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Discovering mechanisms behind forecast busts

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Overview

Our aim through this project is to gain a better understanding of what the mechanisms are behind forecast busts. These are poor forecasts, which can occur because of poorly represented processes in numerical weather prediction models. Despite huge progress in model development (Fig. 1), the influence of mesoscale convective processes on upper-tropospheric atmospheric flows can contribute to what is known as a forecast bust.

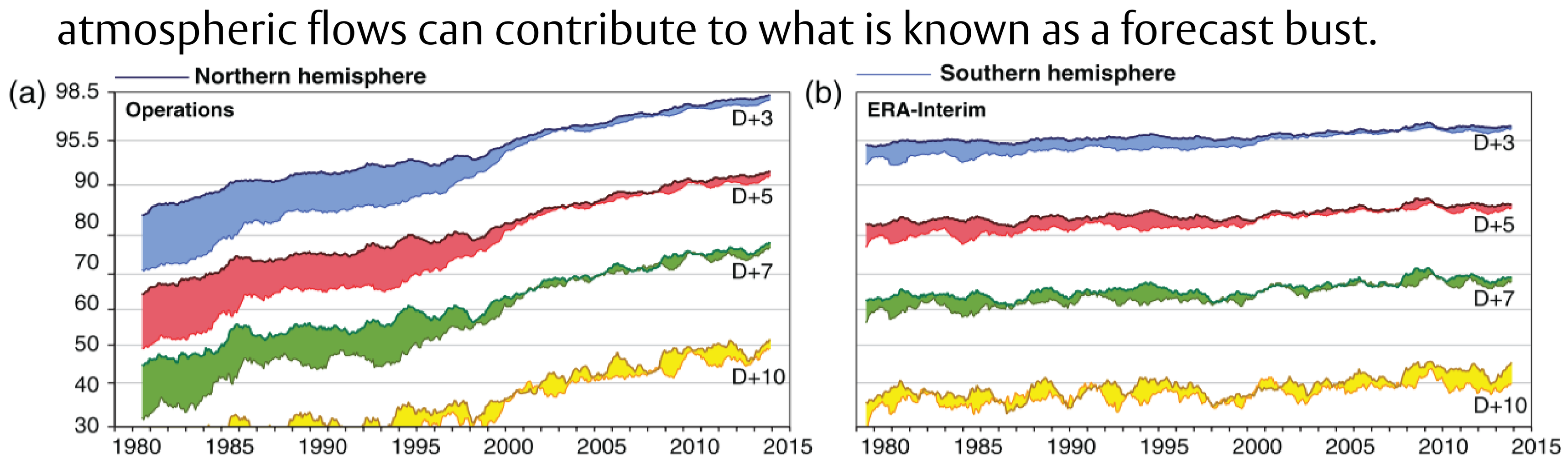

Fig. 1 12 month running mean of 500 hPa geopotential height (Z500) anomaly correlation coefficient (ACC) over the extratropical Northern and Southern Hemispheres for (a) operational ECMWF IFS forecasts and (b) ERA-Interim forecasts (from Lillo & Parsons, 2017)

Defining 'Forecast Busts'

One way of defining forecast busts is in terms of errors in the prediction of the geopotential height of the 500-hPa pressure surface (Z500). Figure 2 shows the errors in the day-6 high resolution (HRES) forecast of European Z500 for which a bust can be defined when there is a root-mean-square error (RMSE) greater than 60 m and an anomaly correlation coefficient (ACC) less than 40% (Rodwell et al., 2013). ACC represents a measure of how well the forecast anomalies have represented the observed anomalies. ACC and RMSE are defined as:

$$ACC = \frac{\sum_{i=1}^{N}(Z500_f - Z500_c)(Z500_a - Z500_c)}{\sqrt{\sum_{i=1}^{N}(Z500_f - Z500_c)^2}\sqrt{\sum_{i=1}^{N}(Z500_a - Z500_c)^2}};$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Z500_f - Z500_a)^2}$$

where, $Z500_f$, $Z500_a$ and $Z500_c$ are the forecast, analysed and climatological Z500, and N is the total number of grid points.

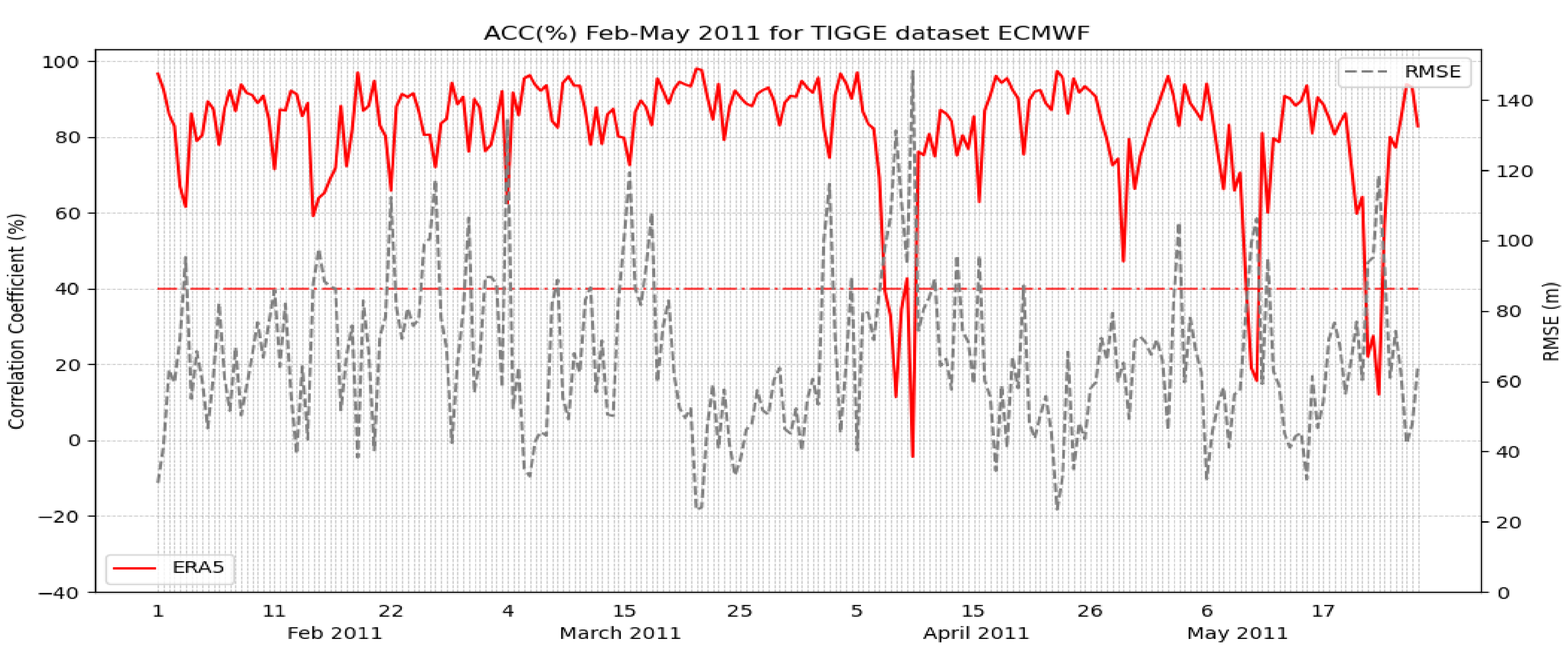

Fig. 2 Time series of (a) RMSE and (b) ACC for Z500 showing the bust case of 10 April 2011, 1200 UTC. The scores are calculated for 6-day forecasts over Europe (35°N–75°N, 12.5°W–42.5°E). The ERA5 climatology from 1989-2008 is used to calculate the ACC.

A Forecast Bust Case

The bust case presented here (Fig. 3) is from March 2014. The mean values for the HRES forecast over the two-month period are 86% for ACC and 72m for RMSE, but for the HRES forecast from 15 March at 0000 UTC the scores were 20% for ACC and 214 m for RMSE.

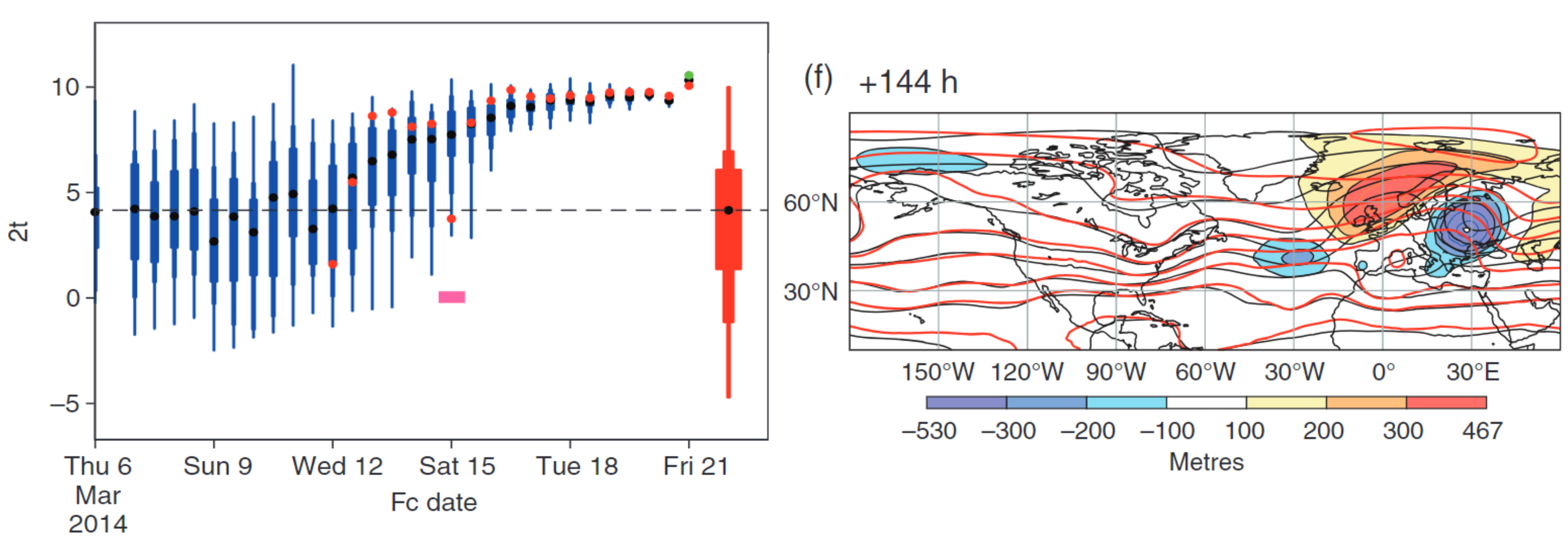

Fig. 3 Bust case on 15 March. (a) daily mean 2m temperature valid on 21 March over Germany, for the analysis (green dot), ensemble median (black dot) and probability distribution (blue box-and-whisker) and the HRES forecast (red dot) and (b) map of Z200 for the HRES forecast (black line), analysis (red line) and forecast error (shaded) for 15th March at 0000 UTC (from Magnusson, 2017).

Causes of Forecast Busts

Amongst various causes of a bust event, mesoscale convective systems forming over the continental US are a possible cause of European forecast busts. Initial conditions of poor forecasts are found to be linked significantly with these features over the United States.

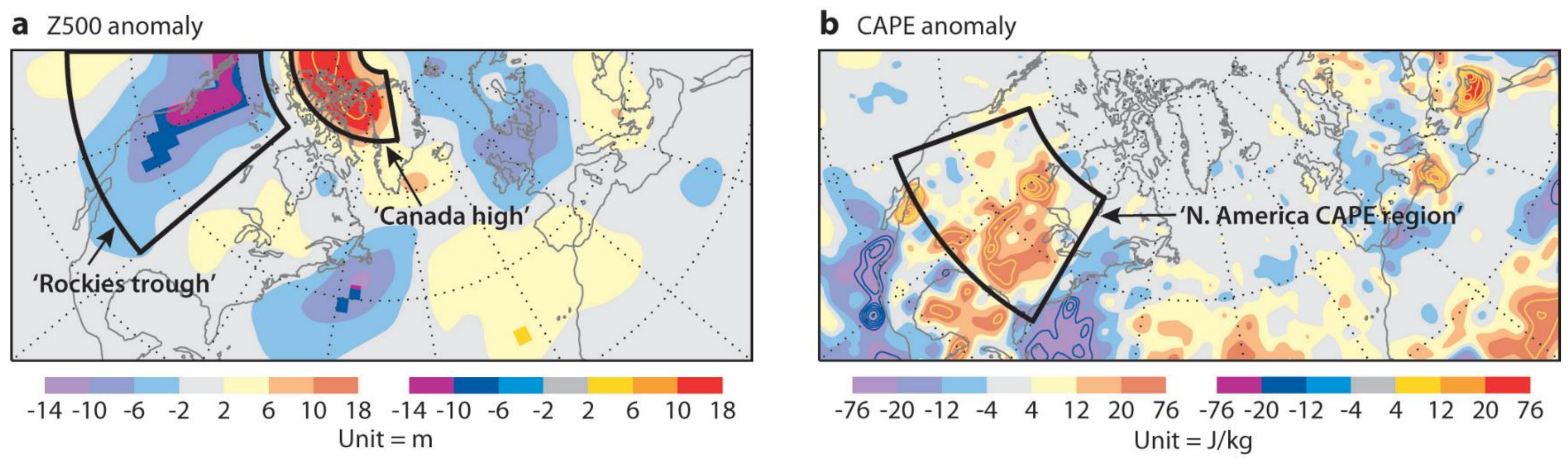

Fig. 4 The mean initial condition anomalies of (a) Z500 and (b) CAPE leading to the same forecast bust. The significant features in the Z500 mean are over "Rockies Trough" which might be embedded in an apparent Rossby wave covering the "Canada High". There is a coherent region of increased convective available potential energy (CAPE) over the US. The downstream effects of such MCS may cause a bust event over Europe (from Rodwell et al., 2013).

The similarities between the bust composite initial conditions (Fig. 4) and the forecast initial conditions on the day of the bust (Fig. 5) are striking. The low-level southerlies, just ahead of the Rockies trough, provide the high CAPE values, which implies the occurrence of deep convection, creating a favourable environment for development of MCSs.

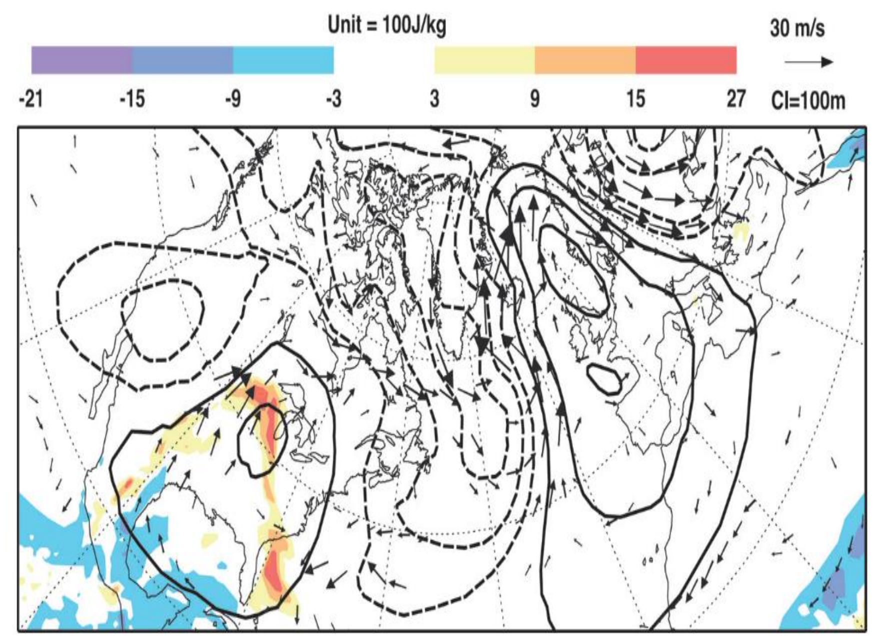

Fig. 5 Operational HRES anomalies of Z500 (contours), CAPE (shading), and 500-hPa wind (vectors) on the forecast bust day (from Rodwell et al., 2013)

Questions to be addressed in my PhD project

- What is the current annual rate of forecast bust events for different forecast models?
- If there is a progress in reducing the frequency of busts in the recent years, then how do different forecast models compare with each other?
- What is the impact of the changing climate (and so underlying climatology) on the forecast bust definition?
- After there is a recovery from a bust event, do the effects carry further into subsequent days? If yes, then how far?
- What marks an end of a forecast bust event? How much time is required to differentiate between two consecutive forecast bust events?
- What is the probability of a European bust event occurring when there is strong convective activity over US?

Conclusions

- Forecast Busts over Europe can be defined in terms of errors in 6-day forecast of Z500 height, where the errors are quantified by RMSE (>60m) and ACC (<40%).
- Poor medium-range forecasts for Europe are much rarer that they used to be, but even a single poor forecast can be problematic.
- Forecast busts are sometimes associated with the influence of mesoscale convective processes on larger-scale atmospheric flows.
- Apart from mesoscale convective systems, there are likely many possible causes of European busts and many ways in which a bust could be defined.

References

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- Rodwell, M.J., Magnusson, L., Bauer, P., Bechtold, P., Bonavita, M., Cardinali, C., Diamantakis, M., Earnshaw, P., Garcia-Mendez, A., Isaksen, L. and Källén, E., 2013. Characteristics of occasional poor medium-range weather forecasts for Europe. Bulletin of the American Meteorological Society, 94(9), pp.1393-1405.
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