Evaluating Auroral Forecasts Against Satellite Observations

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Key Points!

★ We use terrestrial weather verification techniques to evaluate the performance of of the operational auroral forecasting model in use at the Met Office, OVATION-Prime 2013 (or, OP-2013).

★ OP-2013 performs well at predicting the location of the aurora, with a high ROC score of 0.83.

★ Comparing the forecast probability and the observed occurrence of aurora, we find that OP-2013 tends to under-predict the auroral occurrence.

Figure 1: *The aurora from Svalbard. Photo credit: Jennifer O'Kane.*

1. The Aurora as a Space Weather Hazard

- Auroral emission can disrupt radar signals and long range radio communication. Forecasting the aurora is therefore important to the defence and aviation sectors.
- Evaluating the performance of a forecast model against observations is an essential step in model development.
- The current state-of-the-art auroral forecasting model in use by the Met Office is the OP-2013 model (Newell et al., 2013), but its forecasting skill has not yet been fully evaluated.
- An earlier version of this model, OP-2010 (Newell et al., 2010a), was found to forecast the nightside aurora with a 77% accuracy but only had a moderate agreement with observed hemispheric power (Machol et al., 2012; Newell et al., 2010b).

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2. Forecasting the Aurora

- OP-2013 (Newell et al., 2014) is used in daily space weather forecasts at the UK Met Office and delivers a 30 minute forecast of the probability of aurora occurring in the northern and southern hemispheres.
- The model is run in real time, every 30 minutes, using solar wind parameters measured upstream of Earth at the L1 point.

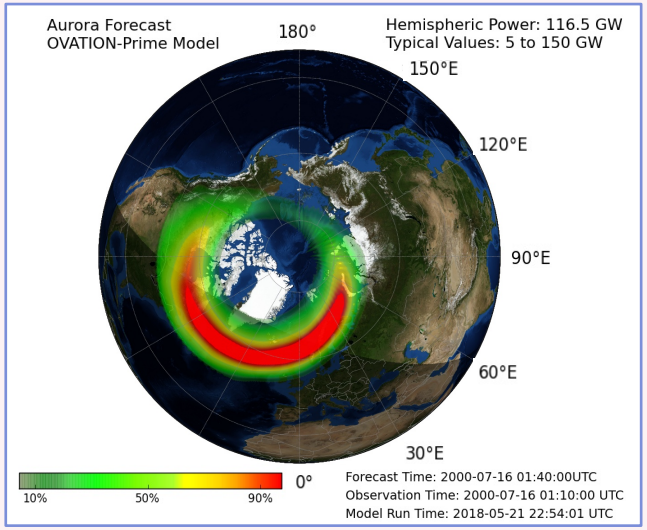

Figure 2: *Example of an OP 2013 auroral forecast. Red/green regions indicate a high/low probability of aurora occurring.*

3. Observing the Aurora

- The IMAGE satellite took far ultraviolet (FUV) images of the auroral oval between 2000-2005.
- Longden et al. (2010) use an automated technique to define the poleward and equatorward luminosity boundaries of the auroral oval between 2000-2002.

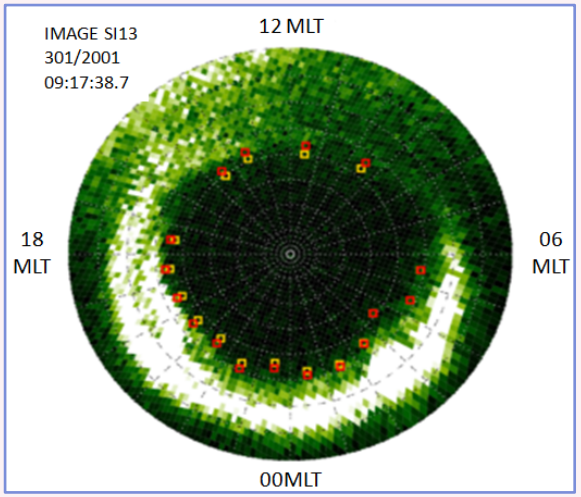

Figure 3: *An example of the poleward auroral boundary location in the northern hemisphere identified from IMAGE data (adapted from Longden et al., 2010).*

4. Comparing Forecasts and Observations

- We use the auroral boundaries from Longden et al. (2010) as our *ground truth* data set to indicate where the observed auroral oval was located and compare with the model output from OP-2013.
- We apply standard weather forecast verification techniques to assess the forecast location and probability of aurora occurring from OP-2013.

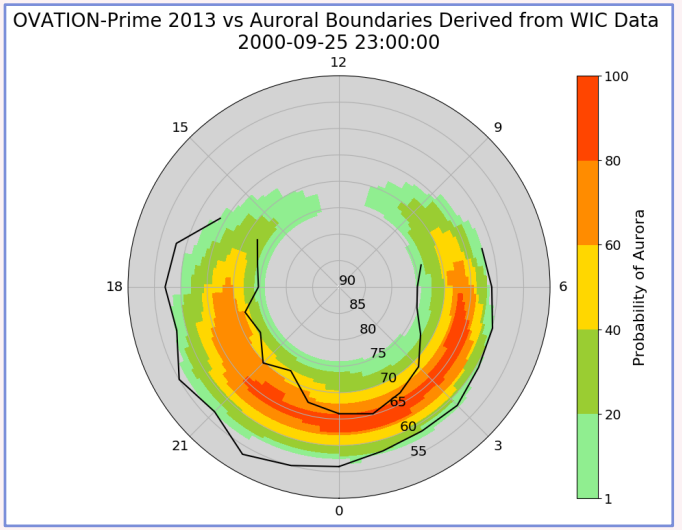

Figure 4: *A comparison of the OP-2013 forecast (in colour) and the observed auroral boundaries from Longden et al. (2010) (black lines).*

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5. Assessing Forecast Discrimination

- **ROC Curves** evaluate how well a model discriminates between events and non-events i.e. aurora and no aurora. The most skillful models will have a ROC curve that tends towards the top left-hand corner.
- The OP-2013 model performs well at distinguishing between regions with aurora and no aurora, with a high ROC Score (area under the ROC curve) of 0.83.
- This means that the OP-2013 model performs well at predicting the location of the auroral oval.

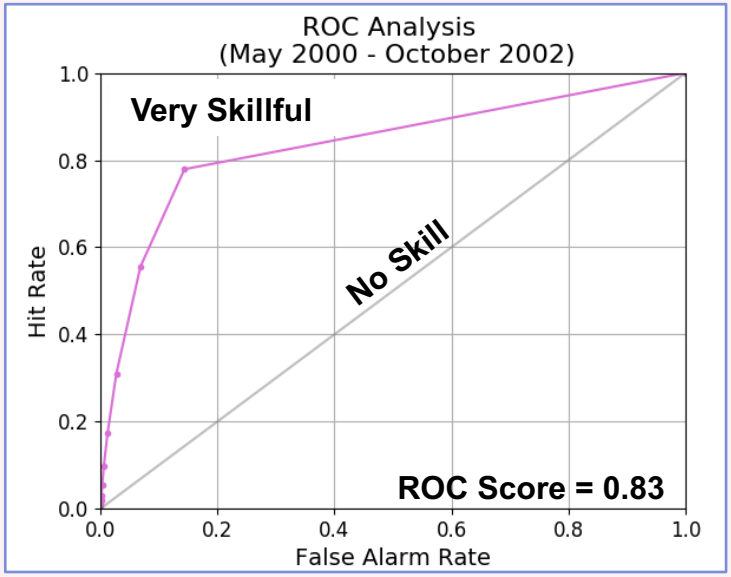

Figure 5: *The ROC curve from the analysis of forecasts between May 2000 - October 2002.*

6. Evaluating Forecast Probabilities

- **Reliability Diagrams** evaluate the forecast probabilities of aurora occurring against the frequency at which the aurora was actually observed.
- For forecast probabilities of ≤ 0.80, OP-2013 under-predicts the probability of aurora occurring by up to a factor of ~ 6.5 i.e. the observed frequency of aurora was 6.5 times higher than the predicted probability of aurora occurring.
- For forecast probabilities of ≥ 0.90, OP-2013 over-predicts the probability of aurora occurring by up to 20%.

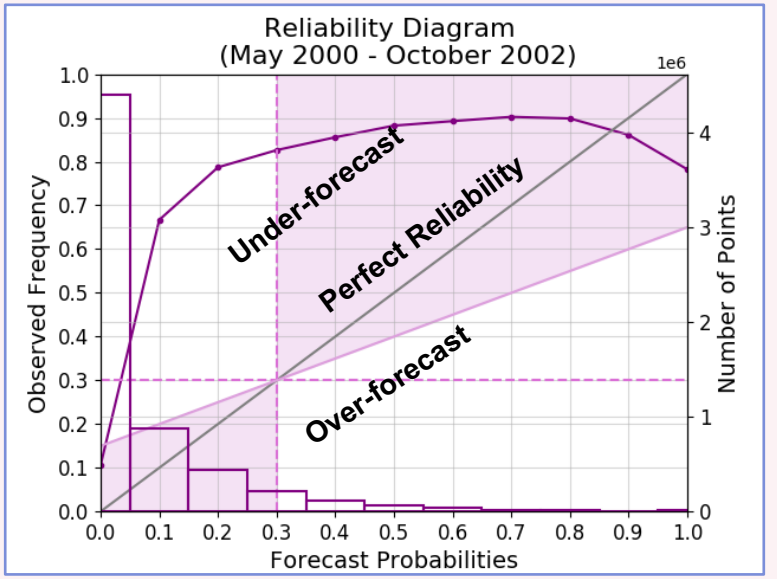

Figure 6: *The reliability diagram from the analysis of forecasts between May 2000 - October 2002.*

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7. Conclusions

★ Our results show that the OP-2013 model performs well at predicting the location of the aurora with a high ROC score of 0.83. Further analysis has shown that this breaks down slightly under higher levels of geomagnetic activity, when the aurora are more active.

★ Our evaluation of the forecast probabilities of aurora occurring show that the OP-2013 model tends to under-predict the probability of auroral occurrence, often significantly.

★ The results of this study will be provided to Met Office Space Weather Forecasters to improve their interpretation of the OP-2013 auroral forecasts.

For more detail on this study, check out our recent A&G article:
How well do we forecast the aurora? Mooney et al., (2019)

8. Acknowledgements and References

An alternative link to the open access version of *How well do we forecast the aurora?* Mooney et al., (2019).
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