Towards Operational Lightning Prediction in High-Resolution Versions of the Met Office Unified Model

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1. Introduction

Traditional forecasting of thunderstorms uses forecaster rules (e.g. lifted index, Boyden ratio).

NWP Models are now starting to resolve thunderstorm activity explicitly.

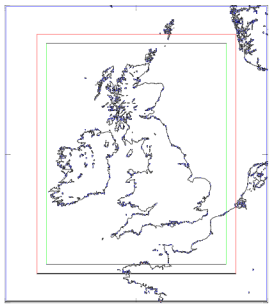
Aims of this work:

- Predict were lightning-activity will occur for operational forecasting.
- Predict location of graupel storms for aviation meteorology.
- Predict where clouds will charge as well as discharge for Helicopter-triggered lightning (Wilkinson et al, 2013).

2. Model and observational data

We use the Met Office Unified Model in the UK Variable (UKV) configuration (Tang et al 2013).

The cloud microphysics scheme is based on Wilson and Ballard (1999) but includes prognostic graupel.



UKV Model

- 1.5 km horizontal spacing in central domain; varying to 4 km at edges, as shown in Fig 1.
- 70 vertical levels

Lightning data is available from the Met Office ATDnet system.

Figure 1. UKV model domain.

3. Lightning schemes

Examine different types of lightning relationships to see which performs best in the UKV model.

- **Price and Rind (1992):** **Empirically based** on satellite data. Uses cloud top height.
- **Deierling et al (2008) and McCaul et al (2009):** Based on a **flux hypothesis.** Uses precipitating graupel/ice mass.
- **Dahl et al (2011):** Based on **Capacitance theory.** Uses graupel mass, graupel cross-sectional area and storm volume.

4. Offline tests with different schemes: Case study of 07 August 2011

Situation
Occluded fronts bringing moist, unstable maritime air over south-west Britain. Showers gradually move north-east. See figure 2 for the synoptic situation.

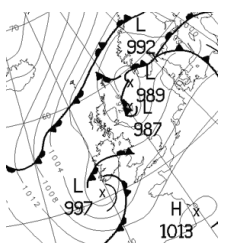


Figure 2: Analysis chart for 1200 UTC on 7 August 2011.

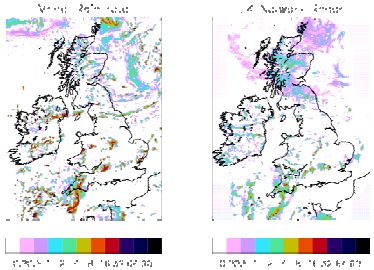


Figure 3: Model rain rate and radar rain rate for 16Z on 07 August 2011

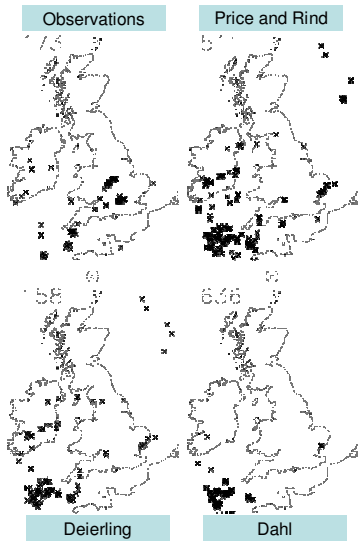


Figure 4: Sferics from 1555-1605 UTC on 07 August 2011 showing observations and with three relations applied to UKV data. Total sferics shown in each plot.

Offline tests: Key results

- Model captures intense storms over south-west (Fig 3) but has storms over the north-east too strong.
- All relations captures lightning activity over south-west Britain and east England (Fig 4).
- Deiering et al (2008) gives the best estimate of the total lightning strikes.
- Dahl et al (2011) relation constrains lightning to only a few key locations.
- All relations miss lightning in middle of UK, despite having storms in the model here.

5. Tests with parametrizations coupled to the UKV model

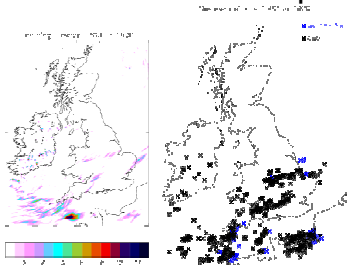


Figure 5: UKV forecast of lightning (left) and sferics (right) for 1300-1900 UTC on 7 August 2011.

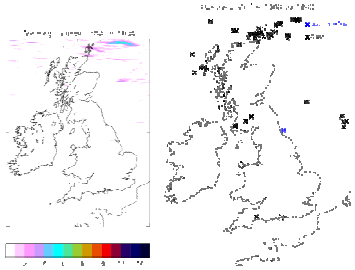


Figure 6: As figure 5, but for 1300-1900 UTC on 25 November 2011.

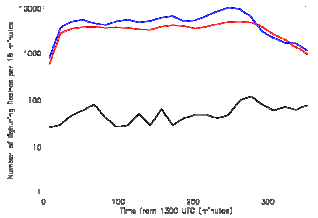


Figure 7: Number of lightning strikes during the forecast period on 7 August 2011, assuming column independence. Black line shows the observations, red is the McCaul et al (2009) parametrization and blue is the Deierling et al (2008) relationship.

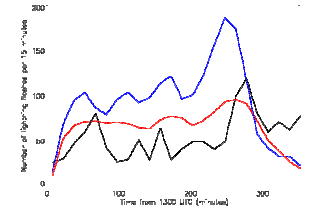


Figure 8: As for figure 7, but with a linear scale on the y-axis and applying a scaling for storm size.

Coupled tests: Key results

- The UKV model captures the signature for lightning and location of lightning in both warm air (Fig 5) and cold air (Fig 6) very well.
- However, UKV but overestimates the number of lightning flashes (Fig 7) when each grid column is assumed to be independent. Scaling by storm size improves this (Fig 8), but performing this in the model is numerically very expensive.

6. Conclusions and Future Work

- Models represent the showers well, but there is a tendency to over-predict lightning rates over the UK. Possible reasons are:
  1) Parametrizations could be designed to work well for high-intensity lightning situations, but are poorer for more marginal cases.
  2) Assuming column-impendence is a bad assumption, but changing this significantly slows down the model. Work to be done to minimise this problem.
- Future work will examine developing long and statistical verification of the different methods to see if it is possible to operationally predict lightning activity for the UK. Of particular interest are cold air outbreak cases as well as investigating performance in cases where observed storms are on a border-line between discharging and not discharging.

References

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