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The Relationship between Warm Conveyor Belts, Tropical Moisture Exports and Atmospheric Rivers

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In the meteorological literature, different concepts exist that describe meso- to synoptic-scale filamentary features of enhanced absolute moisture content or moisture transport (sometimes vertically integrated), clouds and precipitation. These include Warm Conveyor Belts (WCBs), Moisture Conveyor Belts, Moisture Bursts, Atmospheric Rivers (ARs), Tropical Moisture Exports (TMEs), Tropical Plumes and Tropical Intrusions. These concepts – usually promoted by different research groups – deviate from each other by emphasizing different meteorological aspects. For some of these features clear objective identification criteria exist, but others are more loosely defined in a phenomenological way. Naturally, the boundaries between these concepts are not sharp, leading to – at least partly – coincidences in time and space or temporal succession of features. The emphasis on different meteorological parameters leads to differing geographical, seasonal and inter-annual variations in the frequency of these features.

This multitude of concepts and the lack of sharp boundaries and systematic comparisons have led to a certain level of confusion in the scientific community about each concept's specific definition, purpose and usefulness. In this contribution, we systematically clarify and quantify the relationships between ARs, TMEs and WCBs using the following objective identification methods: (a) ARs are filaments of high vertically integrated moisture and moisture transport, (b) TMEs consist of trajectories characterized by an intense horizontal export of tropical moisture into subtropical and mid-latitudes, and (c) WCBs are trajectories with a strong ascent in the vicinity of extratropical cyclones and their fronts. All analyses are based on 6-hourly ERA-Interim re-analysis data for the time period 1979–2014 interpolated to a regular 1°-by-1° grid with 60 vertical levels.

Despite comparable occurrence frequencies, coincidence between the three features (i.e. overlap in space and time) in individual cases is limited. For instance, in summer more than 60% of all AR grid points do not show overlap with either a TME or a WCB; in winter this value reduces to about 40%. The three features reveal a different and asynchronous seasonality: ARs are more frequent in summer, WCBs in winter and TMEs have a weak seasonality with a peak in summer. This reflects the generally enhanced humidity in the warm season (beneficial for ARs) and the stronger baroclinicity and large-scale forcing for ascent in the cold season (beneficial for WCBs). The most frequent overlap occurs between TMEs and ARs, the two features that highlight regions of strong horizontal moisture transport. That TMEs and ARs do not agree more closely is mainly because most ARs do not originate in the tropics. The strong ascent in WCBs and the associated condensation and rain-out are detrimental to the strong horizontal moisture transport required for ARs, and, therefore, WCBs are limiting the meridional extension of ARs. ARs most likely occur in regions with weak baroclinicity and weak large-scale ascent in contrast to WCBs.

Our findings show that TMEs, ARs and WCBs are related but by no means identical concepts of the atmospheric flow. They focus on different aspects of moisture transport and must not be used as synonyms.