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4th International Workshop on Waves, Storm Surges and Coastal Hazards

Incorporating the 18th International Waves Workshop

ASM-SS: the first quasi-global high-spatial-resolution coastal storm surge dataset reconstructed from tide gauge records

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23 Sep, 2025, Santander, Spain

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Background, current status and challenges

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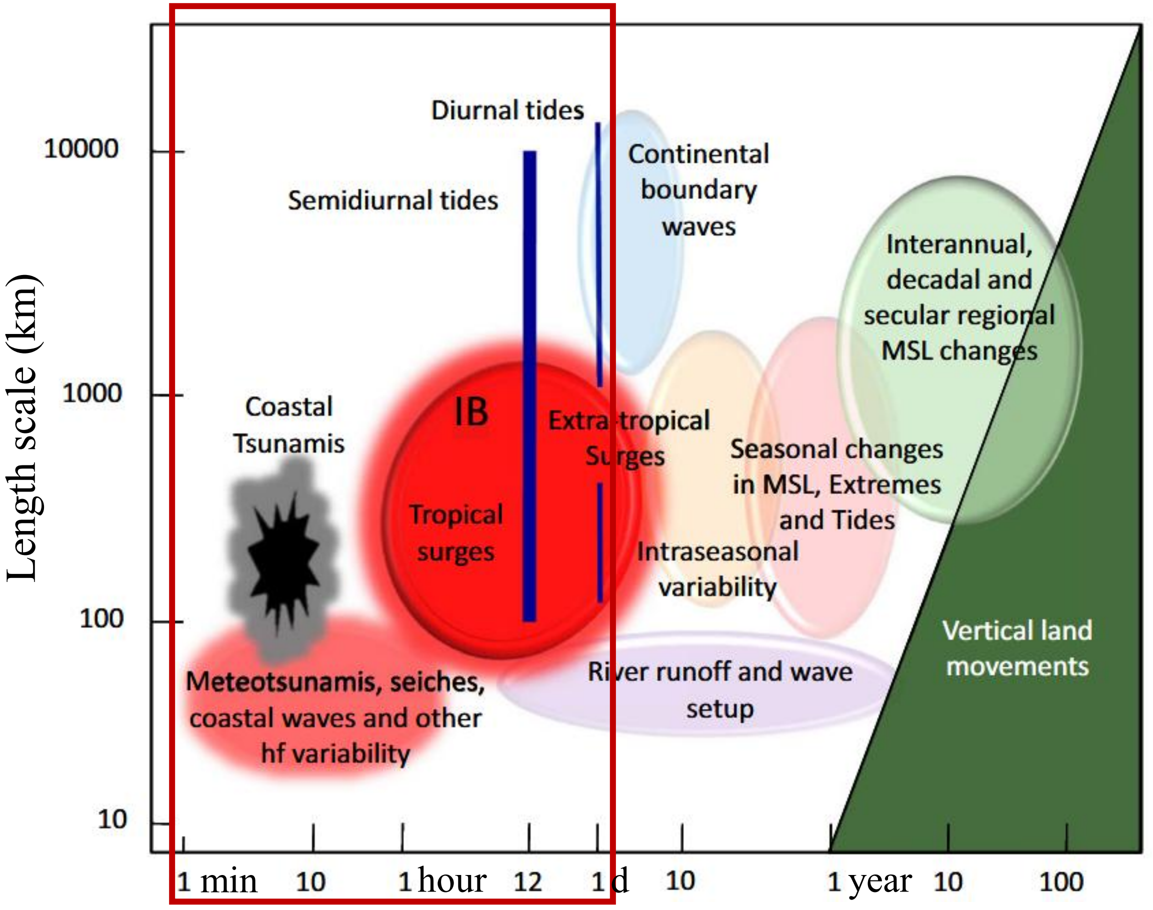
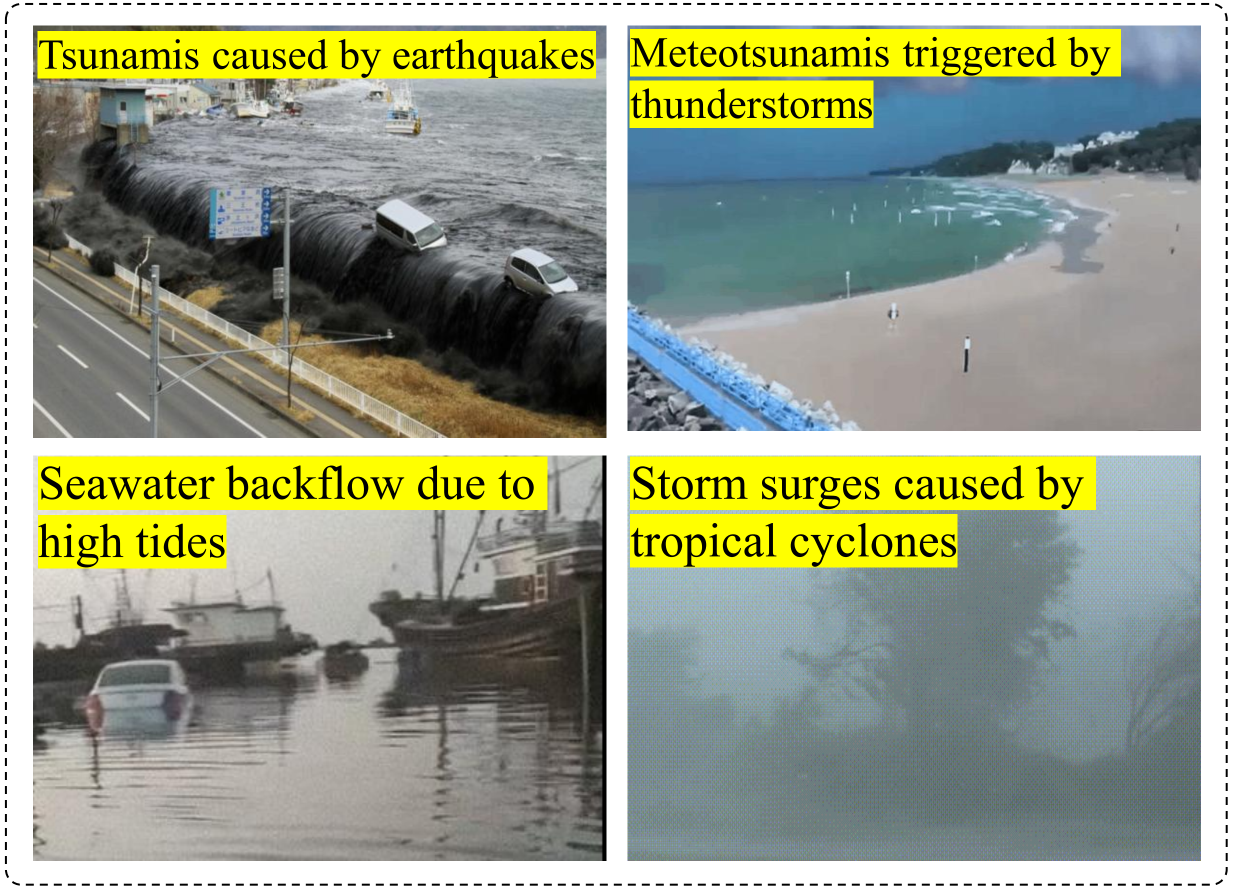
☐ Extreme sea level events are generally abrupt, fast-developing, and highly destructive

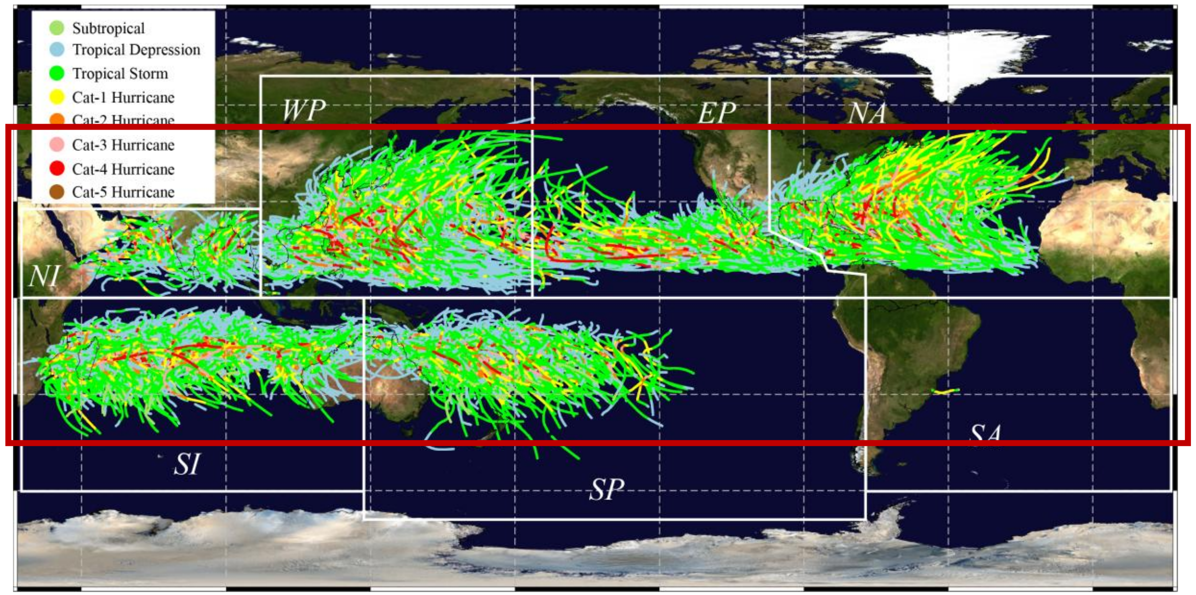


Processes contributing to coastal sea level variability
（Woodworth et al., 2019)

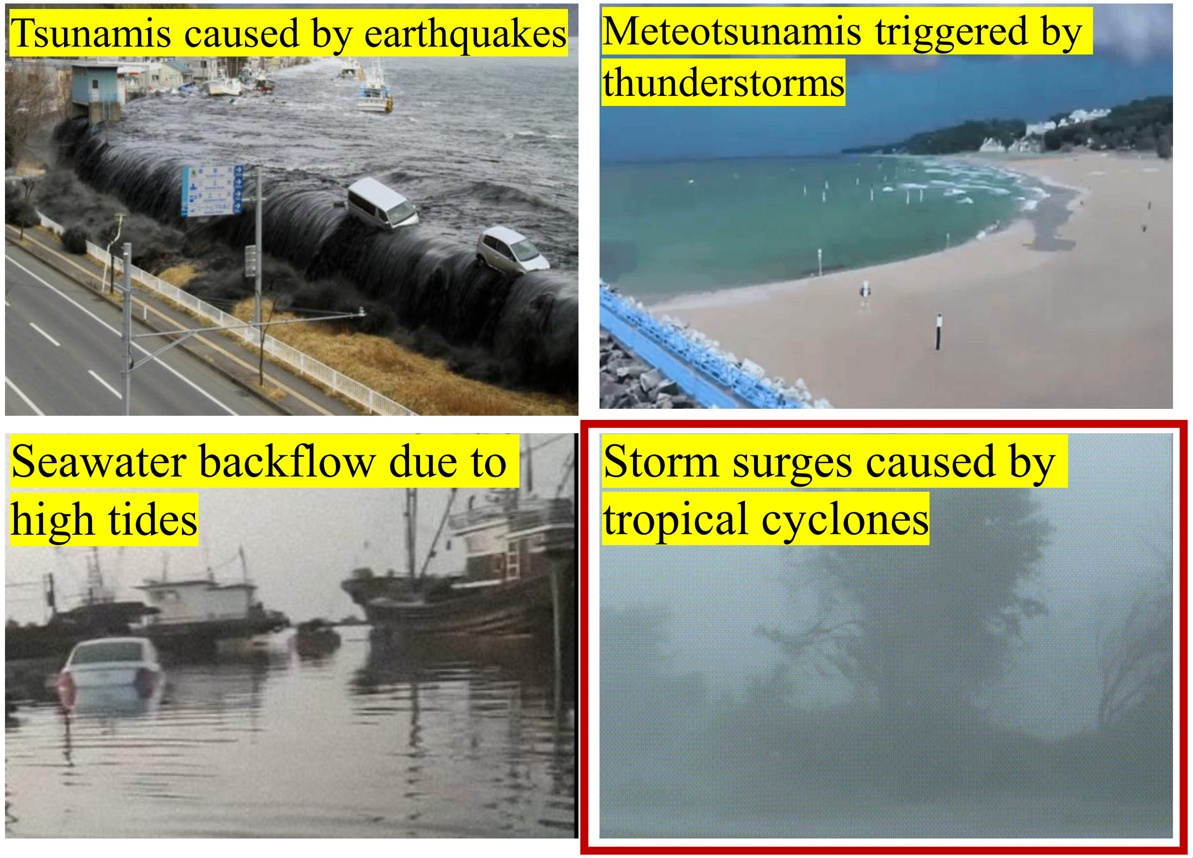


Background, current status and challenges

□ Extreme sea level events are generally abrupt, fast-developing, and highly destructive

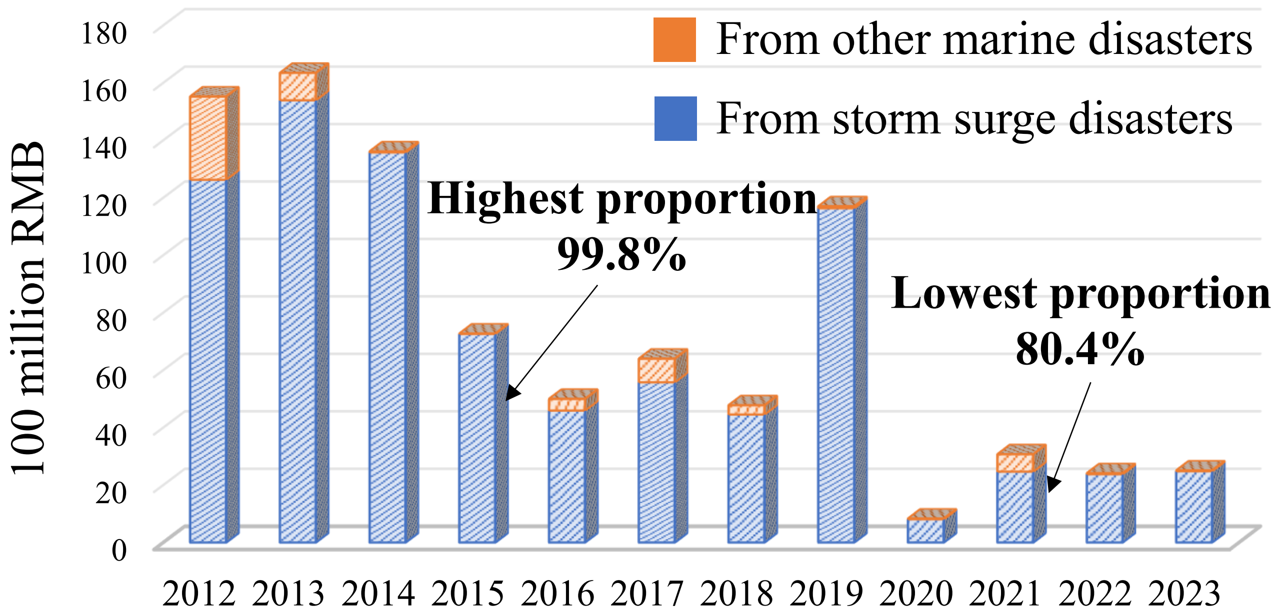


Tropical cyclone paths and intensity (IBTrACS, 2024)

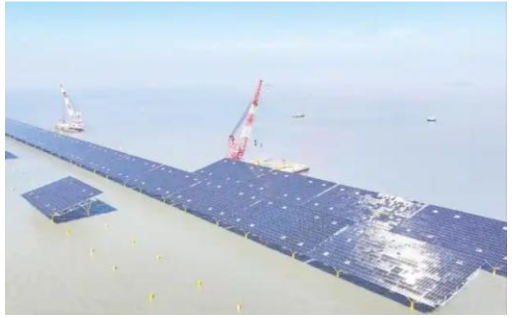


Background, current status and challenges

☐ Storm surge disasters cause the largest losses



Direct economic losses caused by marine disasters in China
(China Marine Disaster Bulletins, 2024)



Disrupt offshore microgrids

Damage coastal defenses

Affect mariculture

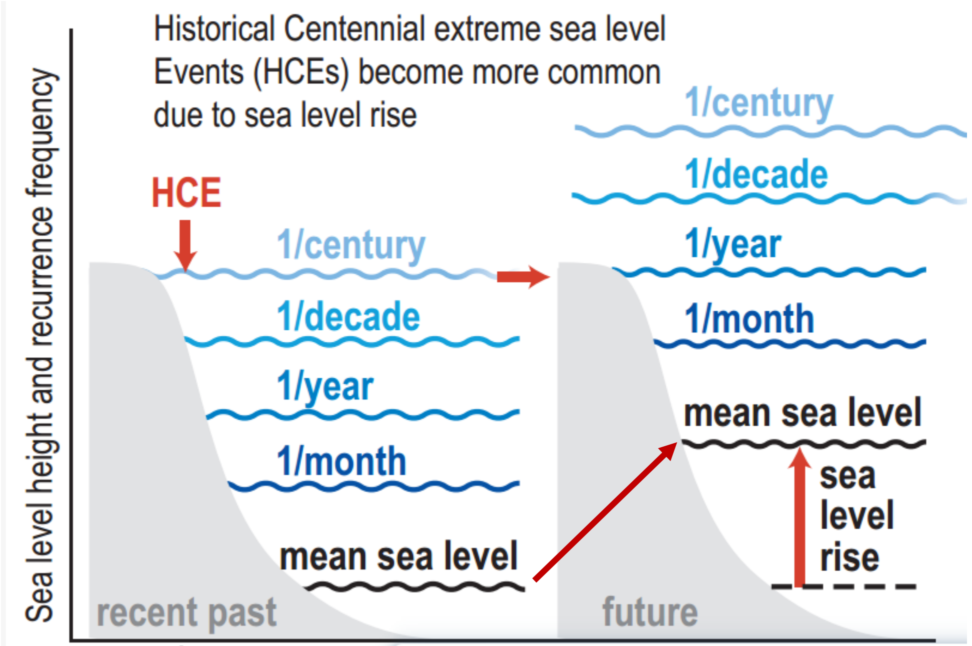
Endanger life and property

Coastal communities already face severe threats from storm surges !

Background, current status and challenges

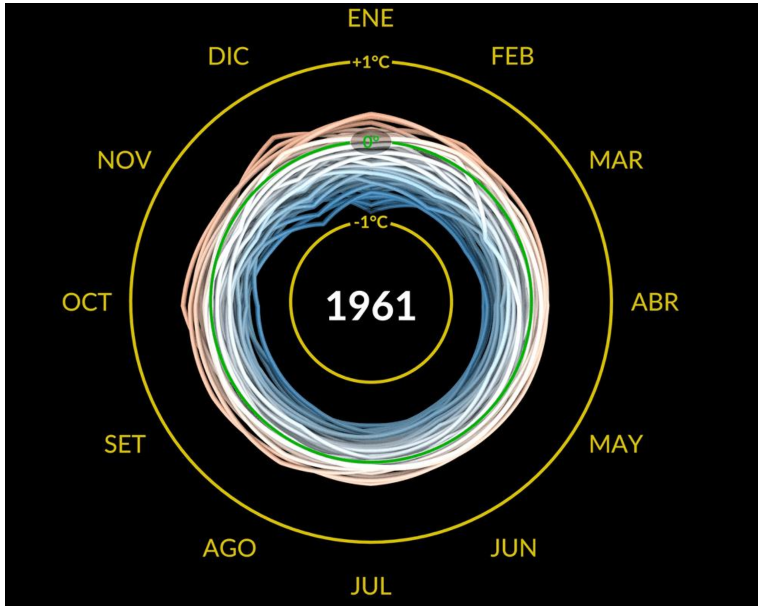
☐ Impacts of storm surges are expected to intensify in the future

SLR increases the baseline water level



The effect of sea level rise on ESL events (IPCC, 2019)

Climate change affects the intensity and frequency of tropical cyclones



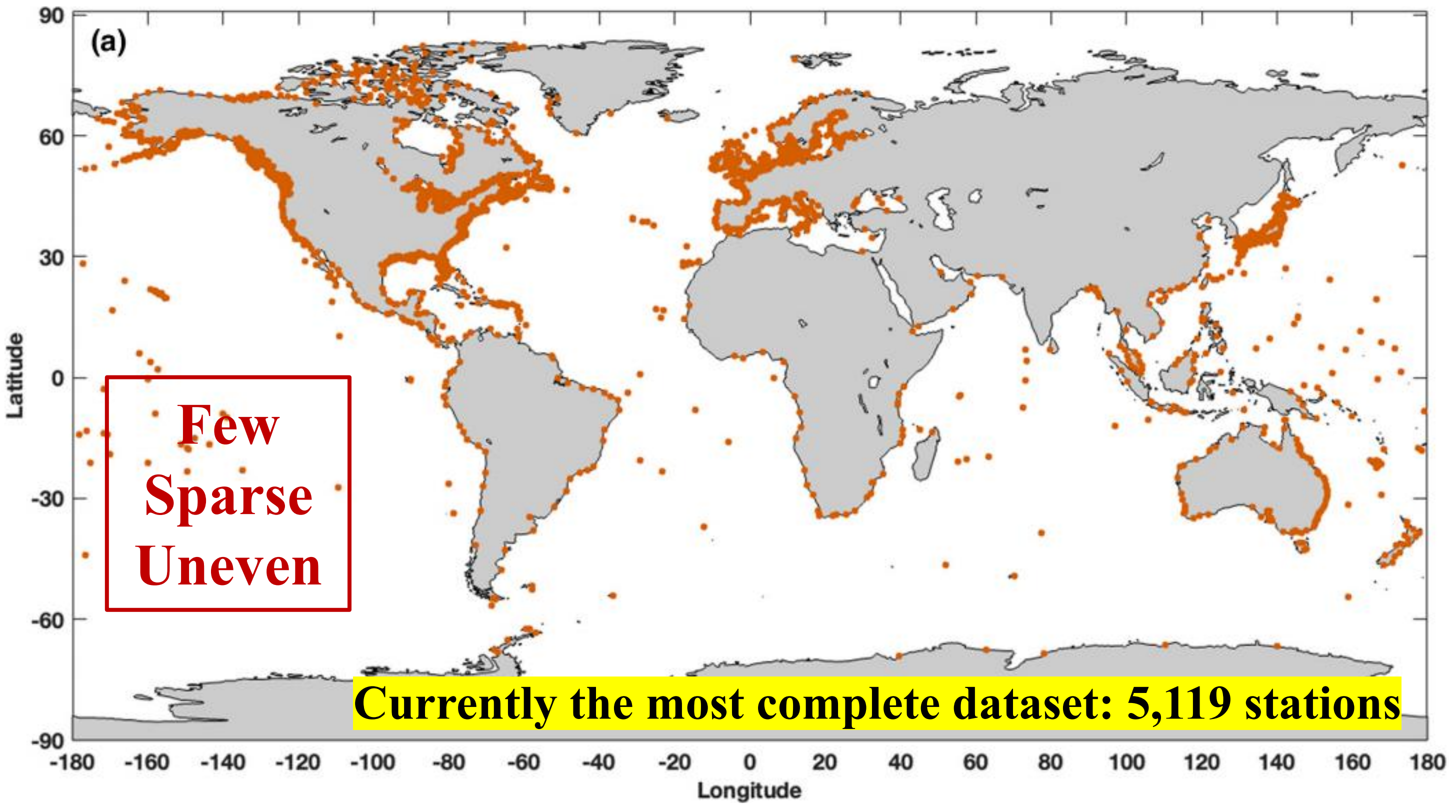
Global temperature anomalies (NASA, 2025)

High-spatiotemporal-resolution and long-term records are important for SS analysis

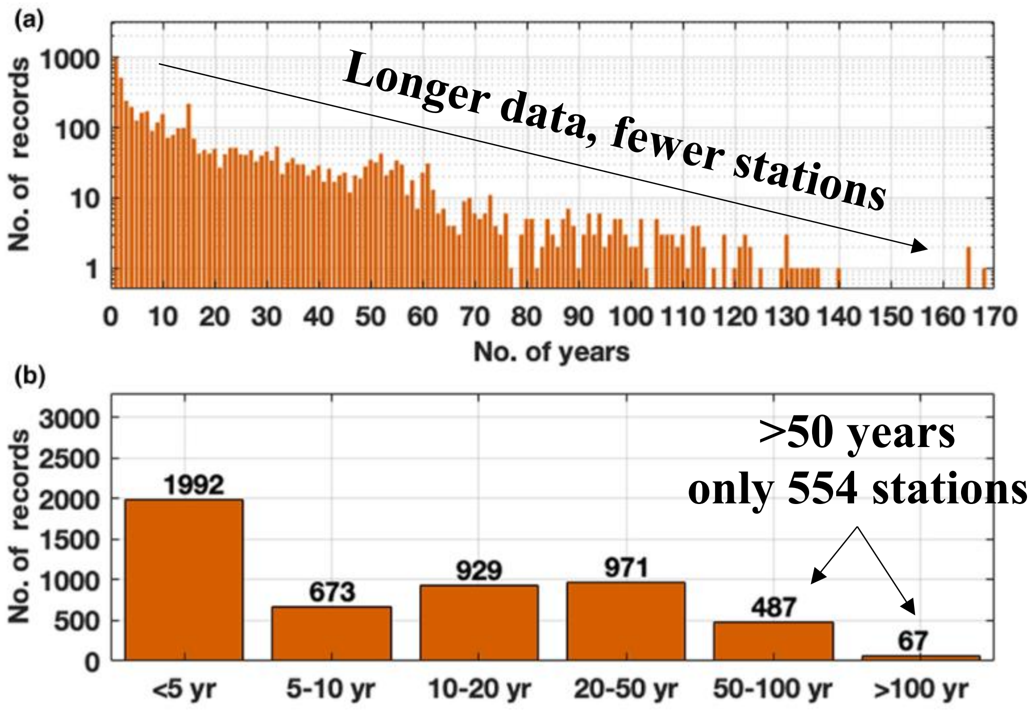
Background, current status and challenges

☐ Storm surge information monitored from tide gauges is limited

Only way to continuously monitor high-frequency data



Most tide gauge records are short

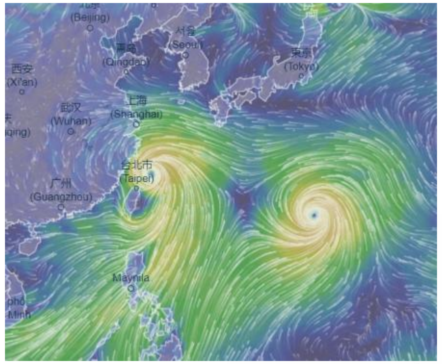


Global Extreme Sea Level Analysis (GESLA) dataset（Haigh et al., 2023）

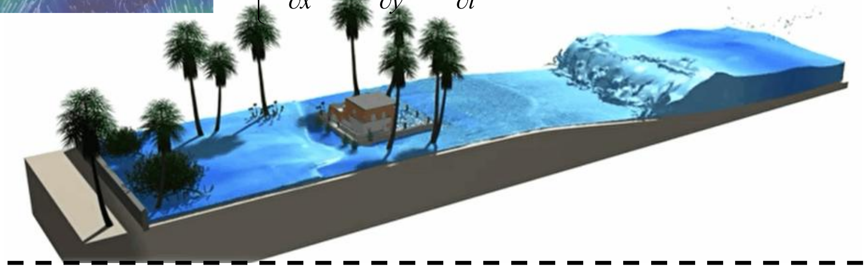
Background, current status and challenges

◻ Numerical model simulation

Wind, pressure fields, bathymetric data… → Numerical → Storm surge



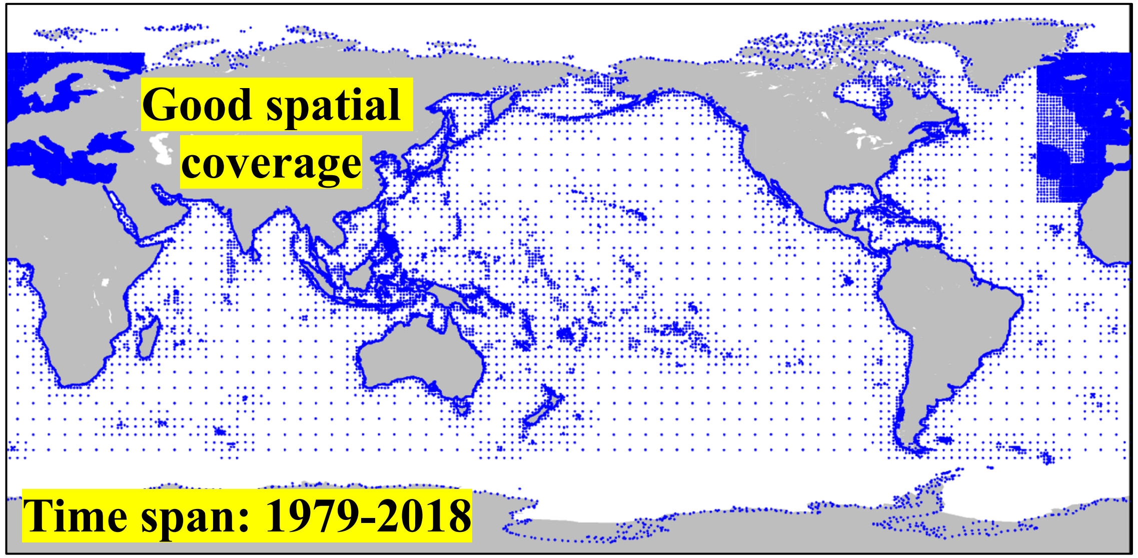
$$
\begin{cases}
\frac{\partial(H\bar{u})}{\partial t}+\frac{\partial\left(H\bar{u}^2\right)}{\partial x}+\frac{\partial(H\bar{u}\bar{v})}{\partial y} \\
=-gH\frac{\partial\eta}{\partial x}+fH\bar{v}+A_h\left[\frac{\partial}{\partial x}\left(H\frac{\partial\bar{u}}{\partial x}\right)+\frac{\partial}{\partial y}\left(H\frac{\partial\bar{u}}{\partial y}\right)\right]+\frac{\tau_{sx}}{\rho}-\frac{\tau_{bx}}{\rho} \\
\frac{\partial(H\bar{v})}{\partial t}+\frac{\partial(H\bar{u}\bar{v})}{\partial x}+\frac{\partial\left(H\bar{v}^2\right)}{\partial y} \\
=-gH\frac{\partial\eta}{\partial y}+fH\bar{u}+A_h\left[\frac{\partial}{\partial x}\left(H\frac{\partial\bar{v}}{\partial x}\right)+\frac{\partial}{\partial y}\left(H\frac{\partial\bar{v}}{\partial y}\right)\right]+\frac{\tau_{sy}}{\rho}-\frac{\tau_{by}}{\rho} \\
\frac{\partial(H\bar{u})}{\partial x}+\frac{\partial(H\bar{v})}{\partial y}+\frac{\partial H}{\partial t}=0
\end{cases}
$$



Storm surge numerical simulation

Accurate and high-resolution bathymetric data are often unavailable in nearshore areas;

Mesh resolution is usually set to several kilometers to balance the computational complexity;



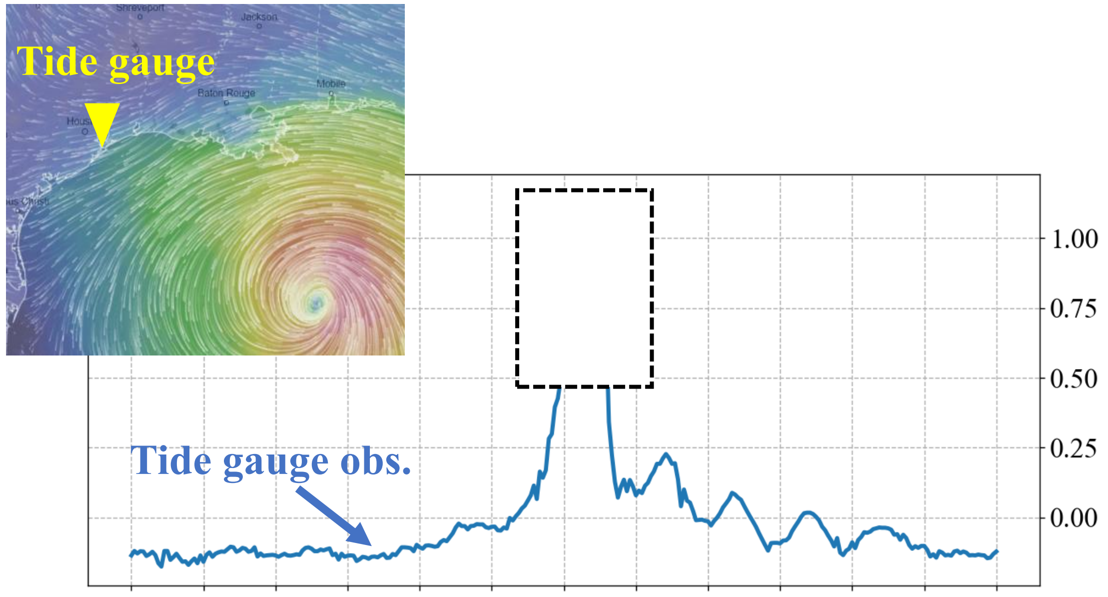
Global Tide and Surge Model (GTSM v3.0) product

(Muis et al., 2023)

Background, current status and challenges

☐ Data-driven model reconstruction

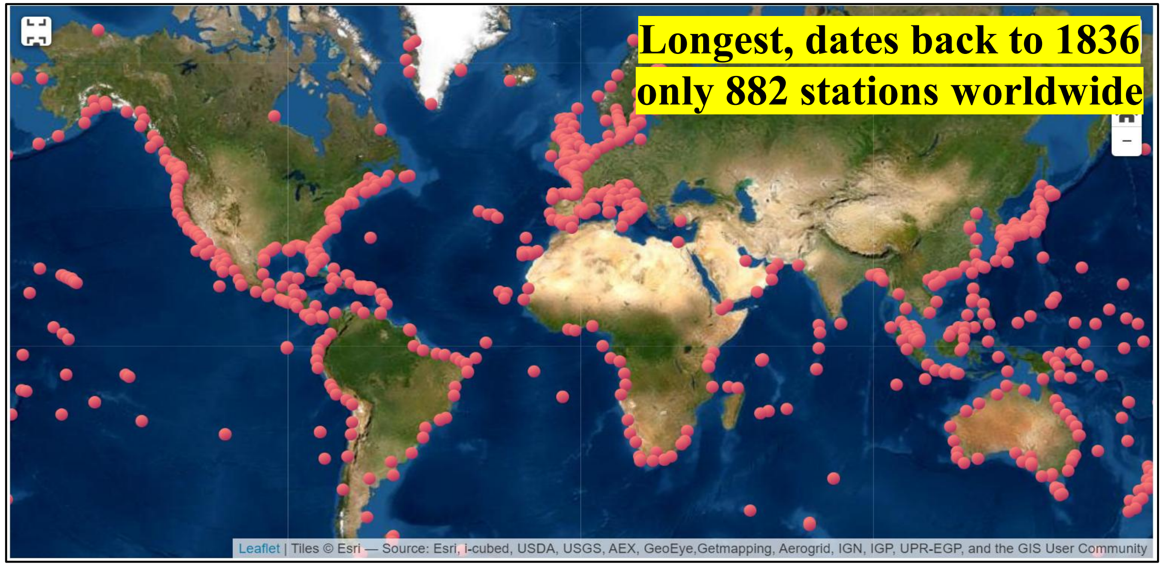
Wind fields, pressure fields… ⇔ Data-driven ⇔ Tide gauge observations



Storm surge data-driven reconstruction

Lower complexity, fewer computational resources, efficient for long-term reconstruction;

Cannot provide SS information for ungauged areas, spatial coverage cannot be guaranteed;



Global Storm Surge Reconstruction (GSSR) dataset

(Tadesse et al., 2021)

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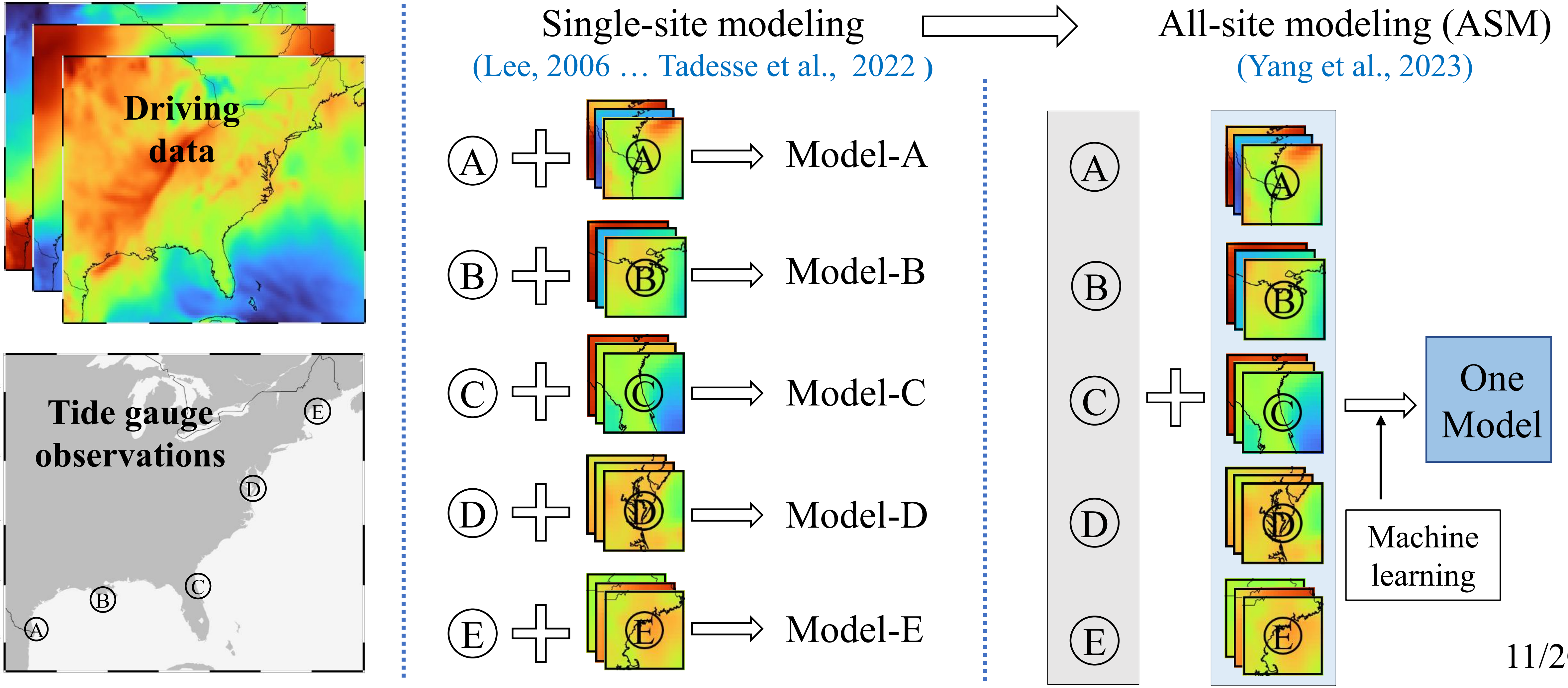
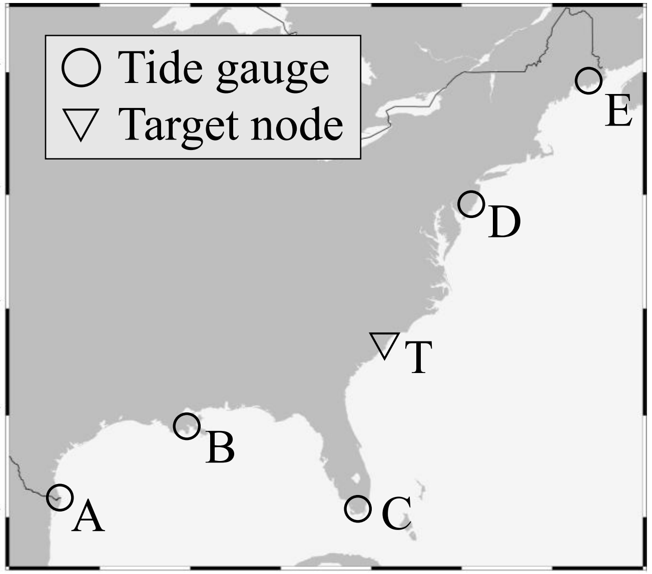
All-site modeling framework for data-driven models

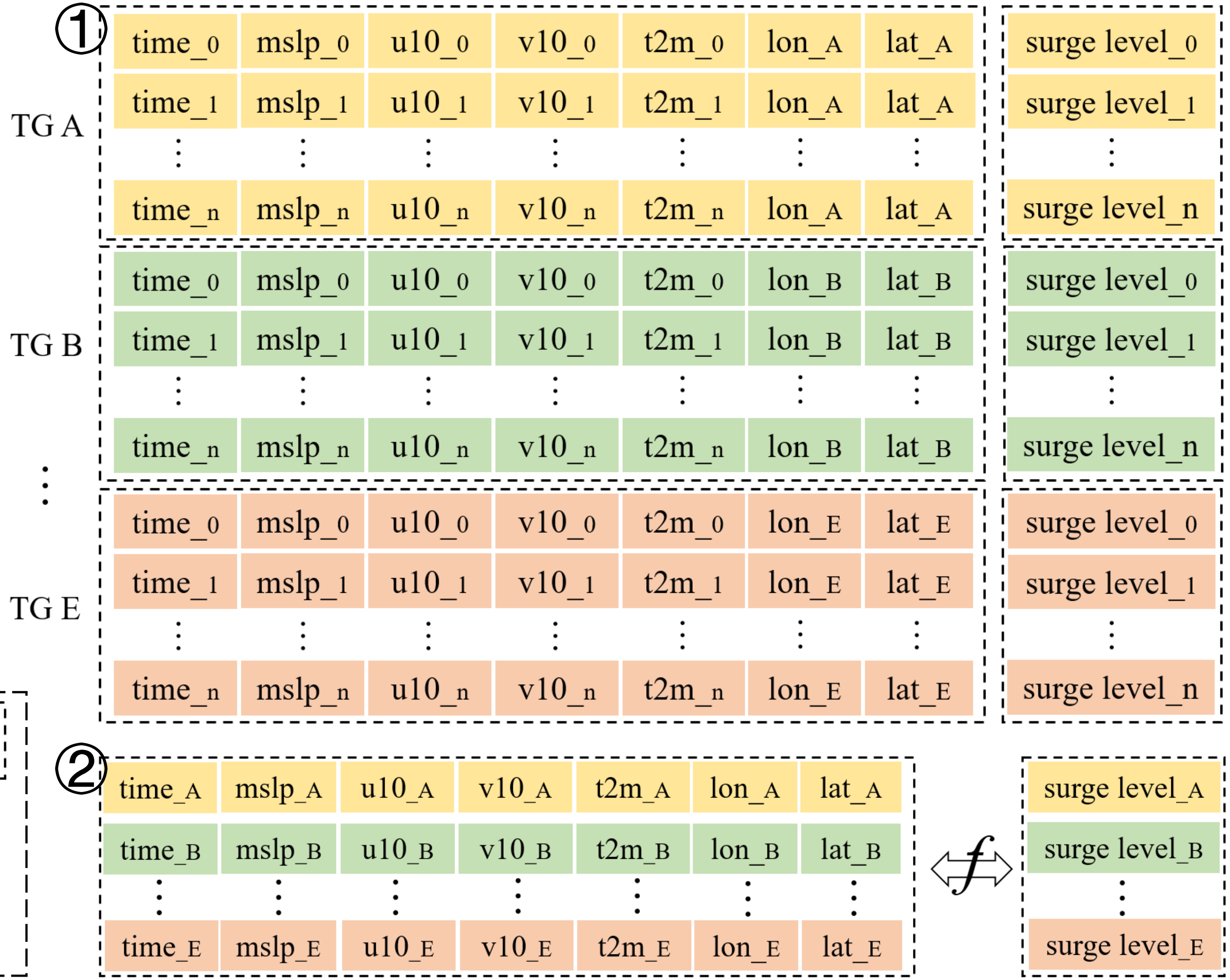
☐ Differences between single- and all-site modeling

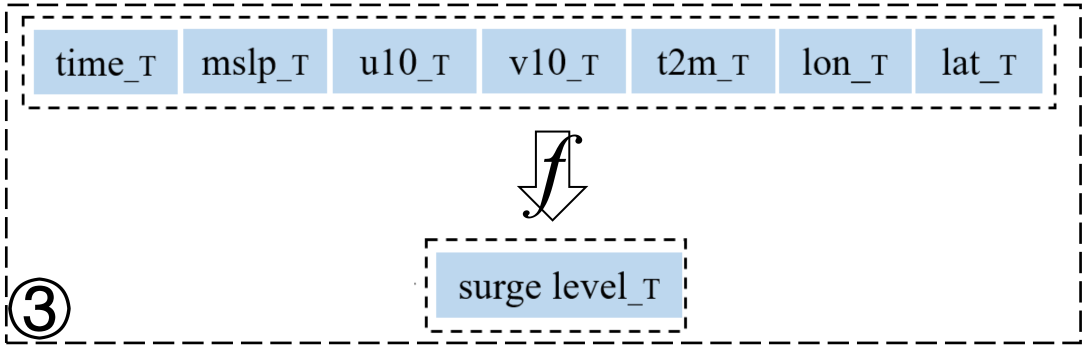


All-site modeling framework for data-driven models

All-site modeling framework

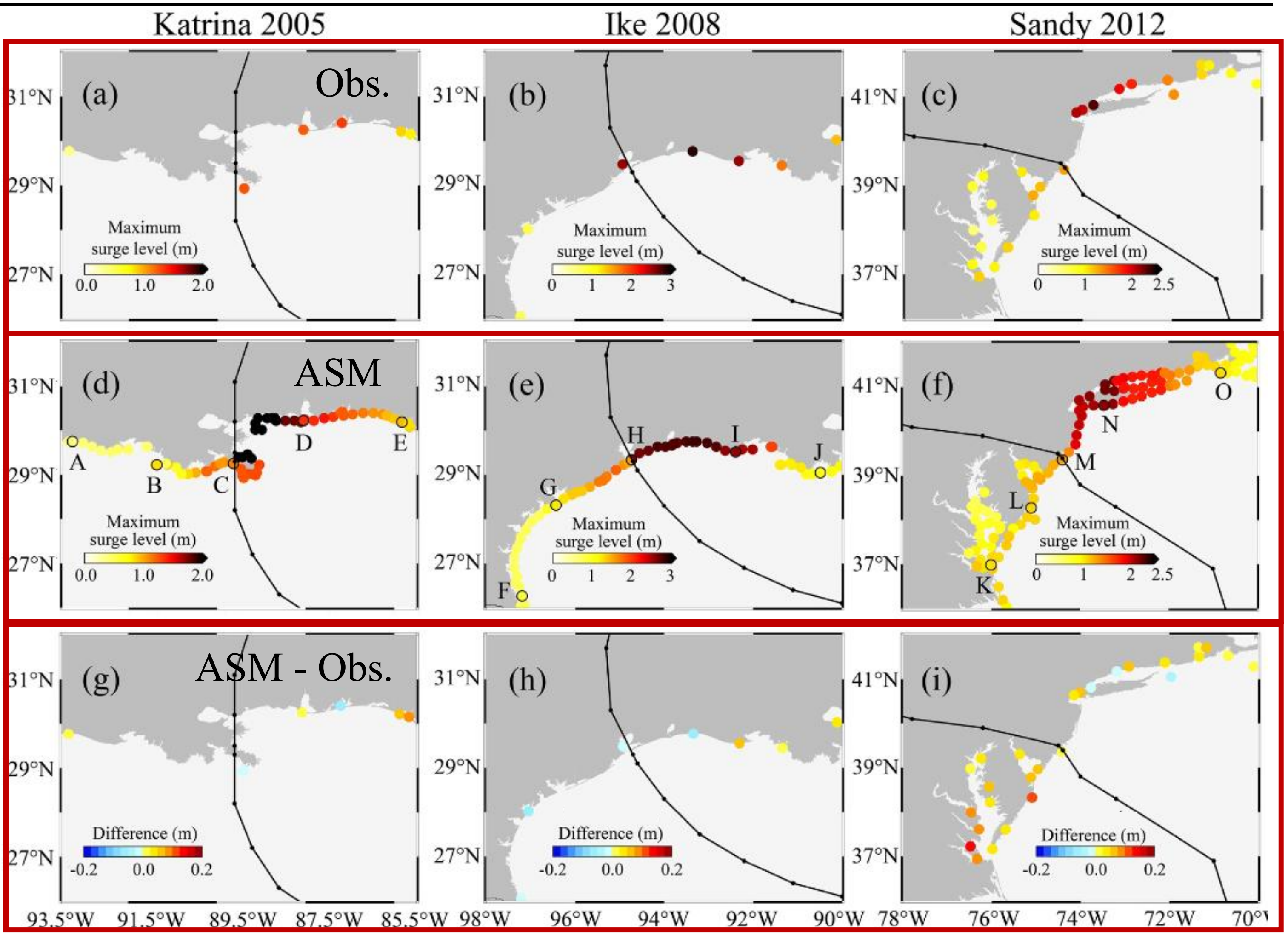






All-site modeling framework for data-driven models

- **Address the spatial coverage issue**
  - A SS dataset for the U.S. east coast with a spatial resolution of 25 km
  - Good agreement with tide gauge observations
  - Reflect the spatial characteristics of storm surges



Storm surge maximum & spatial distribution

(Yang et al., 2023)

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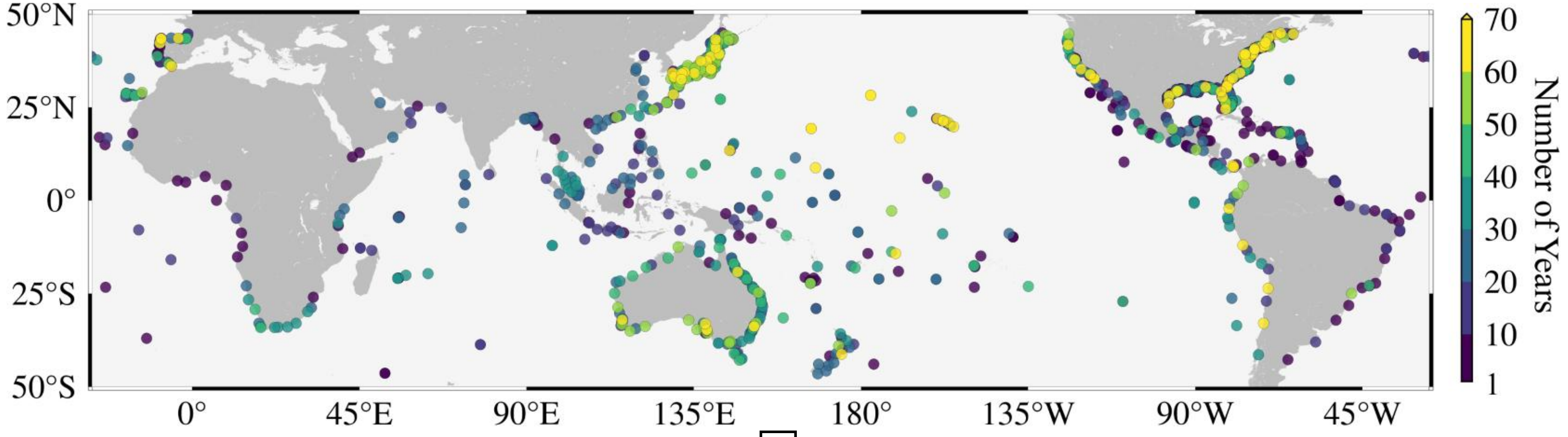
Quasi-global high-resolution storm surge reconstruction

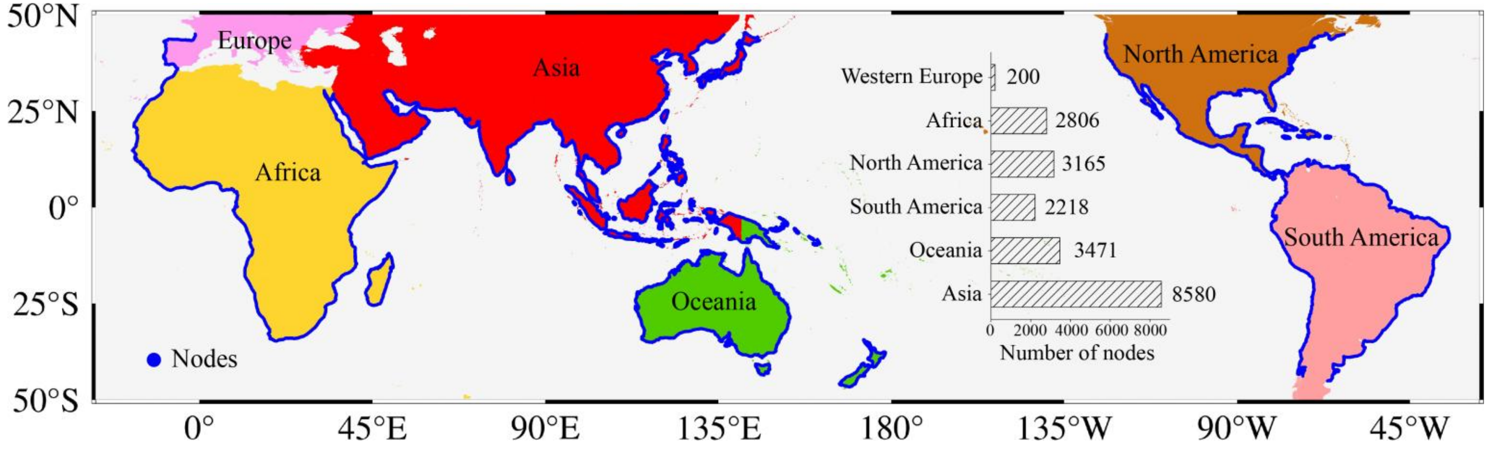
☐ All-site modeling storm surge (ASM-SS) dataset for coasts affected by tropical cyclones

1,315 stations from the GESLA dataset with **lengths >1 year**

Spatial coverage	**45ºS - 45ºN**
Temporal coverage	**1940 - 2020**
Spatial resolution	**10 km** along the coastline, total **20,440**
Temporal resolution	**Hourly**

Training consumes ~80GB of storage, takes ~22 hours on a 16-core AMD processor





The distribution of coastal nodes for reconstructions

Quasi-global high-resolution storm surge reconstruction

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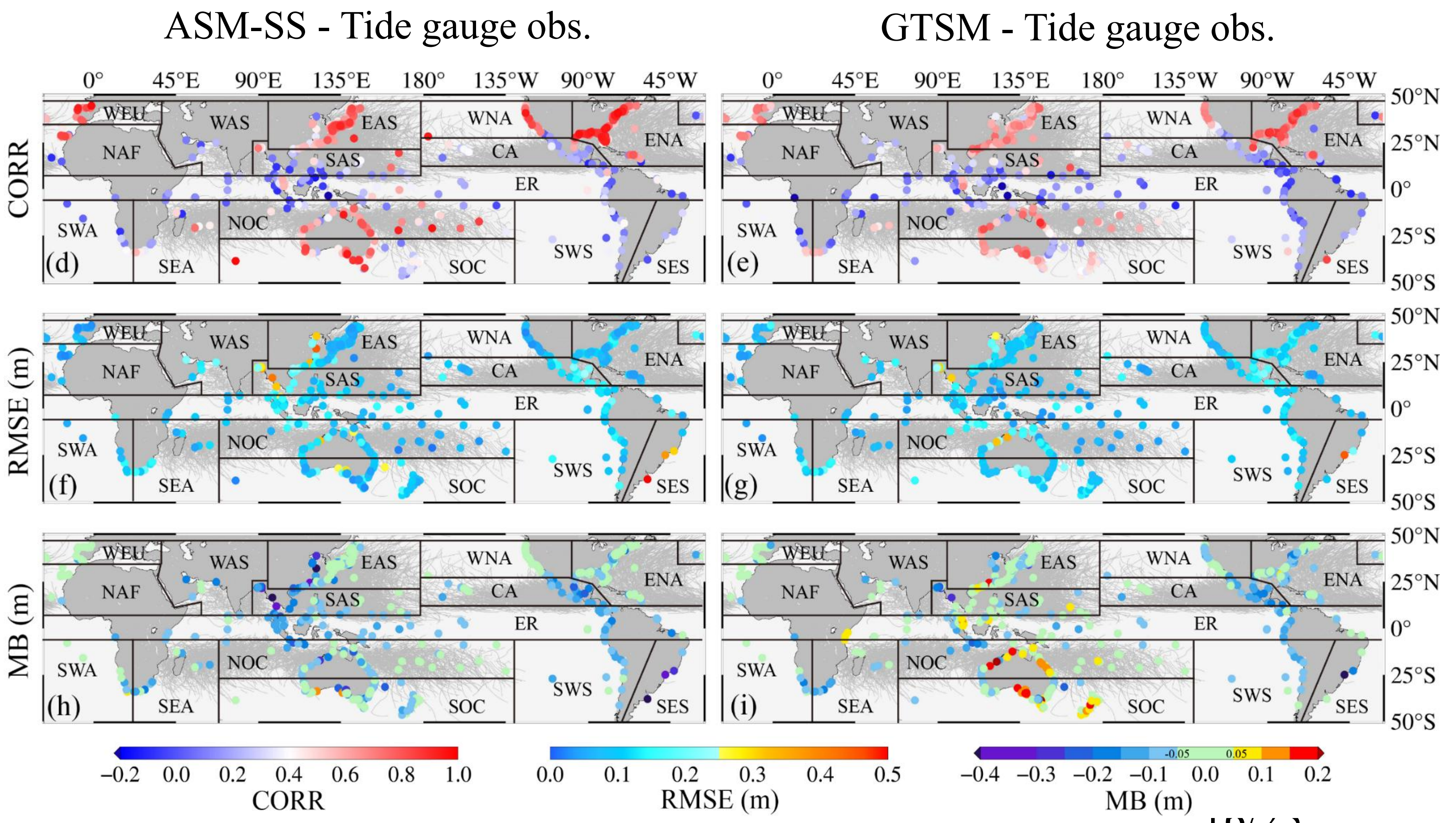
◻ Comparison of ASM-SS dataset and GTSM numerical product with tide gauge obs.

➢ 15 subregions

ER: the equatorial region
WEU: western Europe
NAF: northern Africa
SWA: southwestern Africa
SEA: southeastern Africa
WNA: western North America
ENA: eastern North America
CA: Central America
SWS: southwestern South America
SES: southeastern South America
WAS: western Asia
EAS: eastern Asia
SAS: southern Asia
NOC: northern Oceania
SOC: southern Oceania



95th percentile extremes comparison

Quasi-global high-resolution storm surge reconstruction

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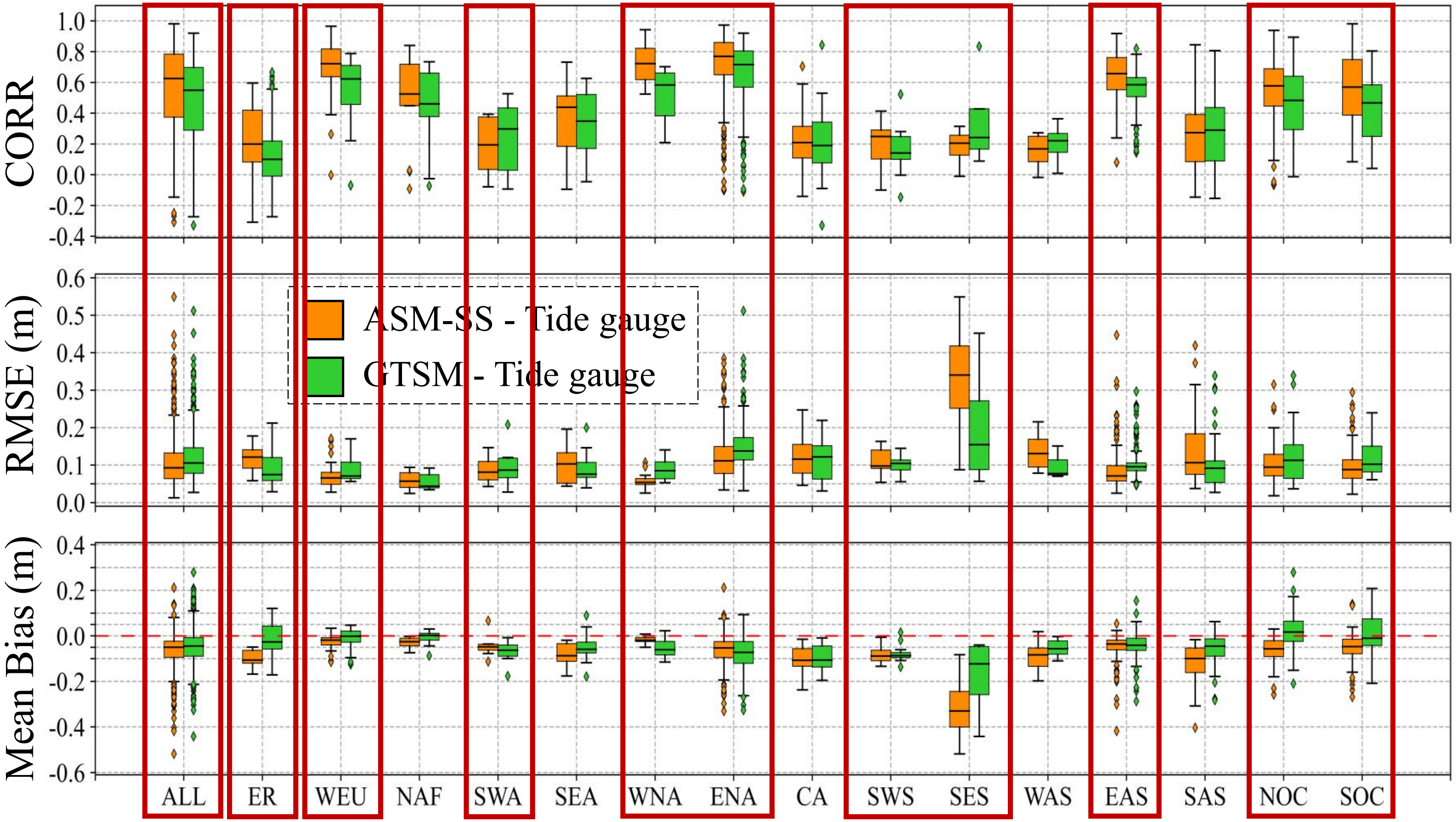
□ Comparison of ASM-SS dataset and GTSM numerical product with tide gauge obs.

At the quasi-global scale, the overall precision is better than that of the GTSM numerical product

	ASM-SS	GTSM
CORR	**0.63**	0.55
RMSE (m)	**0.093**	0.106
MB (m)	-0.050	-0.045

Significant tropical cyclone impact, better than numerical model

Rare tropical cyclones, low precision



95th percentile extremes
comparison

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Conclusion

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- The all-site modeling framework enables data-driven models as an independent way to provide high-resolution storm surge (SS) information for ungauged areas;
- Established a high-spatial-resolution (10 km per node along the coastline), long-term (>80 years from 1940 to 2020), quasi-global (45ºS-45ºN), and hourly data-driven SS dataset (ASM-SS): https://doi.org/10.5281/zenodo.14034726;
- For extreme SSs, the ASM-SS dataset outperforms the state-of-the-art global numerical GTSM product, with medians of CORR, RMSE, and MB of 0.63, 0.093 m, and -0.050 m, respectively, compared to 0.55, 0.106 m, and -0.045 m for GTSM at the quasi-global scale.

[1] Yang, L., Jin, T., Xiao, M., Gao, X., Jiang, W., and Li, J.: Extreme Events and Probability Analysis Along the United States East Coast Based on High Spatial-Coverage Reconstructed Storm Surges, ***Geophysical Research Letters***, 50, 2023.

[2] Yang, L., Jin, T., and Jiang, W.: ASM-SS: the first quasi-global high-spatial-resolution coastal storm surge dataset reconstructed from tide gauge records, ***Earth Syst. Sci. Data***, 17, 2025.

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THANKS FOR LISTENING!

By: L. J. Yang