CSQ-6 Summary

Question	Knowledge Advancement Objectives	Observables	Measurement Requirements	Tools & Models	Policies / Benefits
How do extreme marine weather events impact coastal areas and how is coastal vulnerability changing in response to climate change?	A) Characterise the magnitude, spatial distribution and occurrence of extreme marine weather events in the global coastal zone	- sea surface height - surface winds vectors - directional wave spectra including integral wave parameters (wave height, period, direction) - total surface current vectors - coastal bathymetry	Sub-daily to hourly High spatial resolution (1km or finer) 2D imaging Similar uncertainty levels as offshore	Coupled atmosphere-waves-ocean models Coastal morpho-dynamic models	National policies and strategies for flood and coastal risk Coastal planning and management policies EU strategy on adaptation to climate change (EC, 2013)
	B) Evaluate the vulnerability of coastal environments to extreme marine weather events in the global coastal zone	- land use - coastal morphology, coastline	Land surface imagery 5-10m		
	C) Quantify changes in extremes and associated impacts on coastal regions	- long-term time series - multi-sensor, cross-disciplinary synergy			

CSQ-6 Narrative

Extreme marine weather events like storm surges, high winds and extreme waves are dominant causes of damage and flooding in coastal areas. Their contributions to increasing water levels come in addition to underlying coastal sea level rise and are particularly destructive when they coincide with high tides or large river discharge (e.g. due to extreme precipitation). Projections of future extreme sea level indicate significantly greater vulnerability to coastal flooding in most regions when contributions by surges and waves are included (Vousdoukas et al., 2017; EEA, 2022). Analyses of tide gauge data indicate that trends in surge extremes and sea-level rise both made comparable contributions to the overall change in extreme sea levels in Europe since 1960 (Calafat et al., 2022). Climate projections indicate that episodic events of storm surge and wave setup will, between them, contribute approximately 68% of projected coastal flooding by 2100 (Kirezci et al., 2020). Thus, as coastal sea level rise and severe weather events become more frequent, how well can EO quantify the exposure of coastal areas to these different contributions, and establish the spatial distribution of coastal risks in the global coastal ocean, and how these are changing? Can EO determine how different land properties (e.g. coastal morphology, land use) influence the response of the coastal environment to extreme weather events, and provide evidence where human actions exacerbate or mitigate the impact of extremes on the coast ?

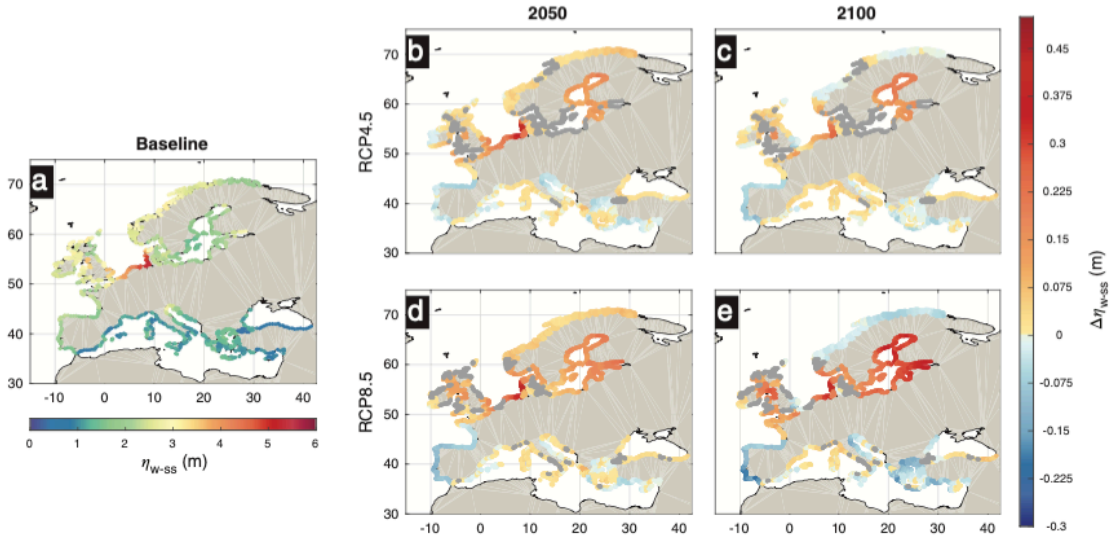

Figure 5. Contribution of climate extremes to extreme sea levels (ESL) along the European coastline and projected changes. Ensemble mean of episodic ESL contributions due to the combined effect of waves and storm surges (η_{w-ss}), expressed as the present-day 100-year η_{w-ss} (a) and projected changes under Representative Concentration Pathway (RCP)4.5 by 2050 (b) and 2100 (c), and under RCP8.5 by 2050 (d) and 2100 (e). Warm/cold colors express an increase/decrease, respectively, while points with high model disagreement are shown in gray (|CV| > 1).

From Vousdoukas et al. (2017)

Observations and Geophysical parameters required: Satellites have been shown to provide useful measurements of extreme marine weather events (e.g. altimetry for storm surges and extreme waves; SAR for extreme winds) but the typical 5-20 days temporal revisit of present-day missions makes them unsuited for extremes analyses. Scatterometers daily quasi-global data Efforts are needed to develop products and missions that deliver sub-daily high-resolution coastal 2D imaging of water levels, waves, winds and currents, to use in combination with existing and improved high-resolution land data.

References

Calafat FM, Wahl T, Tadesse MG, Sparrow SN. Trends in Europe storm surge extremes match the rate of sea-level rise. Nature. 2022 Mar 31;603(7903):841-5.https://doi.org/10.1038/s41586-022-04426-5

Cazenave, A., Gouzenes, Y., Birol, F. et al. Sea level along the world's coastlines can be measured by a network of virtual altimetry stations. Commun Earth Environ 3, 117 (2022). https://doi.org/10.1038/s43247-022-00448-z

Dai M, Su J, Zhao Y, Hofmann EE, Cao Z, Cai WJ, Gan J, Lacroix F, Laruelle GG, Meng F, Müller JD. Carbon fluxes in the Coastal Ocean: Synthesis, boundary processes, and future trends. Annual Review of Earth and Planetary Sciences. 2022 May 31; 50:593-626. https://doi.org/10.1146/annurev-earth-032320-090746

Durand, F., Piecuch, C. G., Becker, M., Papa, F., Raju, S. V., Khan, J. U., & Ponte, R. M. (2019). Impact of continental freshwater runoff on coastal sea level. Surveys in Geophysics, 40, 1437-1466.

EC, 2013. The EU strategy on adaptation to climate change, European Commission

European Environment Agency, 2022. Extreme sea levels and coastal flooding. https://www.eea.europa.eu/ims/extreme-sea-levels-and-coastal-flooding

He Q, Silliman BR. Climate change, human impacts, and coastal ecosystems in the Anthropocene. Current Biology. 2019 Oct 7;29(19):R1021-35. https://doi.org/10.1016/j.cub.2019.08.042

Kirezci, E., Young, I.R., Ranasinghe, R., Muis, S., Nicholls, R.J., Lincke, D. and Hinkel, J., 2020. Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st Century. Scientific reports, 10(1), p.11629.

Macreadie PI, Anton A, Raven JA, Beaumont N, Connolly RM, Friess DA, Kelleway JJ, Kennedy H, Kuwae T, Lavery PS, Lovelock CE. The future of Blue Carbon science. Nature communications. 2019 Sep 5;10(1):3998. https://doi.org/10.1038/s41467-019-11693-w

Mathis, M., Logemann, K., Maerz, J., Lacroix, F., Hagemann, S., Chegini, F., Ramme, L., Ilyina, T., Korn, P. and Schrum, C., 2022. Seamless integration of the coastal ocean in global marine carbon cycle modeling. Journal of Advances in Modeling Earth Systems, 14(8), p.e2021MS002789.

Melet, A., Meyssignac, B., Almar, R., & Le Cozannet, G. (2018). Under-estimated wave contribution to coastal sea-level rise. Nature Climate Change, 8(3), 234-239.

Nielsen DM, Pieper P, Barkhordarian A, Overduin P, Ilyina T, Brovkin V, Baehr J, Dobrynin M. Increase in Arctic coastal erosion and its sensitivity to warming in the twenty-first century. Nature Climate Change. 2022 Mar;12(3):263-70. https://doi.org/10.1038/s41558-022-01281-0

Roobaert, A., Laruelle, G.G., Landschützer, P., Gruber, N., Chou, L. and Regnier, P., 2019. The spatiotemporal dynamics of the sources and sinks of CO2 in the global coastal ocean. Global Biogeochemical Cycles, 33(12), pp.1693-1714.

Siefert, Ronald L., and Gian-Kasper Plattner, 2004. The role of coastal zones in global biogeochemical cycles. Eos,Vol.85, No.45, 9 November 2004, 470-470

Singh, G. G., Cottrell, R. S., Eddy, T. D., & Cisneros-Montemayor, A. M. (2021). Governing the land-sea interface to achieve sustainable coastal development. Frontiers in Marine Science, 8, 709947.

Vousdoukas MI, Mentaschi L, Voukouvalas E, Verlaan M, Feyen L. Extreme sea levels on the rise along Europe's coasts. Earth's Future. 2017 Mar;5(3):304-23. https://doi.org/10.1002/2016EF000505

Winterfeld M, Mollenhauer G, Dummann W, Köhler P, Lembke-Jene L, Meyer VD, Hefter J, McIntyre C, Wacker L, Kokfelt U, Tiedemann R. Deglacial mobilization of pre-aged terrestrial carbon from degrading permafrost. Nature Communications. 2018 Sep 10;9(1):3666. https://doi.org/10.1038/s41467-018-06080-w

Woodworth, P.L., Melet, A., Marcos, M., Ray, R.D., Wöppelmann, G., Sasaki, Y.N., Cirano, M., Hibbert, A., Huthnance, J.M., Monserrat, S. and Merrifield, M.A., 2019. Forcing factors affecting sea level changes at the coast. Surveys in Geophysics, 40(6), pp.1351-1397.