The Surface Water / Ocean Topography Mission (a) : Capabilities for Coastal Oceanography

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(a) *The SWOT mission has not been formally approved by NASA. The decision to proceed with the mission will not occur until the completion of the National Environmental Policy Act (NEPA) process. Material in this paper related to SWOT is for information purposes only.*

Outline

- Science Overview
- Measurement Concept
- Instruments
  - KaRIn – Ka-band Radar Interferometer
  - Microwave Radiometer
  - Precision Orbit Determination systems
  - Nadir Altimeter
- Data Flow Architecture
- Coastal Considerations

- Status
  - Completed MCR Sep '12
  - Plan Ph A Start Nov '12
  - Launch target Oct '20

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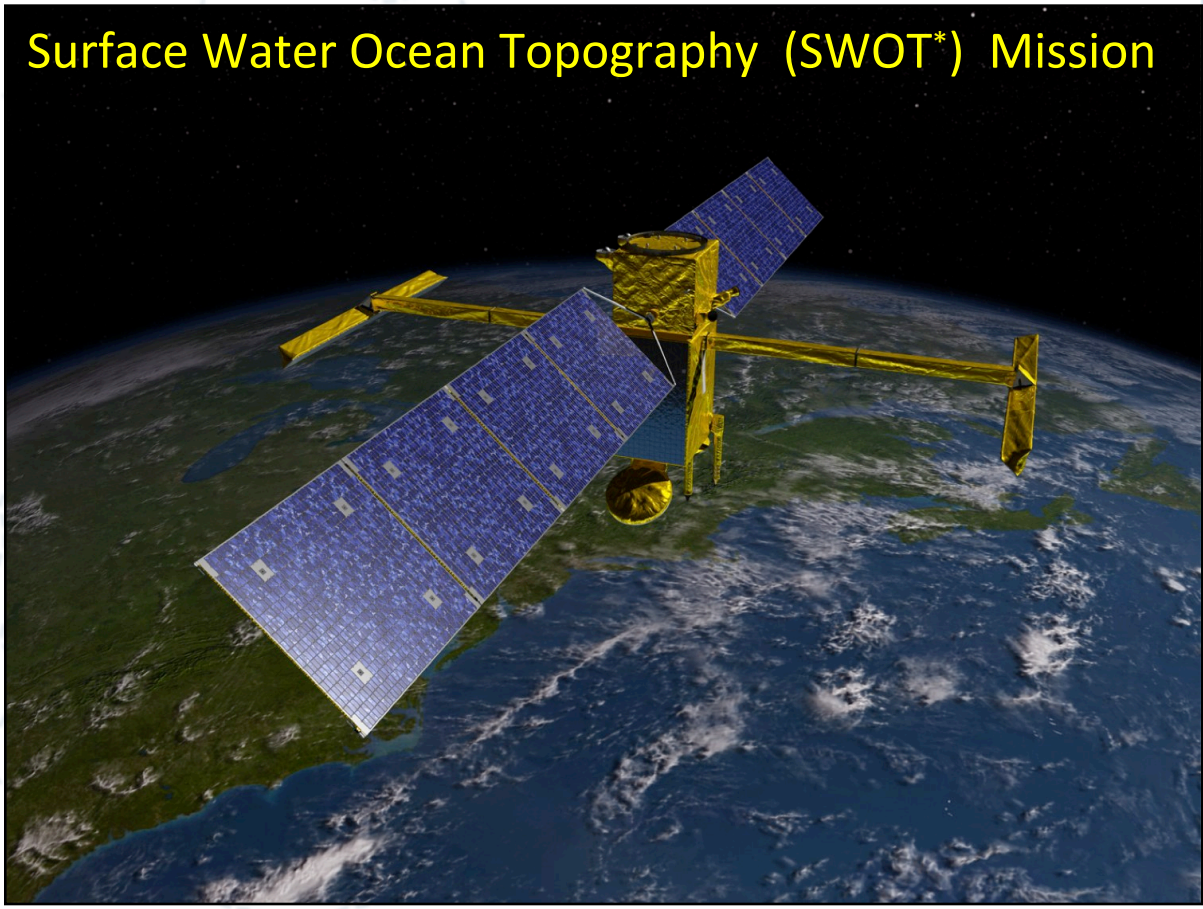

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SWOT* Oceanographic Objectives

• **Ocean topography** is an analog of atmospheric surface pressure: ocean currents flow around the highs and lows of ocean topography, like winds blow around the highs and lows of surface pressure.

• **Satellite altimetry** developed by NASA and CNES over the past 25 years has made revolutionary findings of ocean circulation and **sea level change at scales larger than 200 km**: ocean gyres, the Gulf Stream, El Nino, sea level rise, large eddies.

• **Ocean currents and eddies at scales shorter than 200 km** play key roles in the horizontal and vertical transport of heat, carbon and nutrients. They affect climate via modulation of sea surface temperature and heat flux, as well as the oceanic uptake of carbon from the atmosphere.

• **The primary oceanographic objectives** of the proposed SWOT mission would be to observe the ocean mesoscale and submesoscale circulation at spatial resolutions of 15 km and larger, **providing the missing link between 15 and 200 km for ocean climate studies**.

• Ocean currents and eddies at these short scales are also important to **coastal ocean processes of importance to societal applications.**

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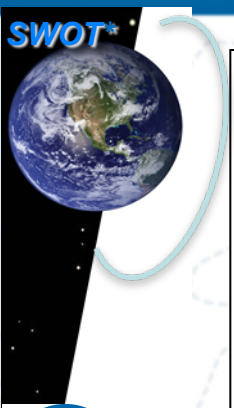
Targeting the Smallest Scales of Ocean Circulation



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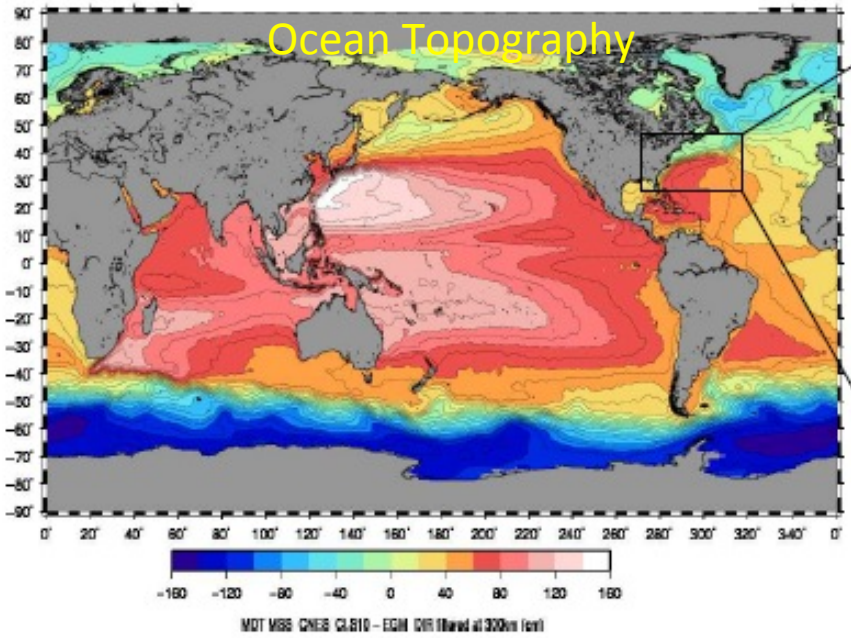
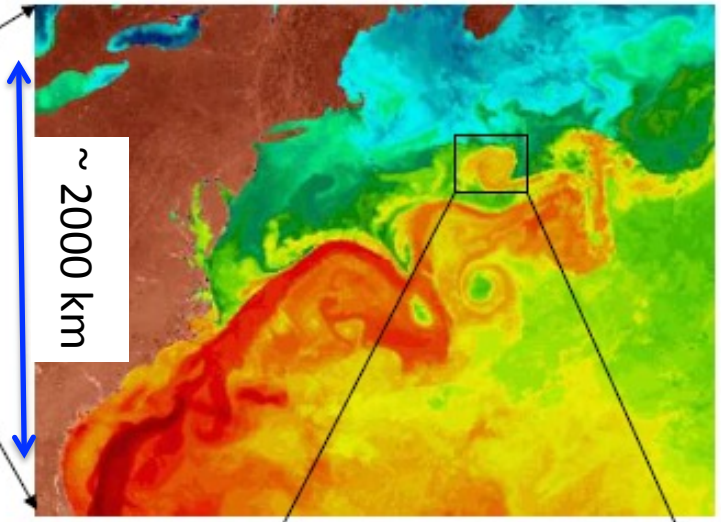
Global basin scale

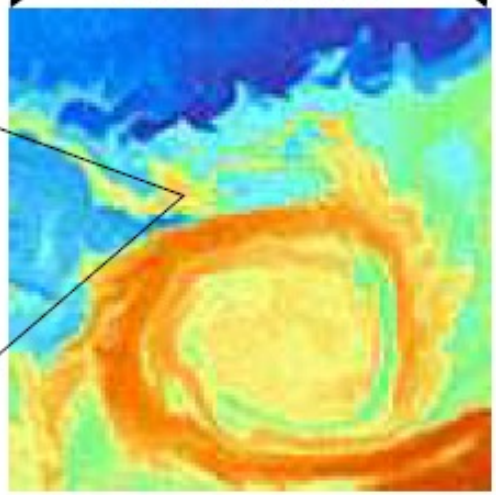


mesoscale

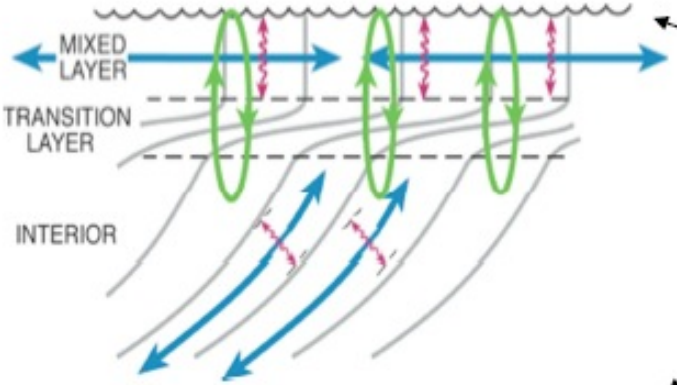


SST

submesoscale



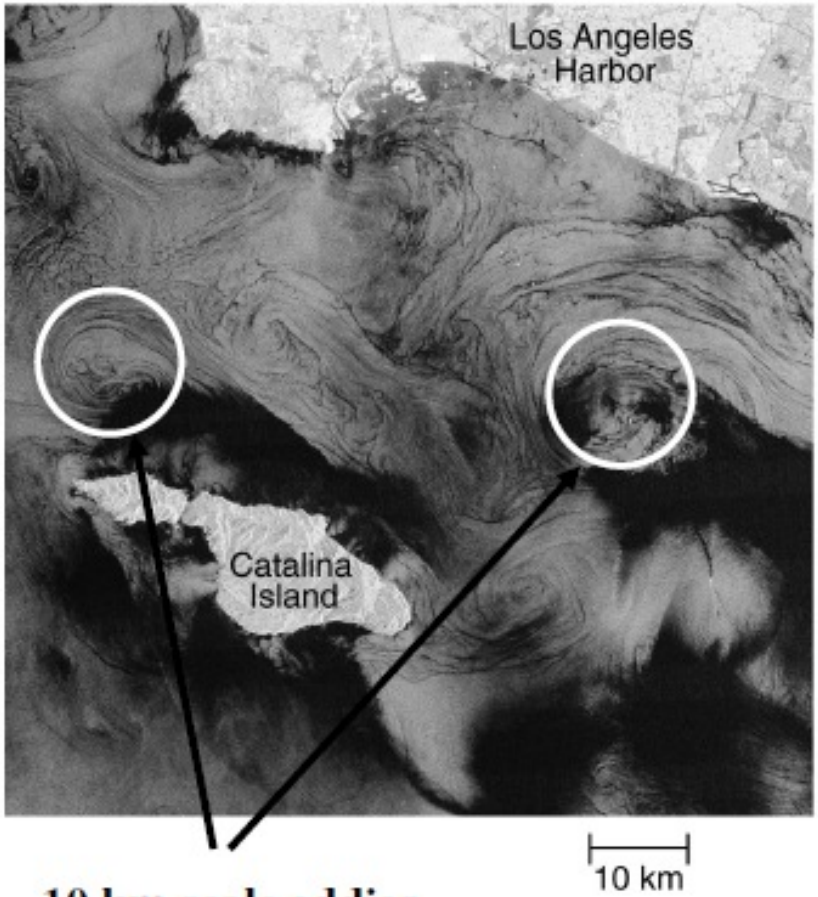
Vertical exchange of heat, CO_2, nutrients between the upper and deep ocean



SSH is needed for dynamics

Submesoscale Ocean Processes

RADARSAT - December 26, 1998



10 km scale eddies Resolvable by SWOT*

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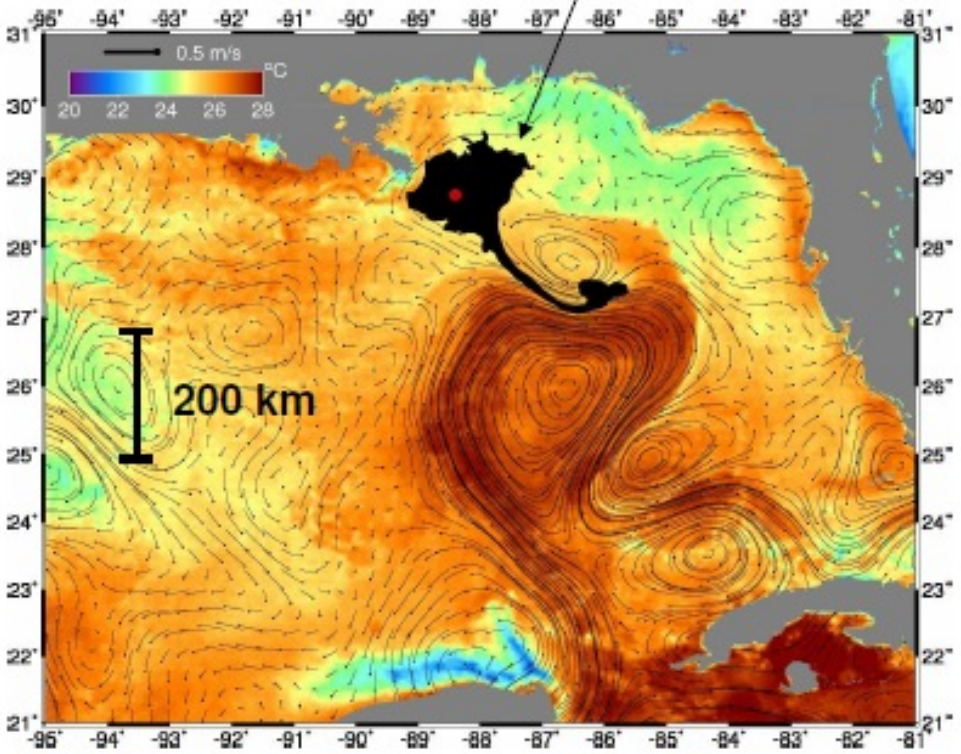
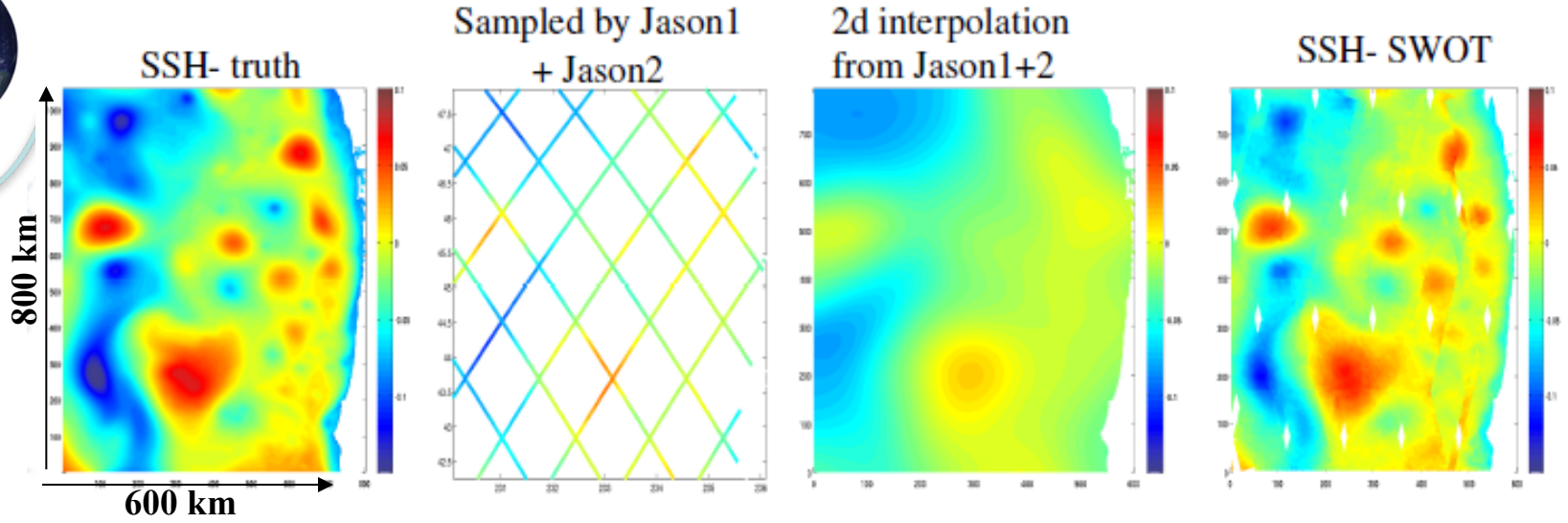
Deepwater Horizon oil spill



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

Simulated SWOT* Ocean Observations – US West Coast



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Integrated Measurement Approach

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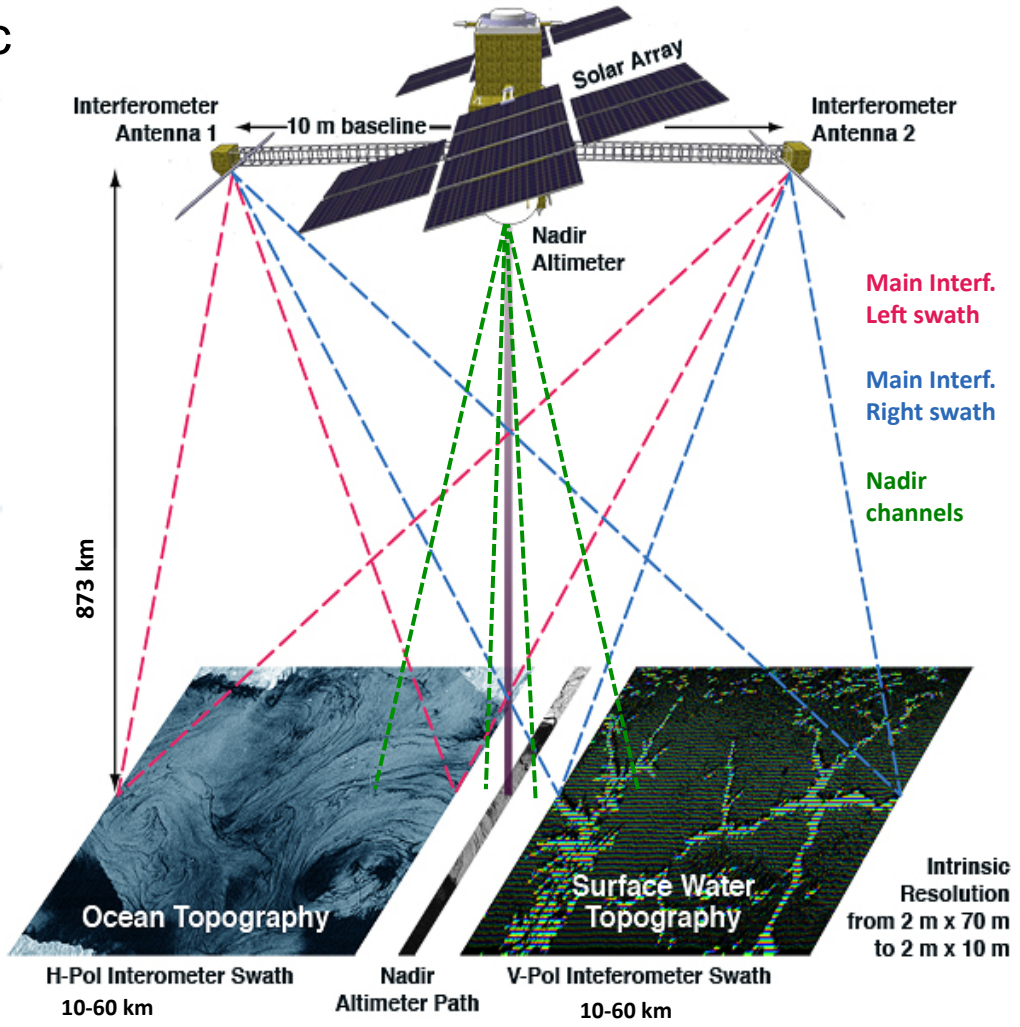
- Ka-band SAR interferometric system (KaRIN) with 2 swaths, 50 km each
  - WSOA and SRTM heritage
  - Produces heights and co-registered all-weather imagery for both ocean and hydrology
  - Onboard data processing over the ocean (1km resolution)
  - No land data compression onboard (~50m resolution)
  - Near-nadir channels (experiment) for altimeter and to close nadir gap
- Additional instruments:
  - conventional Jason-class altimeter for nadir coverage
  - AMR-class radiometer to correct for wet-tropospheric delay
  - GPS, DORIS & laser retroreflector for POD



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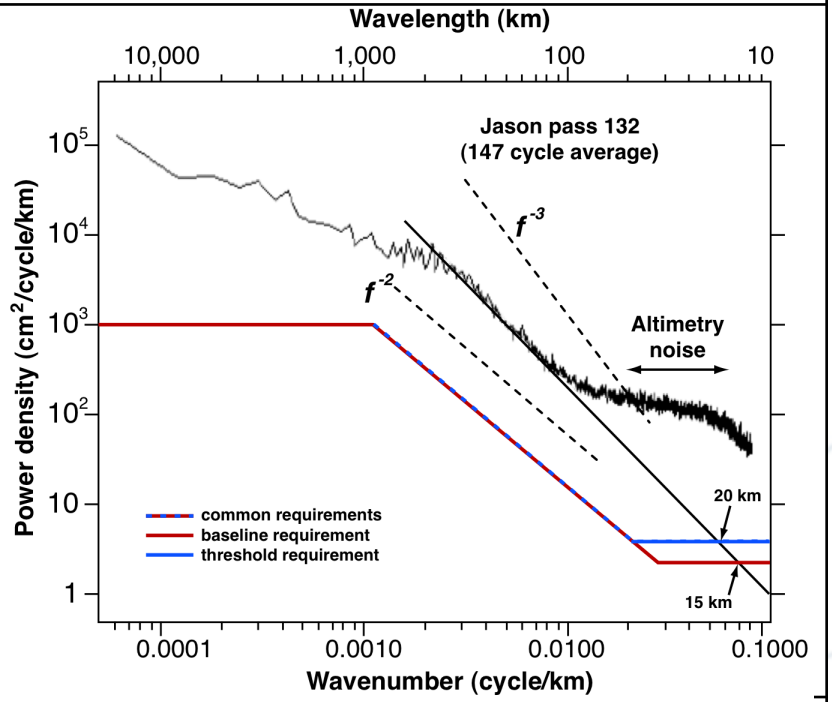
Ocean Accuracy Requirements

Item	Requirement
SSH Posting	The spatial posting of sea surface height measurements shall be ≤2 km
SSH Error Spectrum < 1,000 km wavelength ***Relies on KaRIn***	The sea surface height error spectrum in the wavelength range smaller than 1,000 km shall not exceed the spectrum envelope shown. This error spectrum corresponds to a spatial resolution of 15 km. This requirement holds for significant wave heights (SWH) less than 2 meters.
SSH Error Spectrum 1,000 – 10,000 km wavelengths ***Relies on Nadir Altimeter***	The sea surface height error spectrum for the wavelength range between 1,000 km to 10,000 km shall not exceed the spectrum envelope given in the figure. This requirement holds for significant wave heights (SWH) less than 2 meters.



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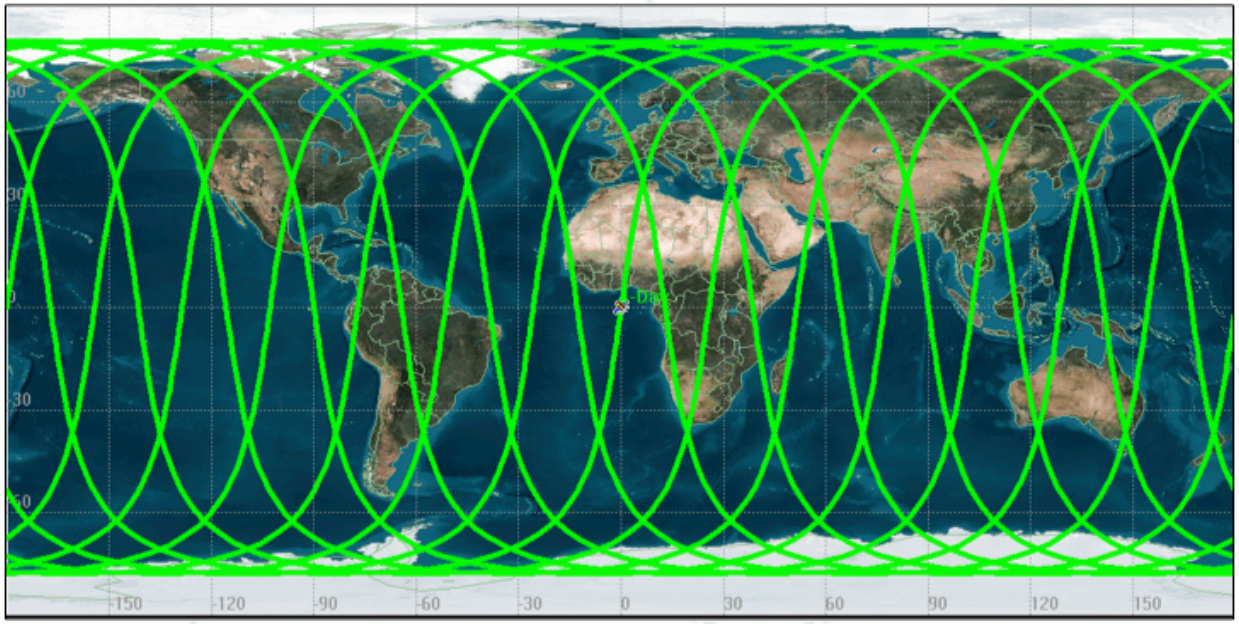
Baseline Orbit: 22 day / 1 day subcycle

- 1-day sub-cycle orbit (baseline orbit):
  - Orbit altitude: 873 km altitude, 78 deg inclination, ~22 day repeat
  - Greater SNR and performance margin
  - Faster calibration
  - Lower de-orbit mass requirement

Fast Sampling / Calibration
1-day repeat
858 km orbit



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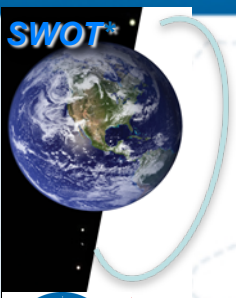
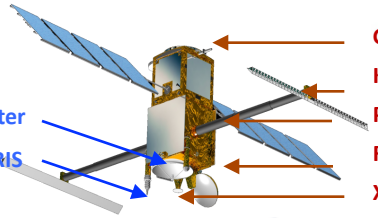
Mission Architecture



(TBD – Med Size) US Launch Vehicle



AirSWOT: Prelaunch, Cal/Val

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CNES Elements
NASA Elements
Joint Elements

800 Mb/s (X-band)

Downlink Science Data

~7 Tbits/day
~15 passes/day

Uplink: S/C & P/L Comm.
Downlink: All Eng Telem

2 passes/day

CNES S+X-band Network: KIR and IVK

Additional (CNES) S+X Sta TBD [AUS or HBK]

CNES S and X-band Network Operations Center: COR

S/C telemetry

P/L commands

To JPL POC:
S/C Telemetry (stored & RT),KaRIn Engineering

To CNES CCC: Payload commands

S/C Control Center (SCC)

To CNES SCC
Payload commands

To CNES POC:
S/C Telemetry
(stored & RT)

X-Band Telemetry

JPL Payload Operations Center

CNES Payload Operations Center

X-Band Telemetry

JPL Science Data Processing Center

To JPL: KaRIn, Jason altimeter L2, POD, Cal/val

To CNES: KaRIn, POD, Cal/val

CNES Science Data Processing Center

JPL Science Data Archiving and Distribution

CNES Science Data Archiving and Distribution

Ancillary Data:
Tropo model(s), Iono info, Tide model(s),
Mean Sea Surface, Digital elevation models

JASON Suite:
- Radiometer
- Payload-GPS
- Nadir Altimeter
- DORIS
- LRA

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SWOT* Considerations for Coastal Altimetry

- Nominal ocean resolution is 1 x 1 km based on onboard processing. Requires ~1 m range accuracy, so mixed ocean/land, large coastal tide pixels may have problems
- High Rate (HR) data would be turned on by mask when any part of swath touches land
  - Nominal HR coverage is 23.5% of orbit cycle includes 120 km buffer around land (but no coverage of Greenland, Antarctica)
  - Total HR data limited by downlink data volume to ~29% of cycle. Additional data volume would be used for "synergistic" science
  - Global 20 km extension of "land" adds ~1% of total data
- HR data could be processed to multiple resolutions >~ 50 m over ocean areas for super-fine resolution
- Tradeoffs of synergistic science options will be worked during early phases of mission
  - Data acquisition mask is uploadable. Likely would be reloaded seasonally.

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Backup

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Proposed Data Products (1 of 2)

Data Product	Products /Day *	Product Size (GB)	Key Characteristics	
L0B KaRIN	14	68.0	Cleaned telemetry separated by instrument (KaRIN – Low Rate (LR) / High Rate (HR)), pass	
L1B LR (Ocean)	28	0.11	Onboard ocean interferograms	
L1C LR	28	0.13	Heights from each onboard ocean interferogram with corrections	
L2B LR	28	0. 12	Resampled Sea Surface Height in fixed swath grid (1 km) with geophysical corrections and fields	
L1A HR	~ 40	~ 150	Single Look Complex images for each swath separated by pass, continent	
L1C HR	~ 40	TBC [~100]	Phase flattened interferograms	
L2B HR Hydrology	~ 40	TBD	Surface water shape files, Triangular height networks with slopes, flags separated by pass, continent. L2B_D: Discharge product	

- * 14 = 1/rev. Ocean products would be by pass (asc/des = 28).
- Land products would likely be divided by continent, so each rev would have several products.

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Proposed Data Products (2 of 2)

Data Product	Products /Day *	Product Size (MB)	Key Characteristics (Archived, unless otherwise noted)	
L0B Rad	28	1	Radiometer telemetry by pass. Radiometer processing would be done by both JPL, CNES as part of KaRIN, Nadir Alt processing with JPL-supplied algorithms.	
L1B Rad	28	1	Radiometer antenna temperatures	
L2B Rad	28	1	Radiometer brightness temperatures, geophysical retrievals	
L0B Nadir Alt	28	30	Nadir Altimeter telemetry by pass. Nadir Alt processing would be done by CNES. L2B product would be provided for KaRIN processing, e.g., crossover calibration.	
L1B Nadir Alt	28	35	Corrected instrument data	
L2B Nadir Alt	28	35	Jason-like SGDR (Geophysical Data Record with waveforms)	
CNES POD	1	0.001	POD from DORIS for Nadir Alt would be produced by CNES	

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- * 14 = 1/rev. Ocean products would be by pass (asc/des = 28).
- Land products would likely be divided by continent, so each rev would have several products.

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Hydrologic Objectives

- The hydrologic science measurement objectives proposed for SWOT* are:
  - To provide a **global inventory of all terrestrial surface water bodies** whose surface area exceeds **$(250m)^2$ (lakes, reservoirs, wetlands) and rivers whose width exceeds 100m (requirement)** (50m).
  - To measure the global change of storage in terrestrial surface water bodies and river discharge at **sub-monthly, seasonal, and annual time scales**.

- These measurements would enable the characterization of the temporal and global spatial variations in surface waters, thus allowing scientists to address the following hydrologic science issues:
  - Better understanding the roles of **storage and discharge in the terrestrial water cycle, globally.**
  - Understand the **dynamics of floodplains and wetlands**, which have important roles in the Earth's carbon budget.
  - Provide a **global assessment, available to all, of water resources**, including transboundary rivers, reservoir storage and dynamics, and flood monitoring, whenever floods would be observed by SWOT.

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