OUTPUT FROM THE WISE 2013 MEETING

BY LUIGI CAVALERI

The WISE meeting (originally Waves in Shallow Environment, but now with a much wider scope) convenes yearly the world's wave modelers to frame the state of the art, identify the critical areas, and plan future work. The meeting is based on presentations and discussion, with no extensive written material before and after the meeting. The focus is on interaction, expanding interest for wind waves in the atmosphere–ocean system, and more generally on climate. The 2013 meeting was held at the National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Environmental Prediction (NCEP) premises in Maryland (United States), and it opened new perspectives in wave research, which are briefly discussed in the following subsections. Outside of this compact summary, the interested reader may consult the list of meeting presentations available online (www.ismar.cnr.it/outreach/meetings/Wise_2013) and contact the individual authors for further information.

WISE 2013

WHAT: Seventy wave modelers from 20 countries met to report on their latest modeling results and to discuss the state of the art of wave modeling as well as to indicate the main lines along which future research should be directed.
WHEN: 21–25 April 2013
WHERE: College Park, Maryland

NONLINEAR INTERACTIONS. The nonlinear wave–wave interactions (NL) continue to be the focus of much attention, both theoretically and for practical applications. For the latter the practical problem is the sheer computer power required for their evaluation, with newly gained computer power being used each time to increase model spatial resolution.

Following the improved performance of wave models and the consequent increasing need for a better evaluation of the nonlinear term, several attempts have been made to develop increasingly efficient methods, with an acceptable trade-off between efficiency and accuracy. The problem is that all such approaches [e.g., two-scale approximation (TSA), sorting resonant quadruplets, and multiple discrete interaction approximations (DIAs)] rely to a different degree on a more or less regular shape of the wave spectrum. Although a frequent reality, such a condition cannot be assumed in operational modeling, especially in the oceanic environment.

A push toward improved methods also comes from the need, supported by increased computer power, for higher spectral resolution, both in frequency and direction. The problem is that DIA was conceived for a well-defined resolution: 1.1 geometrical progression in the considered frequencies and 30° in direction. Any other combination would require specific calibration of the used coefficients, something that is regularly ignored.

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Within the realm of interactions between waves and the atmosphere, an interesting new approach considers the implication of wind generation on the NL. This seems to speed up some apparently second-order effects in NL, leading to the occasional growth of some components much faster than otherwise expected.

Relying on the well-defined theoretical definition of the NL, an attempt has been made to derive, from numerical experiments and measured data, the expression of the two other dominant source terms in NL: wind input and whitecapping. Considering the frequent "modulation" of these two terms, this could lead to an interesting verification.

GENERATION BY WIND. While generally considered well established in its theoretical approach, wind-wave generation is still subject to improvements. Recent experiments suggest that, independent of gustiness, an accelerating or decreasing wind leads within a single time step Δt to different wave growth than a constant wind in Δt.

In general, achieving the correct energy growth does not necessarily imply a proper momentum balance among the atmosphere, waves, and ocean. This is becoming crucial since most operational global models are moving toward full coupling. A keen analysis of the various source terms is required.

An ongoing problem is knowing with precision what happens to the sea surface in very strong winds. Recent numerical experiments suggest that the drag coefficient, after decreasing above 30 m s^{-1}, slowly increases again in winds above 65 m s^{-1}. If true, this could explain the observed bimodal distribution of the intensity of tropical cyclones.

DISSIPATION. At all time scales, whitecapping appears to be the key process for modulating fluxes (energy, heat, water vapor, gases, etc.) at the air–sea interface. Presently described only in statistical terms, its physical complexity requires more detailed attention and description in space and time. At large scales, however, a more detailed view is provided by the spectral density of breaking wave crests. When we isolate a single breaker, recent measurements repetitively suggest that just before breaking, the wave crest decreases its speed. Also, the scale of the relevant breakers is not well defined. Recent evidence suggests that microbreakers, which occur without foam, substantially stir the ocean's surface and, in so doing, contribute in a nonnegligible way to the heat exchange between atmosphere and ocean.

A remarkable improvement is expected given the possibility of remotely measuring the surface breakers. This can be done via radar, with single (sufficiently large) breakers appearing as signals on the screen. Alternatively, the use of two interferometric radar channels provides information about the surface turbulence conditions.

WAVE–CURRENT INTERACTIONS. This is presently an active area of research and application where some of the theoretical aspects are still a matter of debate for the correct balance (see the previous subsection "Generation by wind") of energy and momentum. Aside from the ideal case of a vertically uniform current, the general case of an arbitrary vertical profile must be approached via the Rayleigh equation. Because an exact analytical solution does not exist, the problem is solved via numerical or perturbation methods, possibly representing the vertical profile as a polynomial.

TOWARD SHALLOW WATERS. The old problem of a wave, or a spectrum of waves, passing above a submerged bar has been recently revisited to provide, if possible, a better expression for the ratio between the maximum wave height and depth. While it is clear that this ratio depends on the wave and bottom characteristics, it is interesting that no general formulation has been found, and the best results, on average, are still produced with the classical 0.73 value.

The general problem of nearshore wave dynamics has been tackled with a deterministic (phase resolving) potential flow model. It is based on the Zakharov equation, using a high-order finite difference scheme. Still one-dimensional, the application to a number of cases has shown very satisfactory results. The two-dimensional version is under development.

MEASUREMENTS. Reliable measurements, especially in the field, are the backbone of any validation, theory, or modeling in the open sea. New instruments, from laboratory conditions to satellite remote sensing, are still being conceived and developed. A promising slope-observing device, presently used only in laboratory conditions, is capable of operating in the infrared range and therefore also at night and is suitable for heat transfer studies. Also, sound records are being used to derive wave conditions in the nearby zone. Regarding remote sensing, the German Aerospace Center's Terra Synthetic Aperature Radar at X band (TerraSAR-X) polar-orbiting radar instruments will also operate in the polar regions, providing an unprecedented amount of data. The focus will be on both the large and local scales, the latter at the level of small icebergs.

A new technique has been proposed to derive the wave period from altimeter data. Unlike the conventional approach for determining wave period, this new method does not make any assumption on the wave spectrum. Instead, the approach is based on the contemporary measurement of wind speed and significant wave height (H_s) and the gradient of H_s along the ground track. However, the practical limitation is that the information is only one-dimensional, while the actual field is two-dimensional.

The accuracy reached by present meteorological and wave models requires correspondingly high-quality data in the field. This subject has not been given enough attention. A more precise assessment of the performance of the buoys in stormy and very stormy conditions is desperately needed, and suitable campaigns should be planned.

MODELING. Given the high-quality performance of current global models, possibly the most serious problem they (we) are now facing is the large volume of information coming in on different parameters and with large differences in scale, from the single breakwater to the global ocean, with which we have to deal. This is done either with nesting, possibly in multiple steps, or with a single unstructured grid. If the original (parent) grid covers a large area (e.g., the Pacific Ocean) and different results are required with different resolutions in different areas, it may be convenient to decentralize the local modeling activity. This has been done at NCEP to help different local authorities in each region of the United States set up a local modeling system with local responsibility and distribution, and with regular timely input from the large-scale model. The logistical and operational effort should not be underestimated, but the results and the overall efficiency fully justify it.

A different approach, in an advanced experimental stage, is to use a single relatively coarse grid, with its resolution locally increased, in space and time, according to needs. The obvious examples are hurricanes and typhoons. The computer time saved is more than an order of magnitude, and it grows with increasing maximum resolution.

Areas to work on and improve in the future are at two opposing scales. While performing well on average at the large scale, wave models often show deficiencies at the local scale or in special and unusual conditions. The frequent reason is that we still have some (limited) gray areas in our beautiful machines, spots carefully averaged out but sometimes popping up "out of balance." Physics and numerics can still be improved. The opposite scale for further action is climate. Wind waves are appearing more and more as the tuning knobs of all the (gas, matter, heat, energy, etc.) exchanges between ocean and atmosphere. All these processes are still heavily parameterized, and their detailed physics are still to be explored. This is our work for the next 10 or 20 years.