A precipitation climatology based on the quasigeostrophic omega equation

What is a precipitation event? Despite numerous studies on precipitation events, such studies often separate events based on somewhat arbitrary and inconsistent temporal criteria. Therefore, we propose a more objective and physically grounded methodology for defining and separating precipitation events based on the quasigeostrophic (QG) omega equation. The QG-omega equation can be used to diagnose vertical motion in the atmosphere based on the expected temperature and vorticity advections relative to the positions of the upper-level and low-level cyclones and anticyclones. Based on the QG-omega equation, tropospheric waves can be divided into four quadrants depending on whether unambiguous ascent (both temperature and vorticity advections are positive), unambiguous descent (both temperature and vorticity advections are negative) or ambiguous vertical motions (temperature and vorticity advections compete) are expected. Because ascent is necessary for the production of precipitation, we separate precipitation events based on the identification of these four quadrants from the 500-hPa geopotential heights. For the period from 1979-2018, we identify 6230 quadrant-based precipitation events (where $\geq 0.2$ mm falls) in Montreal, Quebec. We find that precipitation events in the 90th percentile account for approximately 10% of all precipitation events but make up 40-45% of the cumulative 1979-2018 total precipitation in Montreal. As predicted, precipitation events in the unambiguous ascent quadrant (which lies downstream of the upper-level and low-level cyclones and upstream of the upper-level anticyclone) contribute most to the total precipitation in Montreal and are also the most intense in all seasons. Conversely, precipitation events in the unambiguous descent quadrant contribute the least to the total precipitation in Montreal and are the least intense. Finally, we find that annual and winter (DJF)
precipitation is significantly increasing on the whole, and specifically, in the quadrants where warm air advection is expected.