Geophysical Research Abstracts, Vol. 4, on CD-ROM 2003

Three late summer cases of tropical-extratropical interactions causing precipitation in northwestern Africa

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ABSTRACT: Several stations in northwestern Africa, in particular in the semi-arid to arid zone south of the Atlas mountains, receive significant contributions to their annual rainfall amounts from rainy episodes in late summer/early autumn. Three of such cases in September 1988 and 1990 and August/September 1999 are studied with respect to the sources and ways of transport of moisture, anomalies in the upper-level flow, such as position and speed of the Subtropical Jet (STJ), and the associated vertical profiles of divergence and vertical velocity. Beside station reports of precipitation, European Center for Medium-Range Weather Forecast (ECMWF) analysis and re-analysis wind and moisture data and METEOSAT water vapour images are considered. All three cases clearly reveal tropical-extratropical interactions. By the use of trajectory analysis, convective centers over tropical Africa and the adjacent Atlantic Ocean, where moisture is transported from the low-level moist monsoon layer into middle and upper levels, could be identified as moisture sources for the considered rainy episodes. This moisture is then advected northwards ahead of an upper-level subtropical trough, that extends to the northern edge of the Inter-Tropical Convergence Zone (ITCZ). The ITCZ is at its northernmost position at that time of the year. Most of the transport is found between 700 and 400 hPa and thus mostly above the dry Saharan Planetary Boundary Layer (PBL). Triggered by upper-level divergence ahead of the trough, orographic lifting at the Atlas mountains in the southerly flow and surface heating of areas above the stabilizing trade wind inversion, convective rainfalls occur, preferably close to and downwind of the mountain chain. The maximum convergence is observed between 600 and 500 hPa. Precipitation intensities are mostly small to moderate, since parts of the rain evaporate on the way down through the relatively deep and dry PBL, but in some occasions events of more than 20 mm in 12 hours are observed. In spite of the basic similarities between the three cases, some differences are observed, if details are considered. The moisture source is in some cases related to convection or even squall lines associated with African Easterly Waves (AEWs), in others to `normal' ITCZ convective clusters. While in the 1990 case the upper-level trough remains quasi-stationary west of the African continent over the whole 12 days period, in the 1988 case a trough line connecting the ITCZ and the subtropics travels westward parallel to a low-level AEW. Large amounts of moisture from the wave's convection are transported northward at its eastern edge. At the end of this episode, the tropical air is displaced by polar air causing some major rainfall events. In the 1999 case the moisture export from the tropics is initiated by a wave in the upper-level Tropical Easterly Jet (TEJ), that travels northwestward merging with an extratropical trough west of the African coast. Having moved over the Atlantic, the wave transports moisture northward, that is then advected into northwest Africa by an eastward moving extratropical trough.