National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

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SWOT Science Team Meeting

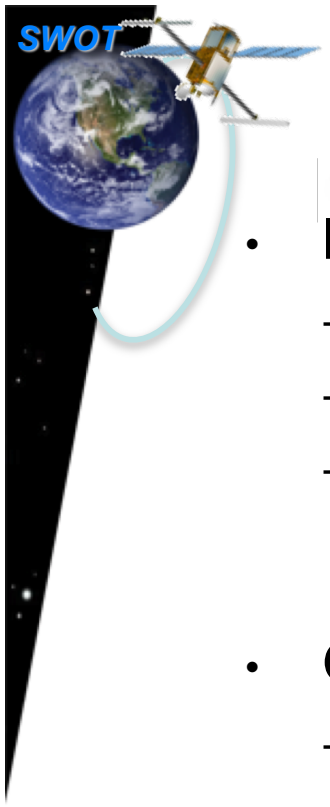
SWOT Short Latency Science Data Products

Status and expected performance

Nicolas Picot
Centre National d'Etudes Spatiales
Shailen Desai
Jet Propulsion Laboratory, California Institute of Technology

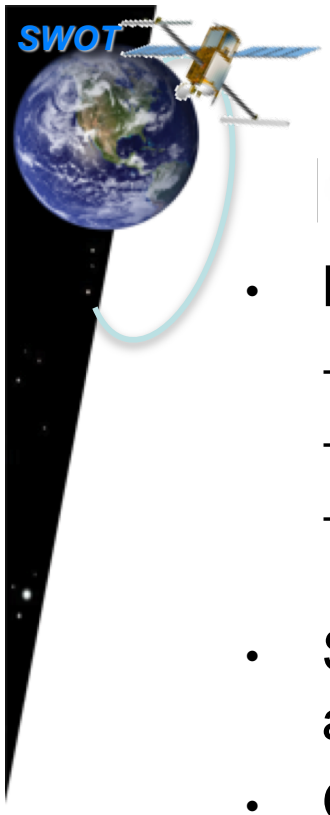
Outline

- Nadir Altimeter Products
- Motivation for Short Latency KaRIn Products
- Performance of Short Latency KaRIn Products
- Revised project plan for SWOT KaRIn Products
- Conclusion



SWOT Nadir Altimeter Products

- Nadir Altimeter Products have strong heritage from Jason-series.
  - Same science data system inherited from Jason-series.
  - Same NetCDF format
  - Expect similar performance as Jason-series.
    - Slightly degraded due to lack of nadir radiometer, and MSS errors in new ground track.
- Generated at three latencies, similar to Jason-series.
  - OGDR: Operational Geophysical Data Record
    - Latency of 3-5 hours.
    - Best efforts resolution of anomalies.
    - **New addition to plan.**
  - IGDR: Interim Geophysical Data Record
    - Latency of < 2 days.
  - GDR: Geophysical Data Record
    - Latency of 45 days.
- **Proven science data system, performance, and reliability at the three latencies.**
  - Over 10 years of experience.



SWOT KaRIn Science Data Products

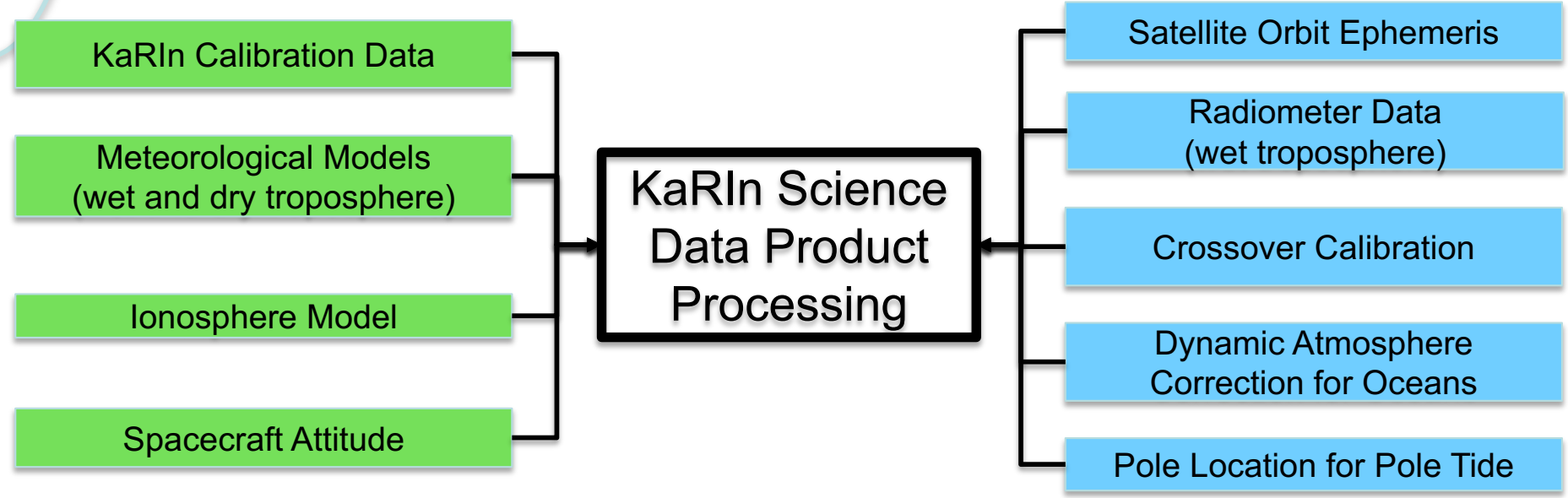
- Baseline approach:
  - Generate KaRIn science data products with a latency of 45 days.
  - One global reprocessing campaign ~ 8 months after launch.
  - One end-of-mission reprocessing of Level 2 hydrology products at end-of-mission.
- Strong interest in shorter latency KaRIn products primarily for applications community.
- Over last year:
  - Evaluated potential impact to science algorithms and processing approach.
  - Evaluated expected performance at shorter latencies.
  - Evaluated plan for generating routine (forward processing) science data products and reprocessed science data products.

Strong Interest in Short Latency Products

- SWOT Applications Working Group has three key recommendations:
  - i) SWOT data availability at a **latency of less than two days has overwhelming demand and critical societal need** wherein a compromise between accuracy and latency appears widely acceptable.
  - ii) While the availability of **short latency SWOT data will spur the most innovative societal applications** and significantly improve many current operational applications, **long latency data will remain valuable for retrospective (post-event) analysis**, large-scale basin or ecological management and policy formulation.
  - iii) SWOT mission needs to engage with application community now to provide education and training on data, uncertainty, access for various levels of expertise among users (layman, beginners and advanced) and in multiple languages and format (in person, online, multi-media tutorials)

Extracted from : '**Engaging the User Community for Advancing Societal Applications of the Surface Water Ocean Topography (SWOT) mission', submitted in** *Bulletin of American Meteorological Society*.

Technical Feasibility of Short Latency Products



- **Same KaRIn science data product processing algorithms can be used to generate products with latency of < 3 days.**
  - KaRIn instrument processing algorithms are identical.
    - **Deficiencies in KaRIn algorithms impact products regardless of latency.**
  - Some input dynamic (changes in time) auxiliary/ancillary data to processing is necessarily different.
    - Impacts accuracy of products.
  - Other input auxiliary/ancillary data is static (not changing in time).
    - Tides, hydrology databases, water mask, etc.

Auxiliary Data Impacting Product Generation and Performance

Auxiliary Data	Impacted Parameter	< 3 days	45 Days
Satellite Orbit Ephemeris	Satellite altitude, Doppler correction, … (Ocean and hydrology products)	**Medium Accuracy Orbit Ephemeris** (MOE)	**Precise Orbit Ephemeris** (POE)
Crossover Calibration	Crossover correction for hydrology products (value-added for ocean products)	**Preliminary** Based Upon Prior Crossovers Only	**Precise** Based Upon Surrounding Crossovers
Radiometer Calibration	Wet troposphere correction, Sigma0 attenuation (ocean products))	**Best Available From < 45 days Prior**	**Calibrated**
Dynamic Atmosphere Corection	High Frequency ocean response to pressure and wind (ocean products)	**Preliminary**	**Precise**
Pole Location	Pole tide height (ocean and hydrology)	**Predicted** Updated twice a week, contains 30 days prediction	**Restituted**

- **Same product suite can be generated at latencies of < 3 days.**
  - Use alternative preliminary or predicted auxiliary inputs that are available within 2-3 days.
  - Requirements for hydrology ice flag can be met with climatology.
    - Improvements possible using routine optical data.
- Other dynamic auxiliary inputs are available within 2-3 days, e.g.,
  - Meteorological models for wet and dry troposphere
  - Ionosphere model
  - KaRIn Calibration data
  - Spacecraft attitude

Performance Drivers for Short Latency Products

- Ocean performance:
  - Primarily impact by:
    - Satellite orbit ephemeris
    - Radiometer calibration
  - Small impact from:
    - Pole tide model
    - Higher frequency ocean response to atmosphere.
  - Additional impact : Value-added crossover calibration
    - Not required to meet spectral performance.

- Hydrology performance:
  - Primarily impacted by:
    - Satellite orbit ephemeris
    - Required crossover calibration
  - Small impact from:
    - Pole tide model

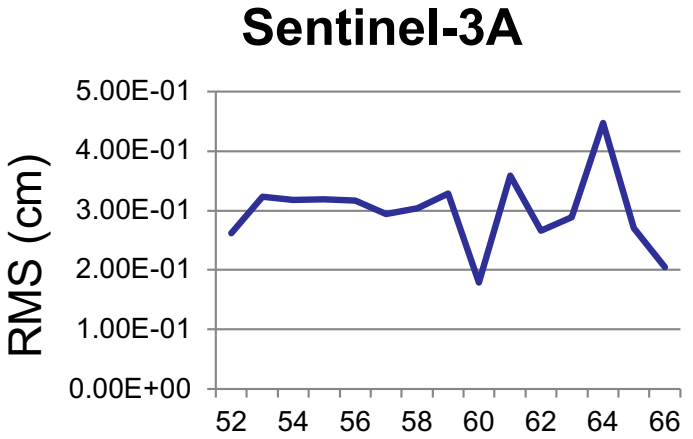
Performance Impact of Satellite Orbit Ephemeris MOE vs. POE

- Recent analysis on Jason-2, Jason-3 and Sentinel-3A missions have demonstrated that performance of MOE and POE are quite similar when using the same tracking data (DORIS + GPS).
  - SWOT MOE and POE will both use DORIS+GPS tracking data.
- POE performance is slightly better due to higher accuracy inputs for processing (e.g., GPS satellite orbits/clocks, Earth rotation parameters, Atmospheric drag, ..).

RMS of radial differences between MOE and POE of the order 3-5 mm

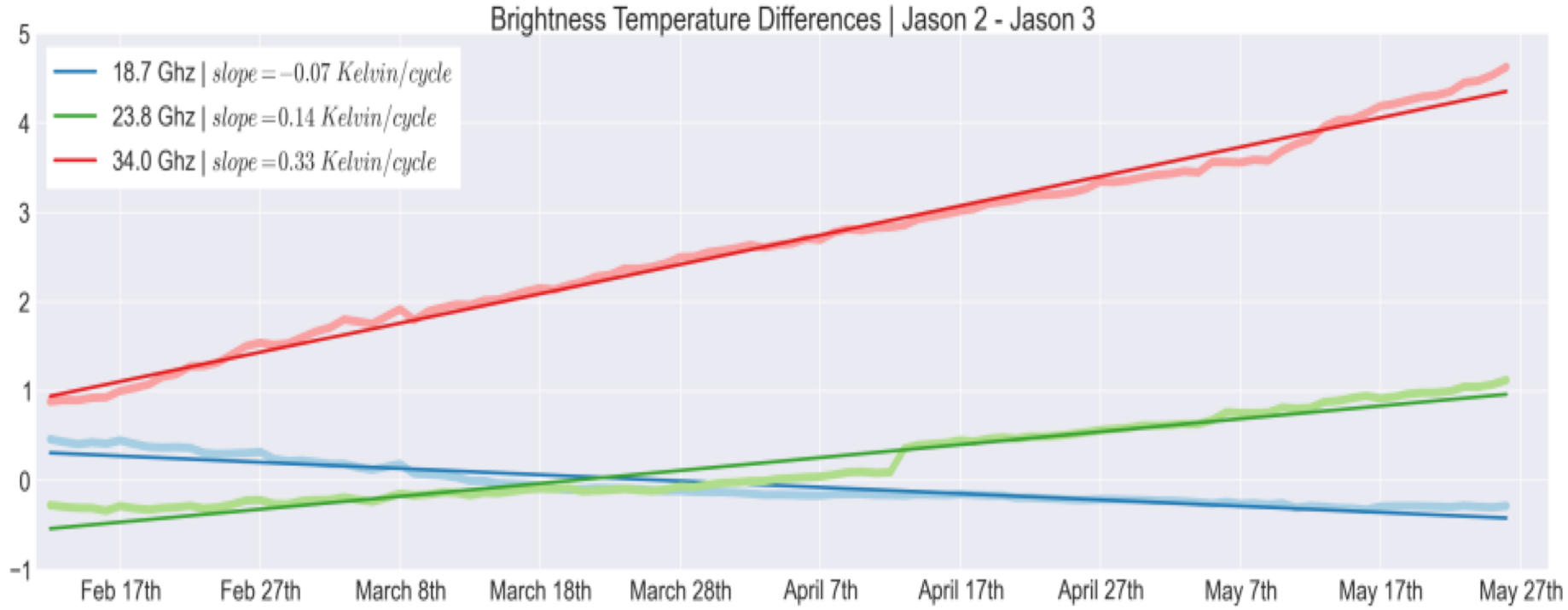
JASON-2 Repeat Cycle	MOE DORIS RMS (MM)	MOE DORIS+GPS RMS (MM)
504	7.1	3.1
505	6.3	3.4
506	6.1	4.3

JASON-3 Repeat Cycle	MOE DORIS RMS (MM)	MOE DORIS+GPS RMS (MM)
056	7.2	3.1
057	7.0	3.1
058	6.9	6.2



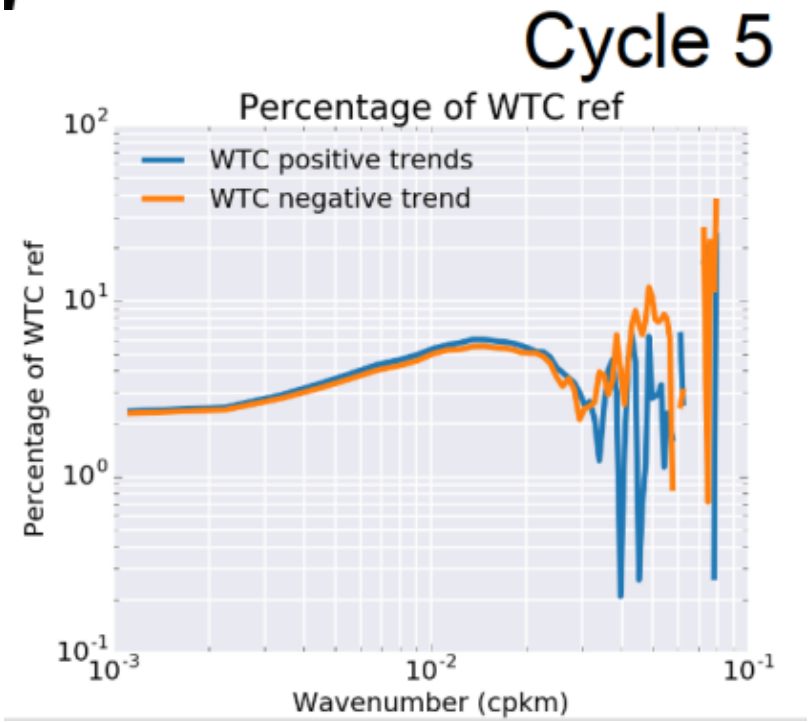
Performance Impact of Radiometer Calibration (1/2)
Calibrated vs. 45-day old Calibration

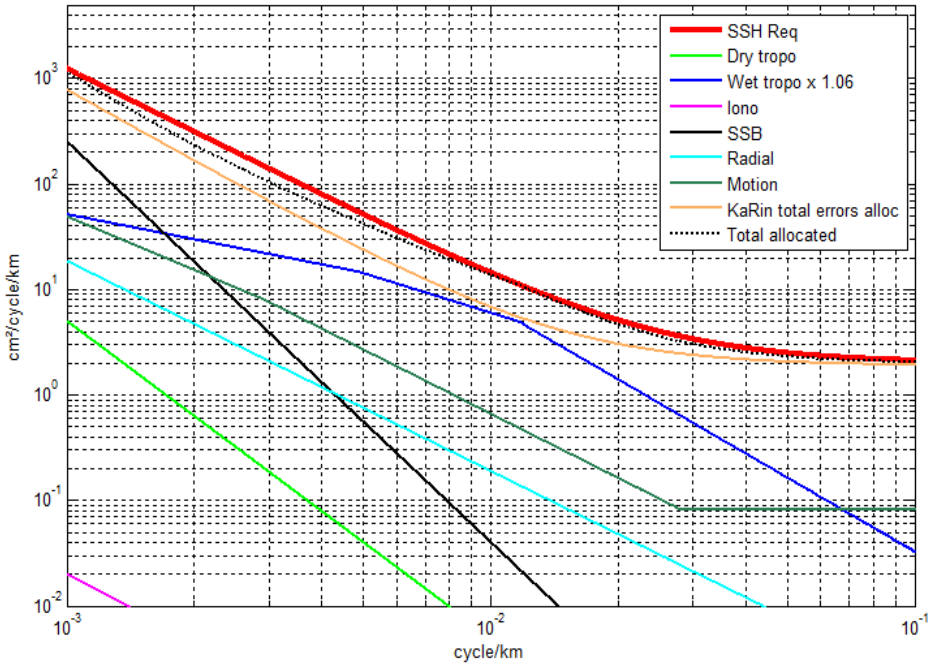
- SWOT carries similar radiometers as on Jason-3.
- Jason-3 radiometer exhibits strong drift.
- Observed drift from Jason-3 during first 10 repeat cycles (100 days) used to evaluate impact of 45-day old radiometer calibration.



Performance Impact of Radiometer Calibration (2/2)
Calibrated vs. 45-day old Calibration

- Assume:
  - Observed drift from Jason-3 radiometer.
  - Opposite sign of drift for each of two SWOT radiometers (i.e., each swath).
  - No calibration available for 45 days.
- **Impact of the order of 6%** of the wet troposphere variance.
- **No observable impact on the WET spectum allocation**.





Performance Impact of Cross Over Calibration (1/4)
Near-Real-Time (NRT) vs. Post-Processed (DT)

SWATH B
T0 - 4 days

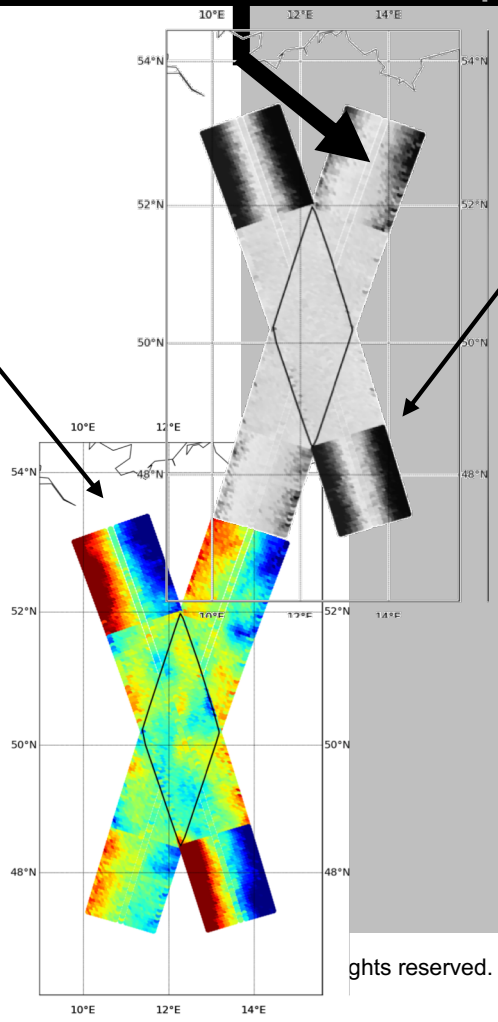
SWATH A
T0

SWATH C
T0 + 6 days

TIME

PAST

FUTURE



XOVER AVAILABLE NOW (can be used as a constraint for NRT propagation)

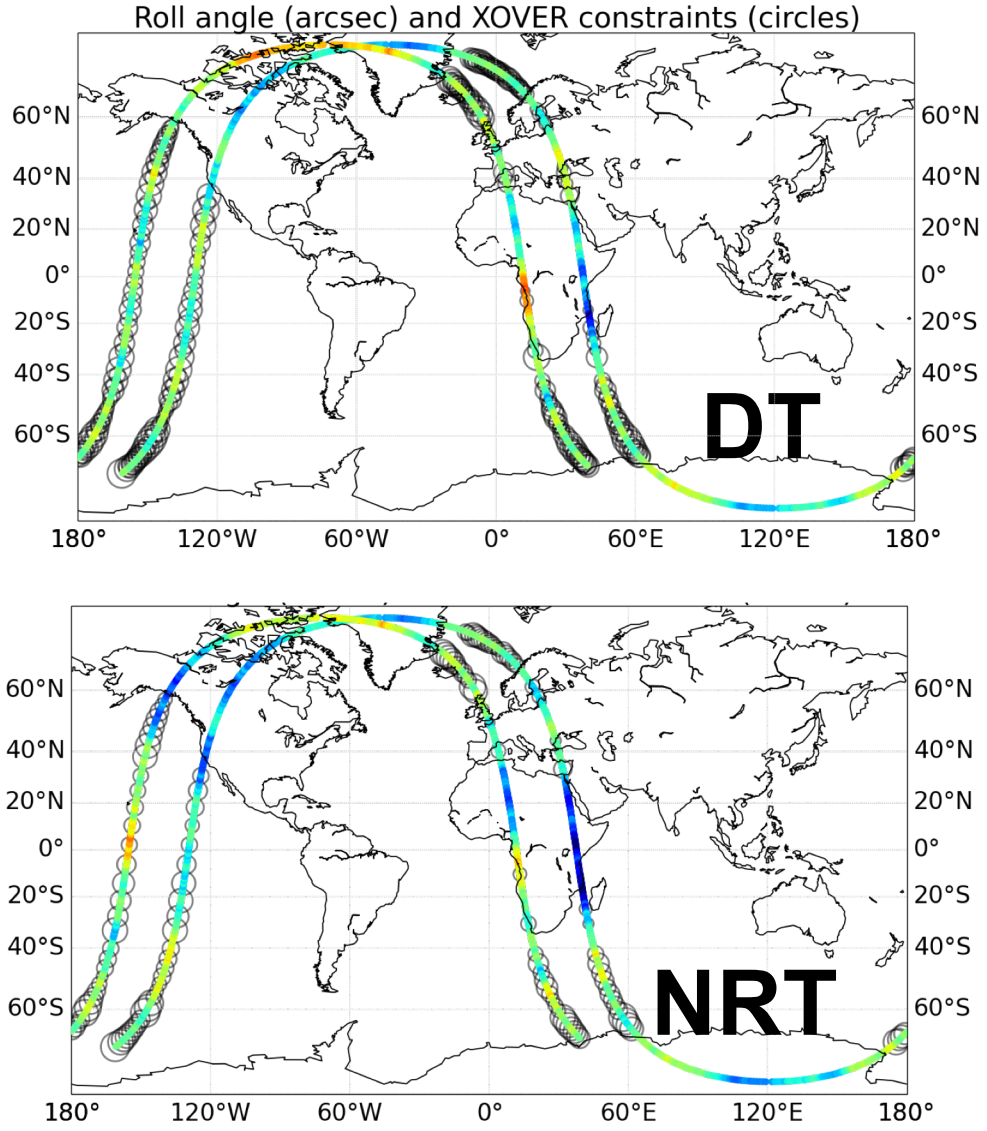
XOVER AVAILABLE ONLY IN 6 DAYS (cannot be used as a constraint for NRT propagation)

Performance Impact of Cross Over Calibration (2/4)
Near-Real-Time (NRT) vs. Post-Processed (DT)

Geographical overview of XOVER locations

- Losing XOVERS in NRT leads to a weaker constraint for roll calibration, but
  - SWOT orbit has a 10.9-d sub-cycle
  - XOVER available in NRT are well interleaved with DT-only XOVERS

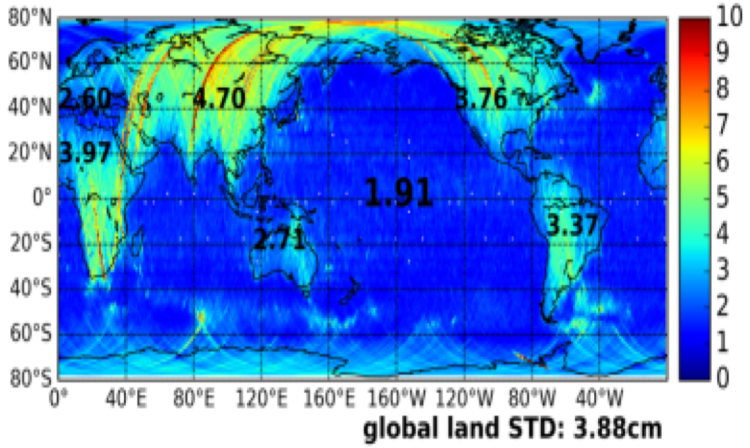
- This is an asset for NRT calibration
  - Ocean XOVERS remains evenly distributed in NRT with no latitude band unobserved
  - Problem well constrained for inland propagation (hydrology)



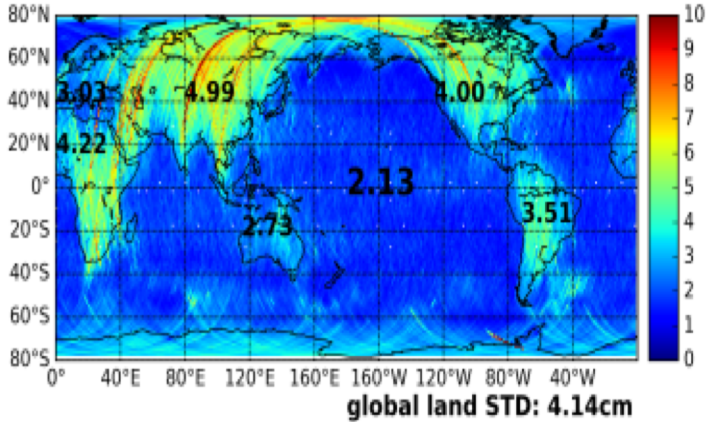
Performance Impact of Cross Over Calibration (3/4)
Near-Real-Time (NRT) vs. Post-Processed (DT)

- **Impact is quite low due to the optimal repartition of the cross-over points over the ocean.**
- **Residual systematic error after crossover correction is significantly below the budget allocation of 7.4 cm for hydrology.**
  - Land (RMS over 1 year):
    - 4.14 cm for NRT versus 3.88 cm for DT.
  - Ocean (RMS over 1 year):
    - 2.13 cm for NRT versus 1.91 cm for DT.

Post-Processed (Using crossovers before and after)



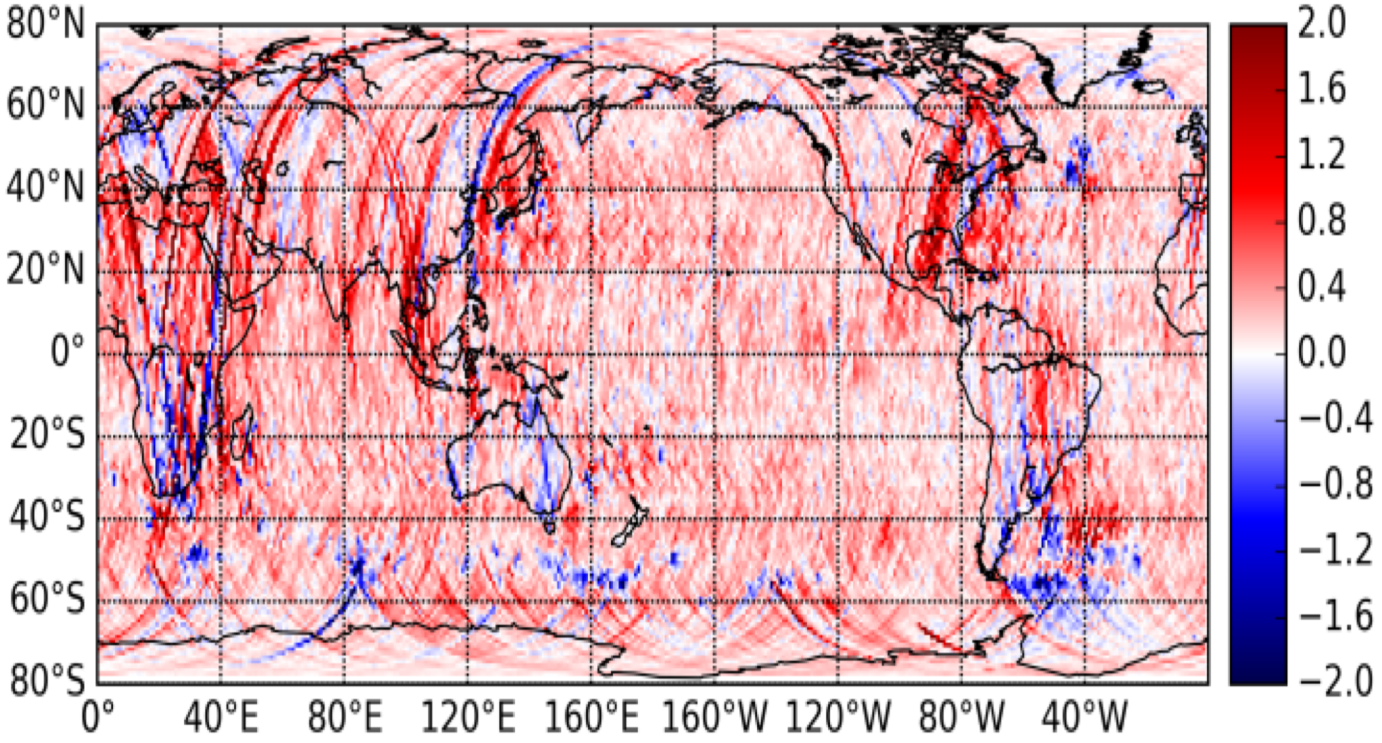
NRT (Only using crossovers before)



Performance Impact of Cross Over Calibration (4/4)
Near-Real-Time (NRT) vs. Post-Processed (DT)

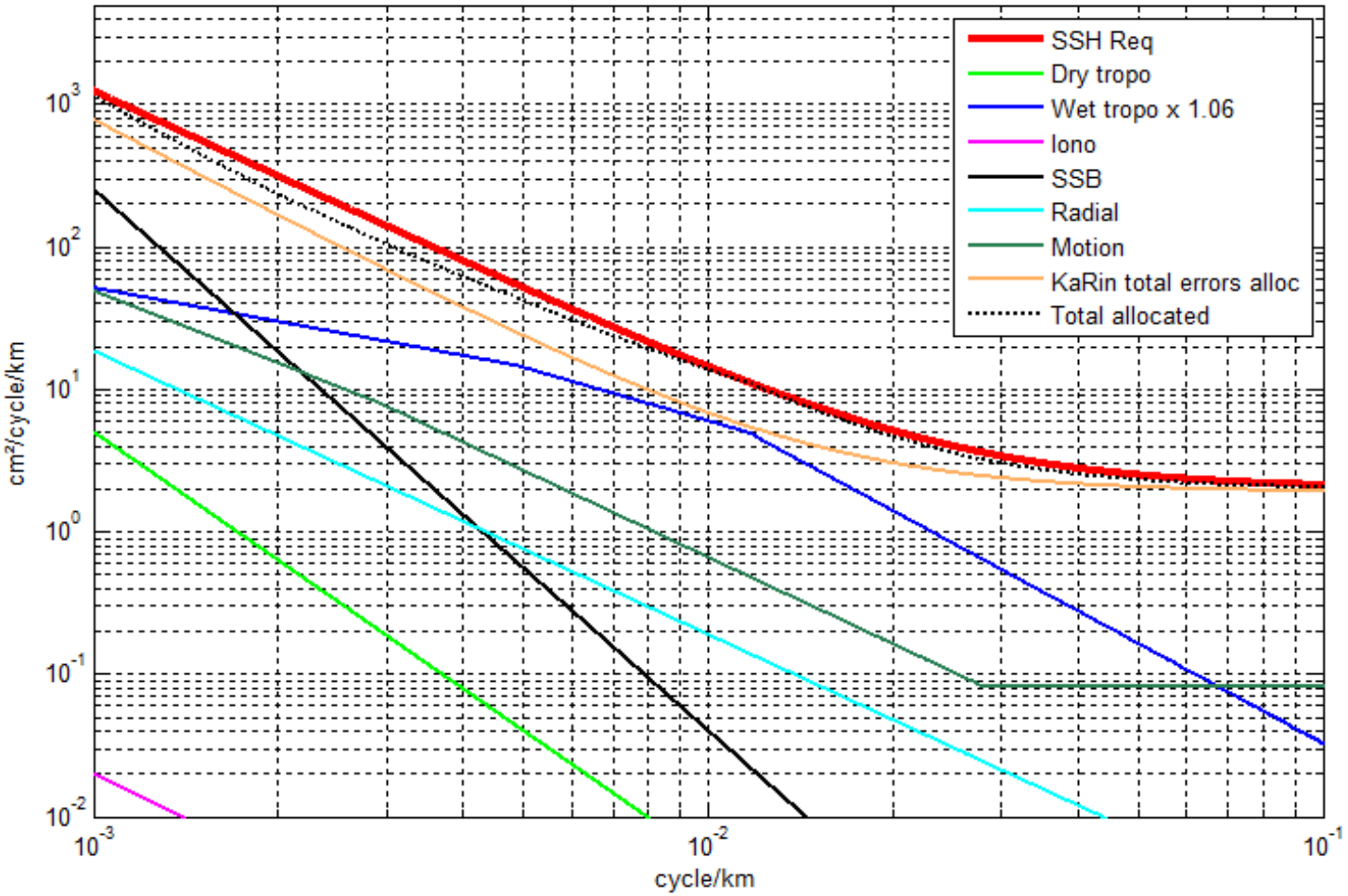
- Differences of residual systematic errors from NRT and Post-processed is typically < 2 cm.
  - Red: Higher residual systematic errors in NRT vs. post-processed.
  - Blue: Lower residual systematic errors in NRT vs. post-processed.
  - Arcs with improved accuracy in NRT linked to the adopted filter.

Near-Real-Time – Post-processed (cm)



Summary of Performance Impact for Oceans

- **Negligible impact to ocean error spectrum** even if scaling wet troposphere error contribution by 6% to allow for calibration error at short latencies.



Summary of Performance Impact for Hydrology

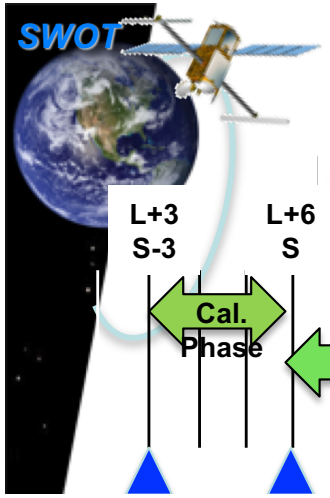
- **Small increase in height error (5.4 to 5.7 cm), and no impact to slope error.**
  - **Significant remaining margin based upon current best estimates.**

	45-Day Latency		3-Day Latency		
Hydrology Error Component	Height Error [cm]	Slope Error [urad]	Height Error [cm]	Slope Error [urad]	Comments
Ionosphere residual	0.8	0.1	0.8	0.1	Same GIM correction is used
Dry troposphere residual	0.7	0.1	0.7	0.1	Same ECMWF model is used
Wet Troposphere residual	1.0	1.5	1.0	1.5	Same ECMWF model is used
Radial Error	1.6	0.02	2.0	0.02	Radial Error (including POD+CoM to Phase Center radial) RMS **MOE has a slightly degraded quality**
KaRIn Random and Systematic Errors after Cross-Over Correction	4.9	10.6	5.1	10.6	KaRIn roll-up, after cross-over correction
KaRIn Random	3.0	10.5	3.0	10.5	Identical
KaRIn Systematic errors after cross-over correction	3.88	1.01	4.14	1.01	Operational Calibration analysis of residual error
High Frequency errors	0.084	<0.1	0.084	<0.1	Identical
Motion Errors	0.4	0.8	0.4	0.8	Identical
Total (RSS)	**5.4**	**10.7**	**5.7**	**10.7**	
Requirement	**10**	**17**	**10**	**17**	
Margin	**46%**	**37%**	**43%**	**37%**	

Proposed Plan for SWOT Science Data Products (1/2)

- **Generate routine (forward processing) science data products with a latency goal of < 3 days.**
  - Accuracy of short-latency (< 3 days) products expected to meet project requirements based upon current best estimates.
    - **Hydrology height error from 5.4 to 5.7 cm.**
    - **No change to hydrology slope error.**
    - **Negligible impact to sea surface height spectrum requirements.**
  - Benefits applications users without significant compromise to science users.
  - Project will maintain requirement to generate science data products with a latency of 45 days.
- **Enhance reprocessing plan (~ once/year)**:
  - **Leverage expected evolution of science data algorithms when in-flight data become available, and hydrology databases.**
    - KaRIn instrument processing algorithms are certain to evolve when first-of-its-kind in-flight data become available.
  - Achieve best accuracy that was originally intended from 45-day latency.
    - E.g., use best orbit determination, radiometer calibration, and crossover calibration.

Proposed Plan for SWOT Science Data Products (2/2)



L+3 S-3 | L+6 S | L+14 S+8 | L+18 S+12 | L+30 S+24 | L+42 S+36

Cal. Phase

Science Validation

Science Operations

Cal. Orbit 1-day Repeat (L+3 = S-3)

Science Orbit 21-day Repeat (L+6 = S)

Science Validation Meeting L+14 = S+8

Beta Products (Beta Software)

Pre-Validated

Validated Products (Repro. #1 Software)

Validated Products (Repro. #2 Software)

Validated Products (Repro. #3 Software)

6 months

Reprocessing #1 (L+9 = S+3)

18 months

Reprocessing #2 (L+21 = S+15)

Reprocessing #3 (L+33 = S+27)

30 months

9 months (Repro. #3 Software) Using Best Available Aux. Data

36 months Global Level 2 Hydrology Only

EOM Reprocesssing (L+42=S+36)

Legend

Routine Forward Processing: 3-day latency goal.

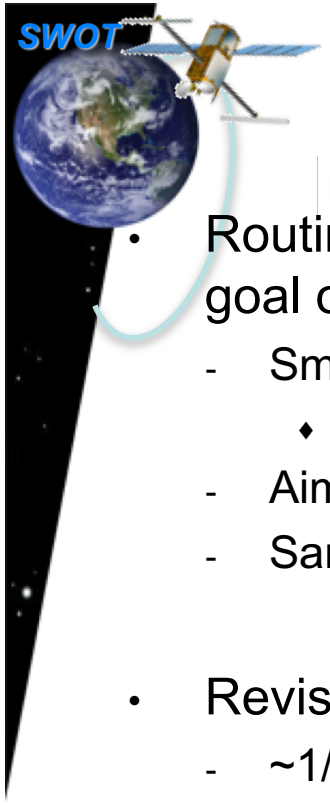
Reprocessing Period.

Motivation for Reprocessing Plan

Repro. #	Date	Duration (months)	Description
1	L+9	6	• **Updates aimed towards science validation meeting.** • **KaRIn calibration updates.** • **Algorithm updates based upon in-flight data.** • Improved orbit ephemeris (POE), radiometer calibration, crossover calibration.
2	L+21	18	• **First update to hydrology apriori databases (12 months).** • **Algorithm updates based upon long-duration in-flight data.** • Improved orbit ephemeris (POE), radiometer calibration, crossover calibration.
3	L+33	39	• **Second update to hydrology apriori databases from longer duration data (24 months).** • **Algorithm updates based upon longer-duration in-flight data.** • Improved orbit ephemeris (POE), radiometer calibration, crossover calibration.
4	L+45	36	• **Third update to hydrology apriori databases from entire science mission data (36 months).** • **Algorithm updates for Level 2 Hydrology products.**

NOTES:

- **Repro. #3 performing routine operational processing for L+33 to end-of mission in repro #3 configuration using POE, radiometer cal., Xover cal. when available.**
  - **Facilitates approach for extension of mission.**
  - **Assumes no updates to algorithms for LR and HR L0 to PIXC between L+33 and L+45, and no changes to apriori hydrology databases for 1-day orbit.**



Conclusion

- Routine (forward processing) science data products generated with a latency goal of 3 days is feasible.
  - Small impact on data quality.
    - **Deficiencies in KaRIn algorithms impact products regardless of latency.**
  - Aim to meet needs of science and applications community.
  - Same product suite as originally intended for 45-day latencies.

- Revised reprocessing approach would be a valuable enhancement.
  - ~1/year during prime mission.
  - Account for expected evolution of KaRIn instrument processing algorithms.
  - Account for expected evolution of hydrology databases.
  - Accommodate best available ancillary and auxiliary data.

- Identical products (routine and reprocessed) would be distributed at JPL and CNES.
  - Ongoing evaluation of distribution of Single-Look Complex (SLC) science data product at short (< 3 day) latencies.
    - Very high data volume product with expected small user community.
    - Will be generated and archived at each reprocessing opportunity regardless of approach at short latencies.