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武漢大學测绘学院
School of Geodesy and Geomatics, Wuhan University

High-Resolution Satellite Altimetry Observations Reveal New Details of Storm Surge

Presenter: Xu Xinzhe
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Email: 2019302140012@whu.edu.cn

自强、弘毅、求是、拓新

Background

Storm Disasters

Strong Winds

Heavy Rain

Primary Disasters

Storm Surge

Secondary Disasters

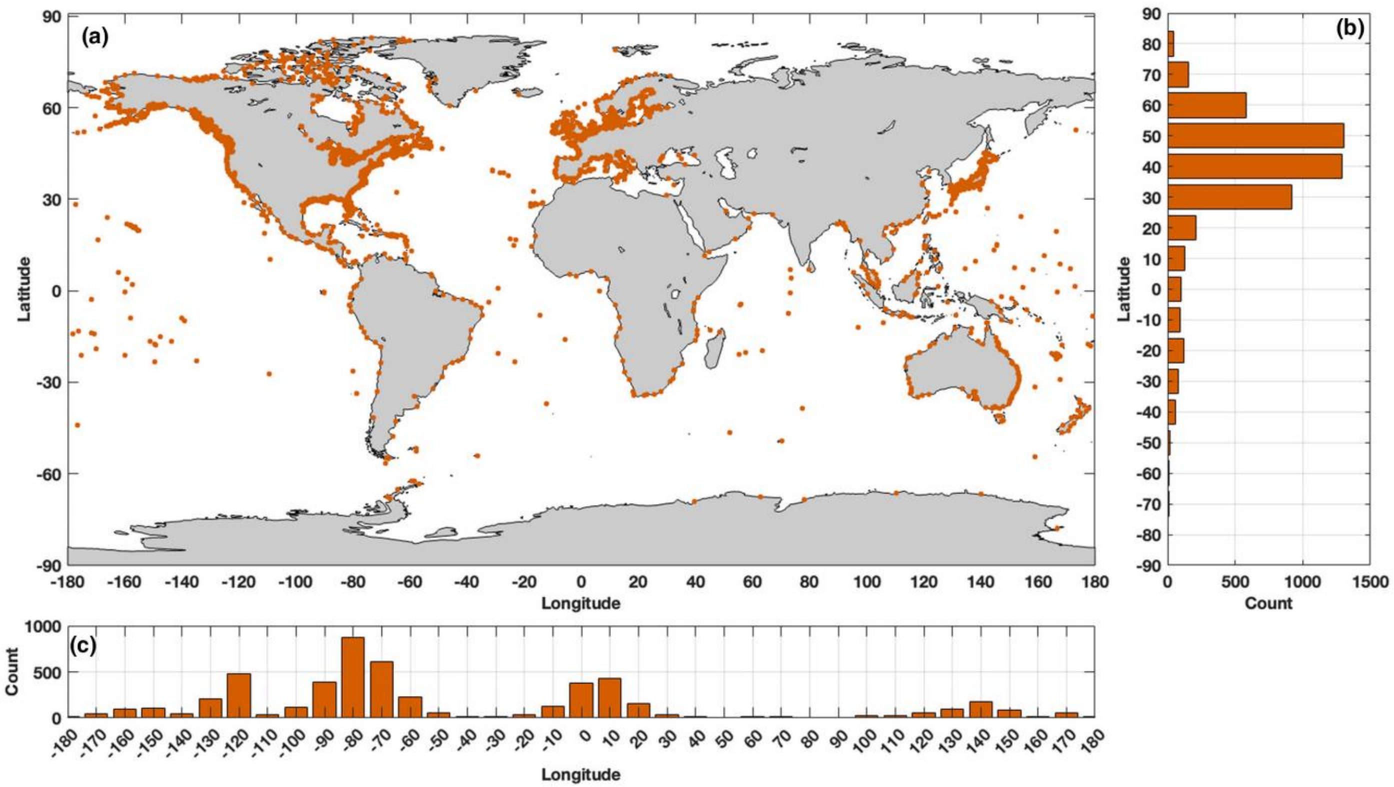
Urban Flooding

Agricultural Losses

Current Monitoring Methods

Tide Gauges

- Storm surge monitoring mainly relies on tide gauges distributed along the coast. Tide gauges can provide continuous and high-frequency water level monitoring, but they are sparsely distributed, provide single-point observations, and are only arranged along the coast.



Global Extreme Sea Level Analysis Version 3 (GESLA-3)（Haigh et al., 2023）

However, most of the storm surge development process occurs in the open ocean!

Satellite altimetry in Storm Surge Observation

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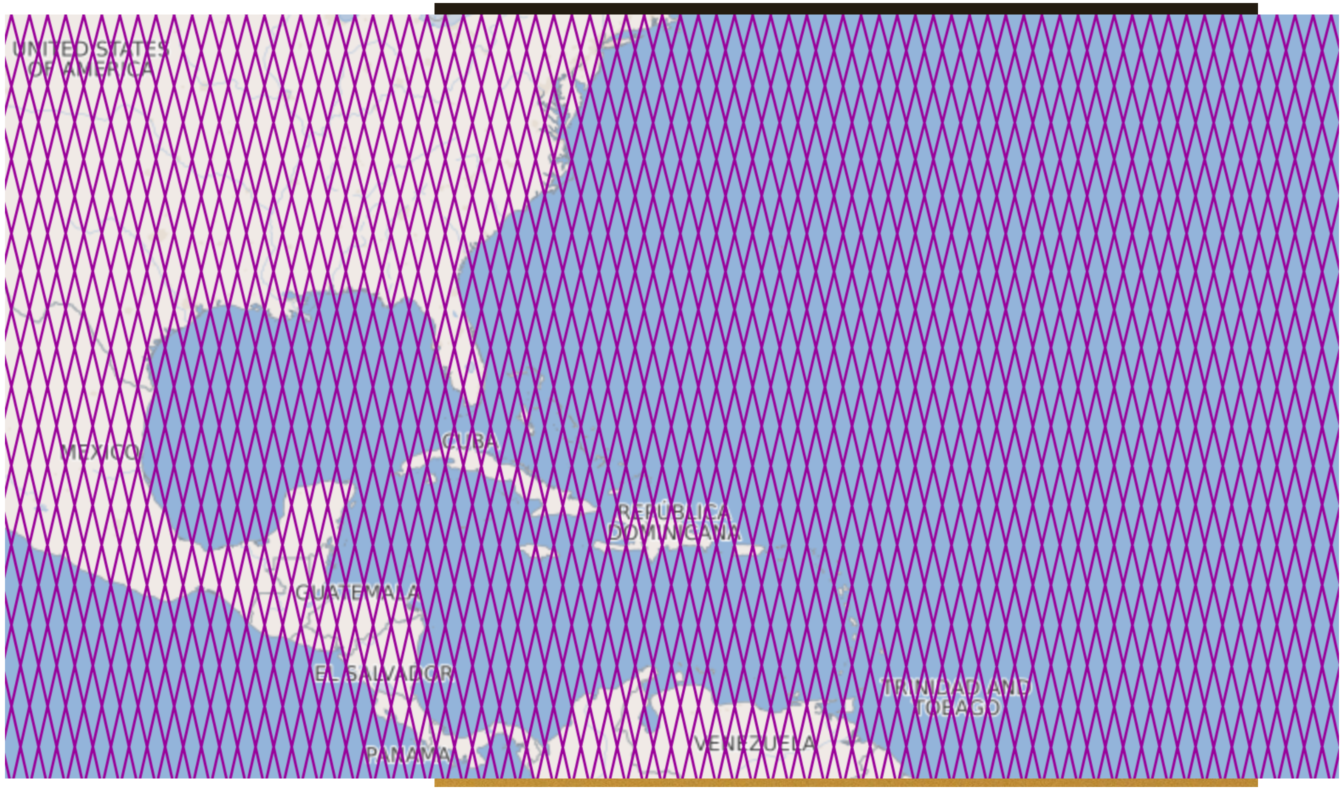
Satellite altimetry

- Satellite altimetry is a technology that uses satellites to observe sea level from space.
- Some researchers have used satellite altimetry to observe storm surge signals.

- However, traditional altimetry satellites can only provide one-dimensional along-track observation data.

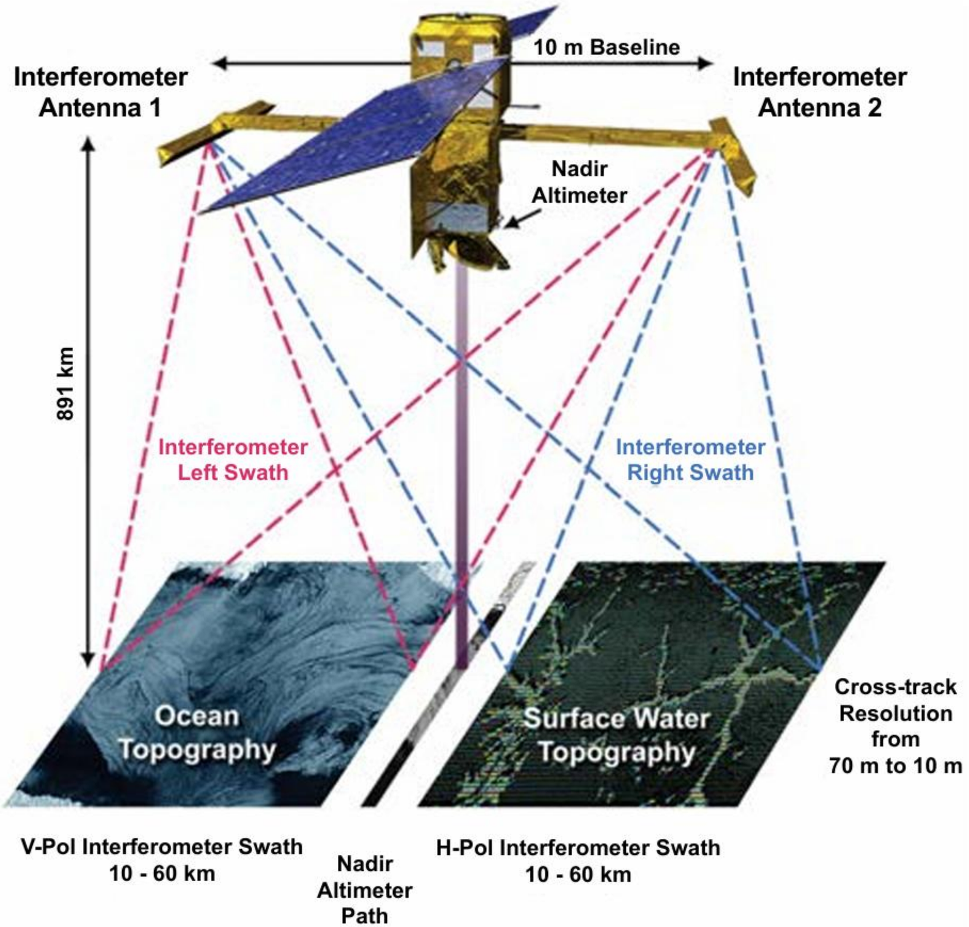


Track of Traditional altimeter
（From OpenADB）

Altimetry Principle
（From AVISO）

SWOT in Storm Surge Observation

SWOT Satellite



SWOT Measurement System
（From JPL）

- SWOT（Surface Water Ocean Topography）provides global, high-resolution, wide-swath sea surface height measurements.
- 120km swath width, global 90% coverage, millimeter-level precision.

SWOT in Storm Surge Observation

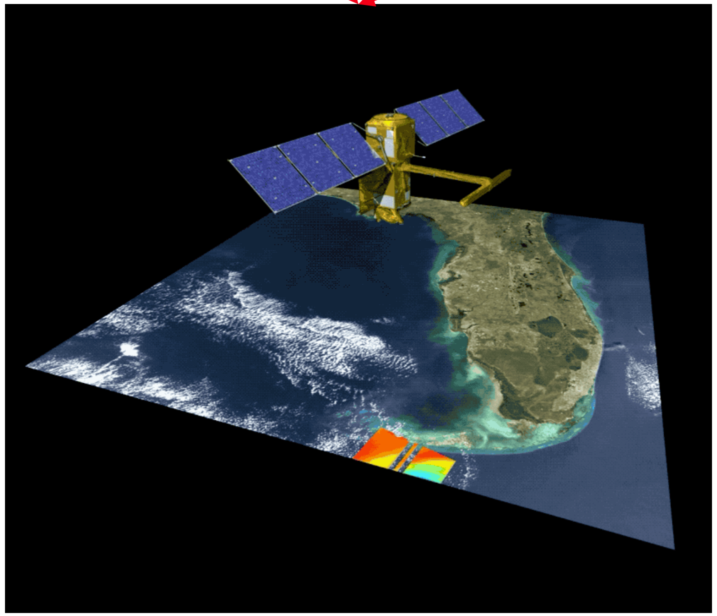
Tide Gauge

- Coastal distribution.
- Sparse distribution.
- Single-point observation.

Traditional Satellite Altimetry

- Along-track one-dimensional observation.
- Limited coverage.

Wide Swath



Coast and Open Ocean

Space coverage of SWOT

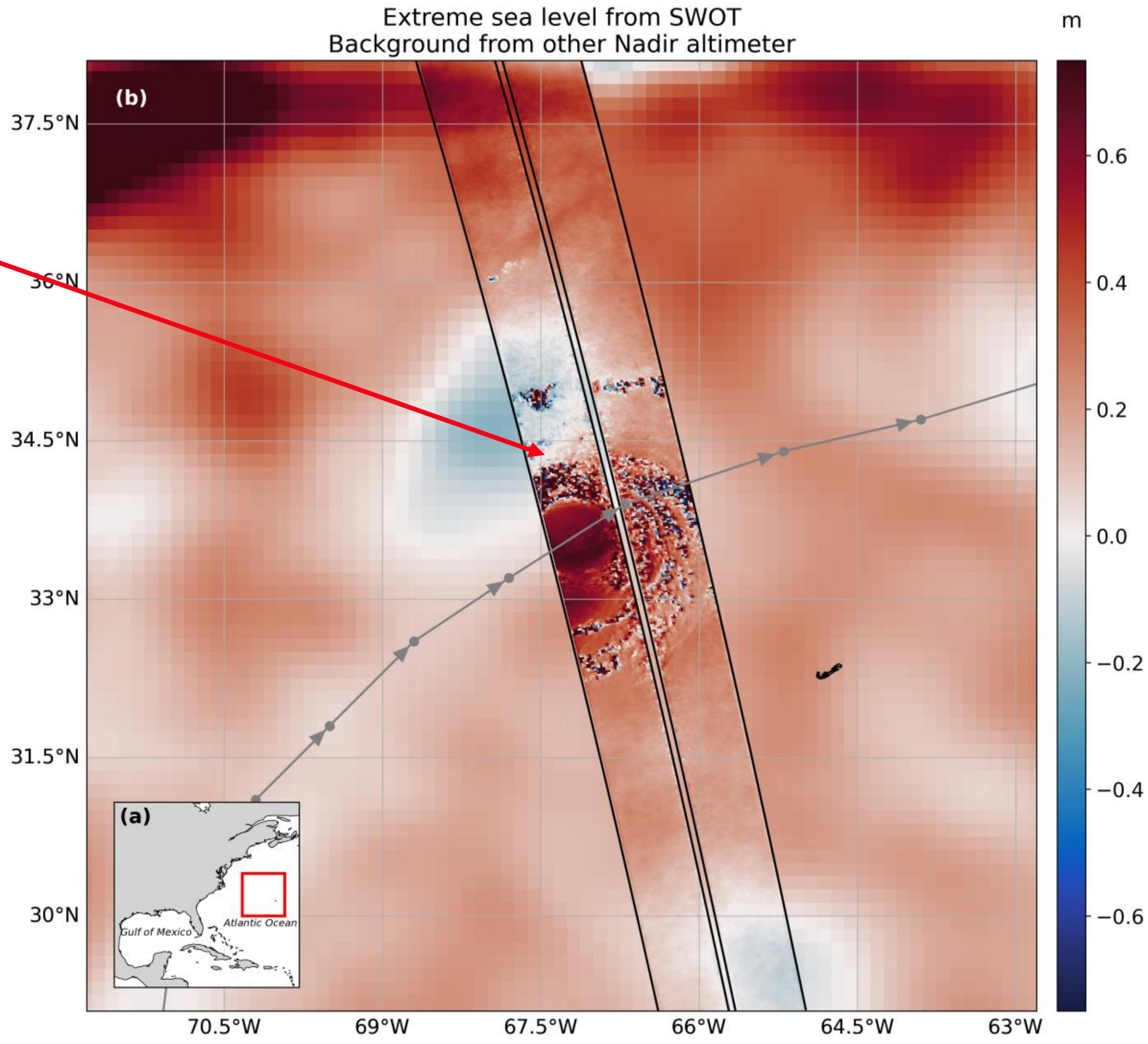
Challenges in Storm Surge Observation

1.Rain Interference

- SWOT observations are heavily affected by rainfall, with highly non-uniform disturbance.

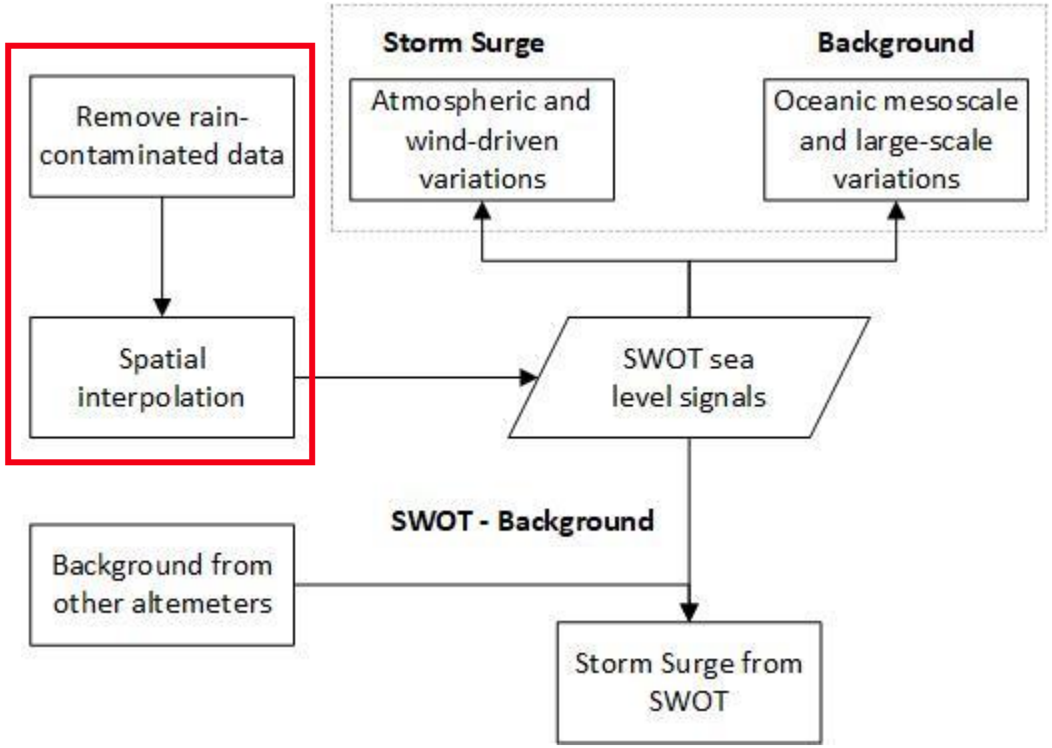
2.Difficult Validation

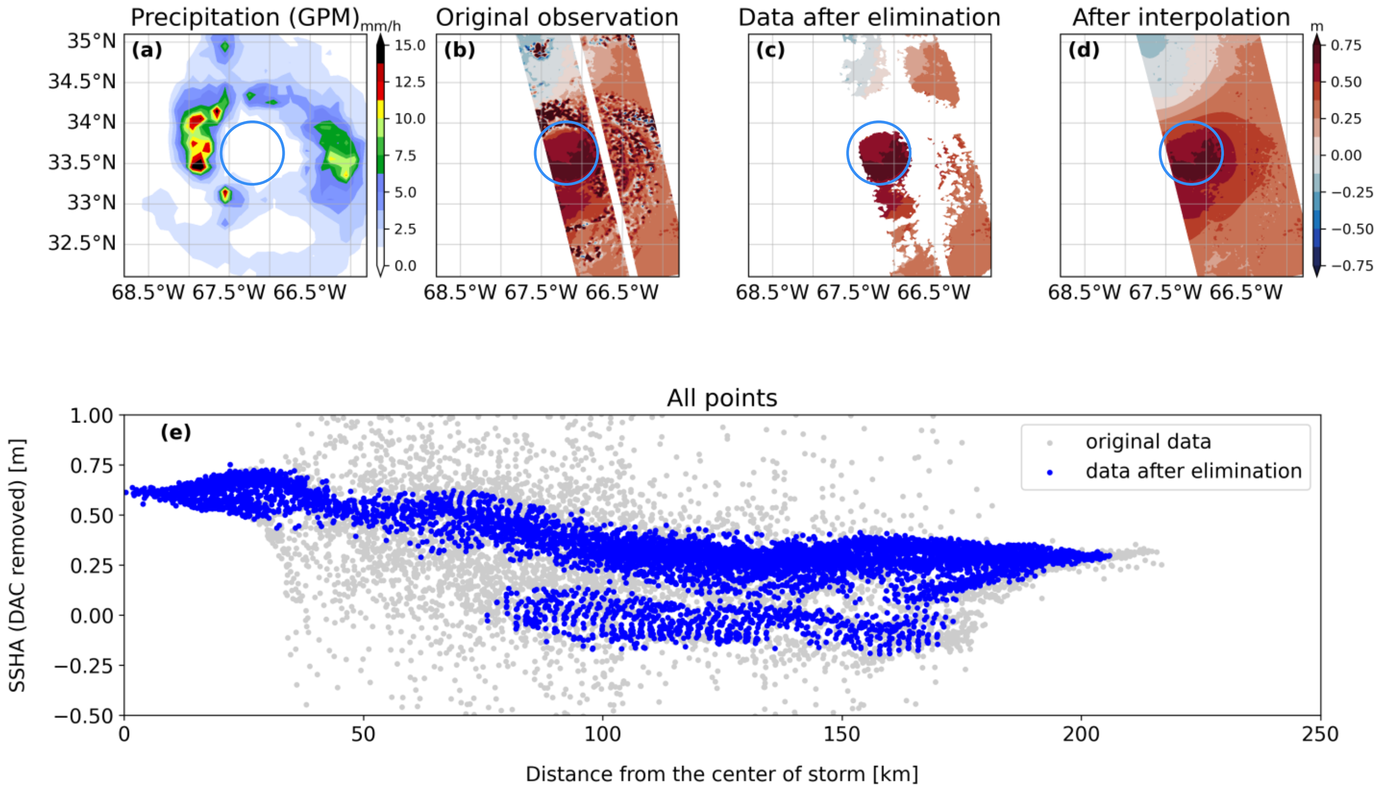
- Few in-situ data exit in the open ocean for validation.



Data processing approach

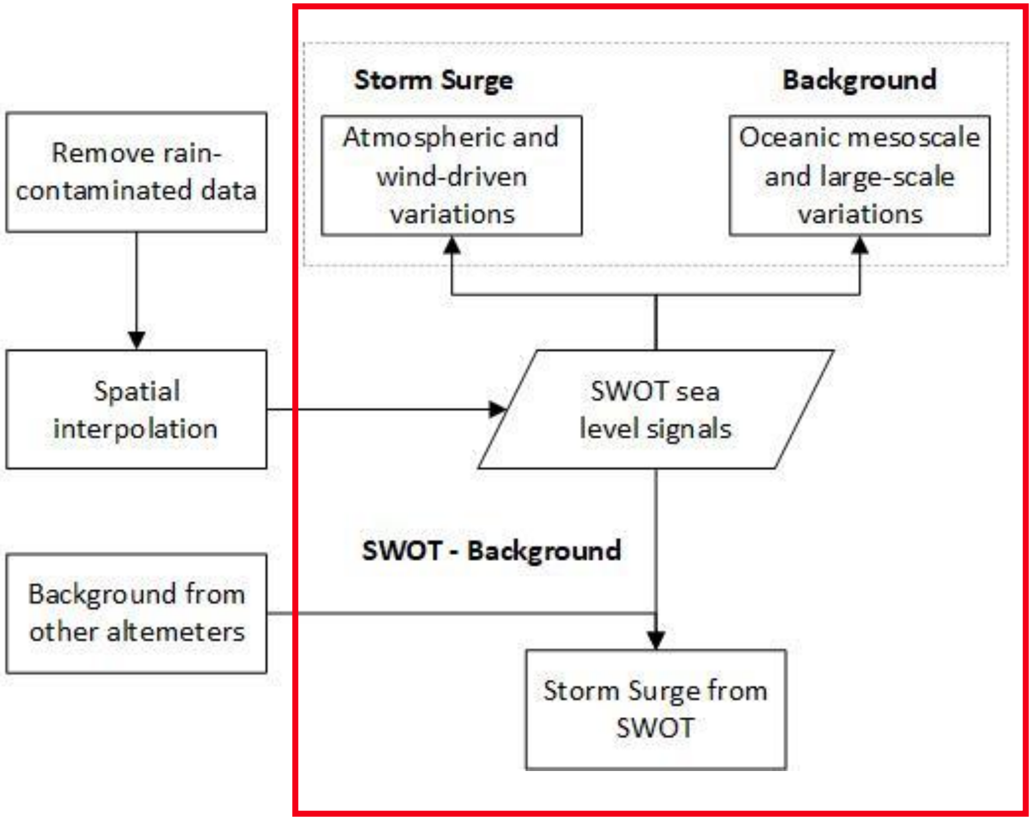
Data elimination and Interpolation

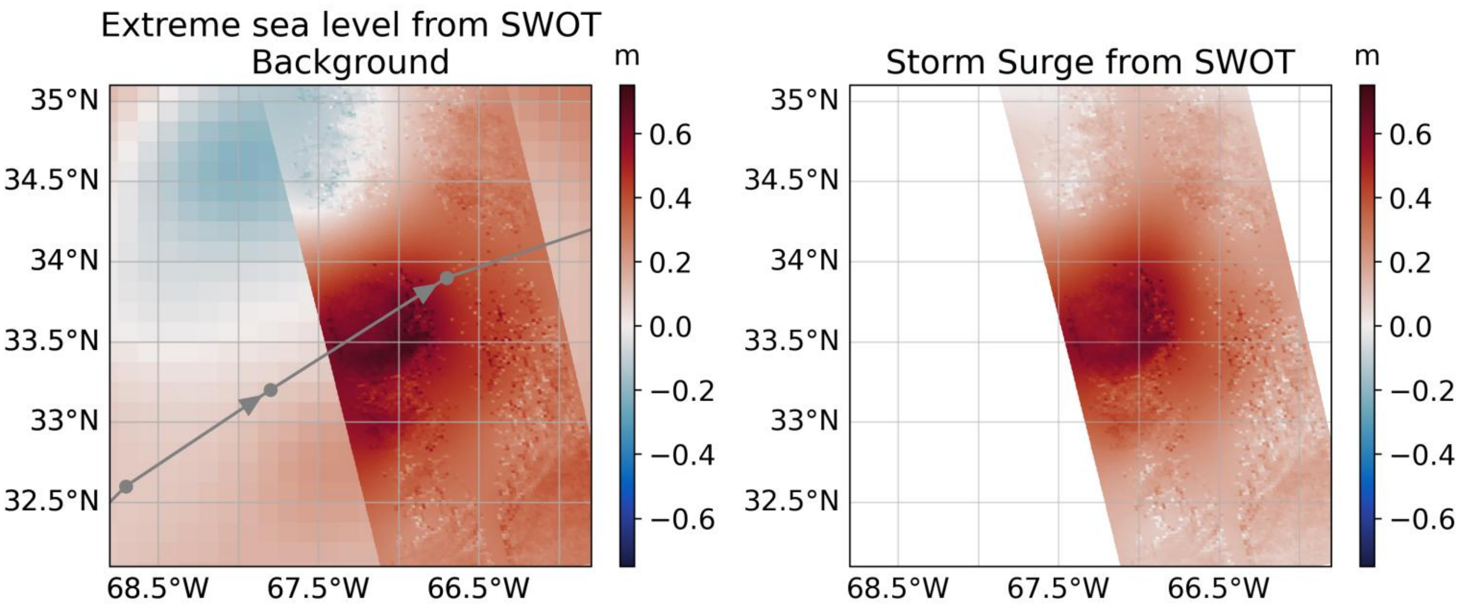




Data processing approach

Extracting Storm Surge from SWOT





Storm Surge Simulation

ADCIRC Simulation

Atmospheric Forcing

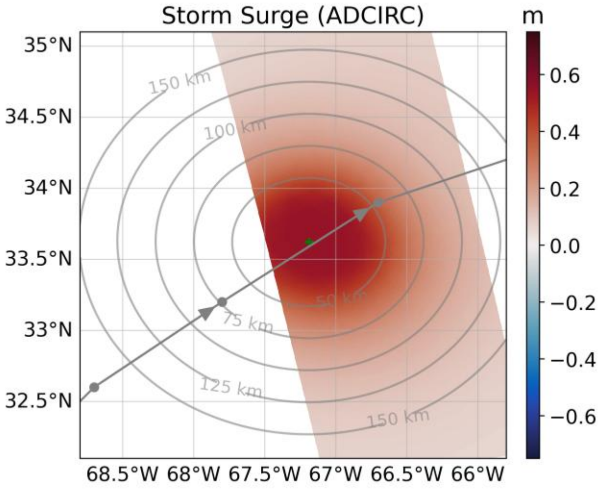
ATCF Best Track file

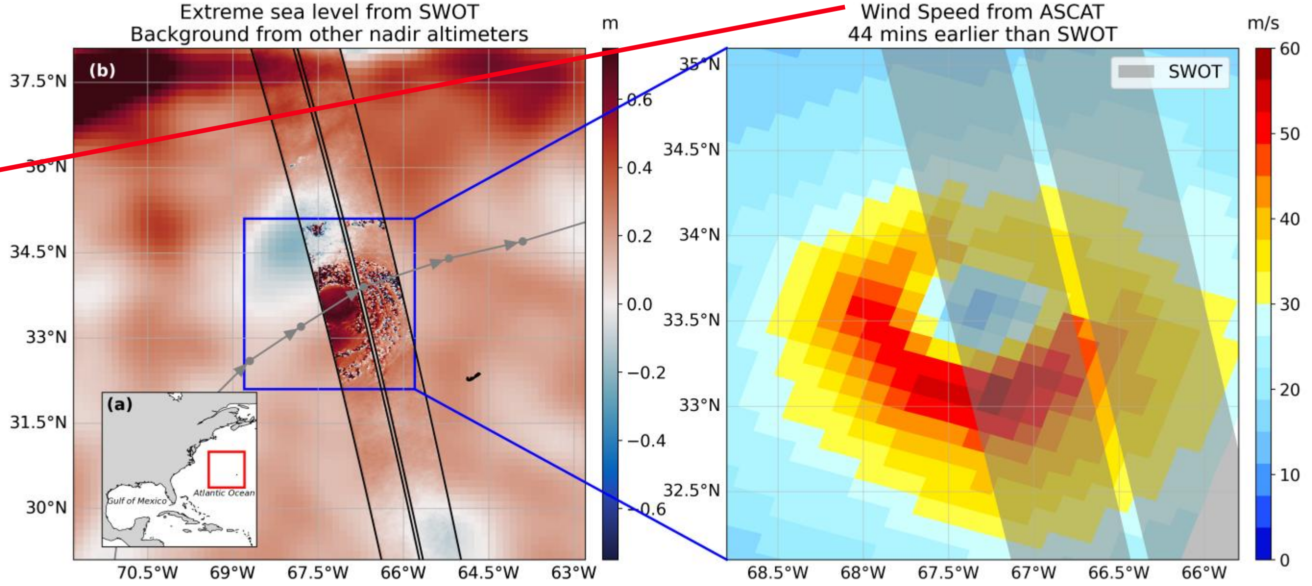
To modify best track file

Wind Speed Data from ASCAT

ADCIRC without tide and wave

Storm Surge from ADCIRC





Preliminary Results

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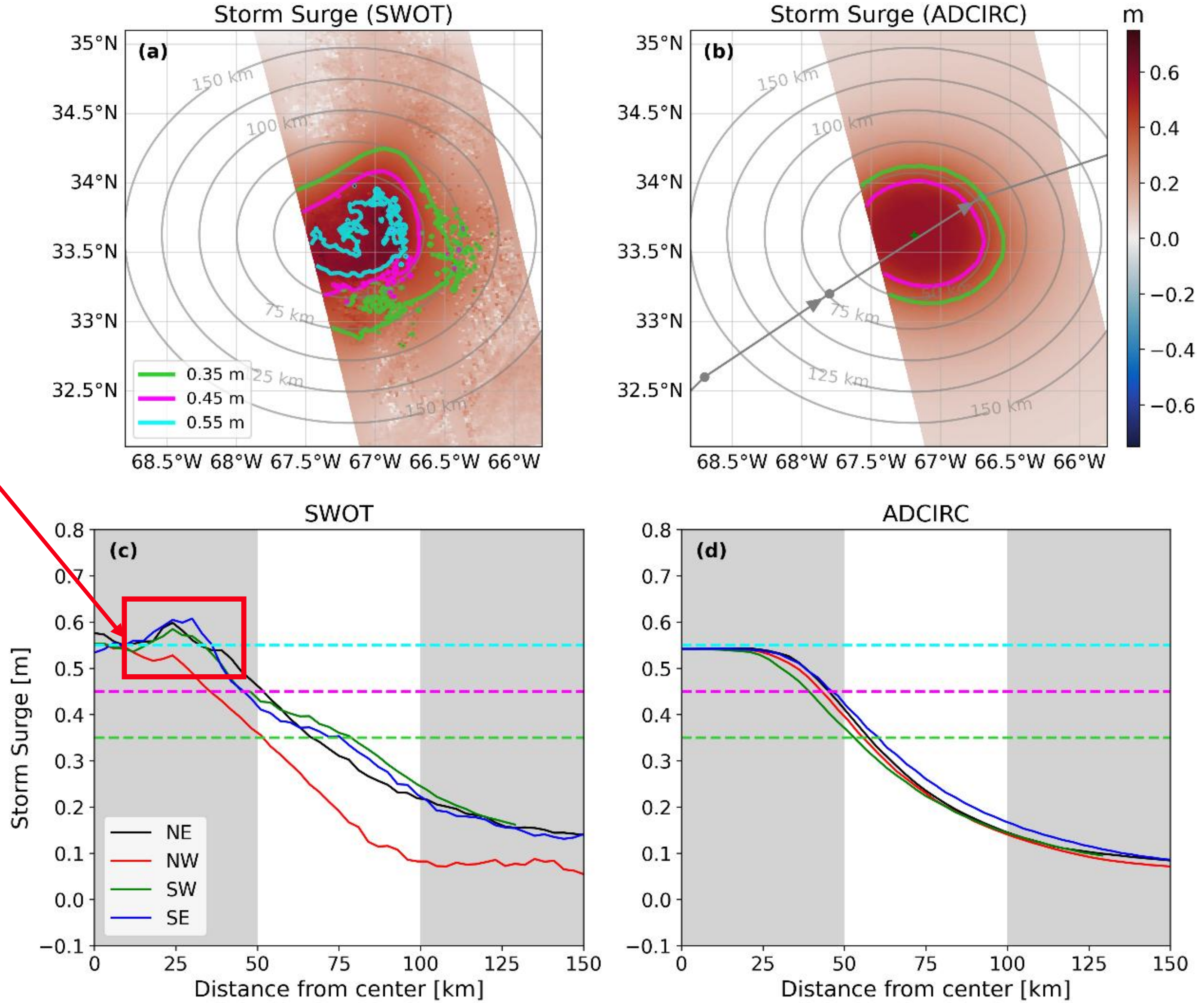
SWOT Obervations

1. Capture storm surge with more fine-scale detials.
2. Stronger asymmetry than the model simulation.
3. Different quadrants showed distinct radial water level variation trends.
4. 0.55 m contour revealed unique asymmetric surge pattern.
5. Maximum surge height not located at hurricane center.



Preliminary Results

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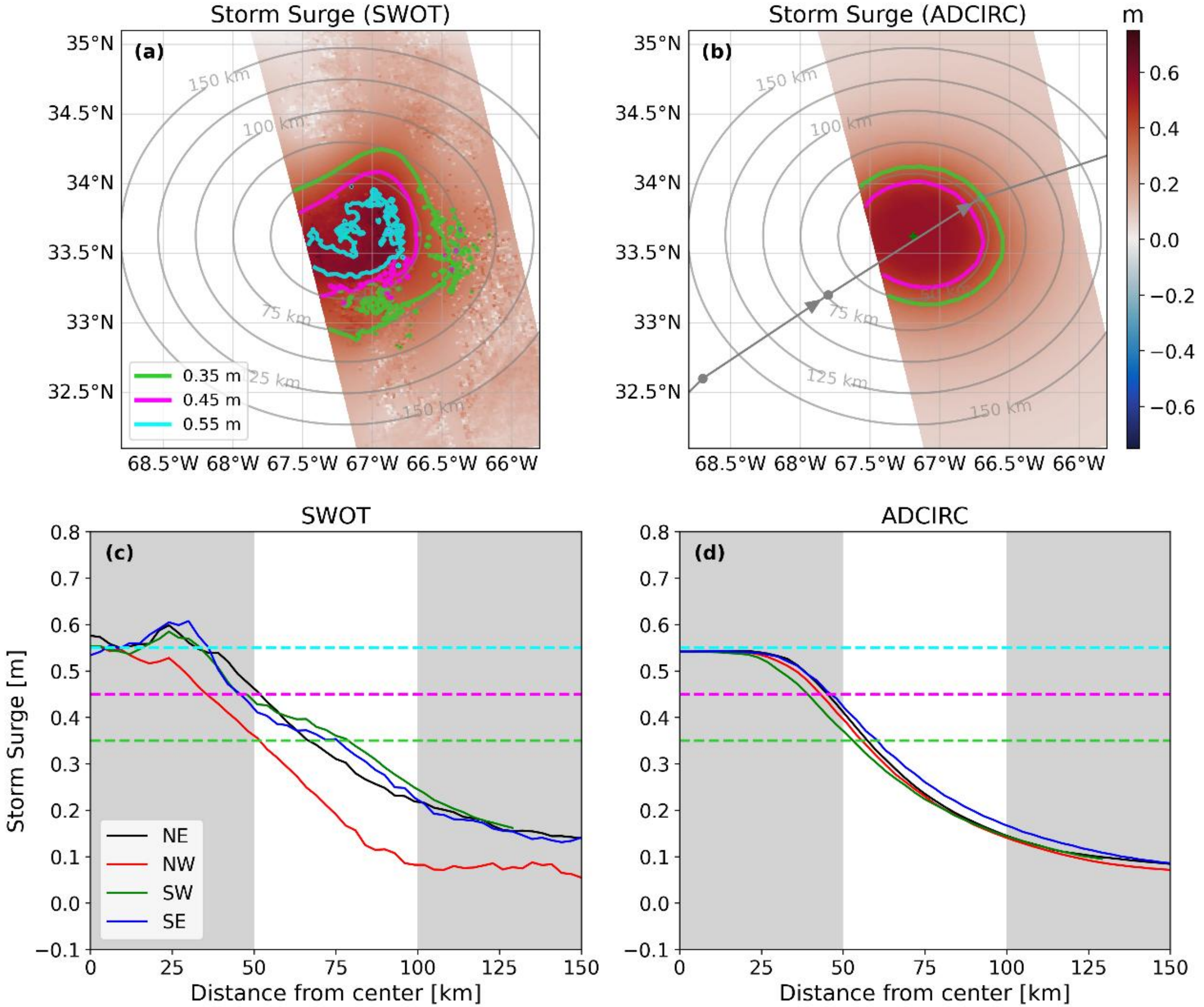
ADCIRC

1. Surge water level distribution more circular and smooth.

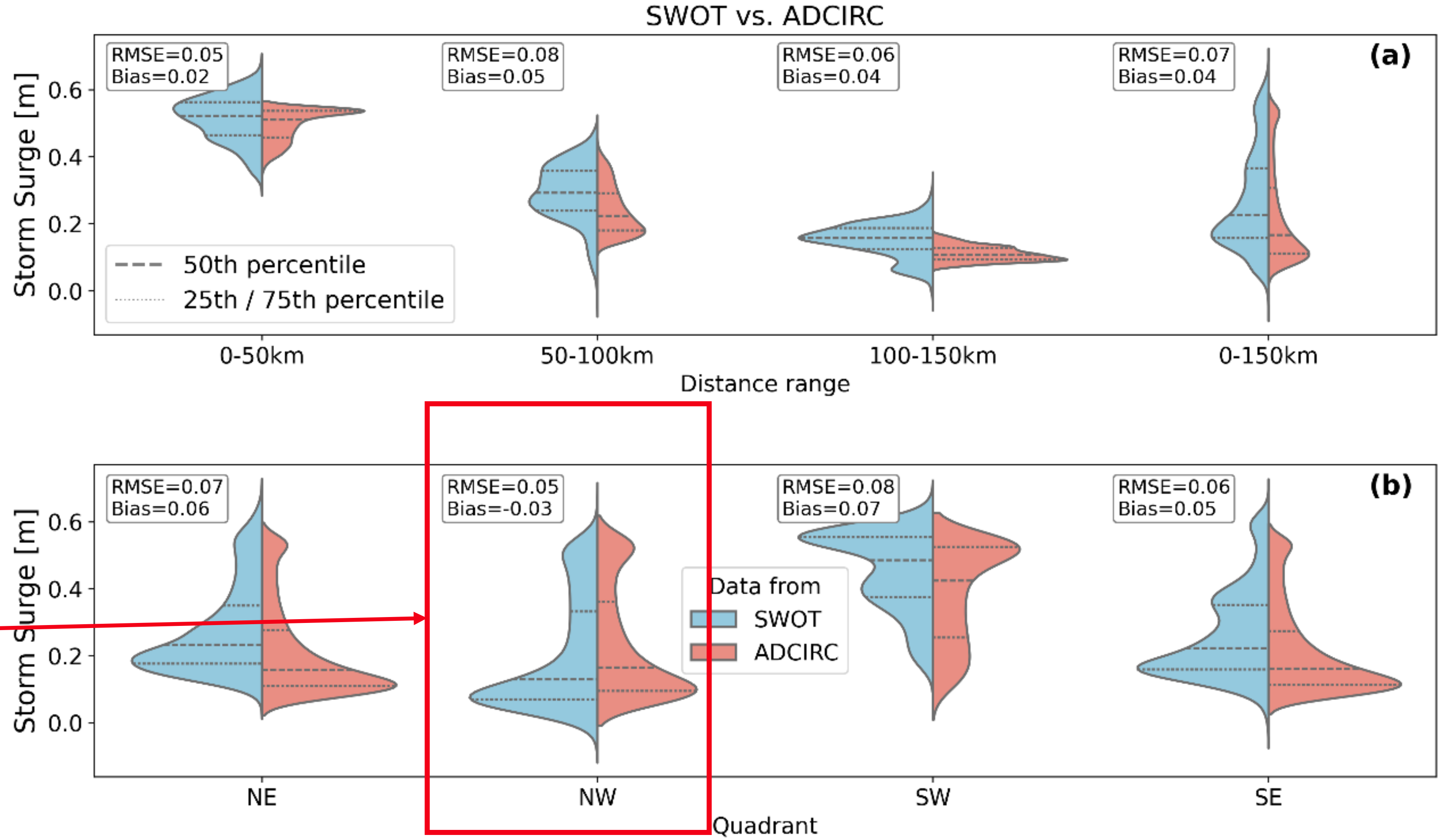
2. Quadrants did not differ significantly in radial variation (only radius differences).



Preliminary Results

SWOT vs. ADCIRC

1. RMSE and Bias differences only at centimeter level.
2. ADCIRC underestimated overall surge median compared to SWOT.
3. In the NW quadrant, SWOT underestimated relative to ADCIRC.



Summary and Outlook

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- SWOT and ADCIRC results differ only at centimeter scale at hurricane scale (~150 km).
- ADCIRC tends to underestimate storm surge compared to SWOT, consistent with prior knowledge.
- In the future, SWOT storm surge observations can be assimilated into forecasting systems to improve storm surge prediction.

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Thanks for Your Attention

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