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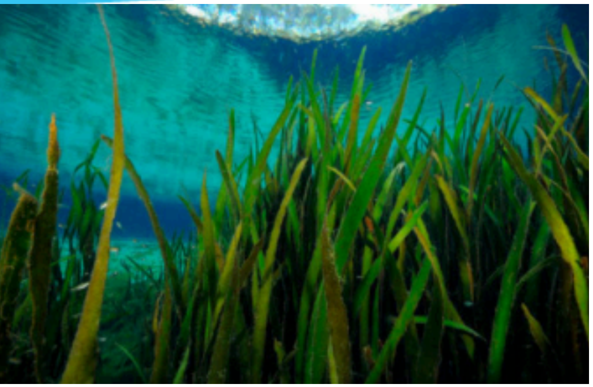
OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks



Towards Nature Based Solution design applications with marine seagrass for Emilia-Romagna coastal belt

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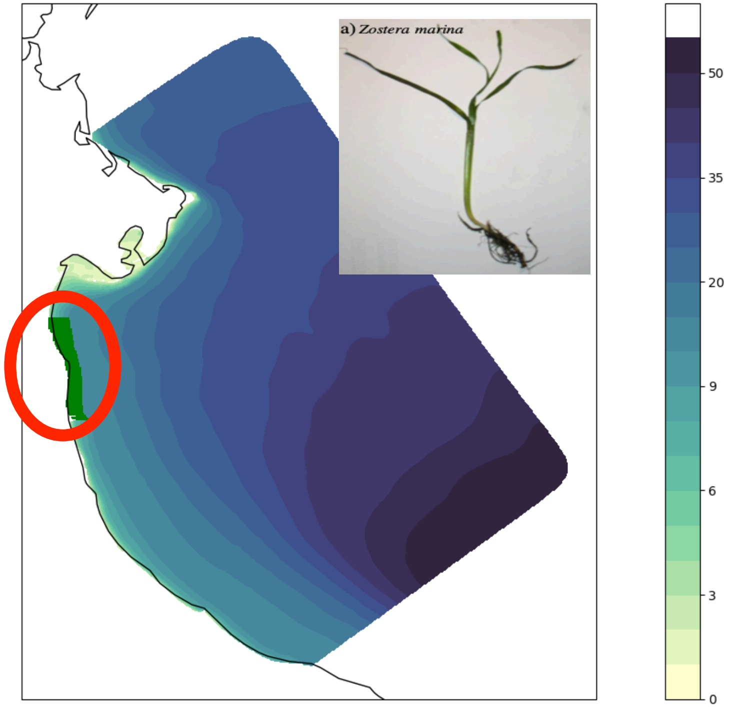
OBJECTIVES

NBS for storm surge mitigation

NBS: *numerical simulations with and without marine seagrass in the Emilia-Romagna (Italy) coastal strip and in the offshore area of the Bellocchio dune.*

- Hindcast studies in the Emilia-Romagna coastal belt, validated with buoy measurements.
- By including a modified bottom dissipation stress due to submerged vegetation in the wave model, the NBS will be considered as a potential mechanism for wave amplitude reduction.
- Seagrass landscape designs – applications with Zostera Marina.
- Comparison of model simulations with and without vegetation.



Bathymetry and Seagrass belt position.

STUDY AREA

Emilia Romagna Coast

The Italian coasts are threatened by coastal flooding and erosion. The Emilia-Romagna region coastline is exposed to marine storms because of its low-lying nature and massive urbanization.

The coast of the Emilia-Romagna Region is located in northern Italy, facing the Adriatic Sea. It is composed of almost 130 km-long sandy beaches characterized by mild slopes and a dissipative nature.

The wave climate is of low energy (60% of Hs below 1.0 m; IDROSER, 1996; Ciavola et al., 2007; Armaroli and Duo, 2018).

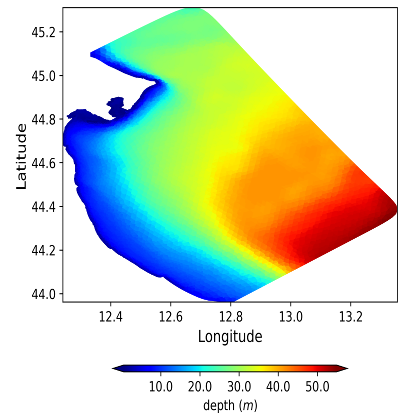
Storm directions are from E–NE (Bora wind) and SE (Scirocco wind).

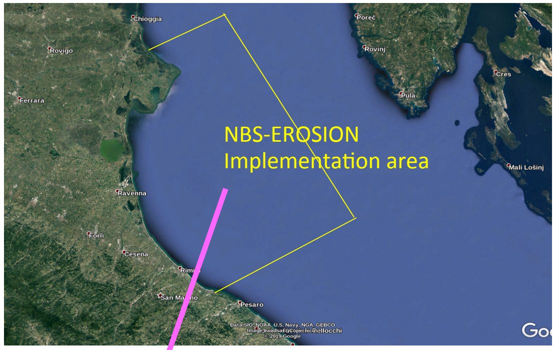
The coast of the Emilia-Romagna Region

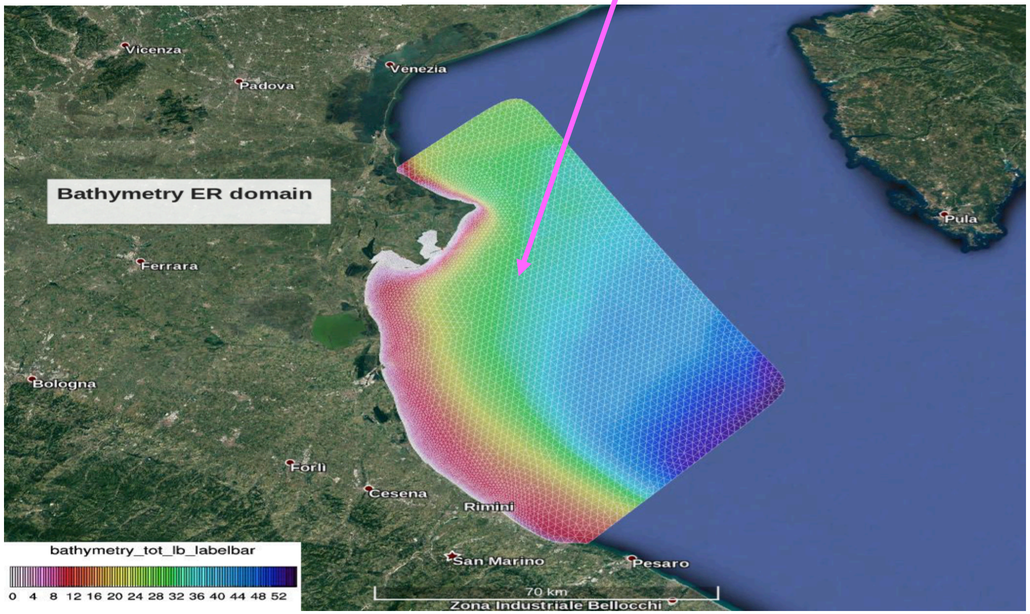
WAVE MODEL SET-UP FOR THE EMILIA-ROMAGNA COASTAL STRIP

Model Details	Remarks
WW3 version	**WAVEWATCH III - Version 5.16**
Grid Resolution	The resolution is of about 300m at the coast and 2.5km at the open boundary.
Wind forcing	The model input includes analysis winds of 0.125 degrees from ECMWF every 6 hourly.
Wave lateral boundary conditions	The wave boundary is taken from the WAM-CMEMS model at a resolution of 4.5kms every 1 hourly.
Output frequency	Every 1 hourly
Variables in the output:	depth (dpt) wave height (Hs) Mean wave period (Tm) Mean wave direction (θm) Peak Frequency (fp) Surface stokes drift (uss) near-bottom velocity (ubr)

Input Grid/ Bathymetry





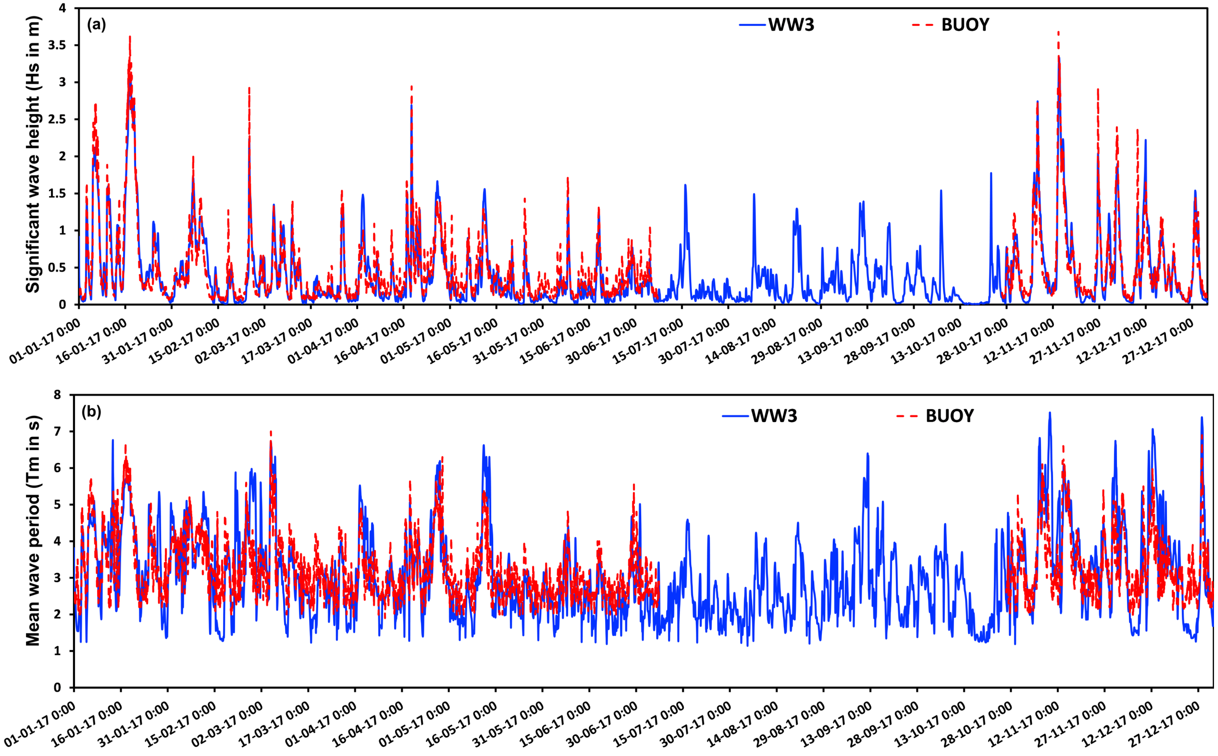


WAVE MODEL VALIDATION

Details of wave buoy

- Datawell Directional wave rider MkIII 70 waveform buoy.
- Nausicaa buoy in Cesenatico (44.2155 °N, 12.4766 °E).
- The buoy is located about 8 km off Cesenatico on a depth of 10 m in an area closed to navigation, mooring and fishing.
- The data are acquired every 30 minutes.

Time series comparison of model simulated variables (a) Hs and (b) Tm with buoy measurements for the year 2017



Variables	R	B	RMSE
Hs (2017)	0.93	-0.03 m	0.19 m
Tm (2017)	0.70	-0.07 s	0.89 s

Coupling Vegetation & Bottom source term

S_{bot}: SHOWEX bottom friction [Ardhuin et al. (2003)]

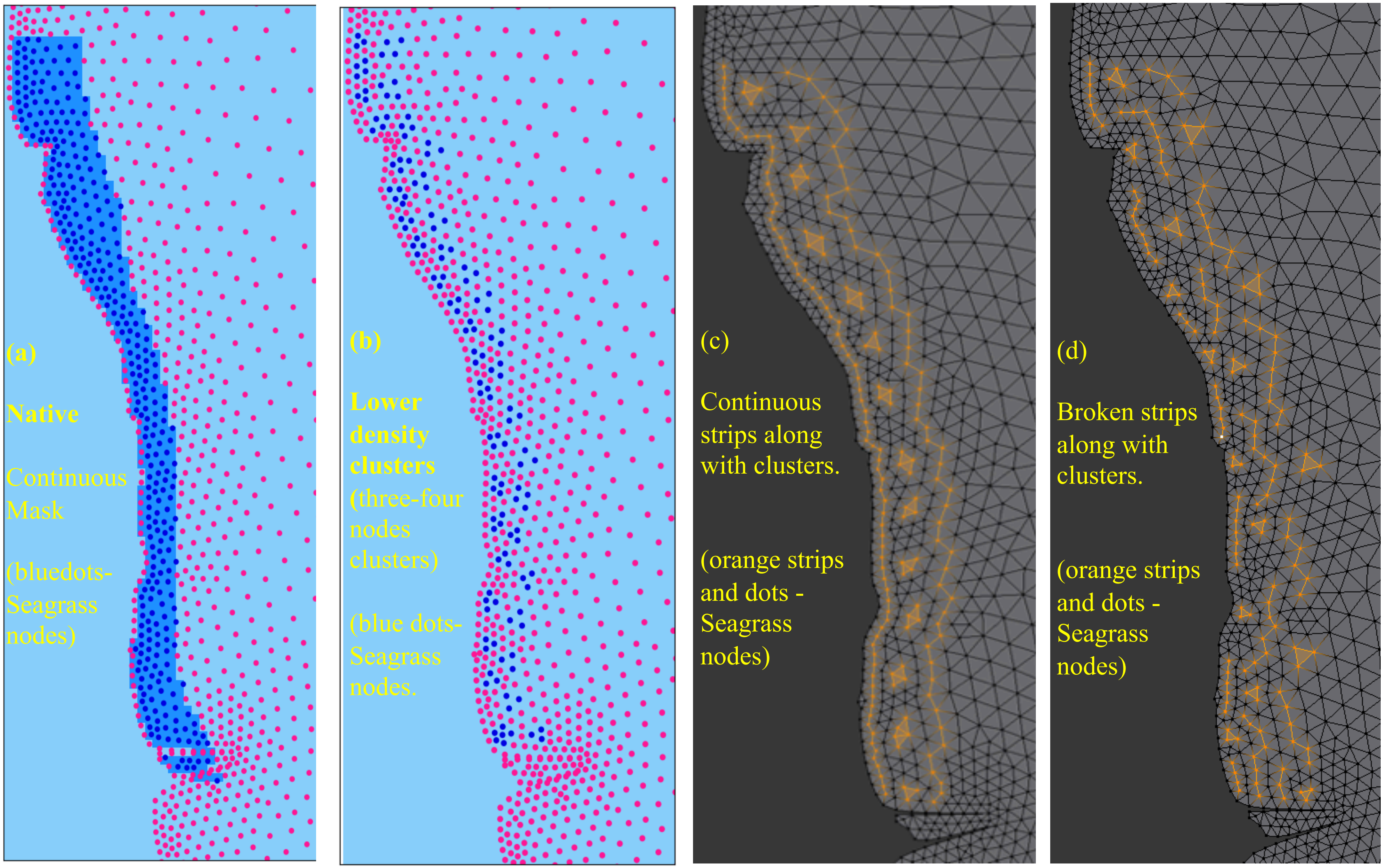
$$S_{bot}(k,\theta) = -f_e u_b \frac{\sigma^2}{2g\sinh^2(kd)} N(k,\theta)$$

Wave damping due to vegetation in SWAN ($S_{ds,veg}$) [Dalrymple et al. 1984, Mendez and Losada, 2004]

$$S_{\mathrm{ds,veg}} = -\sqrt{\frac{2}{\pi}} g^2 \tilde{C}_{\mathrm{D}} b_{\mathrm{v}} N_{\mathrm{v}} \left(\frac{\tilde{k}}{\tilde{\sigma}}\right)^3 \frac{\sinh^3 \tilde{k}\alpha h + 3\sinh \tilde{k}\alpha h}{3k\cosh^3 \tilde{k}h} \sqrt{E_{\mathrm{tot}}} E(\sigma,\theta)$$

$$S_t = S_{bot} + Maskveg \; S_{ds,veg}$$

Seagrass (Maskveg) Landscape Designs



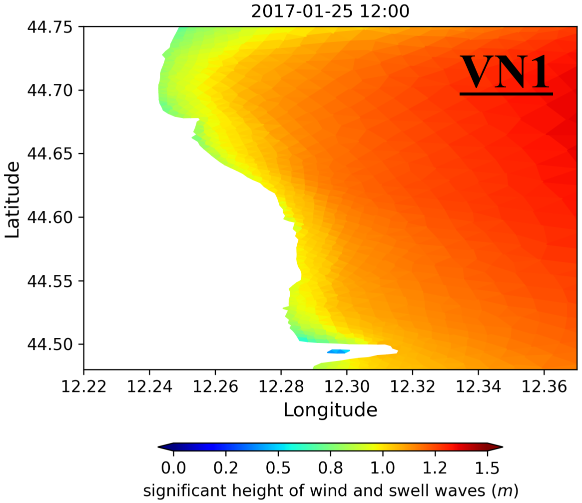
Simulation Experiments with vegetation

$$S_{\mathrm{ds,veg}} = -\sqrt{\frac{2}{\pi}} g^2 \tilde{C}_{\mathrm{D}} b_{\mathrm{v}} N_{\mathrm{v}} \left(\frac{\tilde{k}}{\tilde{\sigma}}\right)^3 \frac{\sinh^3 \tilde{k}\alpha h + 3 \sinh \tilde{k}\alpha h}{3k \cosh^3 \tilde{k}h} \sqrt{E_{\mathrm{tot}}} E(\sigma,\theta)$$

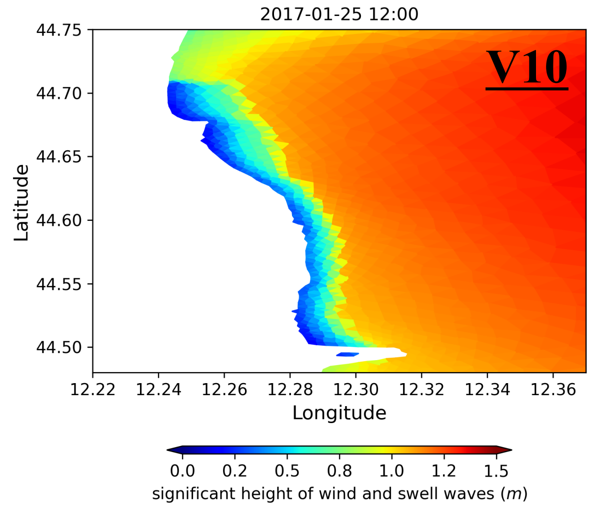
Bottom friction parameters	Zostera Marina (V20) (Mazzella et al., 1998)	Zostera Marina (V21) (Mazzella et al., 1998)	Zostera Marina (V22) (Mazzella et al., 1998)	Cymodocea (V10) (Mazzella et al., 1998)
Stem diameter of plant cylinder **(Bv in m)**	0.0038	0.0038	0.0038	0.0018
No. of plants per square meter **(Nv)**	270	270	270	900
Length of sea grass **(Lv in m)**	0.213	0.213	0.213	0.074
Seagrass Landscape	**Low density clusters (2-10m).**	**Continuous strips along with clusters (2-10m).**	**Broken strips along with clusters (2-10m).**	**Continuous (2 -10m).**

Daily spatial plots with and without vegetation
(Significant wave height)

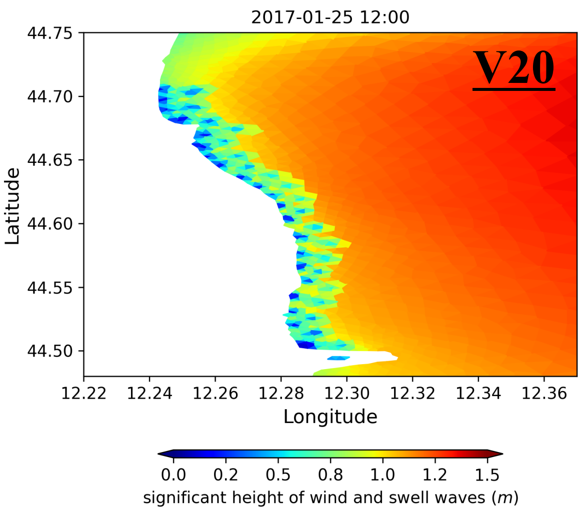
No vegetation (VN1) – 25 JAN 2017, 12:00 hrs

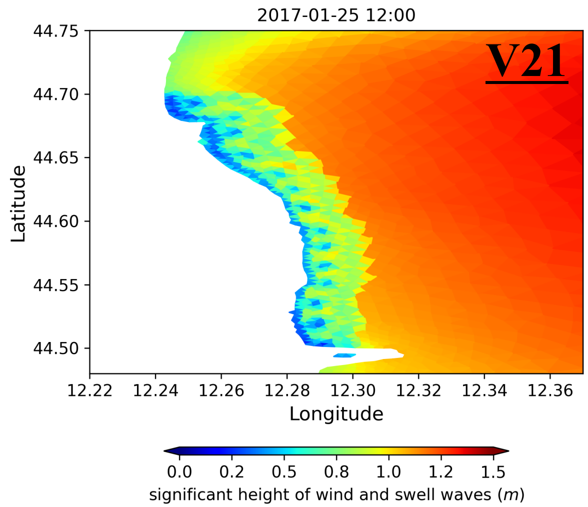


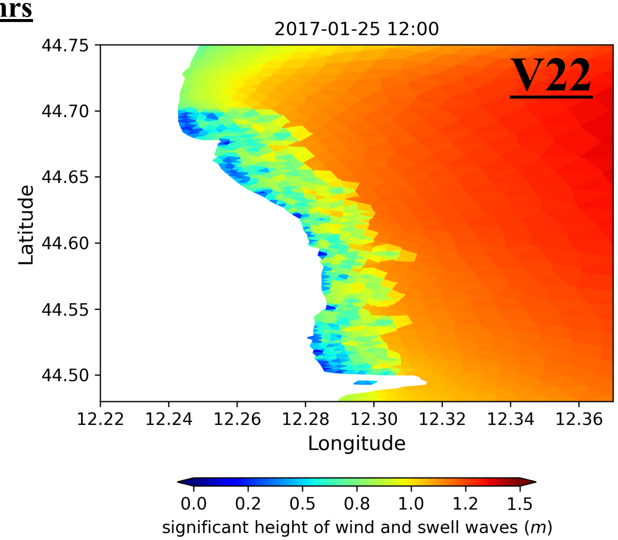
Cymodocea nodosa (V10) – 25 JAN 2017, 12:00 hrs



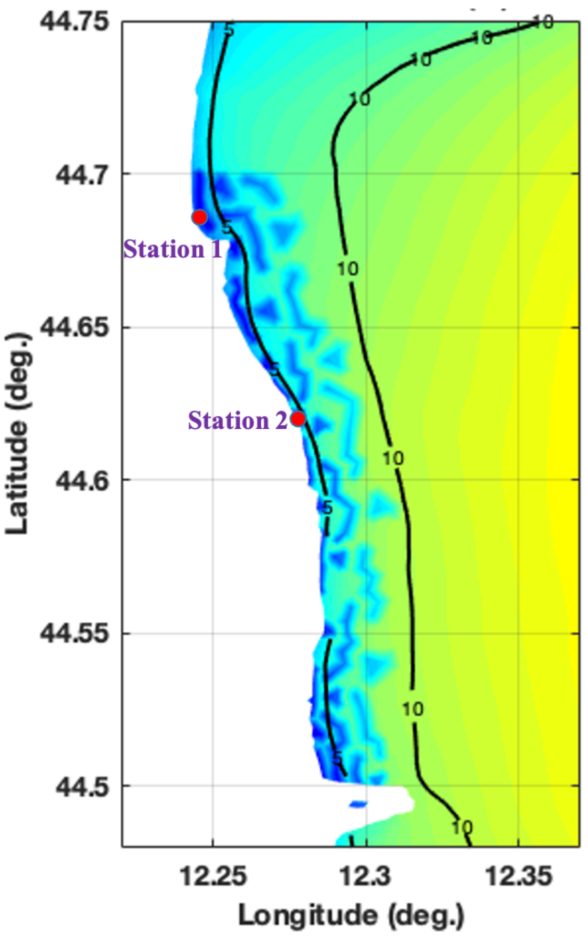
Zostera Marina (V20 to 22) – 25 JAN 2017, 12:00 hrs



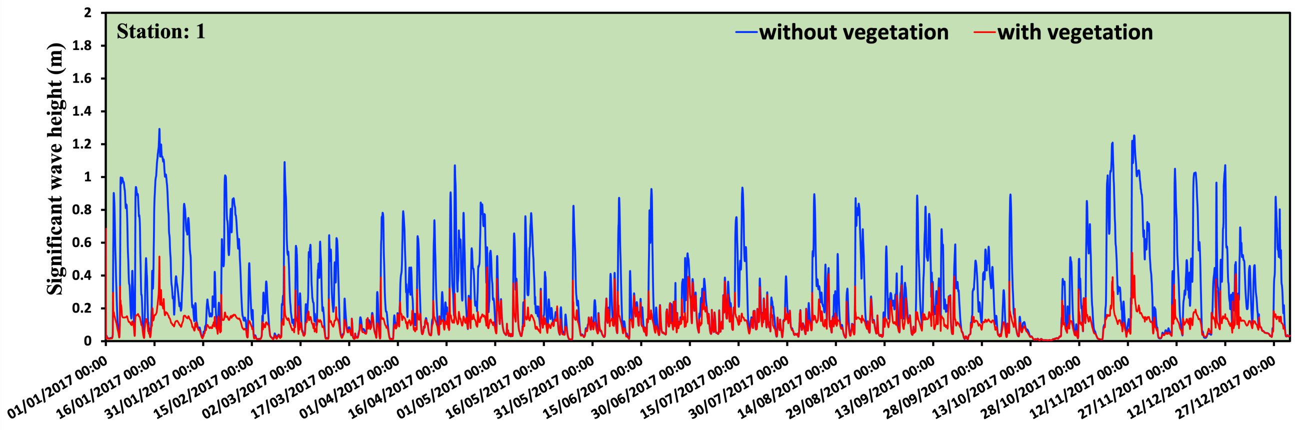




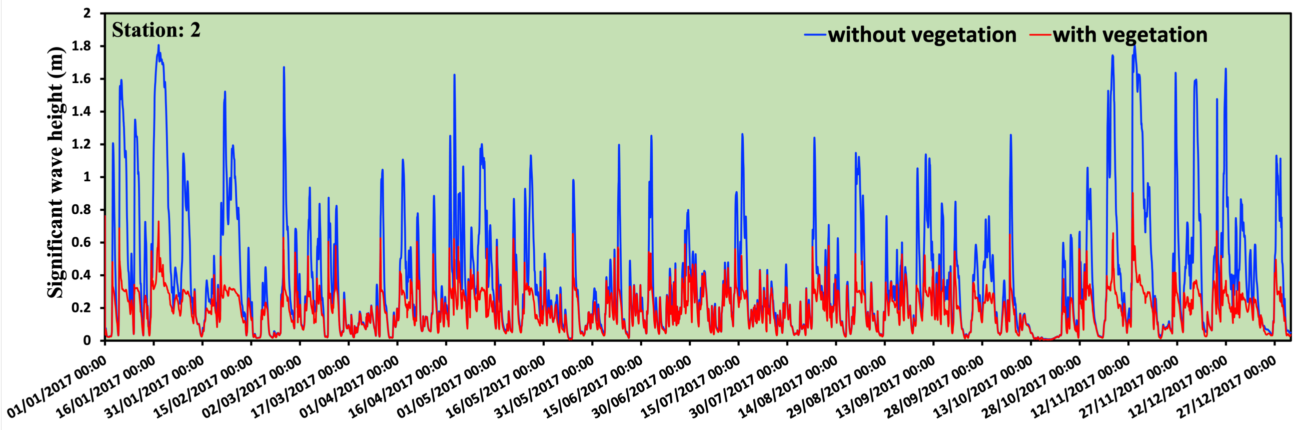
Time-series comparison of Hs (with & without vegetation)



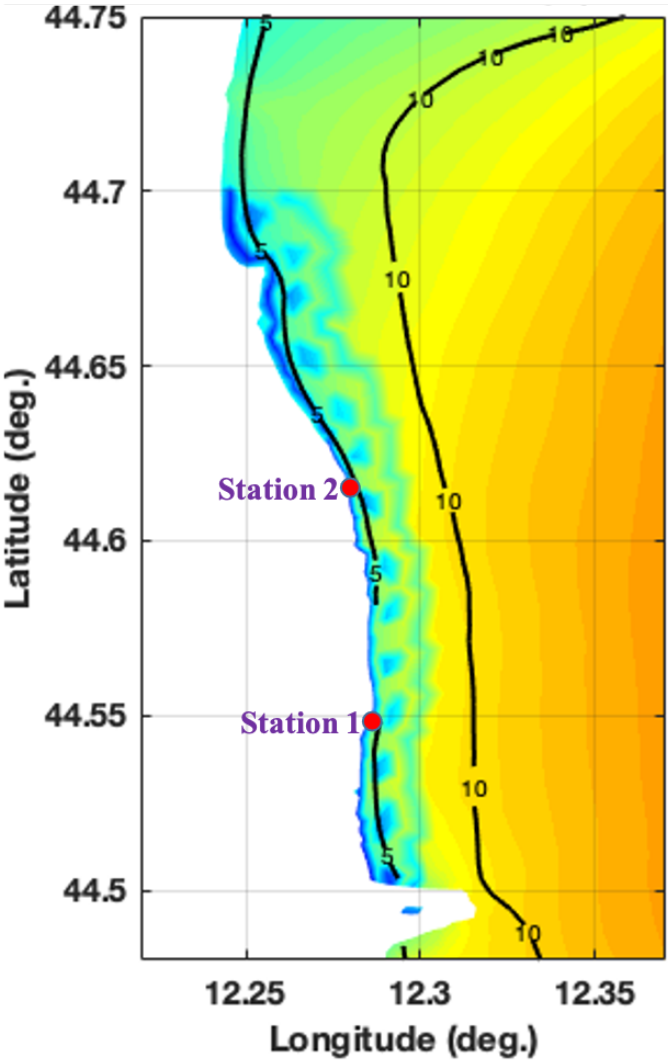
Time-series comparison of Hs at Station 1

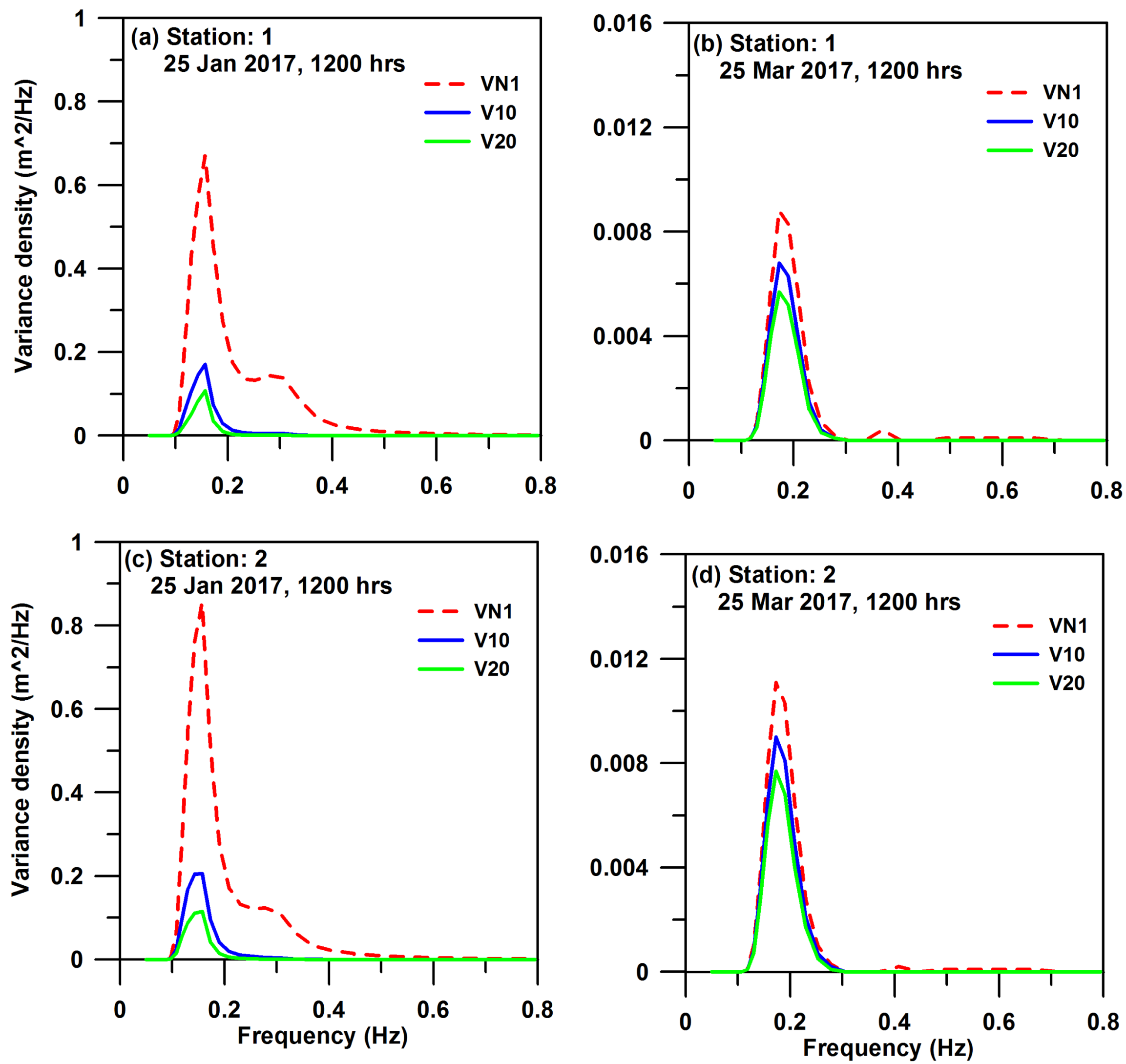


Time-series comparison of Hs at Station 2

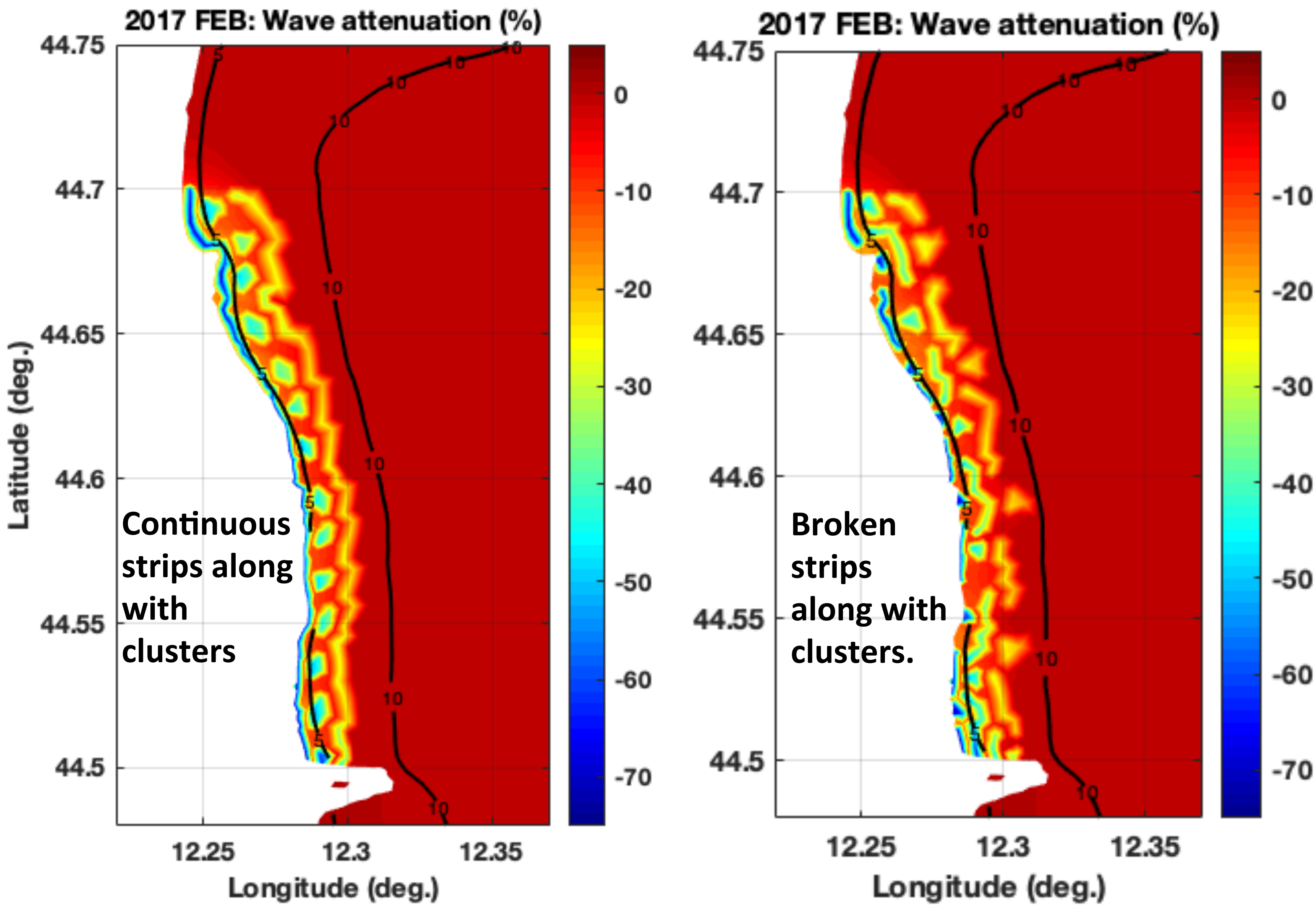


Comparison of wave spectra with different distributions of Cymodocea Nodosa/ Zostera Marina (Jan-Mar 2017)

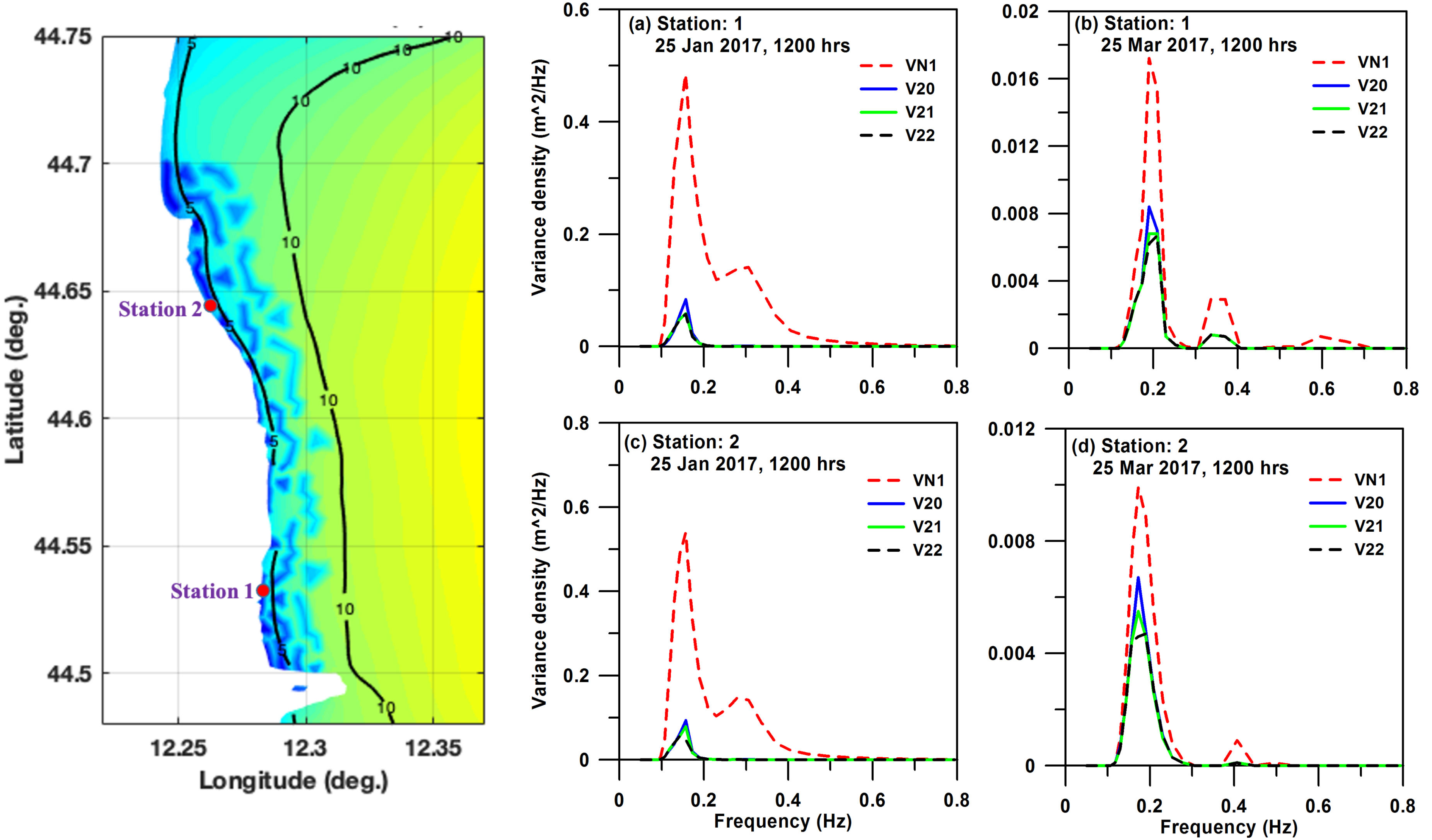




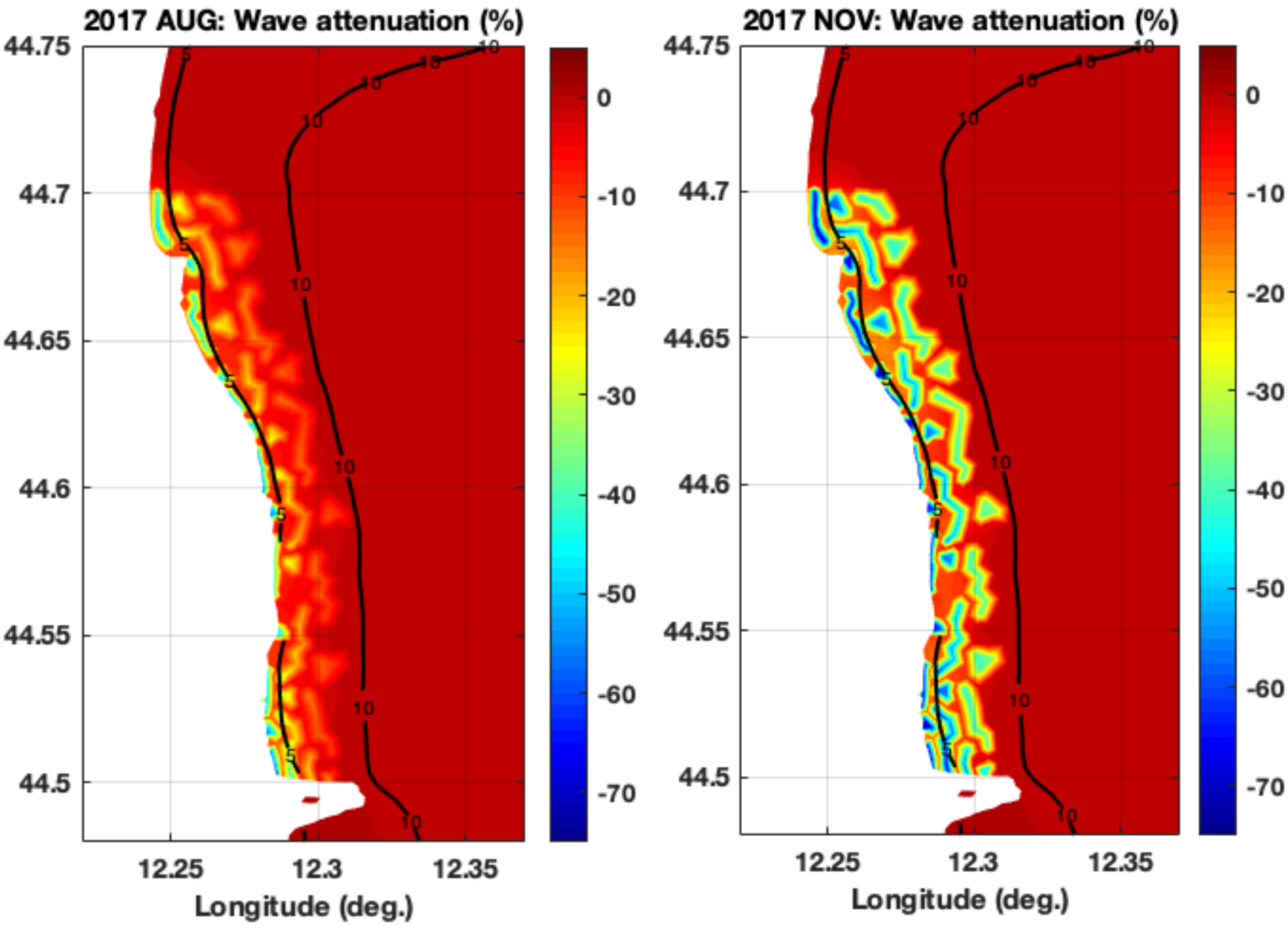
Mean monthly percentage variation of wave height with different clustering of Zostera Marina (February 2017)



Comparison of wave spectra with different distributions of Zostera Marina (Jan-Mar 2017)



Mean monthly percentage variation of wave height with Zostera Marina



Mean monthly percentage variation of wave height using Zostera marina and broken stripes with clusters

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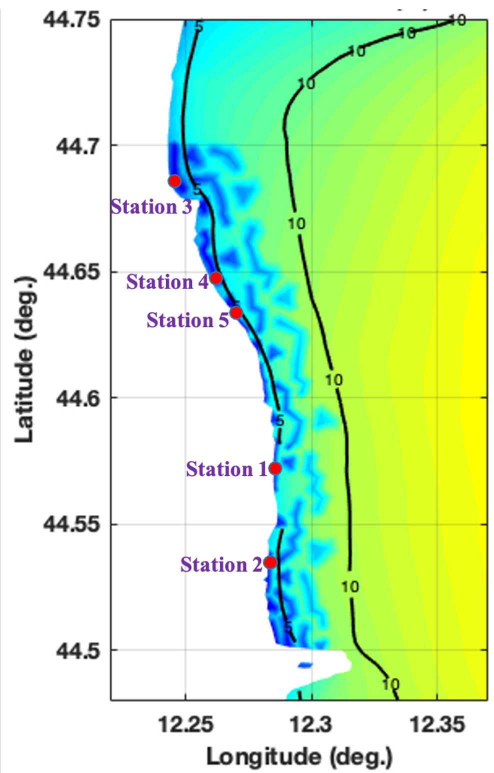


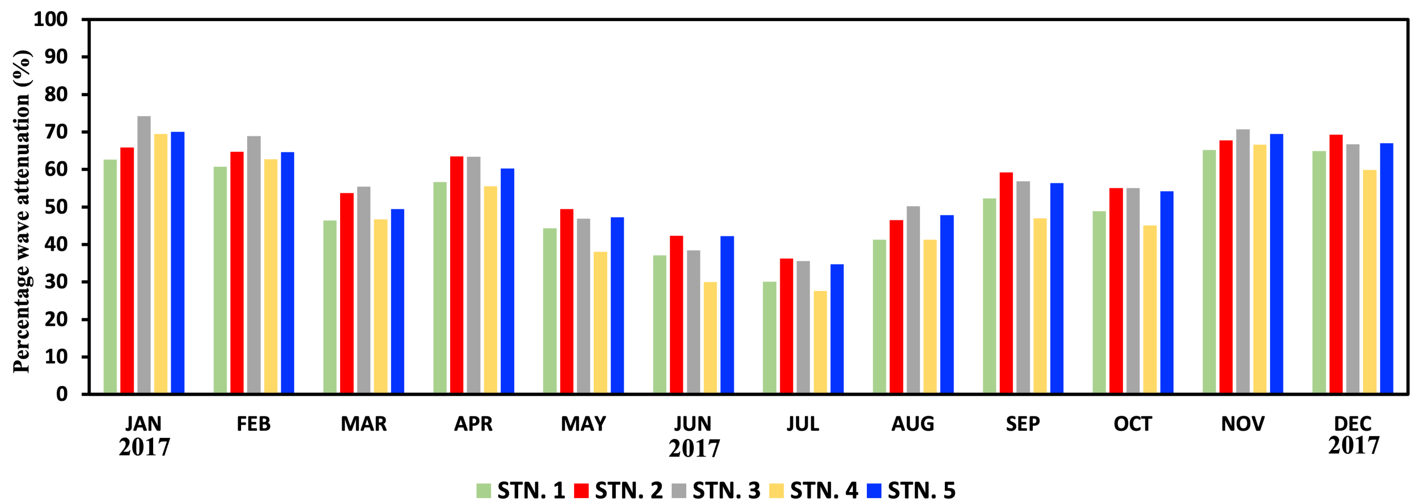
The percentage rate of wave attenuation is defined by:

$$a = h_m^{sg} - h_m^{nsg} / h_m^{nsg} \times 100$$

h_m^{sg} - mean wave height with seagrass

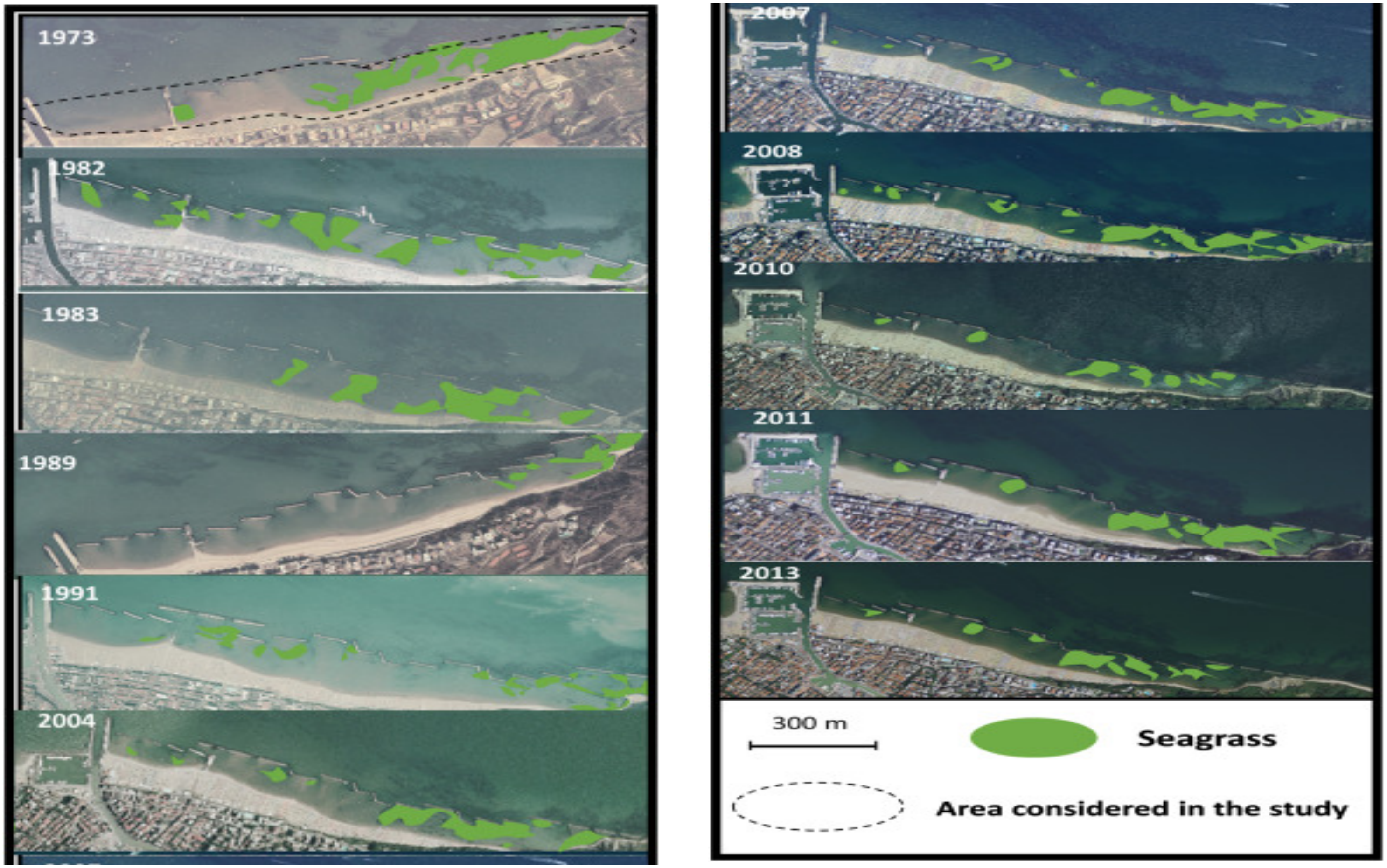
h_m^{nsg} - mean wave height without seagrass

Percentage attenuation at different stations



The need for seagrass monitoring with satellite remote sensing

Aerial photographs along the coast of the Northern Adriatic Sea allow to understand the NATURAL LANDSCAPING



Danovaro, R., et al., 2020. ***Multiple Declines and recoveries of Adriatic seagrass meadows over forty years of investigation, Marine Pollution Bulletin, 161, 111804.***

CONCLUSIONS

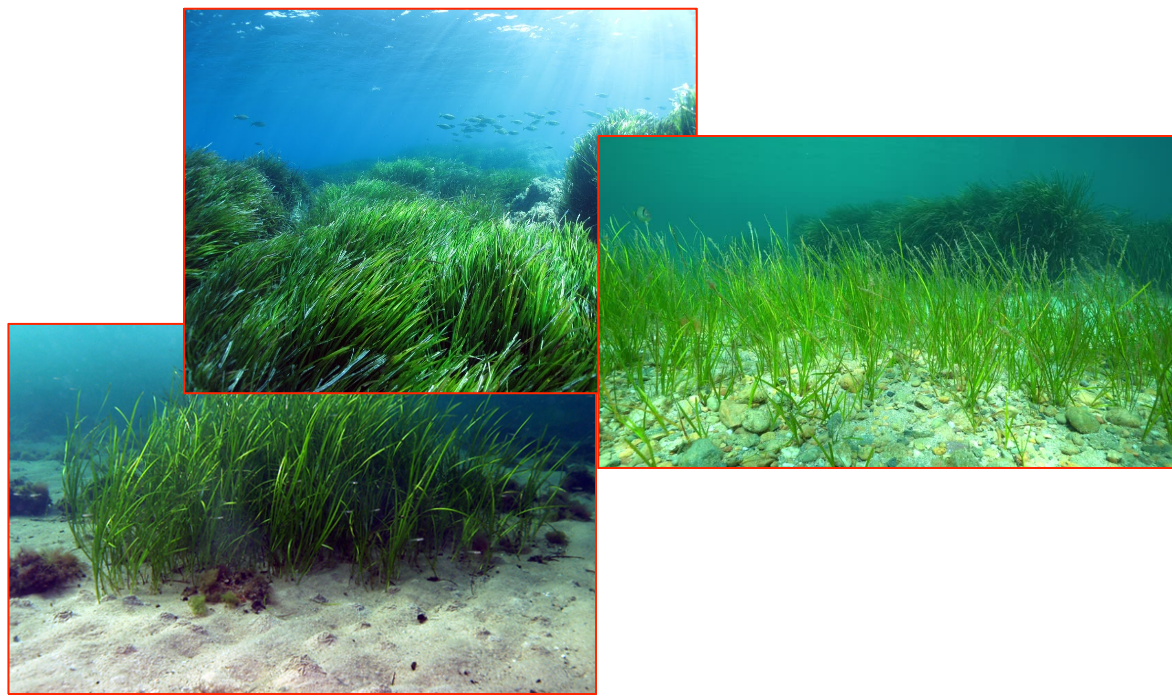
- *The Zostera Marina seagrass applied for the Emilia-Romagna coastal belt was found to be efficient in reduction of wave energy (> 50%). This is still done with rigid seagrass and in the future, we look for advanced parameterization using flexible seagrass.*

- *A combination of broken stripes and clusters of vegetation were seen to be highly capable in reduction of wave energy at the coast in comparison to other landscape designs.*

- *This study points out to the high demand on coastal remote sensing, as an information provider for seagrass monitoring such that the factors causing a decline in seagrass at a coastal location can be identified and addressed with immediate solutions.*

ACKNOWLEDGEMENTS:

This work was performed under the OPEn-air laboRAtories for Nature baseD solUtions to Manage environmental risks (OPERANDUM) EU H2020 project .



THANK YOU