Jet Propulsion
Laboratory
California Institute
of Technology

AltiKa Cal/Val Activities at the Jet Propulsion Laboratory

2013 SARAL/AltiKa Verification Workshop

Phil Callahan, Shailen Desai, Lee Fu, Bruce Haines,
Dimitris Menemenlis, Victor Zlotnicki

Jet Propulsion Laboratory,
California Institute of Technology

August 2013

Outline / Overview

- Overview of Planned JPL AltiKa Activities
- Orbit Improvement Approach and Results
- Retracking Approach
- Jason-2/SARAL Crossover Results
- SWOT Mission Concept

Objectives of JPL AltiKa Data Use

- Cal/Val of AltiKa data including improvement of orbits through crossover analysis and retracking to validate instrument corrections

- Assimilation of AltiKa data into eddy-resolving global ocean and sea ice model in support of ocean circulation and tracer transport studies
  - Improve modeling from additional coverage
  - Need to insure data are consistent with other/previous altimeters

- Pre-mission Studies for SWOT
  - Sigma0 of surface types
  - Rain effects
  - Sea State Bias
  - Fine scale ocean features

Jet Propulsion
Laboratory
California Institute
of Technology

Improving SARAL Near-Real-Time Orbit Accuracy Using Inter-satellite Crossovers with Jason-2

- Approach follows heritage of value-added Jason-1 and ENVISAT NRT SSHA products.
  - Acknowledgement: CNES for providing DIODE orbits.
- High-accuracy, short latency SSHA available from Jason-2 (GPS-OGDR-SSHA)
  - Combines Jason-2 OGDR with NRT GPS-based orbit solutions with ~1 cm (RMS) radial accuracy (Desai and Haines, 2010).
- Generate value-added crossover-based SARAL OGDR-SSHA product.
  - Improve orbit altitude accuracy in NRT using inter-satellite SARAL/Jason-2 SSHA crossovers.
    - High accuracy force models and 1 cycle per revolution filter.
  - Orbit altitude accuracy < 2 cm (RMS).
  - Latency of 5-9 hours.

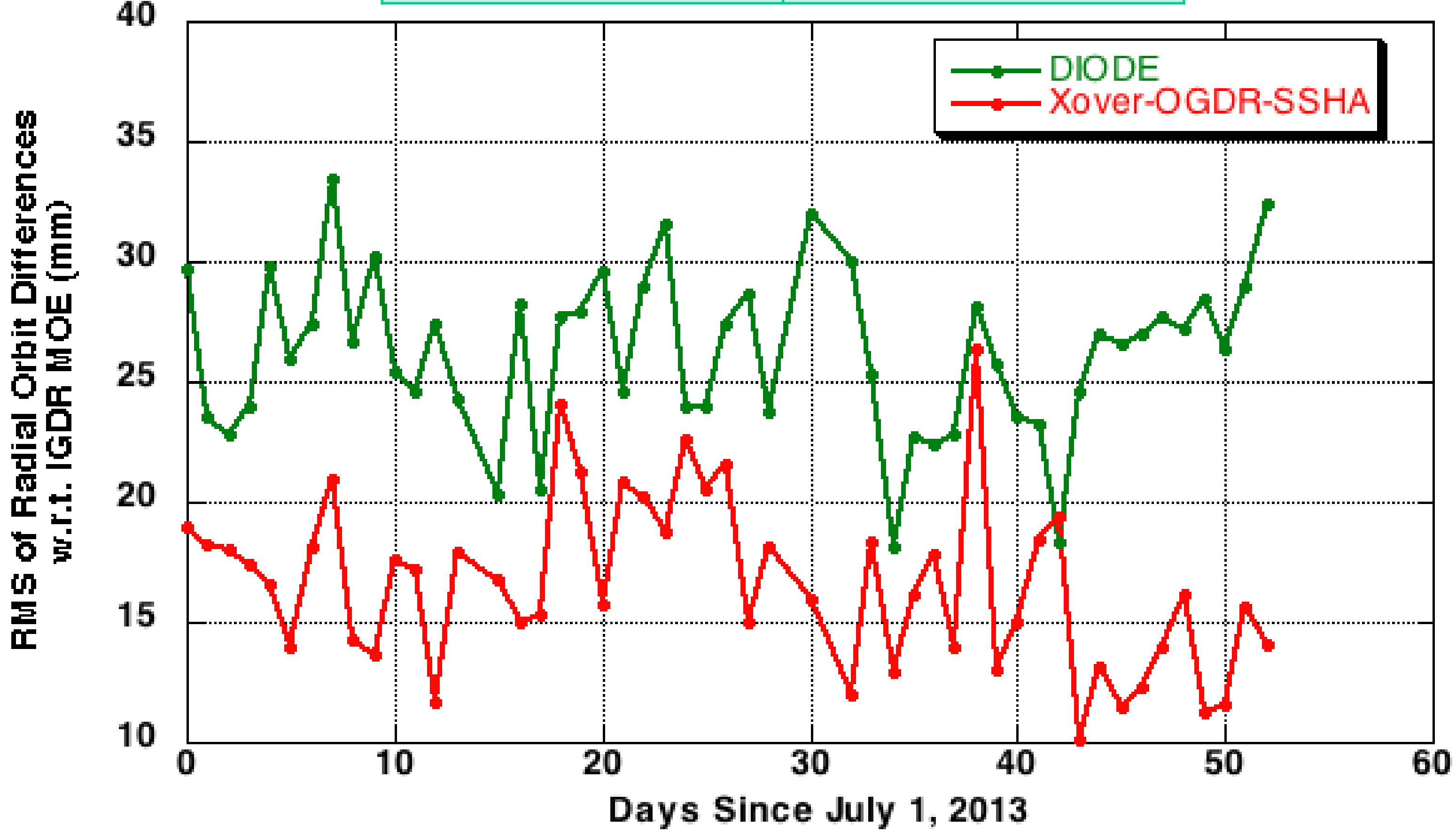
- **Implicitly levels SARAL SSHA measurements to those from Jason-2/OSTM enabling seamless combination of NRT SSH measurements from two missions.**
- **Could routinely release value-added SARAL OGDR-SSHA with crossover-based orbits**

Jet Propulsion Laboratory
California Institute of Technology

Orbit Altitude Differences Relative to IGDR DORIS Medium-Accuracy Orbit Ephemeris

Median of Daily RMS of Orbit Differences

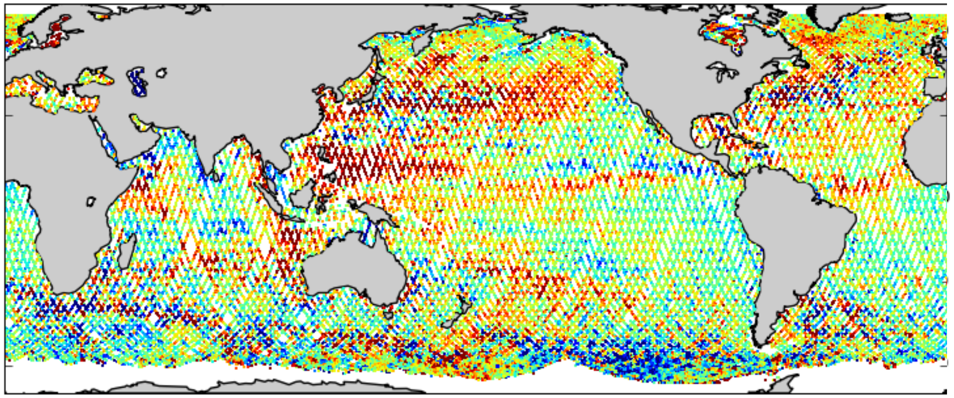
OGDR DORIS DIODE	XOVER-OGDR-SSHA
26.6 mm	16.7 mm



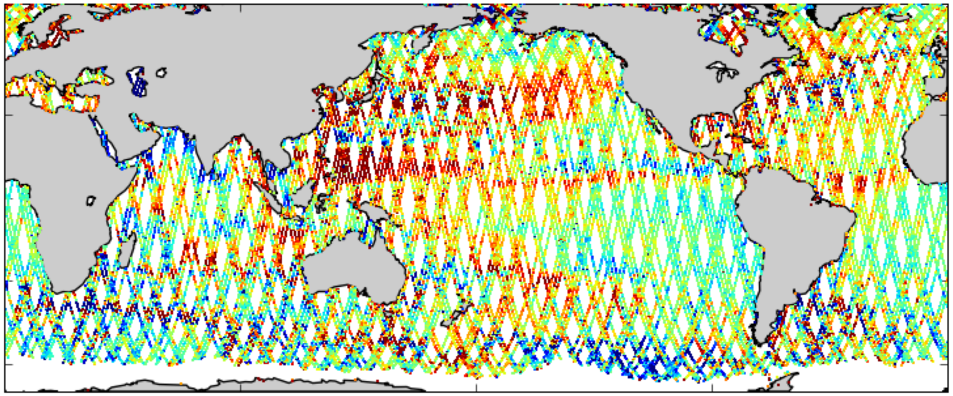
Jet Propulsion Laboratory
California Institute of Technology

10-day Snapshot (Aug 16-25) of NRT SSHA from: Jason-2 GPS-OGDR-SSHA and SARAL XOVER-OGDR-SSHA

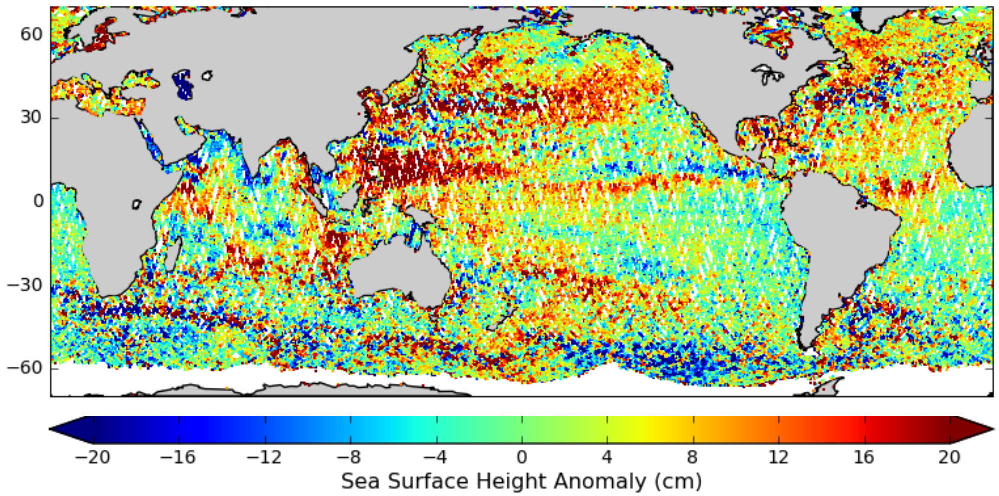
Jason-2 GPS-OGDR-SSHA



SARAL XOVER-OGDR-SSHA



Combined: Jason-2 + SARAL NRT SSHA



- Aug 16-25
- < 9 hour latency
- Each pixel is 1-Hz SSHA data directly from products
- **No Smoothing**

Retracking Approach

- Use JPL retracking software previously used on TOPEX and Jason (Rodriguez and Martin, JGR 94; Callahan and Rodriguez, MG 04):
  - Decomposition of the PTR into sum of Gaussians
  - Arbitrary attitude angle (expansion to higher order terms)
  - Linearized least squares estimation (LSE) and Maximum *a Posteriori* (MAP), including Skewness
  - Added iterative estimation of parameters until retracker fully converged

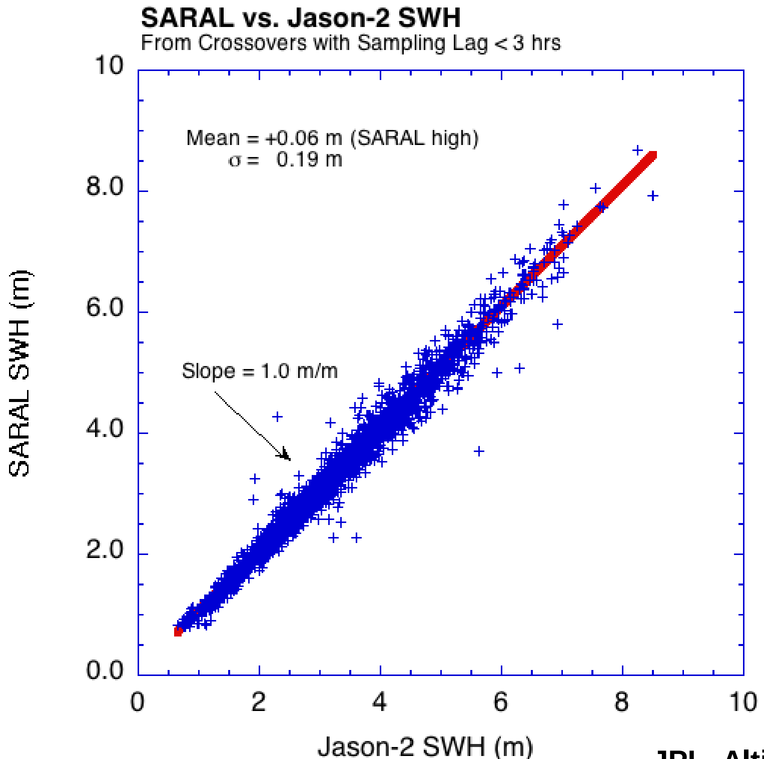
  ➔ 10/frame range, 1/frame other parameters

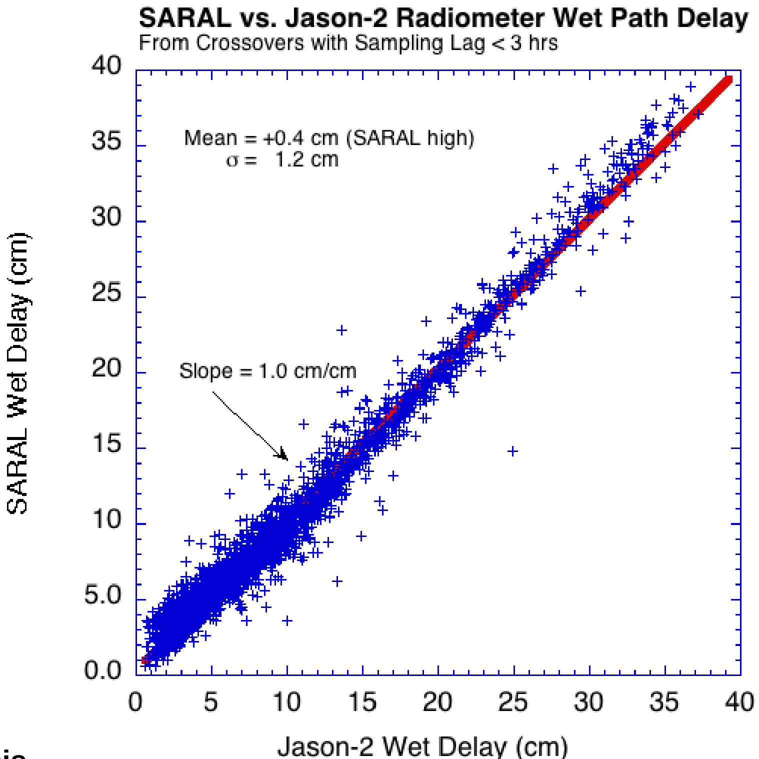
- Initially, convert to Jason-like data: Avg to 20 Hz or select subset; select main 104 WF samples 12-116
- Need Filter Weights, PTR (assume sinc^2)

Jet Propulsion Laboratory
California Institute of Technology

Jason-2/SARAL Crossover Results

- JPL "stack file" of data from all altimeter missions allows rapid comparison among missions
- Found all Jason-2/AltiKa crossovers within 3 hr for cycles 2, 3
- Compared swh, wet, sigma0, difference ssha vs swh (~ssb)
  - Good agreement for swh; reasonable agreement for wet (1-2 cm differences at low and high values)
  - Sigma0 and ssb need further investigation (see next page)

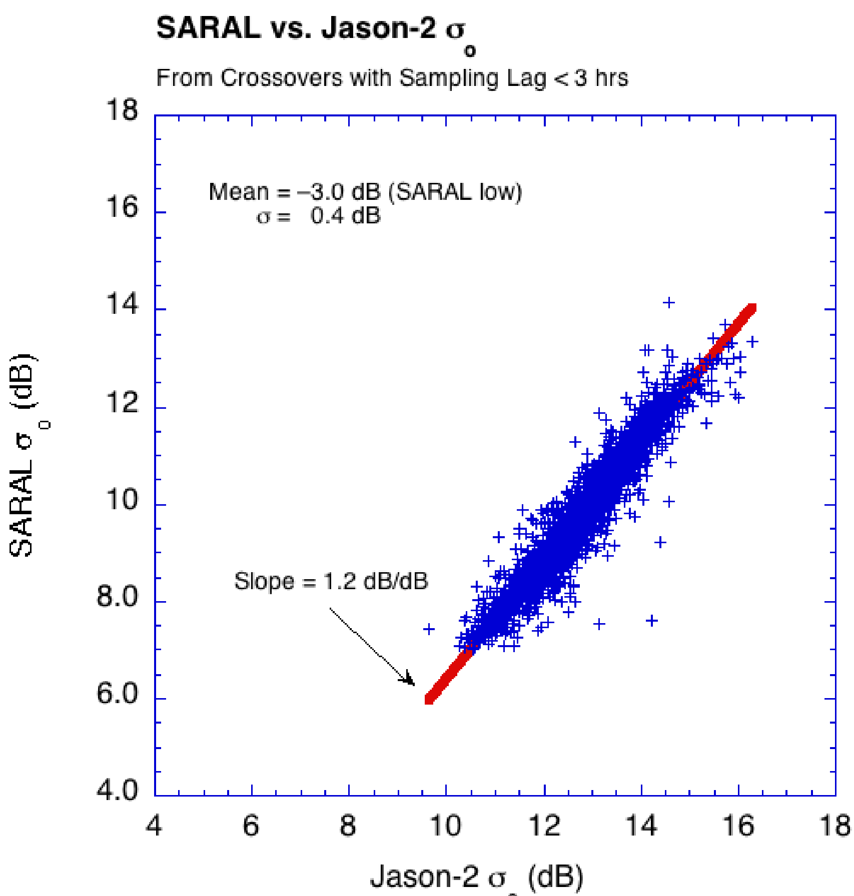


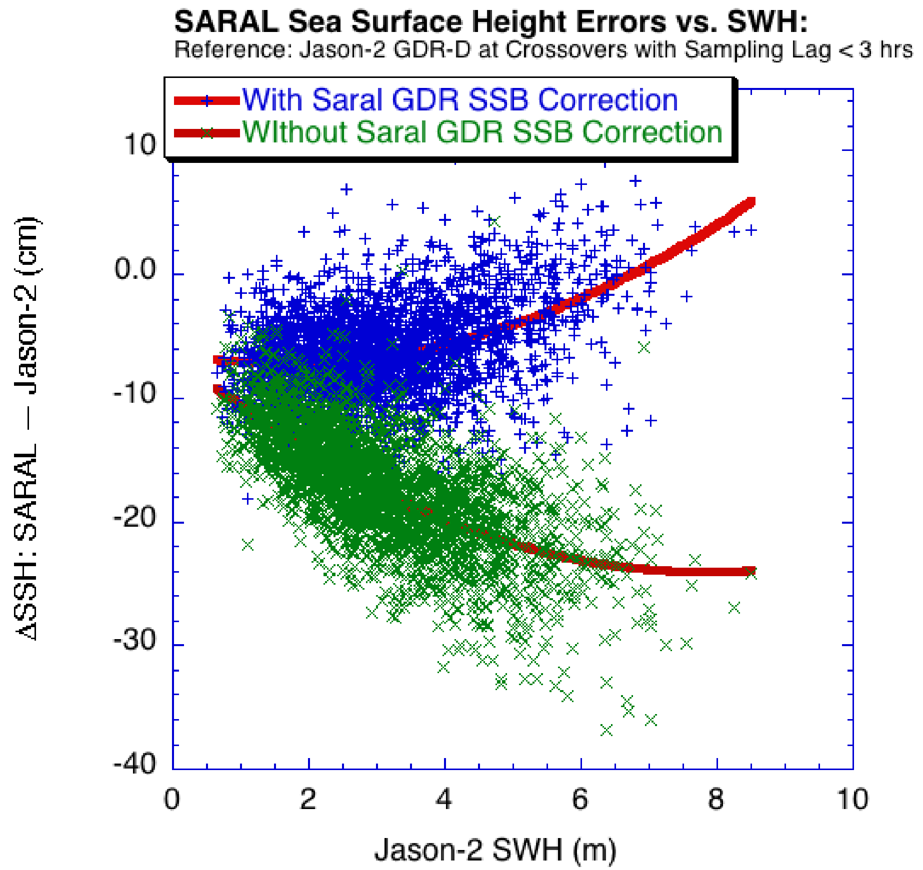


Jet Propulsion Laboratory
California Institute of Technology

Jason-2/SARAL Crossover Results: Sigma0, SSHA vs SWH

- AltiKa Sigma0 lower than expected? [Left]
- SSHA vs SWH [Right] gives indication of Sea State Bias: CNES orbits; J2 SSB applied; AltiKa with (blue) and without (green) (Red line is quadratic fit). A simple linear model for green is 2.5-3.0% SWH





Jet Propulsion Laboratory
California Institute of Technology

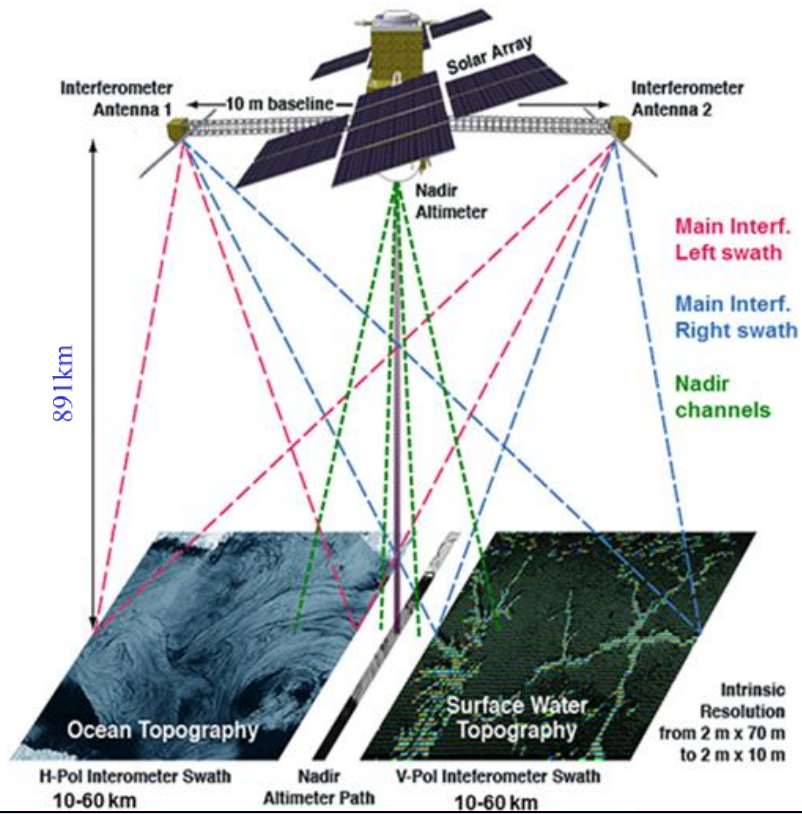
SWOT Mission Concept

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 POD.
- On-board data compression over the ocean (1 km^2 resolution).

- 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: ~1700kg, ~1900W
- Launch Vehicle: NASA Medium class
- Cat 2 Project, Risk Class: C
- Target Launch Readiness: Oct 2020

Summary

- JPL AltiKa activities include, Cal/Val, ocean data assimilation, and pre-mission studies for SWOT.
- Crossovers with Jason-2 can be used to reduce OGDR orbit errors from 27 to 17 mm rms relative to DORIS IGDR with a latency of 5-9 hours.
  - These orbits can be used to make OGDR-SSHA routinely available to project.
- Retracking software previously used for TOPEX and Jason is being applied to AltiKa.
- JPL stack files allow rapid comparison with parameters (e.g., sea level, significant wave height, wet delay, and sigma0) from other altimetry missions (e.g., Jason-2).
- AltiKa SSB appears to be about 2.5% SWH

Backup Material

Retracking Algorithms

Maximum Likelihood Estimator (MLE) Minimizes:

$$-\log(p(x\,|\,a)) \propto \sum_{i=1}^{Ndata} \frac{(x_i - M(a))^2}{\sigma_i^2}$$

Maximum a Posteriori (MAP) Minimizes:

$$-\log(p(x\,|\,a)\,p(a)) \propto \sum_{i=1}^{Ndata} \frac{(x_i - M(a))^2}{\sigma_i^2} + \sum_{n=1}^{Nparams} \frac{(a_n - A_n)^2}{\Sigma_n^2}$$

Where *x* is the data, *a* are the parameters to be estimated, *A* are the parameter a priori values, σ_i are the measurement errors and Σ_n measures the prior confidence level.

Setting the priors and their confidence levels is the trick!

Prior Values: smooth LSE SWH and attitude data over an extent < 80 km relative to center.

Prior Uncertainties: Root Squares Sum residual values in smoothing window with conservative estimate of minimum uncertainty of SWH and attitude variance. Use 1.5 as uncertainty on the skewness, and infinite variances (no priors) on the other parameters, including height.