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WCB characteristics and impacts and how they are interrelated in ERA5

Katharina Heitmann, Hanin Binder, Michael Sprenger, Heini Wernli, and Hanna Joos
ETH Zurich, IAC, Zürich, Switzerland (katharina.heitmann@env.ethz.ch)

The warm conveyor belt (WCB) transports moist air from low levels in the warm sector of an extra-tropical cyclone (ETC) as a coherently ascending airstream to the upper troposphere. WCBs are associated with an elongated cloud band and precipitation and were found to be responsible for 40-60% of the total precipitation in the midlatitude. Furthermore, the release of latent heat during cloud formation has the potential to modify potential vorticity (PV) below and above the level of maximum heating. Due to the modification of PV, WCBs can affect the synoptic-scale flow, e.g., by disturbing the jet stream on triggering Rossby waves in the upper troposphere, as well as the intensification of ETCs.

While the occurrence of WCBs has been studied from a climatological viewpoint before, the spatial distribution and temporal evolution of WCB characteristics and impacts, as well as the link between them, remain largely unknown. Therefore, we developed a novel method to quantify a set of WCB metrics that describe its characteristics (intensity, ascent rate, curvature, moisture content, position, and age relative to the cyclone evolution) and impacts (PV modification at low and upper levels, precipitation rate and volume). In addition, we considered the metric evolution along the whole lifecycle of the WCB. Applying this method in a case study, the WCB reached maximum intensity and ascent rate during the cyclone's strongest intensification. In terms of impacts, maximum precipitation rates decreased over the lifetime of the WCB, while maximum PV values at lower levels increased. We then extended the analysis to the 40-year time span 1980 - 2020 covered by ECMWF's most recent reanalysis ERA5, by calculating WCB trajectories globally for the entire period. Thereby, we were able to identify from a climatological viewpoint for the first time: (i) the global spatial distribution of WCB characteristics and impacts; (ii) the link between them; and (iii) their distinct lifecycle. This analysis showed that the characteristics and impacts of WCBs differ between different regions and seasons while the link between them remains largely constant. For instance, in the North Atlantic, we found two regions of enhanced WCB intensity which are also linked with enhanced precipitation volume. While the precipitation volume correlates strongly with the WCB intensity, the highest precipitation rates are associated with the most rapidly ascending WCBs. On a global scale, WCB-related low-level PV depends mainly on latitude, however, if restricted to a latitudinal band, inflow moisture becomes important.