Background Climatology for the Atmospheric Radiation Measurement Program Mobile Facility Deployment in Niamey: Mean Annual Cycle and 2004-2005 Interannual Variability

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Abstract

This study is comprised of two parts. The first part provides the long-term mean annual cycle context for the deployment of Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF) in Niamey, Niger, Africa, during the entire year of 2006. Documentation includes the annual cycles (calendar month basis) of the following surface meteorological variables that will be important for the ARM deployment–rainfall, visibility (proxy for atmospheric dust), vapor pressure (proxy for column precipitable water), daily maximum and minimum temperature, dew point temperature, and relative humidity. These annual cycles illustrate the strong control of rainfall on the other surface parameters. This theme is further developed in the second part of the poster that presents the annual cycles of the same parameters for the highly contrasting years of 2004 (moderately dry) and 2005 (moderately wet). The 2005 wetness likely reduced the effects of atmospheric dust on the AMF measurements made in Niamey in the early months of 2006.

Introduction

The Atmospheric Radiation Measurement (ARM) Program is one of the largest global climate change research programs supported by the U.S. Department of Energy. A primary objective of the program is to improve scientific understanding of fundamental physics related to interactions and feedbacks between clouds and radiative processes in the atmosphere. To broaden the ARM observational base, the ARM Mobile Facility (AMF) now is deployed in Niamey, Niger, Africa, where extensive measurements are being made during all of 2006. In this paper, we provide a background climatology context for the

AMF deployment in Niamey through analysis of the long-term mean annual cycles of important climate parameters. The same analyses also are presented for the two most recent and highly contrasting years: 2004 (moderately dry) and 2005 (moderately wet).

Objectives

For all of 2006, the AMF will be deployed in a West African semi-arid monsoon climate in contrast to the climate settings in which ARM has operated for 13 years. In addition, the deployment will coincide with the first field phases and special observing periods of the African Monsoon Multidisciplinary Analysis (AMMA) Project. The purposes of our analyses are to:

- provide background information on local climate to help the AMF field staff operate delicate instruments in Niger's extreme weather; and

- inform the atmospheric science community of the climate conditions for which the AMF data are being collected from Niamey.

Results

Seasonal Rainfall

The annual cycle of rainfall (Figures 1a-3a) controls or is closely associated with annual cycles of all other parameters portrayed. The ramping up of the rainy season is considerably more gradual than its quite abrupt cessation. It is also evident that the rainy season was much wetter in 2005 than 2004. Unfortunately, the above average rainfall in May-July 2005 was not sustained through August-September. However, October 2005 was extremely wet compared to the long-term mean and 2004 when no rainfall was recorded for the entire month.

Daily Maximum and Minimum Temperature

Figures 1b-3b show the long-term mean and 2004-2005 average daily temperatures. Two peaks of temperatures are observed. The first, at the very end of the dry season (April-May), occurs when there is little cloud cover and the soil is bone dry. Temperatures decrease after the rains start and continue to decrease through August because of increased cloud cover and significant evapotranspirative cooling that is made possible by the replenished soil moisture. These temperatures rise again at the end of the rainy season (September) as cloudiness and soil moisture decrease before declining to a January minimum forced by the reduced winter solar radiation.

Vapor Pressure and Visibility

Vapor pressure (Figures 1c-3c) is used as a proxy for total column precipitable water (vapor) with which it has a strong linear relation. Visibility is used as a proxy for the atmospheric dust loading (note the inverted visibility scale). The inverse relation between these two crucial radiative transfer parameters is very clear, as are their opposite associations with the monsoon rainfall.

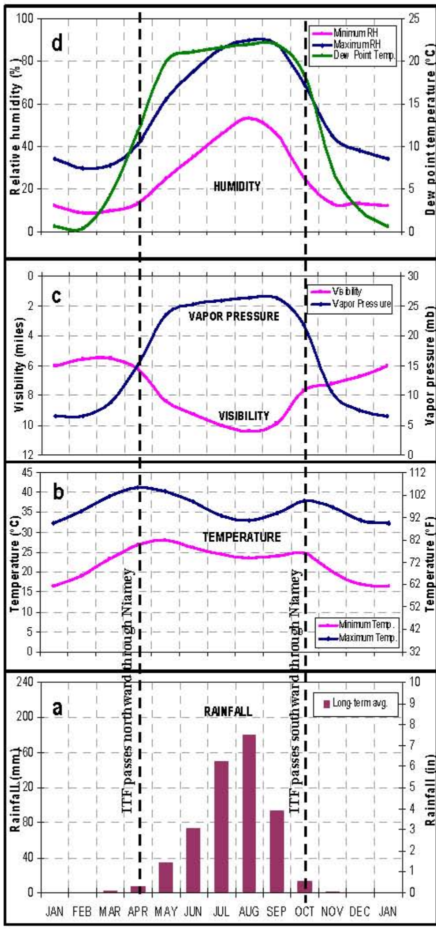


Figure 1. Long-term average annual cycles of climate parameters relevant for deployment of the AMF at Niamey Airport.

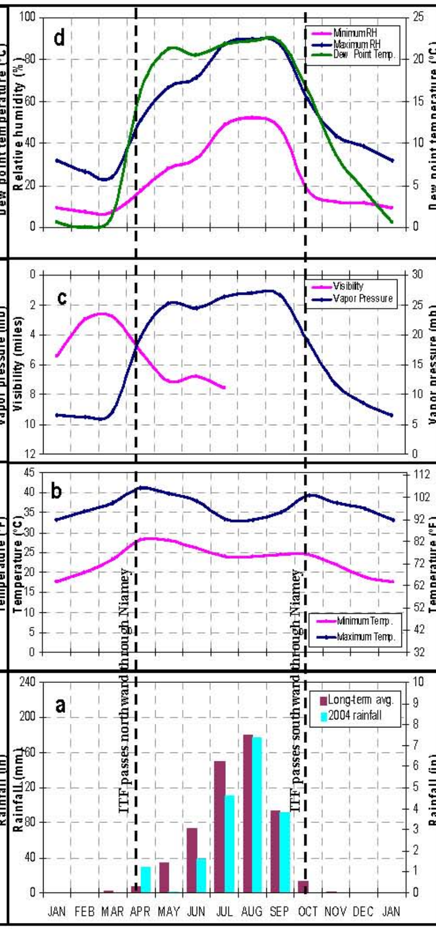


Figure 2. 2004 annual cycles of climate parameters relevant for deployment of the AMF at Niamey Airport.

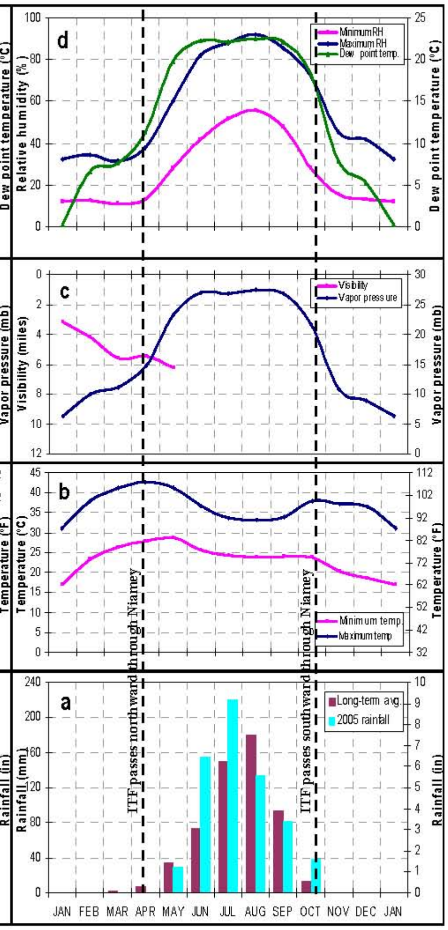


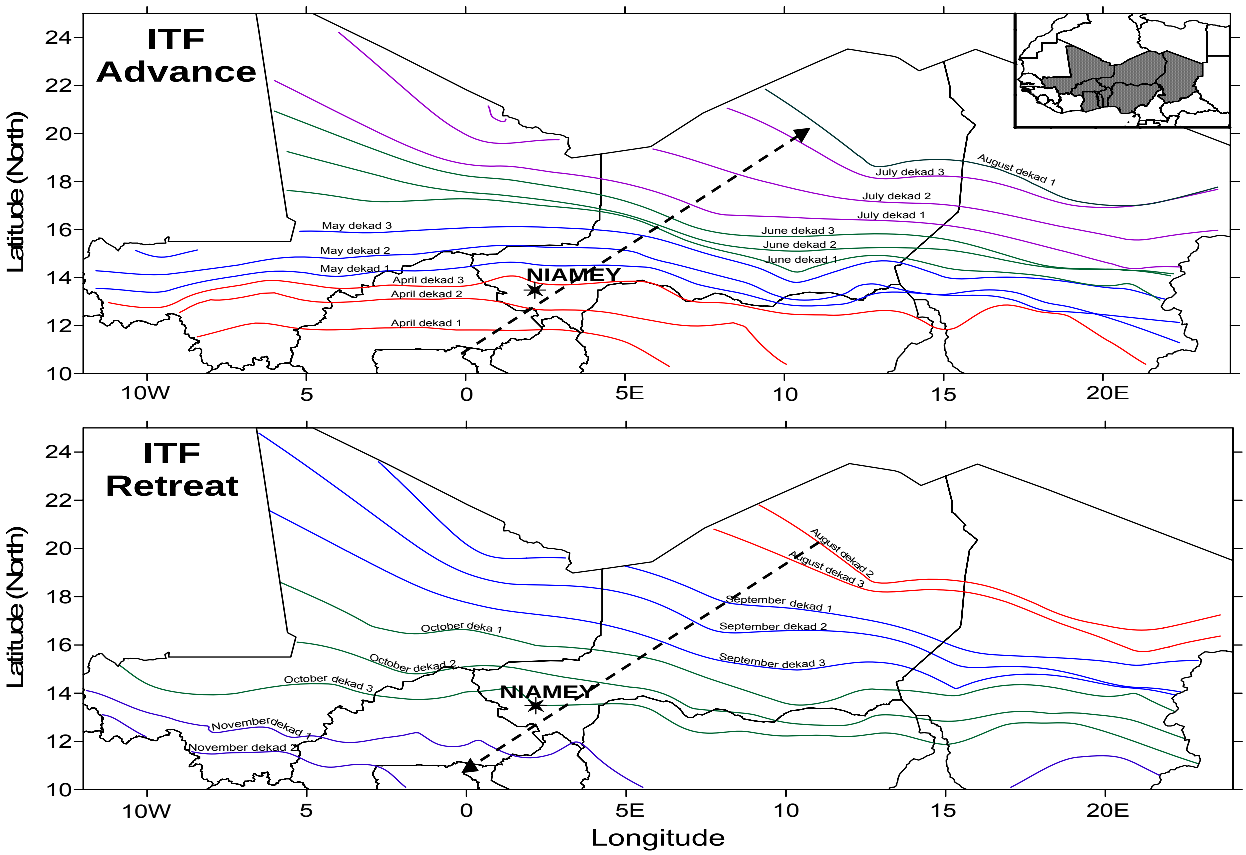
Figure 3. 2005 annual cycles of climate parameters relevant for deployment of the AMF at Niamey Airport.

Maximum and Minimum Daily Relative Humidity

The daily maximum relative humidity tends to occur when temperature minimizes early in the morning, while daily minimum relative humidity is associated with the mid-afternoon maximum temperature. Their annual cycle profiles (Figures 1d-3d) are very similar to that for vapor pressure, featuring a pronounced increase/decrease at the start/end of the rainy season and an intervening plateau indicating the conservative nature of Sahel surface water vapor during the rainy season.

InterTropical Front

Figure 4 shows the long-term mean position of the InterTropical Front (ITF) or InterTropical Discontinuity for 10-day (dekad) periods during April-November. This is the northern edge of the airflow from the tropical Atlantic Ocean. The long-term average ITF passes northward through Niamey in mid-April, about two months before significant rain occurs there, and retreats southward through Niamey in late October, about a month after significant rain ceases there. The further the ITF advances/lies north of the Niamey, the thicker is the monsoon air layer above Niamey and the more it is able to support convective rain in the Niamey vicinity. The slow advance and rapid retreat of the ITF are consistent with the seasonal rainfall characteristics noted already.



moist southwesterly surface monsoon

Figure 4. Long-term dekad average position of West African InterTropical Front (ITF, 1974-2003) for the northward excursion phase (top panel), and the southward surge (bottom panel). ITF appears north of 10°N for the first time in early April and retreats completely below 10°N in mid-November. Note here the abrupt southward surge of the ITF (bottom panel) compared to the more gradual northward advance (top panel).

Normalized April-October Rainfall Departures

Figure 5 shows the normalized April-October rainfall departure (σ) for Niamey from 1941-2005. Clearly, the 2005 summer was substantially wetter than 2004, but not as wet as several other years since the mid-1980s drought maximum and less than half as anomalously wet as most years in the 1950s. Although the above average rainfall in May-July 2005 was not sustained through August-September, significant October rainfall contributed further to increasing the magnitude of the positive departure for the overall season (Figure 3a). As a result, 2005 is the 15th wettest year among the entire 65 years in Figure 5, compared to 2004 which was the 18th driest year. This substantial rainfall improvement from 2004 to 2005 likely reduced the effects of atmospheric dust on the AMF measurements made in Niamey in the early months of 2006.

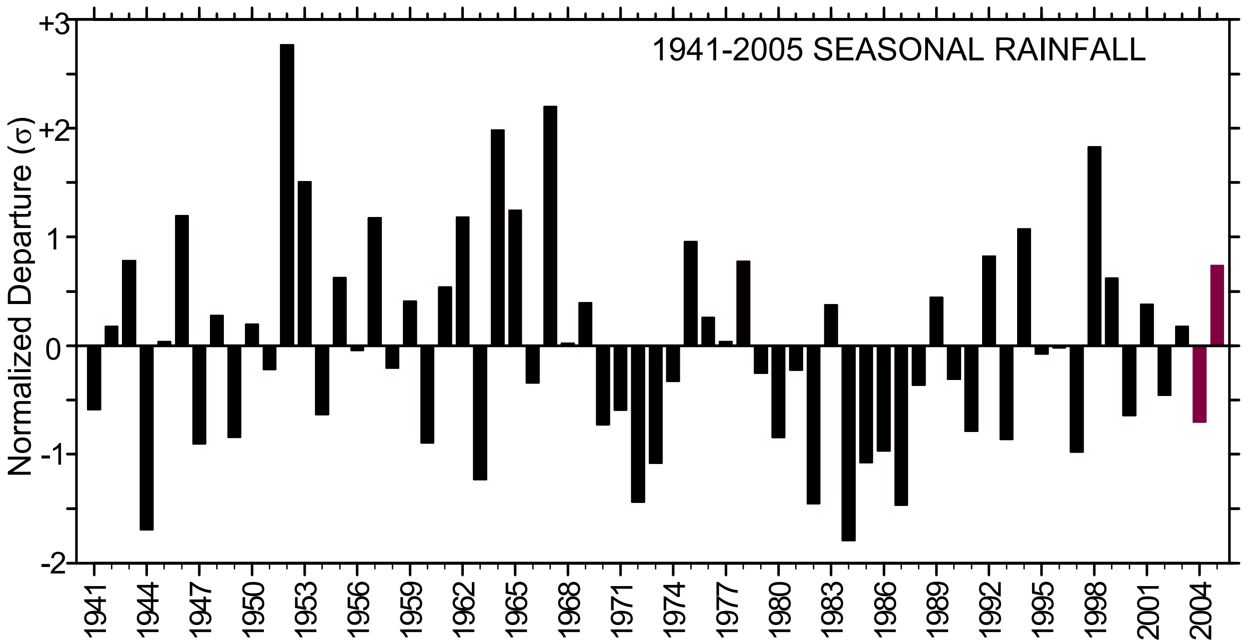


Figure 5. Time series (1941-2005) of normalized April-October rainfall departures (σ) for Niamey Airport (Niger).

Conclusion

The AMF deployment in Niamey for all of 2006 is an important component of the AMMA project. The goal of AMMA is to improve of our understanding of the West African Monsoon and its influence on the physical, chemical, and biological environment regionally and globally. Because North Africa is the world’s major source of mineral dust aerosol, data from AMF site in Niamey will document the interplay between the Sahara dust and monsoon moisture, which should be enlightening for both the ARM and AMMA Programs.

Acknowledgements

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