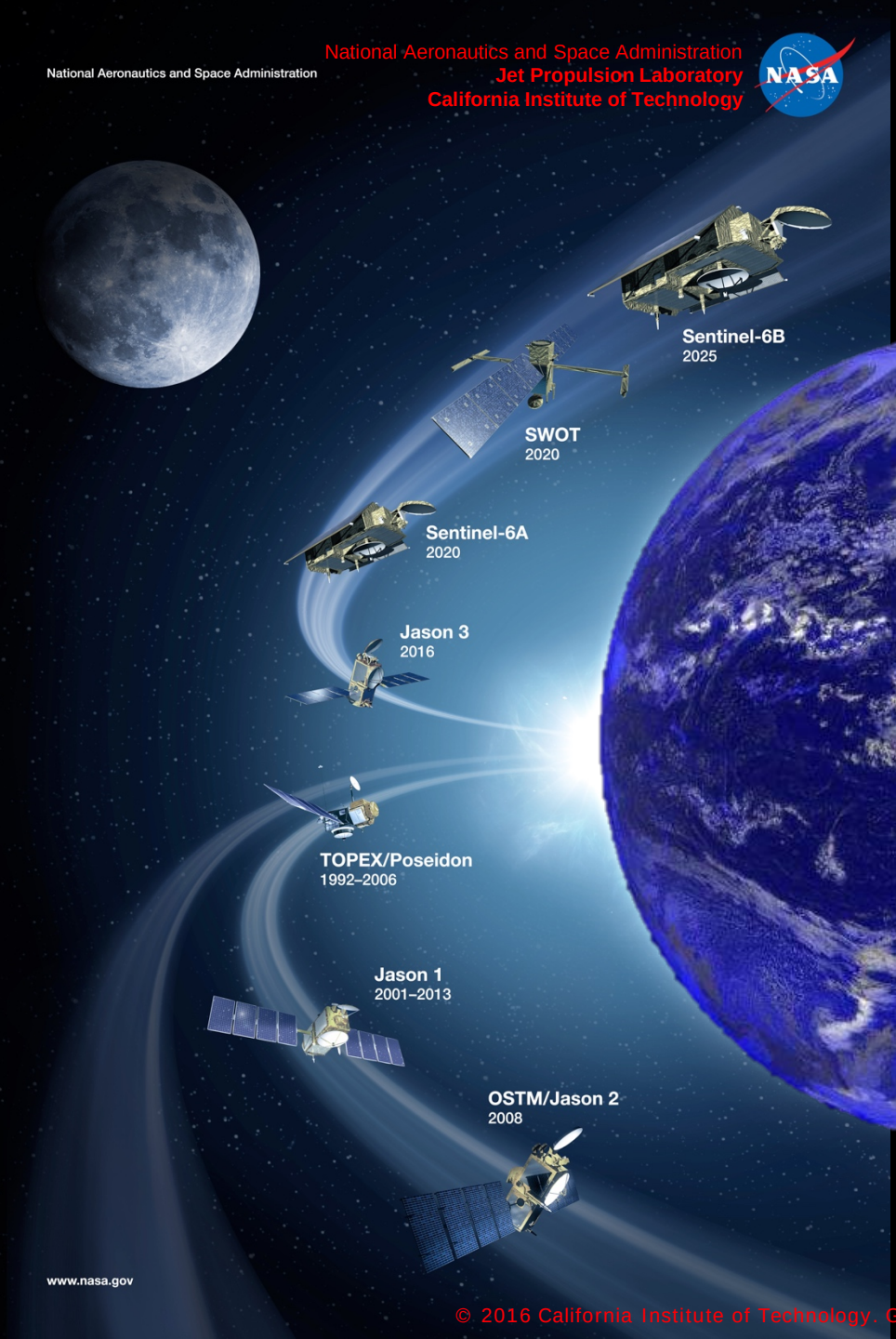
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology



Altimetry for the next decade and overview of the Surface Water and Ocean Topography Mission

Parag Vaze
John Oswald

6 April 2016

SPIE Asia-Pacific Remote Sensing Conference

New Delhi, India

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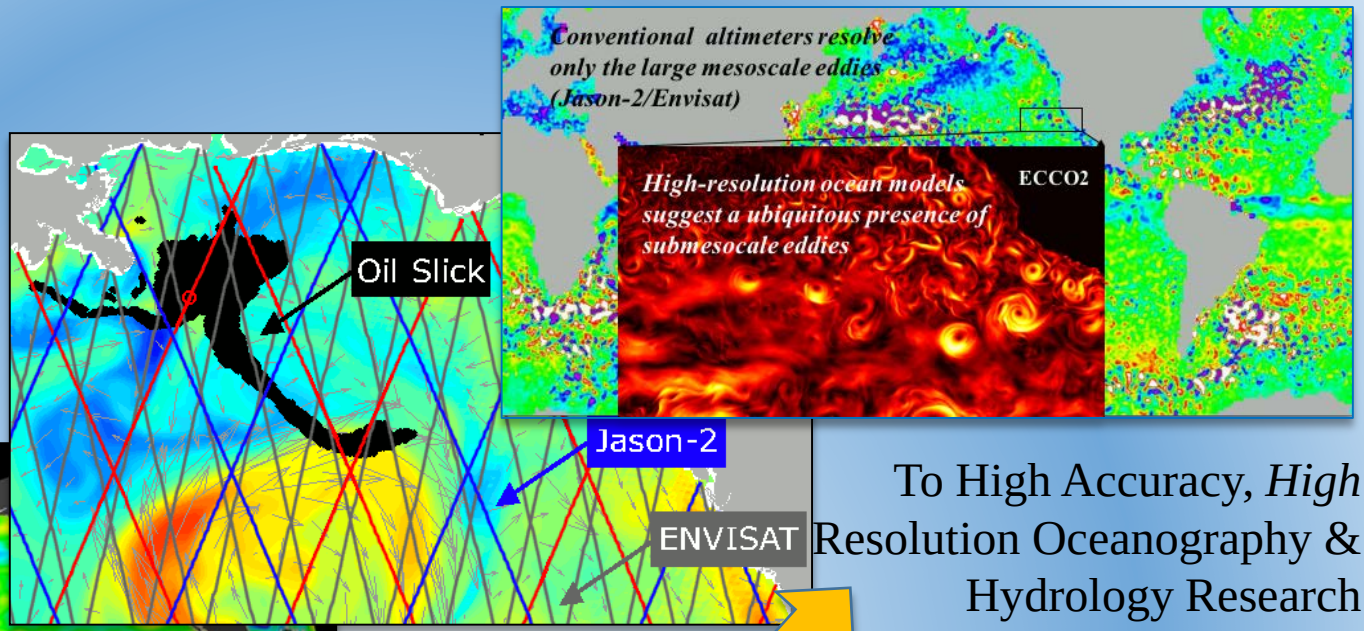
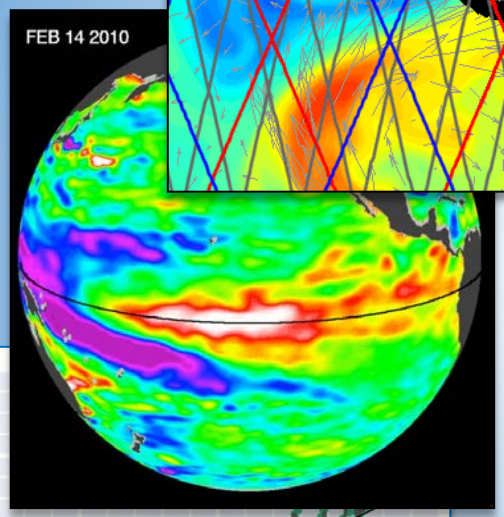
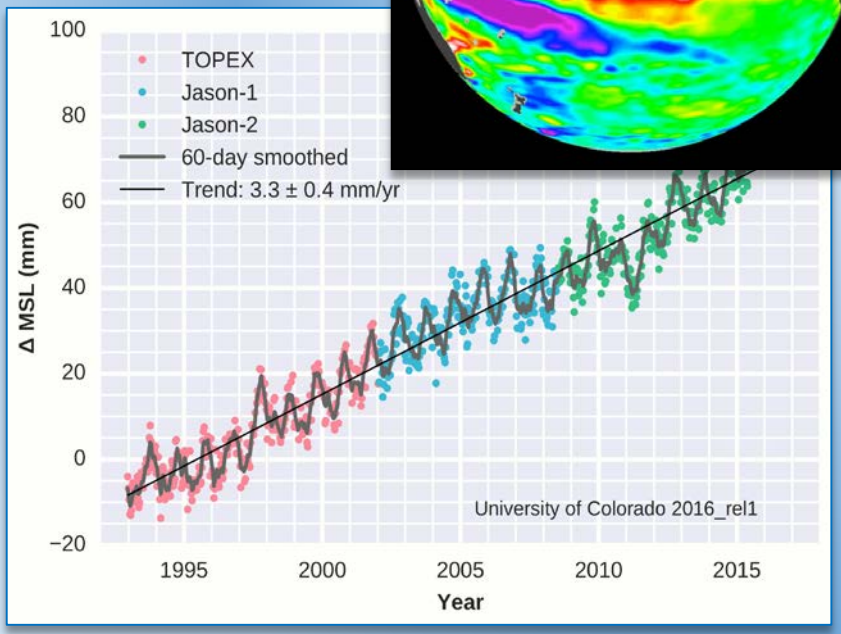
Evolution of Space-Based Altimetry





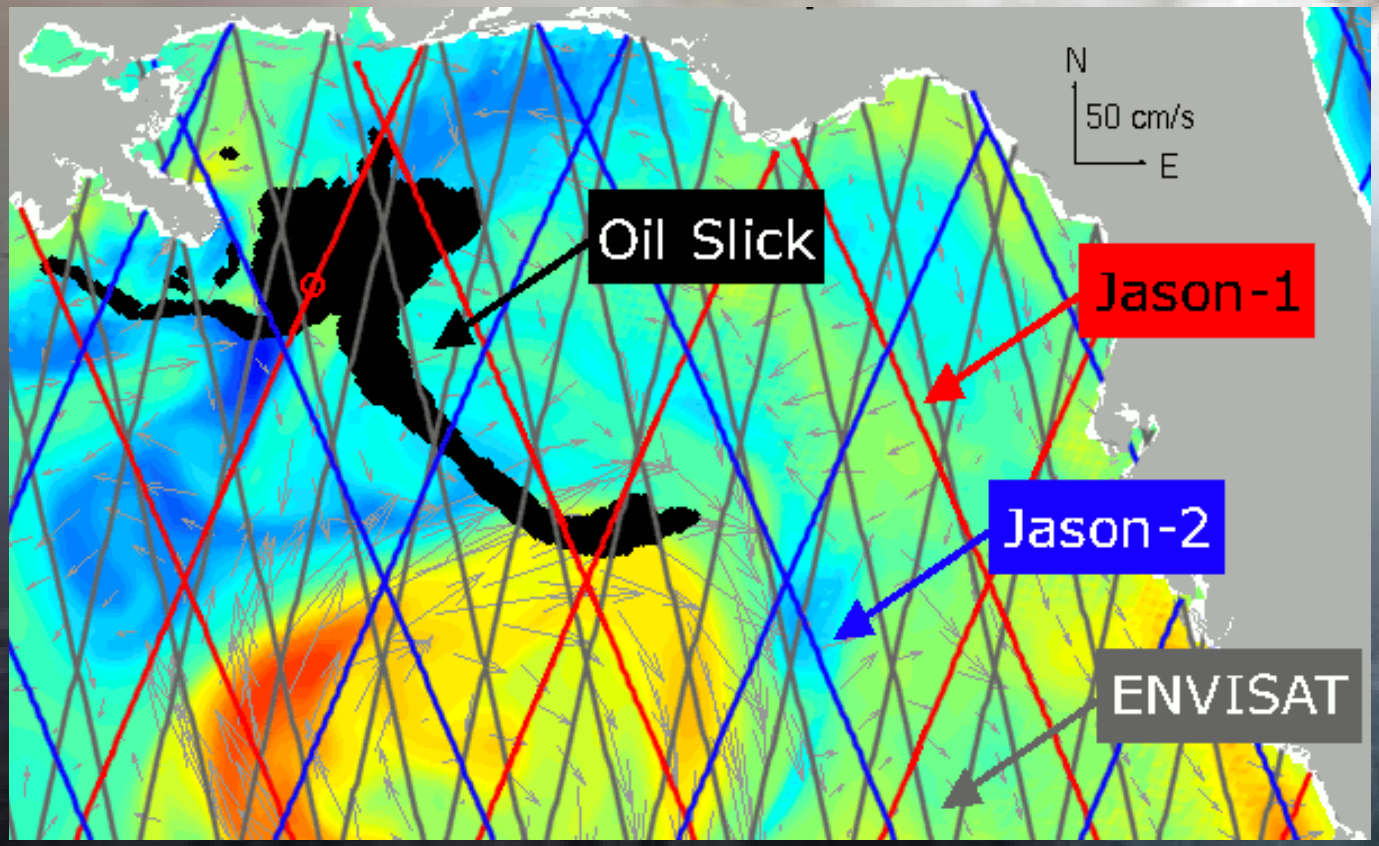


To High Accuracy, *High* Resolution Oceanography & Hydrology Research (SWOT)

From High Accuracy, Medium Resolution Operational Oceanography (Jason Series)

Deep Water Horizon Oil Spill

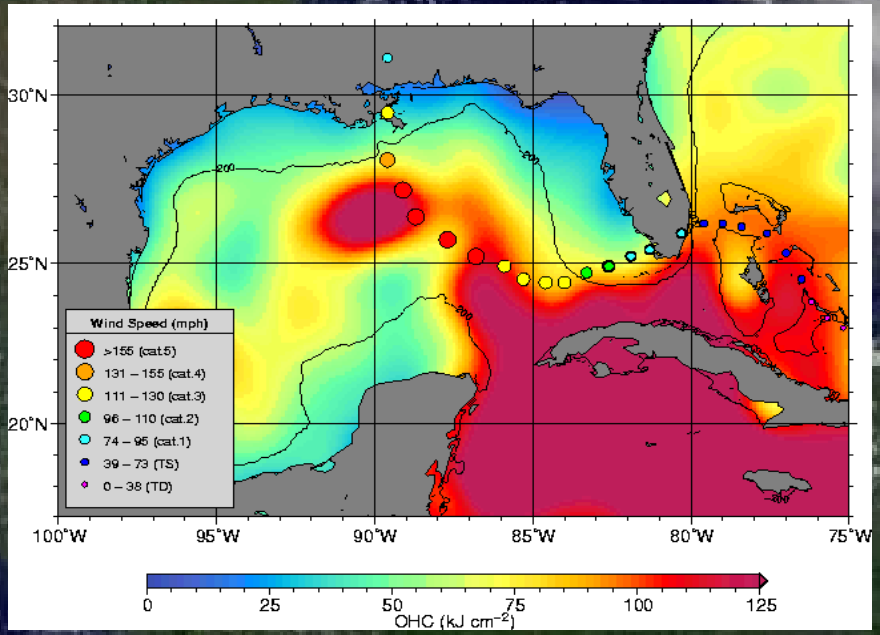
April 2010



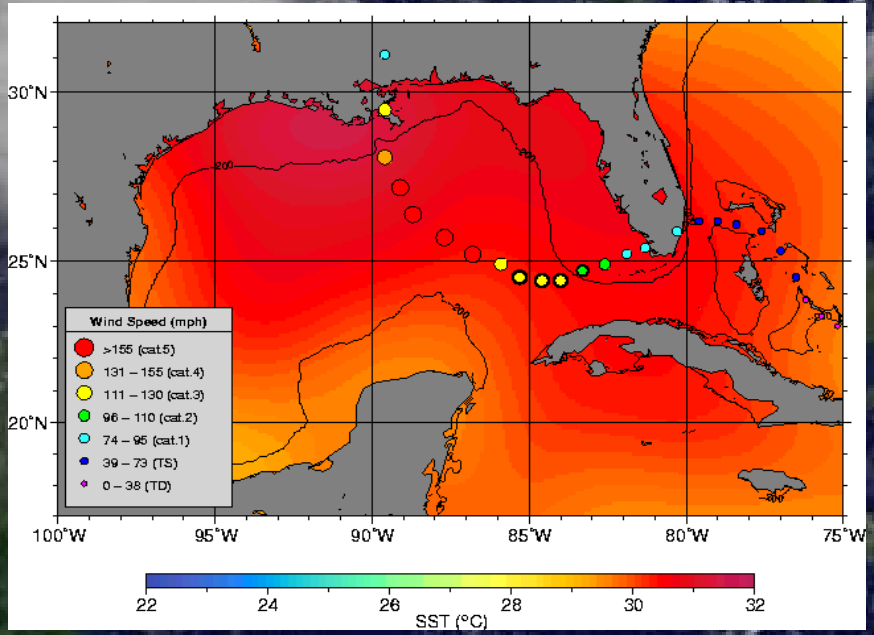
Altimeters tell us about surface currents in real time

Hurricane Katrina speeds up over warm water

Sea Surface Height



Sea Surface Temperature

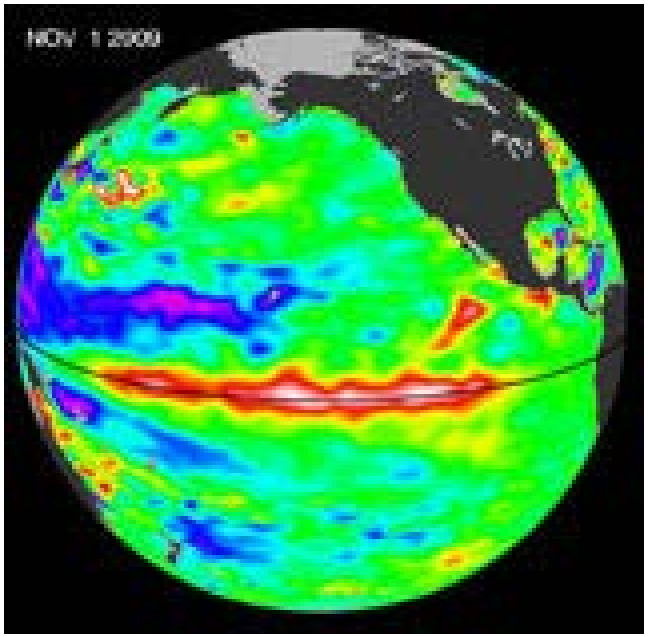


Courtesy of NOAA/AOML

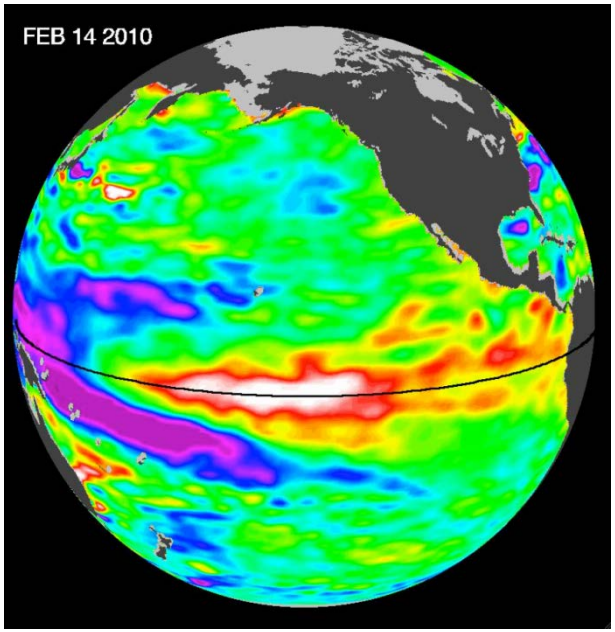
Background Photo Credit: GOES 12 Satellite, NASA, NOAA

2009 El Niño / 2010 La Niña

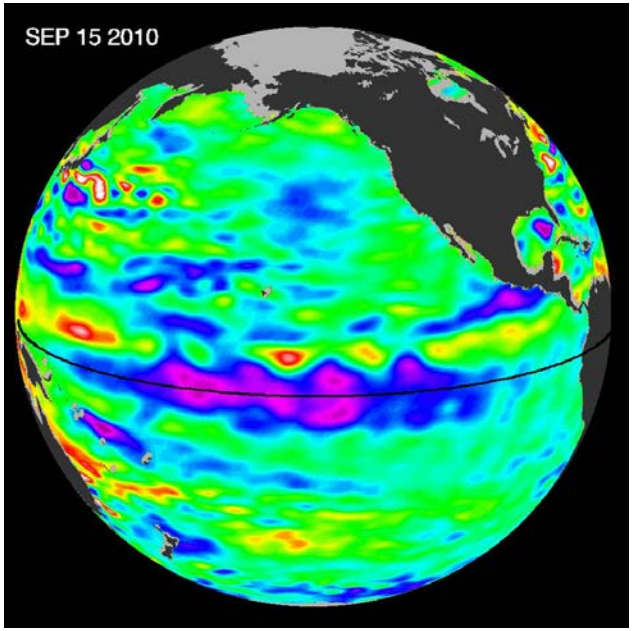
Nov 1, 2009



Feb 14, 2010

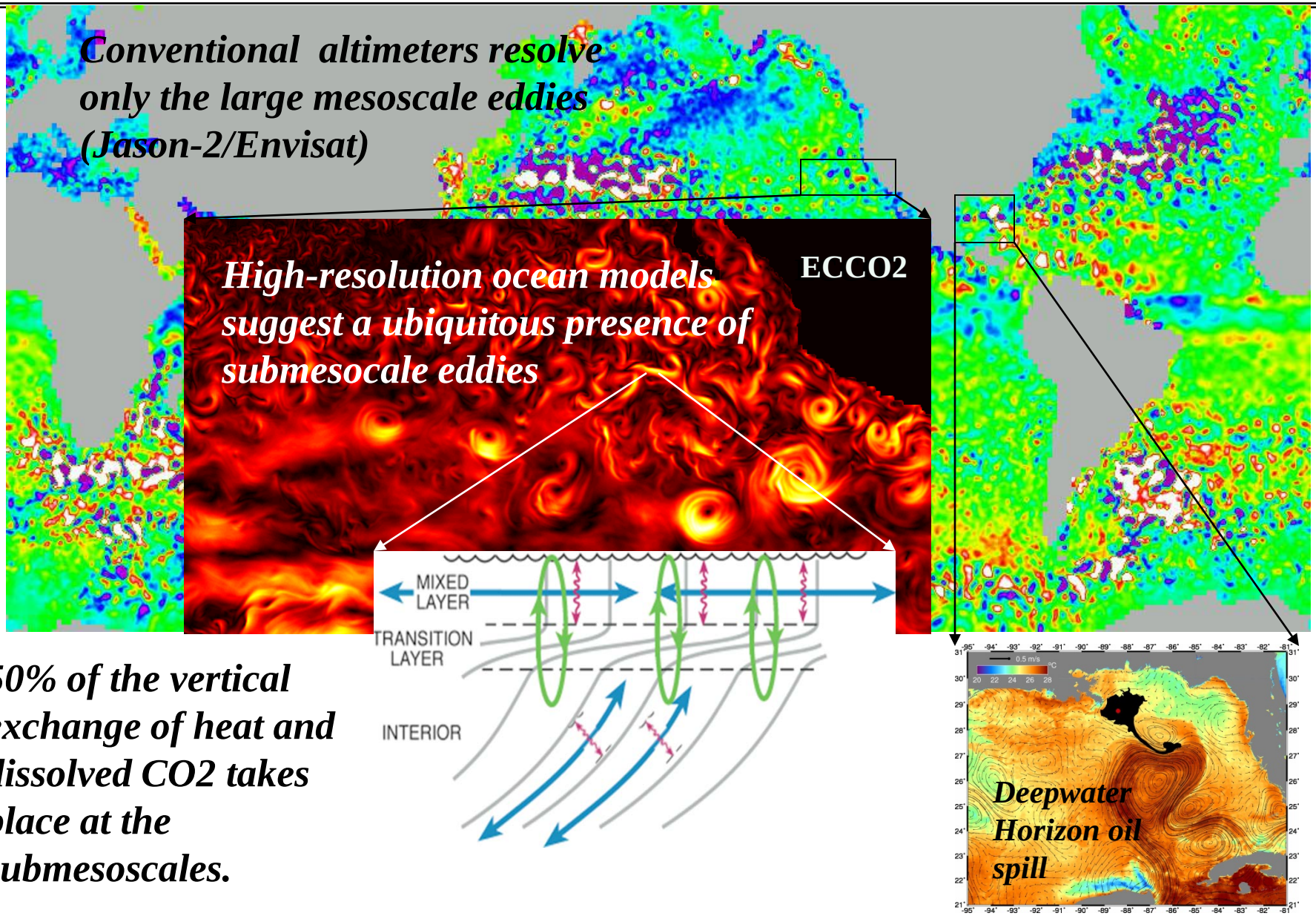


Sept 15, 2010



Altimeter data continue to provide insight into the development of globally important climate phenomena such as El Niño and La Niña

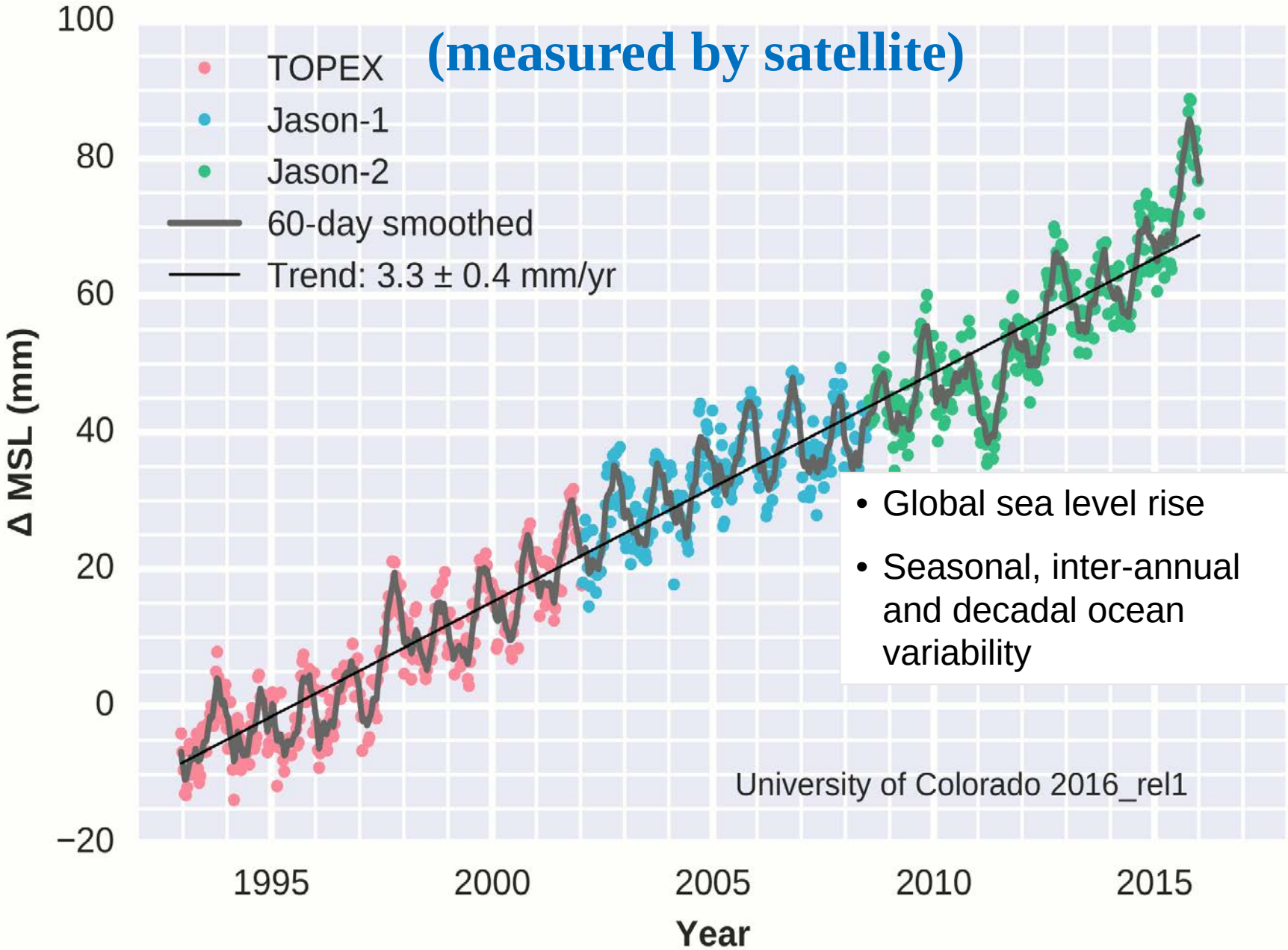
Ocean Currents and Eddies Have Small Scales



50% of the vertical exchange of heat and dissolved CO2 takes place at the submesoscales.

25 Years of Sea Level Rise

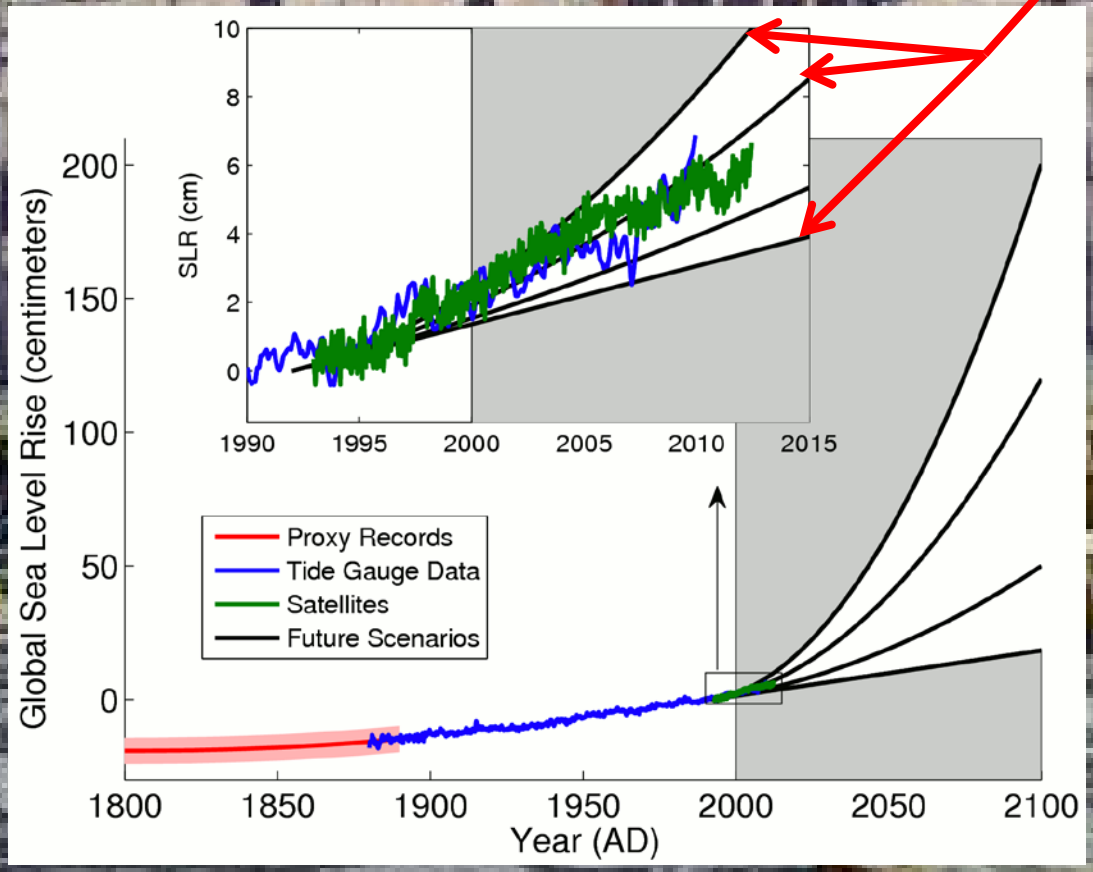
(measured by satellite)



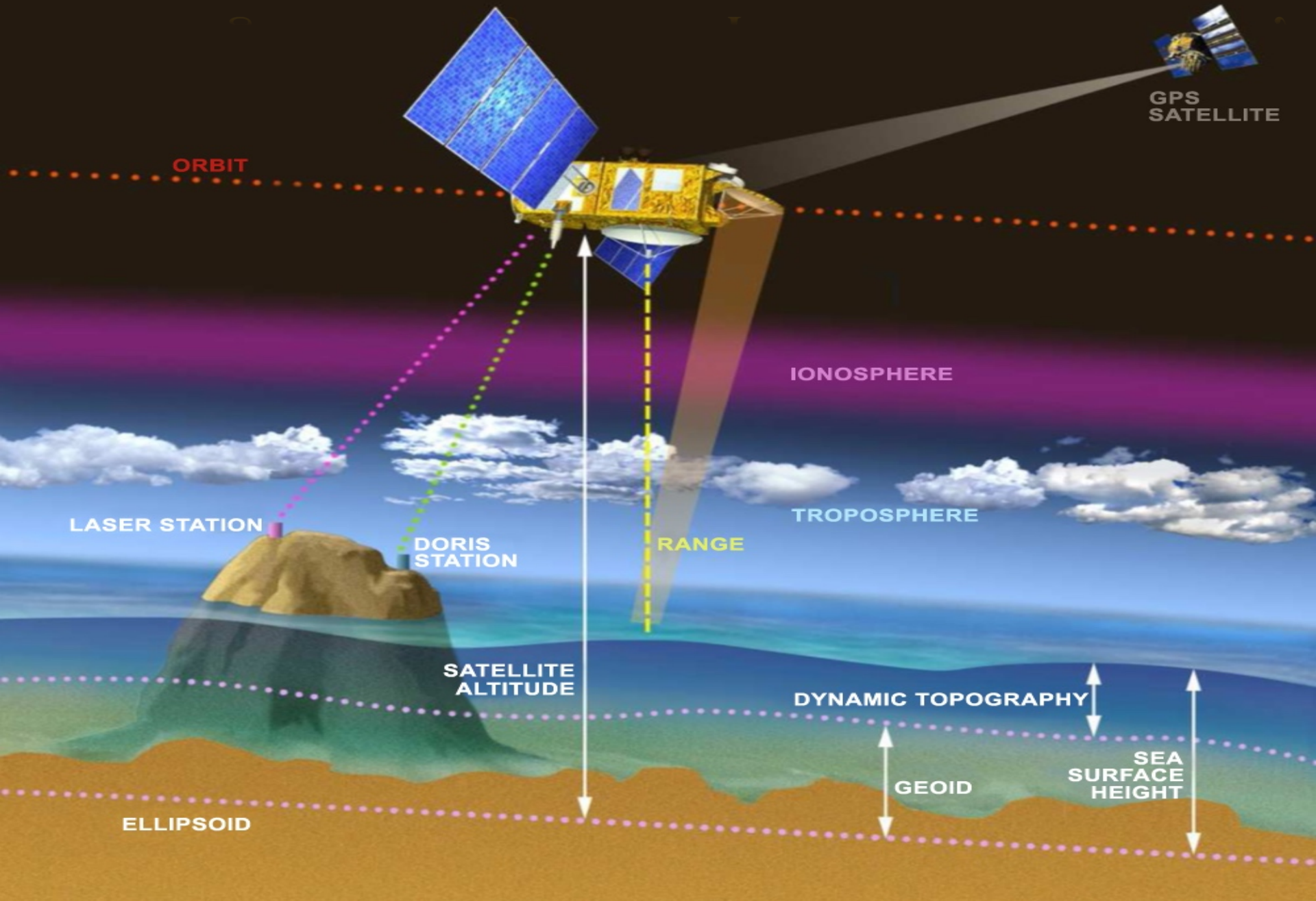
- Global sea level rise
- Seasonal, inter-annual and decadal ocean variability

Future Sea Level Rise…Which Path Are We On?

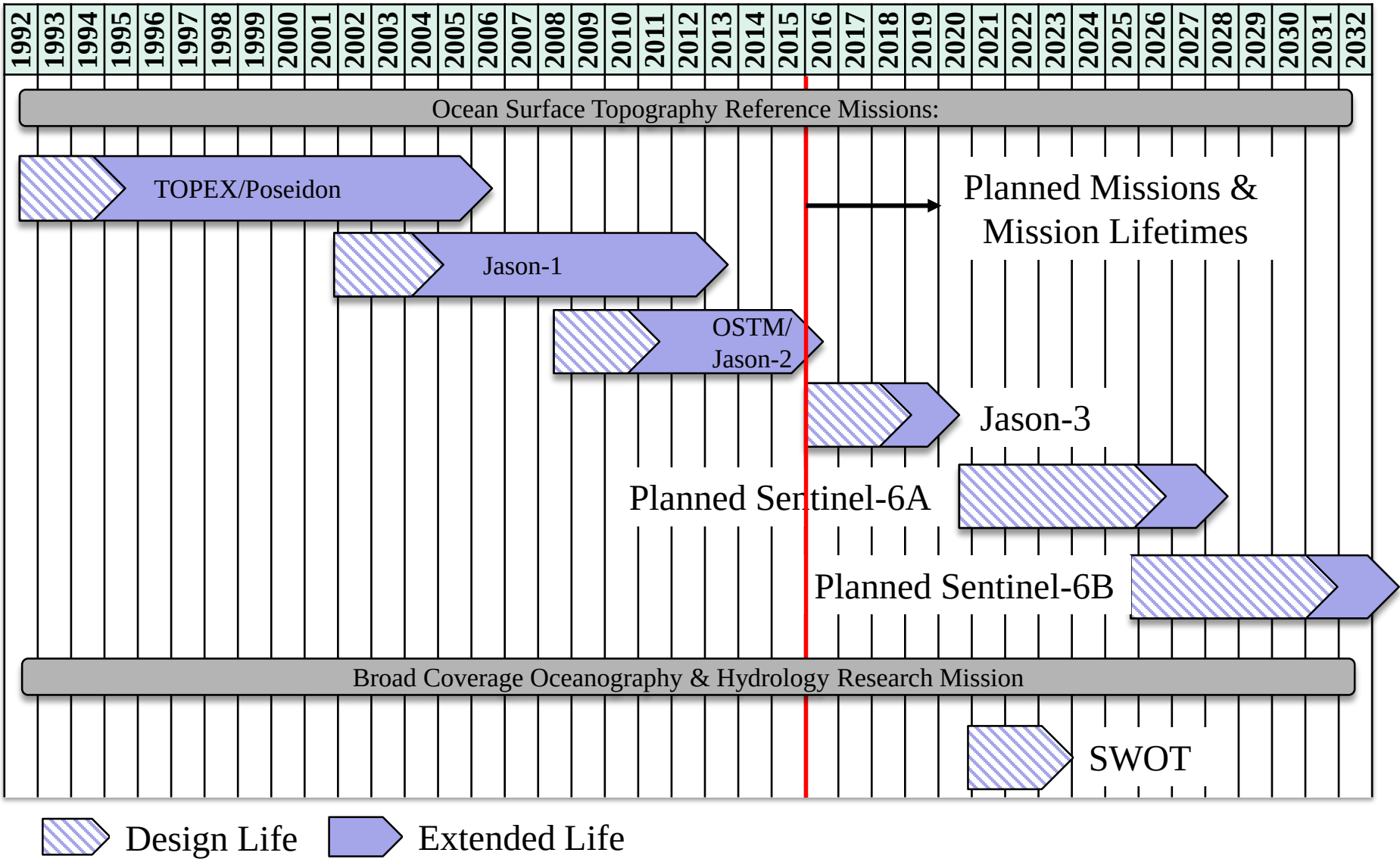
Satellite altimetry is our "canary"



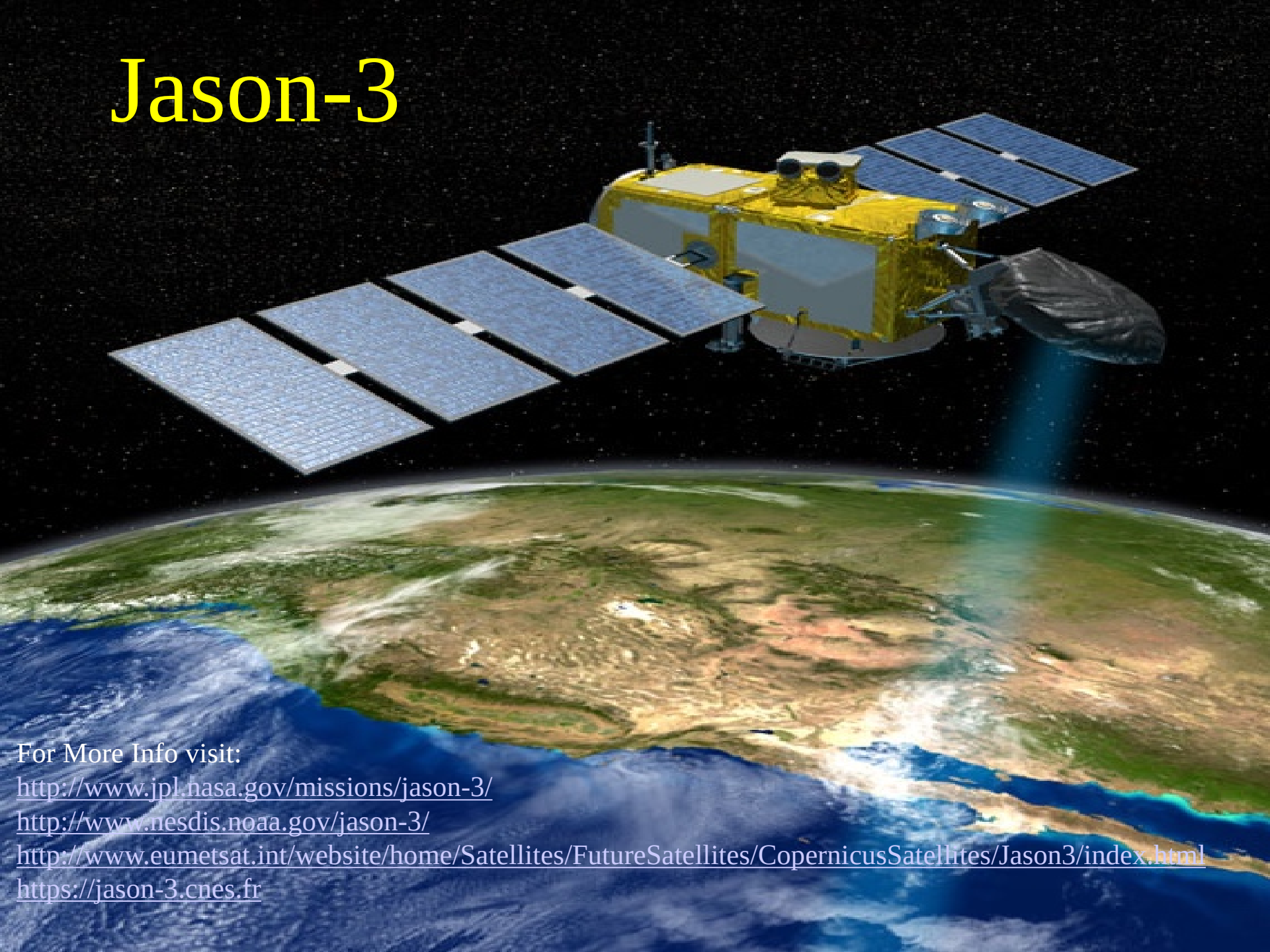
Measuring Ocean Height from Space with Nadir Altimetry



History & Future of Altimetry



Jason-3



For More Info visit:
http://www.jpl.nasa.gov/missions/jason-3/
http://www.nesdis.noaa.gov/jason-3/
http://www.eumetsat.int/website/home/Satellites/FutureSatellites/CopernicusSatellites/Jason3/index.html
https://jason-3.cnes.fr

Jason-3 Mission Summary

Science Measurements

Global sea surface height to an accuracy of ≤ 4 cm every 10 days, for determining ocean circulation, climate change and sea level rise

Mission Objectives

- Provide continuity of ocean topography measurements beyond TOPEX/Poseidon, Jason-1 and OSTM/Jason-2
- Operational ocean altimetry mission to enable the continuation of multi-decadal ocean topography measurements
- Mission Parnters: NOAA, NASA, CNES, EUMETSAT

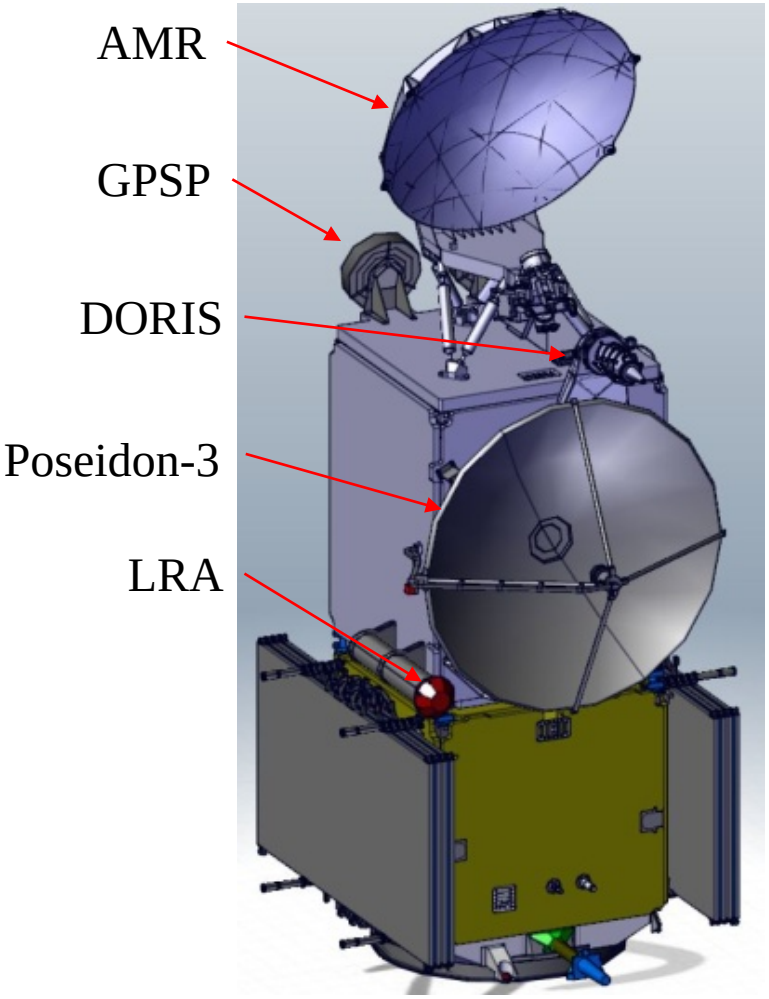
Mission Overview

- Launch Date: 17 Jan 2016
- Launch Vehicle: Falcon 9
- Proteus Spacecraft Bus provided by Thales Alenia Space under contract to CNES
- Mission life of 3 years (goal of 5 years)
- Operational orbit (1336 km Orbit, 66º Inclination) reached on 12 Feb 2016 w/ J3 trailing J2 by 80 seconds

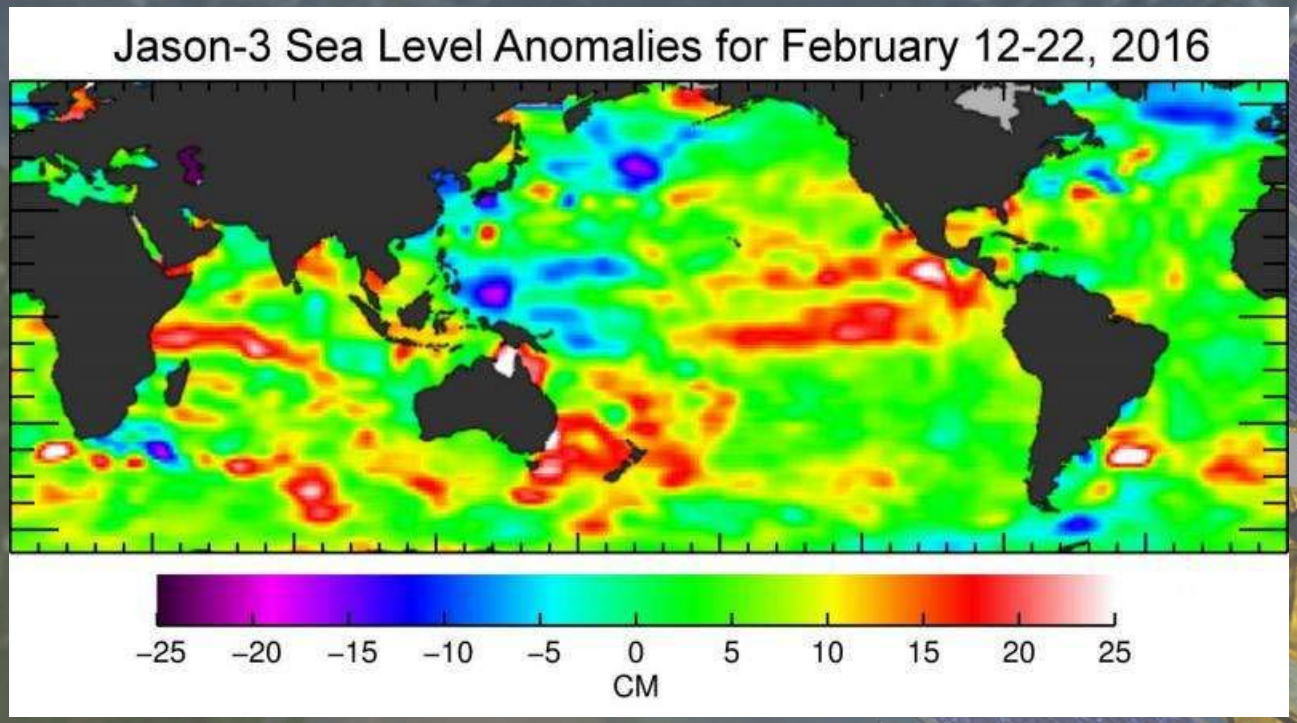
Photo Courtesy of SpaceX

Jason-3 Observatory

	Payload	Description
Range	Poseidon-3: Radar Altimeter	Measures distance between the satellite and the mean sea surface
Correction	Advanced Microwave Radiometer (AMR)	Measures *water vapor* content in the atmosphere to allow corrections for Radar signal path delay
Orbit	DORIS	Provides Precise Orbit Determination (POD) using Earth-based beacon system.
	Laser Reflector Array (LRA)	Supports orbit determination from 40 Earth-based laser tracking stations to centimeter-level accuracy
	GPS Payload (GPSP)	Support precise orbit determination using GPS constellation of satellites



Jason-3 Status



- First global map (above) produced 1 month after launch
- Jason-3 now in Assessment & Cal/Val phase flying in tandem with Jason-2 through summer/fall 2016 to cross calibrate & correlate the two measurement systems

Planned
Sentinel-6/ Jason-CS

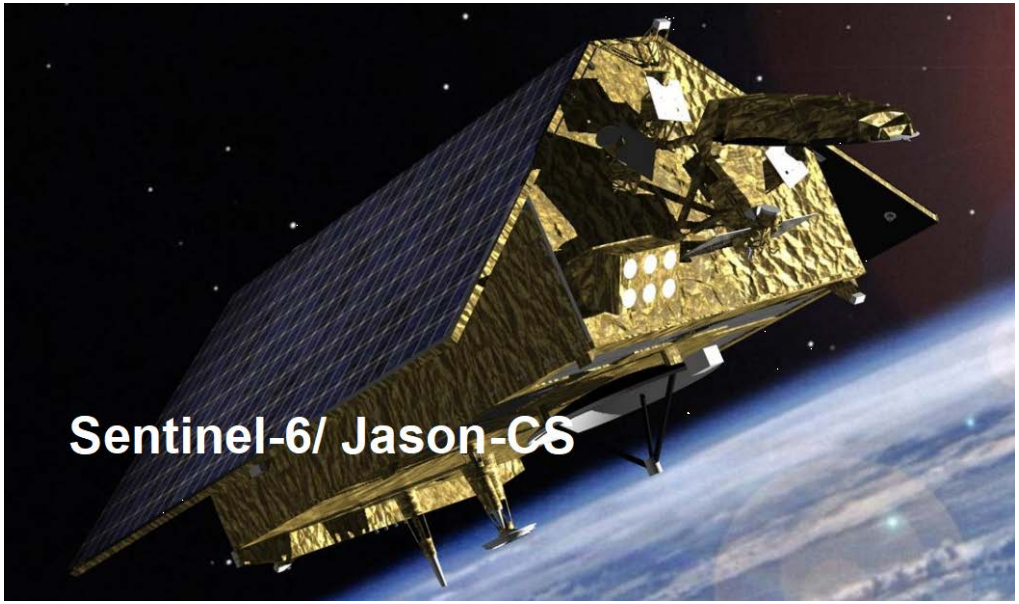
Planned Sentinel-6 Mission Overview

Science Measurements

Global sea surface height to an accuracy of ≤ 4 cm every 10 days, for determining ocean circulation, climate change and sea level rise

Planned Mission Objectives

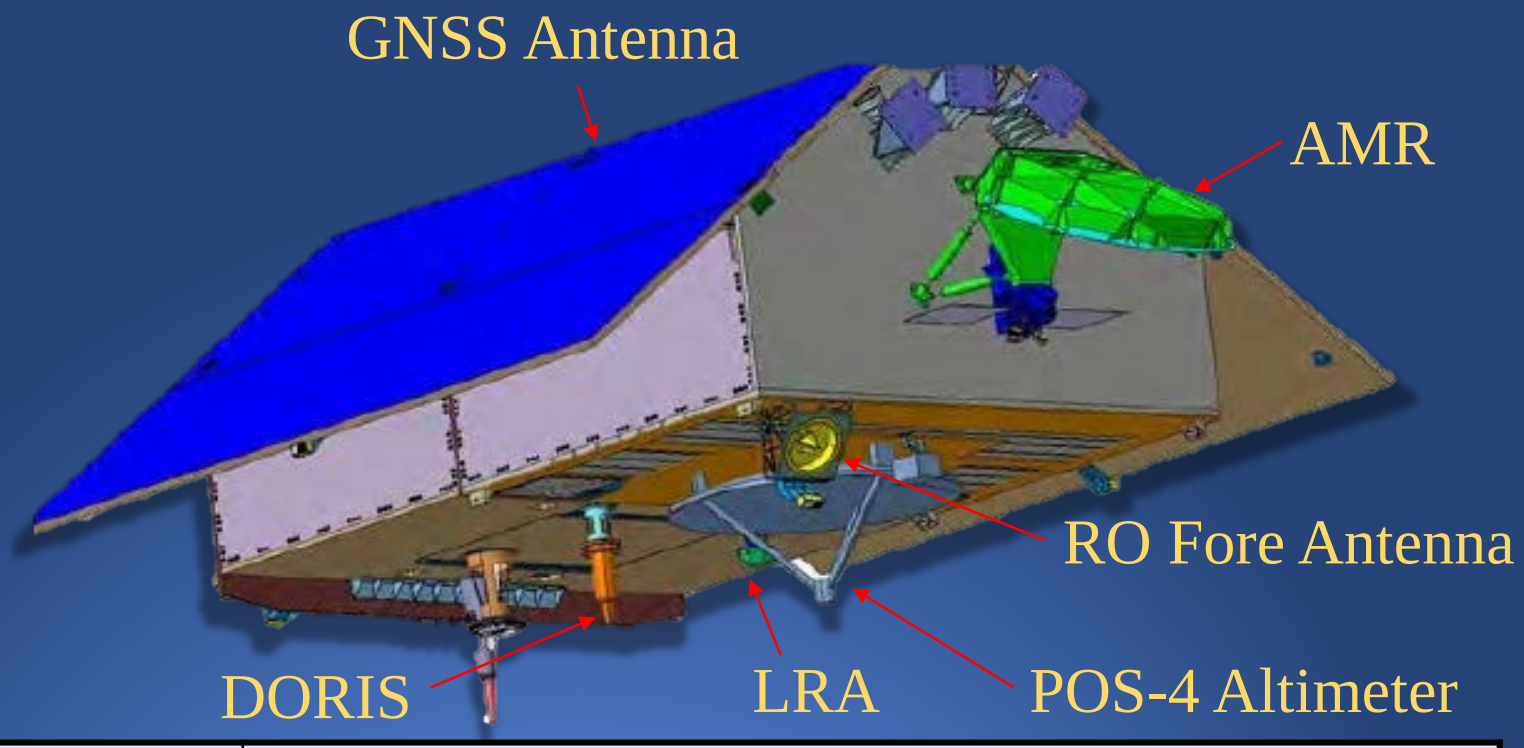
- Operational ocean altimetry to provide continuity of ocean topography measurements beyond Jason-3
- Global sea surface height to an accuracy of ≤ 4 cm every 10 days, for determining ocean circulation, climate change and sea level rise
- NASA, EUMETSAT, ESA and NOAA partnership with CNES providing ESA technical support
- Operational mission as part of a two satellite EUROPEAN altimetry program



Mission Overview

- Two Satellite program
- Launch Dates: 2020 and 2025
- Spacecraft Bus (Airbus: Cryosat Heritage)
- Mission life of 5½ years (goal of 7½ years)
- 1336 km Orbit, 66º Inclination

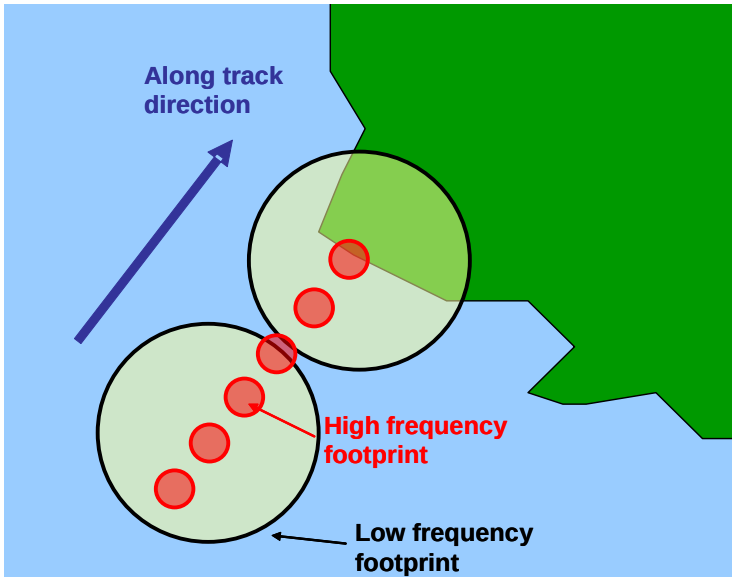
Planned Sentinel-6 Spacecraft

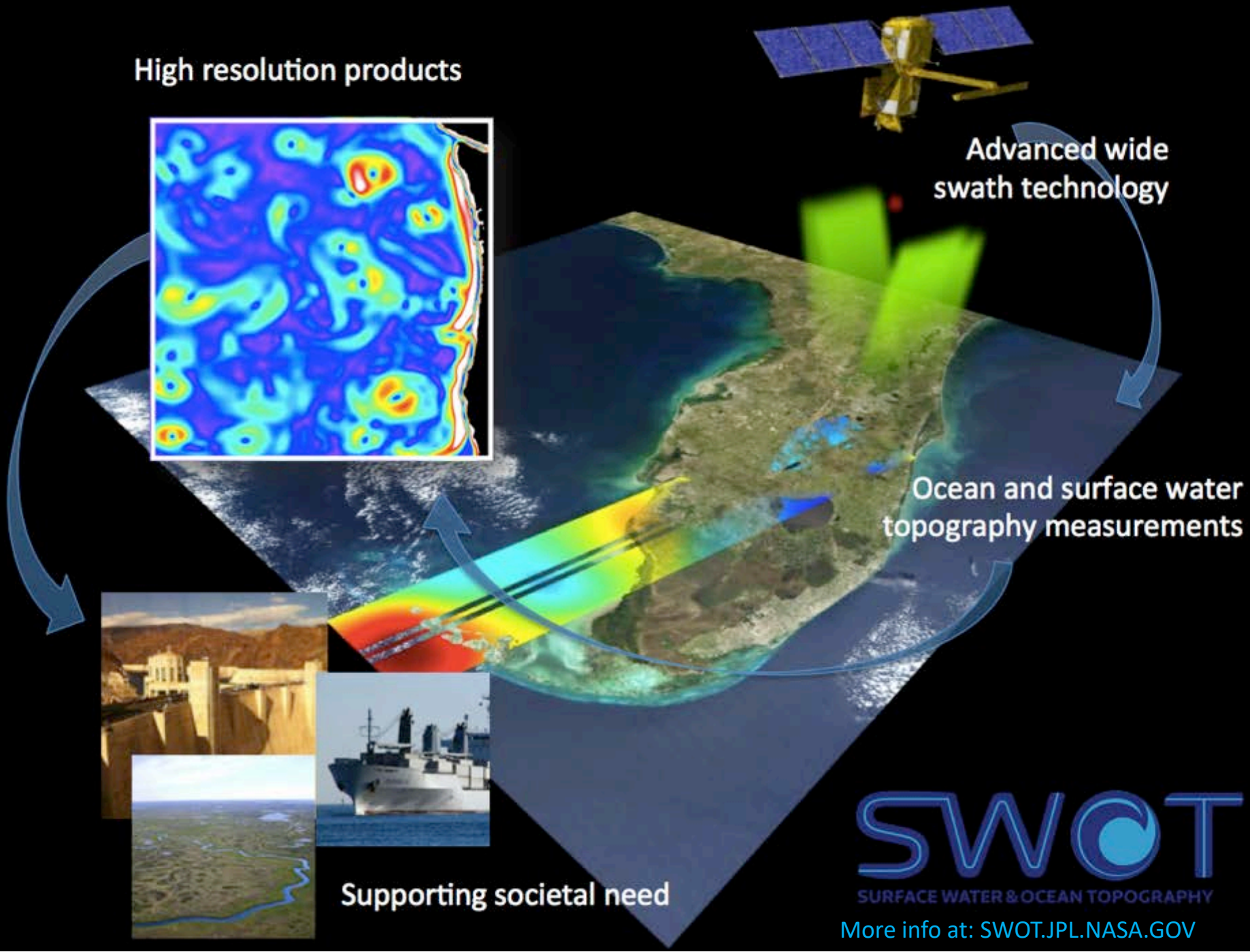


Planned Instruments	Planned Measurement Descriptions
Poseidon-4: Radar Altimeter	Measures distance between the satellite and the mean sea surface; includes enhancements for improved coastal region measurements
Advanced Microwave Radiometer (AMR)	For *water vapor* path delay corrections; includes new high frequency channels for better resolution in coastal regions
DORIS	POD using Earth-based beacon system.
Laser Reflector Array (LRA)	Supports orbit determination by laser tracking
GNSS-POD	Support POD using GPS constellation of satellites
GNSS-RO	High-Res vertical sounding measurements for weather models

Planned Sentinel-6 Mission Summary

- Enhanced radar altimeter would provide higher resolution mode near coastal zones
  - Supported by high frequency radiometer channels to correct
- Would includes Radio Occultation measurement system to support national weather model databases
- Implementation of a 2-satellite program now in progress would ensure continuity of measurement through mid-2030's
  - S6-A projected Launch in 2020
  - S6-B projected Launch in 2025




High resolution products
Advanced wide swath technology
Ocean and surface water topography measurements
Supporting societal need
SWOT
SURFACE WATER & OCEAN TOPOGRAPHY
More info at: SWOT.JPL.NASA.GOV

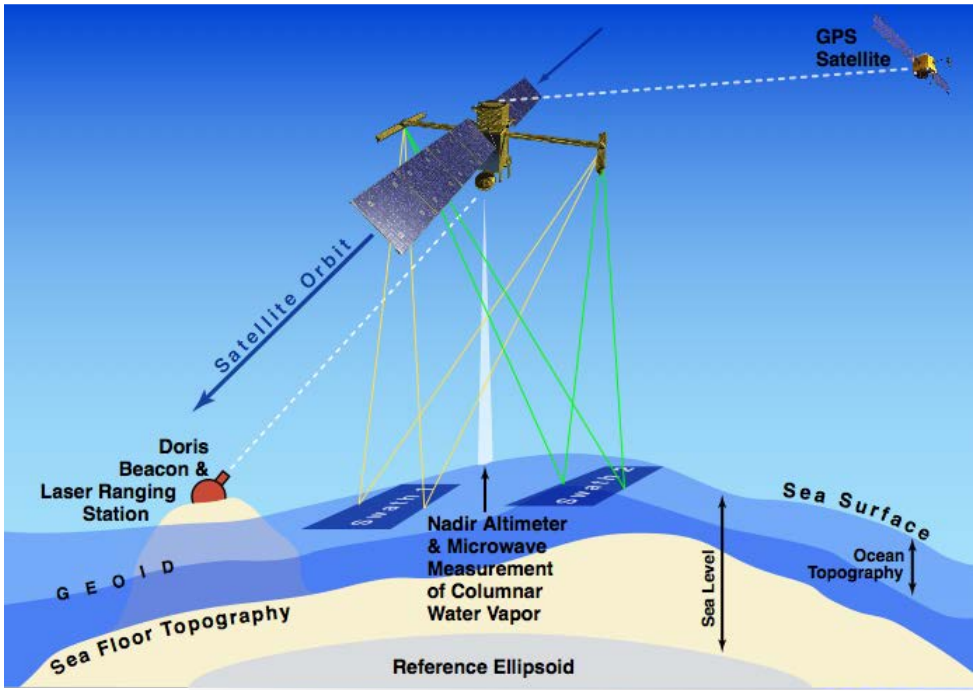
SWOT Mission Overview

Mission Science

Oceanography: Characterize the ocean mesoscale and sub-mesoscale circulation at spatial resolutions of 15 km and greater.

Hydrology: To provide a global inventory of all terrestrial water bodies whose surface area exceeds $(250m)^2$ (lakes, reservoirs, wetlands) and rivers whose width exceeds 100 m (rivers).

- To measure the global storage change in fresh water bodies at sub-monthly, seasonal, and annual time scales.
- To estimate the global change in river discharge at sub-monthly, seasonal, and annual time scales.



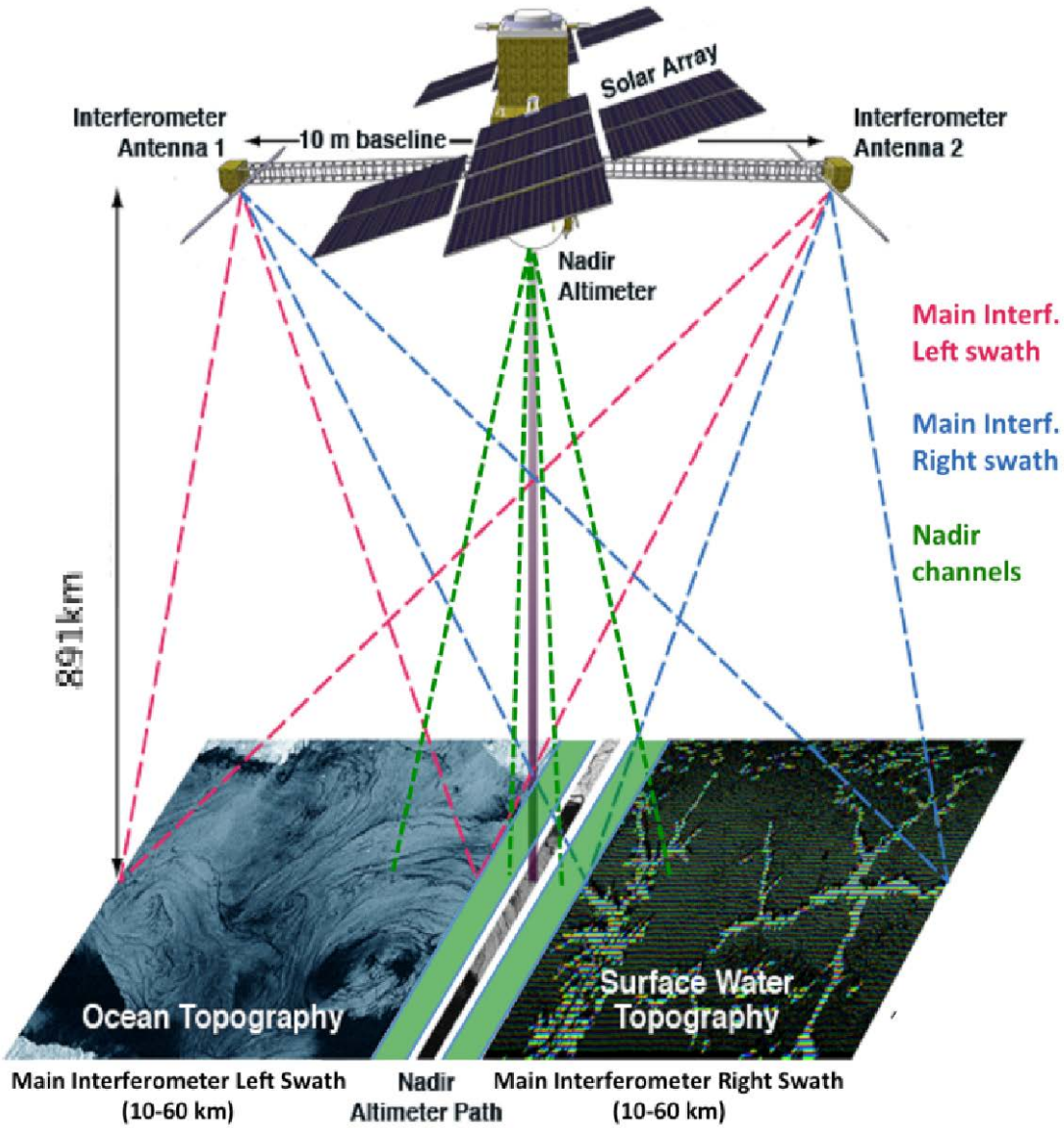
Mission Architecture

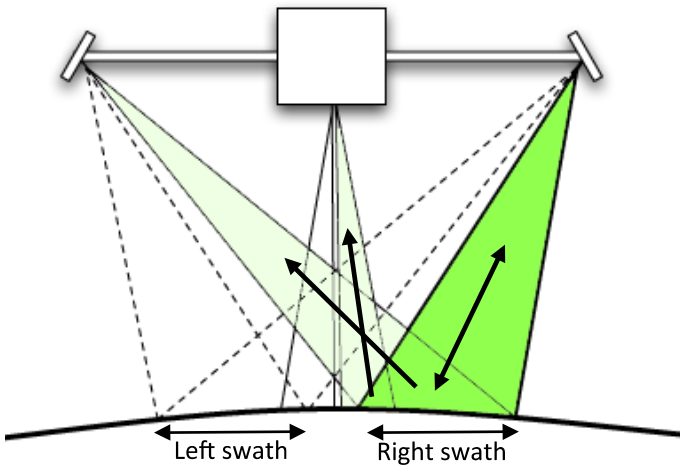
- Ka-band SAR interferometric (KaRIn) system with 2 swaths, 50 km each
- Produces heights and co-registered all-weather imagery
- Use conventional Jason-class altimeter for nadir coverage, radiometer for wet-tropospheric delay, and GPS/DORIS/LRA for Precision Orbit Determination.
- On-Board interferometric SAR processing over the ocean (1 km^2 resolution) for data vol. reduction.

Mission Overview

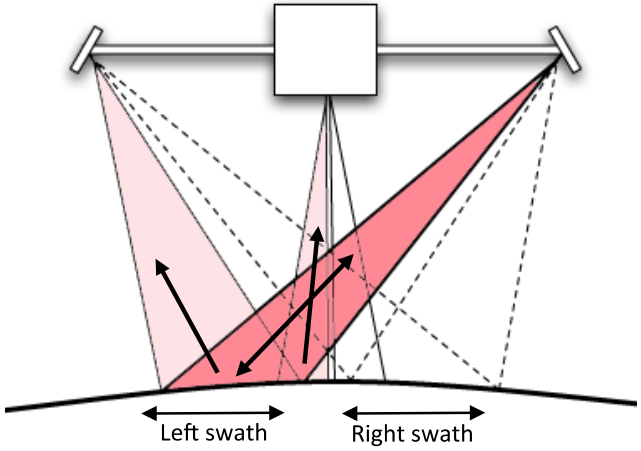
- Partnered mission with CNES & CSA
- Science mission duration of 3 years
- Cal orbit: 857 km, 77.6º Incl., 1 day repeat
- Science orbit: 891 km, 77.6º Incl., 21 day repeat
- Flight System: ~2200kg, ~2000W
- Launch Vehicle: NASA Medium class
- Planned Launch Readiness: 2020

Mission Concept and Integrated Measurement Approach

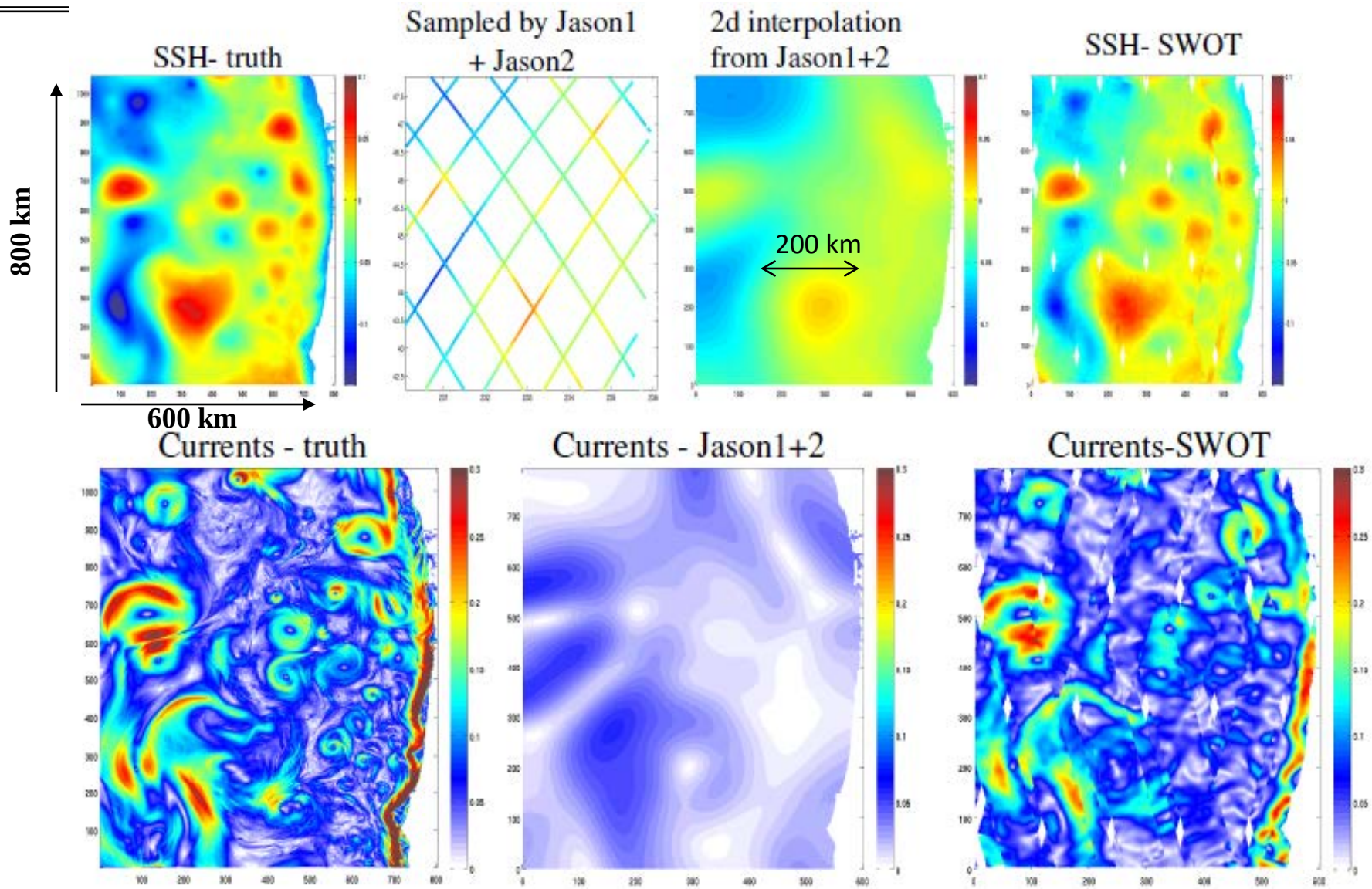




Non-Ping-Pong Mode



SWOT vs Jason-series Reconstruction of Ocean Current



Mission Science

Science questions to be addressed by this mission

Hydrology

What is the spatial and temporal variability in the world's terrestrial surface water storage and how can we predict these variations more accurately?

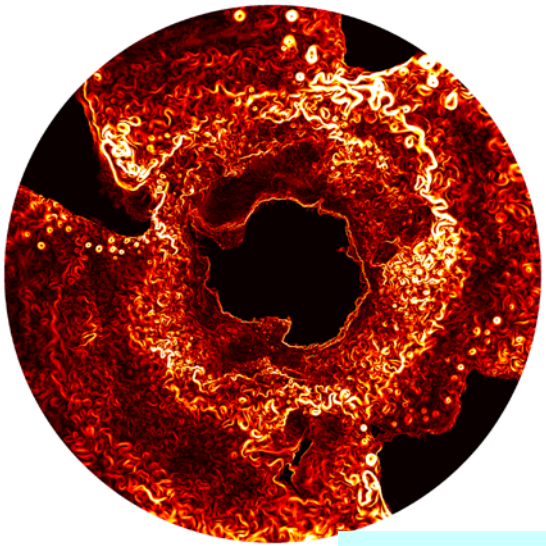
Image credit: Larry Smith

Oceanography

Resolving the ocean sub-mesoscale and kinetic energy containing scales

What is the small-scale (1-100 km) variability of ocean surface topography that determines the velocity of ocean currents, especially in the coastal zones?

What are the effects of coastal currents on offshore operation, navigation, and ecosystem?



Southern Ocean near-surface current speed from ECCO2

Summary: Altimetry for the next decade and beyond

Element	Jason-3	(Planned Mission) Sentinel-6	SWOT
Partners	NASA, CNES, EUM, NOAA	NASA, ESA, EUM, NOAA, CNES	NASA, CNES, CSA, UKSA
Science	Research & Operational Oceanography	Research & Operational Oceanography	Research Oceanography and Hydrology
Orbit	1336 km; 66-deg incl	1336 km; 66-deg incl	891Km, 78-deg incl
Lifetime	3 years (goal: 5 years)	5.5 years (goal: 7.5 yrs)	3.5 years
Mass	510 kg (28Kg Fuel)	1400 Kg (250 Kg Fuel)	~2000 Kg (~325 Kg Fuel)
Power	450 W	720 W	~2000 W
Spacecraft Bus	Proteus - Thales Alenia Space (Cannes, France)	Cryosat - derived Airbus, Germany	Thales (Cannes, France)
Launch	17 January 2017	S6-A: 2020 S6-B: 2025	October 2020

The successful launch of Jason-3 in 2016 will continue the global sea height data record past 30 years

The Sentinel 6 series would continue the data record into the mid-2030's with evolutionary improvement in resolving features in coastal zones

SWOT will build on the successful measurement systems and partnerships developed over the series of Jason missions and implement technology to provide a revolutionary increase in resolution enabling new research opportunities for oceanography and hydrology over land

THANK YOU