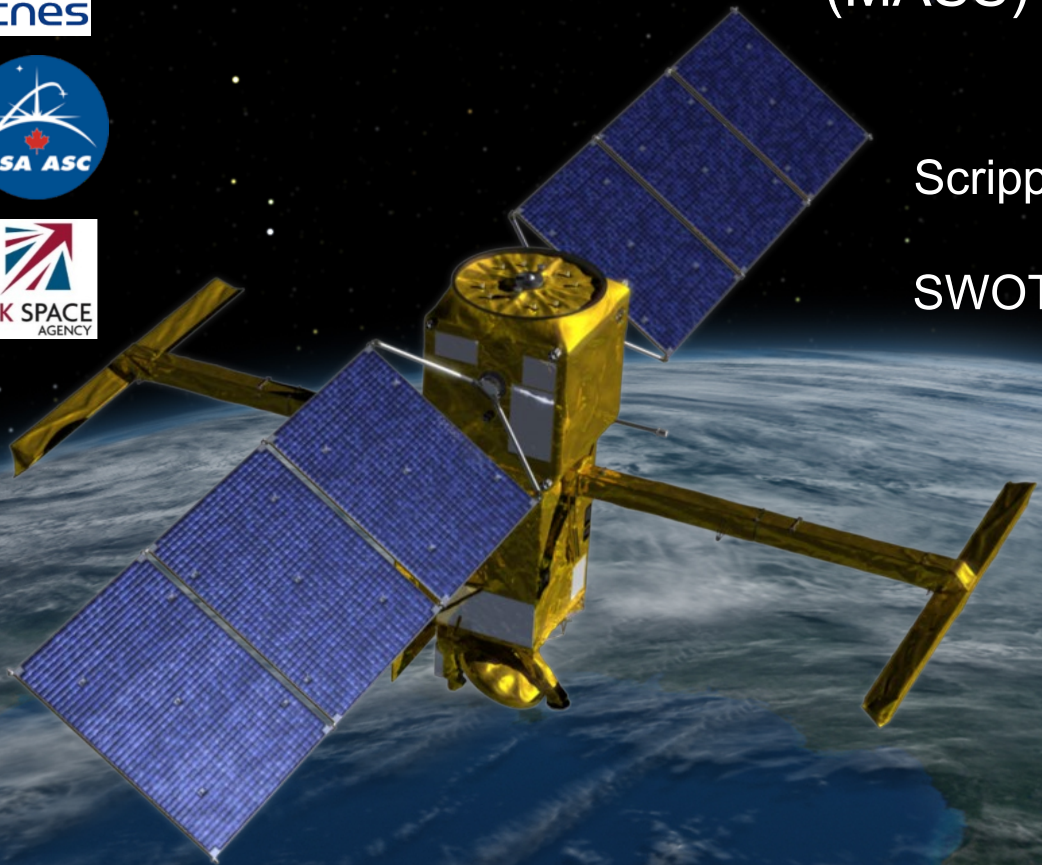
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Broadband 2D ocean topography airborne observations: Modular Aerial Sensing System (MASS) in support of SWOT Cal/Val

Luc Lenain
Scripps Institution of Oceanography

SWOT Science Team Meeting 2023



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Outline

- MASS capabilities and technical description
- post-launch campaign
  - Operational challenges
  - Environmental conditions
  - Flight patterns
  - MASS-SWOT collocated observations

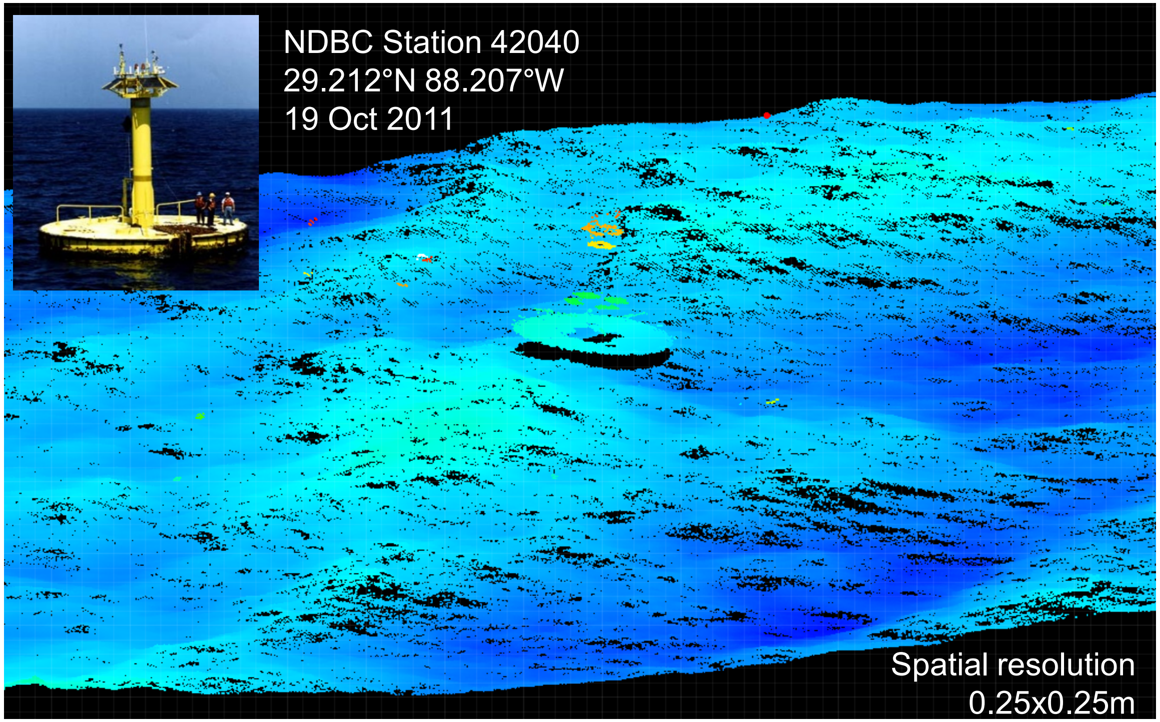
SIO Modular Aerial Sensing System (MASS)

- The MASS is a **mature and proven** portable package of high-resolution instrumentation built specifically for airborne remote sensing applications.
  - Over 800 hours of accumulated flight time over the course of more than **28 different field campaigns.**
  - Successfully operated from a broad range of aircraft (Cessna 206, Partenavia P-68, **Gulfstream-V** and DHC-6 Twin Otter) as well as from a Bell 206 helicopter.
  - ***Major component of S-MODE Earth Venture Suborbital III mission***.

- MASS collects airborne measurements of:
  - Sea surface displacement
  - Temperature
  - Surface kinematics

- MASS data are used to provide measurements of:
  - Ocean waves
  - Currents
  - Stokes drift
  - Sea surface height (SSH)
  - Ocean transport and dispersion
  - Biological activity
  - Hydrological and terrestrial applications include measurements of snow cover, coastal geomorphology, and the built environment

MASS sensor suite



Example of surface elevation as measured from the MASS during a 2011 experiment in the Gulf of Mexico, flying above NDBC buoy #42040. (wind~12m/s, Hs = 3.1m, aircraft altitude = 500m AMSL)

Instrumentation		Measurement
Scanning Waveform Lidar (x2)	Riegl Q680i	Surface wave, surface slope, directional wave spectra (vert. accuracy ~2-3cm)
Long-wave IR Camera	FLIR SC6700	Ocean surface processes, wave kinematics and breaking, frontal processes
High-Resolution Video	JaiPulnix AB-800CL	Ocean surface processes, wave kinematics and breaking, frontal processes
Hyperspectral Camera	Specim Kestrel	Ocean surface and biogeochemical processes
Redundant GNSS/IMU	Novatel SPAN-LN200	Georeferencing, trajectory

Flight schedule - challenges

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NASA JSC GV flight request:

- **Phase I:** Start Date 03/01/2023 End Date 03/30/2023 – **30 days.**
- **Phase II:** Start Date 05/01/2023 End Date 05/21/2023 – **20 days.**

Actual availability caused by limited JSC staff availability & Astronaut Return commitment

- **Phase I:** Start Date 03/28/2023 End Date 04/14/2023 – **17 days (including multiple down days).**
- **Phase II:** Start Date 06/05/2023 End Date 06/09/2023 – **5 days.**

In the end, we only were able to obtain a fraction of the flight days initially requested which impacted our sampling strategies, limiting data collections to 9 flight days for phase I, and 5 flight days for phase II.

Phase I environmental conditions were ok most days, though a persistent cloud layer during all flights constrained flight operations to below the cloud base (~1000-1500ft) with contamination from few lower level clouds/ cloud bank /fog layers in part of the flight track.

Phase II environmental conditions were poor (clouds & low winds)

A total of 36,000km flown with the NASA GV as part of the post-launch CalVal.

MASS installation into the NASA JSC G-V

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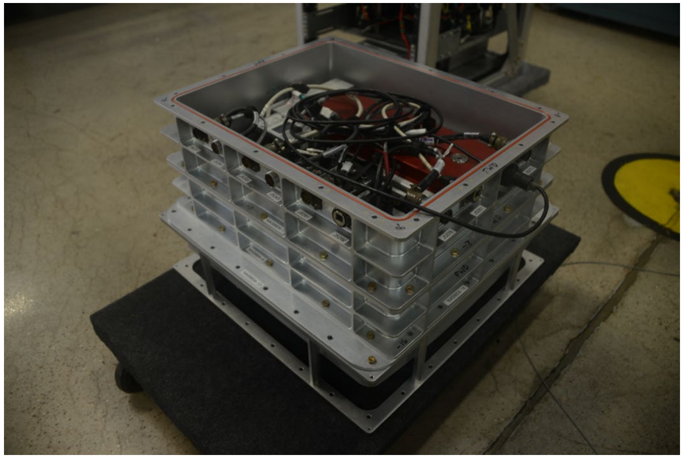
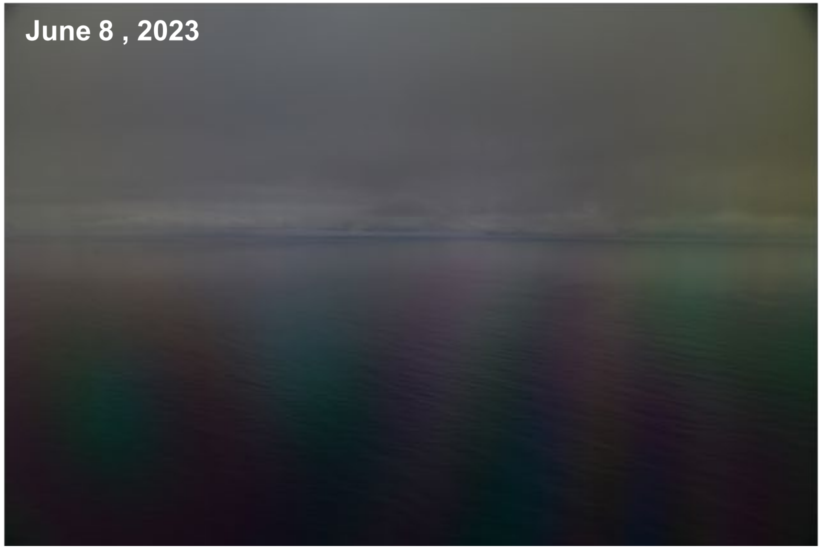
MASS installation at NASA JSC Facilities prior to Phase I – Only one MASS installed due to overlap with S-MODE IOP2 experiment



Transit to Monterey, CA on March 28 2023

Lots of clouds….
Most data collected at low altitudes (1000-1500ft)



Phase I – Environmental conditions

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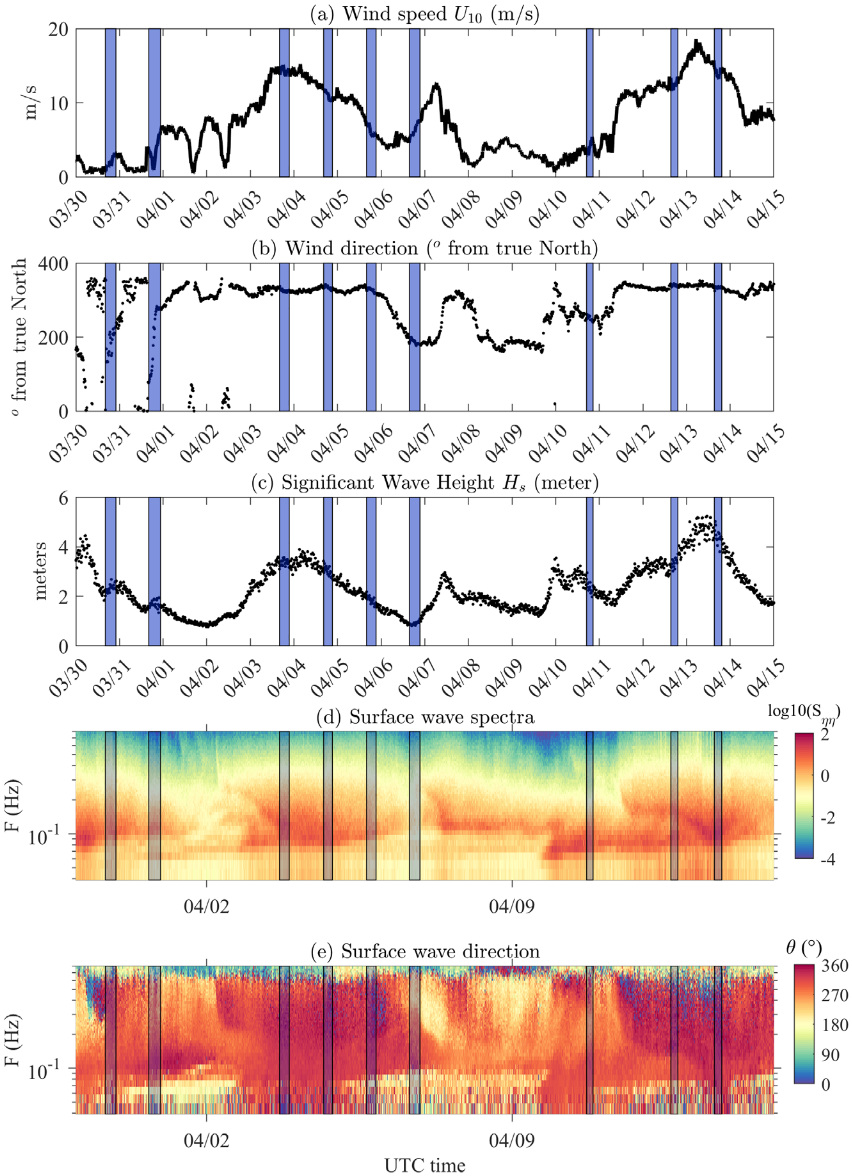
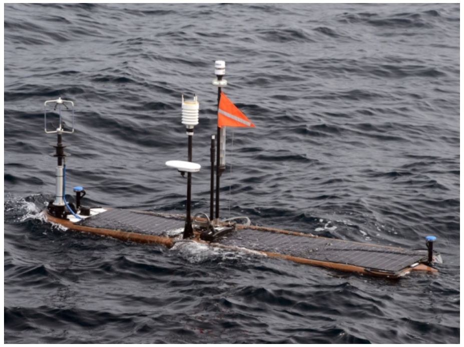
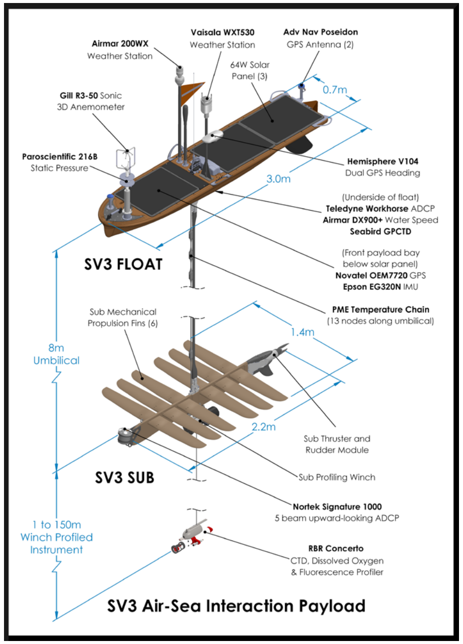
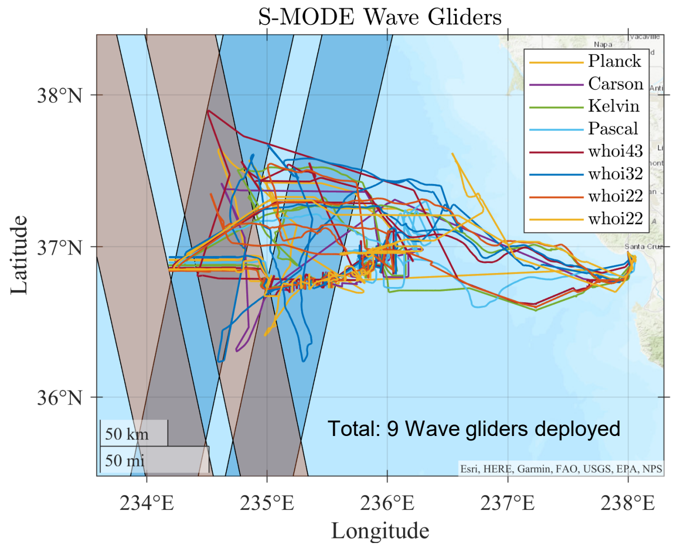
Leveraging NASA S-MODE IOP2 assets: In-situ observations from fleet of instrumented Wave Gliders

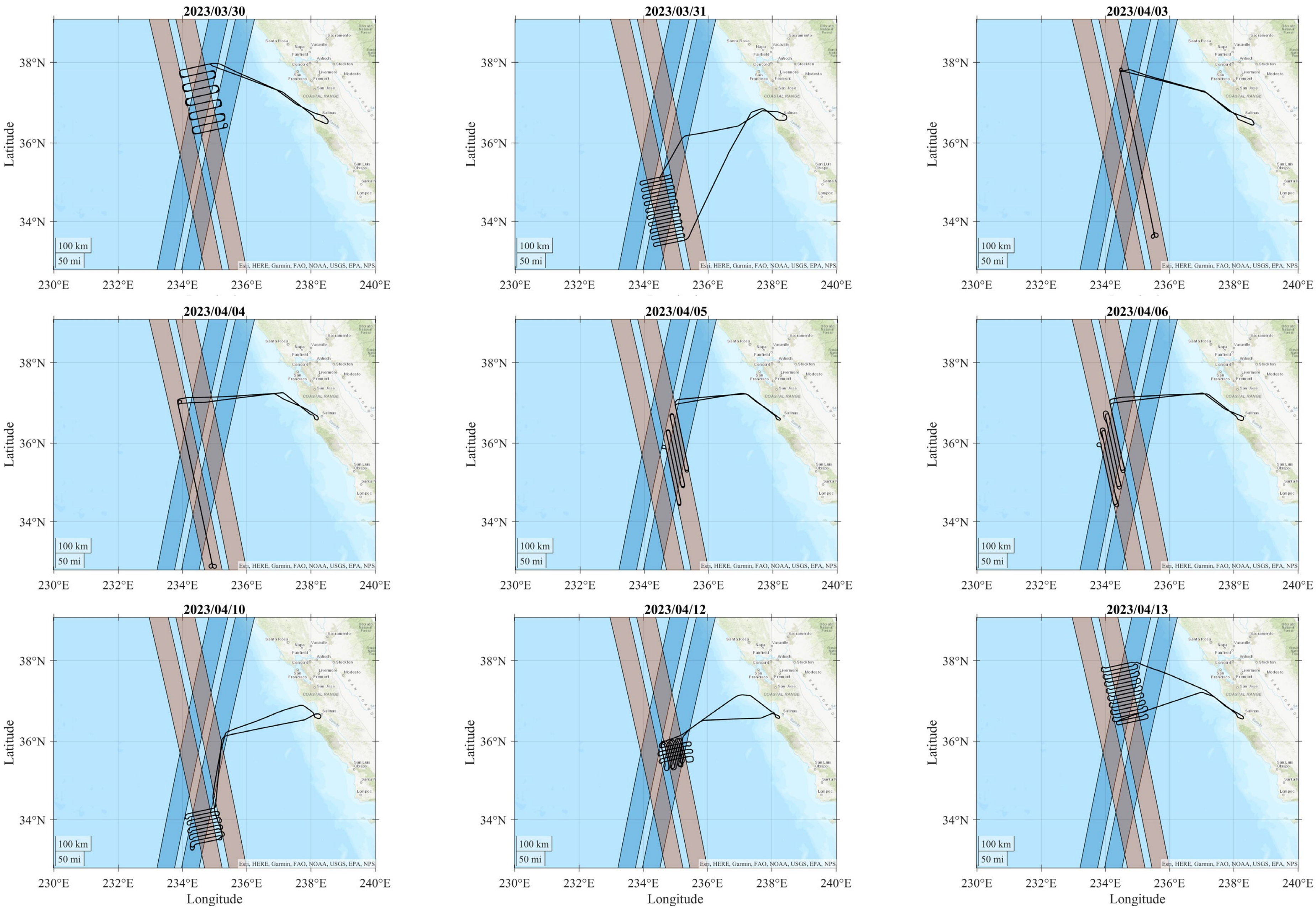








Phase I – Flight tracks



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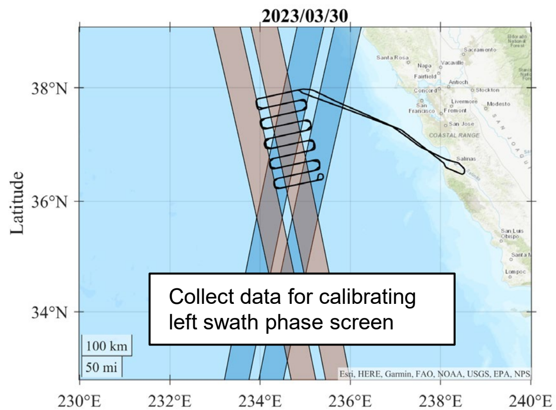

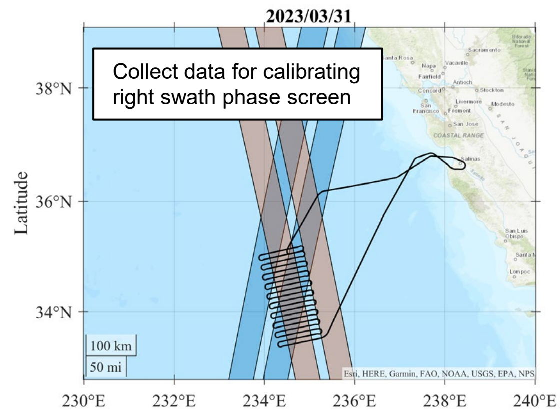

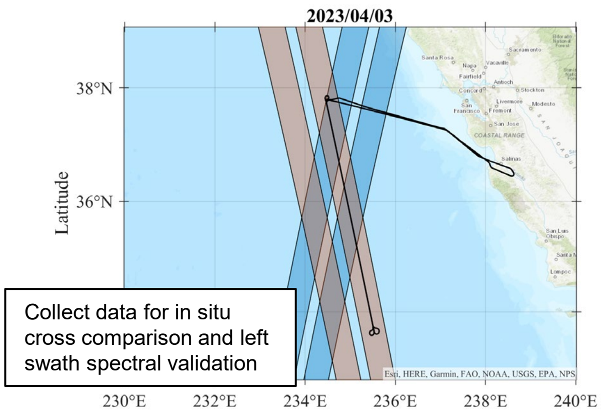

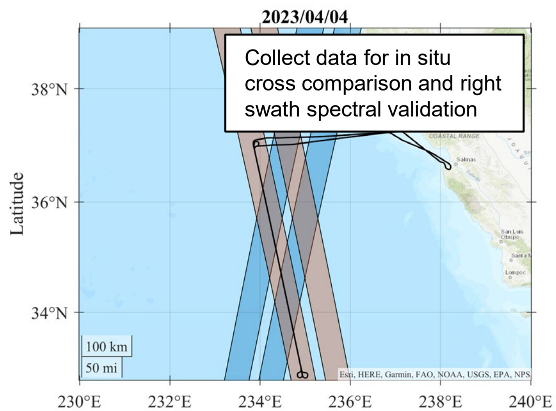

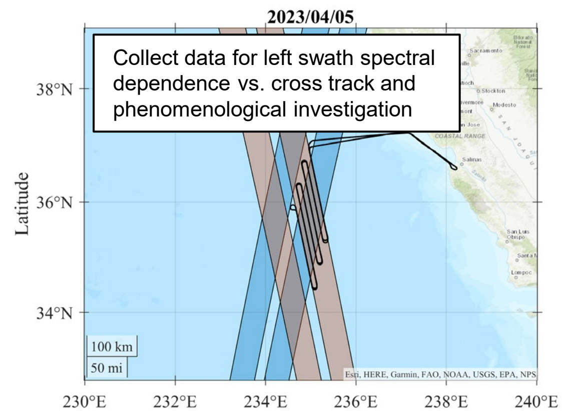

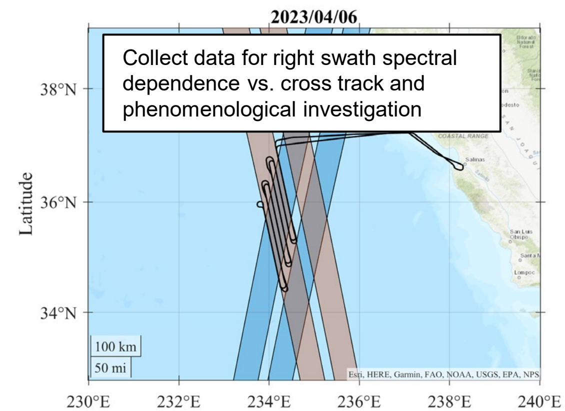

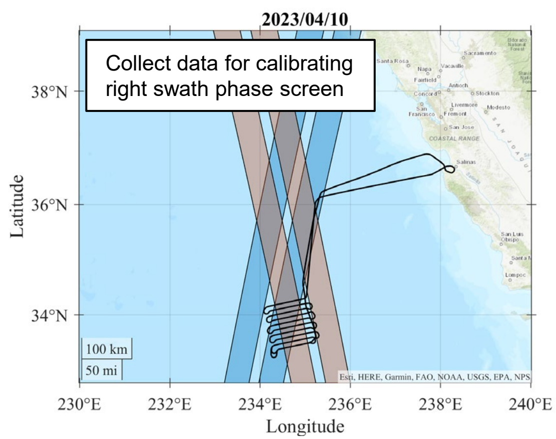

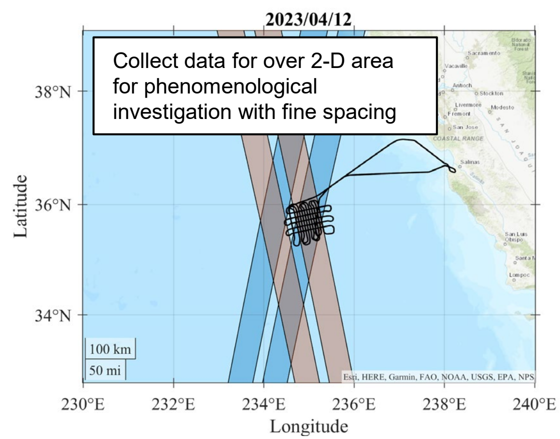

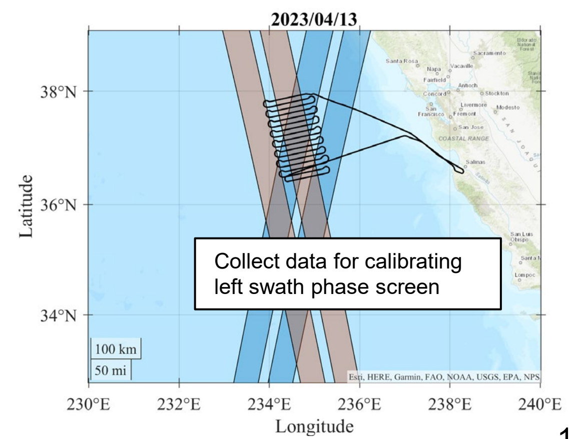

Phase II – Flight tracks

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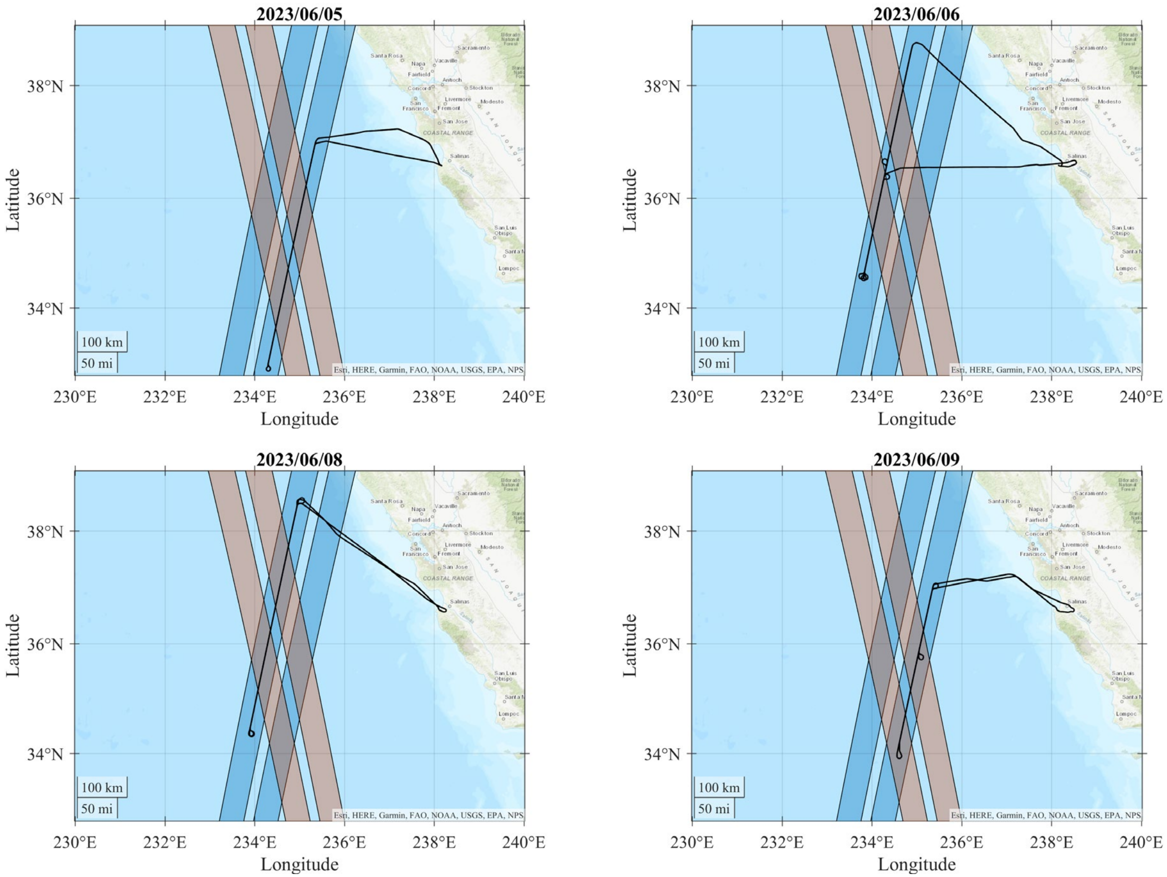

Phase I – March 30 2023 – SST, SSHA, Hs

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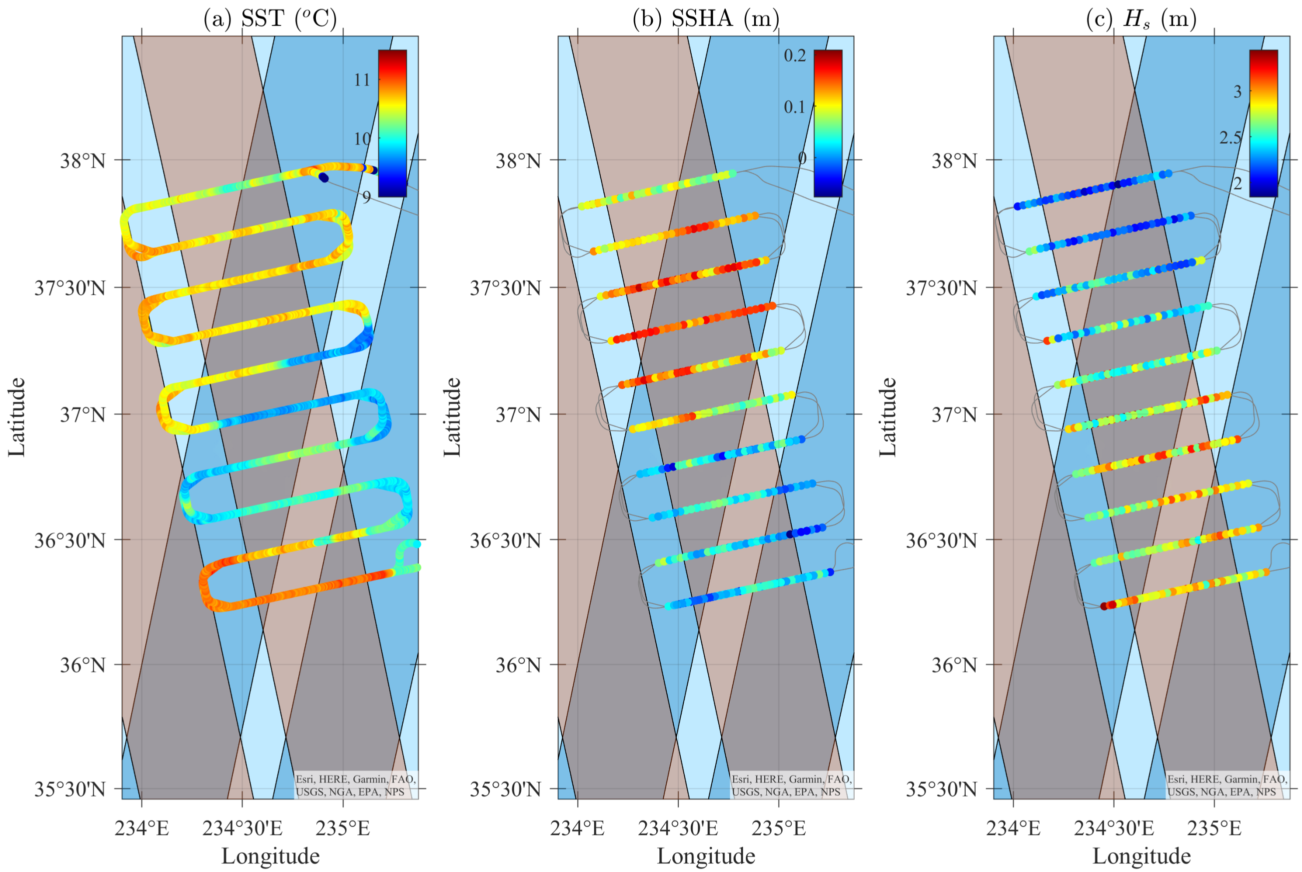
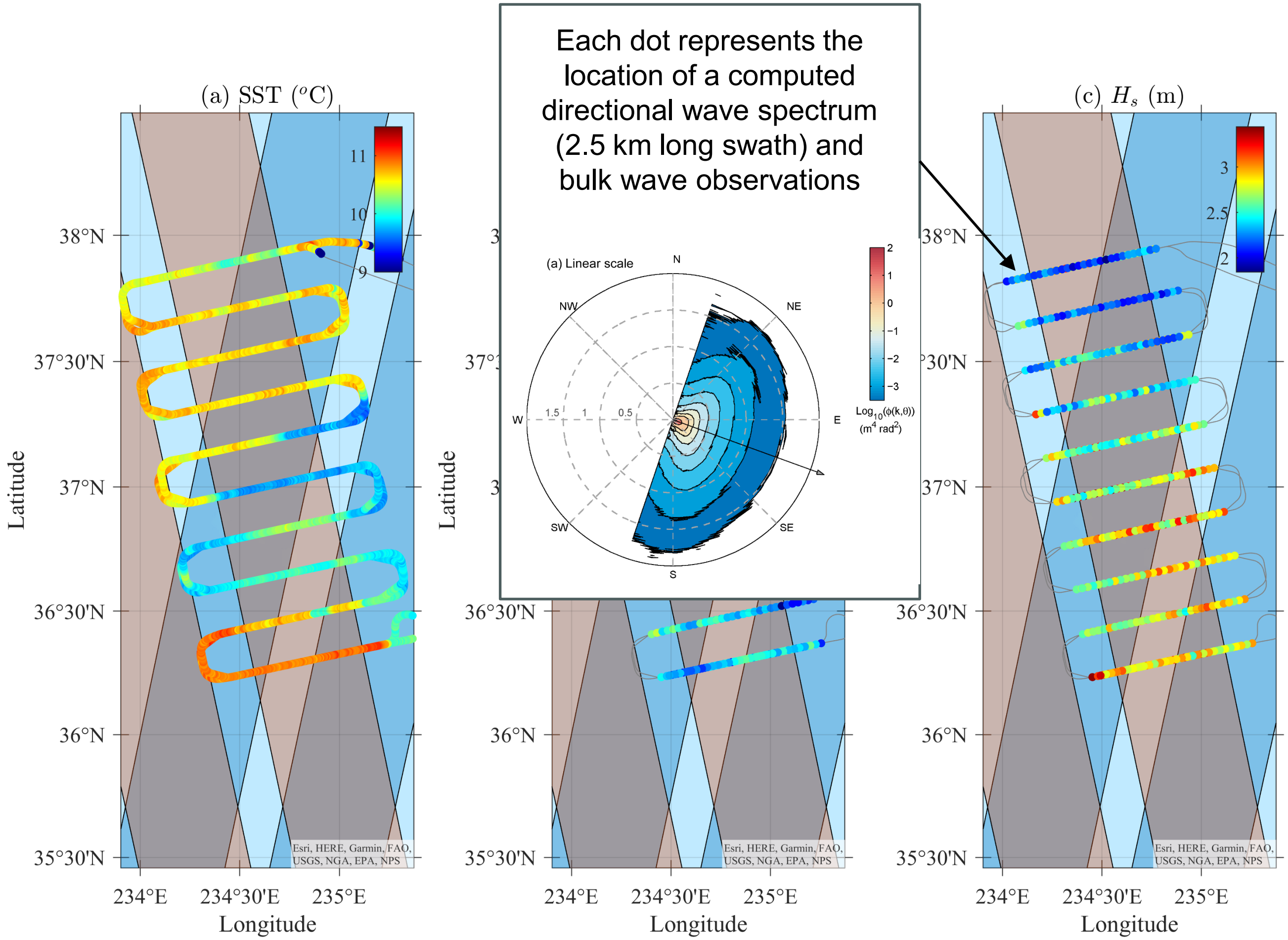
2.5km resolution products

Note the significant variability in significant wave height



Phase I – March 30 2023 – SST, SSHA, Hs

2.5km resolution products



Phase I – March 30 2023 – SST, SSHA, Hs

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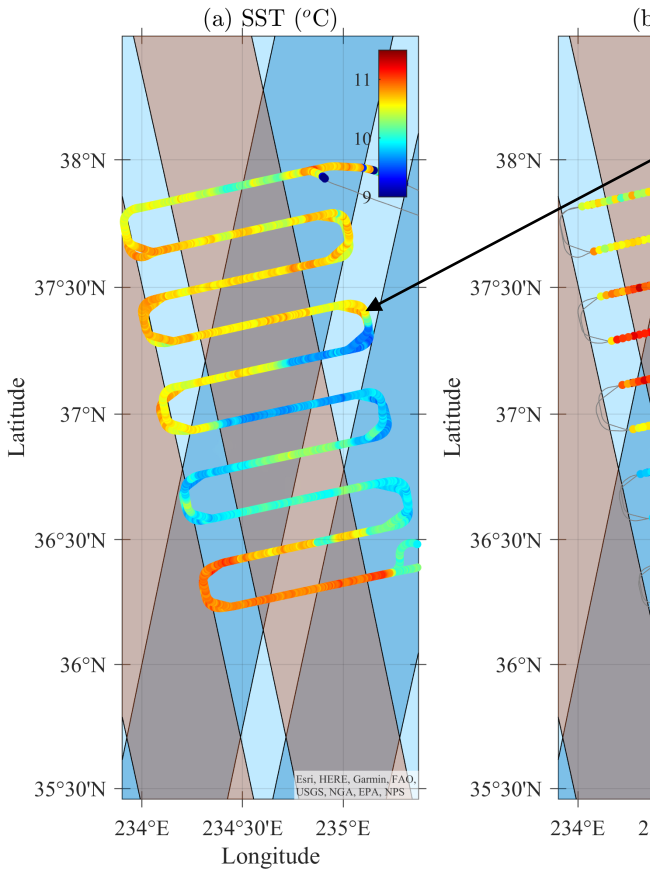
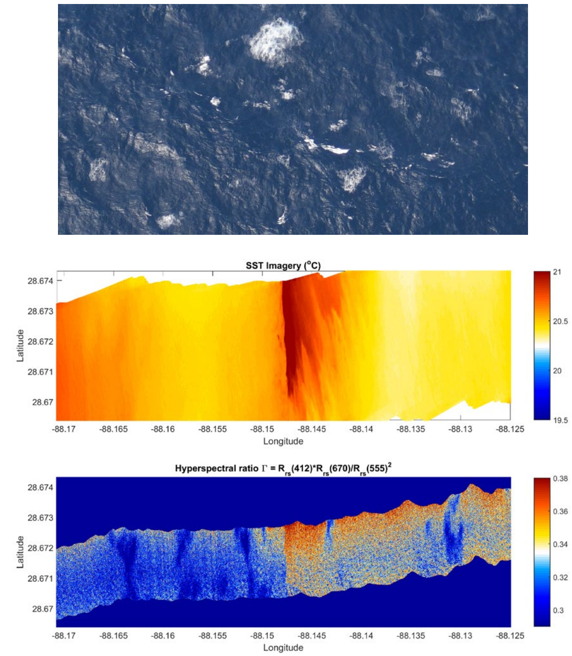
2.5km resolution products



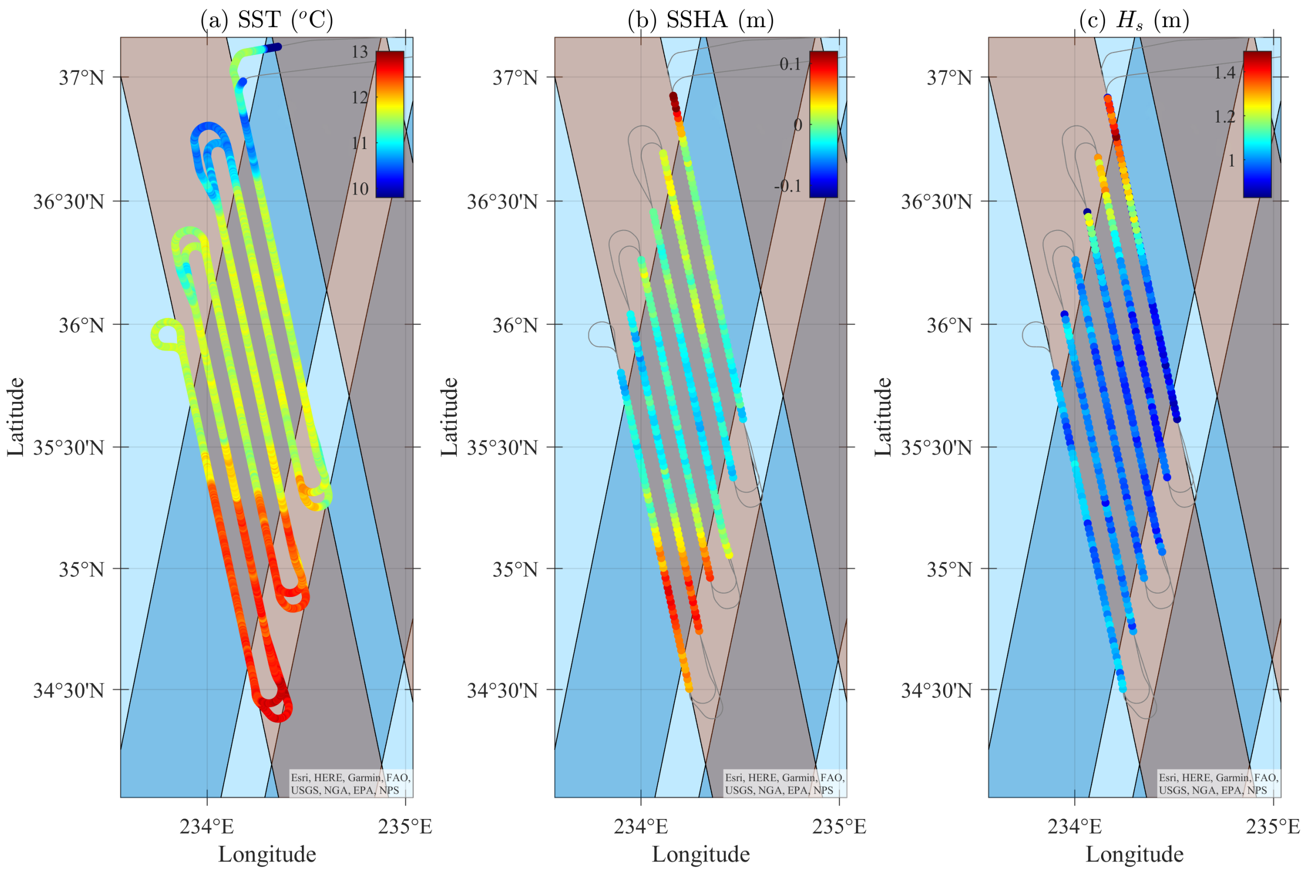
High-resolution IR, visible and hyperspectral imagery also available along the track of the aircraft



Phase I – April 6 2023 – SST, SSHA, Hs

2.5km resolution products

- Collect data for right swath spectral dependence vs. cross track and phenomenological investigation.



Phase I – April 6 2023 – SST, SSHA, Hs +SWOT preliminary data

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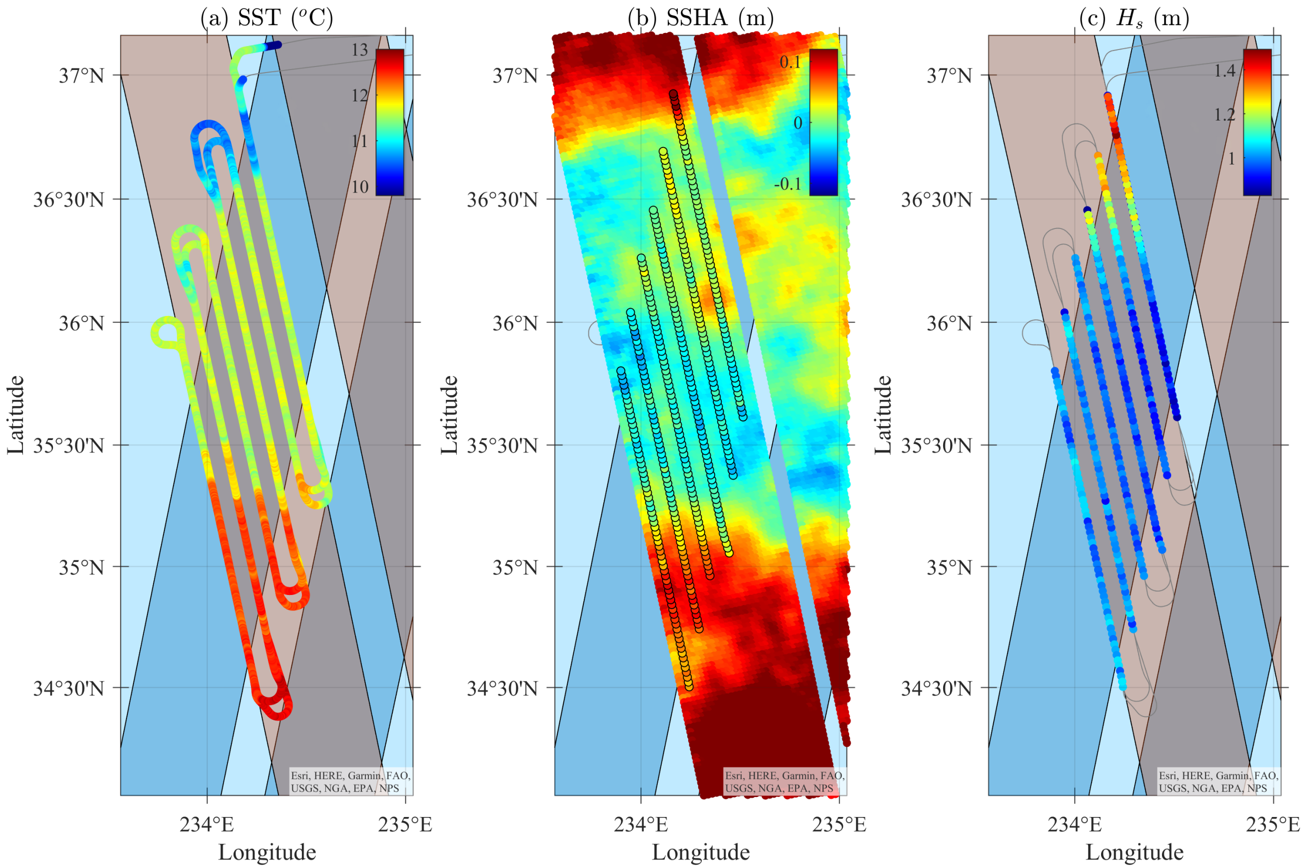
2.5km resolution products

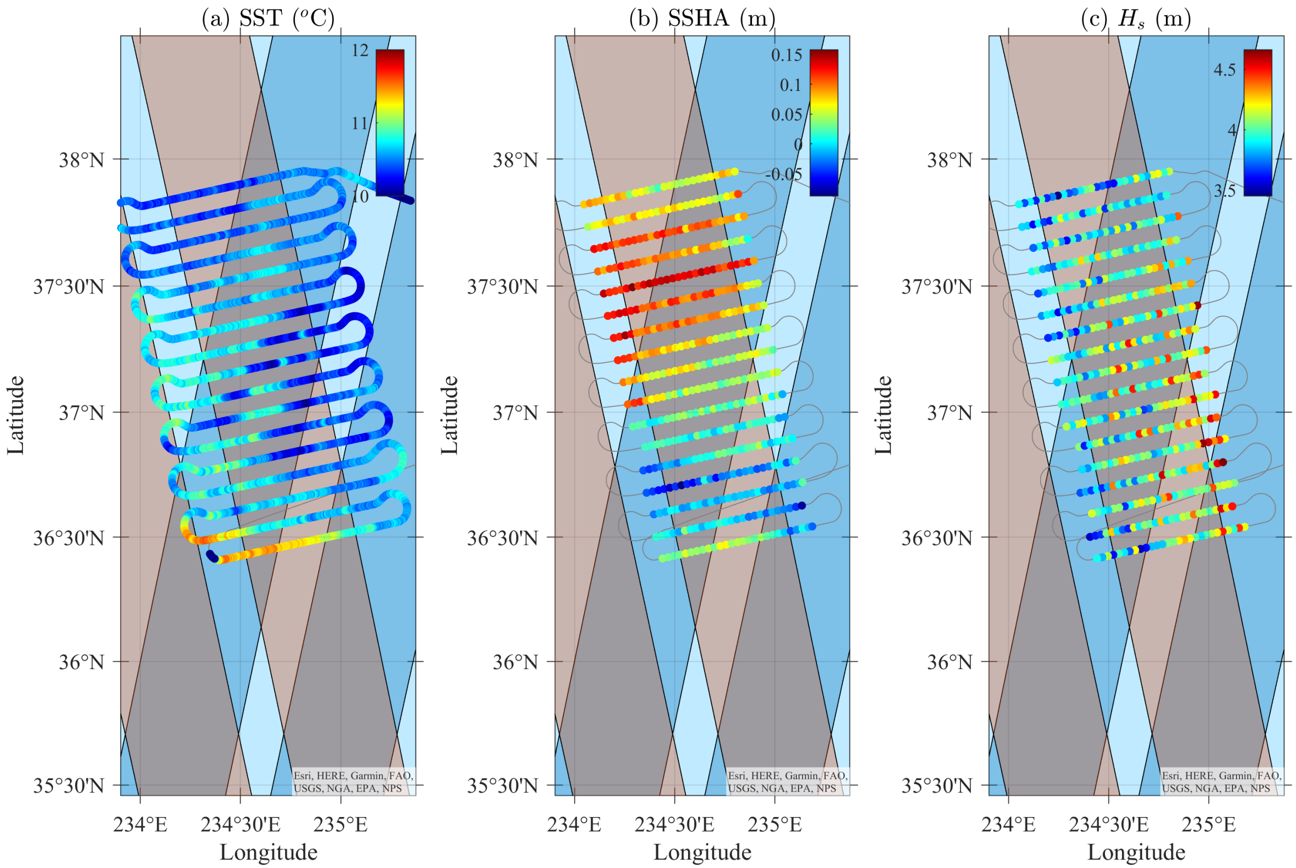
- Collect data for right swath spectral dependence vs. cross track and phenomenological investigation.
- Preliminary SWOT observations (offline processing) with empirical cross-swath correction.



Phase I – April 13 2023 – SST, SSHA, Hs

2.5km resolution products

- Collect data for calibrating left swath phase screen.



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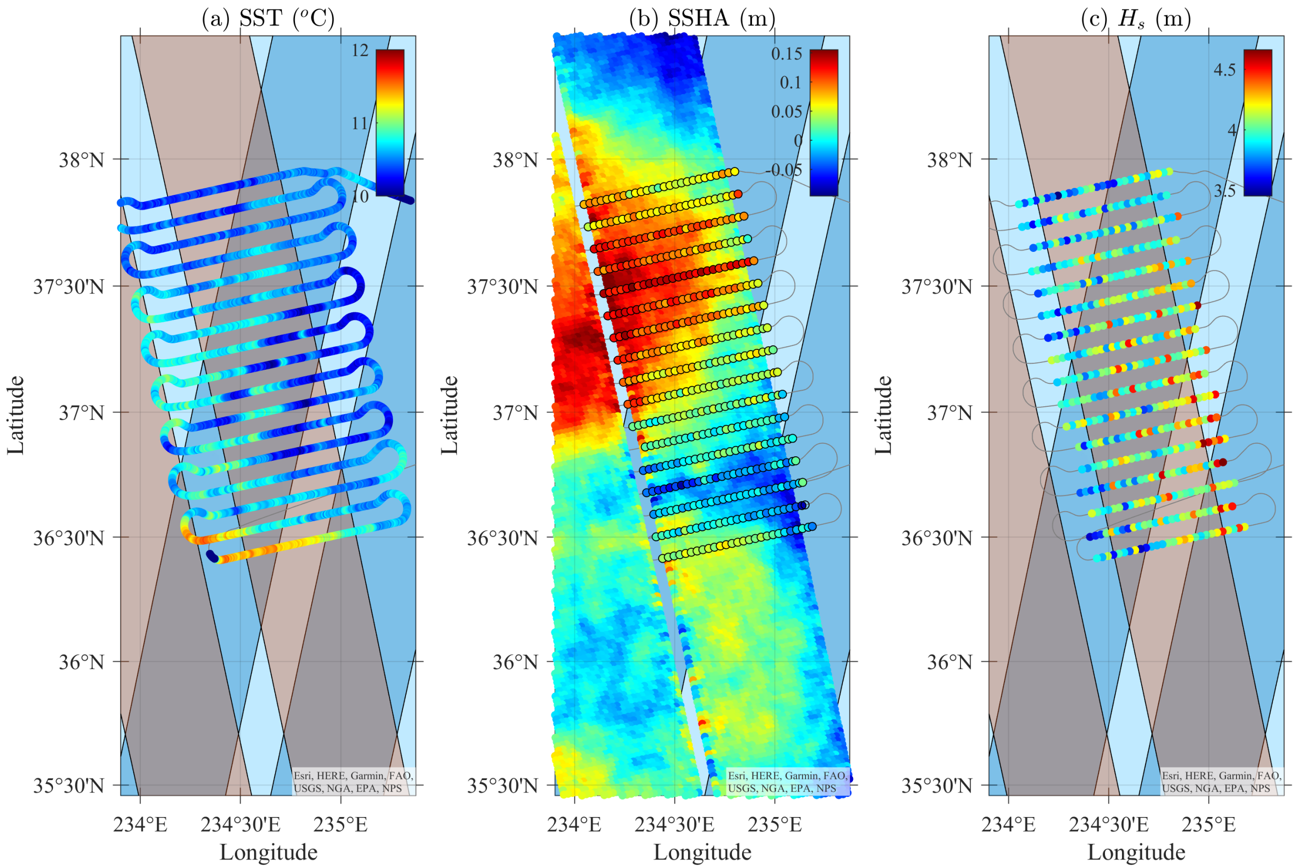
2.5km resolution products

- Collect data for calibrating left swath phase screen.
- SWOT observations (offline processing) with better calibration applied.



2.5km resolution products

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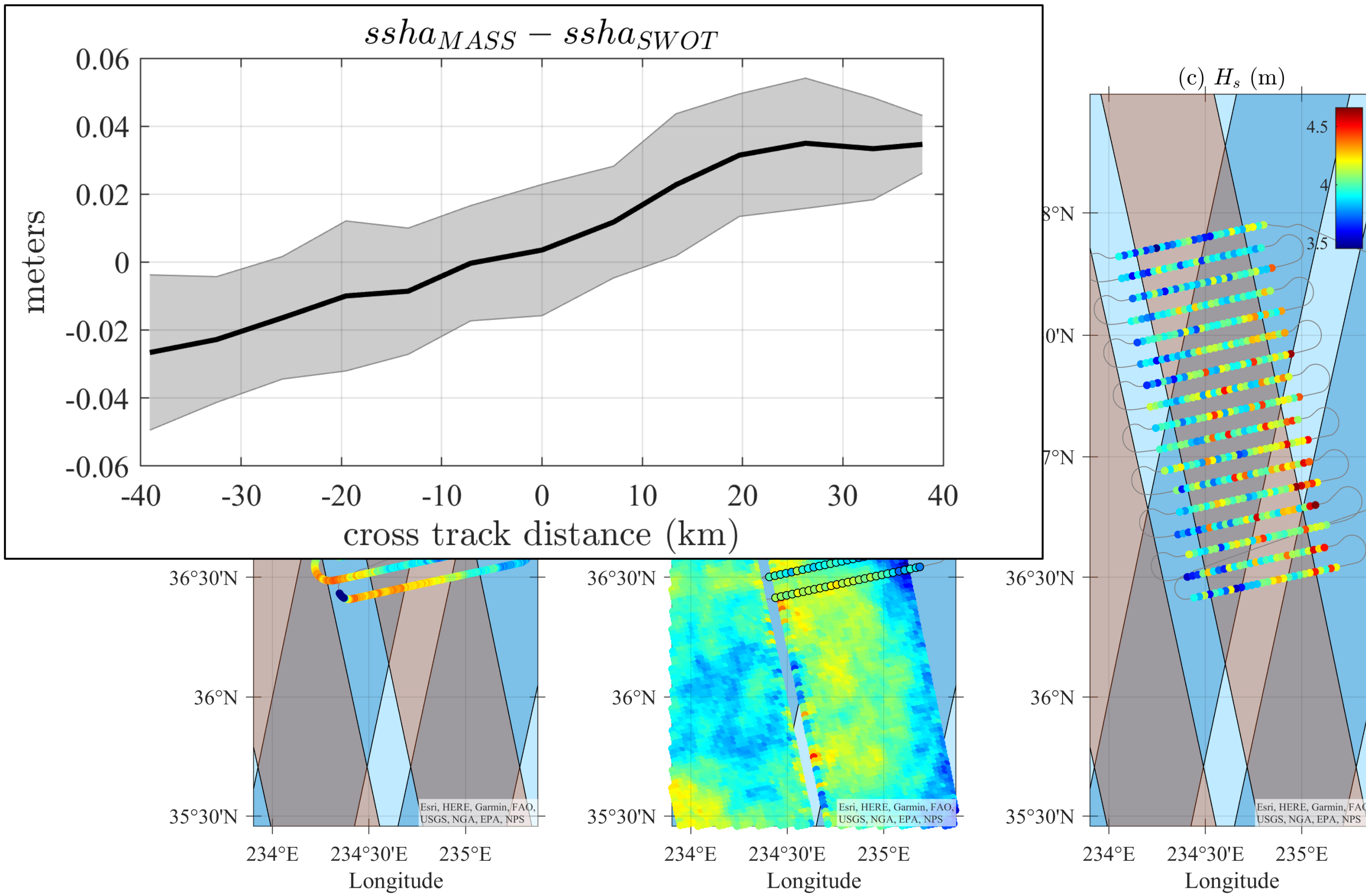
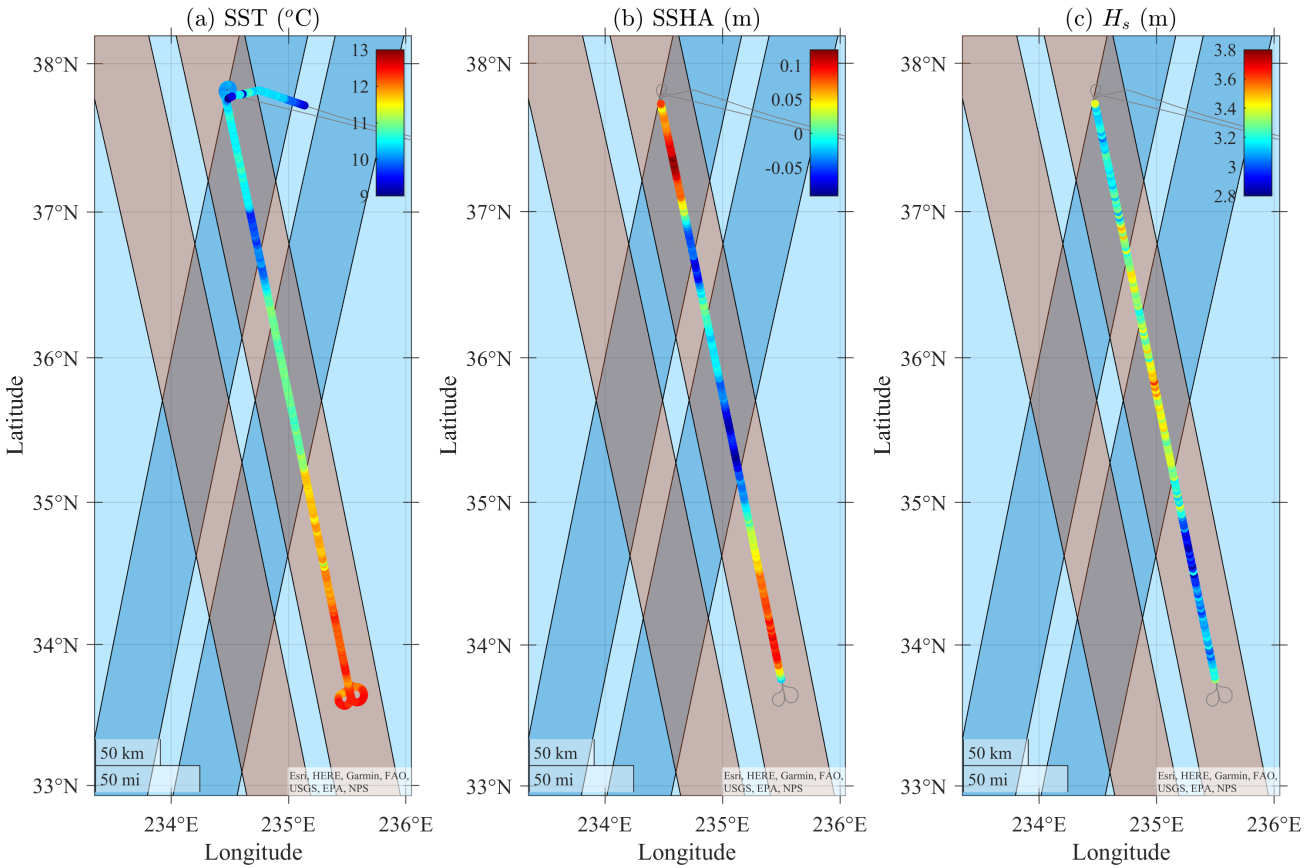


Phase I – April 3 2023 – SST, SSHA, Hs

2.5km resolution products

- Collect data for in situ cross comparison and left swath spectral validation



Phase I – April 3 2023 – SST, SSHA, Hs

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2.5km resolution products

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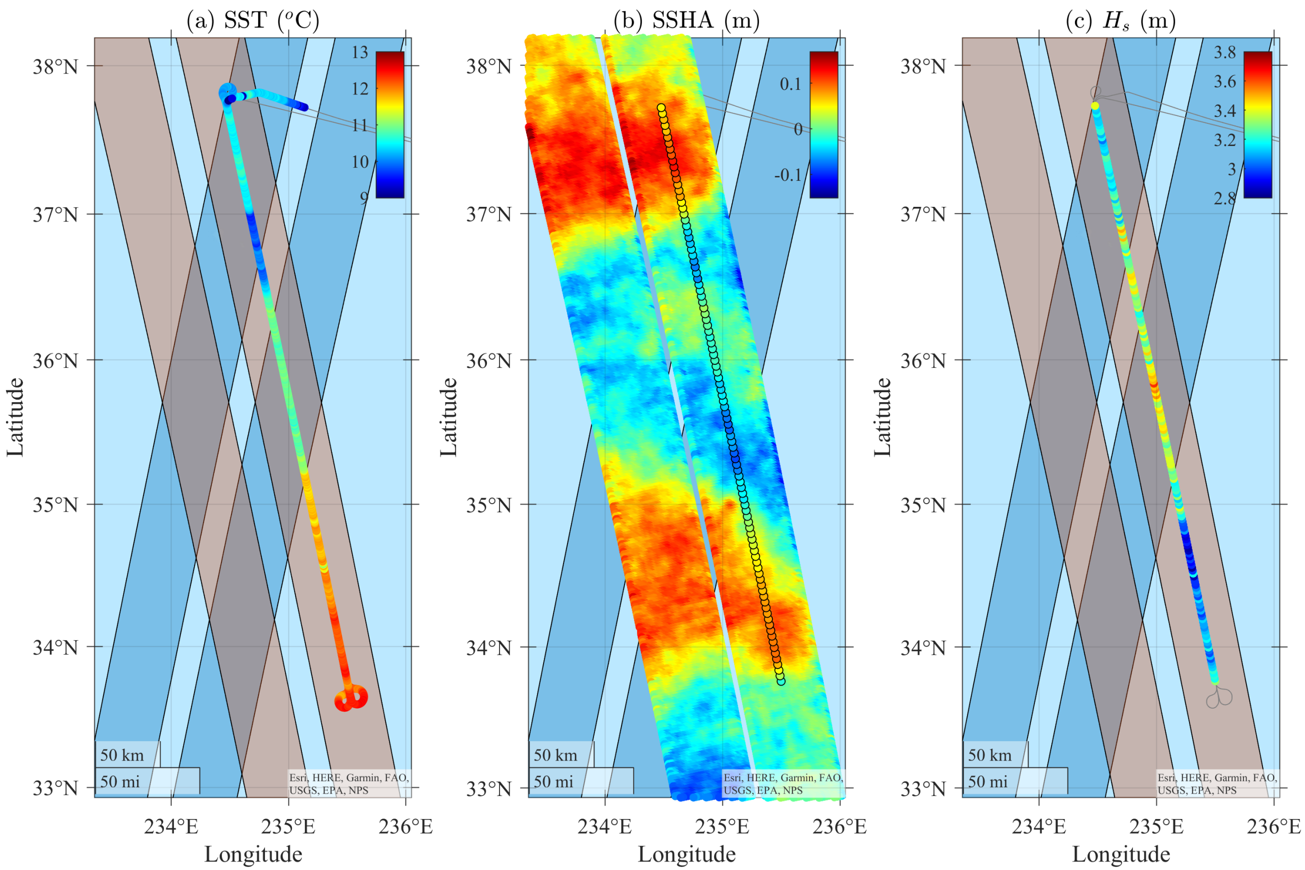
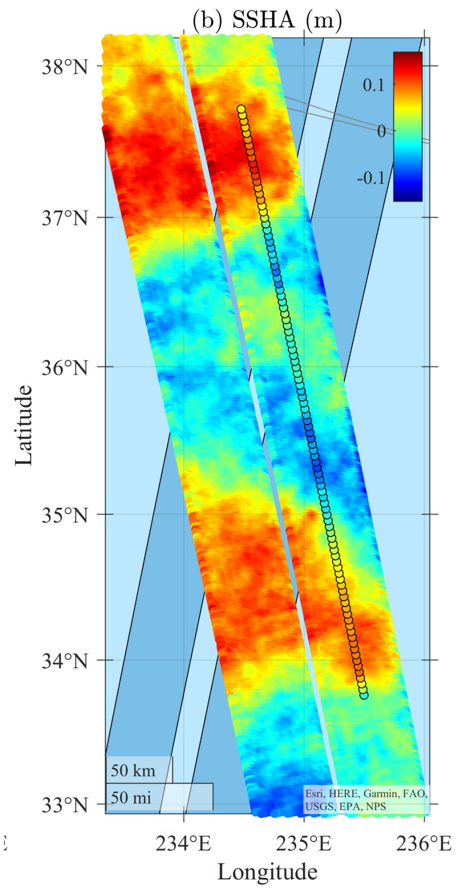
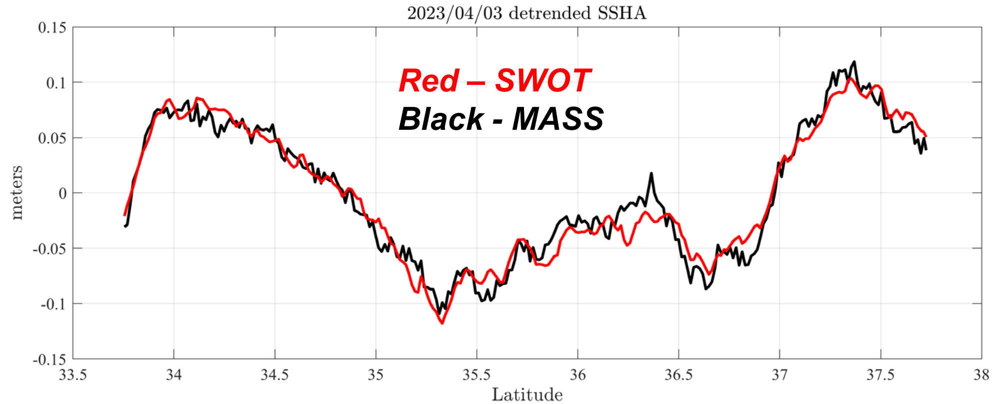
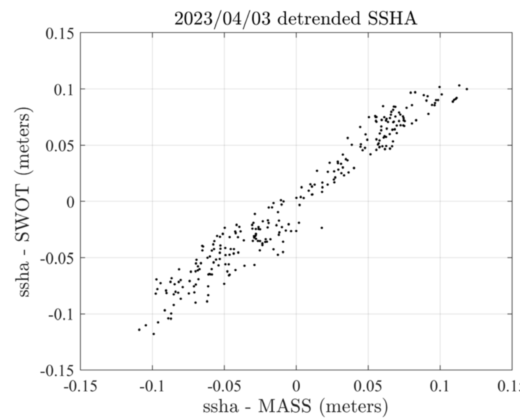


Phase I – April 3 2023 – SST, SSHA, Hs



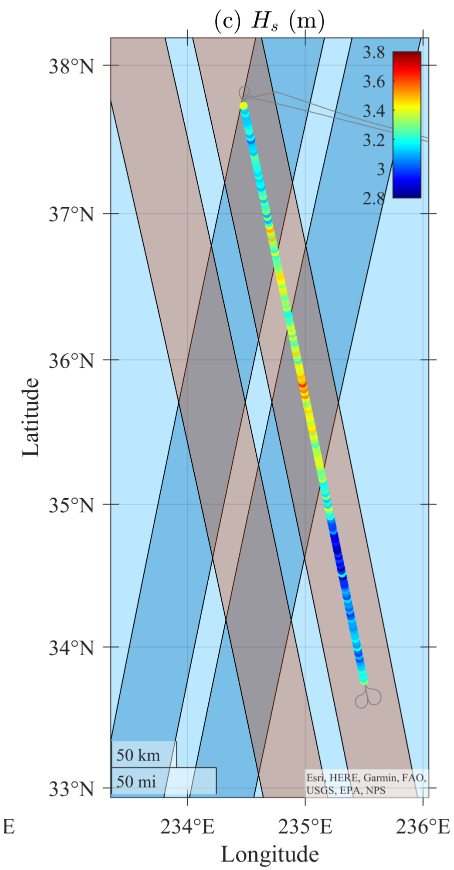


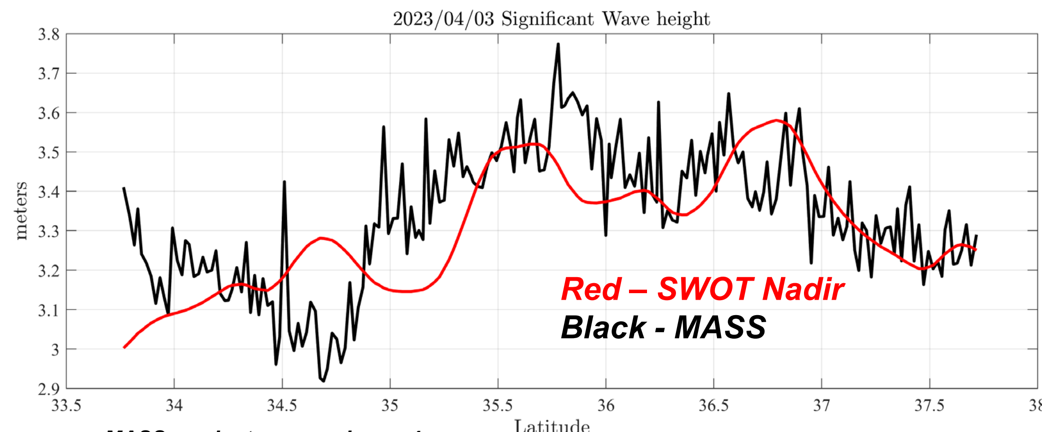
MASS product averaged over 4 passes



Phase I – April 3 2023 – SST, SSHA, Hs

2.5km resolution products





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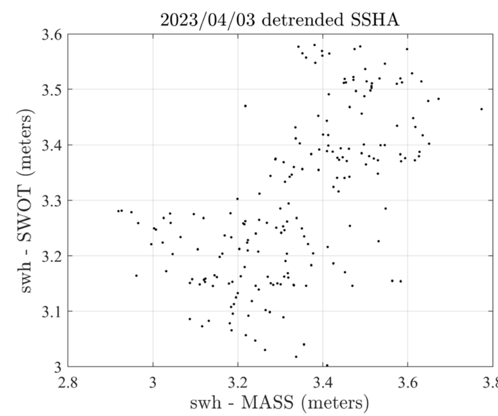

Summary

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- We report here on the MASS surveys conducted as part of the post-launch SWOT CalVal.
- 14 flights were conducted from the NASA JSC GV over a 3-week period (early April and first week of June 2023)
- MASS measurement of 2-D SSH under the SWOT swath enables direct comparison with SWOT data for SWOT calibration, validation, and troubleshooting
- MASS SST, hyperspectral, and other data will enhance overall understanding of SWOT phenomenology during Cal/Val