Comparison of modeling approaches and the resulting warning products in the framework of the Indonesia Tsunami Early Warning System (InaTEWS)

Sven Harig[1], Andrey Babeyko[2], Antonia Immerz[1]

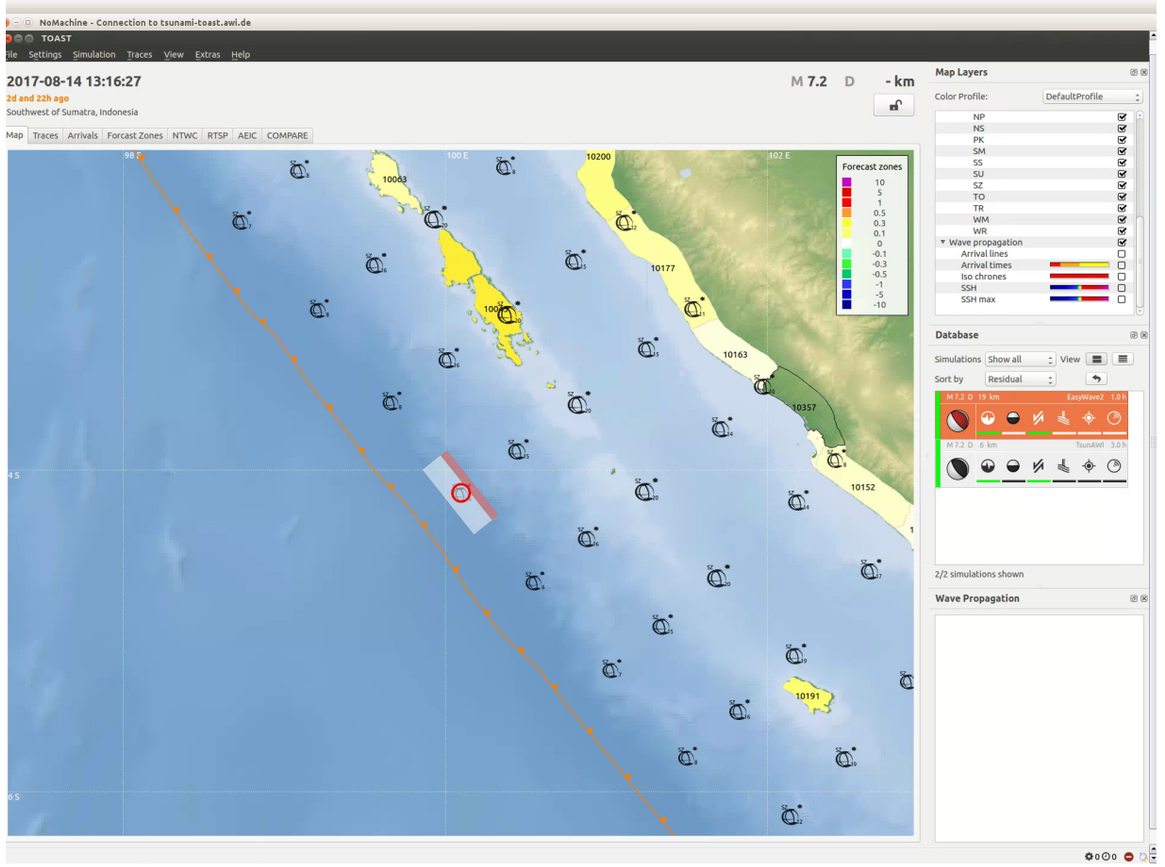
Natalja Rakowsky[1] and Tri Handayani[3]

[1]Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
[2]GFZ German Research Centre for Geosciences, Potsdam, Germany
[3]Agency for Meteorology, Climatology and Geophysics (BMKG), Jakarta, Indonesia

Motivation for the study

- Tsunami Early Warning systems determine and disseminates Warning products like
  - Estimated wave height (EWH)
  - Estimated arrival time (ETA)
- These informations are obtained by numerical simulations and may lead to severe implications like evacuations of the potentially affected population.
- Thus the quality of these products is of crucial importance

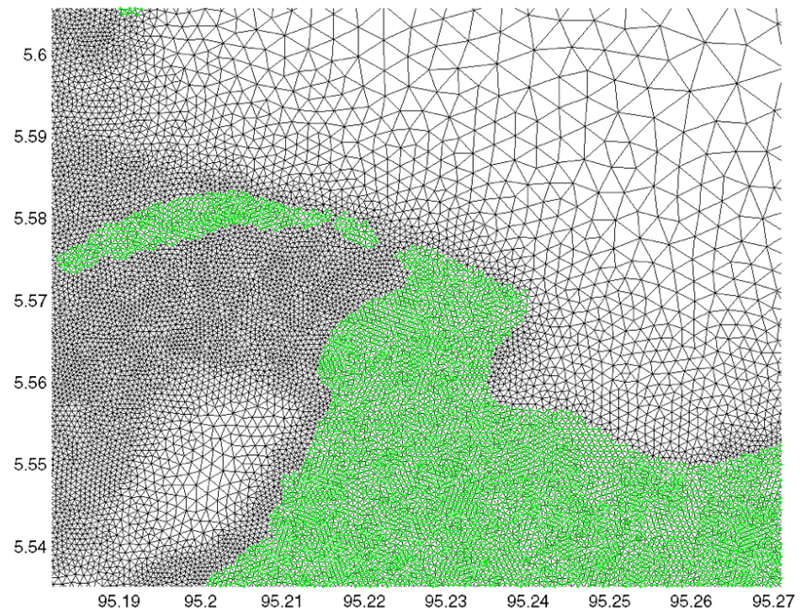
in coastal areas over a large range

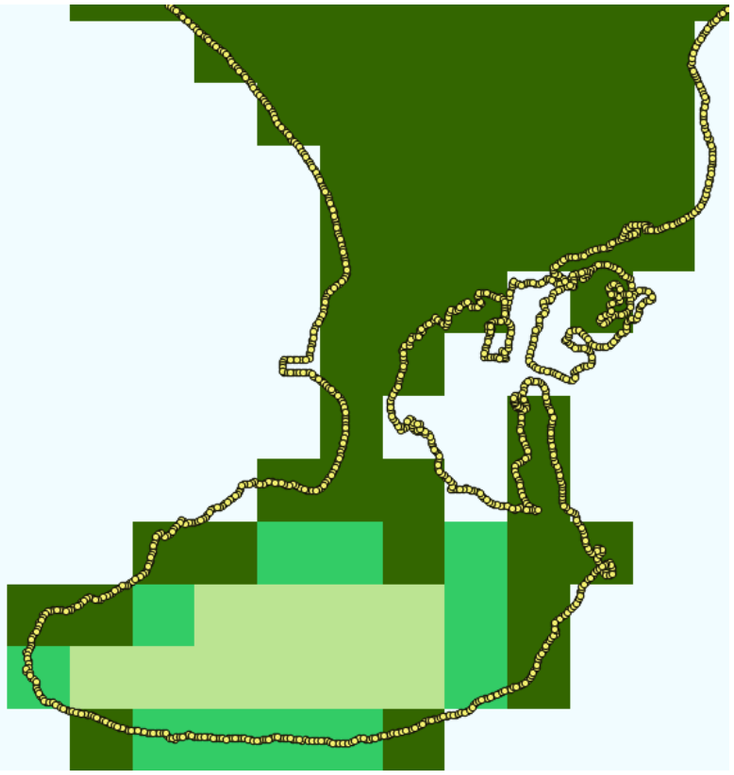


Motivation for the study

InaTEWS contains

- Database of precomputed high resolution tsunami scenarios (TsunAWI) including an inundation scheme
- On-the-fly modeling component for areas not covered by database (easyWave)





Warning products based on values in points of interest (POIs) Full set defined by DLR.

Motivation for the study

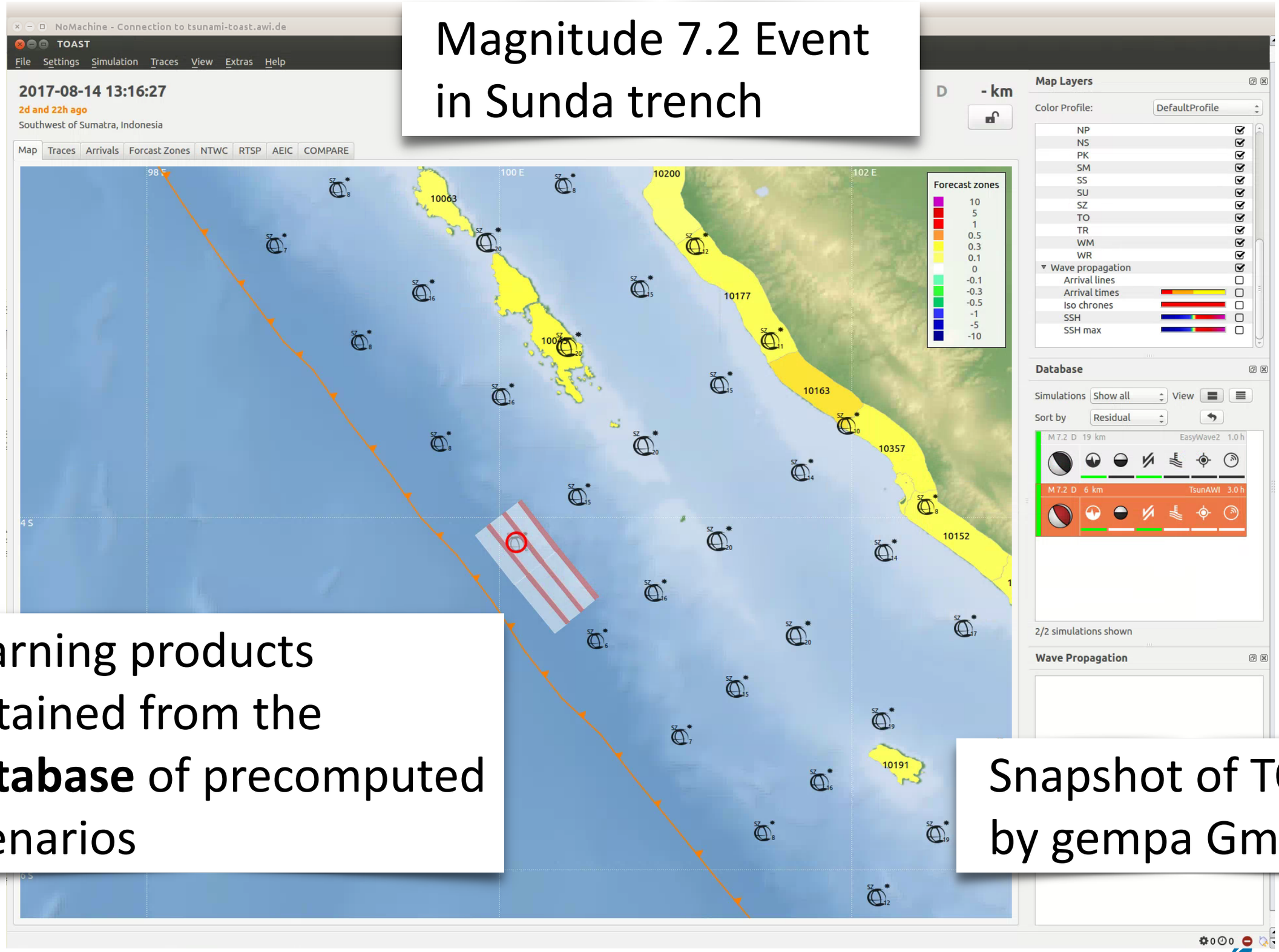
Magnitude 7.2 Event in Sunda trench

Warning products obtained from an **on-the-fly** computation

Snapshot of TOAST by gempa GmbH

Motivation for the study

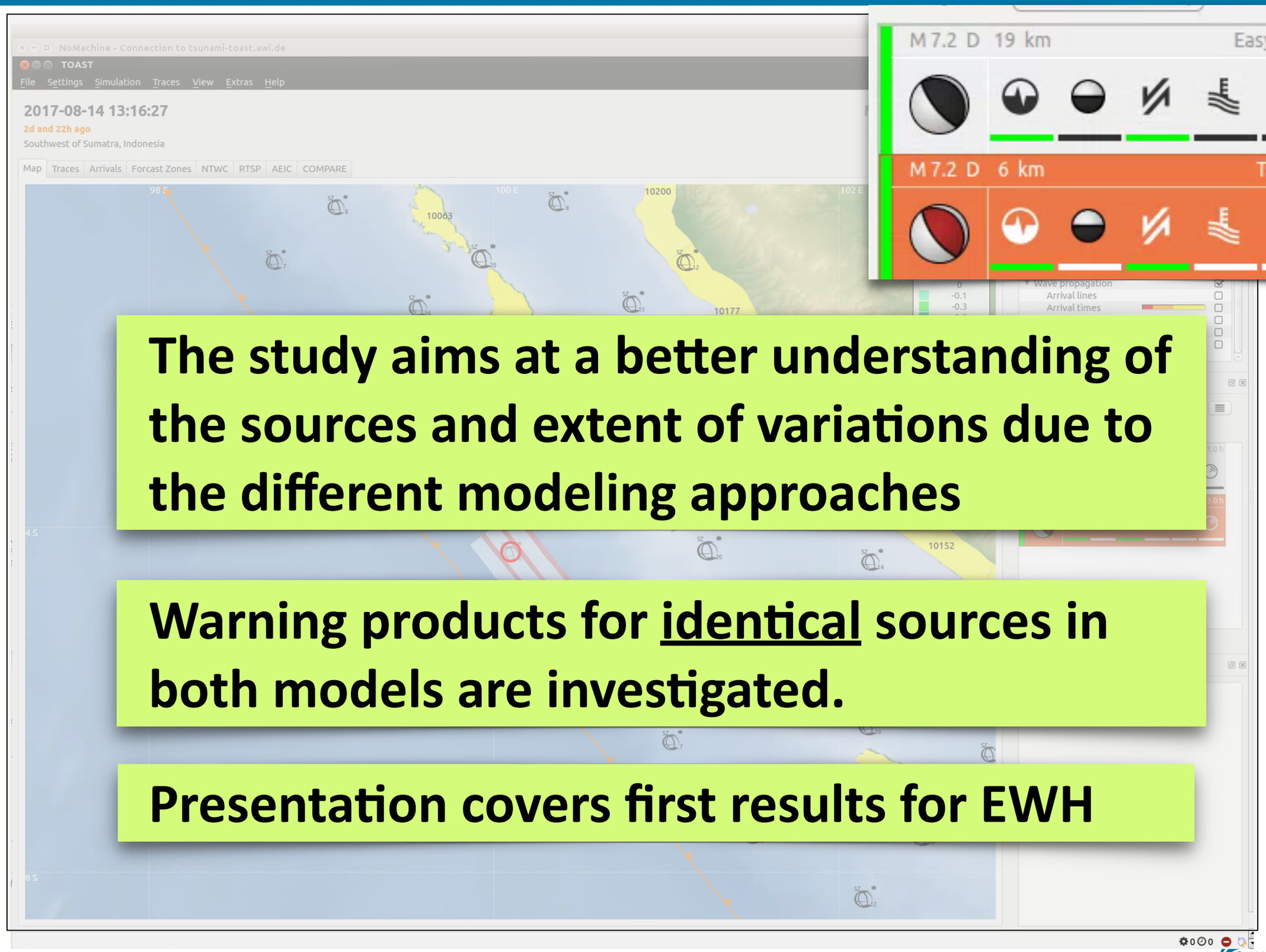
Magnitude 7.2 Event in Sunda trench



Warning products obtained from the **database** of precomputed scenarios

Snapshot of TOAST by gempa GmbH

Motivation for the study



The study aims at a better understanding of the sources and extent of variations due to the different modeling approaches

Warning products for identical sources in both models are investigated.

Presentation covers first results for EWH

Sources for differences of model results

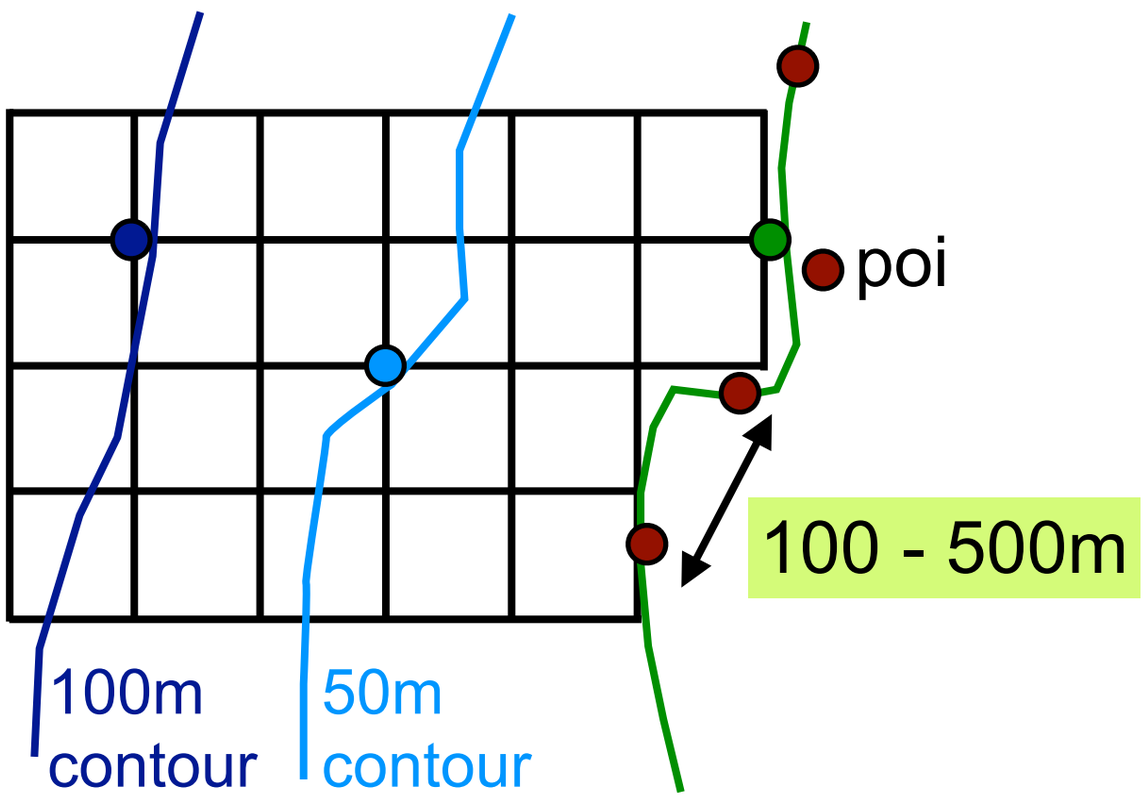
- Model resolution, boundary conditions
- **Topography**
  - easyWave: ETOPO or GEBCO — G08
  - TsunAWI: GEBCO augmented by additional datasets (tcarta, SRTM, some local measurements) — G08MOD
- **Governing equations**: Additional terms in TsunAWI
  - Advection
  - Viscosity
  - Bottom friction
  - Coriolis force

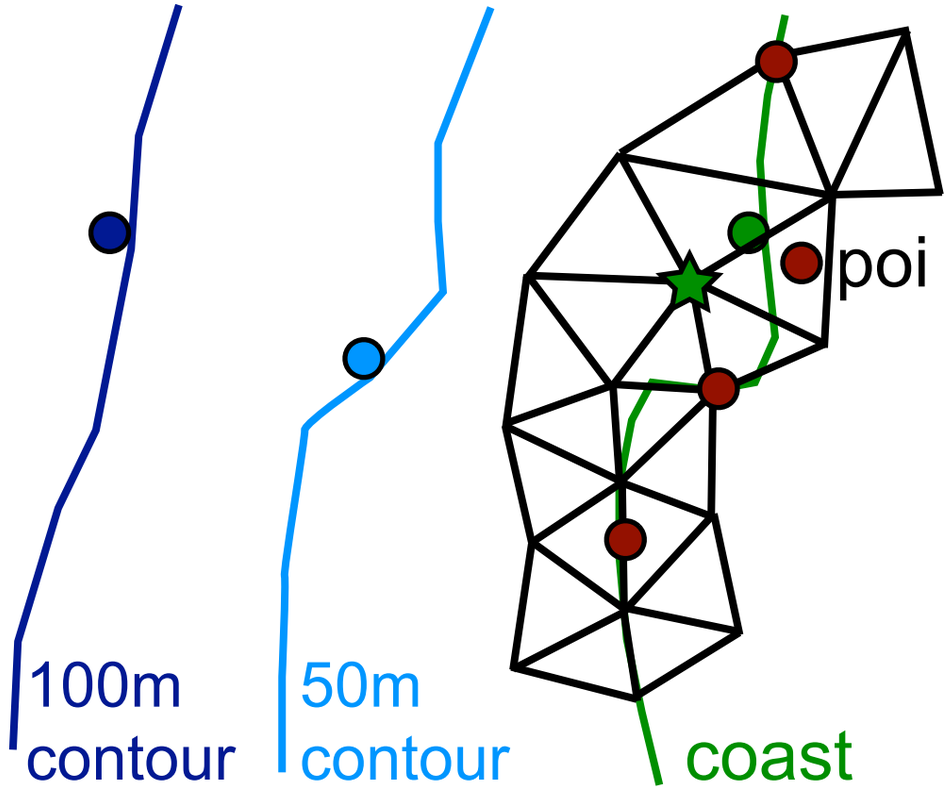
small impact in deep ocean
more important close to the coast

- Determination of warning products (Algorithm: Direct calculation, projection)

The model components in InaTEWS

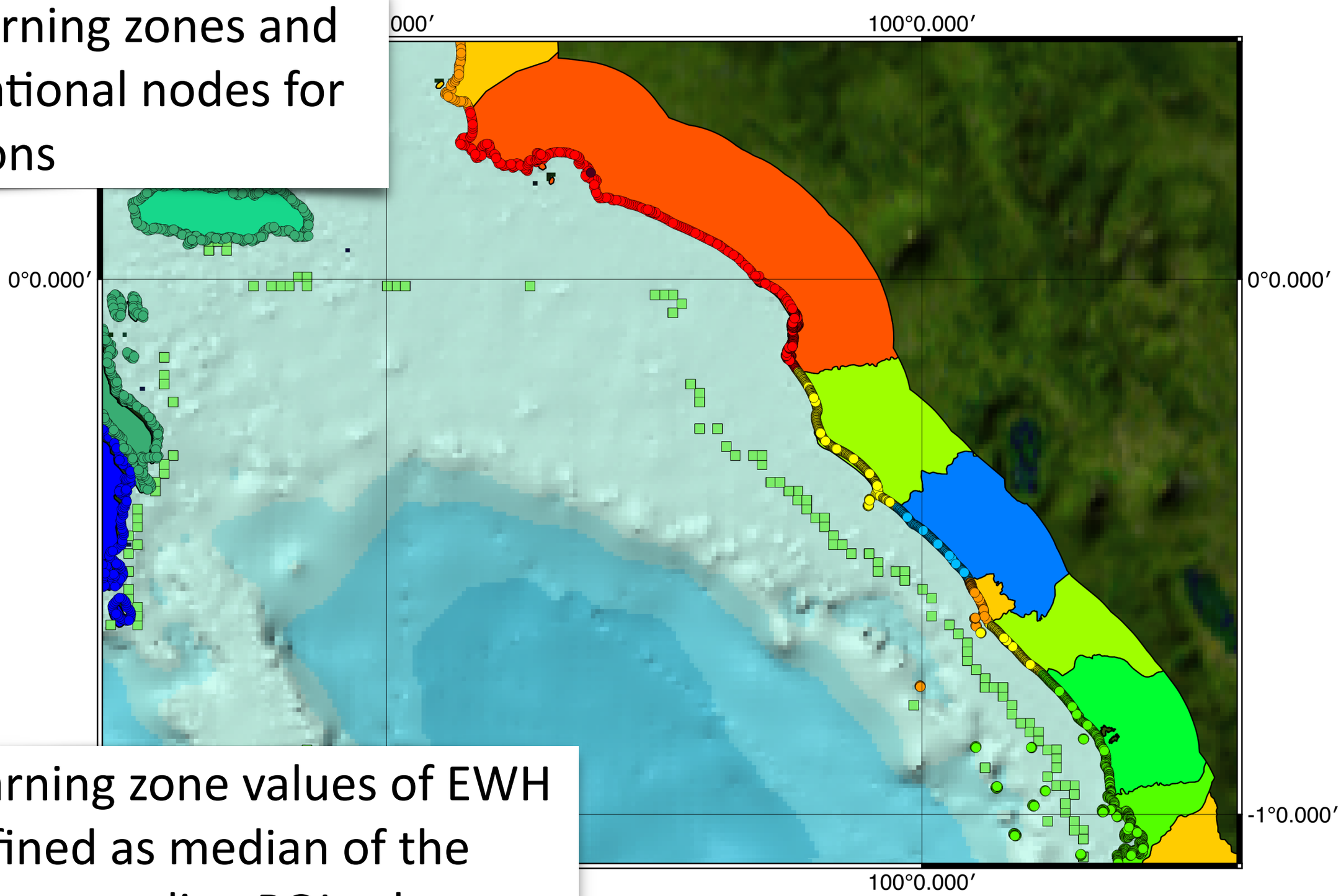
	EasyWave	TsunAWI
Warning products: Determined by aggregation over model results in Points of Interest (POIs) along the coast	Options: - Calculations to nearest coast point - Calculation to given water depth and projection (Green's law)	Mesh covers coastal area up to terrain height of ~50m. Direct calculation of wave height in POIs





Warning zones and POIs

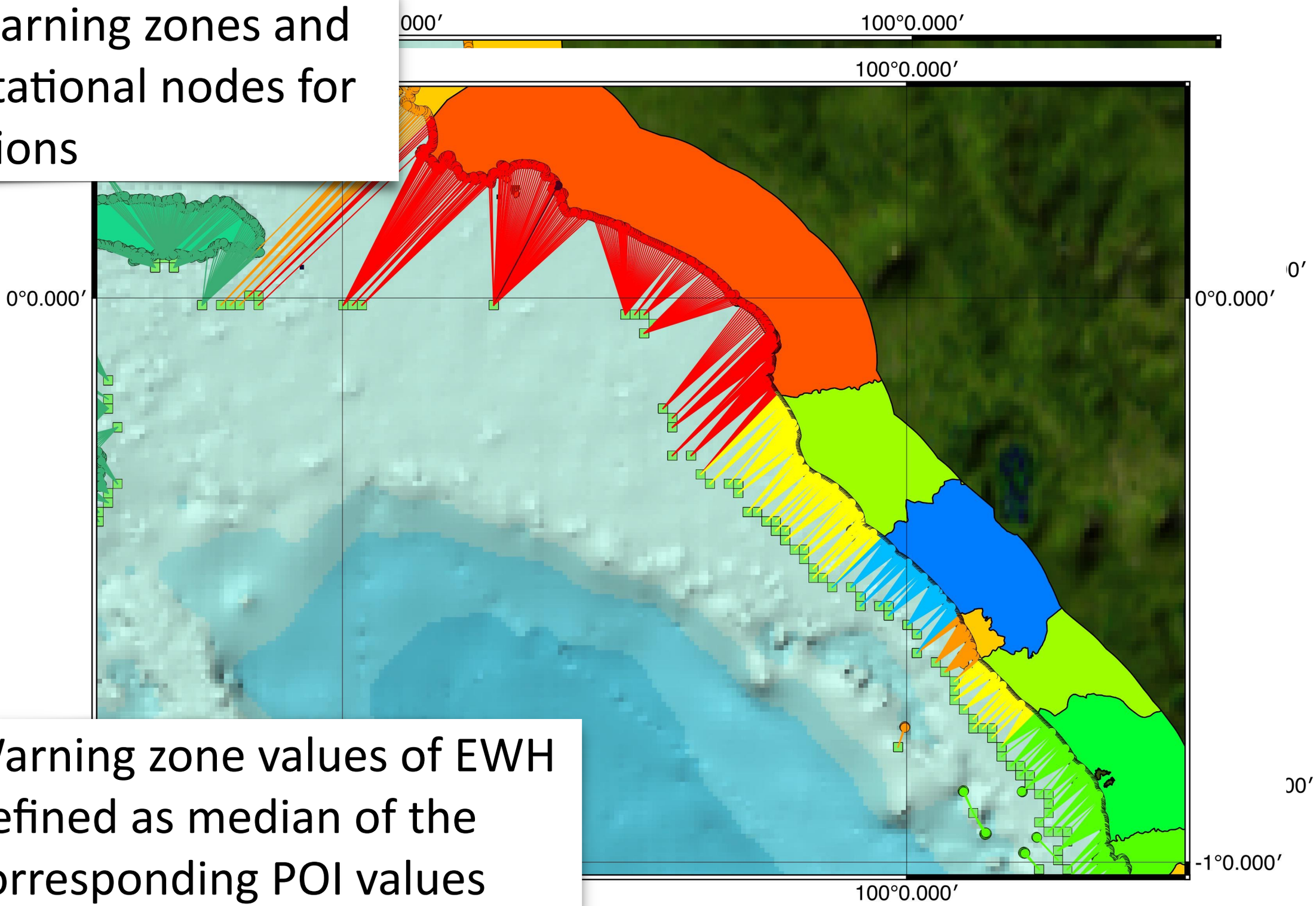
POIs, warning zones and computational nodes for projections



Warning zone values of EWH defined as median of the corresponding POI values

Warning zones and POIs

POIs, warning zones and computational nodes for projections

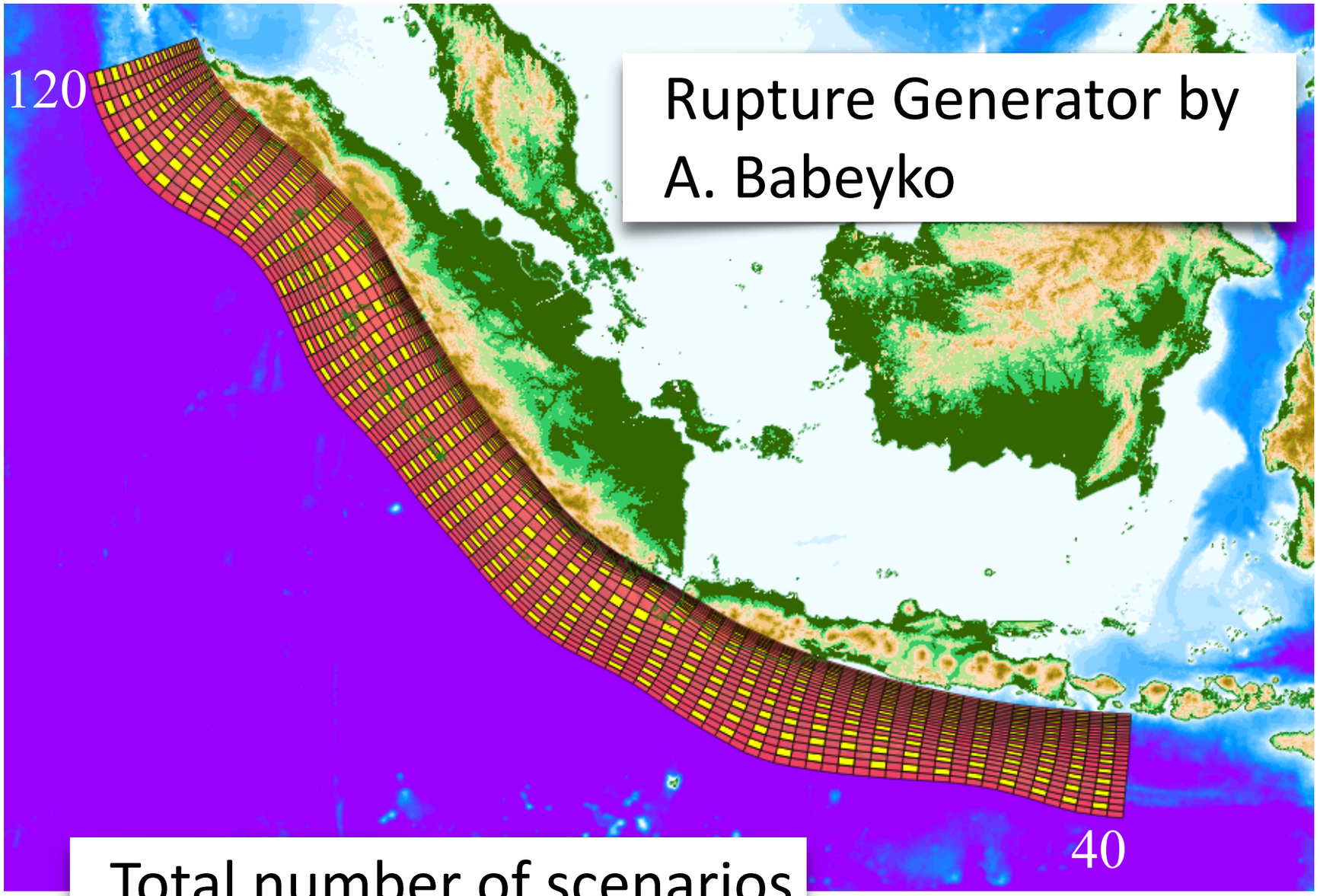


Warning zone values of EWH defined as median of the corresponding POI values

Scenario overview

Magnitude	total nmb
7.0	497
7.2	495
7.4	486
7.6	454
7.8	412
8.0	273
8.2	326
8.4	271
8.6	214
8.8	142
9.0	66
Sum	3636

Central patches of the scenarios involved in the study

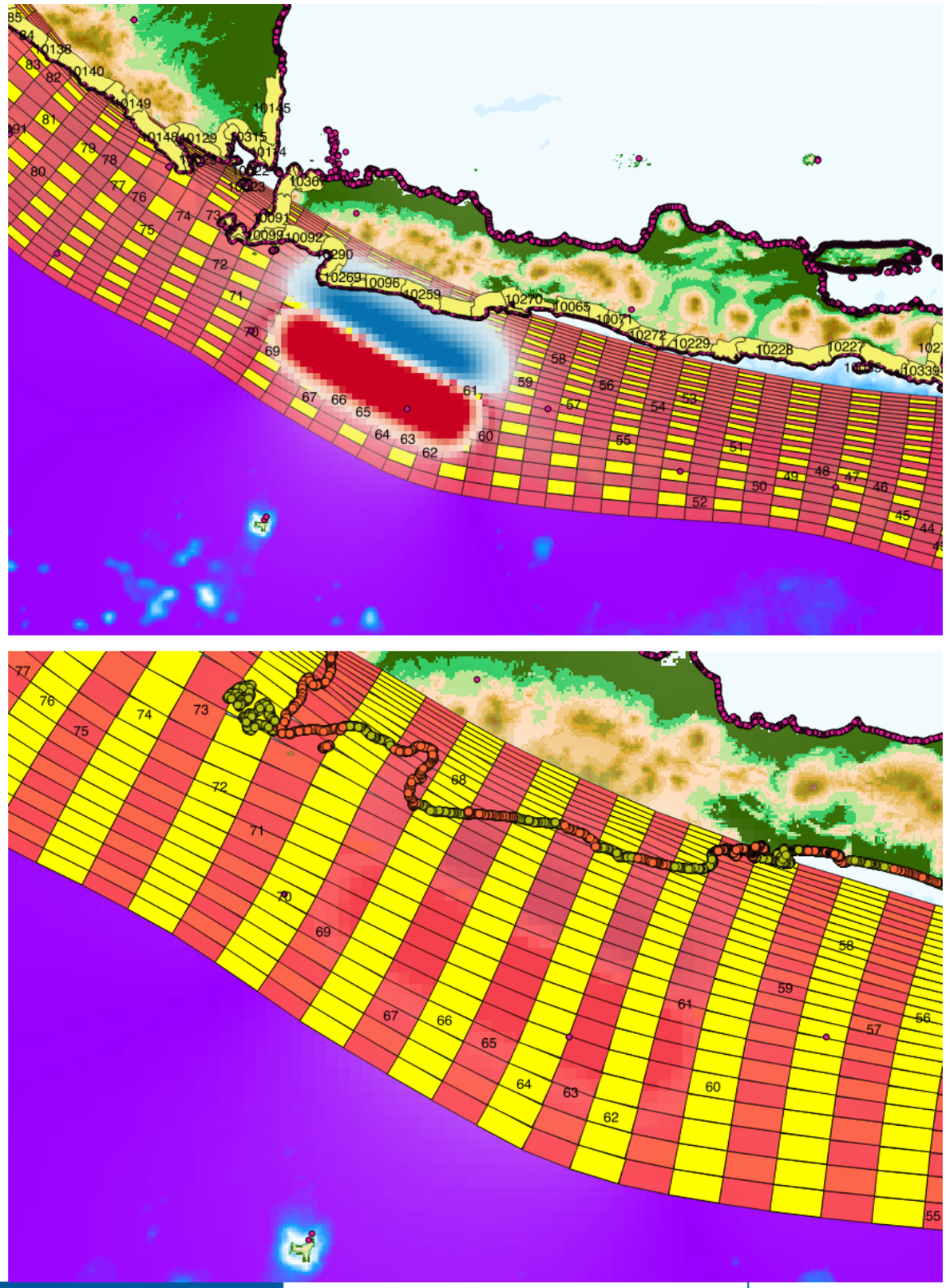


Total number of scenarios in the comparison: 3636

General Strategy

Model configurations:

- **TsunAWI (as in database bathy. G08MOD)**
- **easyWave**
  - **Calc. to coast (G08)**
  - **Calc. to coast (G08MOD)**
  - **Green's law (G08)**



- Identical sources (RuptGen -> indexing of scenarios)
- Bathymetry varies
- Analyse POI values and aggregated warning zone results

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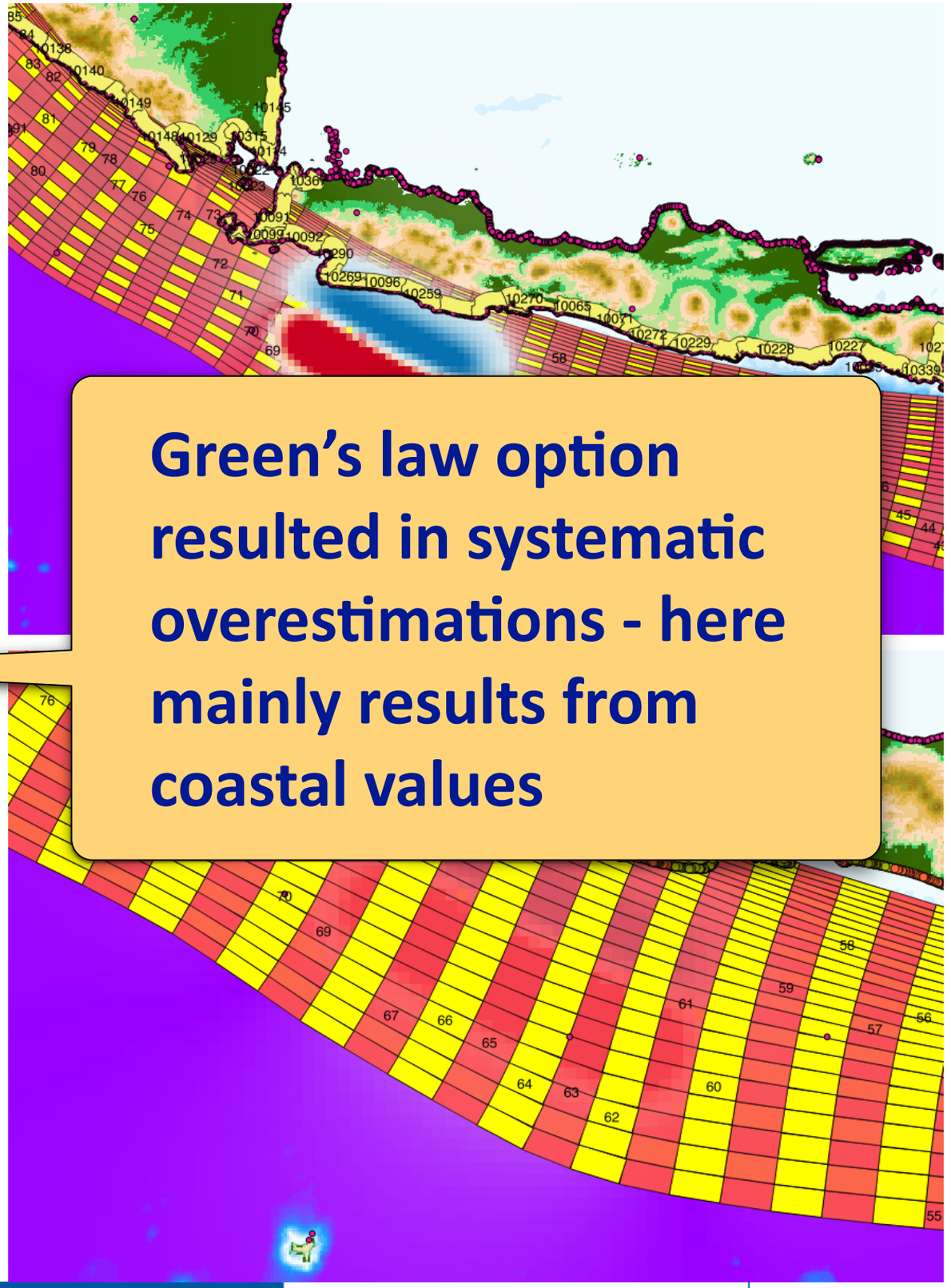

Green's law option resulted in systematic overestimations - here mainly results from coastal values

- Identical sources (RuptGen -> indexing of scenarios)
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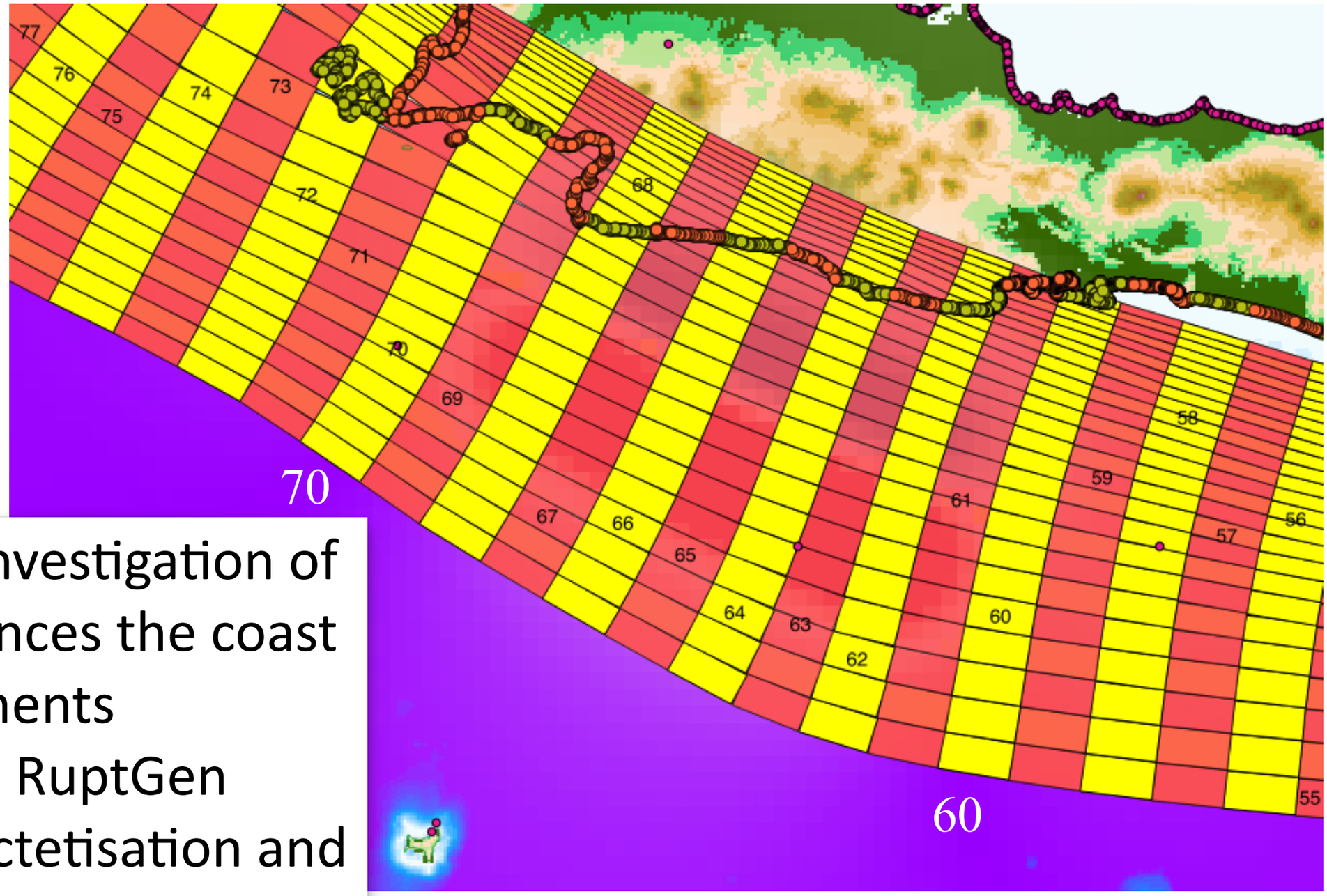
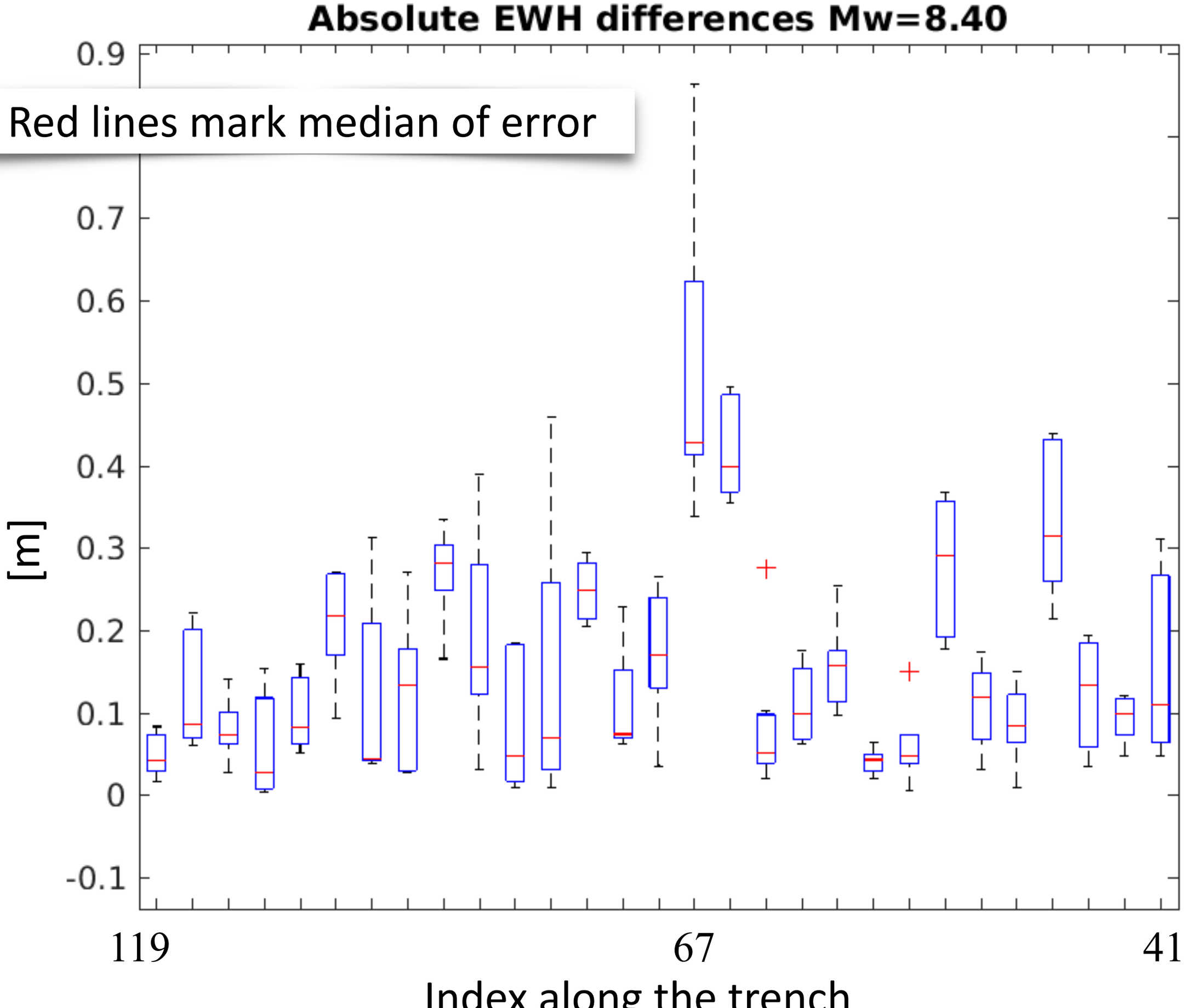
EWH values obtained by the models



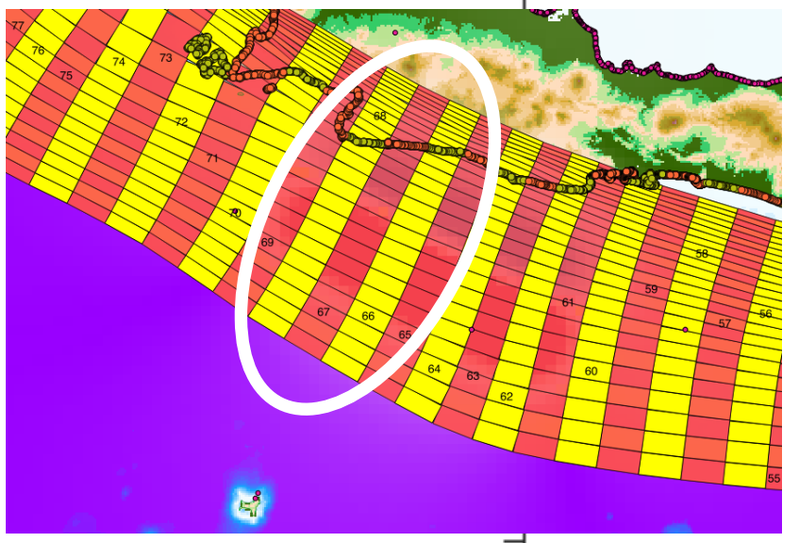
For systematic investigation of the EWH differences the coast is split into segments according to the RuptGen cross-trench disctetisation and determine EWH differences occurring from the wave propagation in one section.

Red lines mark median of error



Red lines mark median of error

Over a range of magnitudes largest errors occur in this section



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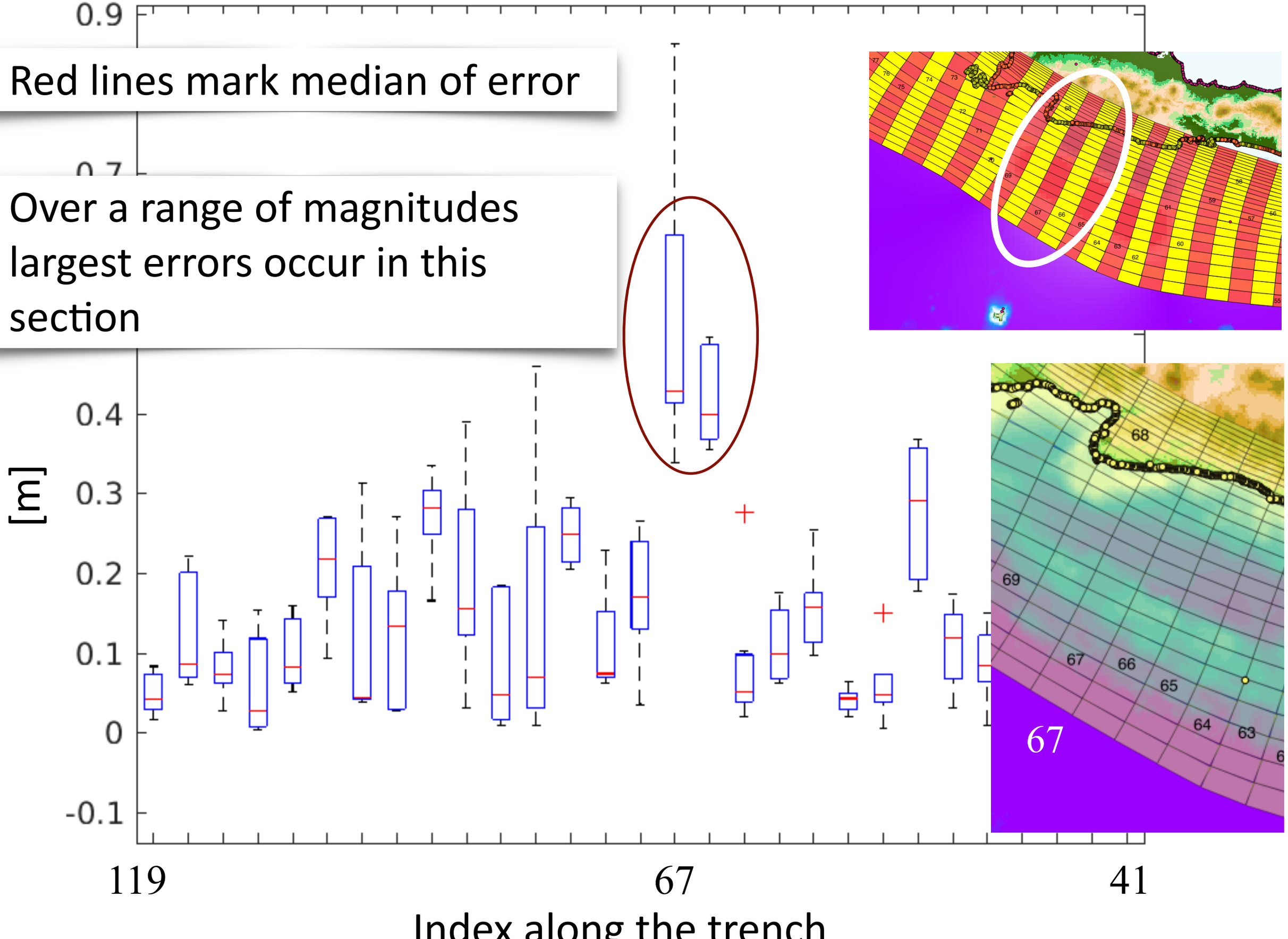
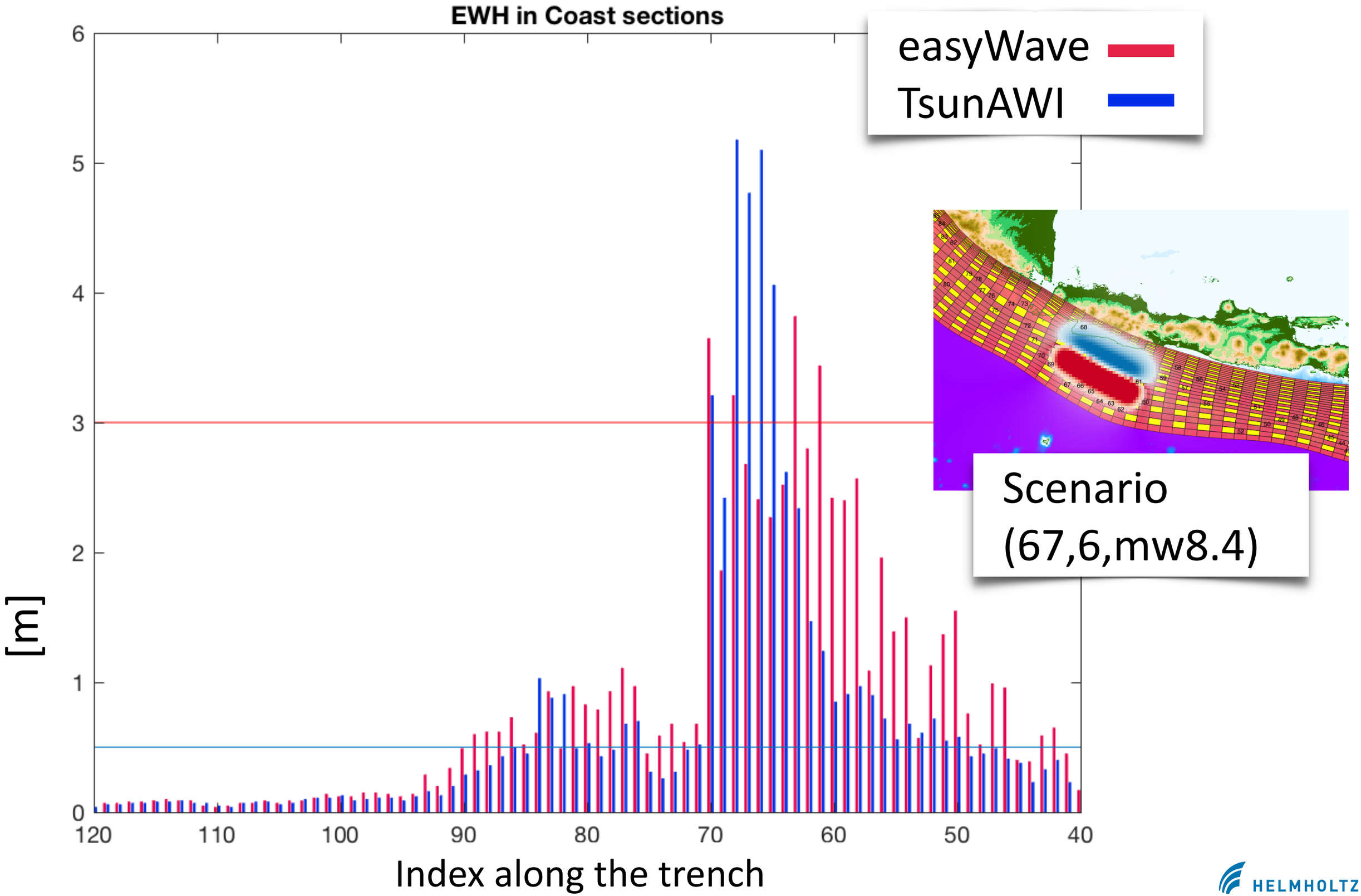


EWH overview in single scenario



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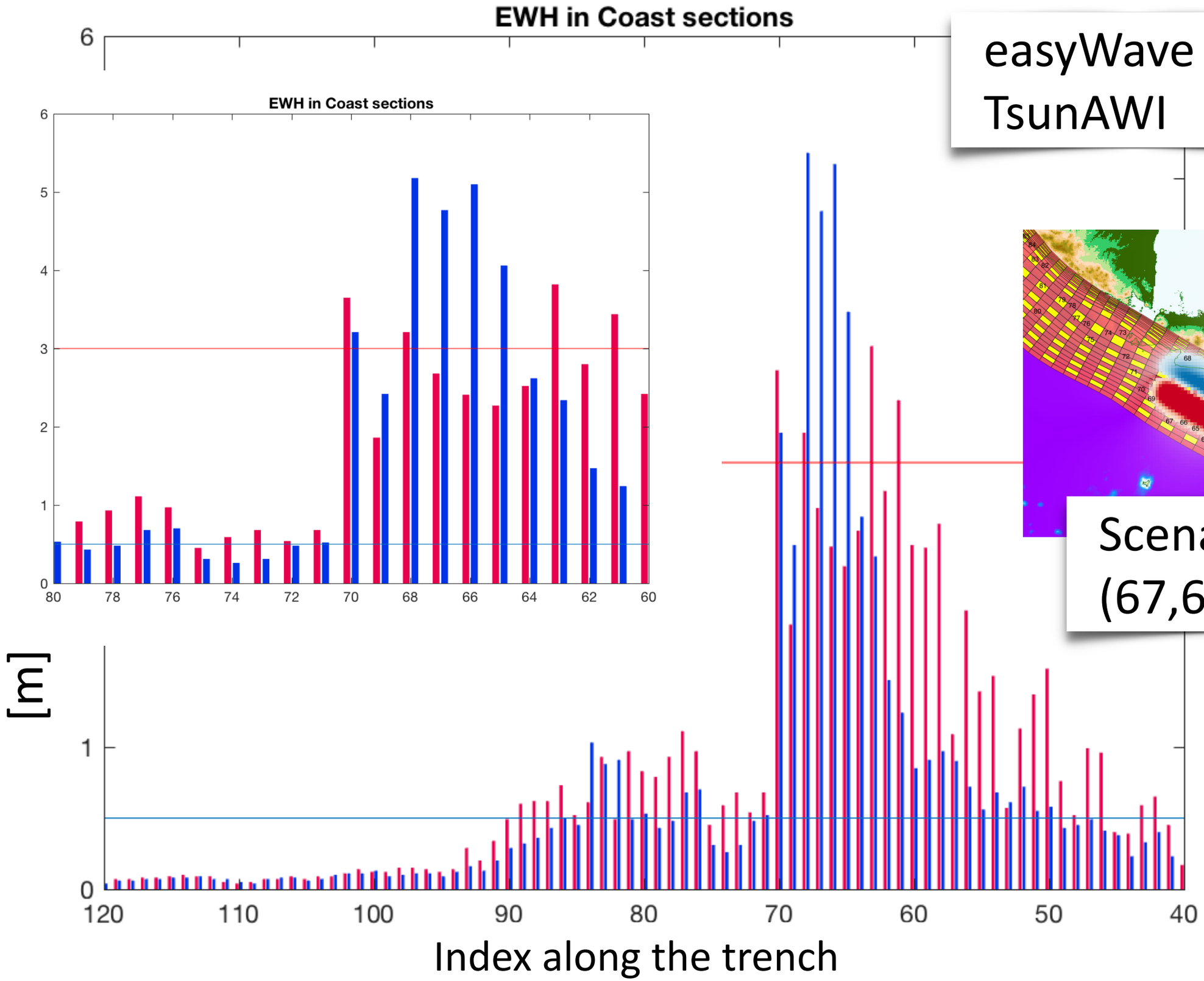
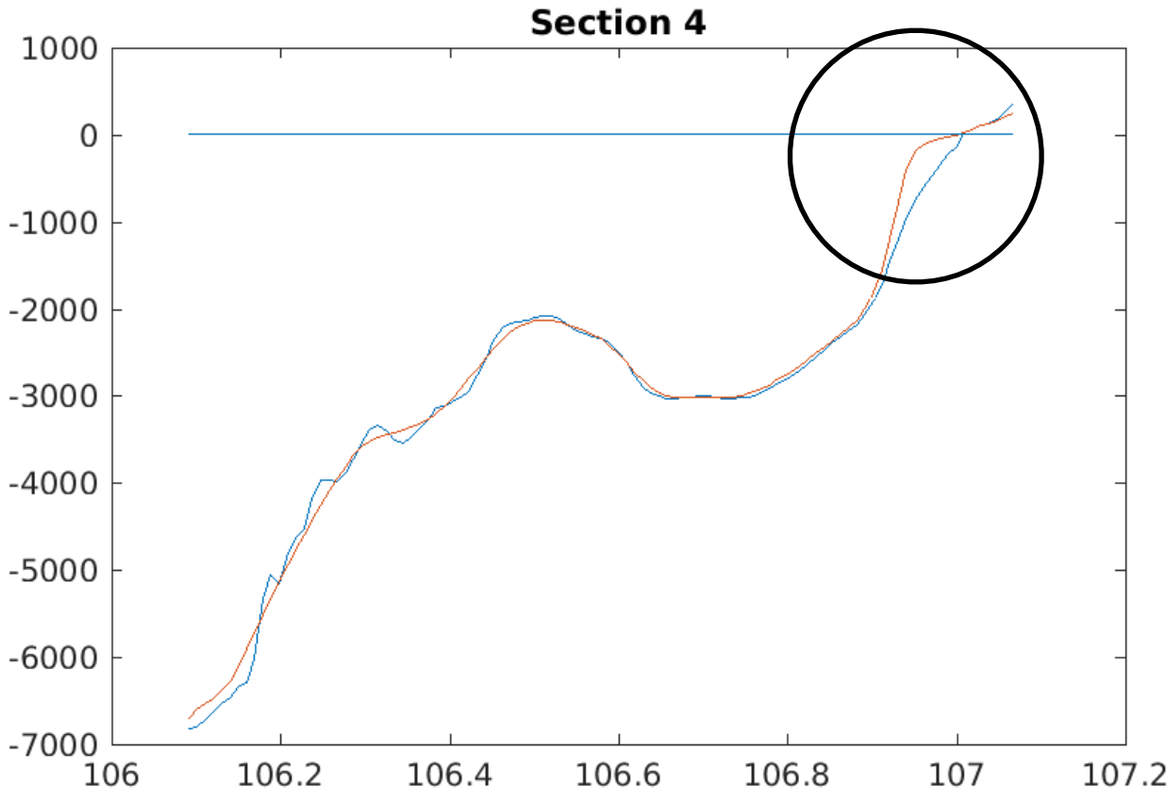
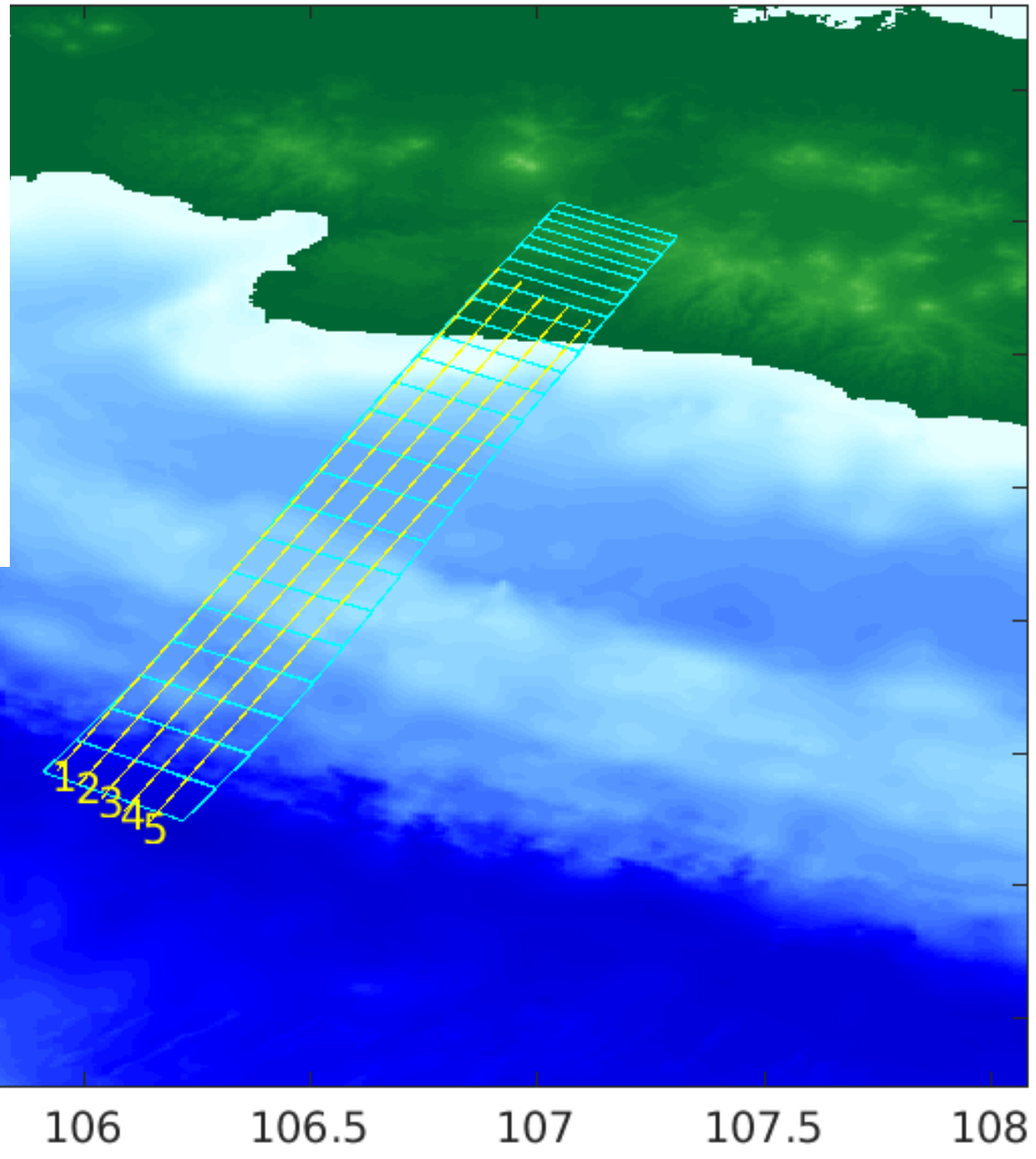
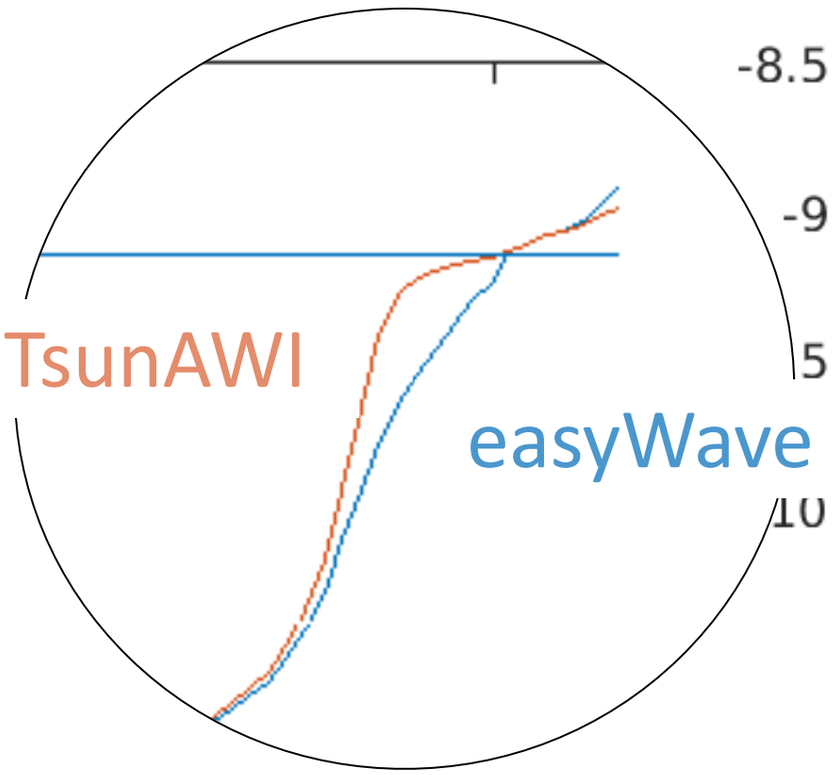


Bathymetry sections







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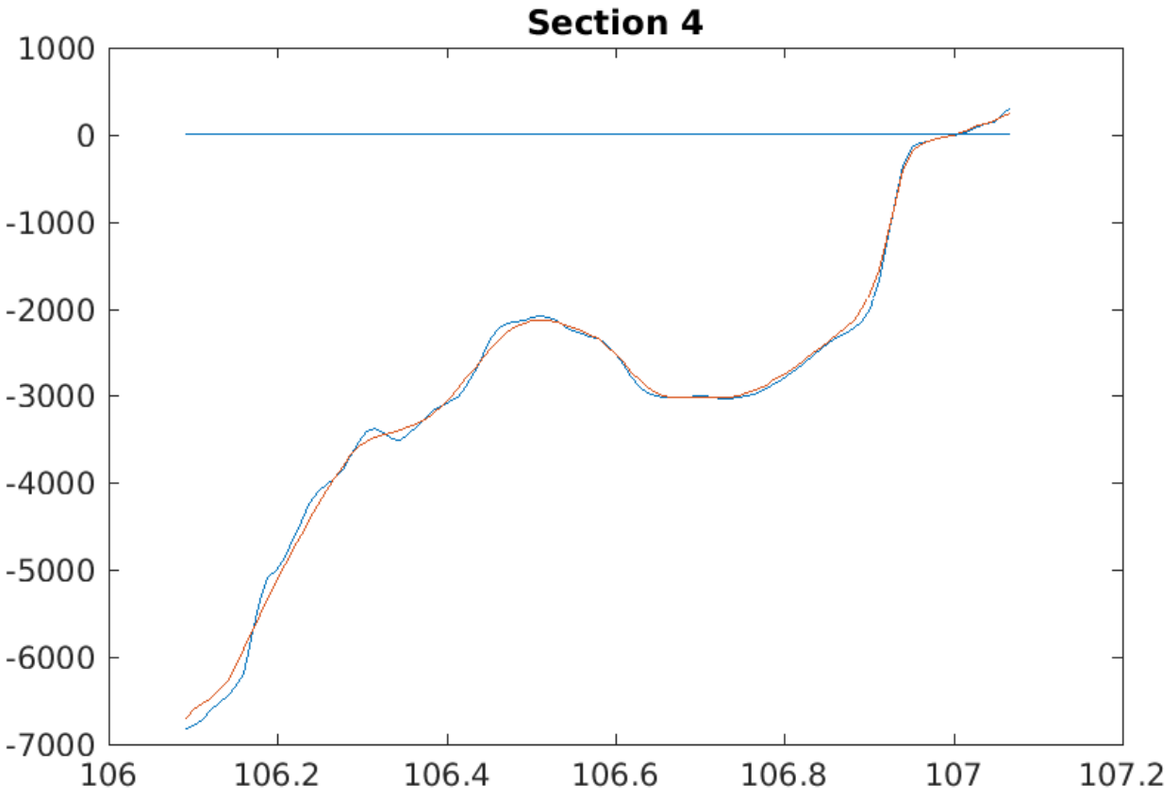
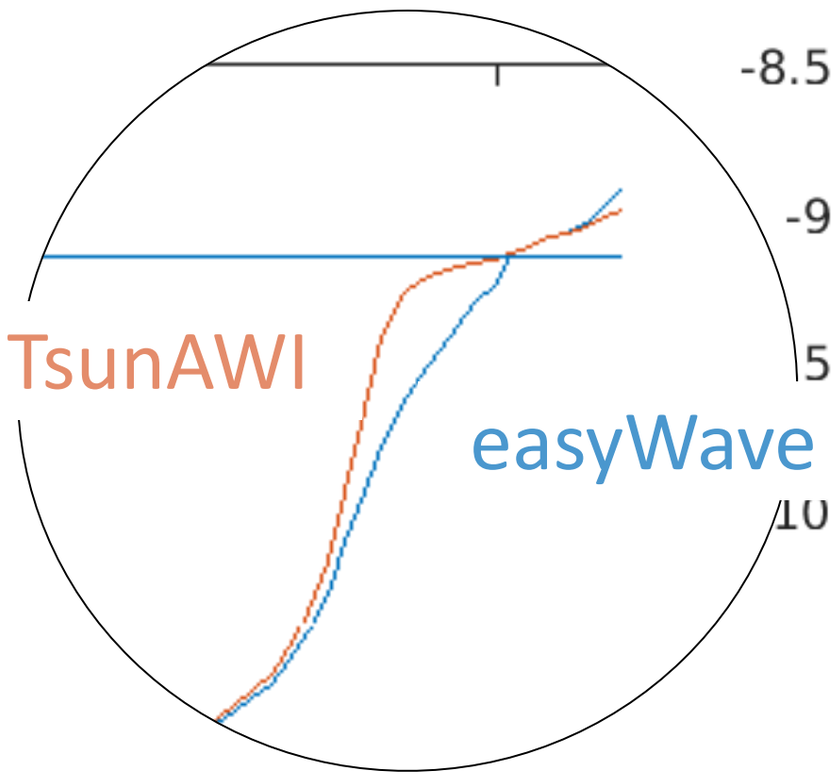
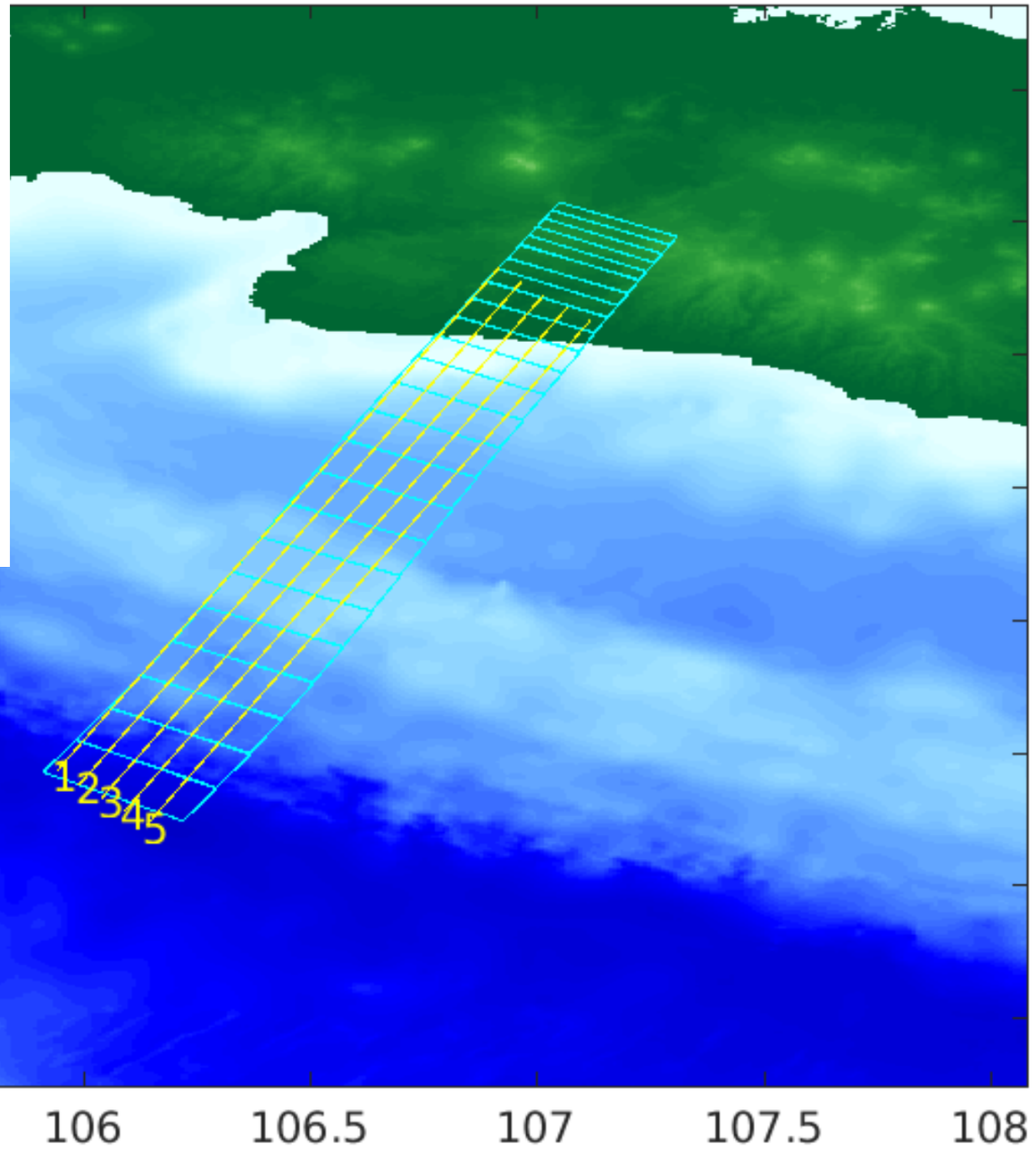
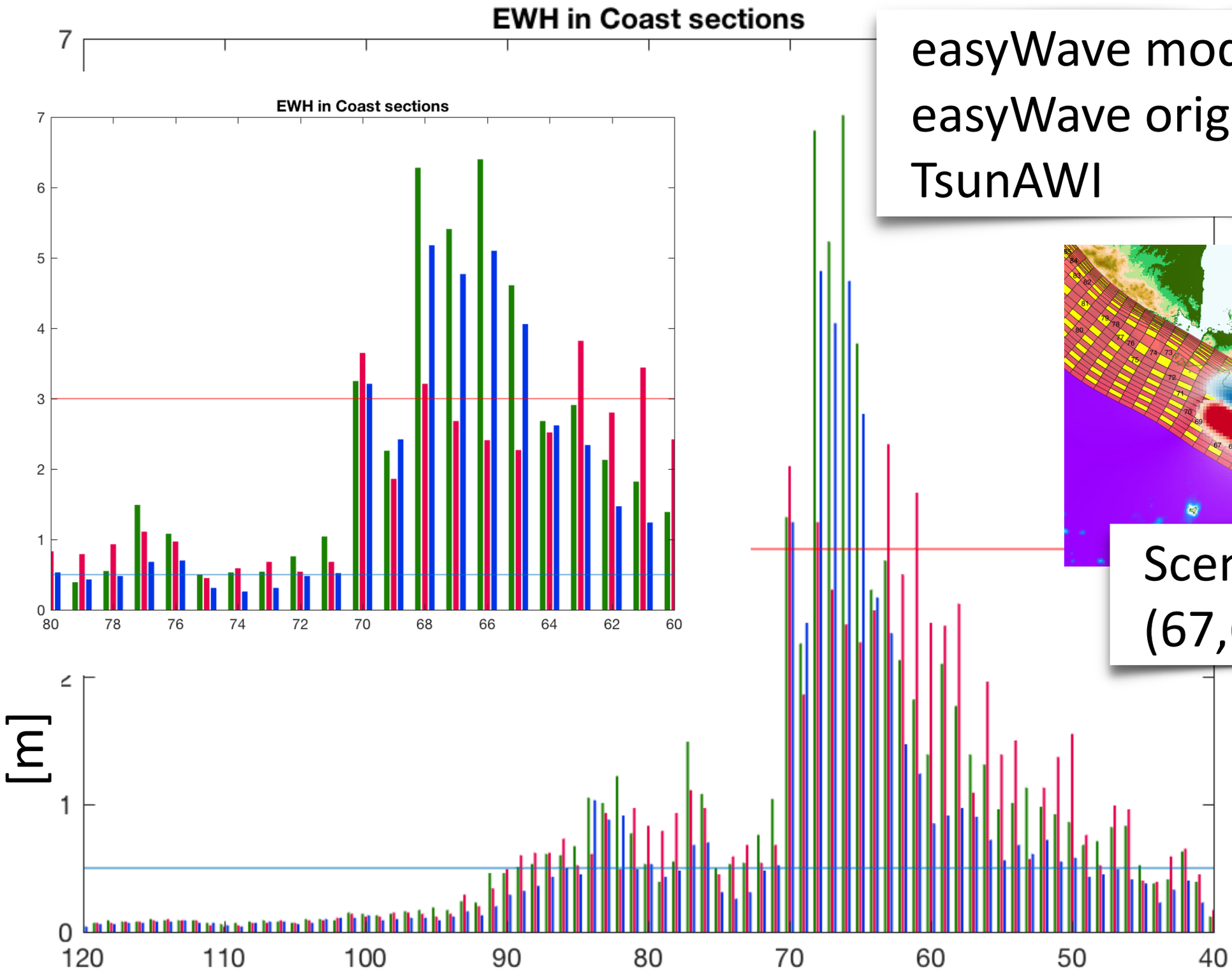
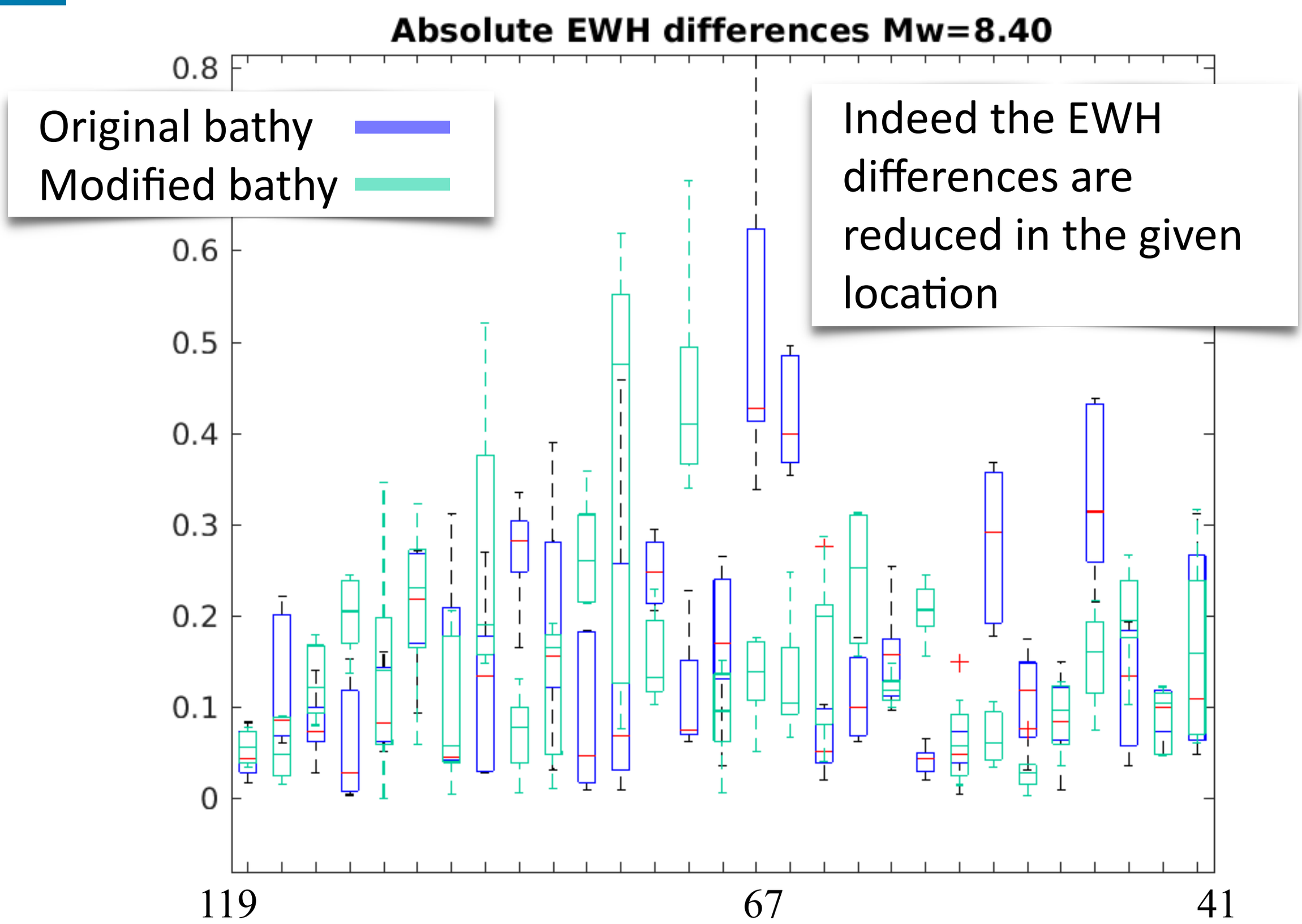




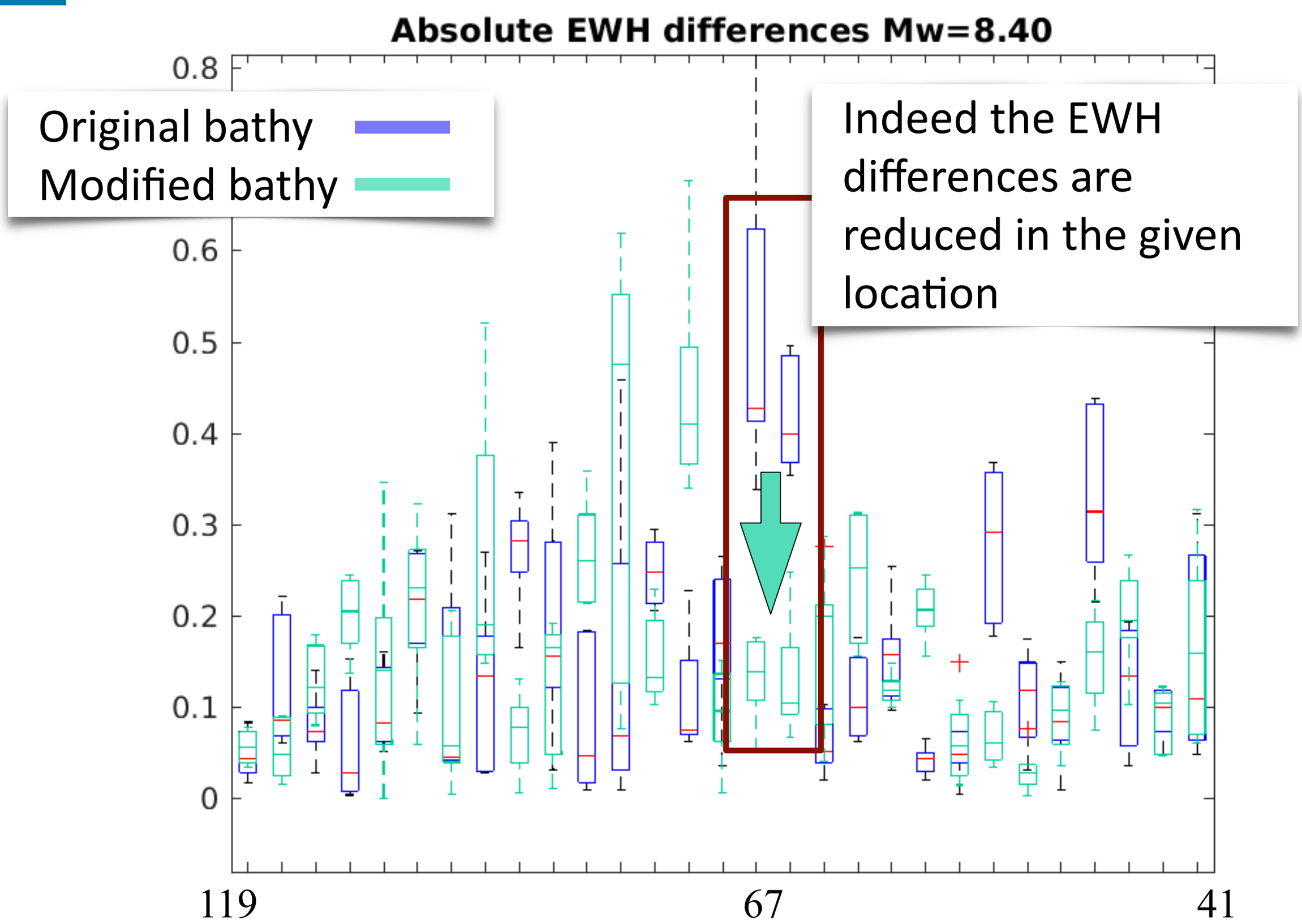


Results after bathymetry adjustment





Indeed the EWH differences are reduced in the given location



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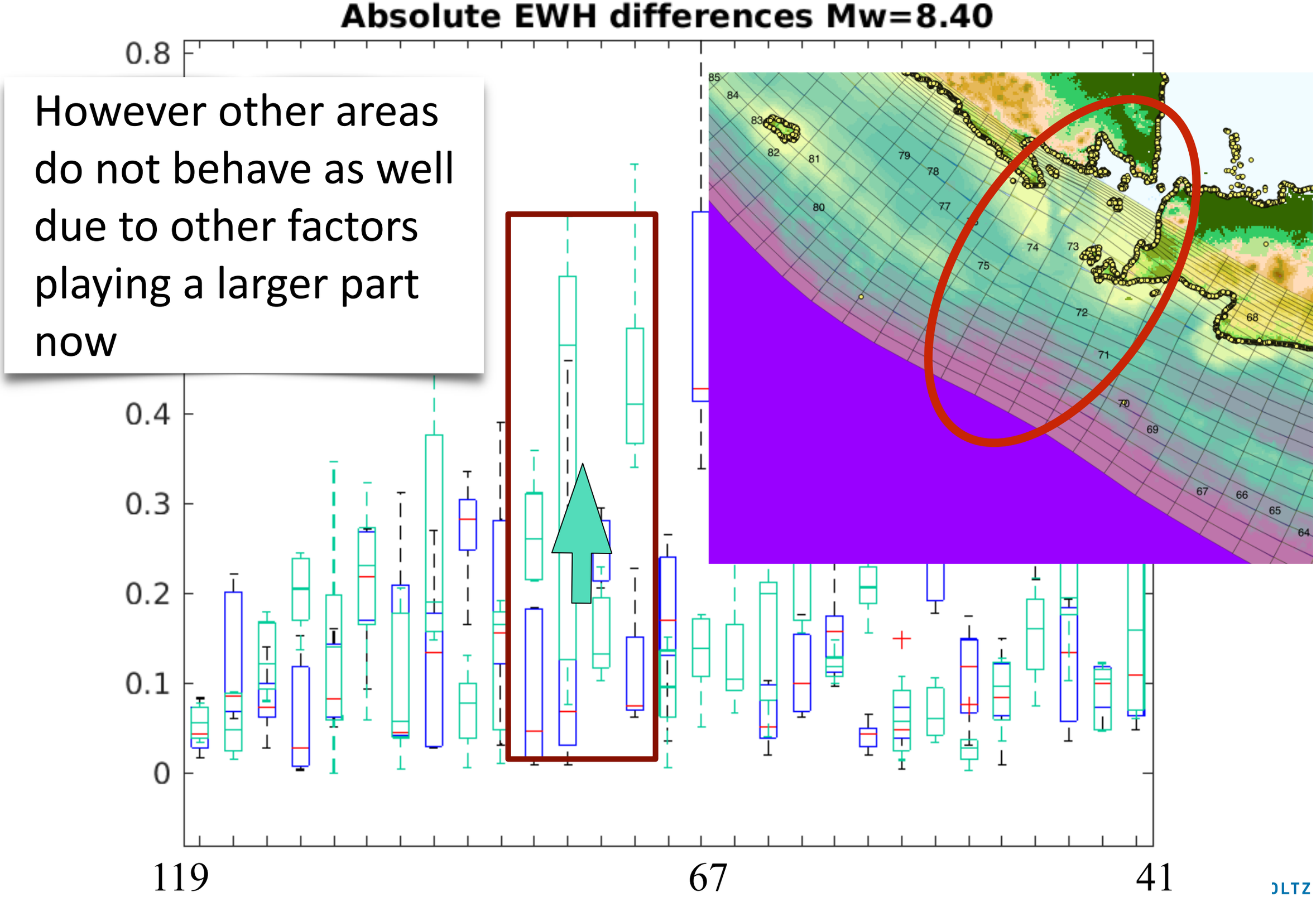
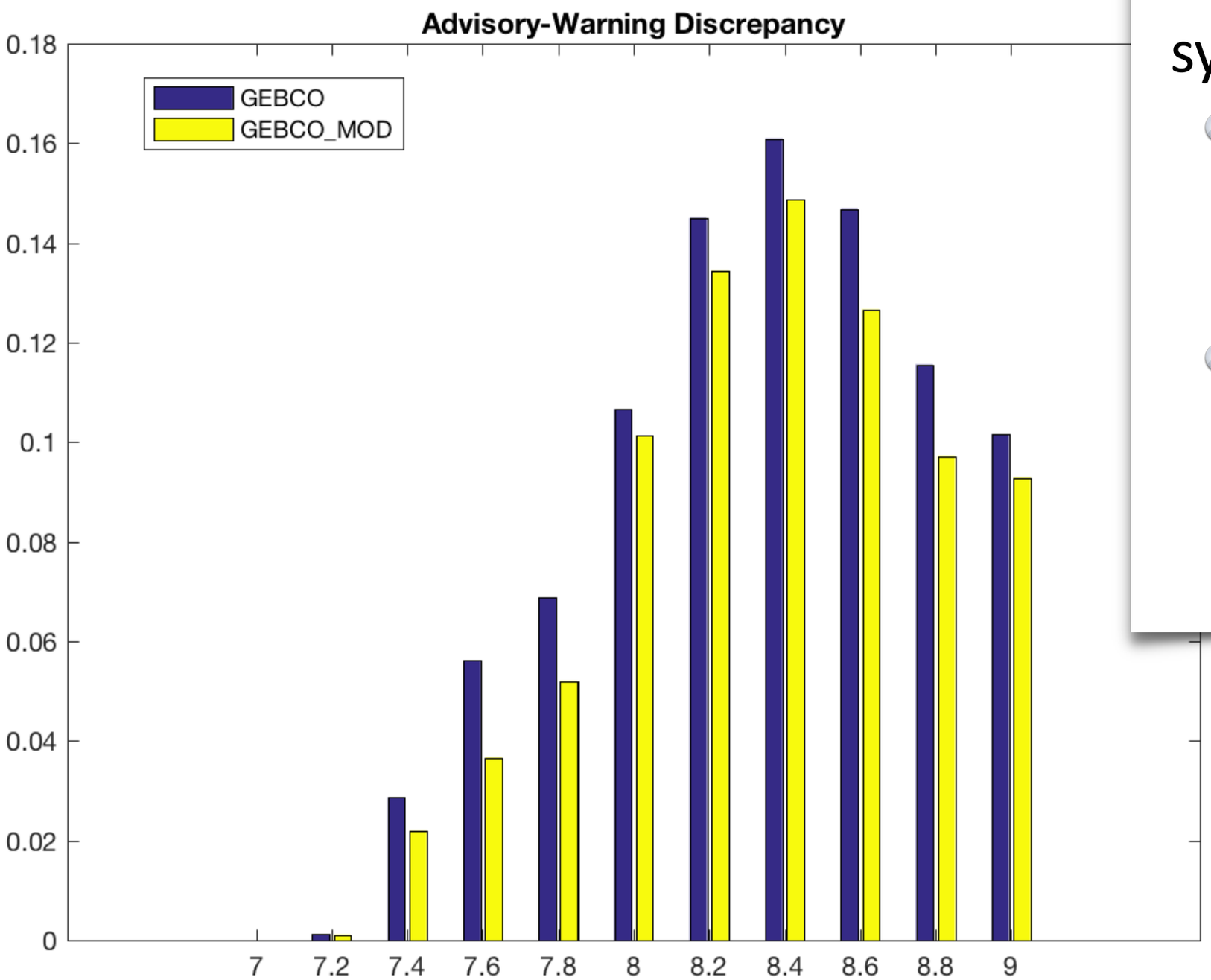

Absolute EWH differences Mw=8.40
0.8
0.4
0.3
0.2
0.1
0
119
67
41
However other areas do not behave as well due to other factors playing a larger part now

The overall mismatches are reduced



Nevertheless the overall state of the system is improved

- The total number of mismatches is reduced
- The correlation between EWH results of both models grows

Correlation overview

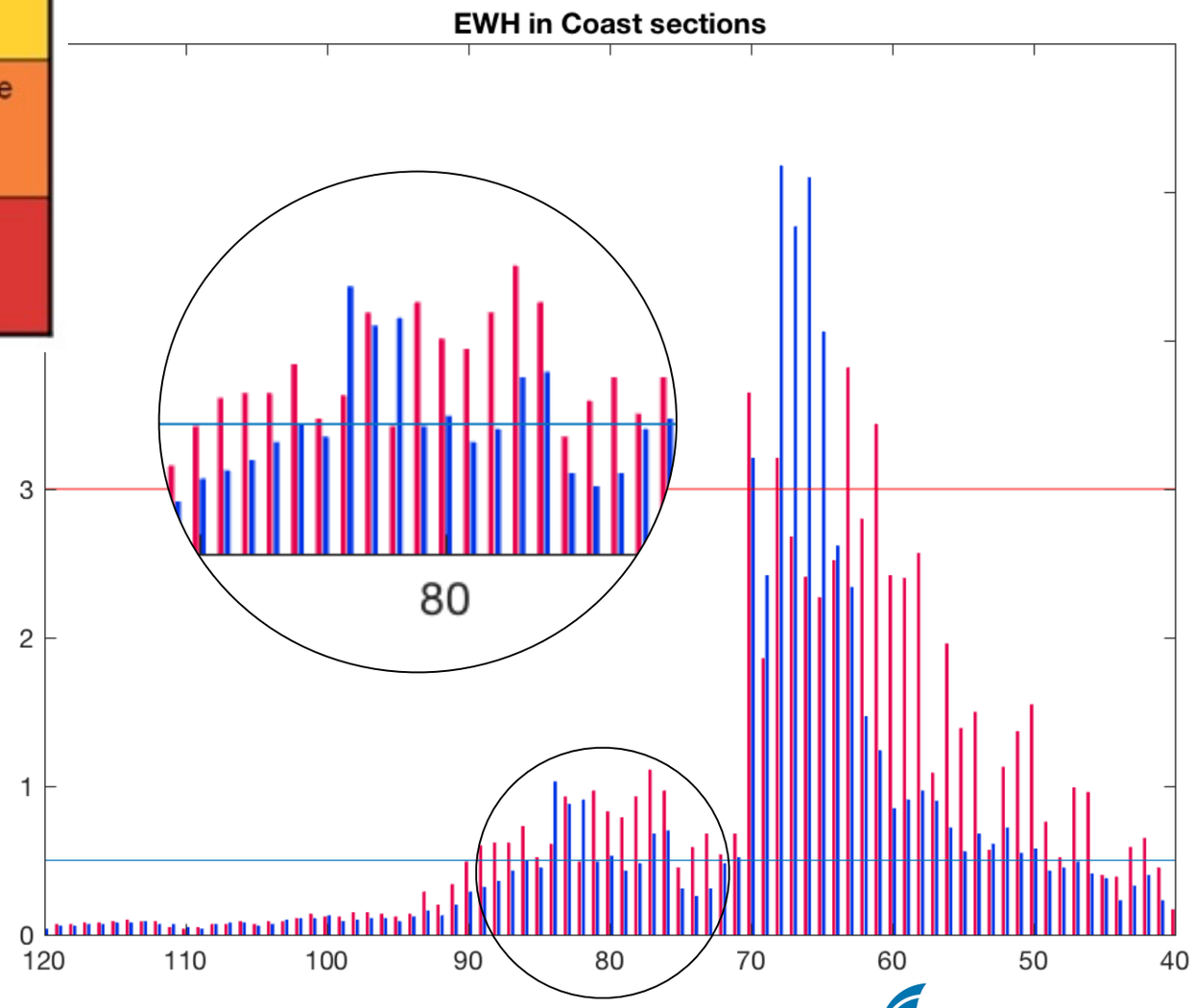
		G08 and Green's law	G08 coast calc	G08MOD coast calc
Magnitude 7.0	**EWH correlation**	0.81466	0.8576	0.91898
	ETA correlation	0.93576	0.9410	0.94768
Magnitude 8.0	**EWH correlation**	0.8096	0.89876	0.95222
	ETA correlation	0.91045	0.94236	0.95046
Magnitude 8.4	**EWH correlation**	0.74616	0.87141	0.95171
	ETA correlation	0.86683	0.91786	0.92824

Warning level mismatches

InaTEWS categories:

Tsunami Category	Warning Level	Wave Height (WH) Range [m]	Color
<none>	<none>	0,0 ≤ WH < 0,1 < 0.1m	Gray
Minor Tsunami	Advisory	0,1 ≤ WH < 0,5 < 0.5m	Yellow
Tsunami	Warning	0,5 ≤ WH < 3,0 < 3.0m	Orange
Major Tsunami	Major Warning	3,0 ≤ WH > 3.0m	Red

Small variations of the EWH can lead to a mismatch of the warning level however this quantity is most visible in the warning system



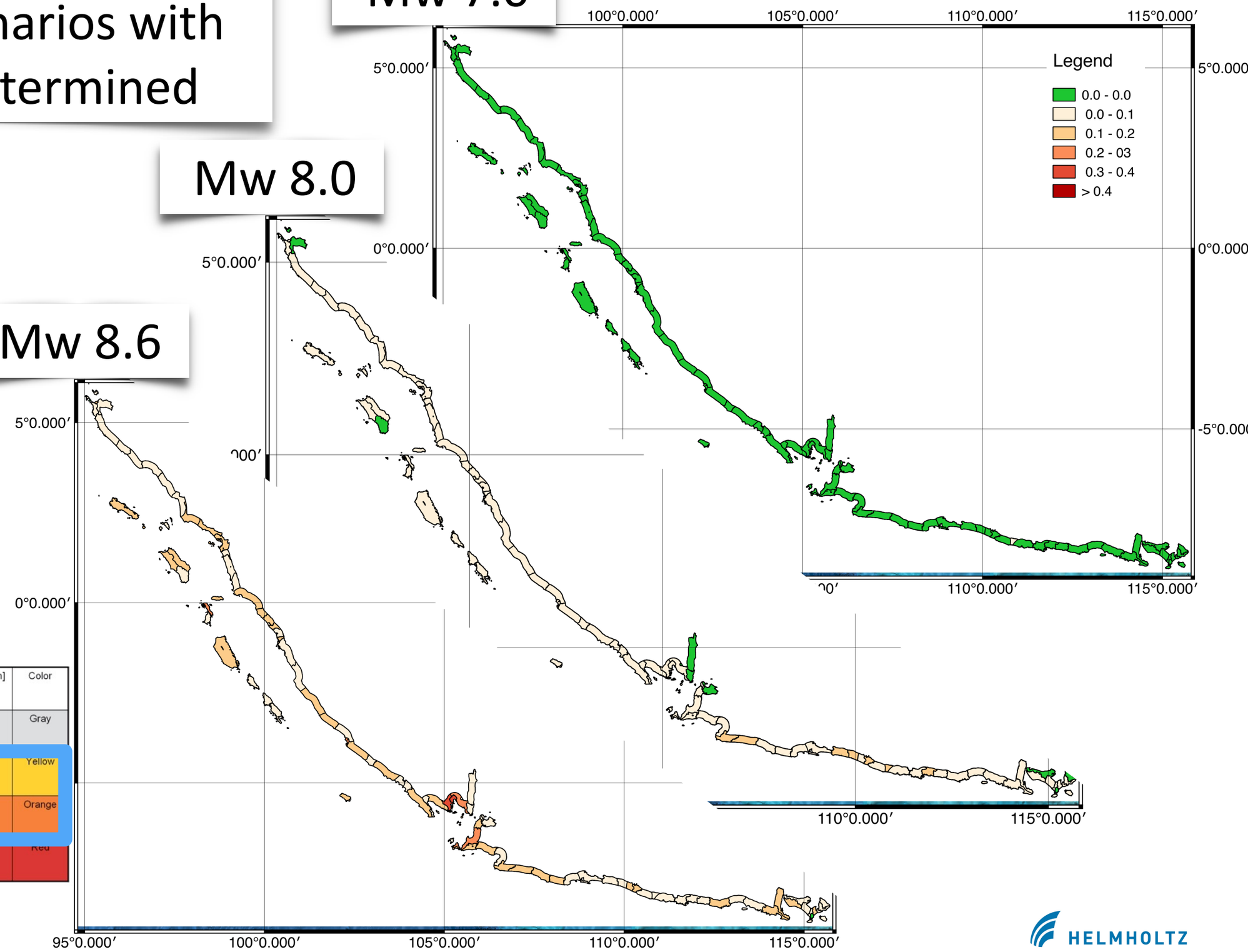
Advisory - Warning mismatches

For each warning zone the fraction of scenarios with mismatch is determined

Mw 7.0

Mw 8.0

Mw 8.6



Tsunami Category	Warning Level	Wave Height (WH) Range [m]	Color
<none>	<none>	0,0 ≤ WH < 0,1	Gray
Minor Tsunami	Advisory	0,1 ≤ WH < 0,5	Yellow
Tsunami	Warning	0,5 ≤ WH < 3,0	Orange
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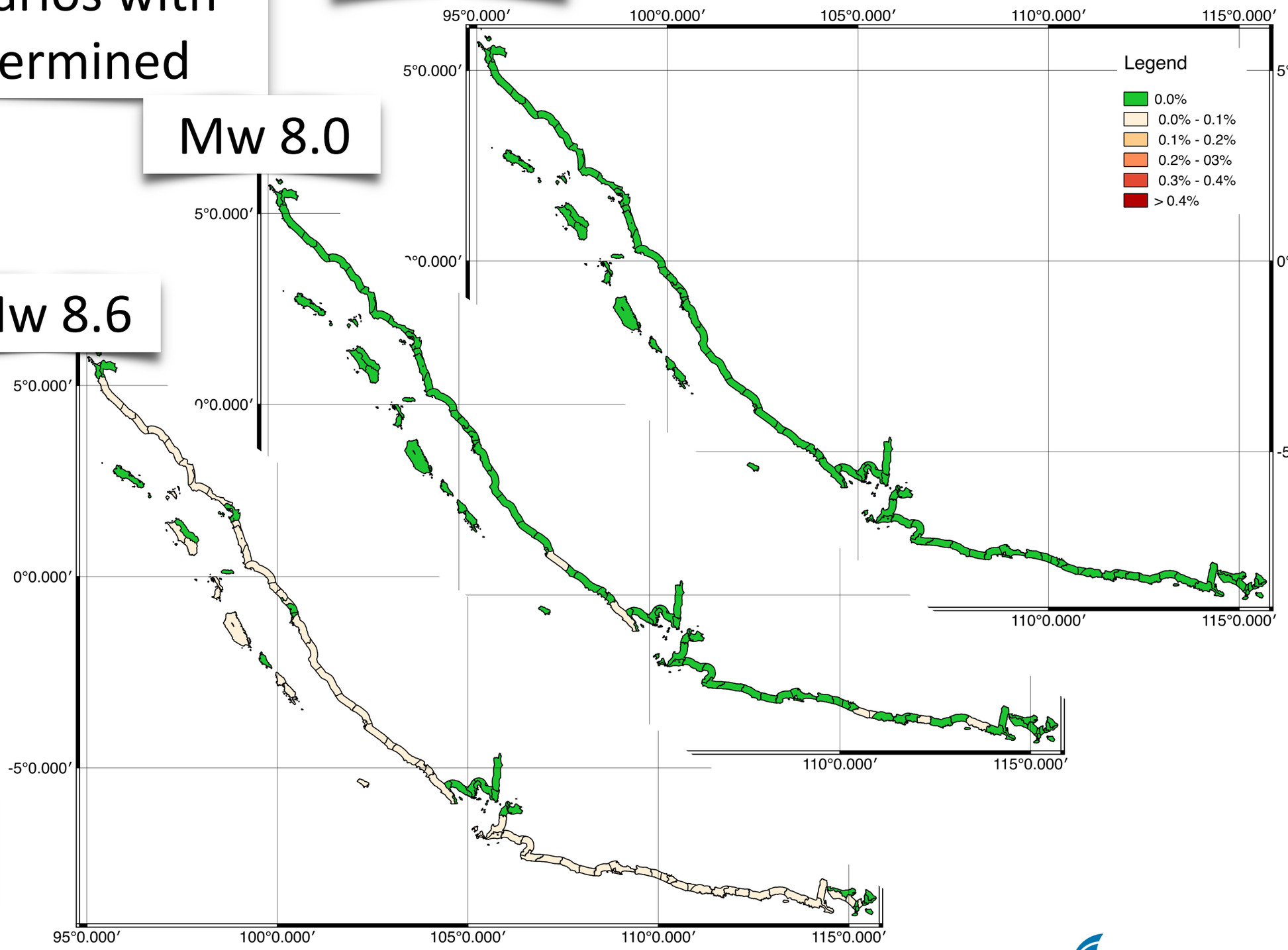
Warning - Major Warning mismatches

For each warning zone the fraction of scenarios with mismatch is determined

Mw 7.0

Mw 8.0

Mw 8.6



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Study ongoing - Conclusions so far

- Overall consistency of warning products good especially for small magnitudes very little discrepancies
- Improvements of the consistency in the system are possible
- Due to the vast range of the topographical setting implications of adjustments are diverse
- Many factors involved in deviating results - improving one may increase the influence of another
- Absolute agreement is not achievable by definition, nevertheless studies like this may help to reduce variations to the minimum