Systematic error in forecasts of atmospheric blocking and upper-level Rossby waves

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The forecast of atmospheric blocking has been a known problem for medium-range weather forecasts for numerous years. Several studies have shown that the frequency of blocking is generally underpredicted in forecasts. Gray et al. (2014) also showed that there is a systematic error in the representation of Rossby waves at the tropopause: the area of ridges and the gradient in potential vorticity (PV) at the tropopause decrease with lead time. The link between these two errors is studied here, with the following questions considered:

- **What impact has the introduction of a new dynamical core* in the Met Office model had on the forecast of blocking and upper-level Rossby waves?**
- **How are forecasts of blocking related to the representation of Rossby waves at the tropopause?**

Methods

- Forecasts for winters 2012/13-2015/16 from the European Centre for Medium-range Weather Forecasts (ECMWF), the Met Office and the Korean Meteorological Administration (KMA) are studied.
- KMA and Met Office run Unified Model (MetUM), both with NewDynamics (2012/13-2013/14), then Met Office with ENDGame (2014/15-2015/16).
- 500 hPa geopotential height (Z) and 320 K PV are used to study the forecast of atmospheric blocking and Rossby-wave structure, respectively. Blocking is diagnosed using a Z-based index, as in Matsueda (2009) (based on the index introduced in D'Andrea et al. (1998)).
- Rossby-wave structure evaluated via Rossby-wave ridge area and PV isentropic gradient at the tropopause. See Gray et al. (2014) for details.
- To assess the accuracy of control forecasts in predicting blocked days, hit rate analyses** were performed at different lead times.

Blocking frequency

- The frequency of blocking across the northern hemisphere has large interannual variability (Fig. 1).
- All the models predict blocking frequency accurately at a lead time of 5 days, but generally underestimate the peaks in blocking frequency after this.
- The Met Office forecasts increase relative to ERA-I (and KMA) in DJFs with ENDGame.

Rossby wave structure: ridge area and PV gradient

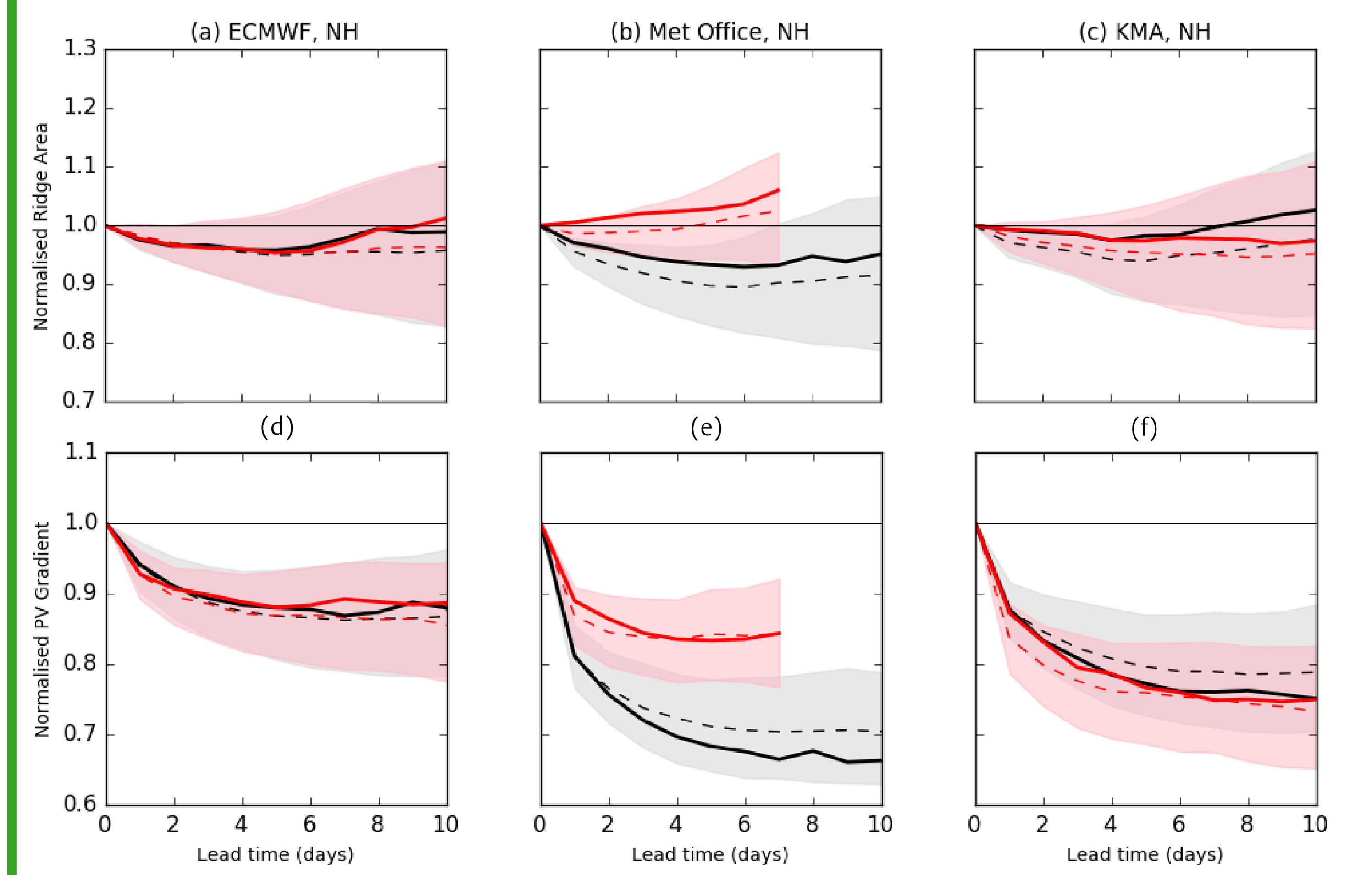

Figure 2: Northern hemisphere ridge area (a-c) and PV gradient (d-f) normalised by their values at the analysis as functions of forecast lead time for ECMWF (left), Met Office (middle) and KMA (right), showing the 25th-75th percentiles of the ensemble (shading), ensemble median (dashed) and control (solid) member averaged over DJF 2012/13-2013/14 (black) and 2014/15-2015/16 (red).

- Ridge area and PV gradient generally decrease with lead time.
- Improvement in maintaining both ridge area and PV gradient for Met Office forecasts in DJFs 2014/15-2015/16, with ENDGame (Fig 2 (b,e)).
- ECMWF and KMA forecasts are consistent across DJFs.

Hit rate analysis: blocked days

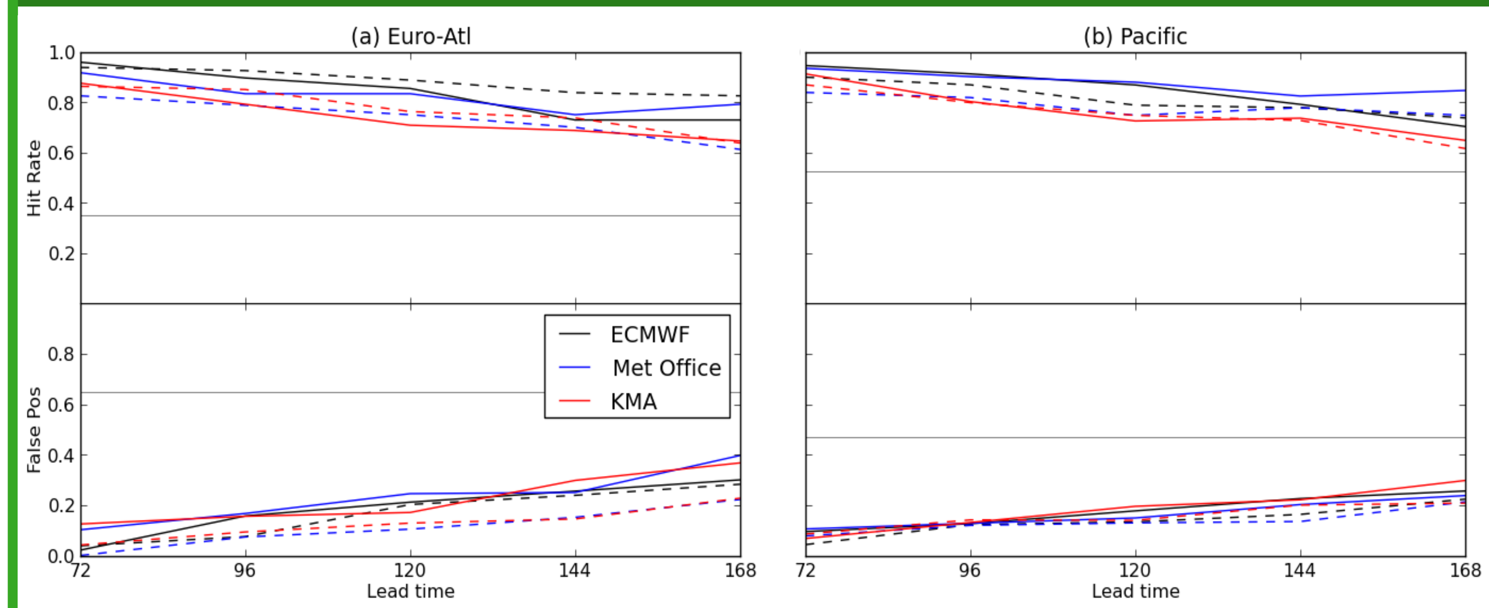

Figure 3: Hit rates and false positive rates for blocked days occurring in the Euro-Atl sector (left) and the Pacific sector (right), in DJFs of 2012/13-2013/14 (dashed) and 2014/15-2015/16 (solid).

- NWP centres forecast timing of blocked days accurately for forecasts up to 7 days lead time.
- Met Office and KMA have similar hit rates when both models use the MetUM with NewDynamics (dashed lines). Met Office has consistently higher hit rates with ENDGame implemented (solid lines). False positive rates remain similar to those of KMA.
- Hit rates and false positives for ECMWF consistent for both sets of DJFs.

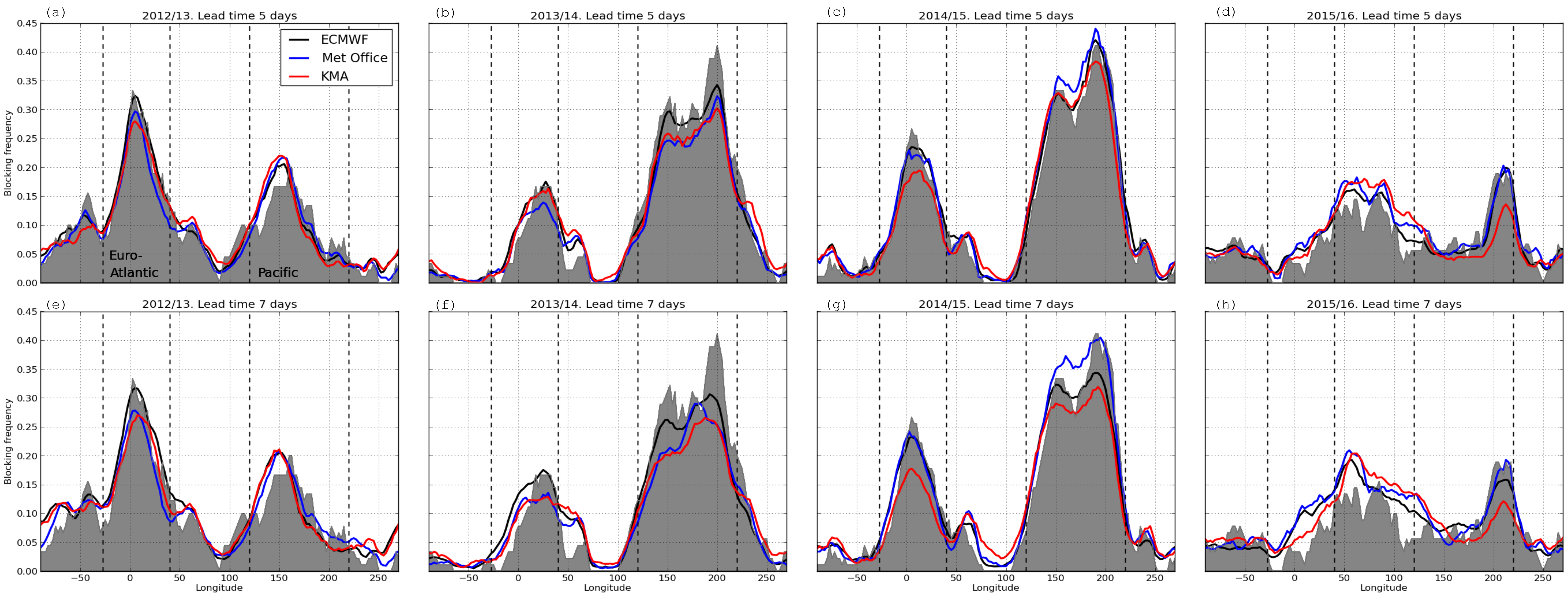

Figure 1: Blocking frequency for DJF (December-January-February) for ensemble mean forecasts and ERA-I. Forecasts with lead time 5 days (a-d) and 7 days (e-h) for 2012/13, 2013/14, 2014/15 and 2015/16. The dashed lines show the sectors most prone to blocking, the Pacific and Euro-Atlantic regions (labelled in (a)).

References

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Matsueda, M., 2009: Blocking predictability in operational medium-range ensemble forecasts. *Sola*, **5**, 113–116.

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*The Met Office upgraded to the ENDGame dynamical core before DJF 2014/15.

**Hit rate is defined as the probability that an event was predicted given that it occurred in the analysis. False positive rate is defined as the probability an event was not observed given that the event was predicted.

Conclusions

1. **The tendency for models to underpredict the frequency of blocking in DJF is consistent with a systematic reduction in upper-level Rossby wave ridge area with forecast lead time.**
2. **An improvement in the representation of upper-level Rossby waves with the introduction of the ENDGame dynamical core is consistent with an increase in the forecast of blocking frequency.**
3. **The prediction of the timing of blocked days has improved in the Met Office model with the introduction of the ENDGame dynamical core.**