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Large-scale circulation and Moroccan precipitation variability: Past and future.

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ABSTRACT: Precipitation data from the Global Historical Climatology Network for 42 stations in Morocco, Western Algeria and Northern Mauritania from the 19th and 20th century is investigated on a monthly mean basis with respect to storm track and cyclone activity, moisture transports, North Atlantic Oscillation (NAO) variations and different weather types (Großwetterlagen) by means of correlation and composite studies. The results are connected with a climate change scenario from a transient greenhouse gas (GHG) simulation with the ECHAM4/OPYC3. With respect to observations the north-western parts of Morocco show a clear relation between precipitation and the position of the North Atlantic storm track during boreal winter (DJF). In months with high amounts of precipitation a southward to south-westward shift of the eastern end of the North Atlantic storm track with a maximum enhancement west of the Iberian Peninsula is found, which is accompanied by more southerly tracks of Atlantic cyclones and an enlarged local cyclone activity north of Morocco and in the western Mediterranean. Both upper and lower tropospheric baroclinicity is enhanced south of 45°N over the Atlantic and the Mediterranean in these situations, whereas baroclinicity is reduced over the northern North Atlantic and north-western Europe. The strong westerly winds, that are associated with cyclones close to the Iberian Peninsula and their accompanying fronts lead to a strongly enhanced moisture transport from the Atlantic into Morocco in the lower troposphere. Consequently, the correlation between north-western Moroccan precipitation and westerly circulation weather types (after Lamb) is high. Since sea level pressure is below normal west of the Iberian Peninsula and over the western Mediterranean in high precipitation months, a negative correlation to the North Atlantic Oscillation (NAO) is found. Nevertheless, the use of different southern poles of the NAO leads to considerable differences in the strength of the relation. While a NAO index calculated from the pressure difference between Gibraltar and Iceland explains up to 60% of the rainfall variance in some months at some stations, an index based on the subtropical centre in Ponta Delgada (Azores) accounts only for up to 36% of the rainfall variance. Very similar, but slightly southward shifted patterns could be identified for the southern Moroccan Atlantic Coast and the Moroccan Highlands north of the Atlas Mountains. Precipitation in north-eastern Morocco and north-western Algeria and in the region south of the Atlas, however, appear to be somewhat more independent of the Atlantic storm track activity and the NAO and stronger related to local cyclone and convective activity. Nevertheless, a strong moisture transport from the Atlantic along the southern flank of the Atlas Mountains associated with cyclones west of Morocco and the Iberian Peninsula can be identified as a decisive factor for precipitation in this region. In contrast to that, north-eastern Morocco and north-western Algeria is dominated by the influence of cyclones in the western Mediterranean that are associated with enhanced baroclinicity over northern Africa and the Mediterranean and

that lead to locally increased storm track activity and a strong north-westerly moisture transport into this area. Relative to the control experiment the results from a 240 year transient GHG simulation with the ECHAM4/OPYC3 reveal a northward displacement of the storm track and cyclone activity over the eastern North Atlantic that is accompanied by a distinct reduction in upper level baroclinicity and low-level zonal wind speed south of 45°N over the Atlantic and the Mediterranean and increased mean sea-level pressure over western Europe. According to our analysis of the observed relationship between the large-scale circulation and Moroccan precipitation, the changes simulated by the ECHAM4/OPYC3 strongly suggest decreasing precipitation for most of the country with potential serious impacts for the future water supply.