P3.20

Longwave Surface Radiation Budget and Climate

Anne Wilber[1], G. Louis Smith[2], Shashi K. Gupta[1] and Paul W. Stackhouse[3]

1. Analytical Services and Materials, Inc.
2. Virginia Polytechnic Institute and State University
3. Atmospheric Sciences Division, Langley Research Center, NASA

1. INTRODUCTION

The surface radiation budget of a region and its climate are strongly related (Smith et al., 2002, or SWGS02). The surface radiation budget consists of upward and downward components of solar radiation and longwave radiation. In this paper we investigate empirically the climatological relation between downward longwave radiative flux (DLW) and upward longwave flux (ULW) at the Earth's surface. These 2 components of surface radiation budget are coupled by the fact that within the planetary boundary layer (PBL), the temperature varies from the surface temperature to that of the free atmosphere. Thus, if the PBL were opaque in the longwave, the DLW would equal the ULW. The specific humidity, which is typically greatest near the ground, will increase the opacity of the PBL and thus increase the DLW. The presence of low clouds will increase the DLW above the clear-sky value by radiating in the 8-12μm longwave window. The instantaneous ULW and DLW are thus governed by the temperature and humidity profiles, especially near the surface, and the cloud cover.

The climatology of a region will relate the temperature and humidity profiles and the cloud cover, so that there will be a climatological relation between the DLW and the ULW. In order to study these relations, this investigation uses the Surface Radiation Budget Data Base which was developed by Gupta et al. (1999) and is available for researchers from the Atmospheric Sciences Data Center of Langley Research Center. This data base uses a quasi-equal area grid to partition the globe into 6596 2.5 degree regions and covers the 8-year period July 1983 through June 1991.

2. EXAMINATION OF DATA

Climatological monthly means of each parameter with were formed for each month of the year by averaging the 8 Januaries, etc. of the data period. Radiation hodographs were plotted as the annual cycle of DLW as a function of ULW for regions of various climate classes. Figure 1 shows such a plot for sites in the Pacific Ocean latitudes of 20^{o}S, 30^{o}S. 40^{o}S and 60^{o}S and longitude 120^{o}W. The dotted line shows DLW = ULW, so that the vertical or horizontal distance of a point from this line is the net longwave radiant flux NLW. Over ocean, the emissivity is near 1 so that ULW = σT^4. For each site, as the sea surface temperature and ULW change, the DLW change is very nearly equal so that the NLW is very nearly constant. Figure 2 is a similar plot for 5 tropical ocean sites. This plot is much like that for the sites in fig. 1, except for the 21^{o}N, 157^{o}W site in the Pacific Ocean, where the NLW is quite small.

Figure 3 presents the annual cycles for 6 mid-latitude land regions, most of which are continental regions. The trajectories in the hodograph plane are very linear and the slope is close to 1. Thus, although the ULW varies by 250 W-m^{-2}, the NLW variation is an order of magnitude smaller. Figure 4 is a similar plot for 4 Northern Hemisphere polar sites and shows that the trajectories for polar regions also have slopes near 1 and lower annual mean DLW than mid-latitude continental regions.

Figure 5 shows the annual cycle of DLW versus ULW for some desert and tropical rain forest sites, or in the nomenclature of Trewartha and Horn (1980), tropical dry and tropical wet sites. The deserts have a larger ULW and NLW than other sites examined. Also, the slope of the trajectory is significantly less than 1, so that the NLW increases as ULW increases. The Australian Desert has NLW smaller than the other deserts examined here.The tropical rain forests have a small range of ULW, because of the small variation of solar incidence and consequently surface temperature, and very low NLW values, due to high humidity and cloudiness. The Sahel is a savanna or tropical wet/dry region, and its trajectory in fig. 5 follows that of the deserts until the monsoon moves in, when it shifts to behave as a tropical wet region until the departure of the monsoon, at which time it moves back to the desert trajectories.

. *Corresponding author address:* Anne C. Wilber, Analytical Services an Materials, Inc., 1 Enterprise Parkway, Suite 300, Hampton, VA 23666, a.c.wilber@larc.nasa.gov

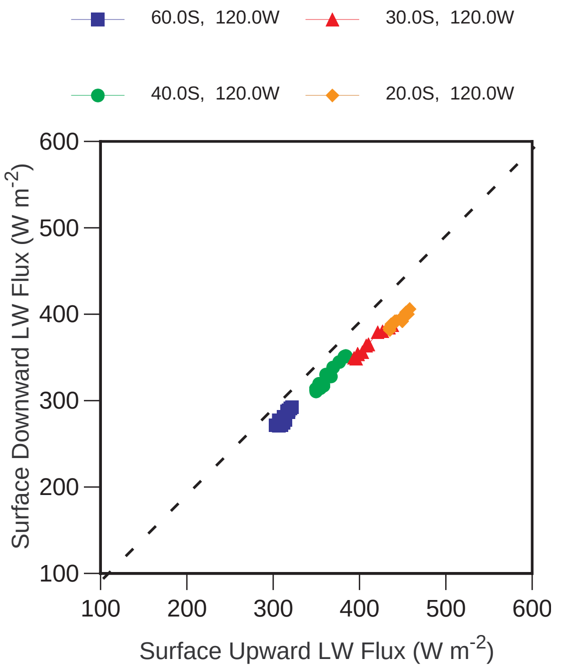

Figure 1. Downward Longwave Flux as Function of Upward Flux Over South Pacific for Several Latittudes.

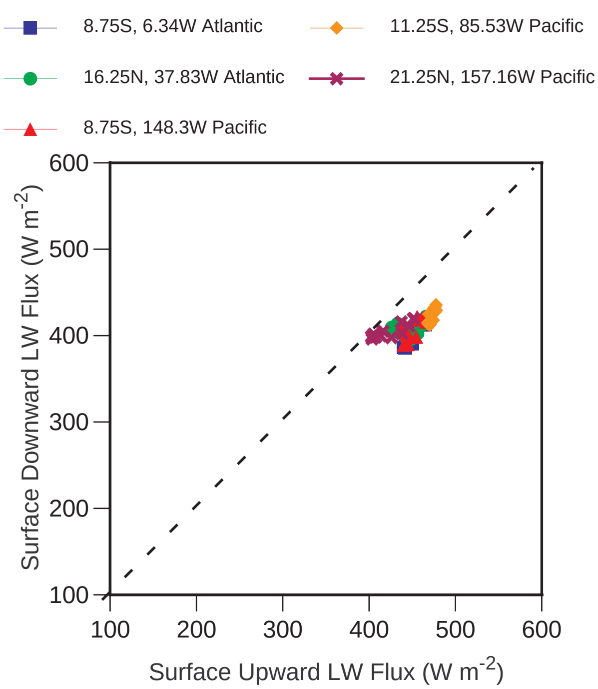

Figure 2. Downward Longwave Flux as Function of Upward Flux Over Tropical Oceans.

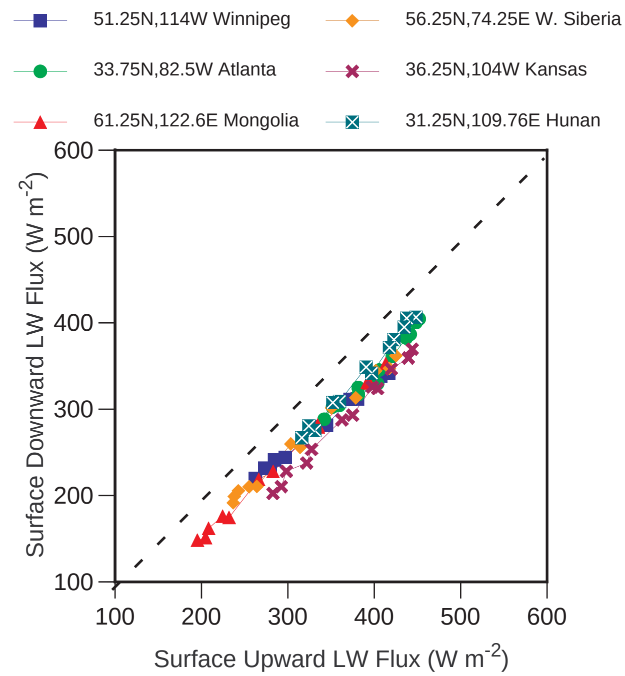

Figure 3. Downward Longwave Flux as Function of Upward Flux for Serveral Continental Locations.

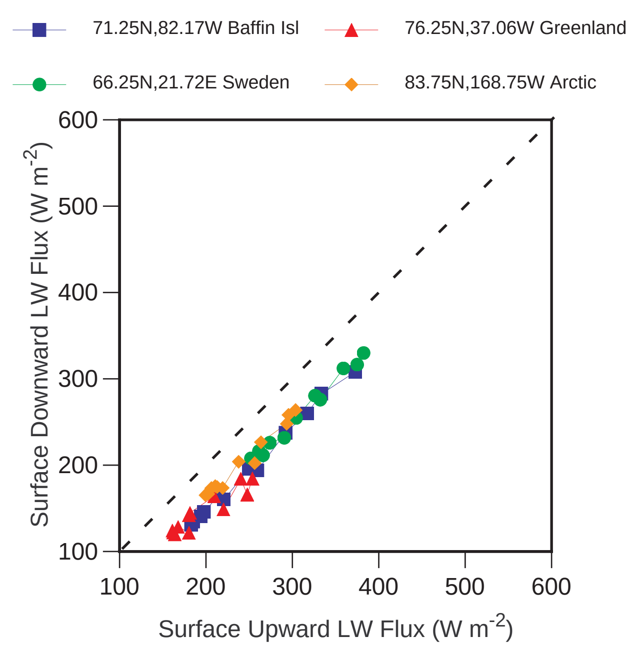

Figure 4. Downward Longwave Flux as Function of Upward Flux for High Latitudes.

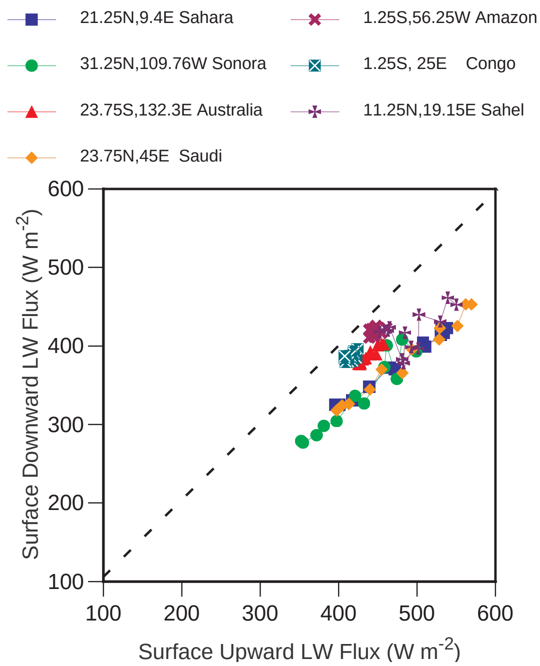

Figure 5. Downward Longwave Flux as Function of Upward Flux for Deserts, Tropical Rain Forests and Savanna.

Figure 6 is a map of the annual mean of NLW. A comparison of this map with the climatology classification maps of W. Koeppen (e.g. in Haurwitz and Austin, 1944), Trewartha and Horn (1980) (TH80) or SWGS02 show that the geographical variations shown here are closely related to the regional climate class as suggested by figs. 1 through 5. Boreal land has NLW of 50 to 70 W-m^{-2}, desert and steppe have NLW more than 70 W-m^{-2}, etc.

Figure 7 is a map of the annual range of NLW. The regions with the largest ranges are tropical wet/dry, steppe or semi-arid, and the Antarctic. The maximum range is 100 W-m^{-2}, over India. TH80 shows that the subcontinent of India is semi-arid and tropical wet/dry. The oceans have very small ranges of NLW, which is less than 40 W-m^{-2} for most of the expanses. For comparison, fig. 8 is a map of the annual range of DLW. A large part of Eurasia and northern Canada has a range of DLW of 200 W-m^{-2}, but a range of NLW less than 20 W-m^{-2}, demonstrating the strong coupling of DLW to ULW.

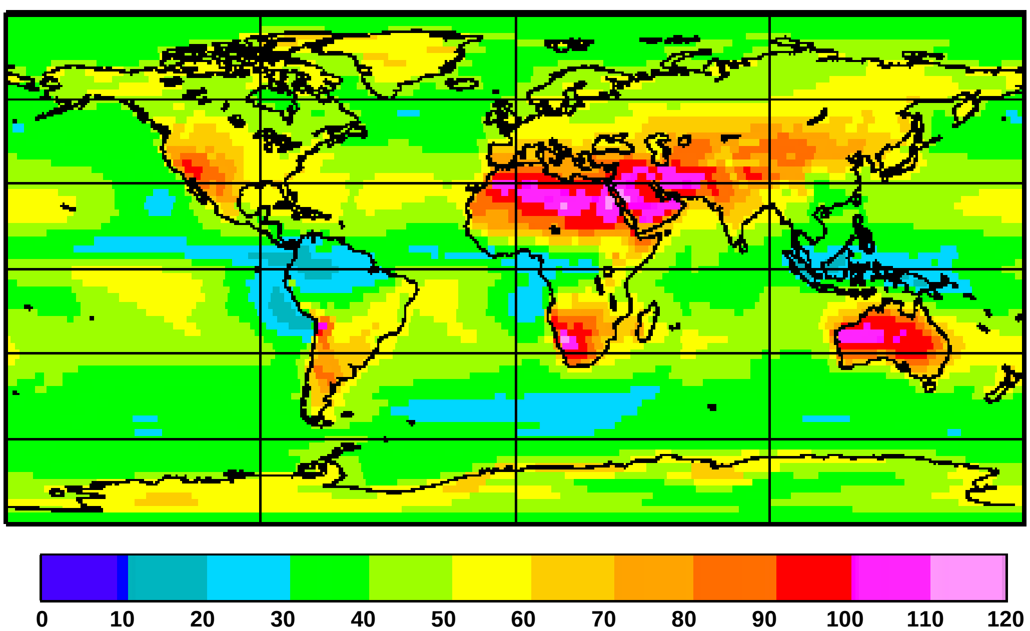

Figure 6. Map of Annual Mean Net Longwave Flux (W m^{-2})

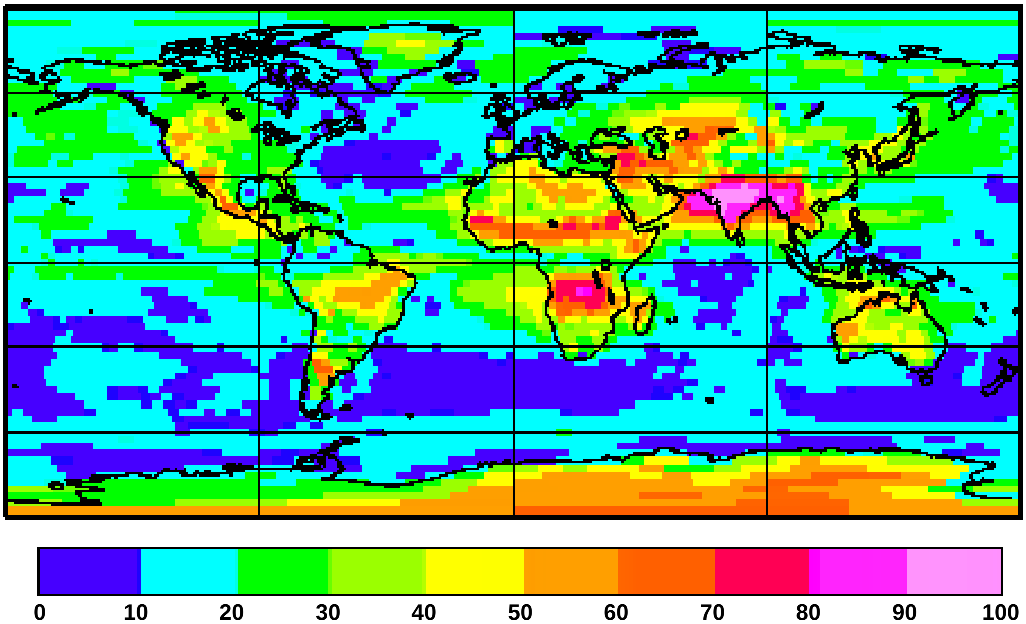

Figure 7. Map of Annual Range Net Longwave Flux (W m $^{-2}$)

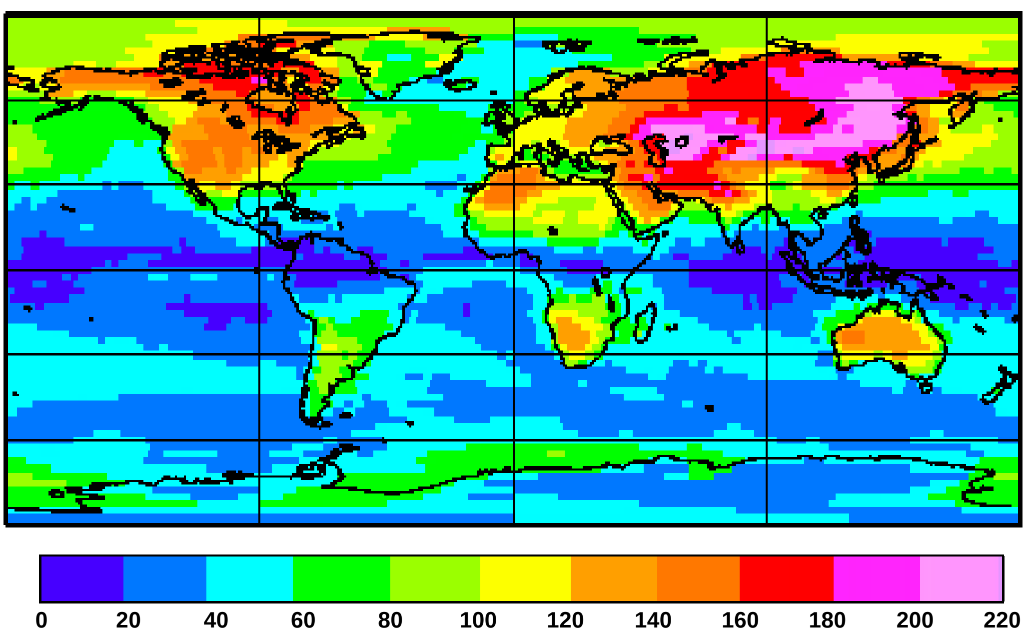

Figure 8. Map of Annual Range Downward Longwave Flux (W m $^{-2}$)

3. DISCUSSION

SWGS02 considered the NLW to be the response of the system to the forcing of the net shortwave flux. In the present paper DLW is considered to be the response of the highly coupled system to the heating of the surface, measured as ULW. In both cases, advection has helped to determine the climate class, so that its effects are intrinsically included.

An examination of the longwave hodograph shows characteristics of the region's climatology. Over ocean regions, the annual cycle in the ULW is small, due to the huge thermal mass of the oceans, which permits only small changes in the sea surface temperature. Because of the strong coupling between the ocean surface and the atmosphere the annual cycle of the DLW and NLW are also small. Most land regions have a larger annual cycle of ULW and DLW in response to the insolation cycle. The ULW-DLW relation is linear except for tropical wet/dry regions, such as the Sahel. As the Sahel changes from dry to wet during the year, its trajectory in the hodograph moves from the radiation space of the deserts to that of rain forest.

Savanna or tropical wet/dry climatological regions such as the Sahel depend on seasonal rain (a monsoon) to transition from tropical dry (desert) to tropical wet. Changes in the timing or intensity of this transition are extremely important to the habitability.of these marginal regions, as has been shown by the droughts of the Sahel.

Acknowledgments: This work was supported by the Earth Science Enterprise of NASA. Langley Research Center supported ACW and SKG by contract with Analytical Services and GLS by cooperative agreement with Virginia Polytechnic Institute and State University. Data were provided by the Atmospheric Sciences Data Center of Langley Research Center.

REFERENCES

Gupta, S. K., N. A. Ritchey, A. C. Wilber, C. H. Whitlock, G. G. Gibson, and P. W. Stackhouse. 1999: A Climatology of Surface Radiation Budget Derived from Satellite Data., *J. Climate,12,* 2691- 2710.

Haurwitz, B. and J.M. Austin, 1944: *Climatology*, McGraw-Hill, New York.

Smith, G. L., A. C. Wilber, S. K. Gupta and P. W. Stackhouse, 2002: “Surface radiation budget and climate classification,” *J. Clim.*, **15**, 1175 - 1188.

Trewartha, G. T. and L. H. Horn, 1980: *Introduction to Climate,* McGraw-Hill, New York.