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Subtropical air masses over eastern Canada: Their links to extreme precipitation

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We investigate extremely warm, moist air masses with an analysis of 850-hPa equivalent potential temperature (θe) extremes at Montreal, Quebec. The utility of using this metric is that it represents the thermodynamic property of air that ascends during a precipitation event.
We produce an analysis of the 40 most extreme cases of positive θe, 10 for each season, based upon standardized anomalies from the 33-year climatology. The analysis shows the cases to be characterized by air masses with distinct subtropical traits for all seasons: reduced static stability, anomalously high precipitable water, and anomalously elevated dynamic tropopause heights. Persistent, slow moving upper- and lower-level features were essential in the build up of high- θe air encompassing much of eastern Canada. The trajectory analysis also showed anticyclonic curvature to all paths in all seasons, implying that the subtropical anticyclone is crucial in the transport of high- θe air. These atmospheric rivers during the winter are characterized by trajectories from the subtropical North Atlantic, and over the Gulf Stream current, northward into Montreal. In contrast, the summer anticyclonic trajectories are primarily continental, traveling from Texas north-northeastward into the Great Lakes, and then eastward into Montreal.
The role of the air mass in modulating the strength of a precipitation event is addressed with an analysis of the expression, P = RD, where P is the total precipitation, and R is the precipitation rate, averaged through the duration, D, of the event. Though appearing simple, this expression includes R, (assumed to be same as condensation, with an efficiency of 1), which may be expressed as the product of vertical motion and the change of saturation mixing ratio following a moist adiabat, through the troposphere. This expression for R includes the essential ingredients of lift, air mass temperature, and static stability (implicit in vertical motion). We use this expression for precipitation rate to study the extreme precipitation events in Montreal that are associated with these same cases of extreme warm, moist air masses, and their physical impacts on the precipitation rate.
Implications of this air mass modulation on precipitation rate are discussed in the context of longer-term global climate change.