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EDITORIAL

The 2nd international workshop on waves, storm surges and coastal hazards incorporating the 16th international workshop on wave hindcasting and forecasting

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1 History of the workshop

The long history of the International Workshop on Wave Hindcasting and Forecasting has been previously described by Breivik et al. (2015, 2017) for the topical collections following the 13th and 14th Workshops. Swail et al. (2019a) described the effort to broaden the scope of the workshops to foster closer integration between the wave and ocean modeling communities and the emerging priority of multi-hazard early warning systems, including the more inclusive naming to the International Workshop on Waves, Storm Surges and Coastal Hazards. The workshop continues to explicitly acknowledge the International Wave Workshop, so as not to lose the name recognition and successful legacy of the previous workshops, including the workshop website www.waveworkshop.org.

2 The 2nd wave, surge and coastal hazards workshop

The 2nd International Workshop on Waves, Storm Surges and Coastal Hazards, incorporating the 16th International Workshop on Wave Hindcasting and Forecasting (henceforth referred to as the Workshop), was held in Melbourne, Australia, from 10 to 15 November 2019, the first time ever in the Southern Hemisphere.

As described by Breivik et al. (2015), the research tools and the topics have changed over the years, but the primary objectives of the first workshop, held in Canada in 1986, as noted below and extended to include similar themes for storm surge and coastal hazards, remain unchanged:

- Provide a forum for the exchange of ideas and information related to wind and wave hindcasting and forecasting, including modeling, measurement, and past and future states of the climate.
- Coordinate ongoing research and development initiatives.
- Discuss priorities for future research and development.

The number of participants in the Workshop was the largest ever, in part due to the attraction of Melbourne as a destination and the increased accessibility from the host nation of Australia and the greater Asia-Pacific region. The Workshop welcomed 238 participants from 30 countries, both records for this Workshop series; 61 of the participants were women, continuing the trend toward gender equality. The sheer number of quality abstracts—226—necessitated a return to two parallel oral sessions, totalling 149 presentations. There were also 77 posters on wide-ranging topics, which were organized into two groups of 4 separate hour-long dedicated poster sessions. The workshop included the following session topics:

- Wave measurement
- Wave theory
- Wave modelling
- Wave forecasting
- Waves and sea ice
- Wave reanalysis
- Wave climatology

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- Wave trend analysis
- Wave climate change
- Wave design criteria
- Wave extreme value analysis
- Rogue waves
- Storm surge modelling
- Storm surge operational forecasting
- Storm surge hindcast
- Storm surge climatology
- Coastal waves
- Coastal hazards
- Coastal modelling
- Coastal forecasting
- Air-sea interaction

In addition to the topical sessions listed above, the workshop had four additional sessions. The opening session of the Workshop was a cross-cutting session dedicated to the memory of our esteemed late colleague, Dr. Vincent Cardone, reflecting the immense impact his work had on many of the topics covered during the Workshop. A second session was similarly dedicated to the late Dr. Mark Donelan, honoring his contributions to wave theory and air-sea interactions. A special session was also convened to showcase the work carried out under the World Meteorological Organization's Coastal Inundation Forecasting Demonstration Project (CIFDP, Swail et al. 2019b), and another to highlight the recent research initiatives in our host country of Australia. The full program including links to most of the 226 oral and poster presentations is available at http://waveworkshop.org/16thWaves/index.htm.

3 Summary of papers

Twelve papers relating to the workshop have been published in this topical collection. A brief summary of these papers follows.

Wave measurement remains a fundamental aspect of all wave-related research and applications, including model development and validation, forecasting and verification, satellite wave calibration and validation, and direct use in wave climate and design statistics.

In this collection, two papers relate to wave measurement evaluation, as contributions to the Data Buoy Cooperation Panel (https://www.ocean-ops.org/dbcp/) Pilot Project on Wave measurement Evaluation and Test. Jensen et al. (2021) examine wave buoy measurements from independent systems in terms of bulk parameters and frequency-spectrum shape. Relying on a multi-year deployment off the western US coast, the authors provide an important contribution to the wave gauge intercomparison literature, focusing on a suite of sensors mounted on a NOMAD hull, comparing them against each other as well as a nearby reference buoy deployed near Monterey, California. Integral wave parameters showed general agreement among the five sensors compared to the reference buoy, even for larger wave heights. The intercomparison demonstrated that NOMAD buoys are capable of measuring directional wave properties along the western US coast, with relatively low biases. Frequency spectral evaluations found similarities in the shape, but a significant underestimation in the high-frequency range. The results from slope analyses also revealed a positive bias in the rear face of the spectra, and a lack of invariance in frequency as suggested by theory.

Magnusson et al. (2021) make an inter-comparison between three wave sensors—radar, laser, and a Waverider buoy—based on measurements made at the Ekofisk platform in the North Sea. The results show that the radar underestimates wave spectral energy in frequency bands higher than 0.125 Hz (8-s waves) up to 4% and that higher underestimation occurs when the sensor is in the lee of the platform. Conversely, laser measurements show approximately 2% more energy than the Waverider in the most energetic bands, while the Waverider buoy has slightly more energy compared to both altimeters in the lower frequency bands, especially in the higher sea states. The authors provide support to growing evidence that the WaveRadar REX underestimates wave heights and highlight potential signal noise issues with the Optech laser. The insight provided on the quality of wave measurements using common platforms is of great importance for the validation of wave forecasting models, satellite wave calibration and validation, wave physics, offshore operations and design, and climate monitoring.

Hwang (2020) presents the results of an analysis of spectral slope using traditional ocean buoy data and ocean surface LPMSS (low-pass-filtered mean square slope from microwave sensor measurements), in order to better understand the behavior of short waves (in the centimeter to decameter wavelength range, cmDm). Using a year of standard buoy data along with extensive archived sets extending into tropical cyclone wind and wave regimes, efforts were made to quantify spectral coefficients of the equilibrium spectrum. It was determined the observed spectral slope common in the ocean is non-constant and indicative of the non-equilibrium nature of surface gravity waves. The results also deviate from constant values inferred from theoretical formulations. It was also determined surface slope quantification is critical to the determination of wave properties in the range of cmDm wavelengths.

End-user applications are also important and reflect the end-to-end scope of the workshop. Knowledge about the statistics of waves, in particular extreme waves, is required for the design and operation of offshore structures. Bitner-Gregersen et al. (2021) describe the challenges for the description of rogue-prone sea states using field measurements and for engineering applications. In particular, they note that wavefield data are affected not only by the accuracy of the instruments recording them but also by sampling variability, an uncertainty due to the limited number of observations, which may dominate over the nonlinear effects. Their study demonstrates, using numerical simulations, that in both unidirectional and directional wave fields, the different effects that sampling variability can have on estimators of nonlinear characteristics of the wave field, such as surface elevation, skewness, and kurtosis, when single 20- or 30-min wave field records are used in an analysis. Both single-point temporal and stereo-video camera data are discussed. They further note that rogue events have typically been recorded at single point locations by in situ measurements which lack information about frequency-directional wave spectra. Often wave spectral models may be the only source of 2-dimensional wave spectra, but some concern exists that the wave spectral models may provide spectra which are too wide compared to those derived from wave measurements. Improving the availability of directional measurements is essential for the description of rogue waves in the future and enhancing safety at sea.

With sea ice melting and Arctic waters opening more to shipping and offshore activities, the topic of waves in sea ice has garnered increased attention. Gemmrich et al. (2021) studied several years of surface wave observations in the Chukchi Sea, finding that wave groups are a common feature in open water and ice-covered conditions. The strength of the groupiness is well correlated with the characteristic wave steepness, the spectral bandwidth, and the Benjamin-Feir Index. The general finding is enhanced groupiness in ice. However, the trends with wave characteristics are opposite from ice to open water and suggest different mechanisms. In ice, groupiness increases with decreasing steepness, increasing bandwidth, and decreasing Benjamin-Feir Index. In open water, the trends indicate that both linear superposition of phase-coherent waves and nonlinear behaviour are important for the generation of wave groups. Directional wave measurements are required to effectively resolve the underlying processes.

Mentaschi et al. (2020) demonstrate how the predictive skill of a regular and an unstructured mesh in a global WAVEWATCH III model application can be improved using the Unresolved Obstacles Source Term (UOST). UOST parameterises the dissipative effects of unresolved features in ocean wave models, for example, subscale islands, cliffs, etc. The approach separates the dissipation from the energy advection scheme, which enables its application to any numerical scheme or mesh type. Satellite altimeter observations of H_s were used to assess the model accuracy. Improvements shown for the regular mesh model are in terms of both the spectral and integrated wave parameters and are attributed to better modulation of the energy dissipation with the wave direction. Large regions characterized by island complexes, such as the whole central-western Pacific Basin, experienced the greatest benefits. Mentaschi et al. (2020) found the skill of a 1.5° model that considers unresolved obstacles is better than that of a 0.4° model that neglects them, while also being ~14 times more computationally efficient. For unstructured mesh models, UOST is the first method available to remove the need for high-resolution meshes around small features. This enables much simpler meshes to now be generated for global applications and significantly reduces the computational demand for such large-scale simulations.

Pushkarev (2021) studied numerically the development of surface wave turbulence in a deep-water strait for constant wind, directed orthogonally to the shorelines. A very similar turbulence structure was previously observed experimentally; this paper presents a theoretical explanation of these results. It is shown that the associated limited fetch growth problem is a complex process, exhibiting multimodal spectra, which splits into various spatio-temporal sub-processes. The paper summarizes the evolution of the observed dynamics of the wave energy turbulence in straits from the initial process of waves excitation from white noise initial conditions, showing that the surface wave turbulence in the channel is divided asymptotically to self-similar wind-sea and quasi-monochromatic waves, radiated nearly perpendicular to the wind. The paper suggests that sharp changes in wind direction at some particular point in space and time creates a condition that is mathematically equivalent to the creation of an inhomogeneity similar to that in the presence of the shorelines. This implies that the effects similar to ones observed in straits could also be observed in the open ocean, which is confirmed by experimental observations from the Ekofisk platform, located about 320 km offshore in the North Sea.

Abdolali et al. (2021) investigate the Hurricane Weather Research and Forecasting (HWRF) atmospheric model and its related ensemble, in order to evaluate the uncertainty relating to hurricane tracks and intensity, and the subsequent errors in wave forecasts. The authors use Hurricane Irma as their test case, which was the first Category 5 hurricane of the 2017 season in the Atlantic basin. Two different methods of generating ensemble forcing fields for the WAVEWATCHIII model are used, one based on re-sampling of the HWRF ensemble surface wind fields, and one based on perturbations of the hurricane track details. Comparisons with in situ and remotely sensed observations of wind speed and significant wave height showed that both ensembles are able to capture the extreme values of the event. Furthermore, it was shown that the greatest uncertainty in the atmospheric fields was around the hurricane eye. This is in contrast to the wave fields, for which there is a decrease in uncertainty around the eye due to less variation of momentum transfer from the wind to wave model.

Investigating the performance of source terms implemented in the wave model WAVEWATCH III, Zieger et al. (2021) provide an analysis of atmospheric and wave model performance in hindcast simulations of 17 tropical cyclones northwest of Australia from 1996 to 2015, using stationary observations. Simulations are made by forcing the wave model with a synthetic wind field constructed from best-track information, with background fields from the ERA-Interim dataset on a high-resolution grid, over a multi-nested domain. Findings from this application study provide a significant contribution to the field of wave modeling under hurricane conditions. Results are important for providing guidelines for source-term selection for both academic and practical applications.

Wave climate trend and variability, both historical and for future projections, has long been a key theme of the workshop, particularly since the establishment of the Coordinated Ocean Waves Climate Project (COWCLIP, www.cowclip.org). De Leo et al. (2021) investigated future changes in wave climate in the Mediterranean Sea, within the framework of the regional projection task of the COWCLIP initiative. To this end, they used wave simulations driven by seven RCM over the 1970–2100 period under the RCP8.5 emission scenario. They performed trend analyses on time series of annual mean, annual 90th percentile, and annual maxima wave heights and periods, as well as wave directions based on the use of polar plots. The results for Hs and Tm were generally consistent with each other, indicating the robustness of the projected changes. Overall, they projected a progressive reduction in the magnitude of wave heights and periods in the Mediterranean Sea, in line with previous studies developed under the same emission scenario at a larger scale. Trends of annual maxima were more uncertain and irregularly distributed through the basin, suggesting that the annual maxima should be used with caution, as they could result in dispersed time series, and lead to unreliable estimations of future trends. A slight eastward trend is expected in wave direction, but such behavior was not homogeneous across the different sub-basins.

Law-Chune et al. (2021) described WAVERYS, a new wave reanalysis providing global 3-h integrated wave parameters with a spatial resolution of 1/5°covering the period 1993–2019, as part of the Copernicus Marine Service. WAVERYS uses version 4 of the MFWAM wave model, driven by ERA5 reanalysis winds, and includes assimilation of altimeter wave data and directional wave spectra provided by Sentinel-1. It also includes wave-current interactions by using 3-h surface current forcing provided by the ocean reanalysis GLORYS. WAVERYS has been validated by comparing with independent altimeter significant wave heights (SWH) and buoy wave data. For the open sea, WAVERYS performs globally with a scatter index of 8.8% with relatively low biases of about 3 cm; due to resolution, the system performs less well in shallow waters and in semi-enclosed seas, where the scatter index of SWH can reach 18%. Assimilation of directional wave spectra resulted in good accuracy of swell propagation, and the contribution of oceanic currents in current-dominated ocean areas such as the Agulhas Current, the North Brazilian Current, resulted in local SI improvements. The wave climatology of WAVERYS is in good agreement with the literature, including other studies on trends and percentiles.

Since the incorporation of storm surge topics into the workshop scope in 2013, there has been increasing content dealing with storm surge and its interactions with waves and coastal processes. Horsburgh et al. (2021) examine the importance of mid-latitude storm variability for coastal water levels. They argue that over the next few decades, natural variability of midlatitude storms is likely to be a more important driver of extreme sea levels than either mean sea level rise or climatically induced changes to storminess. They introduce the term ‘grey swan’ to mean an event which is expected on the grounds of natural variability but has not previously been observed. Six synthetic ‘grey swan’ events were created, based on physically realistic perturbations to the North Atlantic Storm Xaver in 2013 and guided by climatological variability. The storm surges in these synthetic events were found to be comparable to high-end projected mean sea level rises for the year 2100.

In summary, we had a very successful experience in the Southern Hemisphere in 2019. The 12 articles in this topical collection show the continued breadth of the Workshop, which serves as a valuable scientific forum for the end-to-end research to applications work being carried out in waves, storm surges and coastal hazards globally. We now look forward to the 3rd International Workshop on Waves, Storm Surges and Coastal Hazards, incorporating the 17th International Workshop on Wave Hindcasting and Forecasting, to be held, after a one-year delay due to COVID-19, from 23 to 28 October 2022 at the University of Notre Dame in South Bend, Indiana, USA.

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