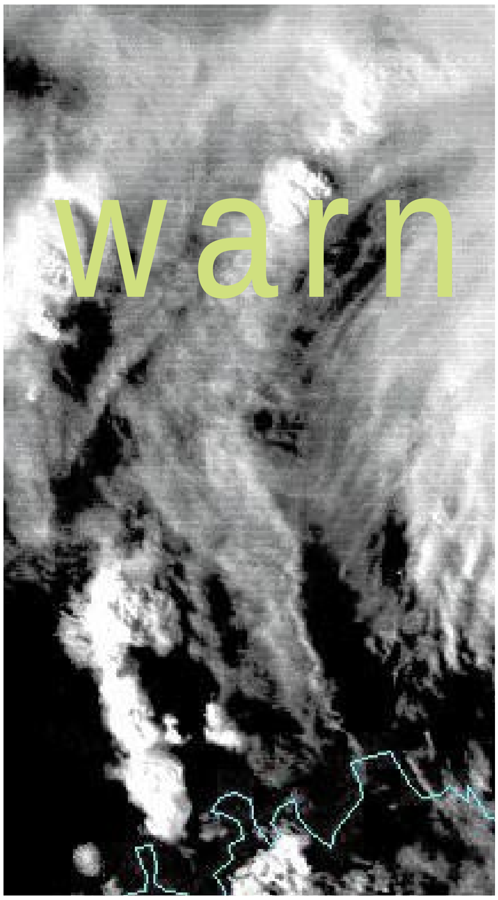
Cyclone warn



Graeme O'Neill outlines efforts to predict the effects of global warming on extreme weather events.

Last December, a powerful tropical cyclone hovered in the Arafura Sea north of Darwin. Cyclone Thelma, one of the few Category 5 cyclones recorded in Australia, with wind speeds exceeding 300 kilometres an hour, threatened the Northern Territory capital, which has been devastated by cyclones three times in its history: in 1878, 1882 and 1974.

Tropical cyclones, typhoons or hurricanes, are the most destructive of all weather phenomena. In March of this year, cyclone Vance devastated the town of Exmouth, Western Australia, producing wind gusts of up to 267 km / hr, the highest ever recorded on mainland Australia.

Cyclone Tracy, which struck Darwin on Christmas Eve, 1974, killed 66 people and left a damage bill estimated at $400 million, making it the worst natural disaster in Australia's history. In January the same year, torrential rains from Cyclone Wanda flooded 7000 homes in Brisbane and Ipswich, causing some $200 million damage.

Such figures pale against the $US27 billion insurance bill for Hurricane Andrew, which devastated southern Miami as it crossed the Florida peninsula in 1992.

Governments, industry, natural disaster organisations, insurance companies, and population centres in cyclone-prone regions are concerned at the possibility that cyclones may become more frequent and severe next century due to global warming.

In Australia, higher sea-surface temperatures could also bring cyclones further south. Cyclones breed where sea-surface temperatures (SSTs) exceed 27°C, in latitudes where the Coriolis effect from the Earth's rotation is strong enough to spin up a large, rising mass of warm humid air.

But until climate models can reproduce realistic cyclones, researchers cannot assess these threats.

Dr Kevin Walsh, of the Climate Impacts Group at CSIRO Atmospheric Research, says cyclones fall through the coarse mesh of global climate models (GCMs), which are a few hundred kilometres along each side (this varies from model to model).

The division's own CSIRO Mk II GCM can generate swirling low-pressure systems with some of the characteristics of cyclones, but lacks the resolution to reproduce the tight circulation and extreme winds of a real-world cyclone.

To enable a more detailed picture, Walsh is 'nesting' a higher-resolution, regional-scale climate model inside a section of the CSIRO Mk II GCM. The regional model, DARLAM, (Division of Atmospheric Research Limited Area Model) has been used to simulate a region of the Queensland coast and adjacent ocean.

Walsh has used DARLAM to study the effect on cyclone activity of a doubling of atmospheric carbon dioxide.

'Our most important conclusion is that cyclone tracks appear to be moving slightly further south, although we don't yet have the confidence in our model to say how far,' Walsh says. 'Sea-surface temperatures appear to be the key variable, but it could also be that climate-induced changes in wind fields in a doubled carbon dioxide regime are pushing the cyclones around.'

The key to improving the model's reliability lies in increasing the number of horizontal 'layers' it contains, both above and below the ocean surface.

Walsh says to simulate the vortex of a big cyclone, the lower atmosphere must be

Bureau of Meteorology

The devastation caused by Cyclone Tracy. Regional modelling indicates that cyclone tracks may move further south in response to a doubling of atmospheric carbon dioxide.

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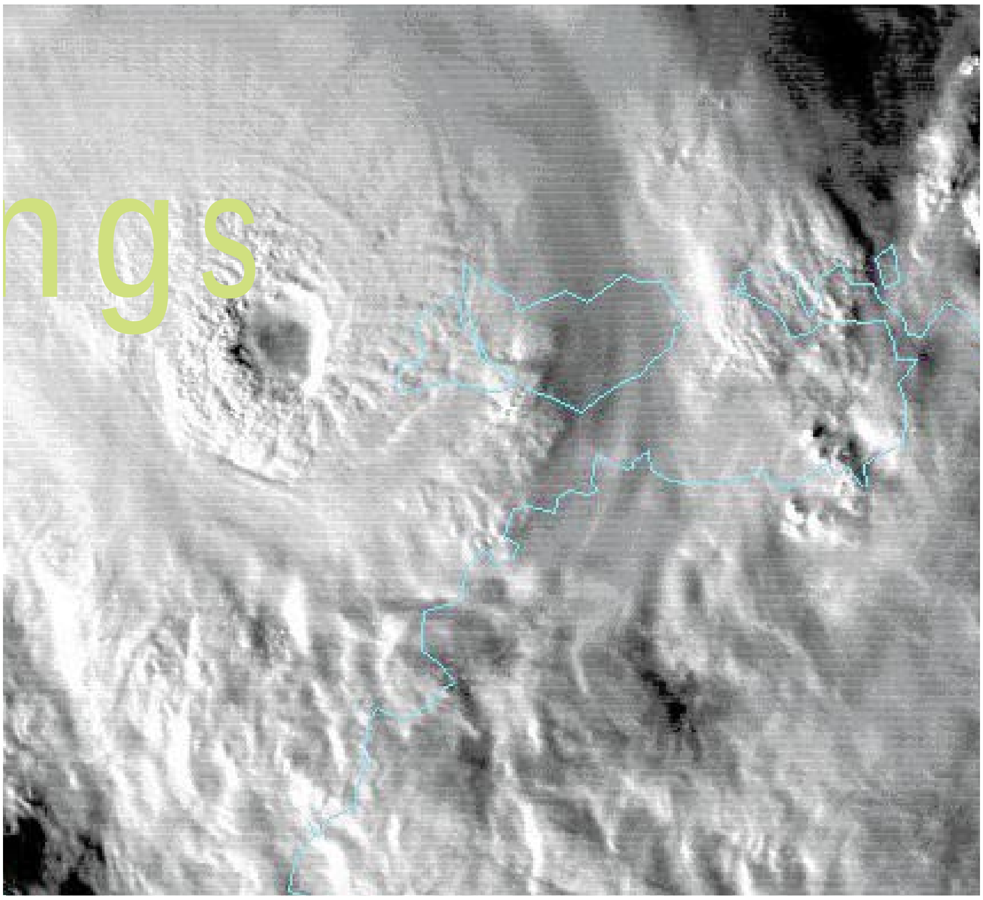

Cyclone Thelma formed about 300 km north of Darwin and caused severe damage in the Tiwi Islands before crossing the coast nine days later in the west Kimberley-Pilbara region, where it caused torrential rains before dissipating. (Satellite image courtesy of the Bureau of Meteorology.)

'sliced' as thinly as possible. He says the vortex may reach from the sea surface into the upper troposphere 15 km above, but wind speeds are highest close to the surface and drop off sharply in the lower atmosphere.

It is also important to simulate the upper layers of the ocean accurately, because beneath a cyclone, seawater becomes cooler and denser. High winds cool the sea surface through evaporation, and mix cooler water from depth with the warmer surface layers.

Satellite thermal images of the sea surface show cooler, mixed waters trailing in the wake of cyclones. But the current version of DARLAM contains only 18 layers, and depicts the ocean surface as a single layer at a uniform temperature. This is because the capacity to simulate 'layers' of the ocean has not yet been built into DARLAM.

Walsh has also used DARLAM to study tropical cyclone intensity. Here, instead of allowing the model to evolve spontaneously, he drops cyclones into it, by 'tweaking' the initial conditions.

Under doubled carbon dioxide conditions, the model produces cyclones with a modest but significant increase in windspeed. But again, confidence in this result is only moderate. Despite frequent media coverage of destructive cyclones, typhoons and hurricanes, climatologists have yet to detect a significant global trend in the frequency or intensity of cyclones. Cyclones are more destructive today simply because there are more people in the world, and more property at risk.

Walsh says further, incremental experiments will improve confidence in the models, but the big improvements will come from increases in computer power. Models will require a horizontal resolution of about 5 km, and many more layers in the vertical dimension, to simulate the most important processes in cyclones.

But an inadequate understanding of the physics of cyclones remains the biggest obstacle to progress. Scientists have yet to develop a useful theory for the formation of a cyclone's eye. That understanding is likely to emerge from a synthesis of theory, real-world observations and computer models.

Walsh recently began analysing Australia's long-term climatic record for evidence that sea-surface temperatures and rainfall across the continent modulate the frequency of tropical cyclones over decadal timescales.

Such a relationship has been established for hurricanes in the Atlantic, and Walsh believes the same will be true of the Pacific, with the El Niño-Southern Oscillation phenomenon playing a dominant role. If climate models reproduce the same decadal variability in cyclone frequency, it would increase confidence in their reliability.

Predicting flooding rains

Cyclonic storm surge is the nemesis of communities around Australia's northern coastline, particularly in low-lying areas subject to large-amplitude tides, such as Onslow and Port Hedland.

The extremely low central pressures of cyclones cause the sea surface to bulge upwards, amplifying the height of the large waves already generated by extreme winds. Even a moderate, 970 hectopascal cyclone, combined with strong onshore winds, can raise sea level at its centre by a metre.

Coastal landforms and topography can magnify storm surge; water tends to mount up inside bays and estuaries. And if cyclones coincide with 'king tides' at certain phases of the Moon, or with coastal flooding, the storm-surge hazard may be extreme.

In 1899, southwesterly winds from Cyclone Mahina generated a 15 m storm surge in Bathurst Bay in far north Queensland, sinking the 55-boat pearling fleet and drowning 300 people, the highest death toll in any Australian natural disaster.

On January 20, 1918, coastal rivers between Mackay and Rockhampton flooded as an intense cyclone approached the coast. As the cyclone made landfall near Mackay, it raised huge waves that met the outrushing floodwaters of Mackay's Pioneer River. The resulting 3.6 m storm surge inundated the town centre, drowning 30 people.

But storm surge is not just a phenomenon of the tropics, nor is it only associated with cyclones, according to Dr Kathy McInnes of the Climate Impacts Group at CSIRO Atmospheric Research. Under certain conditions, severe storm surge episodes can occur along Australia's southern and south-eastern coastlines.

McInnes says that in 1934, runoff from intense storms in the Melbourne region, combined with a swell generated by an intense low-pressure system in Bass Strait, caused severe flooding around Port Phillip Bay. In 1997, huge seas and torrential rainfall from an intense low-pressure system caused severe flooding in Sydney.

Australian port authorities, environment protection agencies, city councils and water authorities are funding McInnes' research into storm surge. They are concerned that rising sea levels and extreme weather associated with global warming next century could cause destructive episodes of storm surge and flooding around Australia's coastline – including major ports.

McInnes is using a model developed by colleague Dr Graeme Hubbert to predict the extent and magnitude of storm surge under different combinations of wind direction, sea-floor bathymetry, topography and tide height. The model will be used to predict storm surge hazards for both tropical and temperate coastal towns and cities.

Cairns, which has been devastated by cyclones six times in the past 130 years, is at particular risk. The CSIRO model shows that a cyclone approaching from the north-east would not only flood the city centre and surrounding suburbs, it would sever the Bruce Highway, the main evacuation route to the south.

McInnes says the factors that generate storm surges in temperate latitudes are more subtle.

Low-pressure systems are broader and less intense than tropical cyclones, but they can also cause sea level to bulge upwards by a few centimetres, amplifying the height of onshore waves. Winds associated with cold fronts moving from west to east, parallel to Australia's southern coastline, can entrain strong coastal currents that are then deflected leftwards against the coast by the Coriolis effect, the twisting force arising from the Earth's rotation. (The Coriolis effect increases in a polewards direction.)

Like cyclones, cold fronts and low-pressure systems can spawn intense storms that cause flooding in coastal regions; floodwaters flowing into the ocean can amplify the height of waves already raised by the deflected ocean currents.

Coastal bathymetry is also important. Along the Victorian and South Australian coastlines, the continental shelf is wide and gently sloping. The long 'fetch', and the tendency of waves to slow and mound up as they interact with the shallow sea floor, further amplifies their height at the coast.

Off Sydney and Brisbane, the continental shelf is narrower and steeper, and not as conducive to storm surge, but McInnes says the effect of regional windfields on wave set-up can still cause elevated coastal seas.

Similar wave set-up effects have caused severe beach erosion on the Gold Coast during major storms or cyclones.

McInnes says lack of historic data on storm surges complicates efforts to model the risk in some regions, but aerial photography is a useful tool for determining the spatial extent of flooding.

By overlaying aerial photographs on contour maps, she and Graeme Hubbert were able to model a severe episode of storm surge associated with a tropical cyclone that struck Port Hedland, in Western Australia, in 1939. In the model run, the entire area flooded, supporting the anecdotal evidence of a line etched in wood inside a local hotel that sea level rose 5.7 m. The model calculated a 5.4 m rise, but did not take into account the effects of wave setup.

McInnes says flood disaster coordinators use calm water levels as a baseline. If a 5 m storm surge is predicted, they assume that the surge will reach the 5 m contour line on adjacent land. But storm surges are dynamic events: water levels can rise even higher if winds are coming from a particular quarter, while opposing winds can actually reduce storm surge.

Because cyclones are such compact systems, wind directions change rapidly, particularly around the eye.

McInnes says that with the prospect of global warming next century, policy makers and planners need reliable predictions about how climate change may affect the frequency and intensity of storm surge events.

With Dr Kevin Walsh, she is analysing regional climatic data to determine the strength and frequency of cyclones, cold fronts on the southern coastline, and the east coast lows that affect the New South Wales south coast and Sydney. Their influence can sometimes reach as far north as Brisbane. They will determine how often events of a particular intensity occur, and then select events representing 10-year, 100-year and 1000-year storms, to drive the storm-surge model.

Probability theory predicts that, in a warmer world, history's extreme events will be brought into the range of normality. Today's 100-year storm, for example, may occur every 50 years, and today's 1000-year storm is likely to occur at least once every several centuries.

From the baseline of historic and recent data, CSIRO researchers will be able to project forward and model the storm surge likely to generated by next century's Category 5 cyclones and superstorms, and give planners fair warning.

The Cairns Post

The CSIRO model shows that Cairns is at particular risk from cyclonic storm surge. This flooding and subsequent crop damage was caused by Cyclone Rona which battered far north Queensland in February this year, forcing the evacuation of 1800 people.

Abstract: Predicting the effects of a doubling of carbon dioxide in the atmosphere is an important part of CSIRO investigations into the impacts of climate change. Habitats and food supplies of Australia's rare, rainforest marsupials are likely to be threatened, and the ecological balance of grasslands in the arid and semi-arid interior upset. Improvements in the resolution and of climate models are enabling extreme weather events such as storms, cyclones and cyclonic storm surge to be more accurately simulated. The aim is to give planners fair warning of next century's Category 5 cyclones and superstorms. A lag effect in the global climate system, caused by temperature gradient across the Southern Ocean, means climate patterns will continue to vary even after greenhouse gas concentrations stabilise.

Keywords: climate change; climate modelling; greenhouse effect; carbon dioxide; greenhouse gases; global warming; Global Climate Model; El Niño-Southern Oscillation; possums; marsupials; tropical cyclones; storm surges; coral reefs; grasslands; grasses.