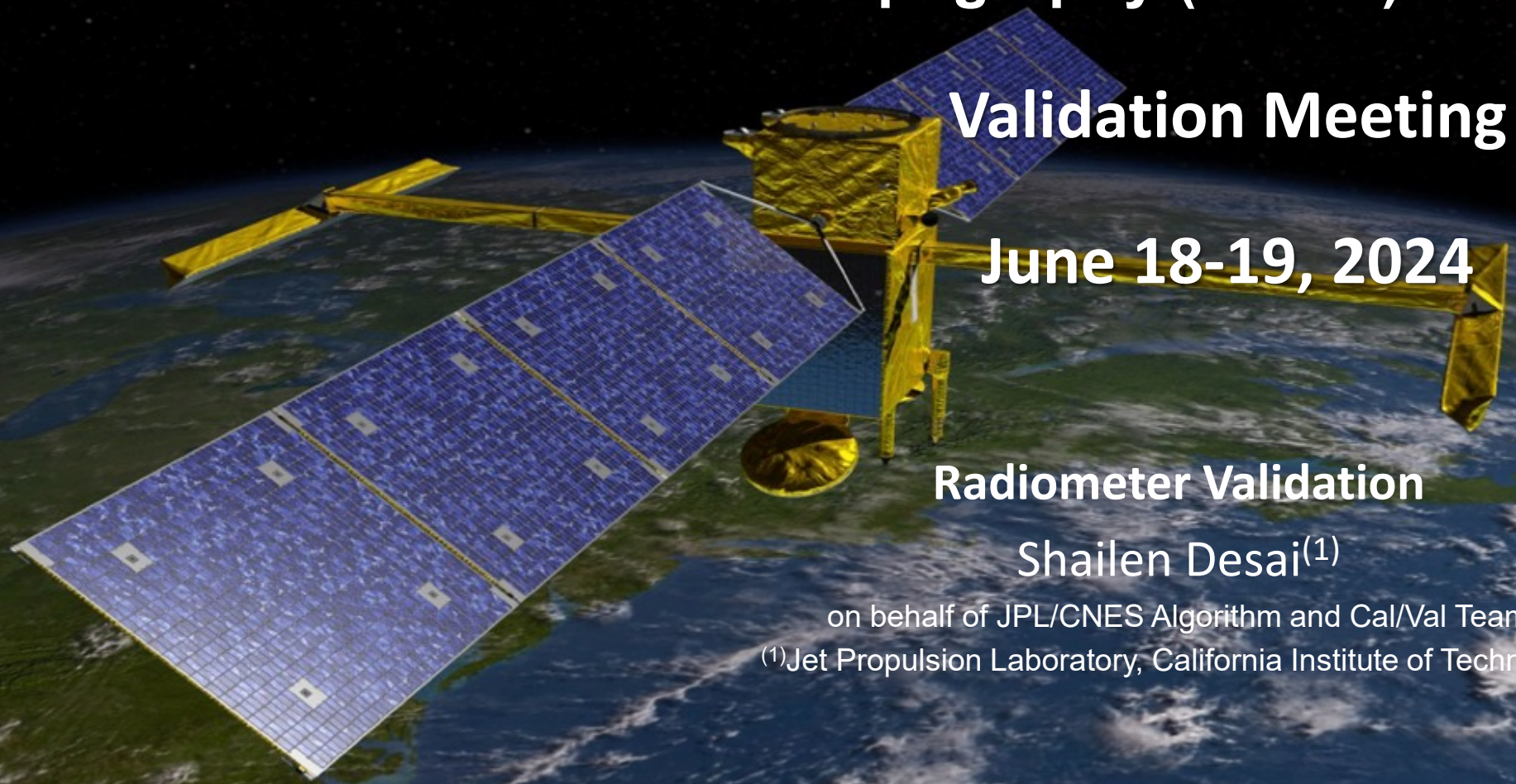
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

Validation Meeting

June 18-19, 2024



Radiometer Validation

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on behalf of JPL/CNES Algorithm and Cal/Val Team

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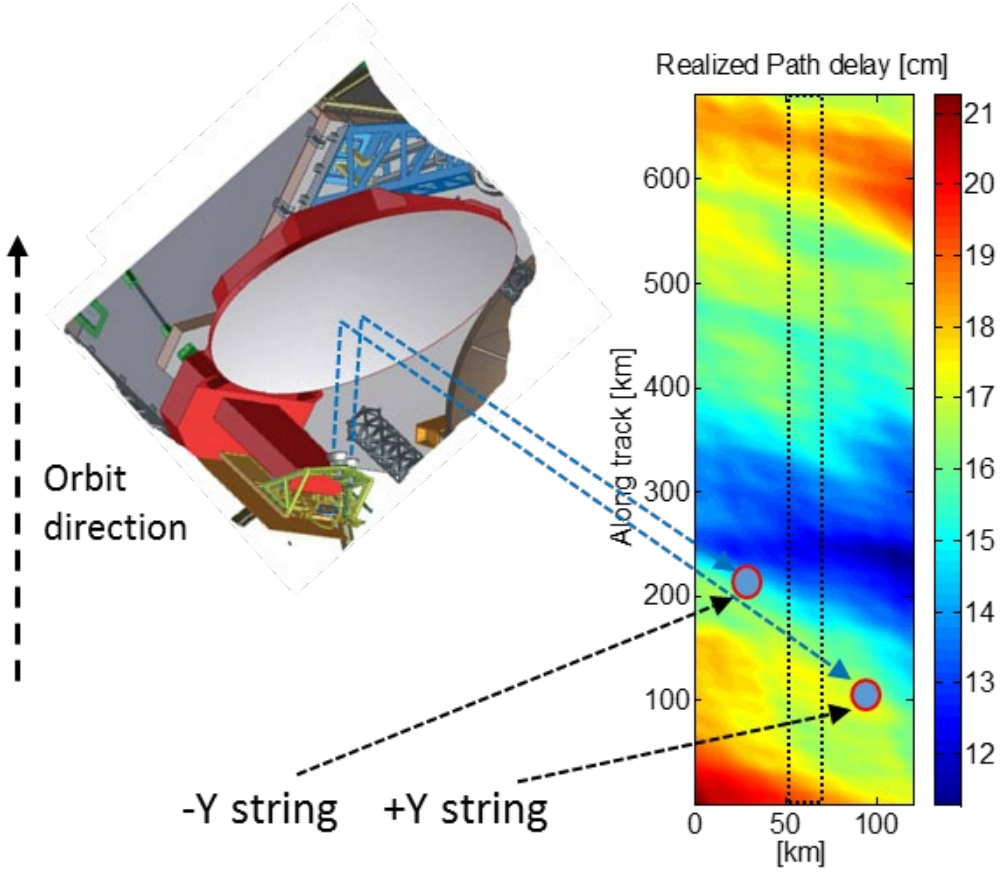
SWOT Advanced Microwave Radiometer (AMR)

- AMR primarily aimed towards **over-ocean measurements** of:
  - Wet troposphere correction for radar range.
  - Atmospheric attenuation correction for radar backscatter (sigma0).
- Dedicated radiometer product (L2_RAD).
  - Provides measurements of wet troposphere geophysical parameters:
    - Wet troposphere range correction, atmospheric attenuation correction, cloud liquid burden, and water vapor content.
    - **Typically valid over open ocean.**
      - May be valid over large inland water bodies (e.g., lakes)
      - Subject to land, rain, ice contamination.
  - Provides global measurements of antenna and brightness temperatures.
  - Provides flags indicating when geophysical parameters are contaminated by land, rain, ice.
- **AMR data are only applied to nadir altimeter and KaRIn ocean products.**
  - **Not applied to KaRIn hydrology products.**

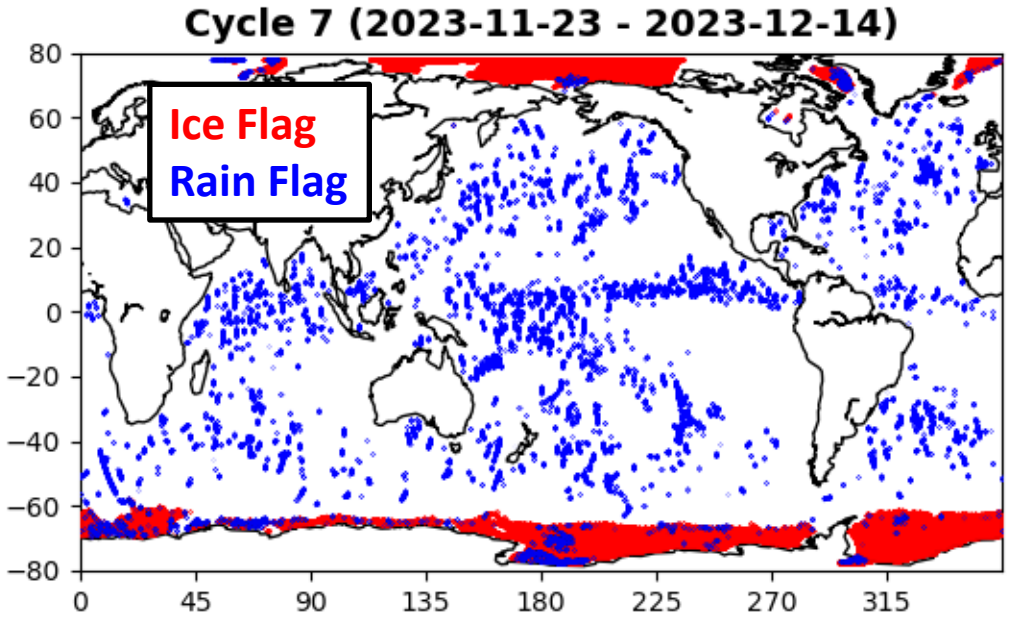
Two Simultaneously Active AMR Strings Operating Independently

- **AMR provides point measurements in middle of each KaRIn swath.**
- Two active strings referred to as +Y and –Y.
  - Reference to side of nadir relative to spacecraft body-fixed axis.
  - Center of each footprint approximately half-way across each swath.
  - Left and right strings approximately 70 km fore and aft of nadir.
- Each string operates at three frequencies.
  - 18.7, 23.8, and 34.0 GHz.
  - Spatial resolution of 31, 27, and 19 km.
- **Data from each string processed independently.**
  - Provided separately in L2_RAD product.
  - Two netCDF groups in single file.
  - Spatially interpolated when applied to nadir altimeter and KaRIn measurements.

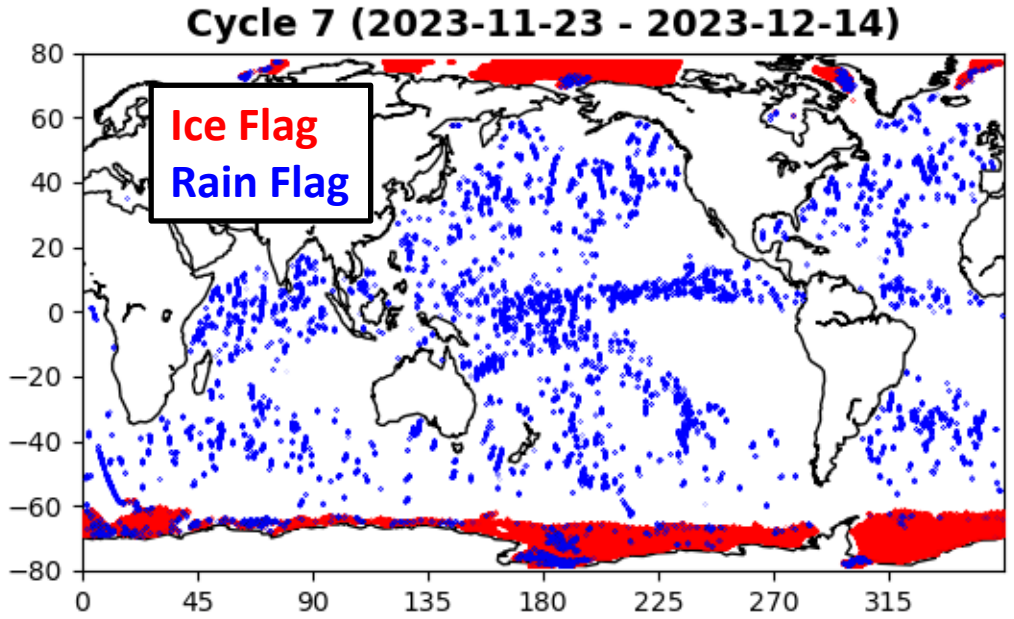


AMR Products Provide Flags to Indicate Ice and Rain Contamination

AMR Side 1 (Open Ocean)

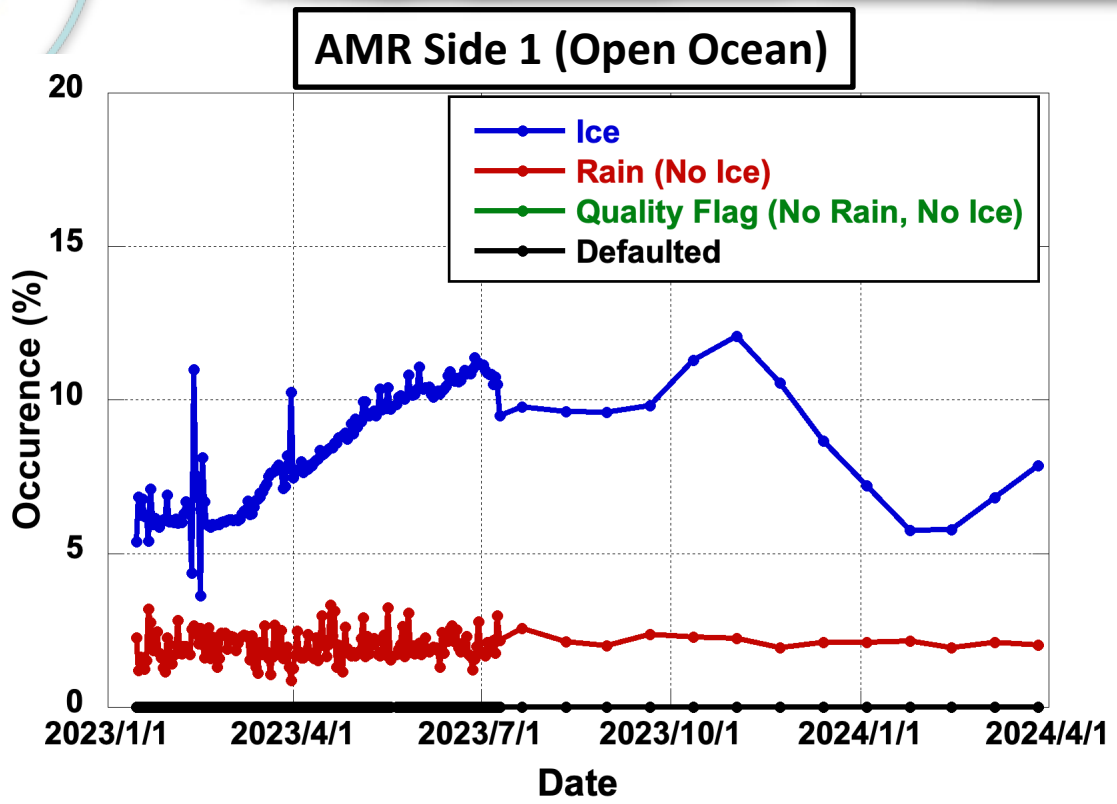


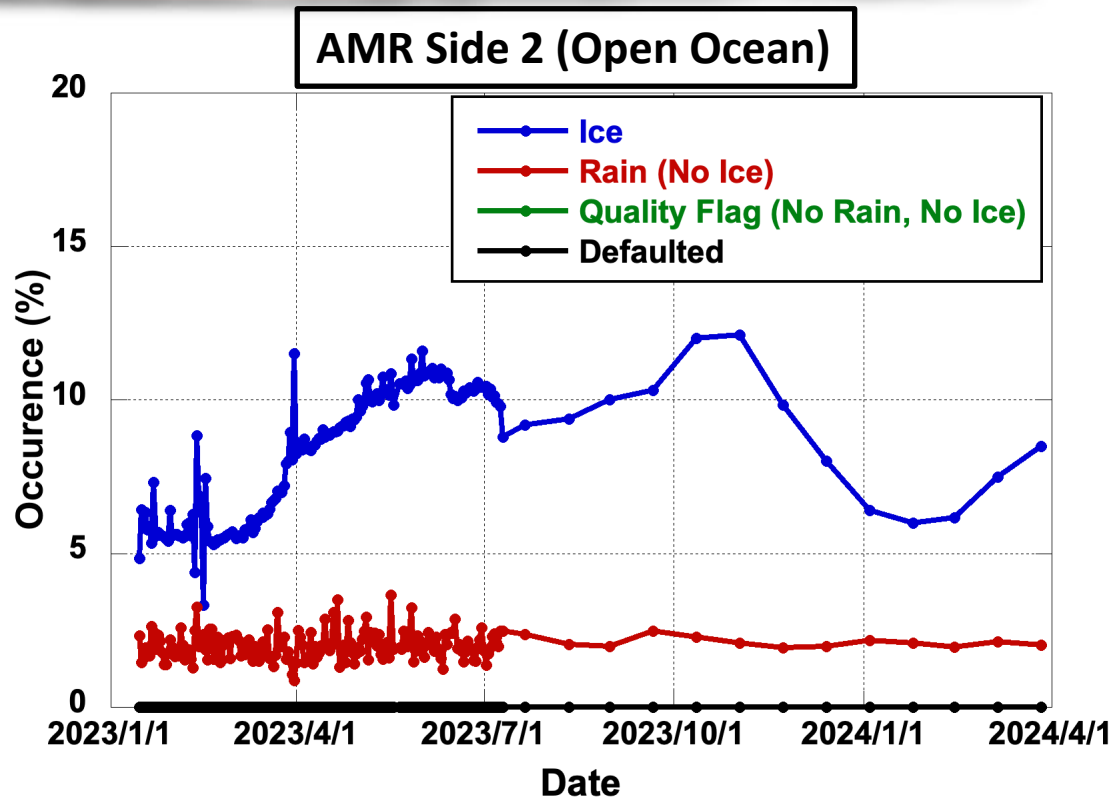
AMR Side 2 (Open Ocean)



- Cycle 7 example from southern hemisphere winter for open ocean data.
- High level agreement in flagging from two sides.
- **Recommend using surface type, ice and rain flags to edit AMR data.**

AMR Flagging Rates

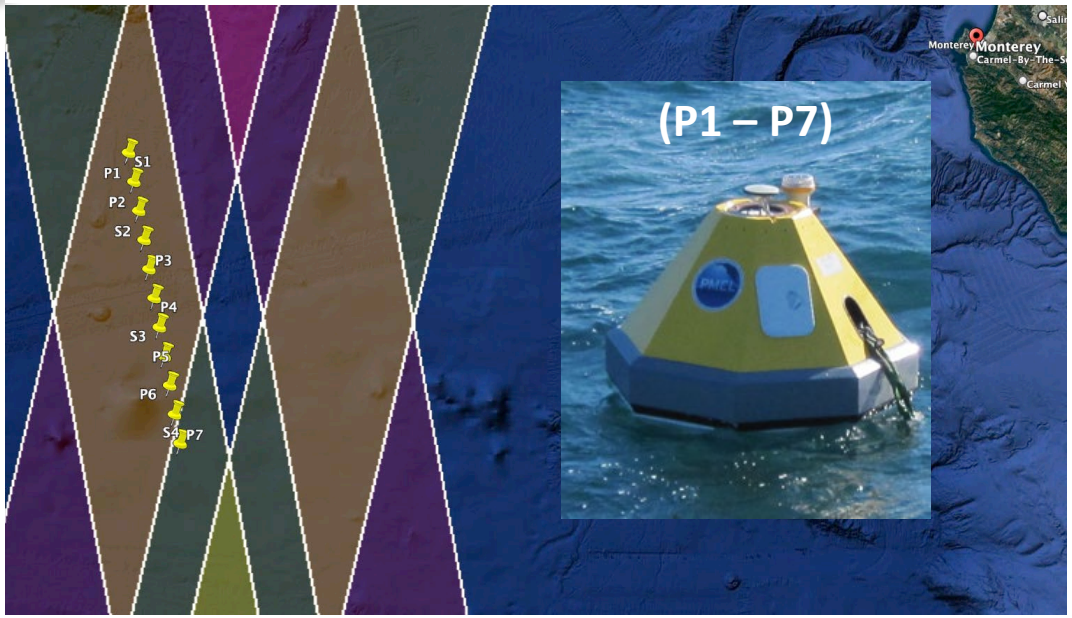


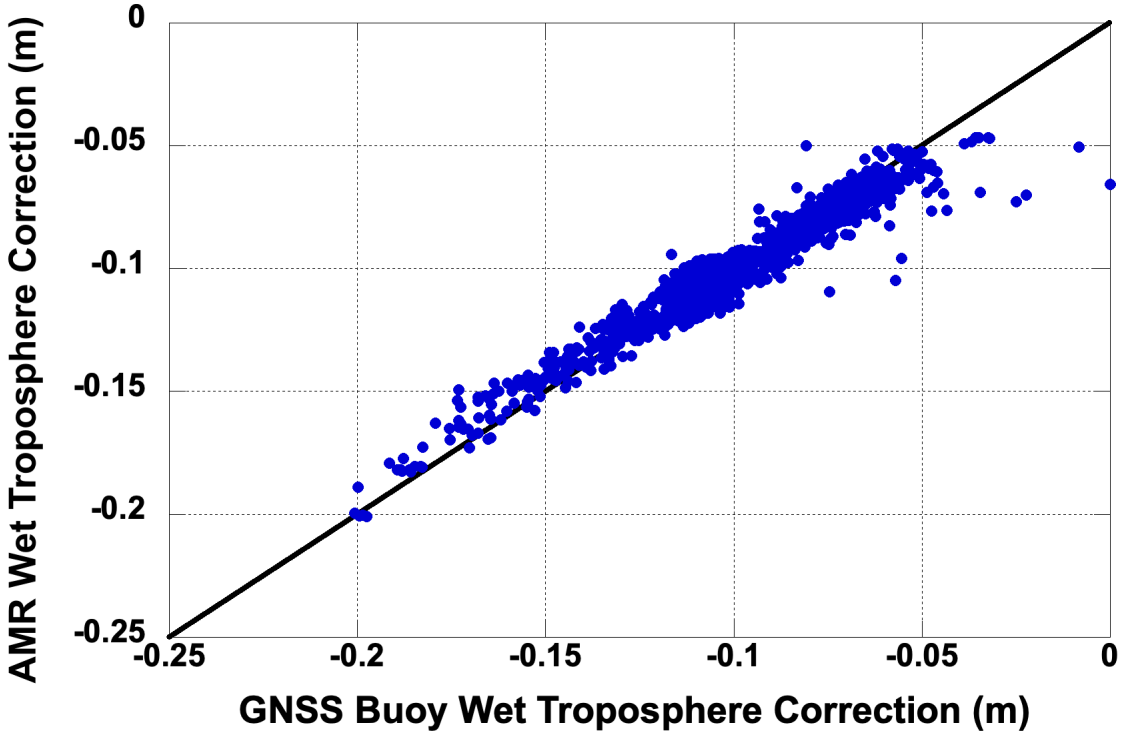


- Statistics for open ocean data only.
- Ice flag tracking seasonal cycles, with maximum occurrence July-Dec.
- Rain contamination impacting ~2% of measurements.
  - Up to 3.6% of measurements during 1-day orbit.
- Almost no bad quality or defaulted measurements after editing with ice and rain flags.

Independent Validation of SWOT AMR Measurements Using In-Situ GNSS Buoys

7 GNSS Buoys at California Crossover Validation Site

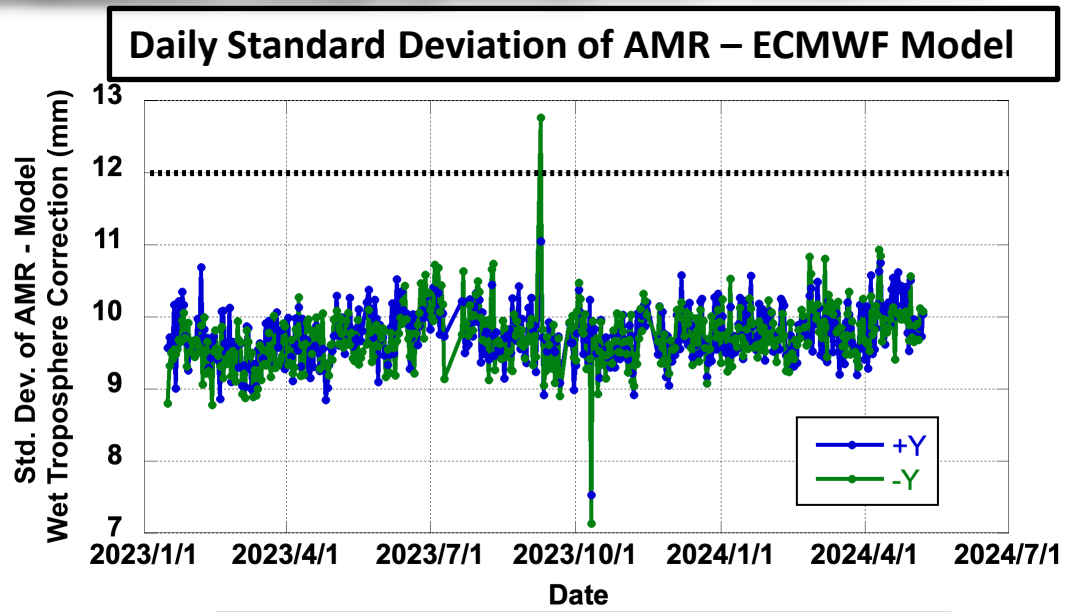


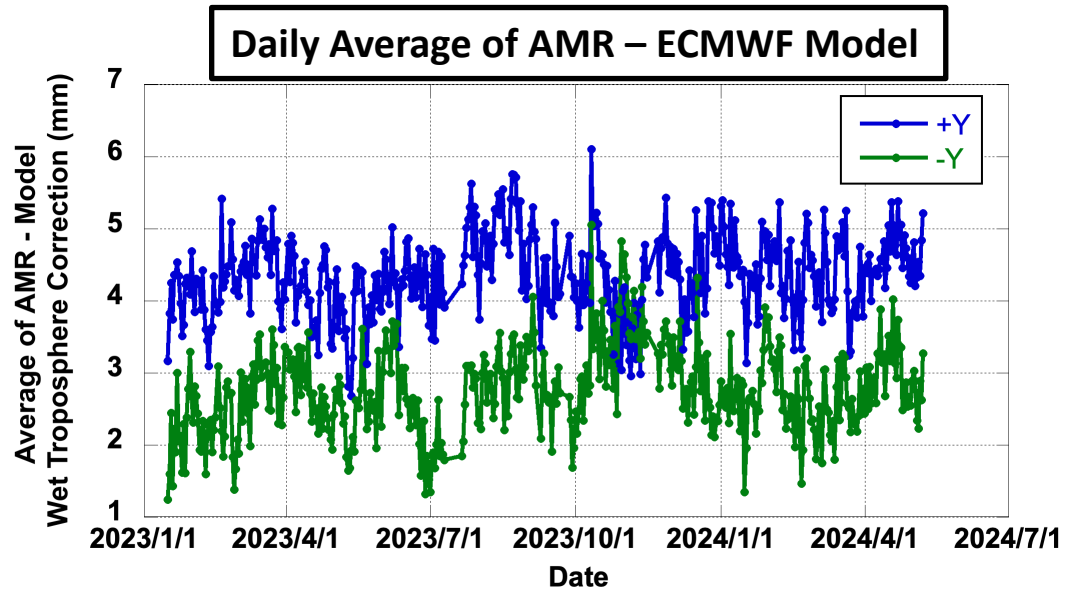


- **< 1 cm accuracy of AMR wet troposphere measurements based upon differences between SWOT AMR and in-situ (open ocean) GNSS buoys.**
  - **Standard Deviation: 7.3 mm,** Average: -1.0 mm
  - Comparisons span ~99 twice per day SWOT overflights of 7 GNSS buoys (1-day orbit).
    - 1210 coincident measurements.

Radiometer Wet Troposphere Correction: Meets Long Wavelength Performance Requirement

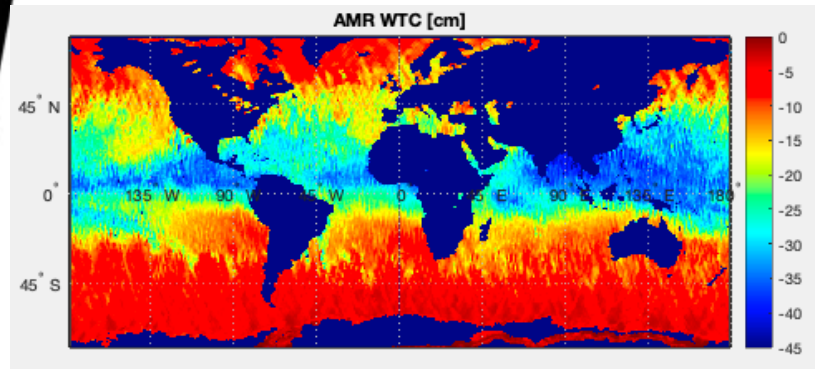
- Long-wavelength performance verified using differences with ECMWF meteorological model.
- **AMR Meets long-wavelength performance < 1.2 cm.**
  - Standard deviation of differences: 1 cm.
  - **ECMWF model also has long wavelength accuracy < 1.2 cm.**
- **Average of differences reveal residual 1.6 mm relative bias between +Y and –Y strings.**
  - Residual relative calibration error.
  - On-going work to mitigate in next version of products.



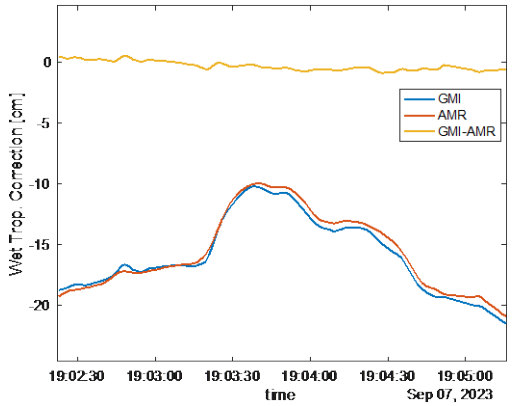


Radiometer Wet Troposphere Correction: Meets Spectral Performance Requirement

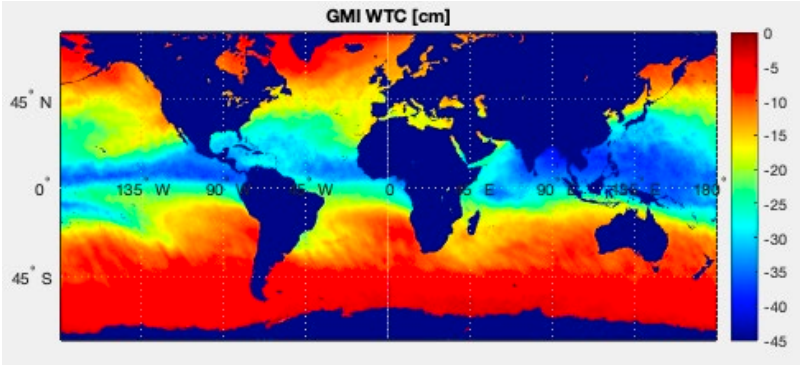
SWOT AMR Wet Troposphere Correction



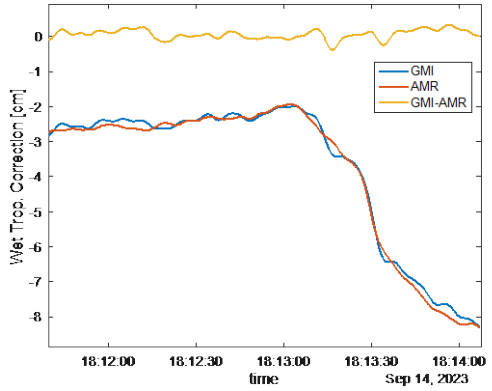
GMI vs. AMR



GMI Wet Troposphere Correction

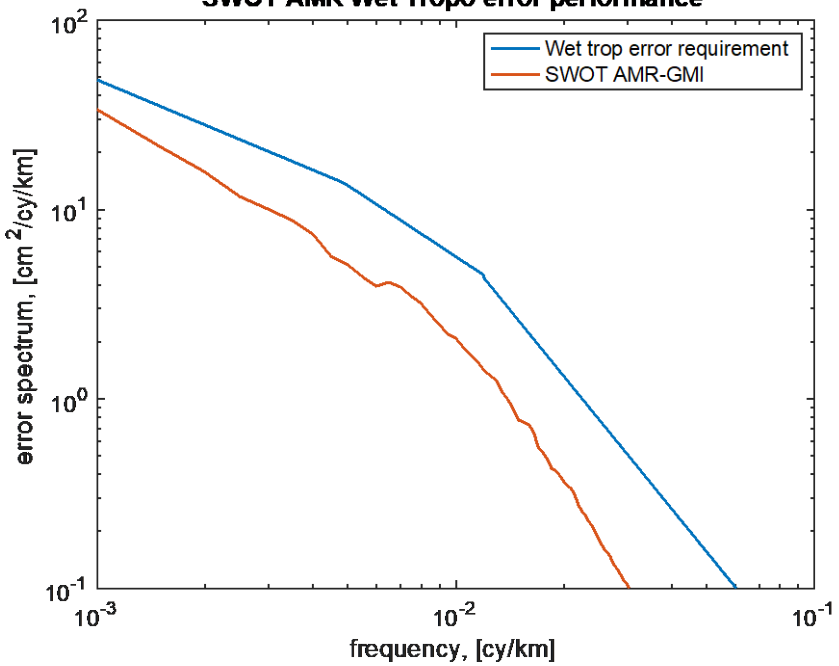


GMI vs. AMR



Courtesy: C. Chae

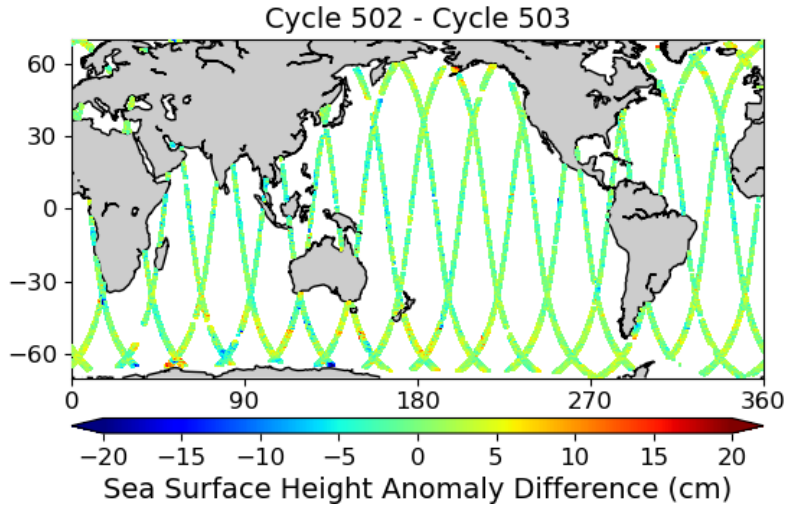
SWOT AMR Wet Tropo error performance

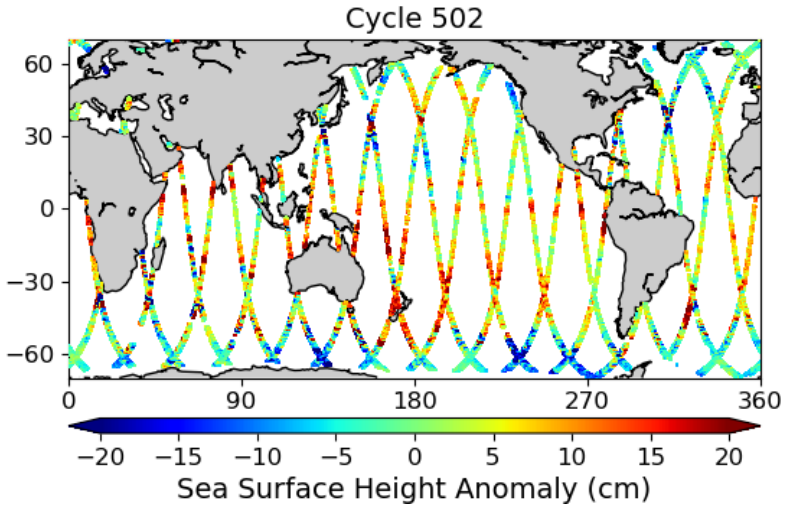


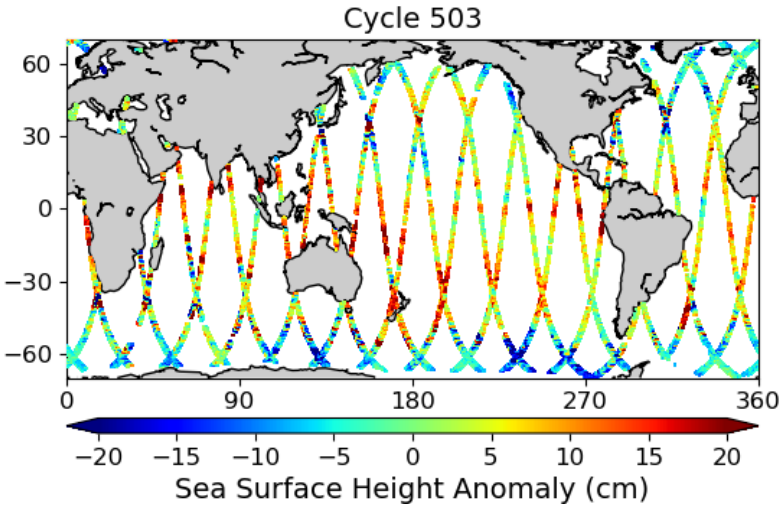
- Spectral performance verified using differences with independent measurements from GPM Microwave Imager (GMI).
  - Coincident spatially interpolated measurements within 15 minutes (~450 swath matches).
  - Comparisons from 9/1/23-11/31/23.

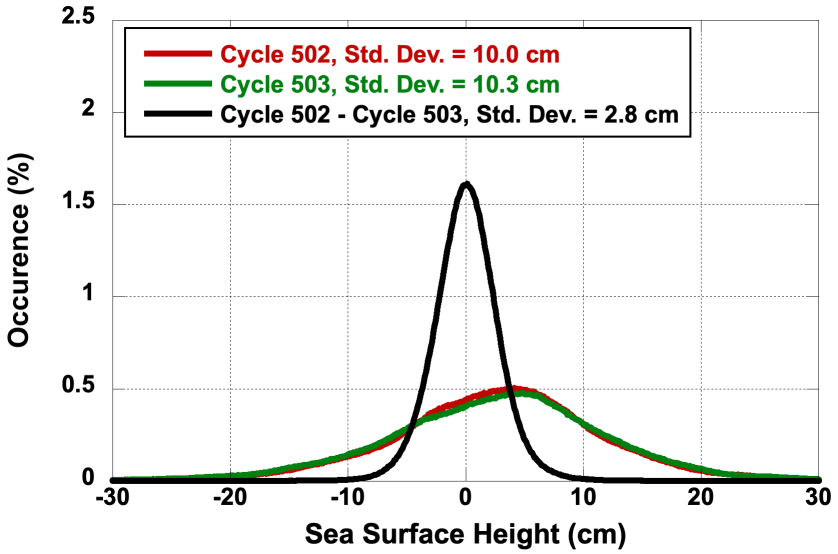
Evaluate AMR versus ECMWF Model Wet Troposphere Correction Using Collinear Sea Surface Height Anomaly (SSHA) Differences

ΔSSHA(lat,lon,cycle N) = SSHA(lat,lon,cycle N) – SSHA(lat,lon,cycle N+1)



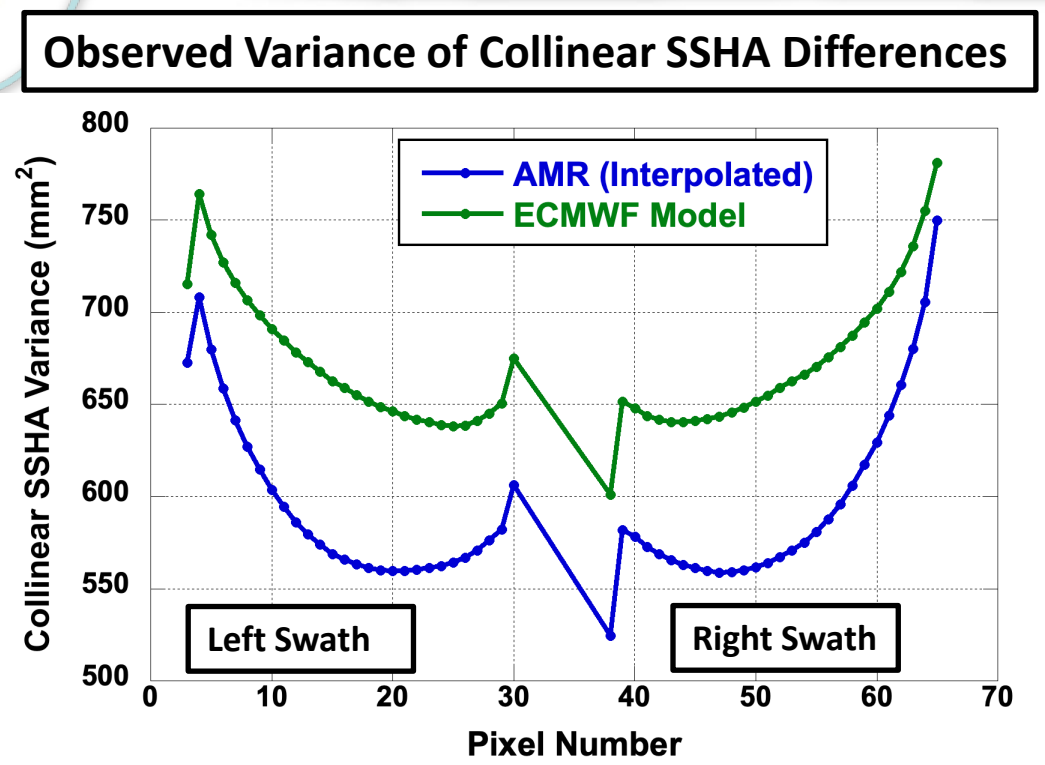


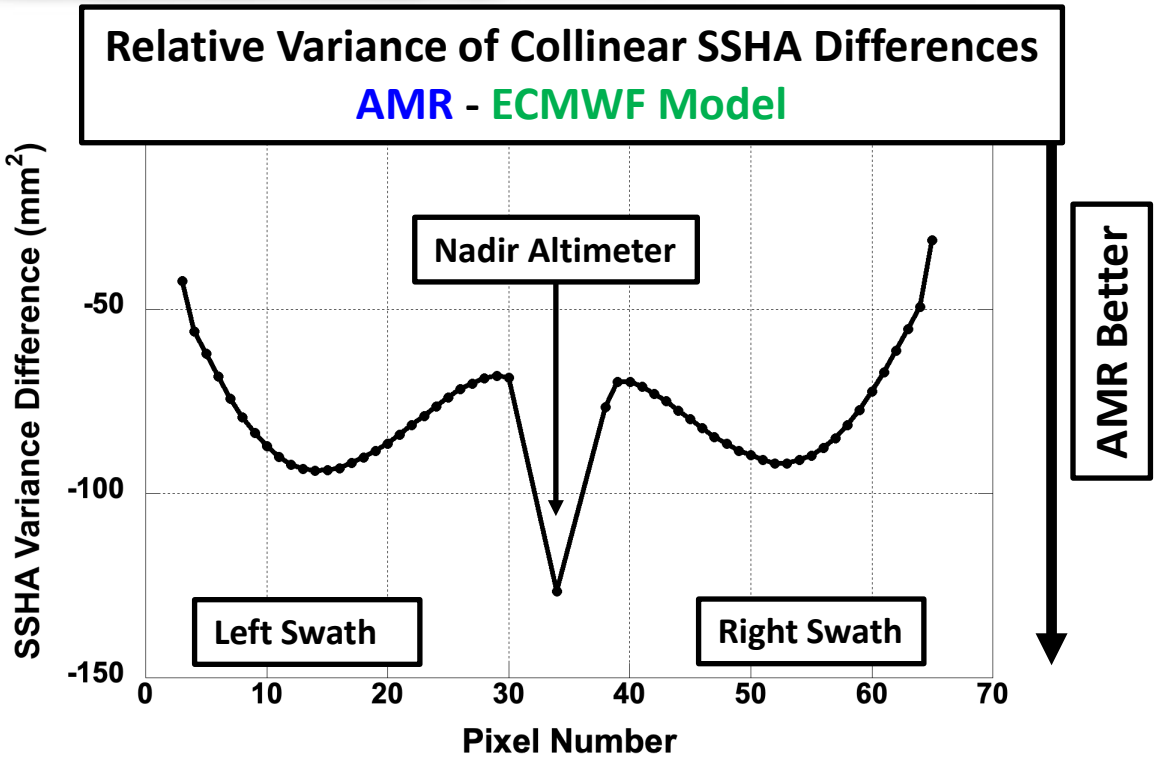




- **Evaluate relative performance of AMR vs. ECMWF model wet troposphere corrections using variance of collinear SSHA differences.**
- **Collinear SSHA difference** => SSHA differences at same location - one cycle apart.
  - Leverage 1-day repeating ground track, March 31-July 9, 2023.
  - **Removes significant portion of ocean circulation (>90% of variance).**
- Compare variance from:
  - ΔSSHA(AMR): Computed using AMR correction.
  - ΔSSHA(ECMWF): Computed using ECMWF correction.

AMR Measurements Improves Accuracy of Sea Surface Height Anomaly (SSHA) Accuracy





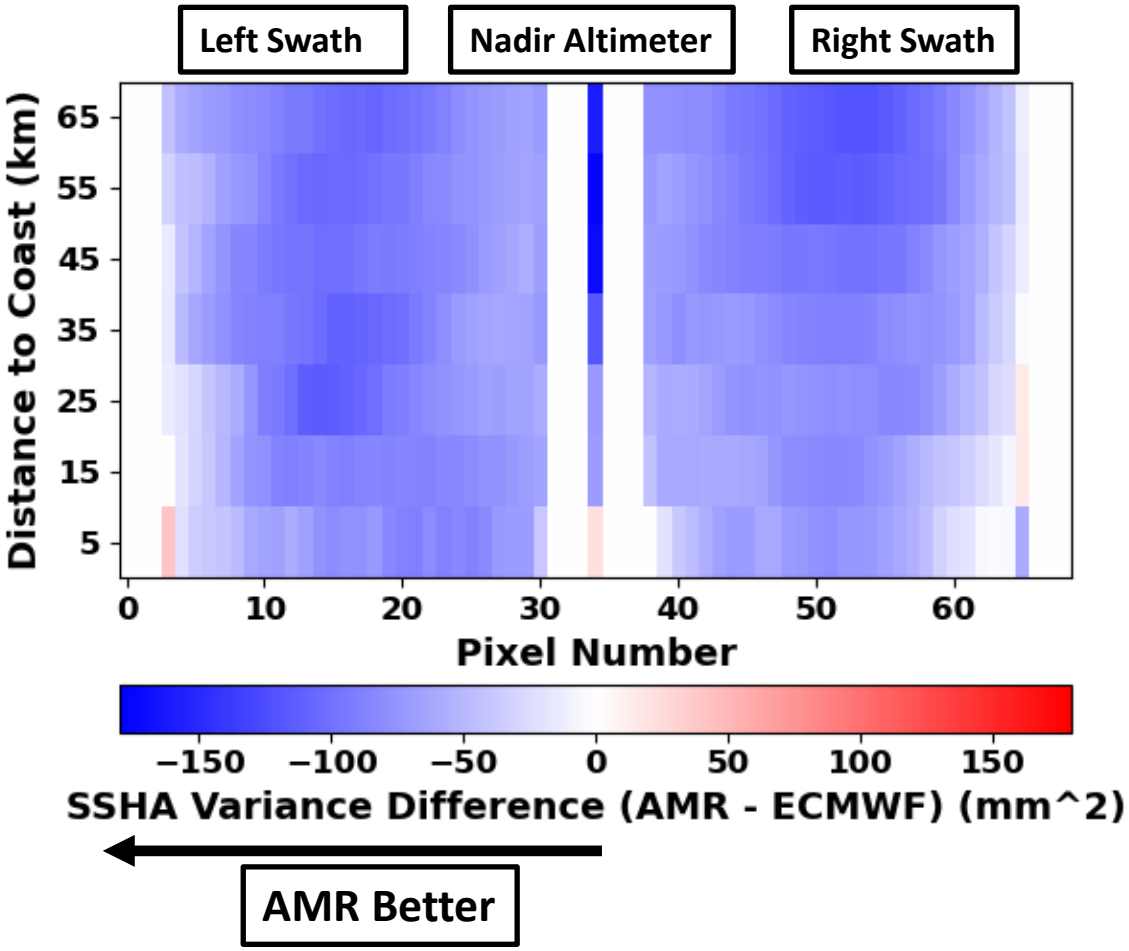
- **~16% lower SSHA variance when using AMR wet troposphere correction.**
- AMR benefits the full extent of the swath measurements.
  - AMR measurements are interpolated/extrapolated.
  - **Largest variance reduction at location of AMR measurements mid-swath.**

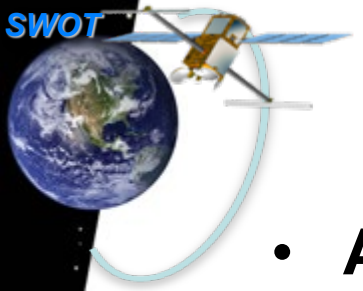
AMR Measurements Near Coasts

- AMR algorithms apply near land wet troposphere correction retrieval algorithm (*Brown*, 2010) on approach to coasts.
  - Aims to mitigate impact of land contamination.
- **Mostly also provides better wet troposphere correction than ECMWF model on approach to coast.**
  - Except < 25 km from coast on outer edge of swath.
  - May depend on particular coastal sampling of 1-day orbit.

Relative variance of collinear SSHA differences using each of AMR and ECMWF wet troposphere corrections.

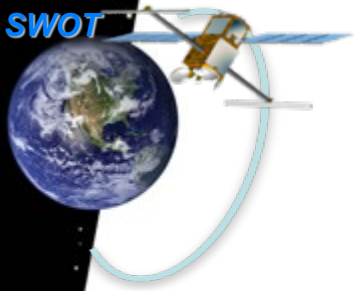
1-day orbit, March 31-July 9, 2023.





Conclusion

- **AMR meeting long wavelength and short wavelength measurement requirements, with margin.**
  - Validated with in-situ buoy measurements, independent data from GPM Microwave Imager, and comparisons to ECMWF model.
- Residual relative bias between two strings < 2 mm.
  - Ongoing effort to reduce bias through calibrations.
- Sea surface height anomaly based upon AMR for wet troposphere correction has significantly better accuracy than using ECMWF model.
  - ~16% lower variance of collinear SSHA differences during 1-day orbit.
  - Rain contaminating ~2% of AMR measurements, up to 3.6% in 1-day orbit.
- AMR wet troposphere corrections provide better SSHA at least up to 25 km from coasts.
  - Exercise caution when using AMR corrections < 25 km from coast.



Backup