A weather-system perspective on forecast errors

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This presentation investigates the linkage between forecast errors and specific weather systems and contributes to addressing the following questions: (i) How well can NWP models represent and predict certain weather systems (e.g., the track and intensity of a cyclone or the lifecycle of a Rossby wave?), and (ii) Are there specific weather systems involved in situations where forecasts errors are large?

In a first part (slides 3-12), a brief overview is given on previous studies quantifying the quality of forecasts of specific weather systems, i.e., tropical cyclones, extratropical cyclones, and Rossby waves (troughs and ridges). The results indicate a general improvement of forecasts during the last decades, the occurrence of cases with still large forecast errors, and a systematic tendencies of medium-range NWP forecasts to underestimate Rossby wave amplitudes, which is likely due to an underrepresentation of diabatic modification and transport of air from the lower troposphere into upper tropospheric ridges (Gray et al. 2014).

The presentation then focuses specifically on so-called warm conveyor belts (WCBs) – coherent airstreams in extratropical cyclones, which produce intense precipitation, latent heating, and lead to a net transport of low potential vorticity (PV) air into upper-level ridges. WCBs can be identified objectively by calculating air parcel trajectories and selecting those that ascend by more than 600 hPa in 48 h in the vicinity of a cyclone (e.g., Joos and Wernli 2012). Compared to climatology, the outflow regions near the jet stream of these WCBs constitute strong negative PV anomalies (Madonna et al. 2014), which can significantly affect the downstream flow evolution and, in certain cases, contribute to the formation of blocking (Pfahl et al. 2015). A specific PAL verification technique is then briefly introduced to quantify three aspects of the quality of WCB forecast: A, the amplitude of the WCB (number of strongly ascending trajectories); L, the location of the WCB outflow; and P, the amplitude of the associated upper-level negative PV anomaly (Madonna et al. 2015). It is shown that (i) all three components of WCB forecast errors increase with forecast lead time (slides 18,19), (ii) WCB forecasts of the high-resolution IFS improved over the last 15 years (slide 20), (iii) in today's forecast system no systematic over- or underprediction of WCB intensity occurs, and (iv) poor forecasts with a low anomaly correlation coefficients (ACC) are also associated with high values of PAL (red circles on slide 19). Finally, first results are shown from an ongoing master thesis project at ETH, in which WCBs are investigated in ECMWF ensemble forecasts. The Brier skill score for the occurrence of WCBs over the North Atlantic indicates fairly high values for 2-day forecasts (BSS > 0.5) and clearly reduced values for 5-day forecasts in particular in a band near 45ºN (BSS < 0.3, slide 23).

The final part of the presentation addresses the underlying meteorology of selected forecast bust events. Martinez-Alvarado et al. (2016) pointed to the importance of WCBs for correctly forecasting a high-amplitude Rossby wave evolution. Rodwell et al. (2013) also emphasized diabatic processes, in this case, MCSs over the eastern US, for European forecast busts (see also presentation at the workshop by Glenn Shutts on forecast errors induced by MCSs). Slides 27-50 then show preliminary results from an investigation of a forecast bust in October 2013. The ACC over Europe dropped below 0.2 at forecast day 5, leading to a too zonal flow in the forecast instead of a strong northerly flow in the analysis, which brought the first cold spell to Switzerland in 2013. Reasons for this poor forecast were (i) a slight mismatch in representation of a WCB over the eastern North Pacific, (ii) subsequently a missed reabsorption of an upper-level PV cutoff over North America (slide 41), and (iii) resulting from this a too weak Rossby wave amplification over the North Atlantic. Very interestingly, in this case the question whether a pre-existing PV cutoff is reabsorbed or not (a strongly non-linear process!) plays a crucial role for the downstream flow evolution. Systematically, the 10 best (worst) ensemble forecasts did (not) reabsorb the cutoff (slides 48,49) and this went along with a systematic shift of the upstream WCB outflow (slide 50).

In summary, this presentation tried to emphasize the following aspects:

1) It is meaningful to look at forecast errors from a weather system perspective. This requires the development of specific algorithms and metrics, which as a drawback involve some subjective decisions (e.g., what field should be taken to identify a cyclone?) and thresholds (e.g., what is the minimum lifetime of a cyclone?).
2) Research during the last years produced several promising results and emphasized the key role of the interaction of moist diabatic processes and the larger-scale flow evolution (e.g., role of latent heating in WCBs for evolution of cyclones and upper-level Rossby waves). It is likely that in certain cases deficiencies in the model physics negatively impact forecast quality, typically on the medium-range and downstream of the main diabatic activity.
3) Much needs to be done to more systematically investigate this pathway of research and to specifically identify critical aspects of model physics and its large-scale flow interaction.

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