Reading the waves

Instilled with a passion for the ocean at an early age, Dr Cristina Forbes uses her enthusiasm to predict storms and storm surge. Here, she describes how her love for oceanography and meteorology developed, and details her efforts to refine a national storm surge prediction model.

What experiences have most shaped your fascination with oceanography and meteorology?

As a child, I sailed along the coastlines of Argentina and Uruguay, where there is a strong, violent wind event called the ‘Pampero’ that blows over the Argentinian Pampas grasslands. This regional storm is dangerous for unprotected sailors in the South Atlantic Ocean, so my parents taught me how to read the ocean waves and skies in order to take advantage of the best winds and be safe under extreme weather conditions. I used this knowledge to race in, and win, sailing regattas. In the process, I developed a great respect for the ocean and the weather.

These experiences drove my passion for using physics and mathematics to simulate and predict oceanic and meteorological phenomena later in life. I went on to study physical oceanography (the mathematical equations that describe waves, currents and other ocean features) in Argentina, earned the equivalent of a Master of Science degree and taught geophysical fluid dynamics and waves and tides at the Instituto Tecnológico de Buenos Aires (ITBA). I later earned a PhD in Meteorology and Physical Oceanography from the University of Miami in Florida, USA.

Could you highlight some of the benefits afforded by your association with the National Oceanic and Atmospheric Administration (NOAA)?

I work at the National Hurricane Center (NHC) in Miami, which is part of NOAA, and for CyberData Technologies – a minority woman-owned company certified by the US Small Business Administration that delivers support services to the US Federal Government, such as the provision of scientists and specialists in information technology for government projects. My main task is to provide operational support to the NHC during tropical cyclone events by generating storm surge guidance for the evacuation of vulnerable coastal areas. I also work on improving the National Weather Service Sea, Lake and Overland Surges from Hurricanes (SLOSH) numerical storm surge prediction model, to provide better water level and inundation forecasts and for effective evacuation planning. It is extremely rewarding to use my experience, knowledge and skills to impact society by helping to save property and lives.

Can you outline the current aims of your numerical ocean modelling?

I am presently incorporating ocean waves into our storm surge modelling system. Waves are particularly important in areas where there is steep bathymetry – an abrupt descent of the ocean floor near the coast. This innovation will enable us to provide better guidance of inundation in islands of the Caribbean, like Puerto Rico, and in the Pacific Ocean, such as the Hawaiian Islands.

Do you have further plans for using the SLOSH model? Will you be focusing your efforts in any other locations?

We will continue using the SLOSH numerical model for storm surge guidance along the US Atlantic and Gulf of Mexico coastlines during the hurricane season (1 June – 30 November). We are also using the SLOSH model to run multiple hypothetical tracks to determine the vulnerability of coastal areas to tropical cyclones of different wind speeds, storm motions, sizes and landfall locations during the off season. These results are used by local communities for long-range planning and evacuation purposes.

Are you collaborating, both nationally and internationally, to carry out your research?

I collaborate with scientists in the US and around the world. We communicate via email, telephone and electronic conferencing software, and meet in person at scientific conferences and workshops. There is an international effort sponsored by the World Meteorological Organization (WMO) in Geneva, Switzerland, to develop a storm prediction system for Hispaniola (Haiti and the Dominican Republic) and other regions around the world. A couple of years ago, I was invited by WMO to serve as an expert to help develop an implementation plan for a storm surge prediction system for the Dominican Republic. It is very exciting to share ideas and discuss technical issues that will help protect the country and the world against this extremely dangerous natural hazard.

Is there a particular message you would like to impart to our readers?

As more and more people migrate to the coast, they urbanise the landscape and build structures there to protect lives and property. In spite of nature’s sporadic wrath, the Earth is an extremely fragile place and we – as world citizens and its caretakers – need to adapt, be gentle, learn and understand the environment to better protect ourselves and our planet. As the Native American Cherokee Indian proverb says: “Let us walk softly on the Earth…”
Hurricane Sandy was the most lethal and destructive hurricane of 2012, and the second costliest hurricane in US history. It began as a wave in the Caribbean, but quickly turned into a tropical storm in a period of just six hours, officially becoming a hurricane on 24 October. Sandy became the largest Atlantic hurricane on record, with winds spanning 1,100 miles. It killed at least 286 people across seven countries, and is estimated to have cost over US $68 billion.

Superstorm prediction

A physical oceanographer and her team at the National Hurricane Center in Miami, Florida, USA, are working on a national storm surge model. Using data obtained during Hurricane Sandy, they are improving the model for future events in order to help protect both people and property.

Hurricane Sandy, and other destructive landfalling hurricanes, are a testament to the importance of capable and reliable prediction systems. Accurate forecasts of hazardous weather can save lives, mitigate property loss and improve economic efficiency. Indeed, this is the mission of the US National Hurricane Center (NHC), part of the National Oceanic and Atmospheric Administration (NOAA).

Dr Cristina Forbes, Physical Oceanographer and Storm Surge Modeller at the NHC, is dedicated to improving predictions of extreme weather events by applying new scientific advances. After working at the University of North Carolina, where she developed real-time storm surge prediction systems for the state, she joined the Storm Surge Unit at the NHC, where she is working to make better storm surge predictions by improving the National Weather Service (NWS) Sea Lakes and Overland Surges from Hurricanes (SLOSH) model.

STORM SURGE SIMULATION

SLOSH, a numerical coastal ocean model, is used by the NWS to develop a range of storm surge prediction simulations, including real-time, historical and probabilistic simulations. Underlying the model is AutoSurge, an automated, event-triggered, storm surge prediction system. Developed by Forbes in 2010, AutoSurge eliminates labour-intensive tasks, computes storm parameters with a high level of accuracy and prevents human input error – essentially, it runs SLOSH. The system automatically generates an array of products, using the output from SLOSH to provide guidance to the Storm Surge Unit at the NHC.

The moment a tropical disturbance is identified as having the potential to develop into a tropical cyclone, AutoSurge begins to generate storm surge forecast simulations. The system then alerts the Storm Surge Specialists, sending guidance via email. In the 2012 hurricane season, AutoSurge was run in surge-only mode (without tides), and more than 1,000 numerical simulations were conducted during Hurricane Sandy.

As a result of subsequent upgrades to the model, SLOSH is now able to predict storm surges in an extremely accurate and rapid manner, typically taking only a couple of minutes. “This enables us to run multiple simulations to take into account the uncertainty in the tropical cyclone track and intensity predictions, and thus provide more reliable information on probable inundation (flooding) levels,” adds Forbes.

To assess the ability of the upgraded model, the team used SLOSH driven by the final version of the NHC’s hurricane track data to create a retrospective model simulation of the storm surge that occurred during Hurricane Sandy.

IMPROVED PREDICTIONS

As Forbes confirms, the results were surprisingly favourable: “The SLOSH model results compared very well with the observed water levels.” Verification analyses showed that the model is capable of accurately simulating the height, timing, evolution and extent of the water driven ashore by Hurricane Sandy. The 2013 upgrades to the model, including the incorporation of astronomical tides,
STORM SURGE MODELLING IN IMPOVERISHED NATIONS

An international effort, spearheaded by the World Meteorological Organization (WMO), is aiming to develop storm surge prediction systems for impoverished nations around the world.

Dr Cristina Forbes was invited by WMO to serve as a storm surge expert to help develop an implementation plan for the Dominican Republic, a nation in desperate need of resources, to save lives during extreme events like tropical cyclones.

A workshop was held in 2011 in order to understand how a numerical storm surge prediction model can be developed and deployed for the country. As a result, a number of important institutions agreed to work together to create a national repository of geophysical data. Once this is complete, a numerical storm surge prediction model will be implemented and a grid built to simulate coastal flooding. These efforts will later be rolled out to other nations around the world. In the past year, an expanded whole-island approach, to include not only the Dominican Republic but also Haiti, was devised to help both nations during tropical cyclone events. Currently, resources are being secured to bring this project to fruition and prevent destruction and the loss of lives in these impoverished island nations.

increased the hindcast accuracy of the model, enabling forecasters to better predict the timing and degree of the water level.

Further quantitative assessments of the simulation results – comparisons with water surface peak elevations measured at 13 NOAA tide gauge stations, by 60 USGS storm surge sensors deployed ahead of the storm and 268 high water marks collected after the storm, a total of 331 observations – showed that the simulated water levels at more than one-third of the measurement locations had under 10 per cent error. Furthermore, the model’s level of efficiency means it is able to run large, automated ensembles of real time predictions in order to account for the variability of tropical cyclone forecasts. In turn, this ensures that guidance offered to the public is more reliable.

PLANNING FOR PROTECTION

The analysis, published in the Journal of Marine Science and Engineering in 2014, provides a baseline for the evaluation of future versions of SLOSH and for comparisons with other modelling systems – which is important as the NWS moves towards a multi-model system. Forbes explains: “The results guided us in improving the storm surge model and input data for future tropical cyclone events”.

At present, Forbes is incorporating waves from the Simulating Waves Nearshore (SWAN) model – a third-generation wave model developed at Delft University of Technology in the Netherlands – into the SLOSH model. SWAN is able to compute random, short-crested, wind-generated waves in coastal regions and inland waters, and she hopes that by combining the two models she will be able to predict inundation caused by tropical cyclones in Hawaii, Puerto Rico and the Virgin Islands, before expanding to other islands in the Caribbean.

Forbes’ ongoing goal, to enhance the SLOSH storm surge model, is driven by a desire to continuously improve the accuracy of predictions, and ultimately protect human life. “I will continue to conduct verifications of the water levels and inundation extent after tropical cyclone events in order to improve our entire forecasting system. So, when the next storm comes, we will have better, more accurate predictions of storm surge,” she explains. By including ocean waves, the model’s prediction of water levels will become more accurate, and emergency managers and government agencies will be better able to plan evacuations in their localities.

SEA, LAKE AND OVERLAND SURGES FROM HURRICANES MODEL

OBJECTIVE

To improve storm surge predictions through developing and upgrading the National Weather Service Sea, Lake and Overland Surges from Hurricanes (SLOSH) model.

KEY COLLABORATORS

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DR CRISTINA FORBES studied physical oceanography in Buenos Aires, Argentina, and subsequently earned a PhD in Meteorology and Physical Oceanography at the University of Miami, Florida. She is now working in the Storm Surge Unit at NHC as Physical Oceanographer and Storm Surge Modeller to help advance numerical storm surge prediction systems.

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INTELLIGENCE