WRF Simulation of wet snow and rime icing incidents in the UK

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***Abstract*—As part of the COST727 programme, the EA Technology site at Deadwater Fell has been used to test icing sensors and this work is described in another paper at this workshop. The site was also used to validate icing models. Separately, a wet snow model has also been validated on a real wet snow blizzard that occurred in the central England area in 1990. The WRF model is used to predict necessary meteorological data to model the ice accretion loads on overhead line conductors strung on a 200m test span at the Deadwater site. This data was compared with actual measurements from meteorological instruments at the site and showed good agreement with both weather data and the ice accretion magnitude. The WRF model and weather data provided by the author and the UK Met Office were used to study prediction of the location, type, amount and timing of the precipitation caused by the weather patterns in December, 1990, in the UK. Predicted precipitation intensity, wetness of snow particles, wind speed, temperature and humidity from the WRF model were used to run the ice accretion models from Cigré, in particular, for wet snow, the Admirat model to turn this data into conductor ice loads. The model was run over 3 days from 7 to 9 December, 1990, using a triple nested model grid with 1 km grid spacing for the affected area (Nottingham). The output from this model, based on new concepts that allow discrimination between areas of dry snow, wet snow, sleet and rain in any particular icing incident, matched experience at the time in 'old' Northern, Yorkshire and East Midlands electricity utility areas.**

I. Background

As part of the modeling work of WG1 within the COST727 programme, data from the Deadwater Fell test site [1,3] and historical data from a wet snow storm in the UK in December, 1990 has been used to validate rime ice and wet snow models. In particular output from the Weather Research and Forecasting (WRF) model was used to drive accretion models for rime icing and wet snow. WRF is basically a regional, non-hydrostatic numerical weather prediction model that can be viewed in detail on http://www.wrf-model.org/. It can be run with very high horizontal resolution ($\Delta x < 1$km) and allows the user to apply sophisticated computation of cloud properties, which is considered important when explicitly predicting the precipitation type. In the current study WRF simulations are initiated with re-analysis data from the ECMWF archive.

II. General

Bjorn Egil Nygaard has used the WRF model in combination with a rime ice accretion model for selected in-cloud icing cases at all the COST 727 test sites, in addition to Deadwater Fell. A description of the method and results are presented in [4]. The work on Deadwater Fell produced very similar results to that by Knut Harstveit, who used an adiabatic cloud water gradient model that uses observations of clod height and standard meteorological from a near by station, to predict icing events. The basics of the two models were thus shown to be able to provide accurate data relating to icing incidents at Deadwater over the 2005/06 and 2006/07 winters. Meteorological data was obtained from Anthony Veal at the UK Met office from the sites marked in Fig. 1 which covers the Scottish borders area and Northern England concentrating around the Deadwater location. The work of Knut Harstveit is reported elsewhere [1]. In the current paper we present some final results of the WRF predictions of rime icing at Deadwater Fell along with the work on the wet snow storm of 1990.

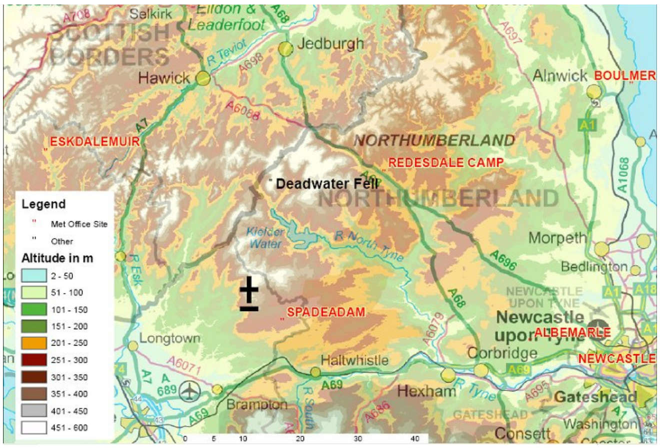

Fig. 1 Deadwater Fell Location in the UK

III. Deadwater Fell Rime Icing

Tests at Deadwater Fell had produced data on rime ice incidents. This was used to test and refine the two models. The results looked at the full 2006/07 winter's data and also specific incidents. The WRF model was used to predict cloud liquid water content (LWC), wind speed and temperature, which in a second step was post processed through an accretion model to calculate accretion loads on the conductors at the Deadwater site. This data (in blue) is compared with actual measurements (in red) in Fig. 2. There is good agreement with wind (apart from time when the cup anemometer was frozen during the 10th of February) and temperature and the ice accretion magnitude (but not full agreement in timing). Fig. 3 shows the predicted ice accretion on a geographic basis. This data was also calculated on a time basis (per hour) and this is available to module members if requested. This type of data can be extremely useful when determining an ice loading map of an area.

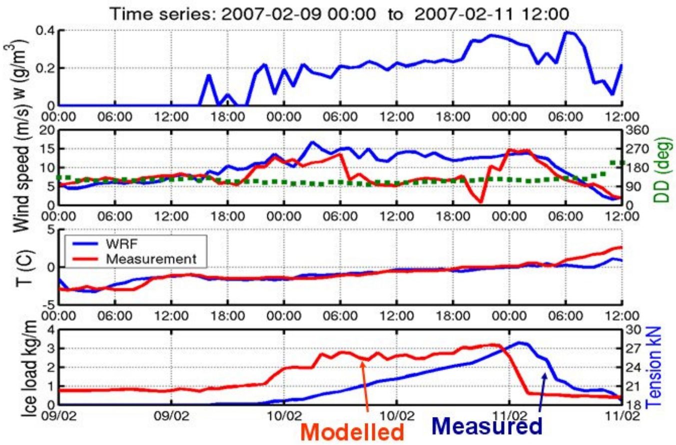

Fig. 2 Measured and modeled data for Deadwater Fell. Red lines are measured data and blue lines are modeled values. Green squares illustrate simulated wind direction.

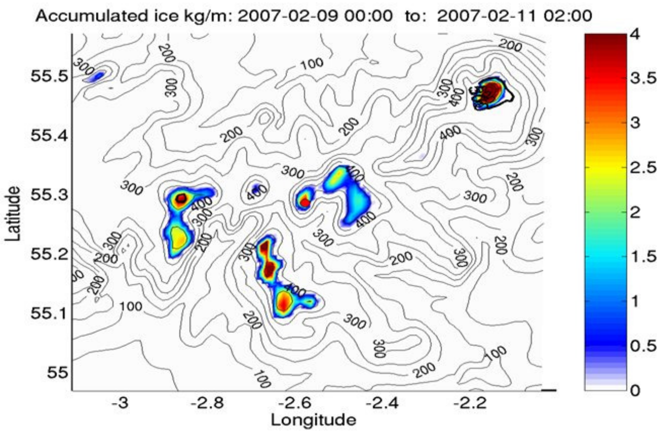

Fig. 3 Accumulated ice load data according to geographical location. Area shown is Scottish Borders with Deadwater Fell at 55.3 Latitude and -2.6 Longitude.

IV. Wet Snow Modeling of 1990 Storm in UK

A. General

The WRF model driven by the ERA40 re-analysis from ECMWF were then used to predict the location, type, amount and timing of the precipitation caused by the weather patterns of 7/8 December, 1990 in the UK. Precipitation intensity, wetness of snow particles, wind speed, temperature and humidity from the WRF model were then used with the ice accretion models from Cigré [2], in particular, for wet snow, the Admirat model to turn this data into conductor ice loads. The model was run over 3 days from 7 to 9 December using a 16km resolution to produce a map of the overall precipitation (Fig. 4). The simulation was further nested stepwise down to 1km grid spacing and is shown in Fig. 5 for the Nottingham area.

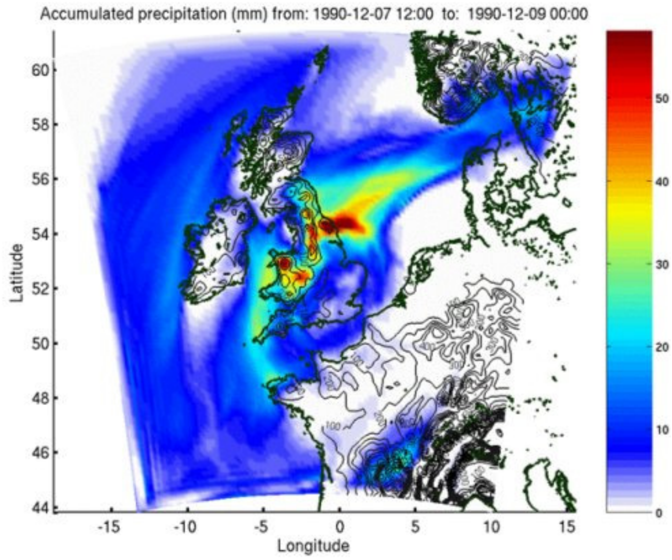

Fig. 4 The overall simulated precipitation (mm) of 7-9 December, 1990.

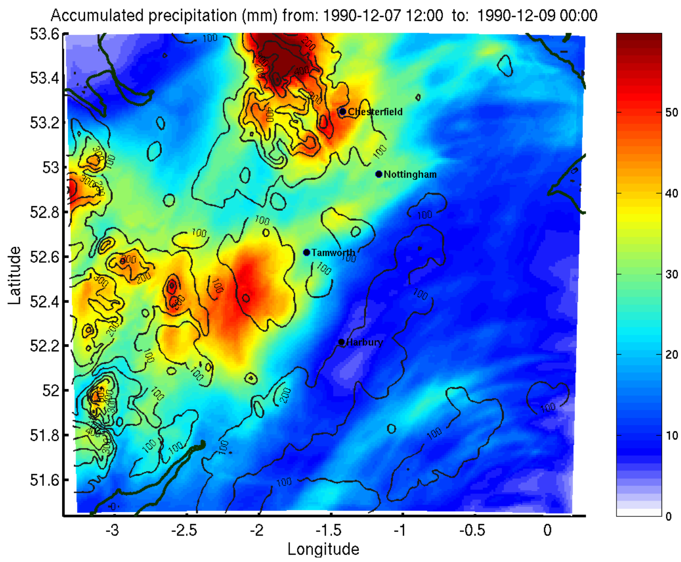

Fig. 5 Accumulated precipitation for the Nottingham area.

The precipitation type was then determined by the water content of the snow flakes. Below 15% the snow will be too dry to adhere to any OHL conductor and above 40% the precipitation will be sleet and will tend to slide off the conductors. By combining the predicted water content of rain, snow and graupel for each model output hour, it is possible to further delineate the areas where precipitation is of specific types e.g. dry snow, wet snow, sleet and rain. Fig. 6 therefore picks out the water equivalent wet snow depth and Fig. 7 the actual accretion of wet snow on the conductors. Note the considerably lower accretion levels at greater land heights as the accretion type turn to dry snow and also the well defined edges of the affected area.

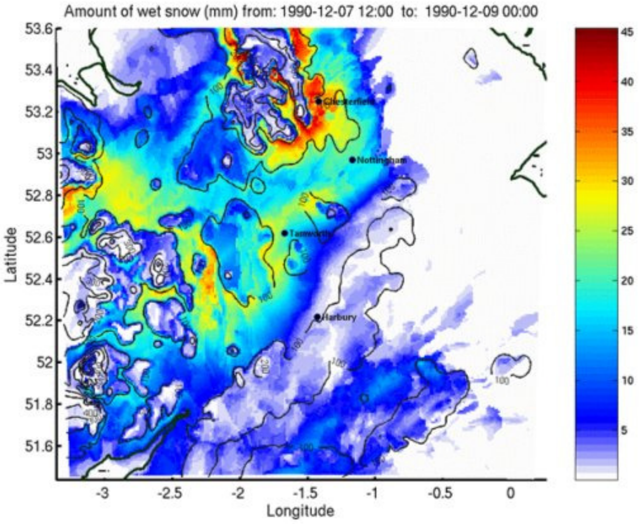

Fig. 6 Wet snow depth for the UK storm

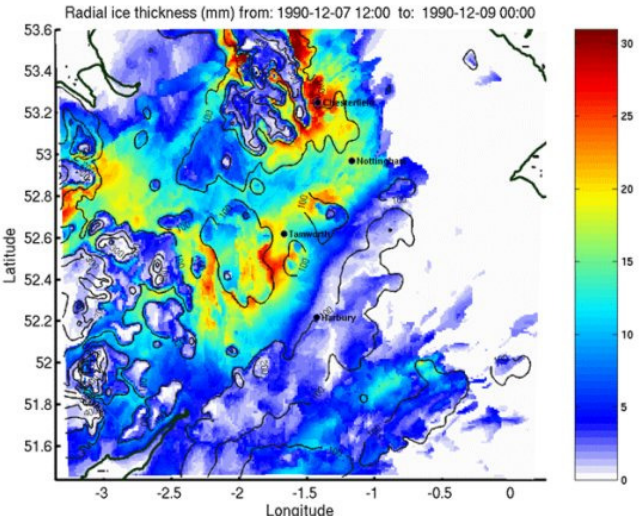

Fig. 7 Wet snow accretion on the conductors in the storm

Fig. 8 details the simulated time series of wind speed, temperature, precipitation and accreted load for the Chesterfield location. The graphs illustrate very typical conditions favorable for wet snow accumulation, with high wind speeds, heavy precipitation and temperature slightly above 0ºC. The model produces almost 2 kg/m wet snow accretion during a 10 hours time period.

Although this has been applied to a specific area of the UK, this procedure can be applied to virtually the entire UK (depending on available computational power). It shows that the model realistically can predict weather conditions from basic meteorological data and topographical input. It can also determine whether maximum loads can come from rime ice or wet snow depending on location and land height. This can be combined with current accretion against conductor size and type determined by other projects at Deadwater Fell.

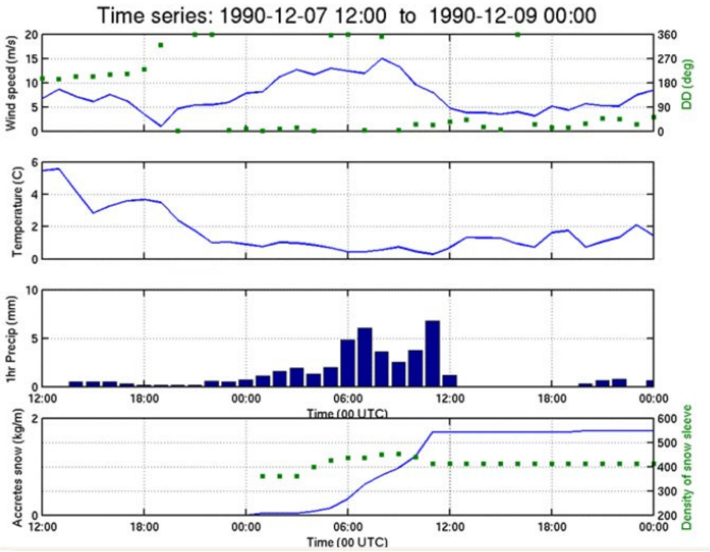

Fig. 8 The time period of wind speed, temperature, precipitation and accreted load of the storm

V. Summary

Modeling in the COST727 programme has been refined down to 1km grid-resolution in many areas. This is considered sufficient to resolve the terrain in 95% of UK. Rime ice conductor loads at Deadwater Fell over 2005/2007 winters and wet snow modeling of 8 Dec, 1990, blizzard in UK were done on basis of models validated in time, place and severity from Deadwater Fell and other site data. The wet snow model is based on new concepts that allow discrimination between areas of dry snow, wet snow, sleet and rain in any particular icing incident. This was applied to 8 December, 1990 storm in UK. The model output matched experiences at the time in ‘old’ Northern, Yorkshire and East Midlands areas. The UK power utilities require a 50 yr return period wind/ice map of UK. This can be supported by using a mesoscale model such as WRF in combination with a model for ice accretion. The effect of climate change can also be included by post processing of climate scenarios. Such a map would be used for line design for efficient, economic and safe operation of the OHL network at all voltages. This would require modelers, meteorologists and people with experience and knowledge of the UK network.

VI. References

Technical Reports:

[1] J. B. Wareing, "Measuring and forecasting atmospheric icing on structures," EA Technology, UK, Report 6138 June 2008.

[2] Cigré SCB2 WG16.03 ‘Guidelines for Meteorological icing models, statistical methods and topographical effects’ Cigré Technical Brochure TB291 April, 2006

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[4] B. E. Nygaard, "Evaluation of icing simulations for the “COST727 icing test sites” in Europe" presented at the 9th IWAIS, Andermatt, Switzerland, 2009.