Understanding

The research team prepares for the Southern Ocean Experiment.

winds and waves

Accurate marine forecasting is central to the success of our endeavours at sea. Improved forecasts are set to flow from the Southern Ocean Waves Experiment, writes Bryony Bennett.

Ocean waves may be quiet ripples lapping the sands of bayside beaches, or rearing monsters that turn ocean yacht races into outsized surf regattas. Either way, they graphically reflect the prevailing atmospheric conditions.

Assessing wave heights at the local beach may help us decide whether or not it's safe to launch the surfboard, catamaran or dinghy. Marine predictions made by meteorologists and oceanographers, however, can be vital to the safety and efficiency of Australia's marine industry, estimated to be worth $16 billion annually.

More accurate marine forecasting, particularly in relation to storm conditions, is set to flow from field observations performed two years ago off Tasmania's south-west coast. These were part of the Southern Ocean Waves Experiment (SOWEX), a joint project between CSIRO, the University of New South Wales and the National Aeronautics and Space Administration (NASA) of the United States.

Analysis of the data collected during the experiment has helped scientists to understand in detail how the wind generates surface waves. This re-assessment of the wind/wave relationship (represented as a numerical formula in computer models used in marine forecasting) relates not only to waves, but to the prediction of near-surface currents, according to Dr Chris Fandry from the CSIRO Division of Oceanography.

'We know that there's a strong correlation between the wind and the ocean currents (especially near the surface), but the exact process by which winds drive currents is still uncertain,' Fandry says.

'It's probably a result of breaking waves. As waves steepen and break, the energy is transferred to the water column, causing currents. The physics of these processes is very complicated, but we need to understand them so that we can derive the mathematical equations which are the basis of wave and current prediction models.'

The new information collected in this project is expected to significantly improve regional marine forecasts and high seas warnings provided by private companies and organisations such as the Australian Bureau of Meteorology. These regular forecasts are relied upon by shipping, fishing and offshore oil and mining industries, and by recreational sailors, surfers and anglers.

Understanding the aerodynamic drag of the sea surface is of primary importance in climate and marine forecasting and in coastal engineering, yet its relationship to the wind is still not well understood, Fandry says.

Most people know of aerodynamic drag in the context of car design. The concept is similar over the sea. The wind will be slowed down when the sea is rough. The difference between cars and the sea, though, is that the wind actually creates the roughness at the sea surface. ⇨

Gas platform breezes through Cyclone Orson

In 1989 Australia's strongest recorded cyclone passed directly over Woodside Petroleum's North Rankin gas production platform. The platform sustained no major damage; it was designed to safely withstand the '100-year return period storm', and Cyclone Orson came close to this event.

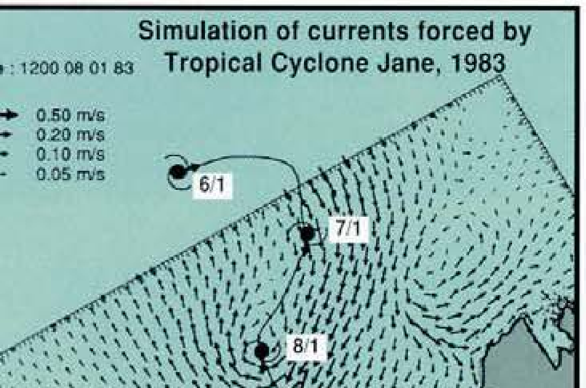
In designing the platform, Woodside's engineers had taken into account predictions of the strongest cyclone ever likely to occur in the North-West Shelf region. Scientists had advised that the platform should be built to withstand the combined force caused by surface currents of about two metres a second, and the 100-year maximum single wave height. These predicted conditions comprise what is known as the 'design value'.

The currents generated by Cyclone Orson's 280-kilometre-an-hour winds and 17-metre waves, however, were measured at less than the design value that projected for North Rankin.

Design values result from predictions based on knowledge of past climatic events in the area; of interactions between the atmosphere and sea; and of the forces generated by these interactions. Their level of accuracy is uncertain, and as a result, offshore platforms are designed to withstand forces stronger than they will encounter.

The total force exerted on a structure in the ocean is a combination of the wave and storm-current loadings. Accordingly, any work that improves storm current estimates will lessen the cost of marine structures.

Woodside Petroleum's North Rankin gas production platform: designed to safely withstand the '100-year return period storm'.



A technique called hindcasting is used to predict the severity of waves and currents caused by cyclones. Historical records and climatic and oceanographic models are used to predict the biggest storm likely to happen. (ms = metres per second)

Most existing models assume that there is a simple relationship between surface (up to 10 metres) wind speed and wind force, which is a major factor driving the ocean currents. But this does not account for the existence of surface roughness (or waves).

Fandry says the reliability of sea state forecasts and surface current predictions, particularly for very strong wind forcing and high sea states, will significantly improve when the portioning of wind energy transmitted to the waves and the surface currents is better known.

Information about wave and current behaviour during events such as tropical cyclones is central to the efficient design of offshore oil and gas production platforms.

'We develop models here that predict the currents associated with cyclones in different parts of the world,' Fandry says. 'It's the storm-driven currents and waves that the design engineers are most interested in because they produce the biggest currents and waves.'

An offshore platform designed to last at least 50 years must be strong enough to withstand any storm that's likely to occur in at least that time-frame. For example, the design of the new Woodside Offshore Petroleum platform at the Goodwyn location recently sited off Australia's North-West Shelf is critically dependent on knowledge of ocean waves and currents that are likely to be caused by tropical cyclones.

The scientists employ a technique called hindcasting to make the necessary predictions. Historical records of atmospheric conditions in the region are used to estimate the biggest storm likely to happen. This information is combined with what is known of the physical relationships between sea-state, winds and currents to predict their behaviour in a 'worst case scenario'.

It is suspected, however, that these predictions often lead to uncertainty about the severity of likely waves and near-surface currents (see box story). This can lead to engineering 'overdesign', at great cost to the petroleum company.

'What (the predictive models) they're using at the moment is by no means accurate,' Fandry says. 'When we finish analysing and understand the SOWEX air/sea interaction project results, we'll see a dramatic improvement in the forecasting of near-surface currents.'

Petroleum companies are not the sole beneficiaries of improved wave and current predictions. The forecasts will improve general ocean weather forecasting methods and are also necessary to chart the safest and most fuel-efficient course for ships (see box story); to safely rescue boats and people; to make oil-spill trajectory studies; and to enhance predictions of global climate variability.

Storms in the ocean

Central to the success of the Southern Ocean Waves Experiment has been the choice of the Southern Ocean as a base for the field measurements.

Scientists often call the Southern Ocean a 'natural laboratory'. Much of it is covered by big waves (the biggest in the world) driven by westerly winds called the 'roaring forties' and 'furious fifties'. Storms are also common. Experimenting in these conditions is the next best thing to taking meteorological measurements in tropical cyclones.

CSIRO's Fokker F-27 research aircraft, specially instrumented to measure winds, waves and atmospheric conditions, flew eight missions from Hobart airport to selected locations off Tasmania's west coast. Each flight leg was up to 100 kilometres long to minimise the risk of statistical uncertainty. While some flights were at 200 m and 800 m, a number of low-level runs were made at altitudes below 60 m, depending on sea state.

It is difficult and dangerous to take measurements during storm conditions, Fandry says. People have designed experiments to get measurements in tropical cyclone conditions, but have met with equipment failure. But this time – although the Southern Ocean performed true to character – all went well for the scientists.

'We flew as low as 20 m over 10 m waves,' Fandry says. It was like driving a car in first gear. The plane was shaking and roaring like hell!'

Dr Ed Walsh from NASA was in charge of the sophisticated, remote-sensing equipment on the aircraft. This was used to measure surface roughness. He too was impressed with the performance of the Southern Ocean.

'We found the biggest waves I've ever seen in my life,' Walsh says . 'I came here hoping to find six metre waves and I got eight metre waves, and I got them on two occasions. I hoped for 30 or 40 knot winds and I got 50 knot winds.'

Walsh and Fandry agree that the range of ocean conditions during the experiment was ideal. This enhanced the quality and amount of data collected. Results of the initial data analysis have confirmed their belief that understanding the influence of surface waves is critical in determining how the wind drives the currents.

Wind, wave and atmospheric monitoring instruments are fitted to CSIRO's Fokker F-27 research aircraft in readiness for the Southern Ocean Waves Experiment.

Wave models in action

Wave and current predictions are the basis of big business for international marine weather forecasting company Oceanroutes and its Australian consulting arm Steedman Science and Engineering.

Oceanroutes, from its offices in Europe, the United States, Asia, Australia and the Middle East, provides about 1200 route recommendations a month to more than 700 shipping firms worldwide.

The term 'ship-routing' describes the technique of planning and guiding vessels on transocean voyages using the principles of meteorology, oceanography, naval architecture, shipping, economics and navigation.

Oceanroutes provides the ship's master with a route recommendation supported by a weather forecast before departure. The recommendation aims to provide the most economic and safe passage for the ship in light of weather and sea conditions and is reviewed and modified as necessary throughout the voyage.

The environmental factors used in preparing a route recommendation include atmospheric pressure patterns and storm paths; winds, sea, swell and currents; hurricanes, tropical storms and typhoons; localised and seasonal weather; sea ice, icebergs and structural ice; and air/sea temperature. Details of the vessel and its cargo and are also considered.

Weather forecasts made by Oceanroutes for ship routing are based on models for forecasting winds and waves around the globe. Detailed, local forecasts for offshore oil operations are also prepared by the company. These are based on widespread meteorological observations, satellite imagery, global numerical model information (including wave models), upper atmospheric level analysis and prognosis charts from various sources.

Steedman Science and Engineering specialises in the setting of extreme storm design criteria. This information is used the offshore oil and gas industry to design offshore structures and marine pipelines. Steedmans also undertakes meteorological and oceanographic measurement services.

Managing director of Steedmans, Richard Timms, says ocean circulation models from CSIRO's Division of Oceanography have been used on about 20 oil and gas development projects on the North West Shelf of Australia in the past 10 years. He says CSIRO involvement also helped the company to win an internationally-contested contract for an oceanographic study of the South China Sea.

More about winds and waves

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