Navy oceanographers delve deeper in wave data to improve forecasts

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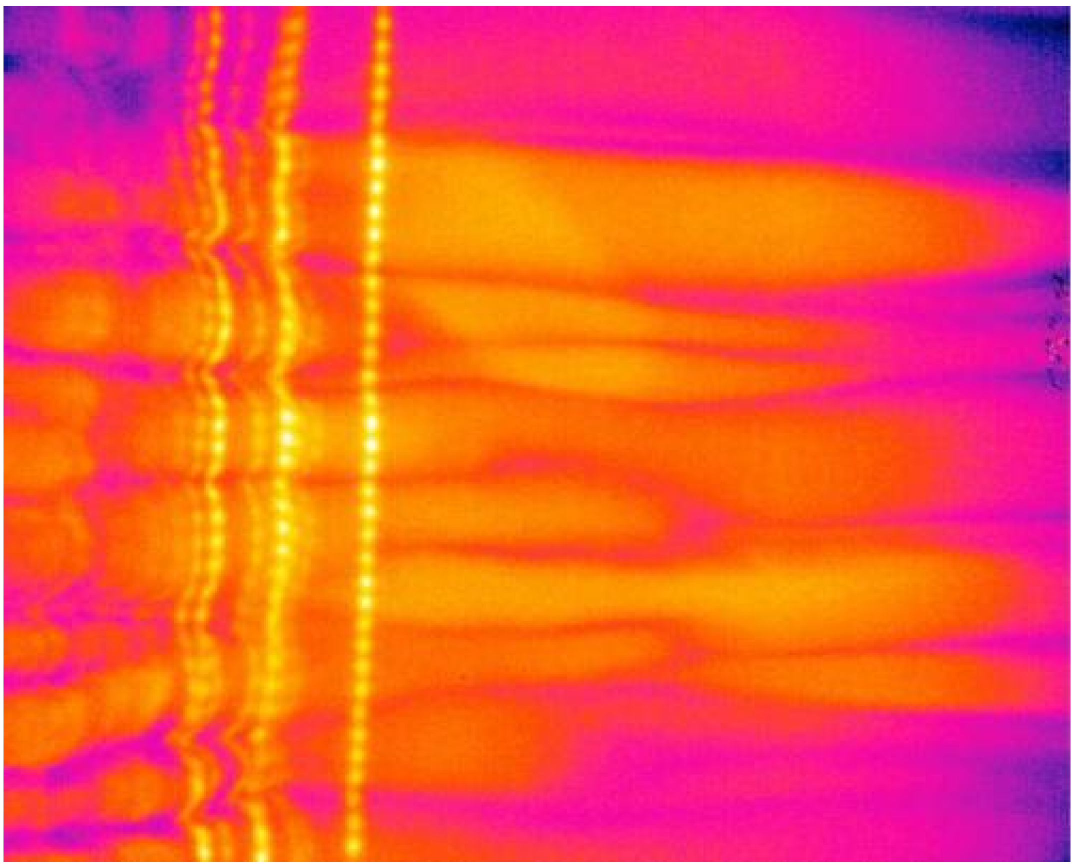

An example of a raw infrared image of the water surface with observed thermal streaks showing the effect of nonbreaking waves, propagating from right to left, on water in a wave tank. The straight vertical row of bright dotted lines are thermal markers, and the lighter horizontal streaks correspond to elongated, near-surface, eddies. Credit: U.S. Naval Research Laboratory

(Phys.org)—Around the globe, mariners and navies alike have long observed and included weather and sea states in navigational planning when plotting course or developing military strategy. And although forecasting had become an integral function by the start of the 20th century, these predictions were often crude and qualitative.

For the U.S. Navy, the years 1941 through 1946 provided an unusual stimulus to ocean wave research, according to pioneer World War II oceanographer Charles Bates. During this brief five-year period, theory, observation, and prediction of sea, swell, and surf made the greatest strides in their history.

As a result, the U.S. Navy has one of the most active and vital operational oceanography programs in the world. Naval oceanography provides critical information to such combat disciplines as anti-submarine warfare, mine warfare and countermeasures, naval special warfare, amphibious operations, and ship transit planning.

Today, U.S. Naval Research Laboratory physicists at the Remote Sensing Division continue to improve the integrity of these forecasts by developing a means to include the effects of the amorphous near-surface phenomenon of turbulence generation by nonbreaking waves.

"Current state-of-the-art ocean wave forecasting numerical models do not take this mechanism into account," says Dr. Ivan Savelyev. "This can potentially account for some forecasting errors and directly impact the Navy's ability to predict wave heights in oceans anywhere in the world."

Historically the parameterization of turbulence production in the upper ocean has primarily relied on the assumptions of wall turbulence, where the wind-generated surface friction velocity acts as a moving boundary. In the top few meters of the ocean another source term is added due to turbulence injection by breaking waves.

Currently there are a number of competing theories and hypotheses attempting to describe a third mechanism, which would account for energy flux from nonbreaking waves to the upper ocean turbulence. However, scarce empirical results struggle to establish the existence of such energy transfer and are not sufficient for thorough validation of existing theories. The variety of approaches is caused, perhaps, both by the complexity of the problem and by the lack of detailed experimental data.

Research being conducted at NRL investigates both experimental and numerical approaches. Turbulent velocities at the water surface were measured in a laboratory wave tank with high precision using the thermal-marking velocimetry technique. Numerically, a fully nonlinear model for the wave motion was coupled with Large Eddy Simulation for the turbulent motion.

Both numerical and laboratory results confirm the turbulence production due to wave motion and the turbulent kinetic energy was found to be a function of time, wave steepness, wave phase, and initial turbulent conditions. Additionally, turbulent motion near the surface was found to be horizontally anisotropic due to the formation of near-surface eddies, elongated in the direction of wave propagation.

"The mechanism responsible for the observed production of turbulence appears to be the result of interaction between pre-existing turbulence and wave motion," says Savelyev. "More specifically, the horizontal shear, associated with wave-induced Stokes drift, stretches and intensifies existing vortices, giving rise to 'streaky' turbulent patterns we observed at the water's surface."

Unlike present wave dissipation formulations, which primarily rely on wave spectrum information, this new mechanism reveals a function of existing turbulence in the upper ocean. This imposes a feedback requirement between ocean circulation and surface wave models and further reveals the added need to couple atmosphere-wave-ocean dynamics within a joint forecasting system.

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