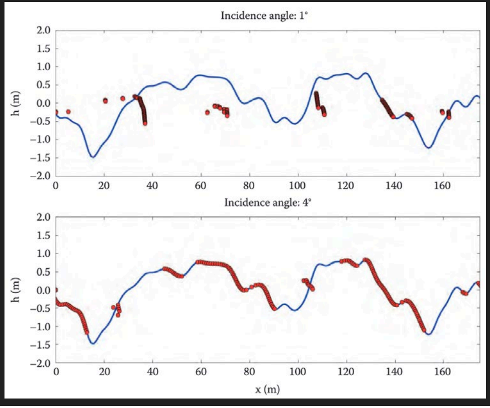
Kick-off: brain storming at UW with M. Durand, S. Biancamaria, K. Andreadis, N. Mognard, D. Lettenmaier in 2008

A first look at river discharge from SWOT satellite observations

Konstantinos M. Andreadis[1], Steve P. Coss[2], Michael Durand[2], Colin J. Gleason[1], Travis T. Simmons[1], Nikki Tebaldi[3], David M. Bjerklie[4], Craig Brinkerhoff[1], Robert W. Dudley[5], Igor Gejadze[6], Kevin Larnier[7], Pierre-Olivier Malaterre[6], Hind Oubanas[6], George H. Allen[8], Paul D. Bates[9], Cédric H. David[3], Alessio Domeneghetti[10], Luciana Fenoglio Marc[11], Renato Prate de Moraes Frasson[3], Pierre-André Garambois[12], Jaclyn Gehring[13], Augusto Getirana[14], Marissa Hughes[15], Jonghyun Lee[16], Pascal Matte[17], J. Toby Minear[18], Jérôme Monnier[19], Aggrey Muhebwa[20], Mohammad J. Tourian[21], Tamlin M. Pavelsky[15], Ryan M. Riggs[22], Ernesto Rodríguez [3], Md Safat Sikder[23], Laurence C. Smith[24], Jay Taneja[19], Angelica Tarpanelli[25], Jida Wang[23], Bidhyananda Yadav[26]

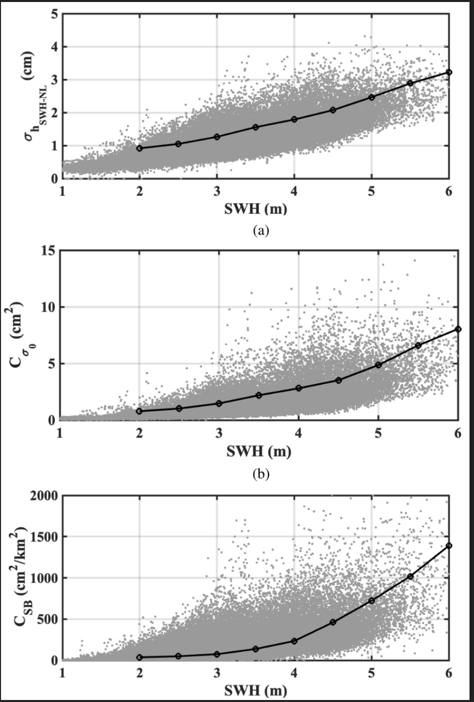
The surfboard effect: wave effects on height

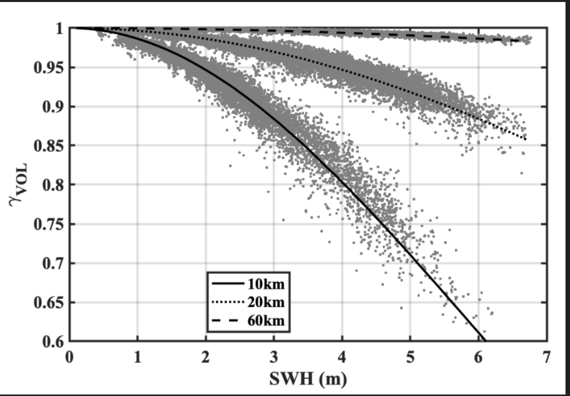




Impact of Surface Waves on SWOT's Projected Ocean Accuracy

Eva Peral *, Ernesto Rodríguez and Daniel Esteban-Fernández

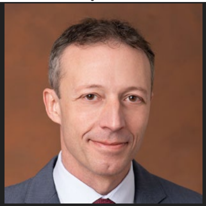




KaRIn, the Ka-Band Radar Interferometer of the SWOT Mission: Design and In-Flight Performance

Eva Peral, Daniel Esteban-Fernández, Ernesto Rodríguez, Dalia McWatters, Jan-Willem De Bleser, Razi Ahmed, Albert C. Chen, Eric Slimko, Ruwan Somawardhana, Kevin Knarr, Michael Johnson, Sermsak Jaruwatanadilok, Samuel Chan, Xiaoqing Wu, Duane Clark, Kenneth Peters, Curtis W. Chen, Peter Mao, Behrouz Khayatian, Jacqueline Chen, Richard E. Hodges, *Life Senior Member, IEEE*, Dhemetrios Boussalis, Bryan Stiles, *Member, IEEE*, and Karthik Srinivasan

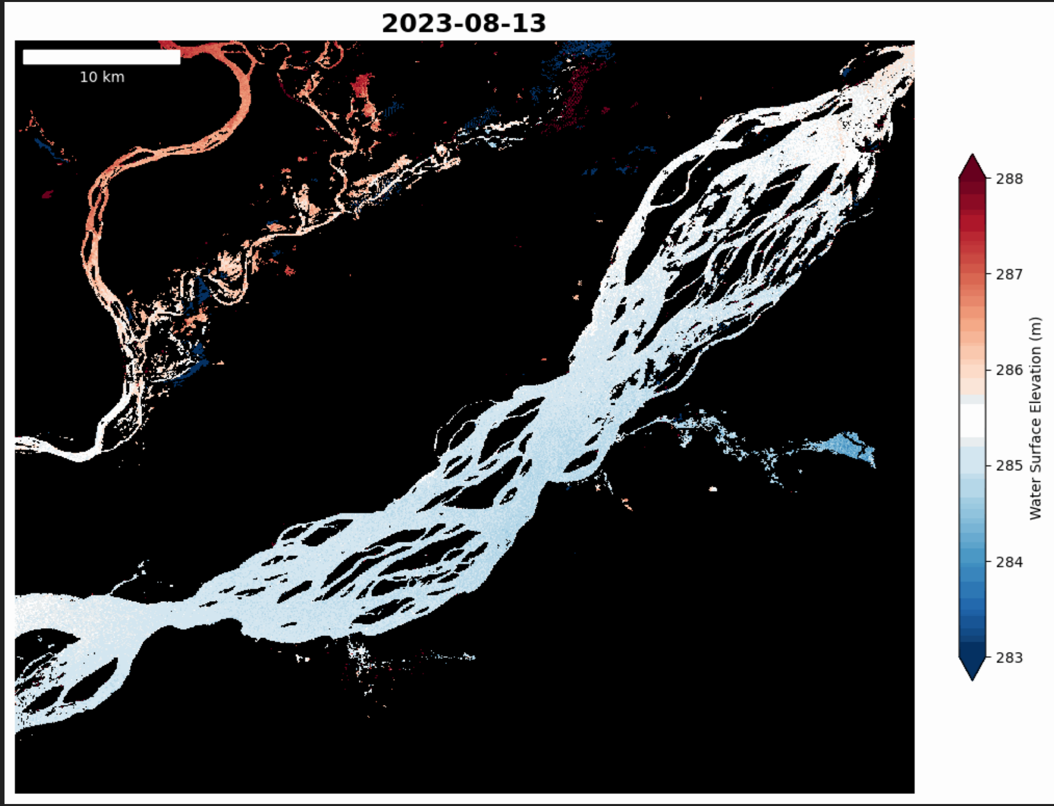
Eva Peral

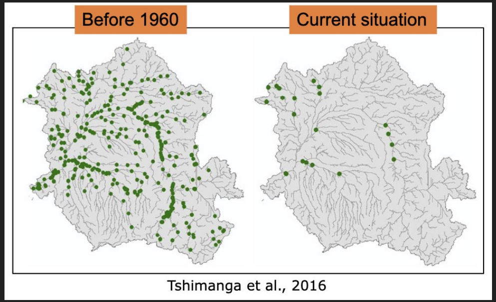


Dani Esteban-Fernandez

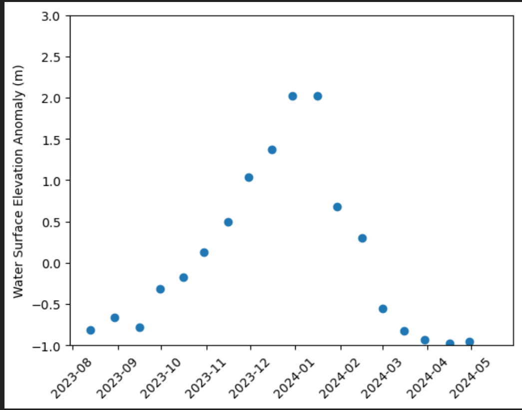
Jet Propulsion Laboratory
California Institute of Technology

SWOT Water Surface Elevations Provide Many Thousand Virtual Stream Gauges





This figure shows the number of physical river gauges in the Congo basin



This figure shows the water surface elevation dynamics for just one SWOT channels over the period of nearly one year. The SWOT data captures clearly the annual variations in river stage due to the rainy season.

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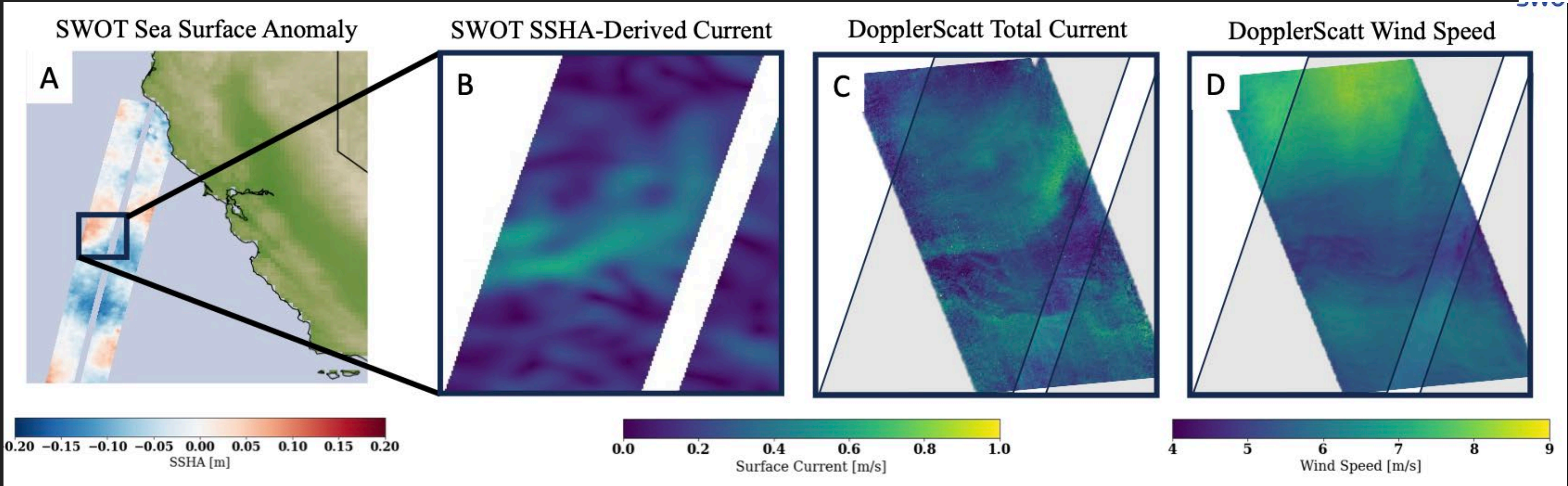
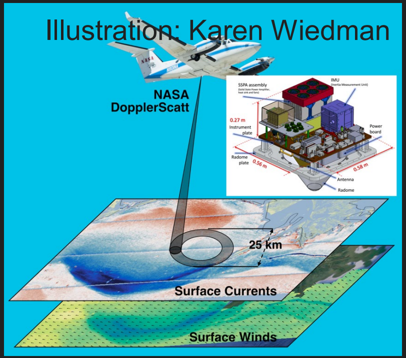
SWOT & ODYSEA

Courtesy A. Wineteer (JPL)

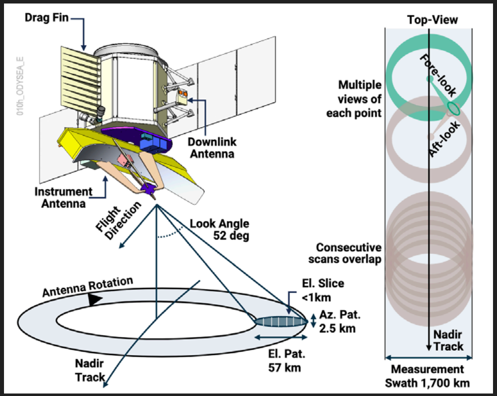




Measurements of total surface current velocities offer a unique complement to SSH measured by SWOT.

Data collected by DopplerScatt during S-MODE shows the potential of combining geostrophic and total currents.

The ODYSEA mission, approved for phase A, may well fly (2031-2033) while SWOT is still operating and provide coincident surface current data.



The future: SWOT-LOAC?

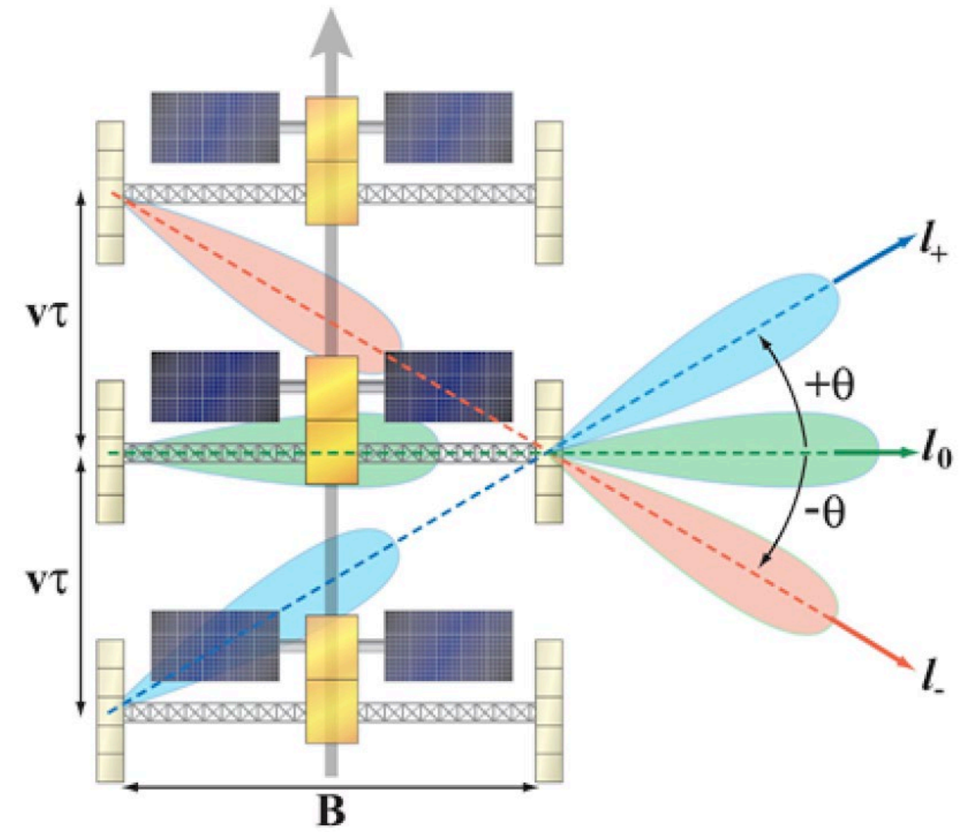


Illustration: Karen Wiedman

SWOT Land-Ocean Aquatic Continuum concept has been developed by a US/French science team for possible future US/French collaboration.

New ideas:

Marry SWOT topography with broader swath and Doppler velocity estimation like DopplerScatt/ODYSEA but at wave resolving scales.

Global mission with a coastal emphasis.

More details of science goals to be provided on Friday.