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#267: Counting the coast: Modeling the oceans of a warming planet

VOICEOVER
Welcome to Up Close, the research, opinion and analysis podcast from the University of Melbourne, Australia.

SHANE HUNTINGTON
I'm Dr Shane Huntington, thanks for joining us. As land dwelling mammals it's very easy for us to forget that 70 per cent of our planet's surface is water. The oceans and seas that ebb and flow on our shores, including near our cities, are constantly changing. Their behaviour is intimately connected to the land masses they touch and the atmospheric conditions above them. The oceans regularly remind us about their power and variability. We have seen mighty storm surges caused by those shifting atmospheric conditions over the planet's oceans. The devastation wrought by Hurricane Katrina on the city of New Orleans in 2005 is hard to forget. Now we must add to the experience of these extreme weather events the prospect of rising sea levels, induced by increasing global temperatures. So how do we predict storm surges and the coastal damage that these events can cause? As the climate changes how will these potential threats also change? Do we have the scientific capacity to make meaningful predictions at all given the daunting complexity of our oceans and the climate systems that influence them? Today on Up Close we speak to Dr Kathleen McInnes, a climate modeller who is trying to answer these questions. Kathy is a research scientist with the Marine and Atmospheric Research Division of the Commonwealth Scientific and Industrial Research Organisation, CSIRO. Welcome to Up Close Kathy.

KATHLEEN MCINNES
Thank you very much.

SHANE HUNTINGTON
You work on understanding severe storms and their effects on coastlines, what actually constitutes a severe storm?

KATHLEEN MCINNES In terms of the coastal impacts a severe storm is one in which the winds and atmospheric pressure falls are significant enough that they can elevate sea levels along the coast. There are two effects in terms of the increase in

sea levels. One is the storm surge effect, and that is the fall in atmospheric pressure which in effect draws up the ocean surface at a rate of about a centimetre per hectare Pascal fall in pressure. But the other is the wind, which exerts a stress on the ocean surface and pushes the water up against the coast. Those two components are the storm surge. But in addition to that, of course, winds also generate waves and those waves impact the coast and they can further enhance the increase in sea levels that we experience, referred to as wave setup and wave runup, which is that uprush of water as a wave breaks and runs up the coast.

SHANE HUNTINGTON
Are they all of one category or are there a variety? I mean we use the terms hurricane and cyclone interchangeably but are there different types of storms in these cases?

KATHLEEN MCINNES
There most certainly are different types of storms. I mean in the tropics as you referred to, different tropical ocean basins, we have hurricanes, tropical cyclones as we call them in Australia and typhoons as they are in Asia. But in the mid-latitude, so away from the tropical band, we also have other types of storms. They can be extratropical cyclones. Even on the South Coast of Australia the movement of a cold front along the South Coast generates storm surges.

SHANE HUNTINGTON
These storms, they're out to sea, they come in, they hit the coast line. What kind of effects do they have when they actually impact the coast line? What things are happening at that point?

KATHLEEN MCINNES
Well, in addition to the wind and pressure effects they can also be raining a lot. So in addition to getting high coastal water levels you can also be getting a lot of riverine run off. The coincidence of those two events can really exacerbate coastal flooding.

SHANE HUNTINGTON
These effects, some of them sound like they're very temporary.

KATHLEEN MCINNES
Well, the severity of a storm surge can be influenced by a number of background conditions. So, for example, on an annual or inter-annual, so several years, timescale you can get influences in just your generic sea level height from climate features such as the El Niño-Southern Oscillation effect which can, for example, in the Pacific have a bit of a seesaw effect, elevating sea levels in the Western Pacific during La Niñas and so on. So your background sea levels can be somewhat higher than normal anyway and then you get a storm surge occurring on that and, of course, the severity is amplified.

SHANE HUNTINGTON
Central to a lot of this is the action of waves. A lot of our listeners will have seen a

wave, but when you talk about a wave what do you mean?

KATHLEEN MCINNES
I'm talking about wind generated waves, so the sort of waves that we see at the coast that break at the shore. That wave breaking process occurs when the oceans start to feel the friction of the ocean shore, so it occurs very close into coast. Of course, that creates challenges in terms of modelling it, because to model that sort of effect accurately we need very high resolution in that coastal zone and we need to be able to prescribe the bathymetric depths very accurately to get that shoaling effect that creates those hazardous wave conditions at the coast.

SHANE HUNTINGTON
With those conditions that cause these hazardous wave scenarios, what are the factors that are actually affecting the intensity of the waves that you get?

KATHLEEN MCINNES
The effect of the waves that impact the shore is also very much influenced by factors like continental shelf width. So when you have a wide and shallow continental shelf flanking a particular coastline that's very conducive to storm surge, you can get very high storm surges out of that. In Australia, for example, on our north-west shelf we can get very large tropical cyclone storm surges. But the converse is true for waves, because waves travel over the interior of the ocean, deep ocean, with little attenuation of their energy. It's only once they start to feel the sea floor that they increase in height and break, and then dissipate their energy. For a coastline that has a very narrow continental shelf that wave energy can propagate very close into shore before we see the effects of that wave breaking and shoaling process.

SHANE HUNTINGTON
Obviously when you're out in the middle of the ocean we don't often know that some of these waves are there underneath us. But as you've mentioned at the shore line they can be quite severe in terms of their impact. What's happening to the way the energy is distributed in a deep region of the ocean, relative to at the coast? Does it travel at the same speed?

KATHLEEN MCINNES
The waves travel over the deep ocean under a deep water wave condition but as they approach the shore you've got effectively a shallower column of water in which that wave energy is focused. So, of course, the waves start to grow in height and then they reach a particular level where they have to break and then create a lot of turbulence and that kind of process is what contributes to coastal erosion and so on. So that's the process by which wave energy dissipation occurs at the coast. Of course, it's a particularly hazardous phenomenon for any coastlines that have little to no continental shelf or no fringing reefs to help break that energy before it impacts the coast. So particularly vulnerable to the wave impacts are, for example, a lot of Pacific Island nations that don't have a significant continental shelf or may not have the buffering effects of fringing reefs that can take away some of that energy before it impacts the coast.

SHANE HUNTINGTON
With the current era of human induced climate change we're seeing changes, significant changes, in the atmosphere and also in the ocean; both their composition and their temperature are changing. How does this affect the waves that you're studying?

KATHLEEN MCINNES
Increase in greenhouse gases is having an effect of warming the atmosphere, and that, in turn, is changing circulation patterns. So where our large weather features occur, for example, we're seeing a bit of a southward shift of the mid-latitude storm tracks. So in other words storms in the mid-latitudes may be tracking a little bit further closer to the poles than they were. We're not talking a big difference there, a few degrees. But also as the ocean warms there's more energy available for other storms like tropical cyclones and so on, so they can reach greater intensities. That's not to say that we've been able to detect a change, tropical cyclones are rare events and so you need a very large statistical sample before you can actually say that there is a change occurring. But in terms of our climate modelling we do see a tendency towards these storms becoming more intense in the future, even though we're also seeing fewer of them spinning up. So there's a bit of a trade-off, they're slightly more intense, of the most intense cyclones, but then, overall, possibly slightly fewer of them occurring. So, a bit of a complex message emerging about tropical cyclones.

SHANE HUNTINGTON
Is that outcome good for coastlines? Do we want fewer of them if they're severe? Would we make that trade off in terms of erosion and damage?

KATHLEEN MCINNES
Of course, erosion is the net effect of our wave climate, so certainly you can get very large erosion occurring during a severe storm event but then over the course of a year you have your calmer seasons where, in fact, the smaller waves that occur are actually putting the sand back on the beach, if we're talking about a sandy beach. The effect of a change in wave climate on the coast can be quite subtle. You can get a directional change in the waves approaching the coast and that can change the longshore transport and so on. So it's actually a little hard to just say oh because we're seeing more intense cyclones but fewer of them what's going to be the net effect it's impossible to say without very detailed modelling and looking at a lot of other factors that contribute to the overall wave climate at the coast.

SHANE HUNTINGTON
I'm Shane Huntington and you're listening to Up Close. Our guest is Dr Kathy McInnes, a climate modeller from CSIRO. Kathy, I want to talk a bit more about climate change in the ocean specifically, because this brings in the idea of just general sea level rise. What are the main drivers for this rise that we hear about so often?

KATHLEEN MCINNES

Yeah, so as the atmosphere warms due to presence of greenhouse gases, some of that heat in the atmosphere, in fact most of the heat that's in the atmosphere, ends up being absorbed into the ocean, so that's slightly warming the oceans. As the oceans warm, it's a bit like liquid in a thermometer, it expands and rises. We call that thermal expansion. Of course, the other effect is that higher air temperatures are melting our large ice sheets, like Greenland and Antarctica and the glaciers scattered throughout the world. So they're adding more mass to the ocean. So we've got the mass increase from the melting and then the volume increase from the thermal expansion.

SHANE HUNTINGTON
Will the sea level rise be the same everywhere around the globe? If not, why would that not be the case?

KATHLEEN MCINNES
Sea level rise won't be uniform for quite a number of reasons. One is that - I mean there are ocean currents playing out, some are warm ocean currents, some are cooler. You might expect higher sea levels in the vicinity of warm pools in the ocean and so on. The other effect is that as ice sheets melt it changes the gravitational attraction, so you can get a slightly different gravitational field playing out across the Earth, typically so that you would tend to get the highest amount of rise the furthest distance from the mass that's melting, so the opposite side of the Earth from, for example, Greenland would experience maybe a couple of centimetres or more of sea level rise relative to around the coastline of Greenland.

SHANE HUNTINGTON
You mentioned the Southern Oscillation earlier, how do you decouple changes in sea levels due to that and changes in the overall sea level due to climate change?

KATHLEEN MCINNES
The scientists that are studying that are looking at how do we factor that into the sea level increases that we've seen. They have quite sophisticated methods for spatially accounting for what was the, for example, the ENSO effect that was playing out over the period that they're analysing, understanding what it is and they can remove it and look at what's left. Around Australia we've had very high, much higher than the global average, rates of rise over Northern Australia, but part of that is due to the fact that since about 1990 we've gone from a period - a change in ENSO such that we've seen very rapid increase in sea levels along the Northern Australian Coast, some of which is related to warming temperatures but the rest is due to the change in El Niño patterns.

SHANE HUNTINGTON
Of course, ENSO stands for the El Niño-Southern Oscillation. Coming back to severe storms though, and waves in particular, how do sea level rises connect to the sorts of work you're doing? Or is it just the precursors to those sea level rises, being ocean temperature, that's important?

KATHLEEN MCINNES
The fact that sea levels are rising is important in the work I do because often we're trying to understand what the impacts are not only of the extreme events under current climate conditions but how they'll be affected in the future. So there are two aspects to that. One is that the storms themselves may be changing, as we were discussing before, cyclones possibly becoming more extreme but less of them. But the other factor is that if you're getting these storms occurring on a higher sea level, then, of course, their impact at the coast will be higher, the waves can impact higher up the beach, creating more erosion and also the inundation that can occur from a storm surge can penetrate much further inland.

SHANE HUNTINGTON
You use mathematical models to understand what's happening during past storm events as well as what might happen in some of these future events. What sources of information do you need to pump into these models to make them work?

KATHLEEN MCINNES
Ideally good bathymetry data to set up our models over a particular coastal region. So depending on what it is we're trying to model. All these processes occur on different scales. So, for example, if we're trying to resolve wave breaking processes we might be down to the tens of metres, so we would need bathymetric information at that level. If we're more looking at storm surge effect over a fairly large region, such as, for example, the East Coast of Australia or something like that, then, of course, obviously we're running lower resolution hydrodynamic models which don't need quite so detailed information. We also need atmospheric data to force our models with, wind and pressure in a spatial sense. Of course, we need observations at the coast to validate the models, to determine that they are behaving in the way we expect them to. In many places that's the difficulty. We might have tide gauge data but that might not be the best data to validate a model that we're trying to understand wave breaking processes for, because the tide gauges are typically in a sheltered location so that they're not actually experiencing the impacts of high waves breaking over them. So that can be a challenge, is getting a lot of data to validate and test our models on before we then use them to look at the impacts under a range of other conditions.

SHANE HUNTINGTON
Most of our listeners would have come across standard meteorological models where the further out you go the probability reduces very quickly of them being accurate. Do you see that sort of thing in your modelling? Is there a temporal relation there or is it not affected by those sorts of problems?

KATHLEEN MCINNES
Yes, it is very much affected by those problems. We, through the work that a lot of my colleagues are doing, we're trying to provide better datasets that can be used to actually apply our models at highest coastal resolution by giving us information we can apply to our boundaries, at the boundaries of our models further out to sea.

SHANE HUNTINGTON
You're listening to Up Close, I'm Shane Huntington, and we're exploring the effects of severe weather events on our coastlines with our guess, CSIRO researcher Dr Kathy McInnes. Kathy, if I was to wander down the average Australian coastline I don't have to go far before things change significantly from one little inlet to the next and so on. Are you capable of modelling large, extensive coastline like that, or is the computer power required just beyond what we currently have?

KATHLEEN MCINNES
Yes, the scale of the effects is very demanding computationally. So if we're getting down to the kind of modelling that is needed to understand, for example, local wave breaking effects then we're coming right down in resolution to perhaps a particular beach or a fairly small segment of coastline maybe 40 kilometres long or something like that, maybe a couple of hundred kilometres long. But we're not talking whole continental coastlines when we're trying to resolve those kinds of processes, because we just need so much underpinning information that often doesn't exist.

SHANE HUNTINGTON
So the 26,000 kilometre coastline of Australia is out of the question in one go?

KATHLEEN MCINNES
Not for storm surge but if you're trying to understand the complex interplay of waves on the coastline it would be very challenging.

SHANE HUNTINGTON
There's a lot of uncertainty at the moment coming out with regard to the exact amount of temperature change that we will be experiencing over coming decades. I think we all agree that it's bad but we don't know exactly what that temperature change will be per decade. What do you do in terms of deciding what input to put in your model? How do you choose, why do you choose particular temperature changes?

KATHLEEN MCINNES
Yes. A lot of the uncertainty about future temperature increase comes back to what humans are going to do about emissions, so, of course, that's something we can't predict. So the way around it is that scientists put forward emission scenarios, so possible pathways on which human patterns of emission of greenhouse gases will follow. We can then, through climate modelling, work out what the climate sensitivity to that is, so how much warming will result in the atmosphere as a result of those concentrations of greenhouse gases. In that way we work with scenarios of future warming. Now in terms of which ones we choose to apply, we often want to understand the full range of the uncertainty that these different emission scenarios produce. It also comes back to what the study is for. So, for example, we might be taking a bit more of a look at the worst case example if our study is to inform decision makers about how to protect really valuable infrastructure where it just cannot be exceeded. So we don't want that threshold exceeded. So sometimes we will work with the worst case, or we'll look at the range but then it'll be up to the decision

makers to say well we'll maybe work with the midrange value, but perhaps we can't afford to work with the midrange parameter because if we were to exceed that the consequences would be disastrous. So we've got to protect ourselves for the worst case scenario. So in other words that's the whole decision making framework that comes into a lot of the people that we are doing our work for and that's the thinking they apply to the process.

SHANE HUNTINGTON
This must come with grave responsibility when you put this data out. I can imagine if you put data out in a certain way economic conditions, property values and the like, I can think of some of the very expensive properties along the Australian coastline that would be susceptible to these conditions, how do you deal with that responsibility? What sort of precautions do you have to put in place to make sure that the information isn't misused?

KATHLEEN MCINNES
Well, certainly in any reports we write up we're very clear on the caveats about the modelling, the assumptions we've had to make, the factors we haven't been able to take into account that may lessen or worsen the situations and we try to present the results with uncertainty bands that would represent this is the central value we're producing but, of course, it could be higher or it could be lower and there are some important factors that should probably be considered in the future but we haven't been able to in this study because maybe the data doesn't exist and so on. So communication is probably the key to ensuring that best alert people to the shortcomings of any modelling that we might have done.

SHANE HUNTINGTON
Kathy, you've got a lot of experience with these wave events, various impacts on coastlines and the like. Recently we've seen some pretty extraordinary and extreme storms around the world, Hurricane Katrina, Superstorm Sandy, two prominent examples. Do you see direct evidence linking these types of very severe storms with climate change, or is it too early to make those kind of connections?

KATHLEEN MCINNES
It's very hard to pull apart all the factors that go into a storm and determine, well could that have plausibly happened from natural variability or what proportion of that might have been a bit of a nudge towards a more severe storm because of climate changes that we've seen. Then, of course, we have to be very careful that is the change that we've seen in the climate due to some natural oscillation like we were talking about before, the El Niño-Southern Oscillation which can have a very strong influence, for example, in Australia. Or is it due to some longer term change.

SHANE HUNTINGTON
Kathy, I just want to finish by asking you whether there is some particular technology otherwise that we need at the moment to really get to the point where we can get this modelling to an accuracy that we can really use effectively to plan, especially if you're in a Pacific Island area and you want to move, for example. What do we need

to get it to that stage, or are we already there?

KATHLEEN MCINNES
We certainly have a lot of challenges with observations and collecting observations around our coastlines - all sorts of observations, we're not just talking sea level measurements but we're talking about degree of erosion, we're talking about current measurements, wave measurements and so on to better inform the long term changes. Even bathymetric surveys, I mean we do a bathymetric survey and think great, we've got some great coastal data but the next storm that comes through actually changes things a bit. But, of course, monitoring's very expensive. It's a real challenge to find cost effective ways to collect as much data as we can so that we can better validate models and use them to understand our climate risks.

SHANE HUNTINGTON
Kathy McInnes, thank you for being out guest on Up Close today and talking with us about coastal impacts of climate change.

KATHLEEN MCINNES
Thank you, it was a pleasure.

SHANE HUNTINGTON
That was Dr Kathy McInnes, research scientist with the Marine and Atmospheric Research Division of the CSIRO. We've been speaking to her about the coastal impacts of climate change. If you'd like more information on this episode visit the Up Close website, where you'll also find a full transcript. Up Close is a production of the University of Melbourne, Australia. This episode was recorded on 18 September 2013. Producers were Eric van Bemmel, Peter Clarke and Dr Dyani Lewis. Audio engineering by Gavin Nebauer. Up Close is created by Eric van Bemmel and Kelvin Param. I'm Dr Shane Huntington, until next time, goodbye.

VOICEOVER
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