The impact of atmosphere-wave-ocean coupling on extreme surface wind forecasts

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Skillful weather and climate forecasts are vital for protecting lives and livelihoods and managing the effects of climate change. The HiWeather World Weather Research Programme of the World Meteorological Organization grew out of recognition that new capabilities in the use of observations, convective-scale numerical weather prediction models (models capable of representing individual convective clouds), coupled modelling (coupling between models of the atmosphere and ocean, wave or land surface models) and ensemble prediction systems (multiple, equally likely, forecasts of the same event to quantify probability and uncertainty) could improve forecasts for timescales of minutes to two weeks, and so improve early warnings. Prediction of the risks due to localised extreme winds (one of the 5 hazards identified as foci) requires advancement in ocean-atmosphere coupling, convective-scale prediction and the use of ensembles. Our project will contribute to this advancement using a new convective-scale coupled atmosphere-wave-ocean model.

The aim of this project is to determine whether atmosphere-wave-ocean coupling improves surface wind speed and gust forecasts associated with extratropical cyclones through improved boundary layer characteristics

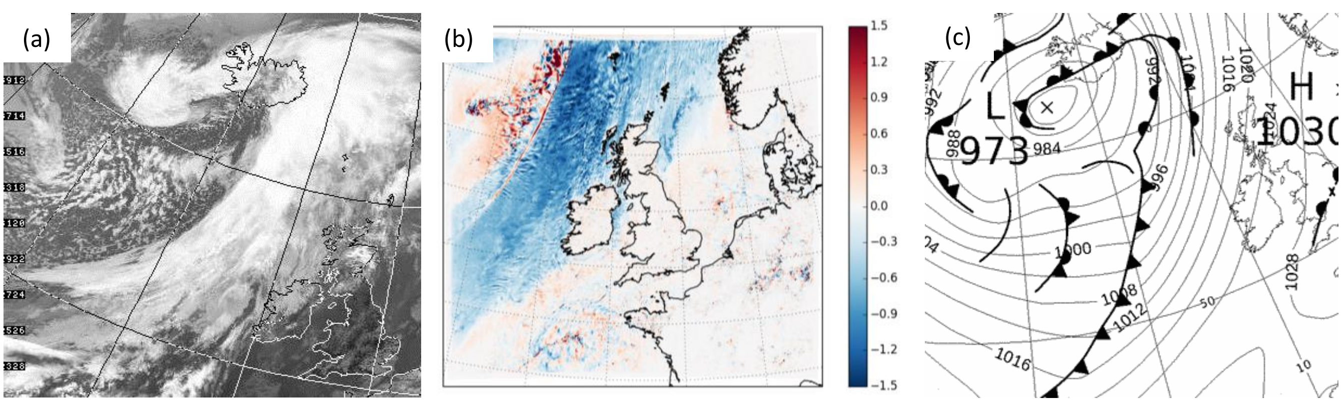

Figure: Coupled extratropical cyclone case study with the UK environmental prediction system for 2 October 2014: (a) infra-red satellite image (1346 UTC), (b) effect on surface windspeed (ms^{-1}) at 1500 UTC of including the wave model component, and (c) Met Office surface analysis at 1200 UTC.

Our CASE partner is the Met Office and our collaboration is with the Environmental Prediction Development Team, part of Weather Science. This project will exploit the new UK Environmental Prediction (UKEP) regional coupled system that was developed by this team. The UKEP system is the first convective-scale coupled model for the UK. A successful prototype project has delivered new insights into the sensitivity of the ocean and surface waves to the representation of feedbacks to the atmosphere. Ongoing work in Phase 2 seeks to consolidate progress and further develop collaborations to exploit this new capability. We will work with our Met Office collaborators to determine whether this UKEP system can yield improved forecasts of surface winds (and gusts) associated with extratropical cyclones and, if so, the reason why this occurs.

Extratropical cyclones (also known as winter storms, windstorms, or low-pressure depressions) are a major wind hazard for the UK (e.g. see the windstorm insured-loss estimations in the Extreme Windstorm Catalogue at www.europeanwindstorms.org). Strong surface winds arise from the three low-level wind jets typically found in cyclones. These jets are associated with the so-called warm conveyor belt that ascends ahead of the cold front, the cold conveyor belt that wraps rearwards around the cyclone to the north (and can lead to strong surface winds when its tip becomes aligned with the direction of motion of the cyclone), and (in some extreme cyclones) a transient, smaller-scale sting jet that can lead to strong winds and gusts, especially in the dry air ahead of the convex "cloud head" seen in satellite images of extreme cyclones.

While many studies have documented the existence of strong surface winds in cyclones, the controlling effect of the atmospheric boundary layer (that comprises the lowest 1-2 km of our atmosphere) has been less explored. Research has suggested though that the strength of surface winds and gusts arising from these jets is critically dependent on the boundary layer stability. Surface heat and moisture fluxes drive the boundary layer and coupling between the atmosphere and the land or ocean beneath is essential to represent these fluxes, and their time variation, accurately. Surface friction also directly moderates windspeeds. In this project we will (1) derive a climatology of UK extreme winds, (2) quantify the forecast improvements arising from atmosphere-wave-ocean coupling in case studies by verifying boundary layer characteristics and surface winds, and (3) determine the relative importance of coupling and initial condition uncertainty to forecast evolution, and so address the computational trade-off between coupled and ensemble forecasts necessary in operational forecasting.

Training opportunities:
This project is in collaboration with the Met Office, the UK's national weather service. The student will spend at least three months at the Met Office working with the Environmental Prediction Development Team during his or her PhD project.

Student profile:
This project would be suitable for students with a degree in physics, mathematics or a closely related environmental or physical science. Students should have a strong interest in the interpretation and numerical modelling of weather processes.

Funding particulars:
This project has funding from a NERC industrial CASE studentship with CASE support from the Met Office.

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