→ 8th COASTAL ALTIMETRY WORKSHOP

23–24 October 2014 | Lake Constance | Germany

Surface Water Ocean Topography (SWOT[1]) Capabilities for Coastal Oceanography

Philip S. Callahan, Ernesto Rodriguez,
Lee-Leung Fu, Parag Vaze

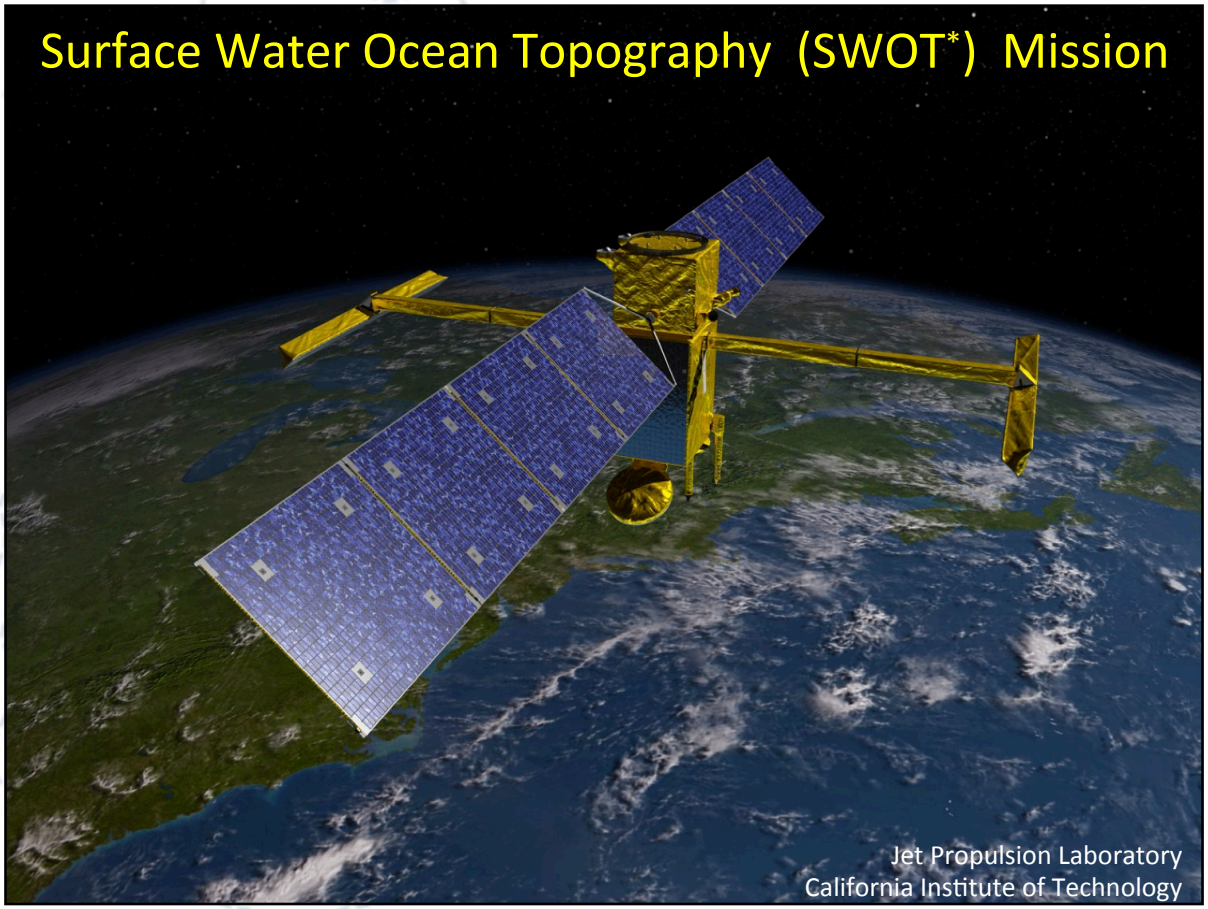
Jet Propulsion Laboratory,
California Institute of Technology

(1)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
- Mission Overview
- Instruments
  - KaRIn – Ka-band Radar Interferometer
  - Microwave Radiometer
  - Precision Orbit Determination systems
  - Nadir Altimeter
- Data Flow Architecture
- Data Products

- Status
  - Completed MDR May '14
  - Started Phase B June '14
  - PDR Planned Jan '16
  - Launch Planned Oct '20



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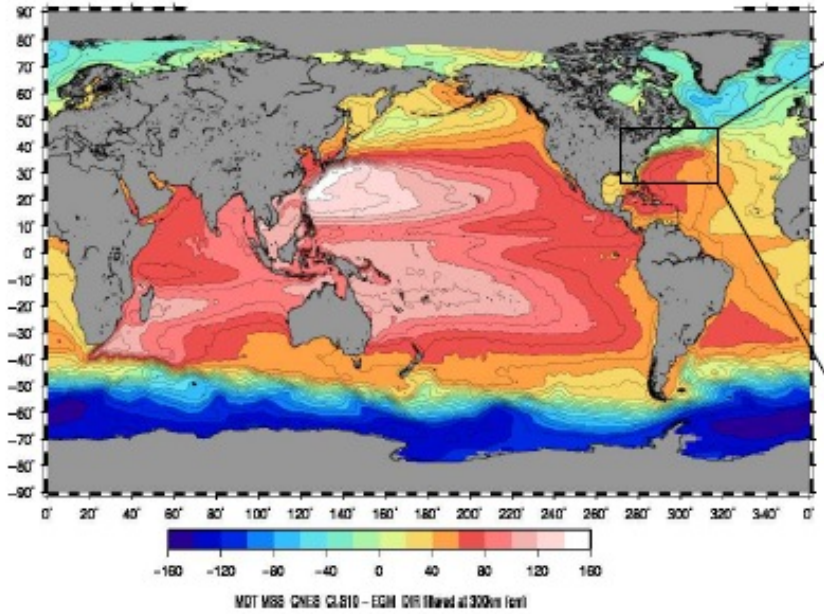
SWOT*

Jet Propulsion Laboratory California Institute of Technology

*Proposed Mission

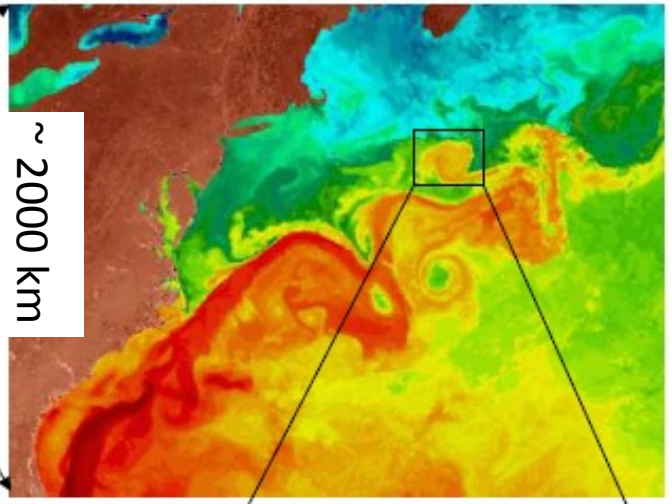
Targeting the Smallest Scales of Ocean Circulation

Global basin scale

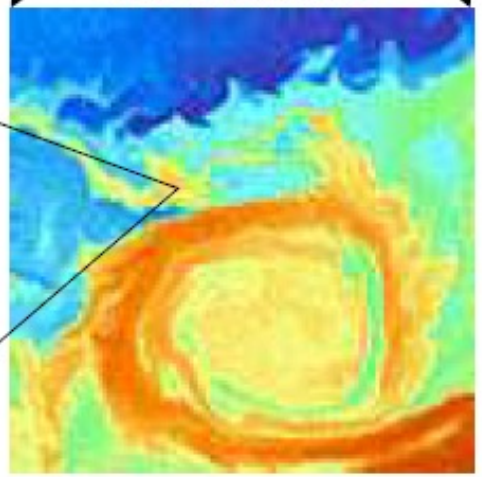


~ 2000 km

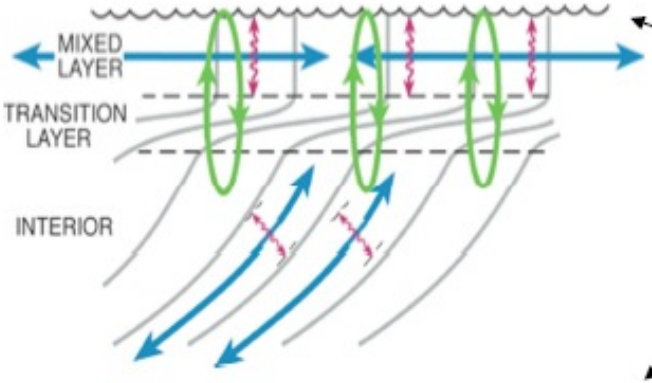
mesoscale



submesoscale

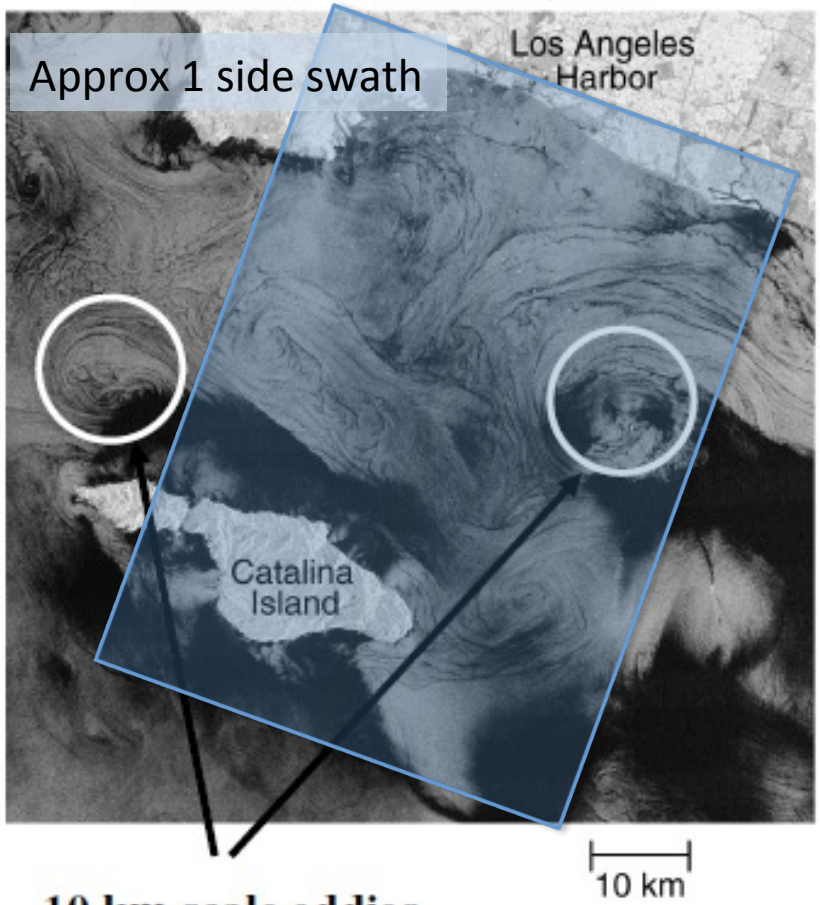


Vertical exchange of heat, CO_2, nutrients between the upper and deep ocean



Submesoscale Ocean Processes

RADARSAT - December 26, 1998



10 km scale eddies Resolvable by SWOT*

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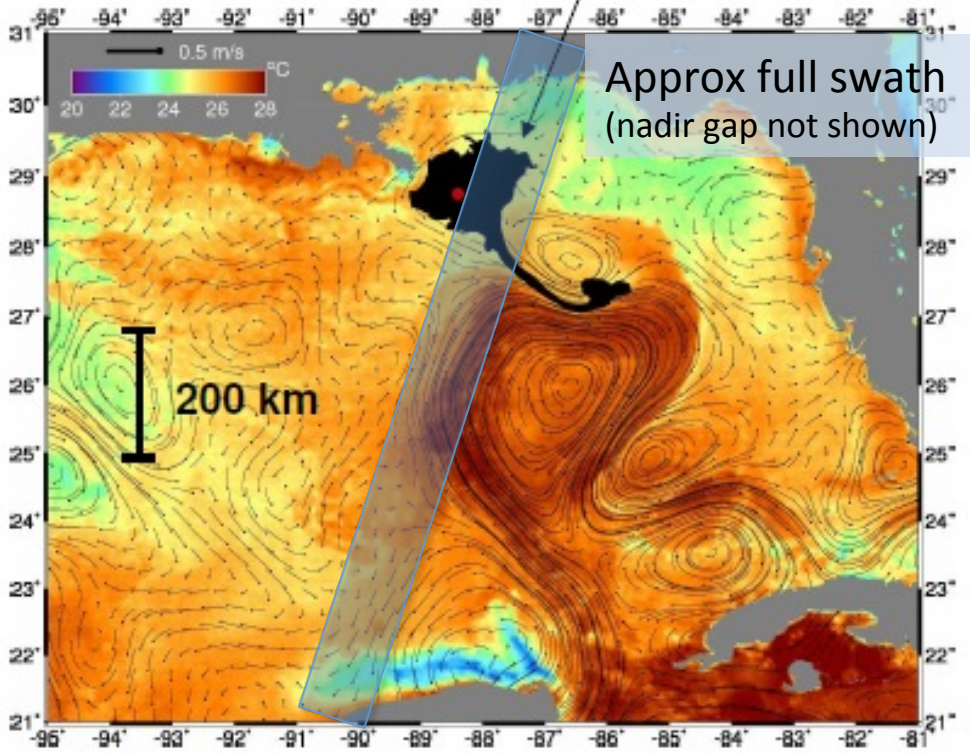
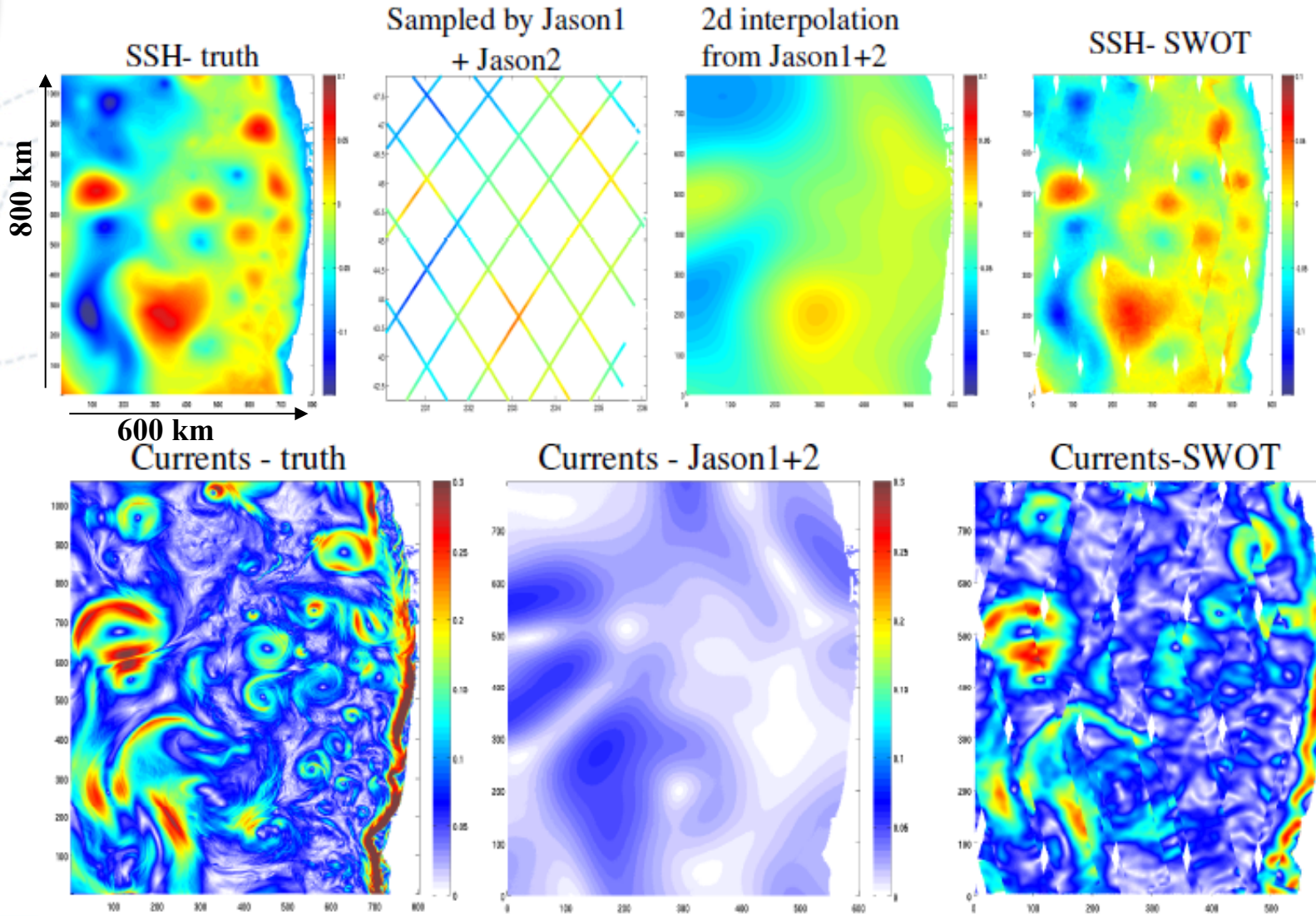
Deepwater Horizon oil spill



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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CSA, UKSA

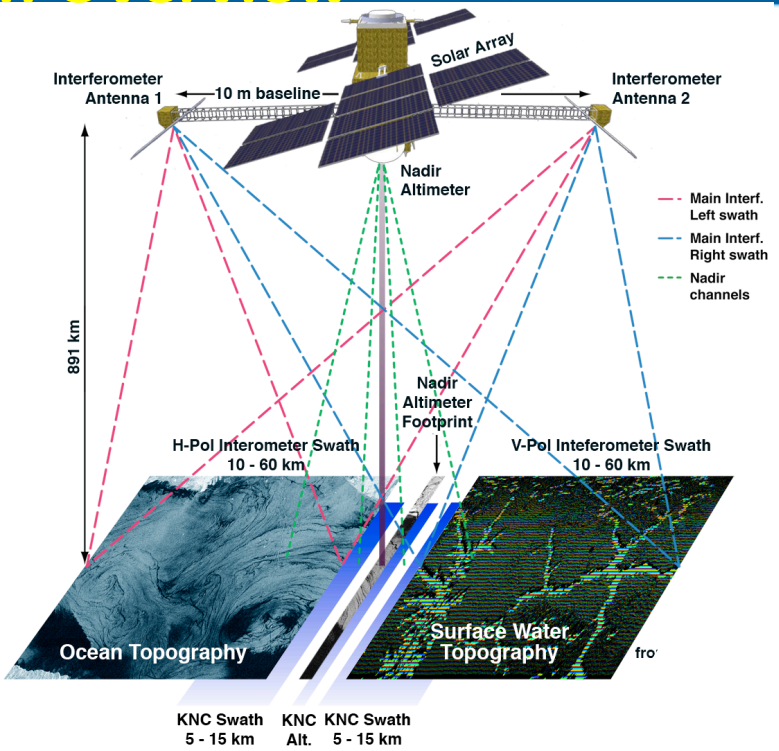
SWOT* Mission Overview

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 (10 – 60 km from nadir, ~1-4 deg)
- Produces heights and co-registered all-weather imagery
- On-Board interferometric SAR processing over the ocean (1 km^2 resolution) for data volume reduction.
- Use conventional Jason-class altimeter for nadir coverage, radiometer for wet-tropospheric delay, and DORIS/GPSP/LRA for Precision Orbit Determination.

- **Major partnership of NASA-CNES, with additional support from CSA and UKSA**
- 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: ~2000kg, ~1900W
- Launch Vehicle: NASA Medium class
- Planned Launch Readiness: Oct 2020
- Entered Phase B June 2014

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KaRIN* Measurement Characteristics

- Ka-band SAR interferometer (KaRIn) 10 m baseline with 2 swaths, 50 km each (10 – 60 km from nadir, ~1-4 deg incidence)
  - 200 MHz bandwidth (~75 cm range resolution). 4400 Hz PRF
    - Because of near-nadir geometry, ground range resolution varies from about 70 m near swath to 10 m far swath
- Downlink Data
  - Low Rate (LR, ~2.4 Mbps) data would be produced by Onboard Processor (OBP) all the time. Main use for ocean, large lakes. Planned resolution: 1 x 1 km. (Note that height error scales as pixel area.)
  - High Rate (HR, ~350 Mbps) data when turned on by mask (nadir point). Presum by ~2 to reduce data rate. Main use for surface water.
    - Coverage limited by available downlink data rate (620 Mbps), transmit and station time, ground links.
    - Full SAR processing on ground
  - Total daily downlink data volume (7.15 Tb/day).
- ~21 day orbit repeat would give nearly full swath coverage at equator
  - Required space-time coverage is 90%

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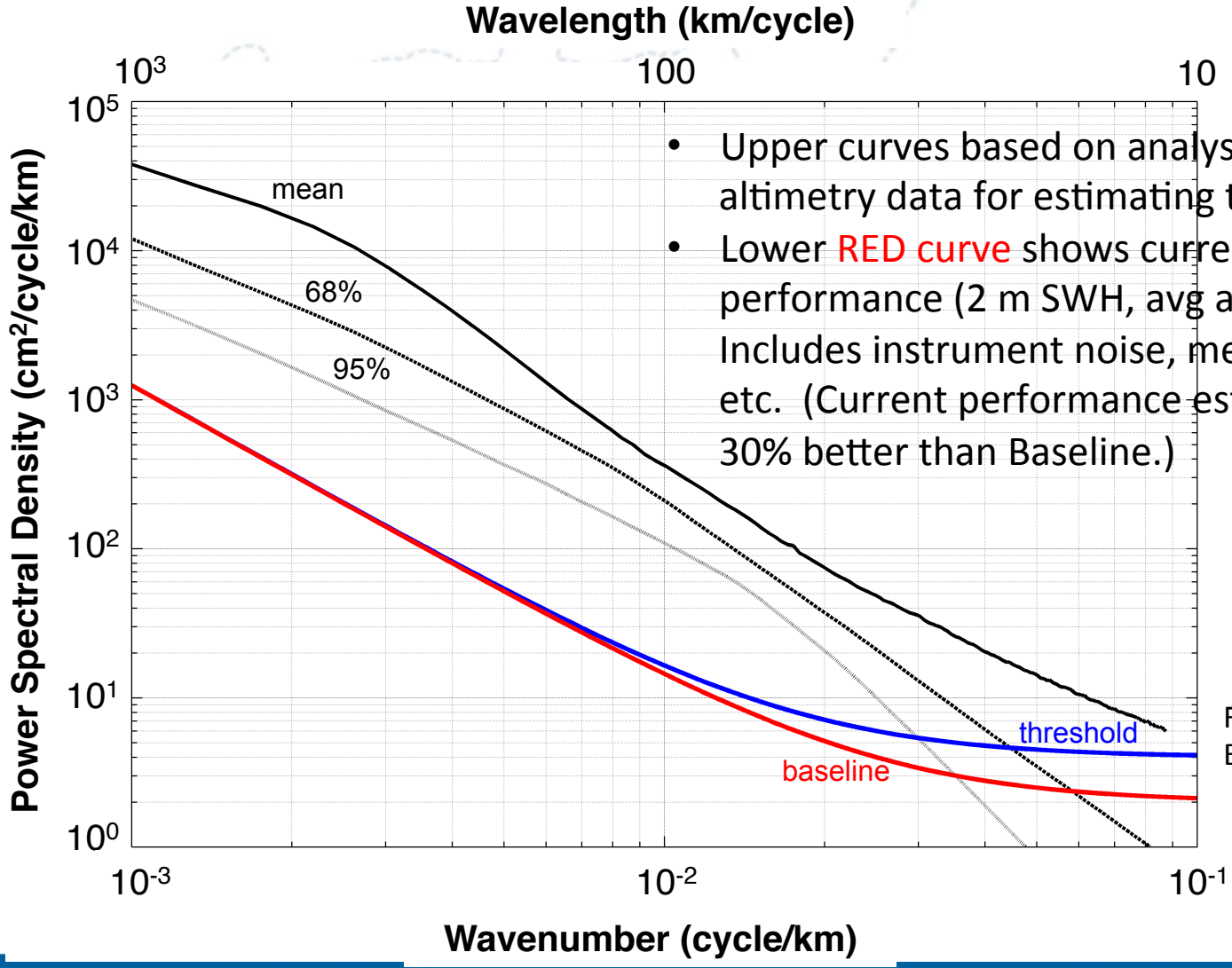
Ocean Performance

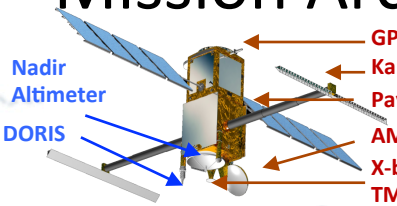


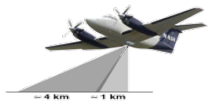
- Upper curves based on analysis of historical altimetry data for estimating the SSH signals.
- Lower RED curve shows current required system performance (2 m SWH, avg across swath). Includes instrument noise, media errors, orbit, etc. (Current performance estimate is about 30% better than Baseline.)

From SWOT System Engineering for MDR

Mission Architecture

NASA – KSC/LSP
Launch Vehicle
(TBD)





AirSWOT

CNES Elements
NASA Elements
Joint Elements

Science Downlink
800 Mb/s (X-band); ~ 20 passes/day
(Info rate: ~620 Mb/s; ~7 Tbits/day)

Uplink/Commanding, HK/Eng. Telemetry
64 Kbps U/L (S-band)
>600 Kbps D/L (S-band)
2 passes/day

*CNES ops

CNES S+X-band Network:
KRX, IVK AUX, HBX, KUX & KER (S-only)

S-band Cmd & Tlm

X-band Telemetry Files

To JPL POC:
S/C Telemetry (stored & RT), Payload R/T Engineering
To CNES SCC: Payload commands

S/C Control Center (SCC)

To SCC: S/C & P/L telemetry
To NOC: Commands
To CNES SCC: Payload Commands
To CNES POC: S/C Telemetry

CNES Network Ops Center (NOC/COR)

CNES
File Exchange Server
(in CNES Science Data Processing Center)

X-Band Telemetry Files
X-Band Telemetry Files

JPL Payload Operations Center

CNES Payload Operations Center

AirSWOT, Instrumented Cal/Val Ground Sites

JPL Science Data Processing Center

Altimeter, KaRIn (Eurasia), POD & Cal/Val data
KaRIn (non-Eurasia,Ocean), Cal/Val data

CNES Science Data Processing Center

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

JPL Science Data Archiving and Distribution PO. DAAC

CNES Science Data Archiving and Distribution

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SWOT* Science Data Products

	Data Product	Description
KaRIn	**L0B KaRIN**	Cleaned telemetry separated by KaRIN – Low Rate (LR) / High Rate (HR)), pass
KaRIn LR – Ocean (JPL process)	**L1B**	Earth located onboard ocean interferogram with corrections
	L2	Sea Surface Height in fixed, geographically located swath grid (1 km) with errors, slope, sigma0, geophysical corrections and fields
KaRIn HR – Hydrology (JPL process non-Eurasia; CNES process Eurasia)	**L1A**	Single Look Complex images for each swath separated by pass, continent
	L1B	Phase flattened interferograms
	L2	Geolocated water mask with elevations, slopes, uncertainties, flags, corrections, metadata separated by pass, continent. Water body polygons in vector format with average water elevation for each cycle. Quality assessment.
	L2 Enhanced	Reach-averaged river discharge, error estimate as a vector product (pass-by-pass). Cross-section map updated yearly. Final discharge data at EOM with bathymetry, roughness estimates. Goal: Floodplain DEM.
Radiometer (JPL, CNES process)	**L0B Rad**	Cleaned instrument telemetry
	L1B Rad	Radiometer brightness temperatures
Nadir Altimeter (CNES process)	**L0B Nadir Alt**	Cleaned Nadir Altimeter telemetry by pass.
	L2B Nadir Alt	Jason-like SGDR (Geophysical Data Record with waveforms (L1B))
DORIS, GPS, LRA (CNES process)	**POE**	Precision Orbit Ephemeris from DORIS and GPS-P

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SWOT* Ocean Data Products

- Ocean data (Low Resolution, LR) would be produced by an Onboard Processor (OBP). 2 swaths 10 – 60 km from nadir.
  - Requires ~1 m range accuracy based on onboard tables and ephemeris from DORIS, so mixed ocean/land, large coastal tide pixels may have problems
  - Planned resolution: 1 x 1 km. Needs more complete science justification (Requirement is 2 km. Note that height error scales as pixel area.)
- OBP provides 9 squinted interferograms. Ground processing:
  - Apply corrections, convert to height and location, resample and combine into final product
  - Can exclude land contaminated interferogram beams from product
- Planned Ocean data product would be passes of Earth-fixed, swath-aligned 1 km grid with sea surface height, slope, sigma0, error information, geophysical corrections (tropo, etc.) and fields (tides, MSS, etc.). Goal to provide wind speed, SWH.

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SWOT* High Resolution Data for Coastal Altimetry

- High Rate (HR) data would be turned on by mask when nadir point touches land – coastal ocean coverage depends on orbit/land/water configuration
  - Nominal HR coverage would be 22.4% of orbit cycle (Includes 3 km buffer around land. Partial coverage of Australia, islands, Greenland; no Antarctica.)
  - Data acquisition mask is uploadable. Plan to reload seasonally
  - Global 5 km extension of mask adds ~1% of total data
  - Total HR data limited by committed downlink data volume (7.15 Tb/day)
- Planned HR data product would be ~140 km tiles with pixel cloud of points that can be geolocated adequately (~0.1 pixel size) with height, sigma0, area, orientation, geophysical corrections and fields
  - Extract vector products from pixel cloud
- HR data over ocean could be processed to resolution >~ 70 m for super-fine resolution, but with noise ~area (noise at 1 km slightly higher than LR because of presum).
  - A localized coastal product containing both LR and HR data could be defined

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SWOT* Additional Considerations

- During the first 6 months of the mission, the orbit will be a 1-day repeat to allow fast sampling of phenomena. Much of this time will be devoted to check out and calibration, but science objectives will also be supported.
- Probably need improved models
  - Cross-track and land (model only) wet troposphere is a significant error source
  - Coastal and Internal tide models. Putting together open ocean and local tide models may be a big job
  - High resolution Mean Sea Surface, Geoid
- Tradeoffs of "synergistic science" (ice, geodesy, etc.) options will be worked during Phase B and early Phase C (~Jan '17) of mission
- Comments on basic Ocean Product or additional products should be conveyed to Science Definition Team and Algorithm Development Team

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BACKUP

Orbit Characteristics

- Global coverage and more frequent sampling dictates a compromise in orbit **repeat period of ~21 days**
- **Inclination between 74 and 80 degrees** to achieve non sun-synchronous orbit to minimize tidal aliasing and to ensure coverage of major water bodies on land.
- **1 day repeat period during the initial cal/val phase** for fast sampling to achieve the cal/val objectives and study rapidly changing phenomena.