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A shipboard monitoring system is giving researchers much-needed measurements of Antarctic wind, waves and ice

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The Southern Ocean is "the engine room" for the world's climate and weather system. Across its large expanses of uninterrupted water, winds pick up speed and waves gather energy.

Strong winds and large waves fuel the exchange of heat and gas—including carbon dioxide—between the air and sea. As a result, the Southern Ocean has the capacity to store and release more heat than anywhere else on Earth.

These processes change throughout the year, as wind speeds and water temperatures fluctuate. They are also influenced by the seasonal ice cycle, in which sea ice melts in austral (southern hemisphere) spring and summer and regrows in autumn and winter.

The best place to study these interactions in the Southern Ocean is the marginal ice zone, where the open ocean meets areas of free-floating sea ice. However, direct observations in this zone are sparse and unreliable, and satellite-based remote sensing does not provide consistent data at high detail and over short time intervals.

The chronic lack of observations for the Southern Ocean limits our ability to detect critical changes in this region and assess their causes and effects. It also hinders the development of Earth system models, which rely on accurate observations for predicting future climate.

To solve this lack of data, our team of ocean engineers at the University of Melbourne is working with Australian and international researchers to develop an autonomous, multi-camera monitoring system for measuring different properties of the ocean surface, including waves and sea ice, from a moving vessel.

The monitoring system uses off-the-shelf equipment fitted onto icebreaking ships, that routinely travel to the Antarctic for research and to resupply research stations. As these ships cross the marginal ice zone, they provide an opportunity for researchers to regularly observe this inhospitable environment safely from afar.

The equipment includes a stereo camera system that takes two pictures of the same area from slightly different vantage points, which are then resolved to create a 3D image—like human binocular vision.

It also includes an infrared camera that records information about the thermal properties of the ocean surface and sea ice. An inertial measurement unit detects the ship's motion, so it can be removed from the resulting data.

We use an automatic algorithm to analyze the images, which calculates the direction, length and height of waves, and the size and distribution of sea ice sheets. In this way, we can take measurements at resolutions that are not possible using other remote sensing technology.

And because the equipment is installed close to the ocean surface, it is not subject to the cloud cover that can obscure satellite images.

A prototype of the monitoring system was deployed on the South African icebreaker SA Agulhas II on several winter and spring voyages in 2017 and 2019.

On one trip, the ship traveled through a polar cyclone, providing a close-up view of the wave-ice interactions at maximum intensity.

This revealed that the sea state deep in the marginal ice zone during a cyclone is more complex than previously thought. This is in an area where the water is completely covered by small floes of pancake ice and a loose, slushy mix of ice crystals called frazil ice.

Here, we found intensive wave motion, with waves as tall as 9 meters. This was unexpected as current knowledge suggests that the amount of ice cover should suppress such wave motion almost instantly.

This indicates that waves have a significant role in shaping the properties and extent of sea ice cover.

Thermal images in winter and spring provided a new perspective of the sea ice state. Even hundreds of kilometers into the marginal ice zone, the ocean surface is a blend of open water and several types of sea ice, which are formed through a continuous cycle of freezing and melting. A study on this is published in *Earth and Space Science*.

The concentration and type of ice affect the temperature at the ocean's surface, which in turn affects the heat exchange between the ocean and the atmosphere.

Our team is now designing an even more comprehensive monitoring system in collaboration with the Australian Antarctic Division, CSIRO and national and international partners as part of an Australian Research Council Linkage Infrastructure, Equipment and Facilities (LIEF) project.

In addition to stereo and infrared cameras, the new system has a bow camera for taking pictures of the ice as it's broken up by the ship's progress—letting us calculate the ice thickness.

We'll also add cameras that record in the near-infrared range, so we can study what's on the ice surface, like snow, water and even organic matter like algae.

Anything that covers the ice can affect how much solar radiation is absorbed or reflected, so these substances have an important role in the heat exchange between the ocean and atmosphere, which contributes to the Earth's weather and climate.

The monitoring system will also be integrated with the ship's meteorological station, providing data on wind, humidity and other basic atmospheric parameters.

The new system will be installed in December on the new Australian icebreaker RSV Nuyina to monitor the Southern Ocean and marginal ice zone during its resupply expeditions.

Occasionally, part of the equipment will be moved to the RV Investigator, CSIRO's research vessel, to monitor sections of the Pacific and Indian oceans in the lower latitudes.

We will build a comprehensive database of wave and sea ice properties in the Southern Ocean, which will be integrated with other atmospheric data.

This much-needed resource will be crucial not only for validating data from satellite-based remote sensing but also for advancing climate model capabilities so we can better understand future climate change scenarios.

More information: Ippolita Tersigni et al, High-Resolution Thermal Imaging in the Antarctic Marginal Ice Zone: Skin Temperature Heterogeneity and Effects on Heat Fluxes, *Earth and Space Science* (2023). DOI: 10.1029/2023EA003078

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