Annual Variations in the Surface Energy Balance of the Sahel

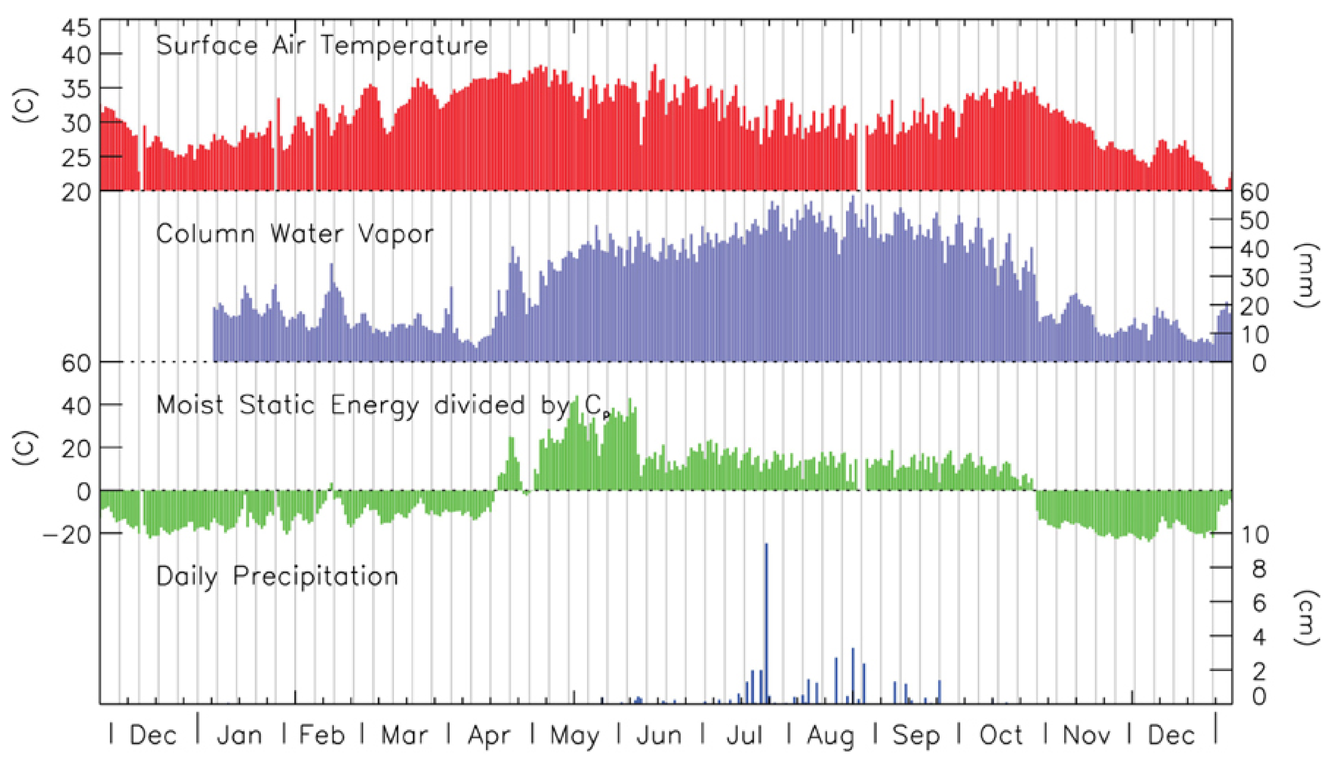
Ron L. Miller

NASA Goddard Institute for Space Studies,

Dept of Applied Physics and Mathematics, Columbia University

Introduction

- Over most of the world ocean, heating of the surface by sunlight is balanced predominately by evaporative cooling. Even over land, moisture for evaporation is generally available from vegetation or the soil reservoir. However, at the ARM Mobile Facility in Niamey, Niger, soil moisture is so limited that evaporation makes a significant contribution to the surface energy balance only at the height of the rainy season, when rainfall has replenished the soil reservoir. In the absence of significant evaporation, heating of the surface by sunlight must be balanced by longwave radiation and the sensible heat flux.
- **We use measurements at the ARM Mobile Facility from late 2005 through 2006 to consider how heating at the surface by sunlight is balanced during the dry and rainy seasons.** This has implications for the climate impacts of aerosols.



Seasonal Variations in Climate

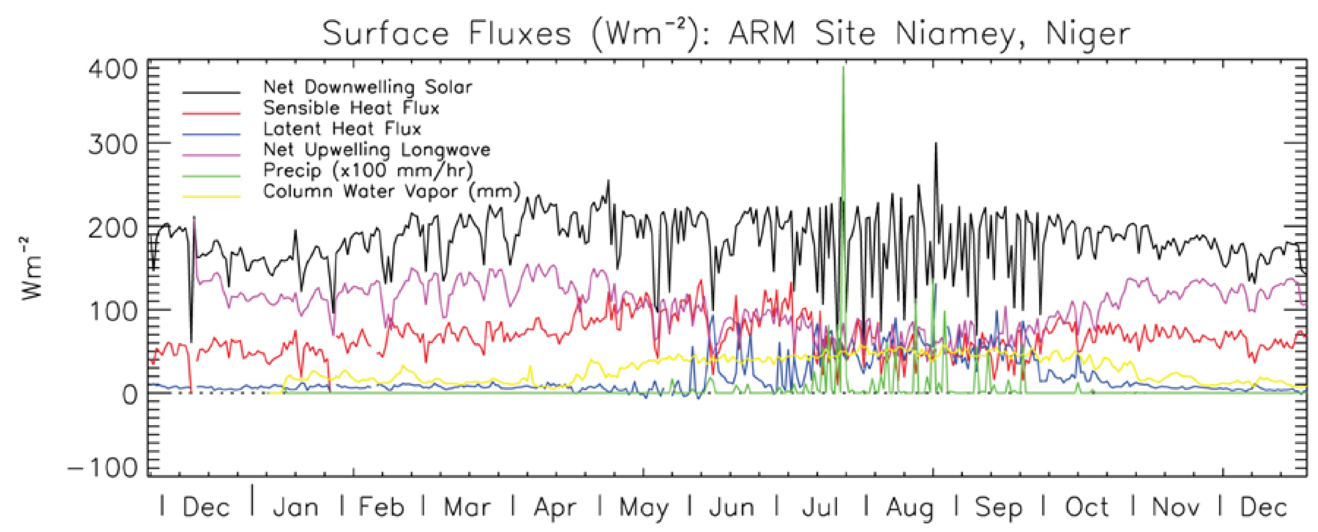
The climate at Niamey can be divided into two seasons:

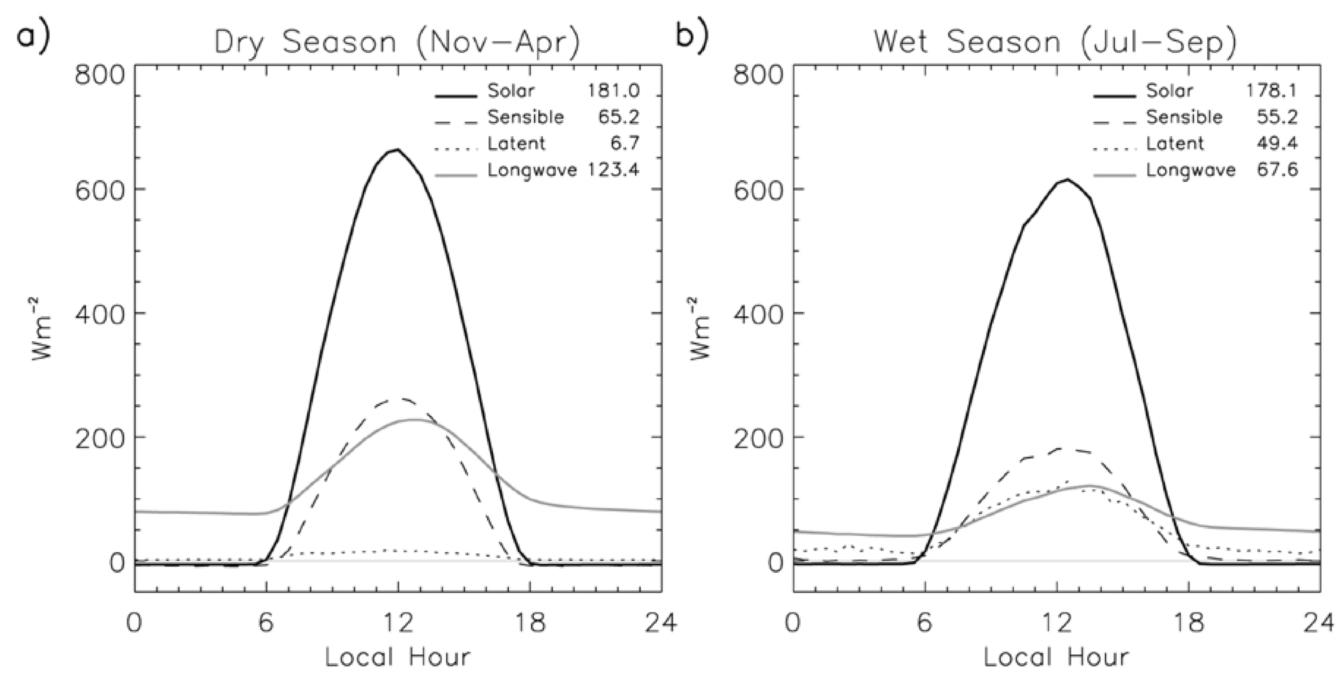
Dry Season (Nov-Apr): Northeasterly Trade winds carry dry, continental air toward the Atlantic ITCZ.

Rainy Season (May-Oct): Southwesterly winds carry moist air inland. This season is marked by high column-integrated water vapor and moist static energy.

Data

The ARM Mobile Facility is distinguished by its ability to provide measurements of all the surface energy fluxes simultaneously throughout an entire seasonal cycle. Turbulent fluxes, along with surface air temperature and moisture, are from eddy correlation flux measurements. Radiative fluxes are from sky radiometers. Four times daily radiosondes provide column moisture.





Surface Energy Balance

Dry Season: Solar heating is balanced mainly by longwave radiation, which can efficiently cool the surface because the greenhouse effect is small in the absence of significant column moisture.

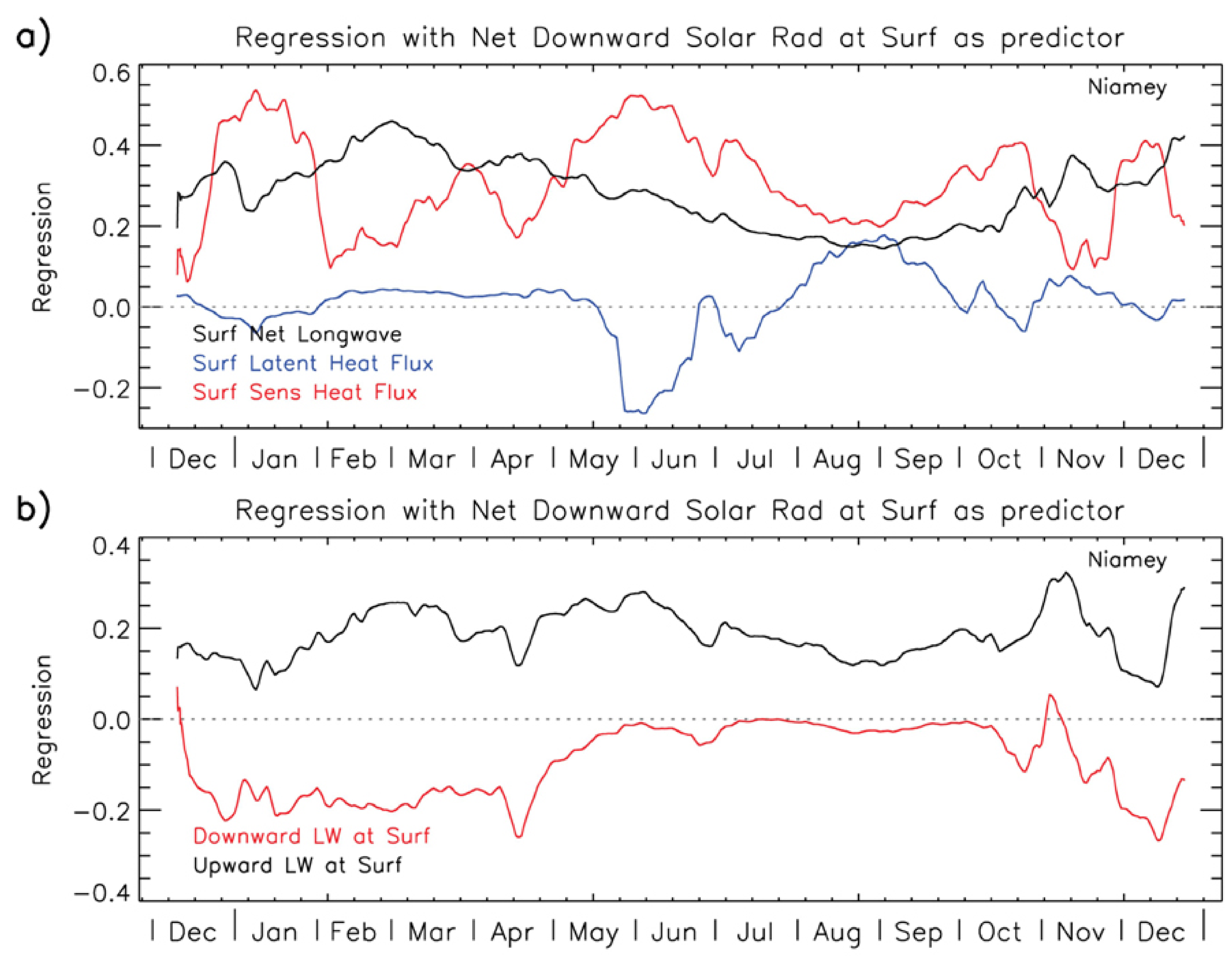
Rainy Season: Column moisture increases so that longwave radiation becomes less efficient. Solar heating is balanced additionally by the turbulent flux of sensible heat, with a comparable contribution from the latent heat flux after soil moisture has been replenished by the summer rains.

Subseasonal Fluctuations

Sunlight incident upon the surface varies as a result of changes in column water vapor, cloud cover, and aerosol outbreaks. During the dry season, increased sunlight is balanced mainly by longwave cooling *(right column):* upward longwave radiation increases as the surface warms. The removal of column constituents causing the increase in sunlight also reduces downward emission of longwave into the surface. During the rainy season, column moisture is larger and downward longwave varies less. Turbulent fluxes of sensible and latent heat are of comparable importance in balancing the change in sunlight.

Conclusions

- On both seasonal and subseasonal time scales, surface heating by sunlight is balanced predominately by longwave radiation during the dry season. During the rainy season, turbulent fluxes of sensible and latent heat make comparable contributions.
- This contrast is because the onshore flow of moisture during the rainy season makes the column relatively opaque, inhibiting longwave cooling.
- How the surface energy balance responds to perturbations has **implications for aerosol impacts** upon climate. Precipitation decreases when the turbulent flux of latent heat is reduced beneath an aerosol layer. A decrease of the turbulent flux of sensible heat reduces mixing within the planetary boundary layer, along with the surface wind speed and dust mobilization. Both of these impacts are reduced when the surface adjusts efficiently through longwave radiation to a reduction in sunlight beneath the aerosol layer.



Acknowledgments

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Contact: rmiller@giss.nasa.gov