Ocean Sci., 13, 495–501, 2017
https://doi.org/10.5194/os-13-495-2017

Ocean Science Open Access EGU

Preface: Oceanographic processes on the continental shelf: observations and modeling

Sandro Carniel[1], **Judith Wolf**[2], **Vittorio E. Brando**[3,a], **and Lakshmi H. Kantha**[4]

[1]Institute of Marine Science, National Research Council (ISMAR-CNR), Venice, Italy
[2]National Oceanography Center, Liverpool, UK
[3]Institute of Electromagnetic Sensing of the Environment, National Research Council (IREA-CNR), Milan, Italy
[4]University of Colorado, Boulder, CO 80309, USA
[a]present address: Institute for the Study of Atmosphere and Climate, National Research Council (ISAC-CNR), Rome, Italy

Correspondence to: Sandro Carniel (sandro.carniel@cnr.it)

Published: 22 June 2017

1 Introduction

Oceanographic processes in the shallow continental shelf and coastal regions have a major impact on human life, since a large fraction of human population lives within 100 km of the shoreline (Halpern et al., 2008). At the same time, the processes occurring in these regions are difficult to analyze and disentangle, because of their intrinsic complexity, the variability of temporal and spatial scales, their multidisciplinary nature, and the influence of offshore boundary conditions (Dickey, 2003; Mitchell et al., 2015).

To improve our knowledge of processes typical of these regions, there is a strong need for an integrated approach, combining numerical coupled systems (of ocean, atmosphere, waves, biology, and sediments) at selected scales (Carniel et al., 2016a), validated with data resulting from either distributed coastal observatories or remote sensing approaches (point-wise data from multivariable buoys, high-frequency radar images, satellite images, drifters, AUVs, gliders, etc.). This scientific challenge has to take into consideration a wide range of processes involving tides, resuspension, stratification, mixing, land boundaries, surrounding land use, river discharges, distributed run off, pollutants from densely populated areas, etc. (e.g., Mitchell et al., 2015 and references there in).

All these aspects are even more relevant nowadays, in a framework of changing climate (Collins et al., 2012). Shallow coastal and transitional areas, wetlands and lagoons, coastal cities, and valuable infrastructures are being threatened by potential impact of climate-change-induced hazards, such as inundation of low-lying areas, exposure to accelerated sea-level rise, and increased rates of coastal erosion. At the same time, these are also the regions where it may be feasible to harvest renewable energy economically, or where state-of-the-art prototypes can be more readily deployed for specific studies.

To improve understanding of shelf processes and to identify key parameters that allow detection and monitoring of likely changes, we invited investigators to contribute original research articles, resulting in the special issue "Oceanographic processes on the continental shelf: observations and modeling".

In Table 1, we summarize how the papers in this special issue have addressed some of the specific aspects that characterize shelf sea process studies as a sort of *fil rouge*: the spatial scale of the processes investigated (regional, meso- and sub-mesoscale, and fine scale); the need to address them using different measurements (in situ, remote sensing, physical or biogeochemical parameters); how and when numerical models can integrate existing data (representing only specific processes like hydrodynamics or waves, or presenting a "coupled" approach); and the length or timescale of the events described (single event, short period, seasonal, yearly, etc.). Readers can therefore identify the most significant characteristics of each paper with respect to these key aspects.

2 Bringing together data and numerical models

Coastal observatories provide sustained information for the thorough understanding of the mechanisms regulating shelf

Table 1. Summary of some specific aspects that characterize the study of shelf processes: the spatial scale of the processes investigated, the timescale of the events described, the need to address them using different measurements, and numerical models typology. Readers can therefore identify the most significant characteristics of each paper with respect to these key aspects.

Papers	Spatial scale				Event/timescale				Measurements			Models				
	Reg	Meso	Sub	Fine/ Small	Years	Months	Days	Severe/flood/ Bora/storm	Satellite	In situ phys	In situ biogeo	Operational	Coupled phys	Wave	Bio Geo	Statistical/ reanalysis method
Brando			X	X			X	X	X			X	X			
Falcieri				X			X	X		X						
McKiver			X			X	X	X					X			
Iuppa					X									X		
Umgiesser			X		X								X			
Lanotte			X				X			X		X	X			
Licer			X				X	X		X			X	X		
Olita	X	X			X	X			X				X			
Grifoll			X					X		X			X			
Samaras	X							X								
Barbariol			X		X			X		X						X
Gutierrez		X	X		X			X	X							X
Kraus		X			X						X				X	X
Bonamano			X	X		X			X	X	X		X		X	
Signell		X	X			X	X		X	X	X	X	X			

regions (e.g., Lynch et al, 2014). However, as they are relatively scarce and sparse, they do not often provide sufficient spatial coverage to observe extreme events (Dickey et al., 2003). Brando et al. (2015, this special issue) examine how they can be integrated with high-resolution satellite observations and into coastal numerical model outputs. Namely, sea surface temperature (SST) and turbidity (T) maps derived from Landsat 8 imagery at 30 m resolution were used to characterize river plumes in the northern Adriatic Sea during a significant flood event in November 2014. Circulation patterns and sea surface salinity (SSS) from an operational coupled ocean–wave model supported the interpretation of the plumes' interaction with the receiving waters. A good agreement was found between SSS, T, and SST fields at the sub-mesoscale and mesoscale delineation of the major river plumes, enabling also the description of smaller plume structures, such as the different plumes' reflectance spectra related to the lithological fingerprint of the sediments in the river-catchment basins.

Most of the coastal measurements and data available in coastal regions rely on state-of-the-art measurements such as CTD (conductivity, temperature, and depth) or ADCPs (acoustic current doppler profilers), which nowadays constitute the benchmark for improving our understanding and assessing numerical models. However, relatively uncommon, but very useful, data exploring the small scale are becoming more available (Thorpe, 2005; Carniel et al., 2012). As an example, Falcieri et al. (2016, this special issue) present the very first turbulence observations in the Gulf of Trieste (northern Adriatic Sea), acquired during different water column stratifications. Almost 500 microstructure profiles allowed the demonstration that, during the 2014 winter, the water column in the gulf was not completely mixed, due to the influence of bottom water intruding from the open sea. One type of water intrusion comes from the northern coast of the Adriatic Sea (i.e., cooler, fresher, and more turbid water), which acted as a barrier to wind-driven turbulence. A different water mass, coming from the open sea in front of the Po Delta (i.e., warmer, saltier, less turbid, and with a smaller vertical density gradient) was not able to suppress downward penetration of turbulence from the surface.

Sea-truth data can then be used directly in order to validate modeling tools implemented to describe shelf sea processes in coastal regions (Usui et al., 2015); given the fact that there are several existing typologies of such numerical models, in each case the use of the most appropriate one is required. Bricheno et al. (2014) show the importance of resolving the appropriate spatial scales and using suitable metrics to compare models and data in the nearshore zone. McKiver et al. (2016, this special issue) compare the ability of a finite-difference (SHYFEM, shallow water hydrodynamic finite-element model) and a finite-element model (MITgcm, Massachusetts Institute of Technology general circulation model, Sannino et al., 2014) to simulate coastal processes in the northern Adriatic Sea. The study focused on the northern Adriatic Sea during a severe event that occurred at the beginning of 2012, and gave the opportunity to understand how these events (related to dense water formation) may affect coastal processes, like upwelling and downwelling, and how they interact with estuarine dynamics. Both models capture the dense water event, though each displays biases in different regions, showing large differences in the reproduction of surface patterns and highlighting the relevance of identifying suitable bulk formulas for the correct simulation of the thermohaline structure of the coastal zone. McKiver et al. (2016, this special issue) highlight that, while a coarser resolution offshore is acceptable for the reproduction of the dense water event (during which the non-hydrostatic processes were found to have little importance), a finer horizontal resolution in the coastal zone is important to reproduce the effect of the complex coastal morphology on the hydrodynamics.

3 Planning the coastal maritime space

Sea regions close to the continental shelf are also those from which it could be feasible to extract renewable energy with the highest efficiency and lowest cost (Cruz, 2008). Iuppa et al. (2015, this special issue) discuss potential sites around the island of Sicily for energy extraction from surface gravity waves, with the aim of selecting possible sites for the implementation of wave energy converters (WECs). A third-generation wave model was adopted to reconstruct the wave data along the coast over a period of 14 years, which allowed the characterization of the most productive areas on the western side of the island and in the Strait of Sicily (i.e., relatively high wave energy and proximity to the coast), which makes them possible sites for the implementation of WEC farms.

Coastal lagoons represent peculiar and fragile situations that can often be in direct contact with coastal and shelf processes. Umgiesser et al. (2016, this special issue) explore the variability of water renewal due to heavy river discharges in the very shallow Curonian Lagoon, connected by a very narrow strait to the Baltic Sea. The lagoon is simulated, using a finite-element hydrodynamic model, to reproduce the circulation patterns for 10 years, focusing on the salinity distribution and the renewal times of the system when forced by river runoff, wind, and Baltic Sea sea-level fluctuations. Results demonstrated how the river discharge within the lagoon was the most important factor triggering the water renewal time.

As stressed above, numerical models are extremely useful for integrating the paucity of marine data available in order to better disentangle different dynamical contributions and provide a synoptic picture of the oceanographic shelf processes (Warner et al., 2010). A careful blending of observations and model data makes it possible to conceive of functional tools to control, for instance, the horizontal spreading of small organisms or substance concentrations, thus being relevant for marine biology and pollutant dispersion as well as oil spill applications. In this special issue, Lanotte et al. (2016) study the role of vertical shear on oceanic horizontal dispersion of passive tracer particles on the continental shelf in the southern Mediterranean, by means of observation and model data. In situ current measurements reveal that vertical gradients of horizontal velocities in the upper mixed layer decorrelate quite fast ($\sim$ 1 day), whereas an eddy-permitting ocean model, such as the Mediterranean Forecasting System, tends to overestimate such decorrelation times (possibly due to unresolved scale motions and mesoscale motions that are largely smoothed out at scales close to the grid spacing).

4 The need for a coupled approach

Although the different processes characterizing the shelf regions are intrinsically connected, in order to simplify the numerical approach, historically these different components (e.g., atmosphere, ocean, wave, sediment, biology etc.) have been modeled separately (Mihanovic et al., 2013). However, mostly thanks to increases in the understanding of mutual feedbacks and advances in computer power, this reductionist approach can be now overcome. Licer et al. (2016, this special issue) describe work dealing with a one-way and two-way coupled ocean–atmosphere system during an intense Bora event in the northern Adriatic. Comparing modeled atmosphere–ocean fluxes and sea temperatures from both model setups to platform and CTD measurements from three locations in the northern Adriatic, Licer et al. (2016, this special issue) found that, using two-way coupling, ocean temperatures exhibit a root mean square error (RMSE) 4 times lower than those from a one-way coupled system. Sensible heat fluxes were also improved in the coupled approach, at all stations, while coupled and uncoupled circulations in the northern Adriatic (being predominantly wind-driven) did not show significant mesoscale differences.

There are, of course, several other interesting aspects that should be encompassed when dealing with coupled numerical models (Carniel et al., 2016b). In this special issue, Olita et al. (2015) study the impact of current speeds on the parameterization of surface fluxes and their feedback on regional-scale ocean dynamics. The computations of heat and momentum fluxes in uncoupled models generally happen through standard (Fairall et al., 2003) bulk formulas, where the wind speeds do not take account of their relative effects with respect to the ocean currents. From the results obtained from twin numerical experiments around the island of Sardinia (western Mediterranean), Olita et al. (2015, this special issue) demonstrated that, even at local scales and in temperate regions, it would be preferable to take into account such a contribution in flux computations. The modification of the original code, substantially cost-free in terms of numerical computation, improves the model response in terms of surface fluxes (SST validated) and it also likely improves the dynamics, as suggested by qualitative comparison with satellite data.

Complementing numerical model results, Grifoll et al. (2016, this special issue) used a set of observations to investigate the inner-shelf response due to the storm passage in the inner-shelf of the NW Mediterranean Sea. The two-peak storm induced an interesting evolution in the momentum balance terms: the appearance of fluctuations with both super-inertial (12–16 h) and sub-inertial (1–2 days) periods. In contrast to the first peak of the storm, during the second one the temporal sequence of increased acceleration reoccurred, but with the along-shelf flow largely influenced by the sub-inertial (likely topographic) waves. The work encompassed water-current observation analysis and the application of theoretical models to describe the shelf wave propagation and the shelf response to the wind.

Although risks associated with climate change may indeed change the frequency and nature of storms in the Mediterranean Sea (Lionello et al., 2012), shelf regions are also prone to other risks, such as coastal inundation related to tsunami generation and propagation. Samaras et al. (2015, this special issue) presented an advanced tsunami-generation, propagation and coastal inundation 2-D (horizontal) model based on the higher-order Boussinesq equations, applied to simulate representative earthquake-induced tsunami scenarios in the eastern Mediterranean. Two areas of interest were selected after evaluating tsunamigenic zones and possible sources in the region: one at the southwest of the island of Crete in Greece and one at the east of the island of Sicily in Italy. Model results are presented in the form of extreme water elevation maps, sequences of snapshots of water elevation during the propagation of the tsunamis, and inundation maps of the studied low-lying coastal areas. This work marks one of the first successful applications of a fully nonlinear model for the 2-D horizontal simulation of tsunami-induced coastal inundation; acquired results are indicative of the model's capabilities, also showing how areas in the eastern Mediterranean would be affected by potential larger events.

5 Detecting a changing sea

Characterizing the meteo-oceanographic climate in coastal regions is a fundamental step in being able to distinguish between natural and human-related fluctuations and to detect extreme events (Rockel et al., 2007). When analyzing long-term series, a number of statistical approaches can be evaluated. In this special issue, Barbariol et al. (2016) presented wave extreme characterization for the wave climate at the "Acqua Alta" oceanographic tower (northern Adriatic Sea, Italy), during the period 1979–2008, using self-organizing maps (SOMs, Liu et al., 2006). An application of the proposed two-step approach demonstrated that a proper representation of the extreme wave climate leads to enhanced quantification of, for instance, the alongshore component of the wave energy flux in shallow water. Focusing also on the peaks of the storms, Barbariol et al. showed how practical oceanographic and engineering applications can benefit from the novel SOM processing strategies developed. Besides improving the statistical analysis of long-term wave series, in recent years increasing attention has been devoted to wave reanalysis as a powerful source of information for wave climate research and engineering applications. However, the problem remains that, in coastal areas or shallow water, waves are poorly described due to a lack of spatial resolution, and wave downscaling procedures are needed; there is also a need for higher-resolution wind fields (e.g., Rockel et al., 2007; O'Neil et al., 2017).

Gutierrez et al. (2016, this special issue) demonstrated the feasibility of the use of wind fields detected with synthetic aperture radar (SAR) for the wave climate downscaling of the northern Adriatic Sea, by using a hybrid methodology and global wave and wind reanalysis as forcing. The wave fields produced were compared to wave fields produced with SAR winds that represent the two dominant wind regimes in the area: the Bora (east-northeast direction) and Sirocco (southeast direction). Although differences existed between SAR and modeled wind fields, a good correlation was found for the downscaled waves forced with different wind products. Overall this work showed how Earth observation products, such as SAR wind fields, can be successfully taken up into oceanographic modeling, producing similar downscaled wave fields when compared to waves forced with reanalysis wind.

The relevance of long-term data acquired at sea, also from the biological perspective, was confirmed by Kraus et al. (2016, this special issue), who explored the factors favoring phytoplankton blooms in the northern Adriatic Sea analyzing an oceanographic data set derived from monthly oceanographic cruises covering the 1990–2004 period. Kraus et al. (2016) found that while in winter and early spring the phytoplankton abundances depended on circulation fields, in summer and autumn they were related to Po River discharge rates up to 15 days earlier and on concomitant circulation fields. On the other hand, late spring phytoplankton abundances increased 1–3 days after high Po River discharge rates regardless of the circulation fields. These findings create the basis for the construction of an empirical ecological model of the northern Adriatic, which can ultimately be used in the sustainable economy of the region, as well as for validation of a numerical ecological model which is currently being developed for the region.

6 Towards integrated ocean observing systems

Last but not least, in order to converge towards an integrated ocean observing system capable of providing useful information and contributing to effective management and planning activities, all data collected in our shelf regions should be brought in contact and integrated with existing numerical models (Williams et al., 2011). In this special issue volume, Bonamano et al. (2016) presented a multiplatform observing network in the coastal marine area of Civitavecchia (Latium, Italy), integrated with numerical models, to analyze coastal processes at high spatial and temporal resolution. The in situ data acquired at long-term fixed stations and during dedicated surveys are integrated with satellite observations (e.g., temperature, chlorophyll a, and TSM), and then used to feed and validate numerical models to describe the dynamics of pollutant dispersion under different conditions. Such integrated ocean observatory systems turn out to be very useful during the activity of marine planning and management (e.g., bathing water quality assessment, evaluation of the effects of the dredged activities on *Posidonia* meadows) and are a practical tool to improve the conflict resolution between anthropic and conservation uses in coastal sensitive areas. They should become more and more commonly used involving transnational actors in order to reach an integrated system capable of connecting national efforts.

In recent years it appeared more and more clear how, in order to be really effective, the increasing amount of collected data (either from single point or remotely) and model output currently available need to be quickly accessed and distributed among the scientific community (see Bergamasco et al., 2012). Signell and Camossi (2016, this special issue) present a solution that allows even small research groups to provide meteorological and ocean model data through standardized web services and tools. A simple, local brokering approach was presented that lets modelers continue producing custom data, but virtually aggregates and standardizes the data using NetCDF Markup Language. The THREDDS Data Server is used for data delivery, pycsw for data search, NCTOOLBOX (MATLAB$^{®}$) and Iris (Python) for data access, and Ocean Geospatial Consortium Web Map Service for data preview. Such an approach dramatically improves the effectiveness of data distribution and sharing in research communities with limited IT resources, (i) making it simple for providers to enable web service access to existing output files; (ii) using technology that is free, and that is easy to deploy and configure; and (iii) providing tools to communicate with web services that work in existing research environments.

We therefore hope that *Ocean Science* readers will then find much of the material in this special issue of interest, paradigmatic of processes that can be analyzed in other geographical contexts with respect to those presented, and a point of reference for cutting-edge ideas in theory, numerical models, and observations.

Acknowledgements. Sandro Carniel thanks the RITMARE National Flagship project, Phase I and Phase II. Judith Wolf acknowledges support from the UK Natural Environment Research Council. Vittorio E. Brando was supported by the RITMARE Flagship project and the European Union (FP7-427 People Co-funding of Regional, National and International Programmes, GA no. 600407). Lakshmi H. Kantha thanks CNR-ISMAR for providing the opportunity to interact with European oceanographers. All authors gratefully acknowledge the support of *Ocean Science* Executive Editors and Editorial assistants, and the useful suggestions received from John M. Huthnance.

References

Barbariol, F., Falcieri, F. M., Scotton, C., Benetazzo, A., Carniel, S., and Sclavo, M.: Wave extreme characterization using self-organizing maps, Ocean Sci., 12, 403–415, https://doi.org/10.5194/os-12-403-2016, 2016.

Bergamasco, A., Benetazzo, A., Carniel, S., Falcieri, F., Minuzzo, T., Signell, R. P., and Sclavo, M.: From interoperability to knowledge discovery using large model datasets in the marine environment: the THREDDS Data Server example, Adv. Oceanogr. Limnol., 3, 41–50, https://doi.org/10.1080/19475721.2012.669637, 2012.

Bonamano, S., Piermattei, V., Madonia, A., Paladini de Mendoza, F., Pierattini, A., Martellucci, R., Stefanì, C., Zappalà, G., Caruso, G., and Marcelli, M.: The Civitavecchia Coastal Environment Monitoring System (C-CEMS): a new tool to analyze the conflicts between coastal pressures and sensitivity areas, Ocean Sci., 12, 87–100, https://doi.org/10.5194/os-12-87-2016, 2016.

Brando, V. E., Braga, F., Zaggia, L., Giardino, C., Bresciani, M., Matta, E., Bellafiore, D., Ferrarin, C., Maicu, F., Benetazzo, A., Bonaldo, D., Falcieri, F. M., Coluccelli, A., Russo, A., and Carniel, S.: High-resolution satellite turbidity and sea surface temperature observations of river plume interactions during a significant flood event, Ocean Sci., 11, 909–920, https://doi.org/10.5194/os-11-909-2015, 2015.

Bricheno, L. M., Wolf, J., and Brown, J.: Impacts of high resolution model downscaling in coastal regions, Cont. Shelf Res., 87, 7–16, 2014.

Carniel, S., Kantha, L. H., Book, J.W., Sclavo, M., and Prandke, H.: Turbulence variability in the upper layers of the Southern Adriatic Sea under a variety of atmospheric forcing conditions, Cont. Shelf Res., 44, 39–56, 2012.

Carniel, S., Bonaldo, D., Benetazzo, A., Bergamasco, A., Boldrin, A., Falcieri, F. M., Sclavo, M., Trincardi, F., Falcieri, F. M., Langone, L., and Sclavo, M.: Off-Shelf Fluxes across the Southern Adriatic Margin: Factors Controlling Dense-Water-Driven Transport Phenomena, Mar. Geol., 375, 44–63, https://doi.org/10.1016/j.margeo.2015.08.016, 2016a.

Carniel, S., Benetazzo, A., Bonaldo, D., Falcieri, F. M., Miglietta, M. M., Ricchi, A., and Sclavo, M.: Scratching beneath the surface while coupling atmosphere, ocean and waves: Analysis of a dense water formation event, Ocean Modell., 101, 101–112, https://doi.org/10.1016/j.ocemod.2016.03.007, 2016b.

Collins, M., Chandler, R. E., Cox, P. M., Huthnance, J. M., Rougier, J., and Stephenson, D. B.: Quantifying future climate change, Nature Climate Change, 2, 304–409, 2012.

Cruz, J.: Ocean wave energy: current status and future perspectives, Green Energy and Technology, Springer, 2008.

Dickey, T.: Emerging ocean observations for interdisciplinary data assimilation systems, J. Marine Syst., 40–41, 5–48, https://doi.org/10.1016/S0924-7963(03)00011-3, 2003.

Fairall, C. W., Bradley, E. F., Hare, J. E., Grachev, A. A., and Edson, J. B.: Bulk parameterization of air–sea fluxes: Updates and verification for the COARE algorithm, J. Climate, 16, 571–591, 2003.

Falcieri, F. M., Kantha, L., Benetazzo, A., Bergamasco, A., Bonaldo, D., Barbariol, F., Malacic, V., Sclavo, M., and Carniel, S.: Turbulence observations in the Gulf of Trieste under moderate wind forcing and different water column stratification, Ocean Sci., 12, 433–449, https://doi.org/10.5194/os-12-433-2016, 2016.

Grifoll, M., Aretxabaleta, A. L., Pelegrí, J. L., and Espino, M.: Temporal evolution of the momentum balance terms and frictional adjustment observed over the inner shelf during a storm, Ocean Sci., 12, 137–151, https://doi.org/10.5194/os-12-137-2016, 2016.

Gutiérrez, O. Q., Filipponi, F., Taramelli, A., Valentini, E., Camus, P., and Méndez, F. J.: On the feasibility of the use of wind SAR to downscale waves on shallow water, Ocean Sci., 12, 39–49, https://doi.org/10.5194/os-12-39-2016, 2016.

Halpern, B. S., Walbridge, S., Selkow, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. F., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., and Watson, R.: A global map of human impact on marine ecosystems, Science, 319, 948–952, https://doi.org/10.1126/science.1149345, 2008.

Iuppa, C., Cavallaro, L., Vicinanza, D., and Foti, E.: Investigation of suitable sites for wave energy converters around Sicily (Italy), Ocean Sci., 11, 543–557, https://doi.org/10.5194/os-11-543-2015, 2015.

Kraus, R., Supic, N., and Precali, R.: Factors favouring phytoplankton blooms in the northern Adriatic: towards the northern Adriatic empirical ecological model, Ocean Sci., 12, 19–37, https://doi.org/10.5194/os-12-19-2016, 2016.

Lionello, P., Galati, M. B., and Elvini, E.: Extreme storm surge and wind wave climate scenario simulations at the Venetian littoral, Phys. Chem. Earth, Parts A/B/C, 40–41, 86–92, 2012.

Lanotte, A. S., Corrado, R., Palatella, L., Pizzigalli, C., Schipa, I., and Santoleri, R.: Effects of vertical shear in modelling horizontal oceanic dispersion, Ocean Sci., 12, 207–216, https://doi.org/10.5194/os-12-207-2016, 2016.

Licer, M., Smerkol, P., Fettich, A., Ravdas, M., Papapostolou, A., Mantziafou, A., Strajnar, B., Cedilnik, J., Jeromel, M., Jerman, J., Petan, S., Malacic, V., and Sofianos, S.: Modeling the ocean and atmosphere during an extreme bora event in northern Adriatic using one-way and two-way atmosphere-ocean coupling, Ocean Sci., 12, 71–86, https://doi.org/10.5194/os-12-71-2016, 2016.

Liu, Y., Weisberg, R. H., and He, R.: Sea surface temperature patterns on the West Florida Shelf using growing hierarchical self-organizing maps, J. Atmos. Ocean. Tech., 23, 325–338, https://doi.org/10.1175/JTECH1848.1, 2006.

Lynch, T. P., Morello, E. B., Evans, K., Richardson, A. J., Steinberg, C. R., Roughan, M., Thompson, P., Middleton, J. F., Feng, M., Sherrington, R. B., Brando, V. E., Tilbrook, B., Ridgway, K., Allen, S., Doherty, P., Hill, K., and Moltmann, T. C.: IMOS National Reference Stations: a continental scaled physical, chemical and biological coastal observing system, Plos ONE, 9, e113652, https://doi.org/10.1371/journal.pone.0113652, 2014.

McKiver, W. J., Sannino, G., Braga, F., and Bellafiore, D.: Investigation of model capability in capturing vertical hydrodynamic coastal processes: a case study in the north Adriatic Sea, Ocean Sci., 12, 51–69, https://doi.org/10.5194/os-12-51-2016, 2016.

Mihanovic, H., Vilibic, I., Carniel, S., Tudor, M., Russo, A., Bergamasco, A., Bubic, N., Ljubešic, Z., Vilicic, D., Boldrin, A., Malacic, V., Celio, M., Comici, C., and Raicich, F.: Exceptional dense water formation on the Adriatic shelf in the winter of 2012, Ocean Sci., 9, 561–572, https://doi.org/10.5194/os-9-561-2013, 2013.

Mitchell, S. B., Jennerjahn, T. C., Vizzini, S., and Zhang, W.: Changes to processes in estuaries and coastal waters due to intense multiple pressures–An introduction and synthesis, Estuarine, Coast. Shelf Sci., 156, 1–6, https://doi.org/10.1016/j.ecss.2014.12.027, 2015.

Olita, A., Iermano, I., Fazioli, L., Ribotti, A., Tedesco, C., Pessini, F., and Sorgente, R.: Impact of currents on surface flux computations and their feedback on dynamics at regional scales, Ocean Sci., 11, 657–666, https://doi.org/10.5194/os-11-657-2015, 2015.

O'Neill, A. C., Erikson, L. H., and Barnard, P. L.: Downscaling wind and wave fields for 21st century coastal flood hazard projections in a region of complex terrain, Earth Space Sci., 4, 314–334, https://doi.org/10.1002/2016EA000193, 2017.

Rockel, B. and Woth, K.: Extremes of near-surface wind speed over Europe and their future changes as estimated from an ensemble of RCM simulations, Climatic Change, 81, 267–280, 2007.

Samaras, A. G., Karambas, Th. V., and Archetti, R.: Simulation of tsunami generation, propagation and coastal inundation in the Eastern Mediterranean, Ocean Sci., 11, 643–655, https://doi.org/10.5194/os-11-643-2015, 2015.

Sannino, G., Sanchez Garrido, J. C., Liberti, L., and Pratt, L.: Exchange flow through the Strait of Gibraltar as simulated by acoordinate hydrostatic model and a z-coordinate nonhydrostatic model, in: The Mediterranean Sea: Temporal Variability and Spatial Patterns, John Wiley & Sons Inc., Oxford, UK, 25–50, 2014.

Signell, R. P. and Camossi, E.: Technical note: Harmonising metocean model data via standard web services within small research groups, Ocean Sci., 12, 633–645, https://doi.org/10.5194/os-12-633-2016, 2016.

Thorpe, S. A.: The Turbulent Ocean, Cambridge University Press, Cambridge, UK, 439 pp., 2005

Umgiesser, G., Zemlys, P., Erturk, A., Razinkova-Baziukas, A., Mežine, J., and Ferrarin, C.: Seasonal renewal time variability in the Curonian Lagoon caused by atmospheric and hydrographical forcing, Ocean Sci., 12, 391–402, https://doi.org/10.5194/os-12-391-2016, 2016.

Usui, N., Fujii, Y., Sakamoto, K., and Kamachi, M.: Development of a Four-Dimensional Variational Assimilation System for Coastal Data Assimilation around Japan, Mon. Weather Rev., 143, 3874–3892, https://doi.org/10.1175/MWR-D-14-00326.1, 2015.

Warner, J. C., Armstrong, B., He, R., and Zambon, J. B.: Development of a coupled ocean–atmosphere–wave–sediment transport (COAWST) modeling system, Ocean Model., 35, 230–244, https://doi.org/10.1016/j.ocemod.2010.07.010, 2010.

Williams P. D., Cullen, M. J. P. and, Huthnance, J. M.: How mathematical models can aid our understanding of climate, EOS Transactions of the American Geophysical Union, 92, p. 482, 2011.