ESTIMATING GLOBAL SEA LEVEL VARIATIONS AND RESULTING INUNDATION EXPOSURE

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INTRODUCTION
Motivation

More than 600 million people reside in the low-lying coastal areas globally

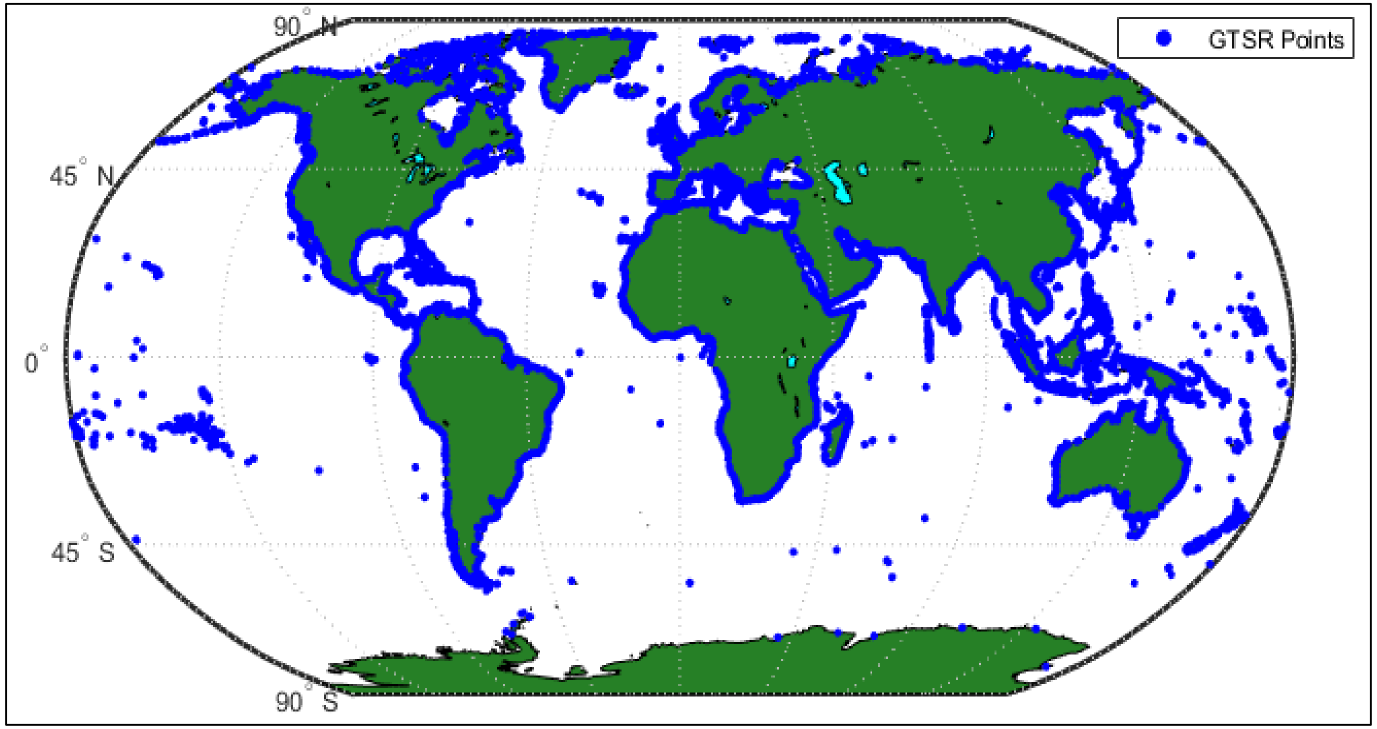
Extreme sea levels are of great concern

Climate Change and Sea level rise will further increase the resulting effects

Many recent studies on global analysis regarding extreme sea levels such *as Muis et al (2016, 2017), Vitousek et al (2017), Wahl et al (2017), Vousdoukas et al (2018) …*

INTRODUCTION
DIVA Database and GTSR

- A sufficient **temporal** and **spatial resolution** for global assessments
- To date, many regional and global extreme sea level studies undertaken based on
- **Dynamic Interactive Vulnerability Assessment (DIVA)** database for coastal locations
- **Global Tide and Surge Reanalysis (GTSR)** dataset developed by Muis et al. (2016) based on the DIVA input database



GTSR Dataset Locations (16,611 points)

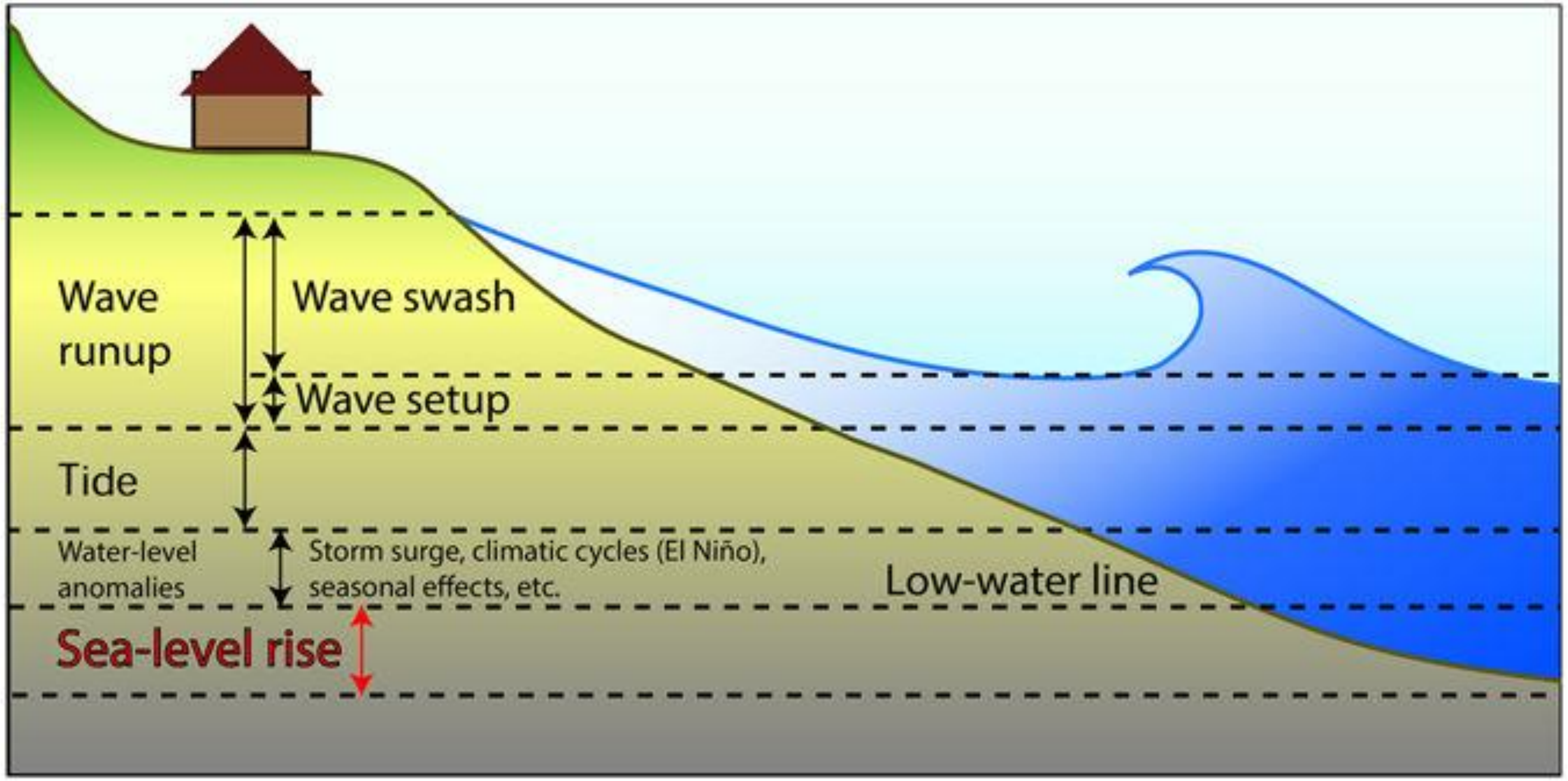
INTRODUCTION
Mean Sea Level Contributors

Sea Level Extremes occur due to;

- Tide Levels (Deterministic)
- Surge Heights (Stochastic)
- **Wave Setup (Stochastic)**

+

- **SEA LEVEL RISE ?**



Adopted from: Vitousek et al 2017-Doubling of coastal flooding frequency within decades due to sea-level rise

METHODOLOGY
Our Approach

A linear addition of the contributors:

Mean Sea Level = Tide* + Storm Surge + Wave Setup**

For 16,611 coastal points

GTSR Dataset

Tide*: FES2012

Surge: GTSM

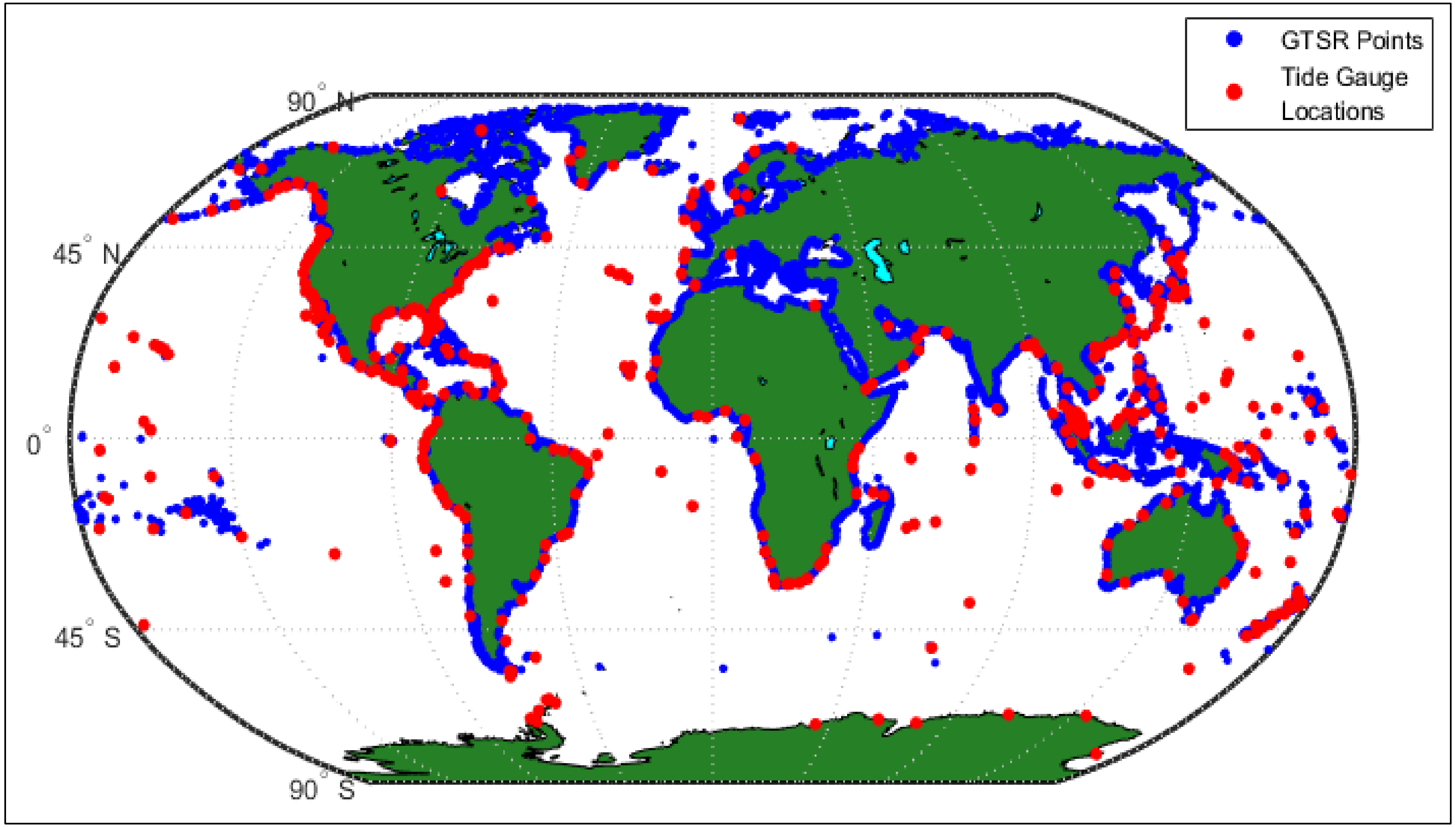
We use

Tide: FES2014

ERA-Interim and GOW2 Significant Wave Heights with SPM method

Validated at 472 University of Hawaii Sea Level Centre Tide Gauge Dataset locations (similar to GTSR dataset)

METHODOLOGY
Our Approach



Validation at UHSLC Dataset Locations (472 locations in total)

METHODOLOGY
Dataset and Model Descriptions

Tide Model:

Previously in GTSR used FES2012

Here, we adopted the updated version

FES2014:

Better gridding

Improved data assimilation by adding tide gauges in addition to Satellite Altimeter Data

Surge Model:

GTSR surge levels

(modelled previously with Delft3D FM)

6h temporal

0.75 x 0.75 spatial

Time Period:

1979-2014

Wave Setup:

Two SWH datasets:

ERA-I

GOW2

Wave setup is determined with SPM method and bed slope is assumed between

m=1/15

m=1/30

m=1/100

Thus, 6 different WS results

METHODOLOGY
Extreme Value Analyses

We have applied seven different Extreme Value Analysis (EVA) methods to each of these locations

-GUMBEL Distribution with Annual Maxima

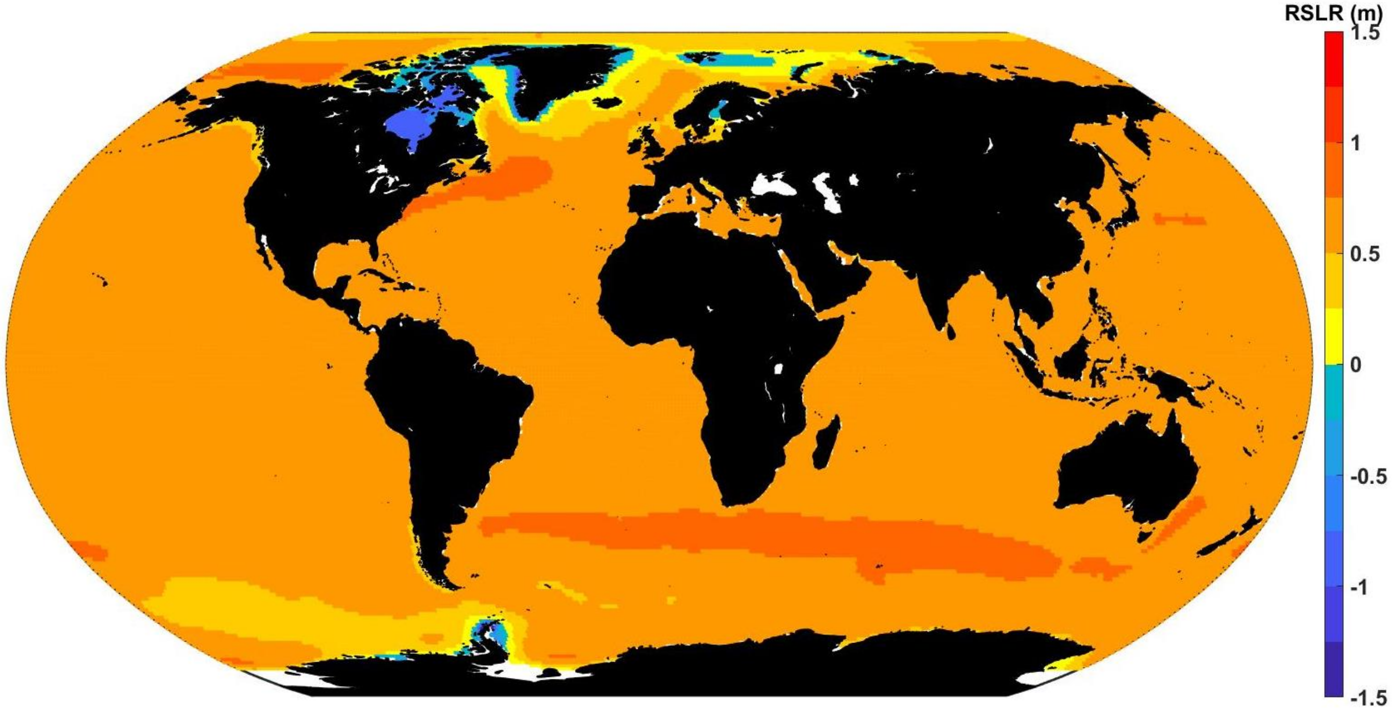
-Generalized Extreme Value Distribution (GEVD) with Annual Maxima

-Generalized Pareto Distribution (GPD) with Peaks-Over-Threshold Method (POT) with four percentile thresholds (ranging 98.0-99.5)

-Exponential Probability Distribution with POT method with 99-percentile

METHODOLOGY
Relative Sea Level Rise

Regional Sea Level Rise (difference between the mean MSLs 1986-2005 and 2081-2100) for scenario RCP8.5 (Church et al 2013) is included to determine the further increase in the inundation levels



METHODOLOGY
Inundation Analysis

- A simple approach is applied to determine the effects of wave setup and SLR

-Shuttle Radar Topographic Model (**SRTM**) with **1 km** resolution

- Analysed with ArcGIS

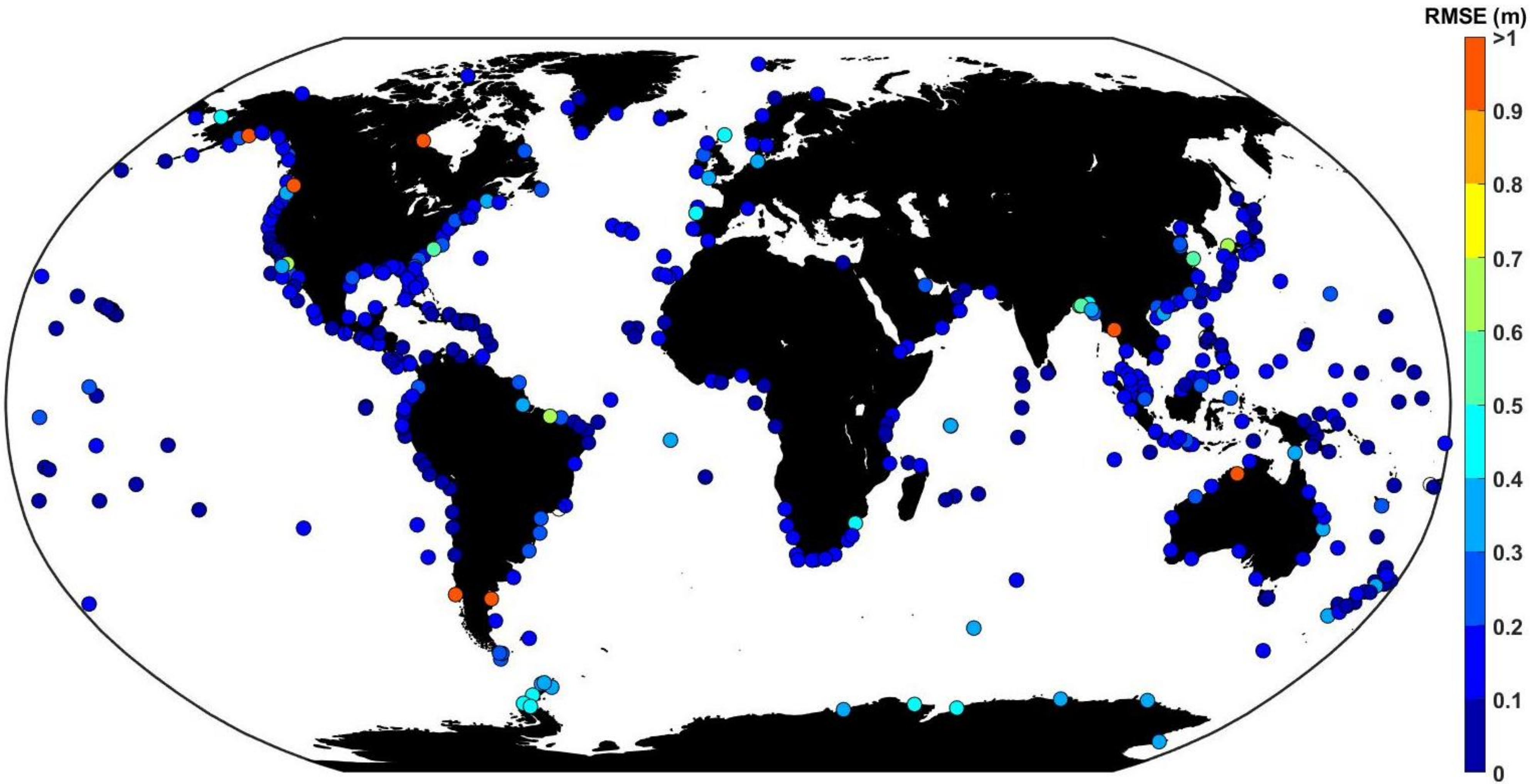
- **Bathtub** approach (connection to coastline)

- GTSR dataset is referenced to mean sea level

- To be consistent with the SRTM vertical datum, the GTSR extremes are corrected with **Mean Dynamic Ocean Topography** (MDOT) to determine inundation (As indicated by Muis et al, 2017)

RESULTS
RMSE-Without Wave Setup

RMSE BETWEEN MODEL(SURGE+TIDE) vs OBSERVATIONS



RESULTS
RMSE-With Wave Setup

RMSE BETWEEN OBSERVATIONS vs MODEL LEVELS

RMSE (m)	ERAI	GOW2	NO WAVE SETUP
m=1/15	0.169	0.173	
m=1/30	0.168	0.171	0.17
m=1/100	0.167	0.170	

ON AVERAGE; ALMOST NO DIFFERENCE

RESULTS
RMSE-Wave Setup Contribution

Among the tide gauge locations, the mean RMSE for the MSLs was 0.17 m in Muis et al. (2016) and here with the WS contribution we found RMSE unchanged with either wave models since:

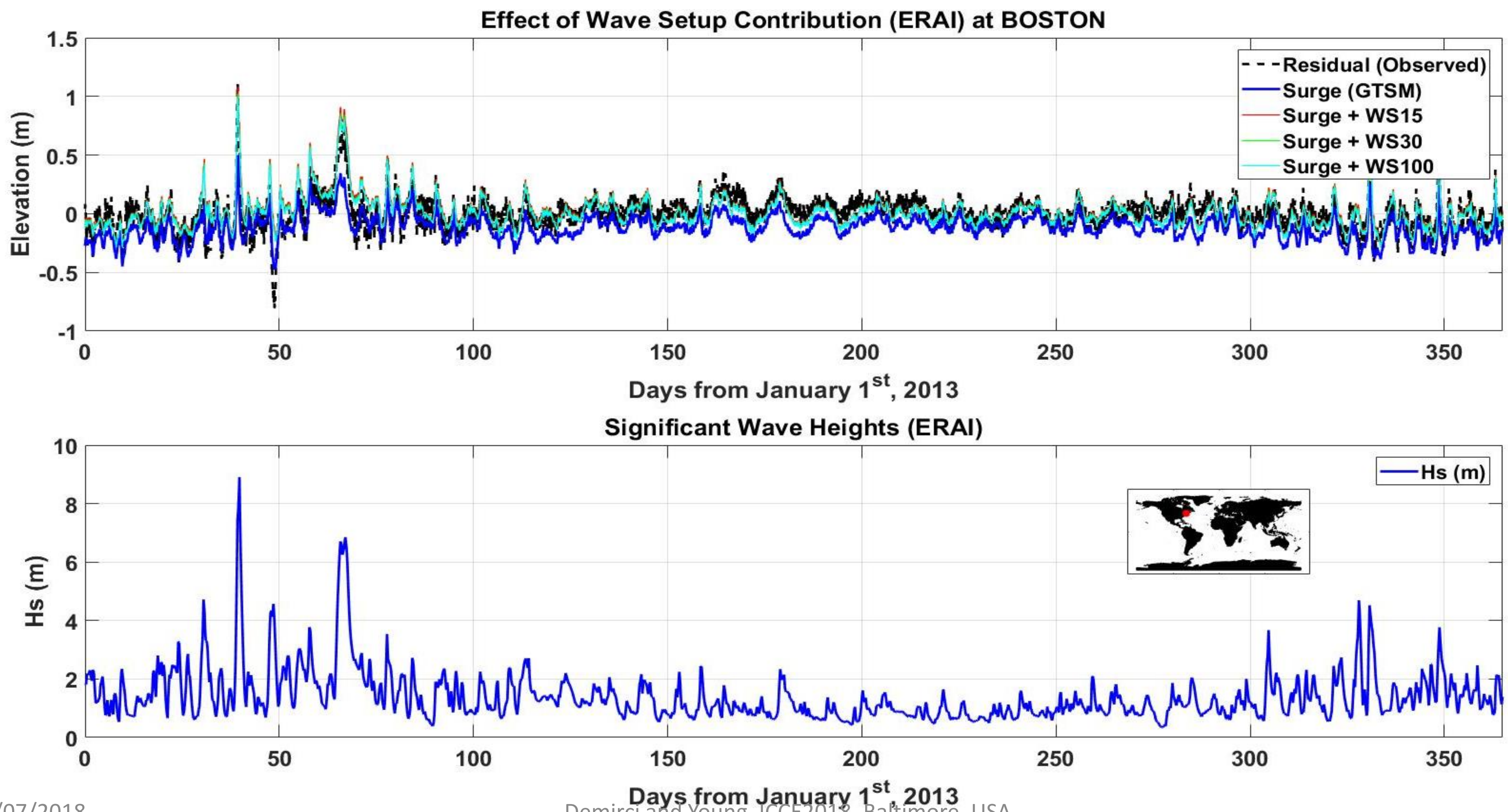
1- Tides dominate the mean sea level fluctuations (surge and WS effects are smaller relatively)

2- WS exacerbates the surge level mainly during storm periods

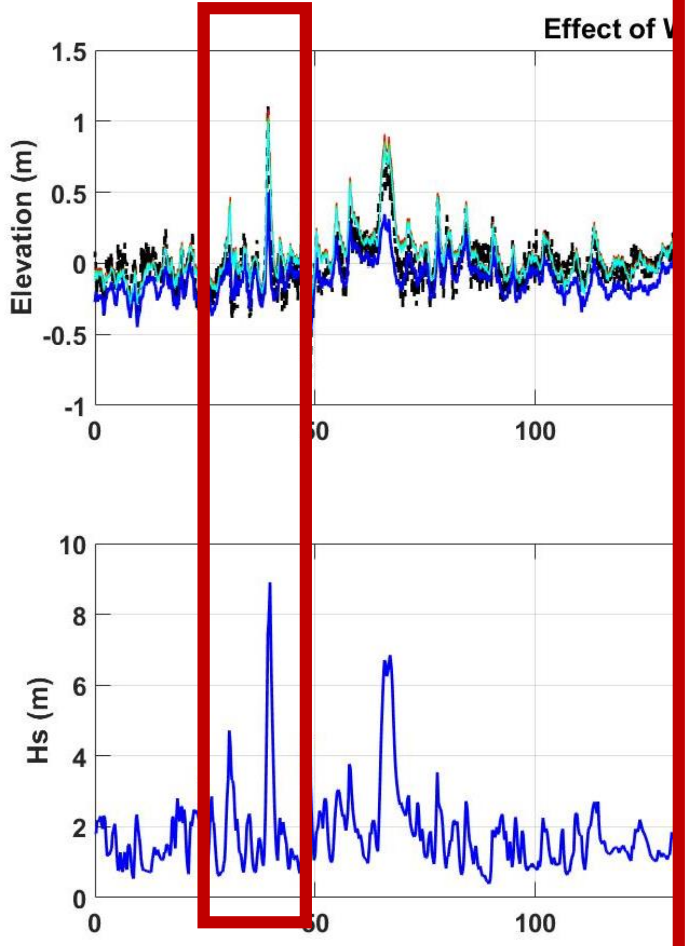
3- Tide gauge locations may not “feel” the WS as most of them are located in calmer regions where those are not exposed to waves

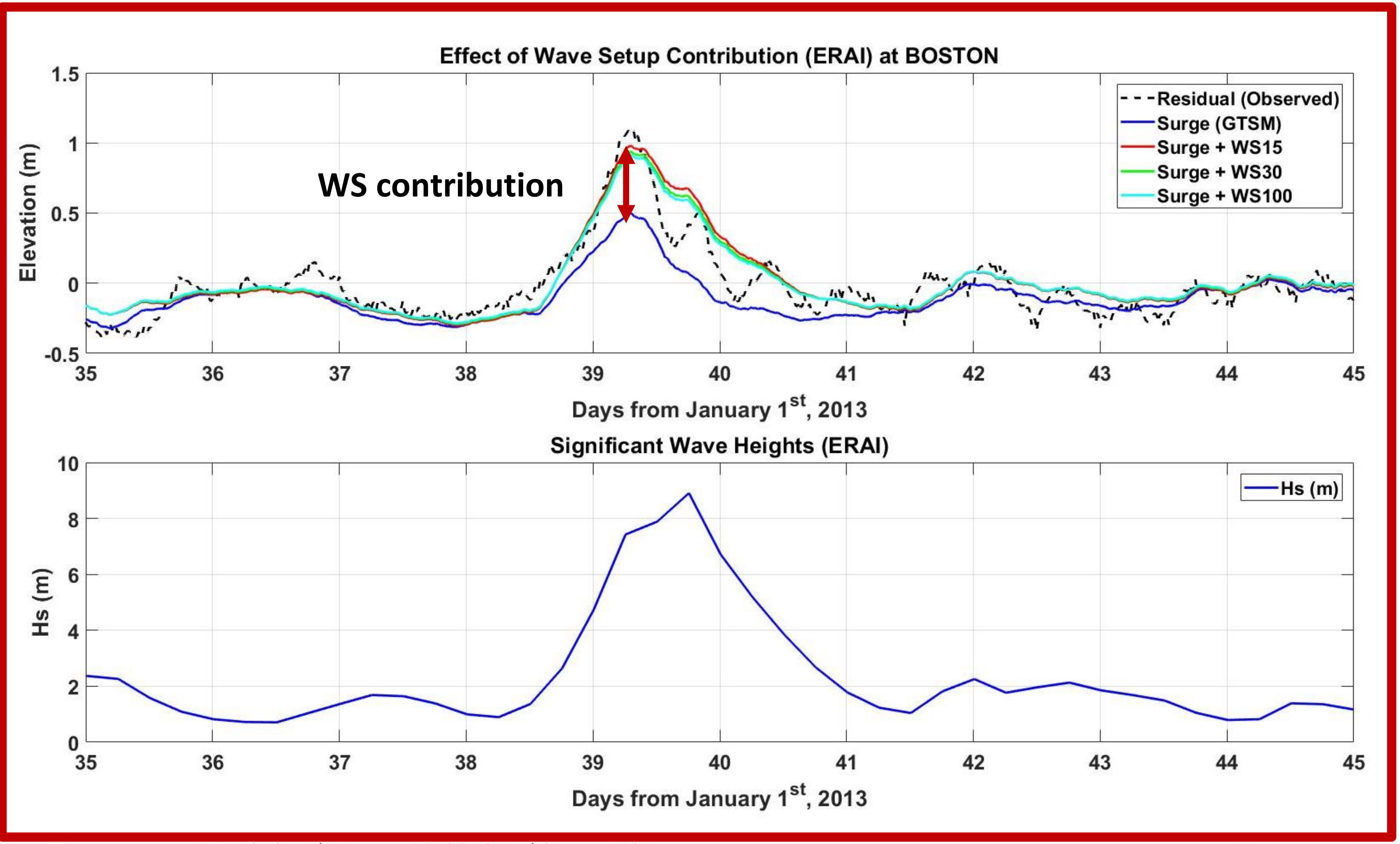
HOWEVER, we see local effects site specifically

RESULTS
Wave Setup Contribution



RESULTS
Wave Setup Contribution - ERA-I

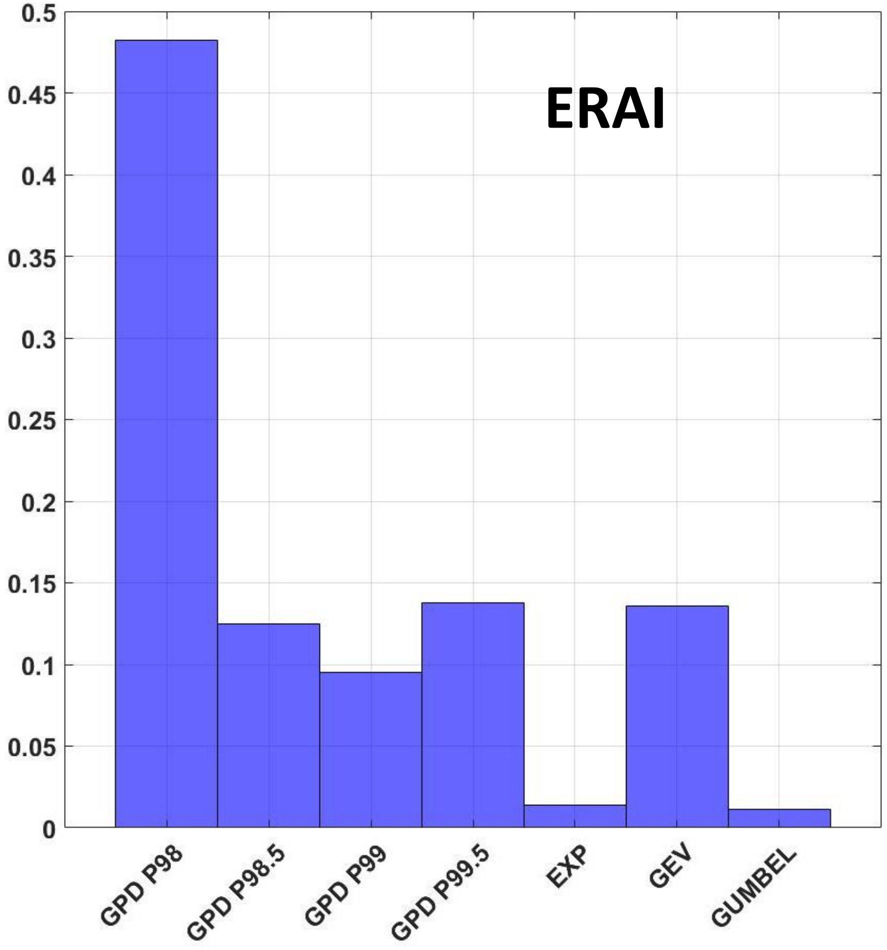


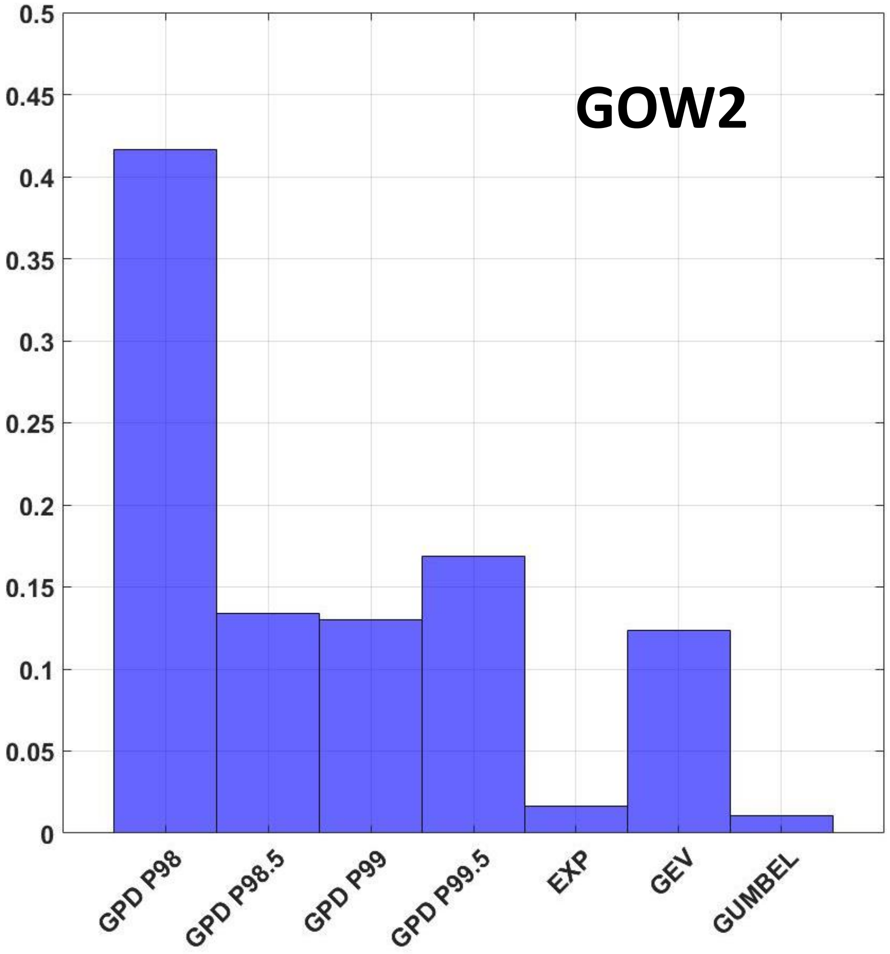


RESULTS
Extreme Value Analyses

Decision on the globally best fitting method

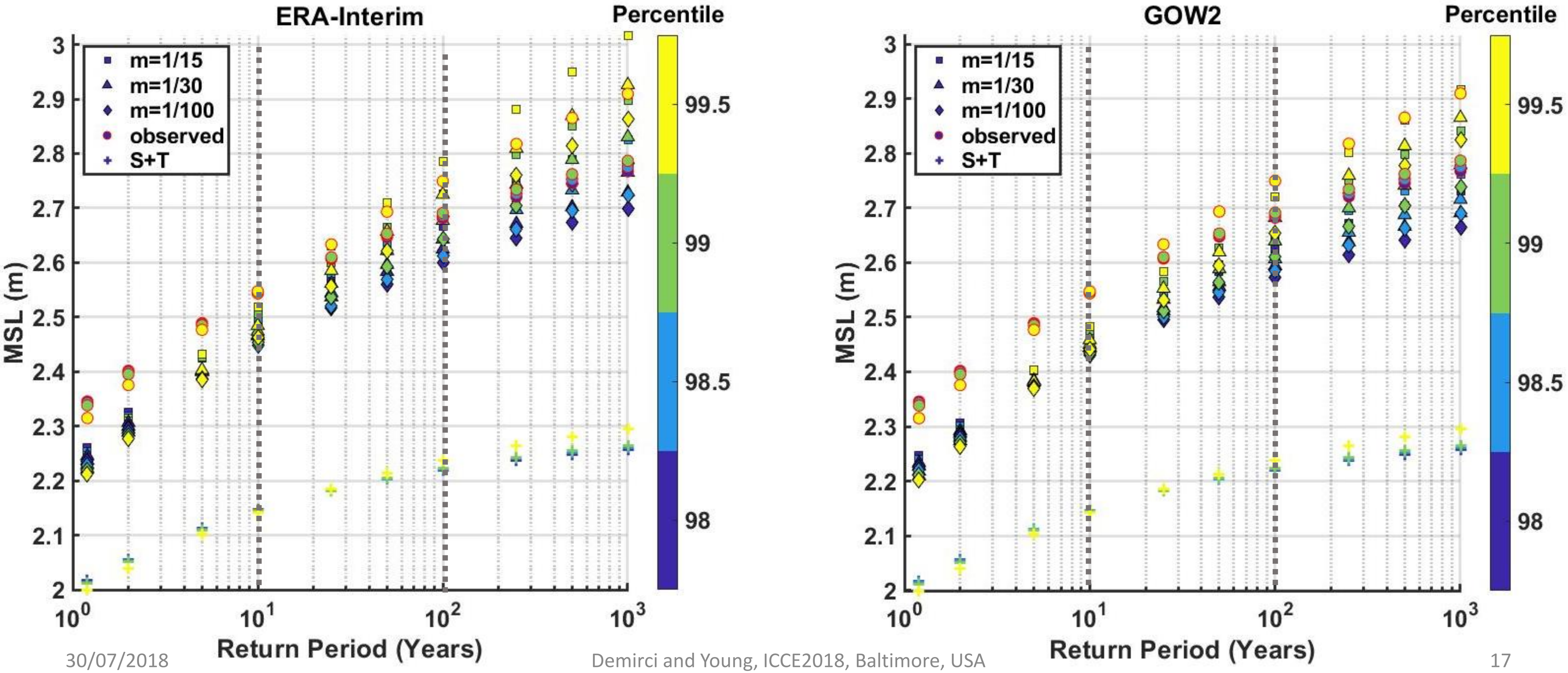
Histogram of the EVA methods





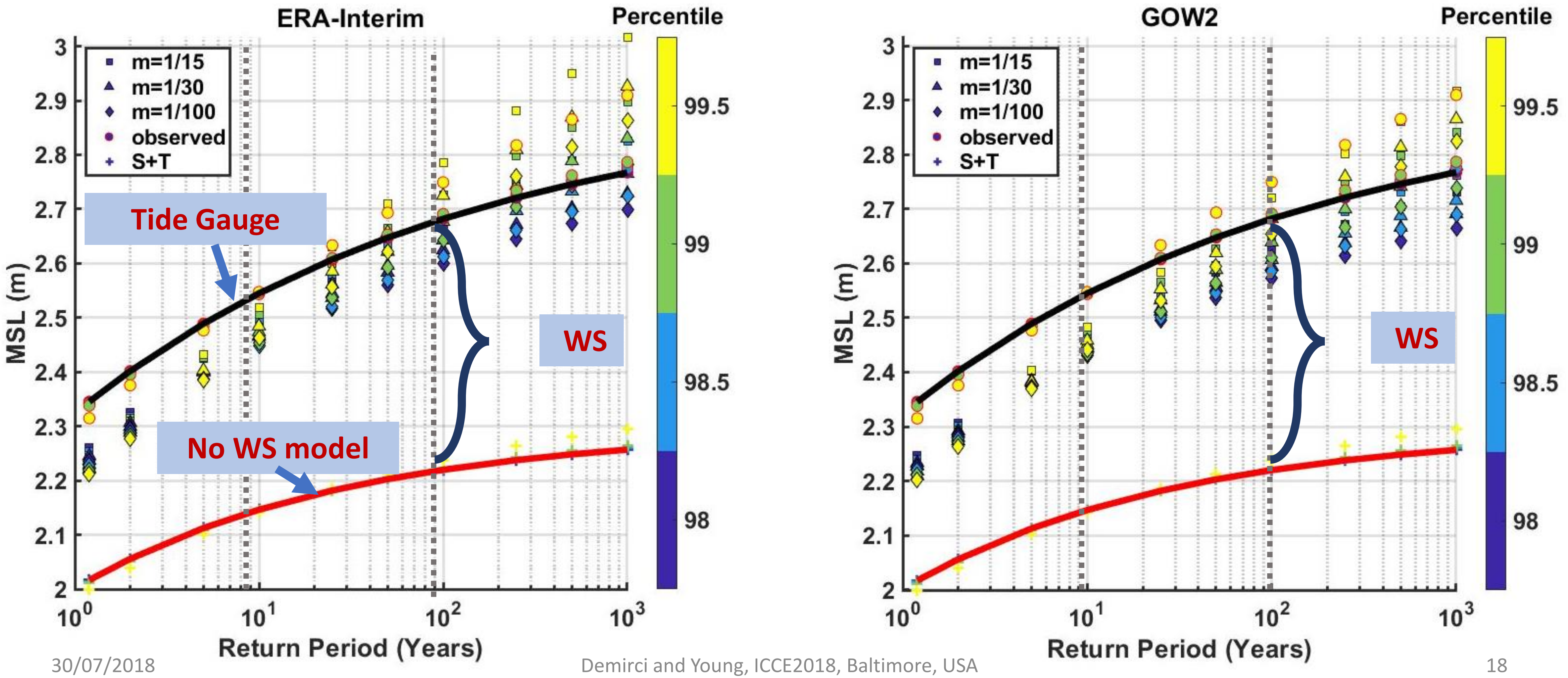
RESULTS
Extreme Value Analyses

Performance of wave setup contribution with varying EVA method



RESULTS
Extreme Value Analyses

Performance of the wave setup contribution with varying EVA method



RESULTS
Extreme Value Analyses

Significant improvement in the bias of the return period values

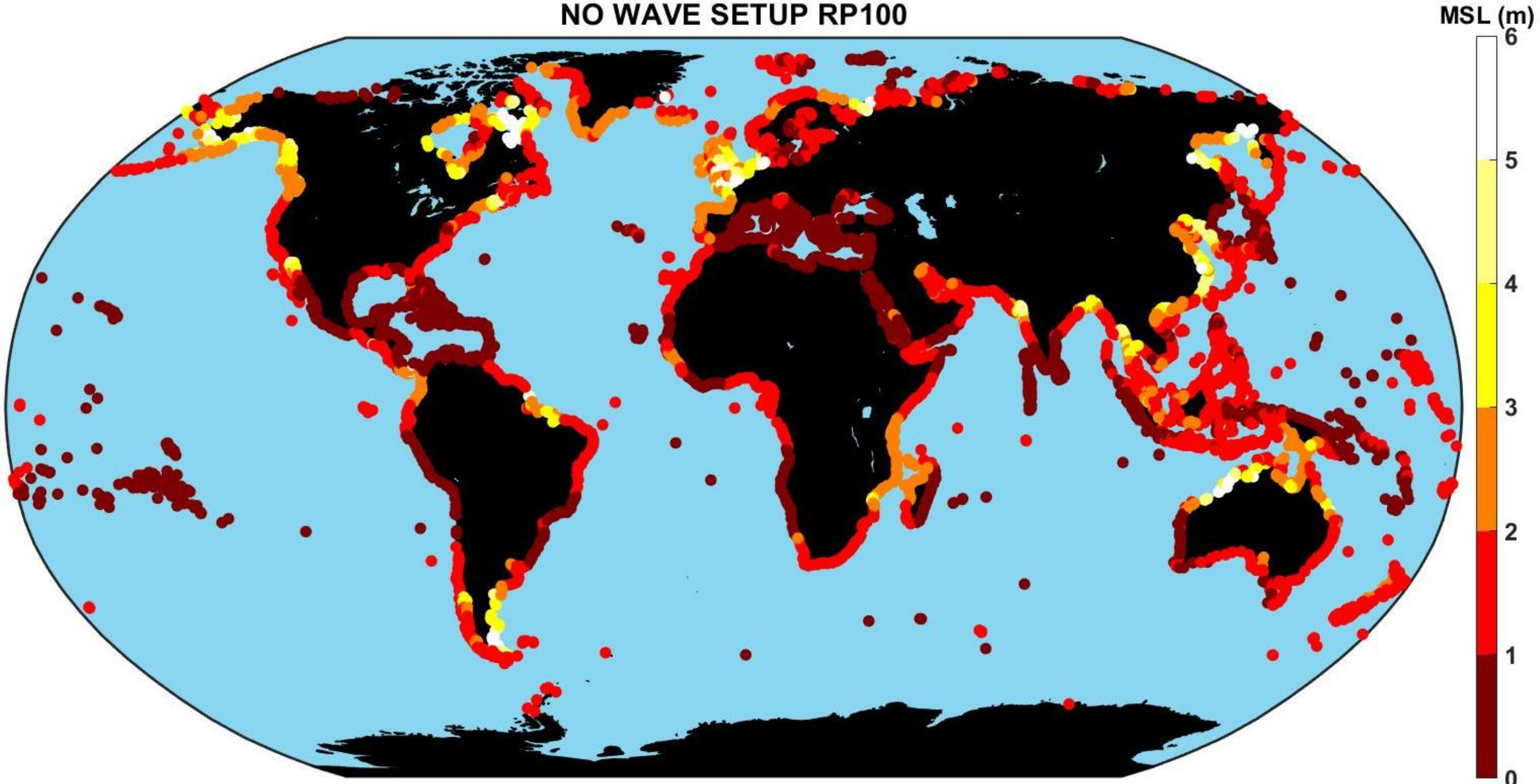
Biases for RP10 GPD P98

	NO WAVE SETUP	ERAI	GOW2
m=1/15	-0.200	0.014	0.035
m=1/30		-0.008	0.010
m=1/100		-0.022	-0.005

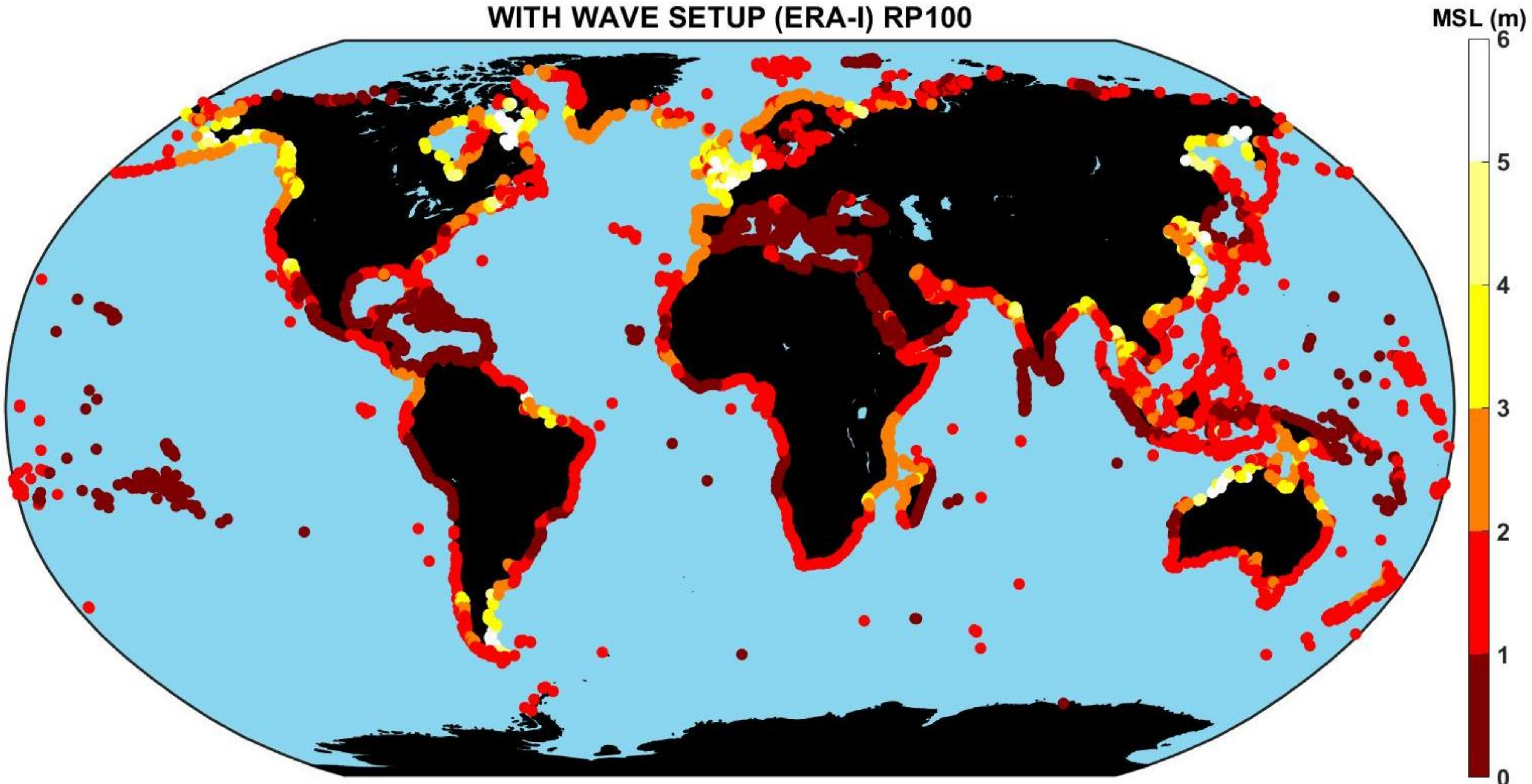
Biases for RP100 GPD P98

	NO WAVE SETUP	ERAI	GOW2
m=1/15	-0.248	0.006	0.038
m=1/30		-0.022	0.005
m=1/100		-0.039	-0.014

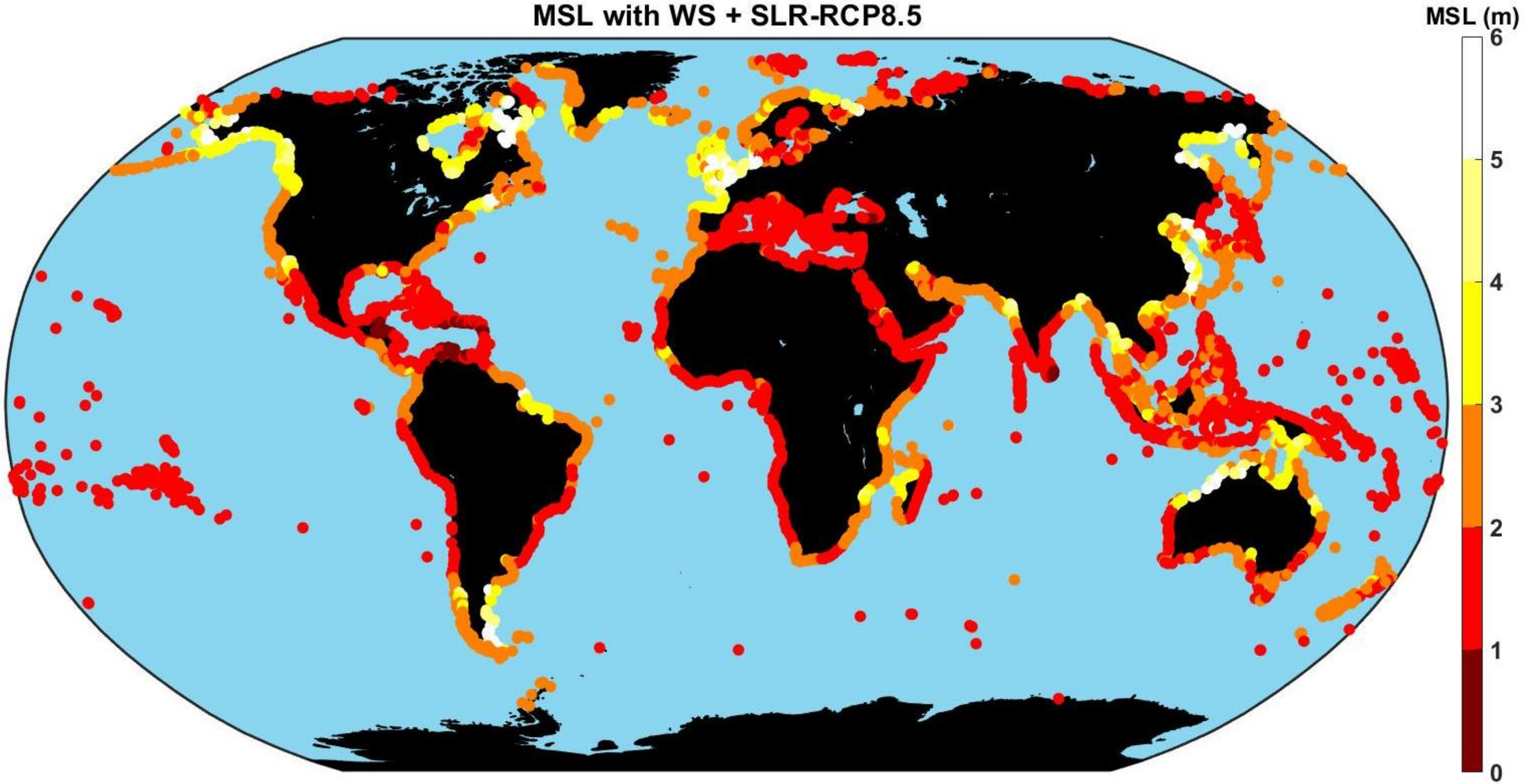
RESULTS
Extreme Value Analyses-No WS



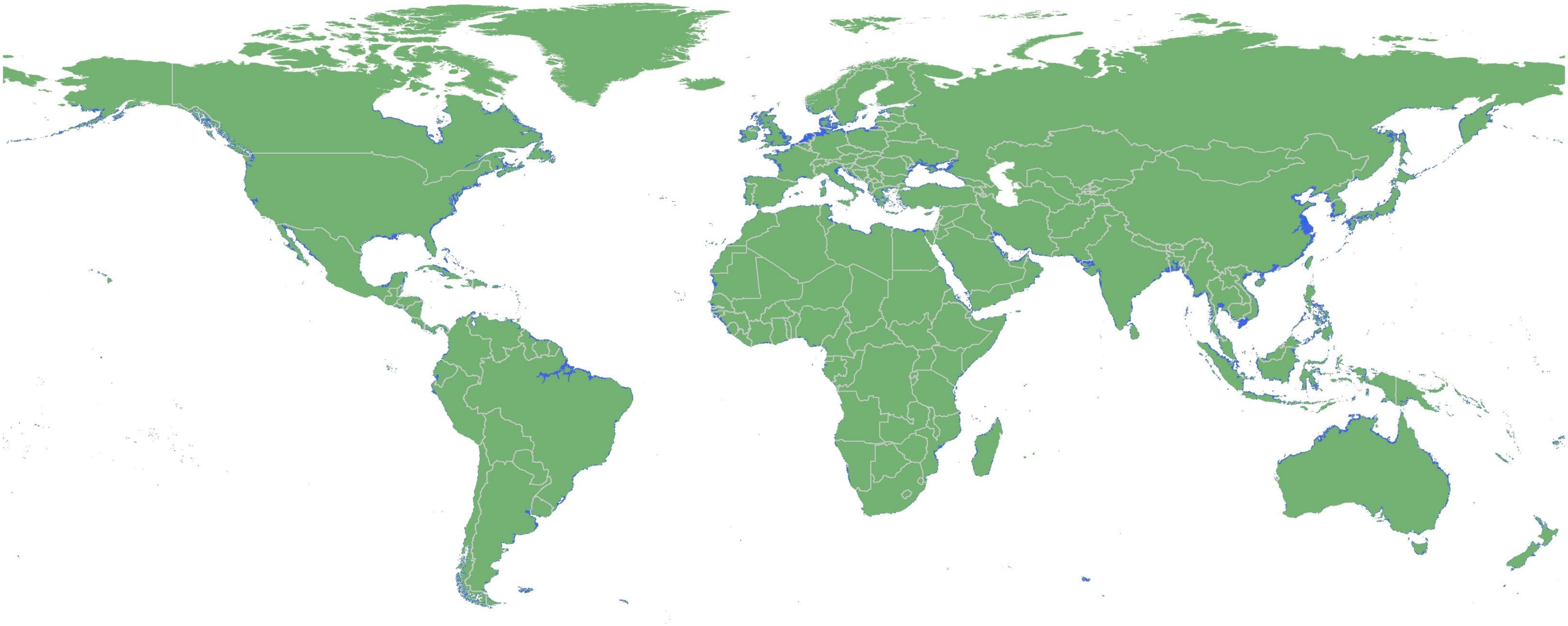
RESULTS
Extreme Value Analyses-With WS



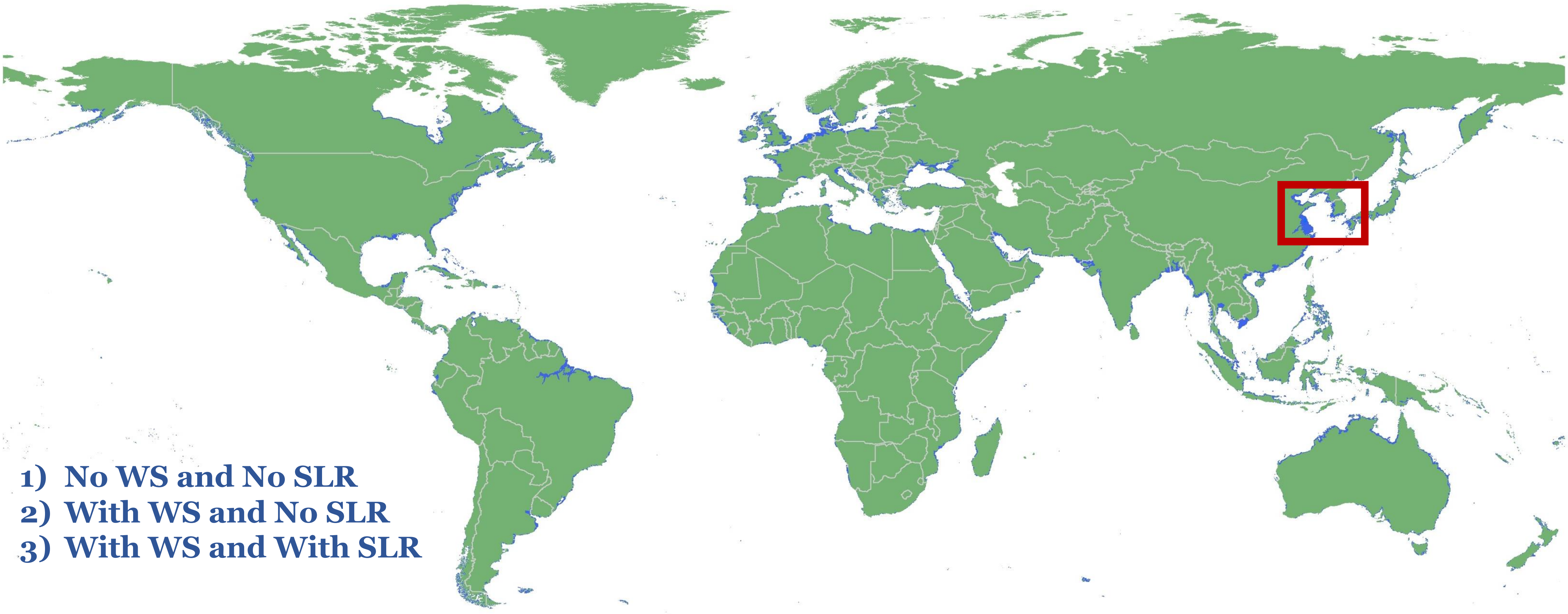
RESULTS
SLR contribution for the next century



RESULTS
Inundation Extent

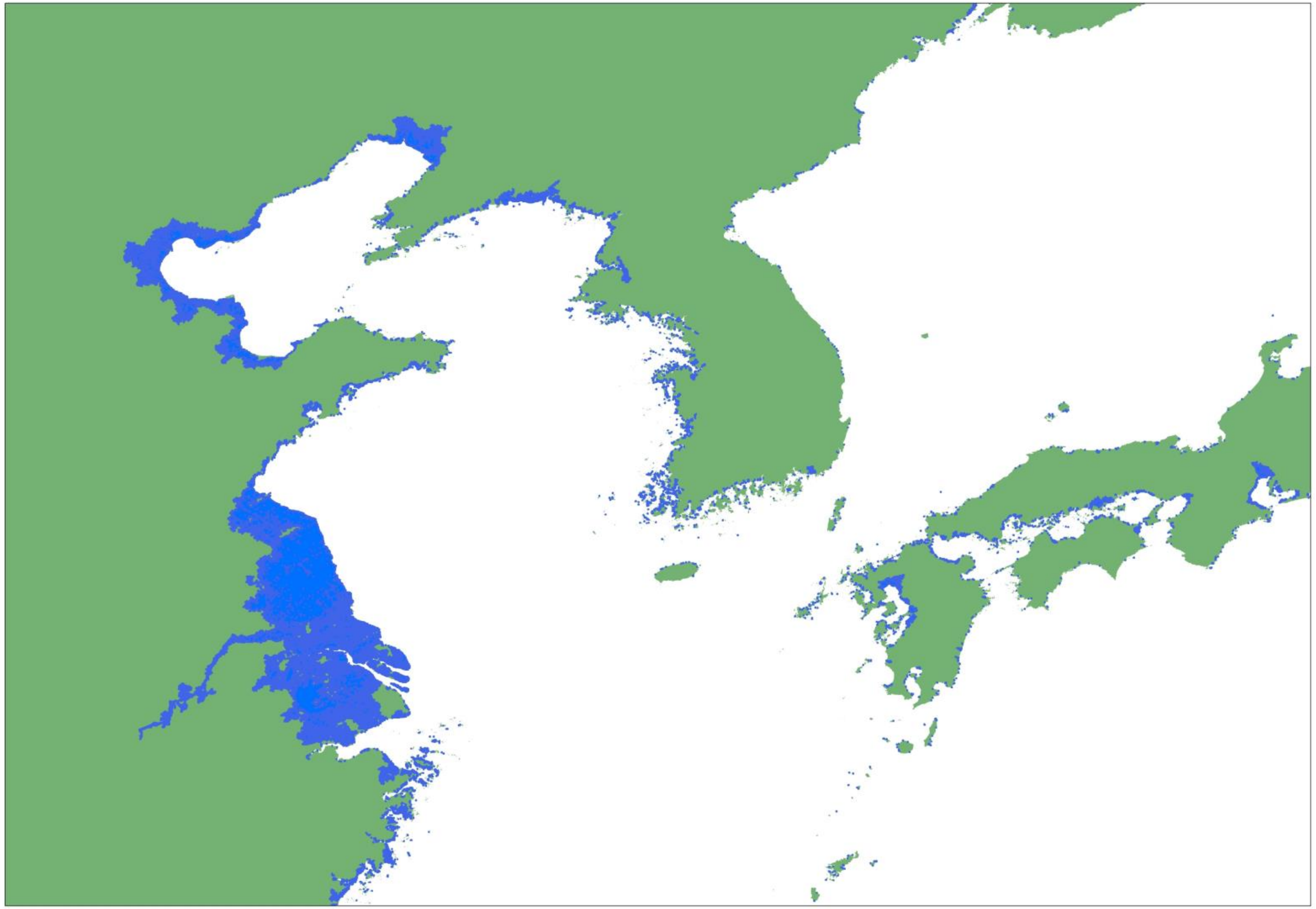


RESULTS
Inundation Extent (for 3 cases)

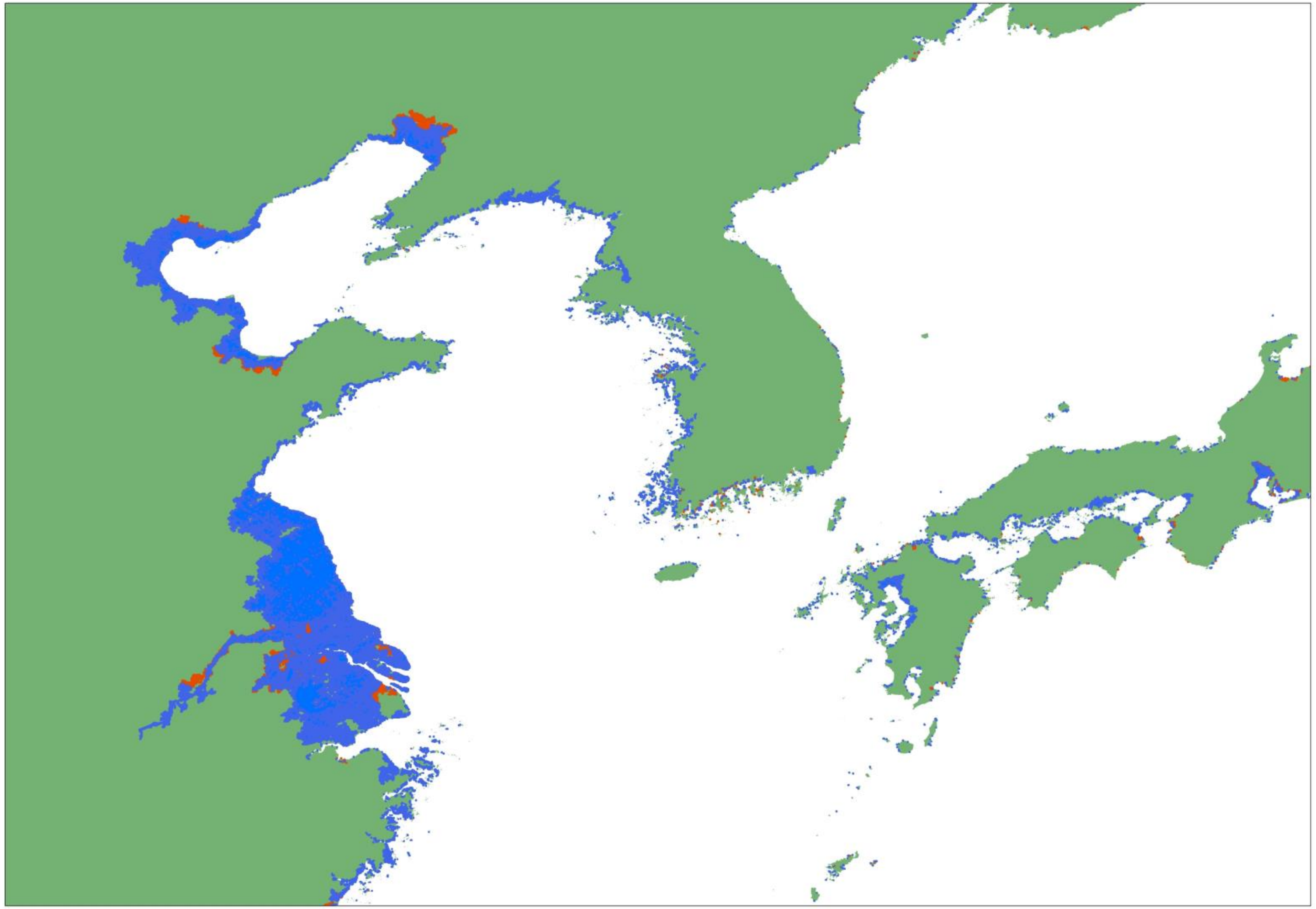


1) No WS and No SLR
2) With WS and No SLR
3) With WS and With SLR

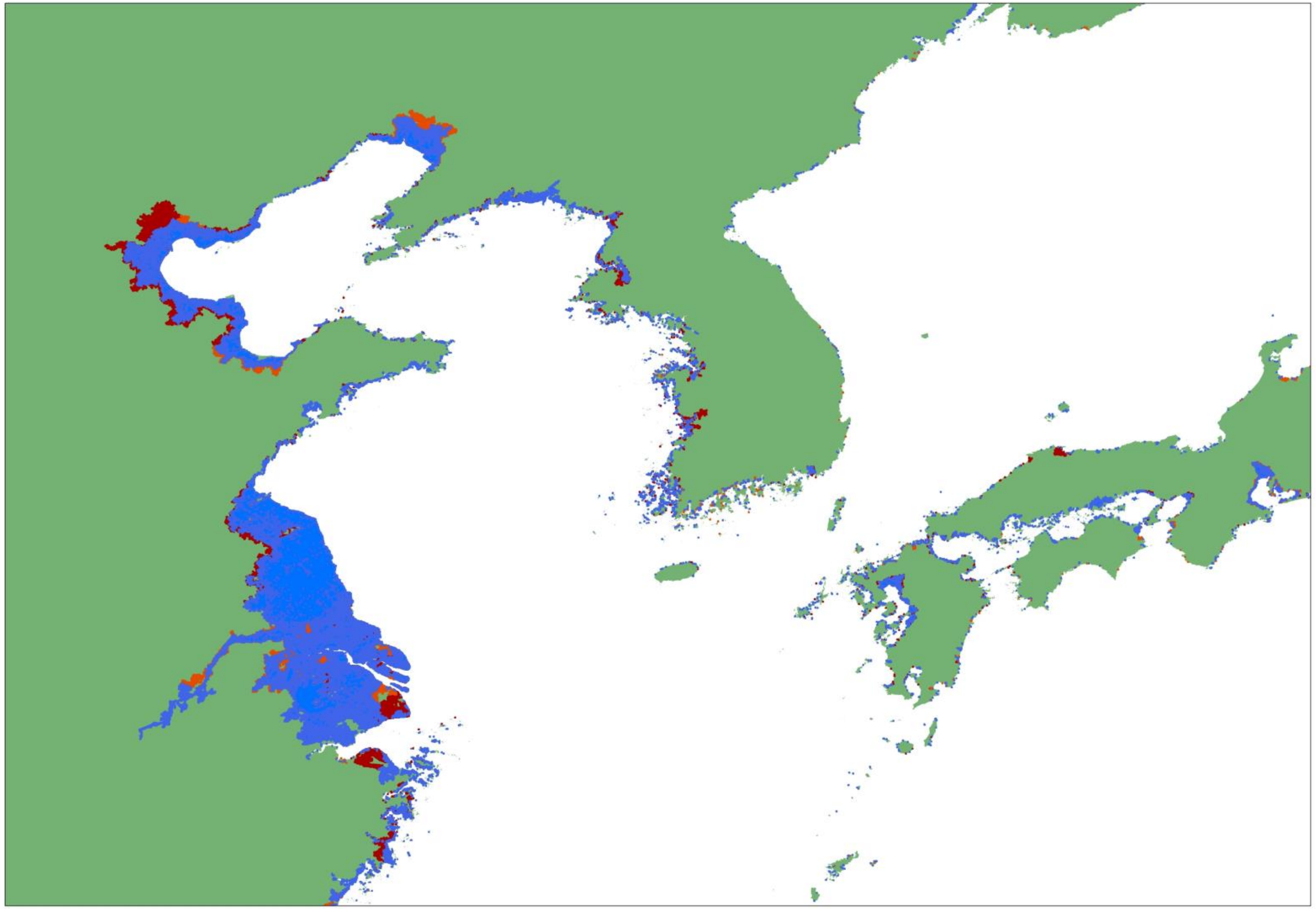
RESULTS
Inundation Extent -No WS & No SLR



RESULTS
Inundation Extent - With WS & No SLR



RESULTS
Inundation Extent -With WS & With SLR



CONCLUSION-1/2

- Increase in coastal flood risk requires a global assessment to highlight **high risk** coastal zones
- **GTSR** dataset for global sea levels is **adopted and modified (with more recent FES2014)**
- ***Wave setup contribution to mean sea levels is included***
- The modified sea levels are validated with global tide gauge data
- ***No significant change*** is observed globally with respect to **mean RMSE of the *sea levels***

CONCLUSION-2/2

- ***HOWEVER*, it is observed that wave setup creates a significant difference with respect to Extreme Sea Levels**
- **GPD with 98-percentile is selected as the best-fit EVA globally**
- **No comparable difference between ERAI and GOW2 wave setups with respect to RMSE of MSL and ESLs**
- **A preliminary approach is adopted for SLR contribution (worst case scenario RCP8.5)**
- Wave setup contribution **impacts** the inundation exposure.
- Addition of the wave setup increased inundated areas by **7 %** whereas further inclusion of SLR increased inundated areas by an additional **28 %**.

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THANK YOU