**3B.1**

# TROPICAL-EXTRATROPICAL INTERACTIONS CAUSING PRECIPITATION IN NORTHWEST AND WEST AFRICA: PART I: SYNOPTIC EVOLUTION AND CLIMATOLOGICAL RELEVANCE

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## 1. INTRODUCTION

The synoptic evolution of a particular type of tropical-extratropical interaction and its relevance for precipitation in subtropical northwest Africa and tropical West Africa will be presented by means of case studies of three significant precipitation events [September 1990 (Knippertz et al. 2003) and March/April 2002 (Fink and Knippertz 2003) in Morocco/Algeria; January 2002 in Senegal/ Mauritania]. A climatological study based on 20 years of twice-daily trajectories by Knippertz (2003) revealed that such cases contribute up to 40% of the annual precipitation in the semiarid southern foothills of the Atlas Mountains, in contrast to the extratropical winter-rain dominated regions along the Atlantic and Mediterranean coasts in northwest Africa. Part of the presented research was achieved within the German multi-disciplinary research project IMPETUS (An integrated approach to the efficient management of scarce water resources in West Africa). The paper is followed by a companion investigation (3B.2) on the large-scale upper-tropospheric dynamics that lead to a succession of two deep upper-level troughs to the west of West Africa, which is instrumental for the production of record precipitation in the two 2002 cases.

## 2. RESULTS

The analysis of three late summer/early autumn precipitation events affecting northwest Africa by Knippertz et al. (2003) reveals the following common synoptic features: (a) an upper-level trough in the subtropics that extends into the tropical belt, (b) a subtropical jet (STJ) streak at the eastern flank of the trough, (c) a mid-level moisture transport from the deep West African/East Atlantic Tropics, and (d) a forcing of rainfall due to dynamical lifting under the inflection point of the STJ and daytime heating of elevated terrain. Knippertz et al. (2003) noted that, although dynamical characteristics of 'classic' tropical plumes (TP; McGuirk et al. 1987), are fulfilled by these cases, the cloud bands associated with the STJ streaks often appear too broken or scattered in infrared (IR) satellite imagery, and/or are too short to meet the requirements of McGuirk et al.'s TP definition. Nevertheless, the moisture transports from the Tropics to the subtropics are clearly detectable in water vapor imagery or through trajectory analysis. Consequently it appears more appropriate to designate the considered cases 'moisture bursts' than TPs. A typical example of such a rainy episode occurred between 09 and 20 September 1990 (Case I in Knippertz et al. 2003). During this period, two phases of active afternoon convection were observed. Even though accumulated precipitation amounts only ranged between 2 and 30 mm, the frequent occurrence of such rainfall situations at this time of the year contribute considerably to the annual precipitation at arid stations along the Saharan foothills of the Atlas Mountains.

A more extreme example for tropical-extratropical interactions affecting precipitation in northwest Africa is the heavy rainstorm that moved from the hyper-arid northwestern Sahara into the High Atlas between March 30 and April 01, 2002 (see Fink and Knippertz 2003). The 72 mm it caused at the Moroccan town of Ouarzazate corresponded to 62% of the annual average, the highest daily accumulation measured since at least September 1977. In contrast to the summer cases described above, IR satellite images reveal that the rainfall event began when a classic TP, stretching across the (sub-) tropical Atlantic, reached northwest Africa. A main factor for precipitation generation over north-western Africa appeared to be the uplift associated with the strong upper-level divergence at the inflection point of the trough, accompanied by an equally strong convergence of moist air at mid-levels that originated from the West African Tropics near the Guinea Coast. Orographic lifting at the Atlas range in the southwesterly to southerly flow and uplift through cross-frontal circulations during frontogenesis presumably further enhanced precipitation. Surface heating appeared to have played a minor role. The upper-level trough responsible for the extreme event was preceded by a comparably potent trough in nearly the same location to the west of northwest Africa 3–5 days earlier (Fig 1, right panels). While the first trough did not produce significant precipitation [Fink and Knippertz (2003) noted several light rain events at hyper-arid stations in the central and western Sahara] it initiated a mid-level poleward transport of moisture from the African Tropics as revealed by trajectory analysis. Thereby the first trough modified the thermodynamic environment upon which the vertical motion field of the next wave could act. Vertical soundings of equivalent potential temperature $\theta_e$, and relative and specific humidity to the southeast of the two upper-level troughs that have been produced by nudging the UW-NMS model at 75 km horizontal grid resolution with ECMWF

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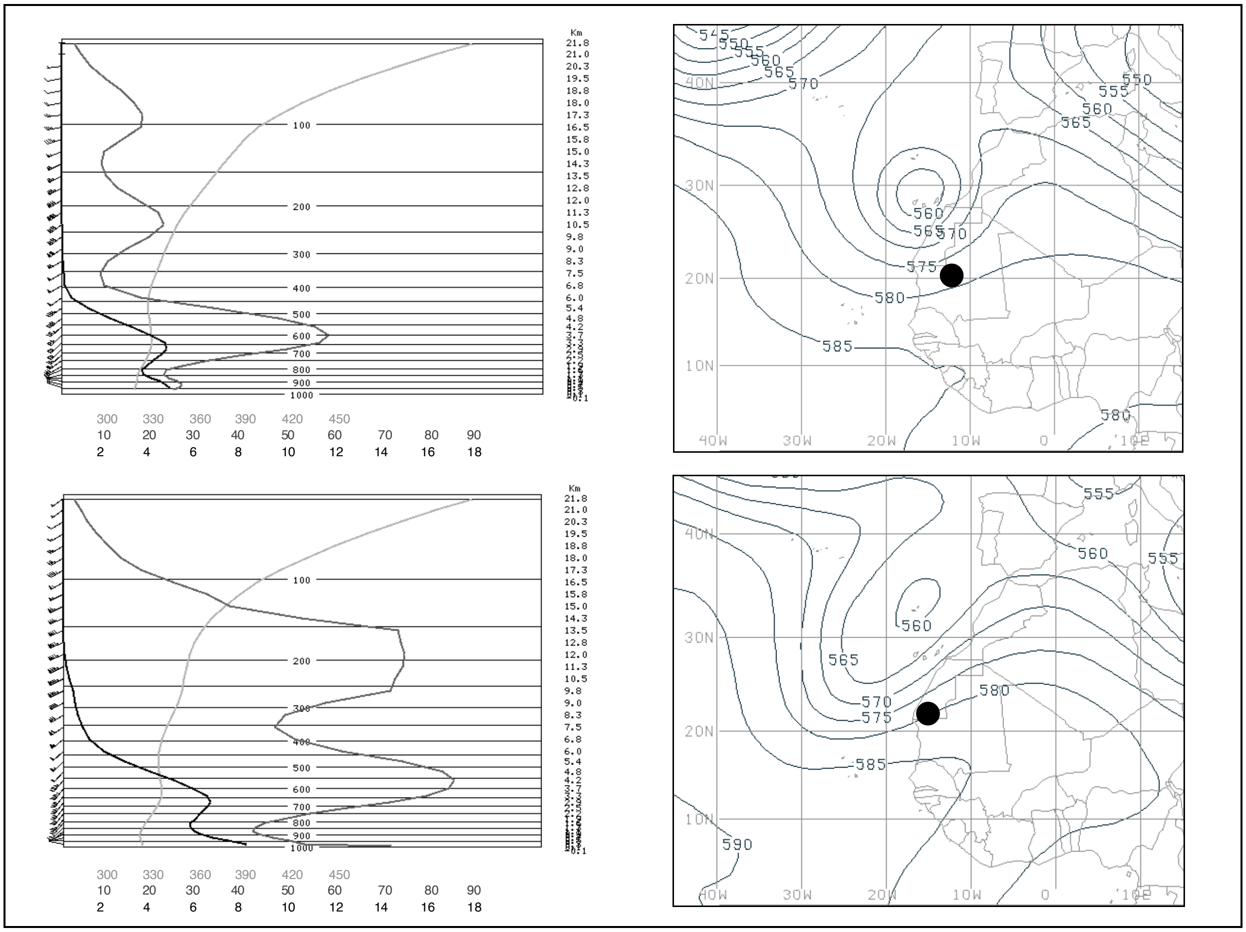


FIG. 1. Left: Vertical profiles of equivalent potential temperature $\theta_e$ (K; light gray), and relative (%; gray) and specific humidity (g/kg; black); right: 500hPa geopotential height (gpdm) for 6 UTC on 27 (upper panels) and 31 March 2002 (lower panels). The black dots indicate the position of the vertical profiles.

gridded analyses are shown in Fig. 1 (left panel). While the thermodynamic environments of both troughs are characterized by potential instability around 650hPa, indicated by the decrease of $\theta_e$ with height and caused by the import of tropical moisture at mid-levels, only the second trough finds sufficiently high absolute and relative moisture contents to release this instability through dynamically generated ascend. Radiosonde ascents from Tindouf (Algeria; see Fink and Knippertz 2003) equally show indications of potential instability. The existence of the TP is reflected by high relative humidity at 200hPa in Fig.1 (bottom left panel).

Another example of extreme rainfall in connection with tropical-extratropical interactions occurred in Senegal and Mauritania in the West African Tropics between 09 and 11 January 2002. The event with up to 116 mm accumulated rain (in Podor, Senegal) in the middle of the dry season (January average $<$ 2 mm) had dramatic socioeconomic impacts (50 casualties, large losses of livestock and seeds, destruction of infrastructure). In analogy to the case described above, a succession of two subtropical troughs and water vapor advection from the northern margin of the ITCZ causing potential instabilities over West Africa were instrumental in producing the record breaking dry season rains. Again a classic TP was observed over West Africa during the event.

## 3. REFERENCES

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