IRS2012-540
International Radiation Symposium 2012
Dahlem Cube, Berlin, Germany, 06 – 10 August 2012

Seasonal and Regional Diurnal Variations of Cloud Effects on Atmospheric Radiative Heating/Cooling From the ISCCP-FD Product

Y. Zhang (1) and W. Rossow (2)
(1) United States (yz7@columbia.edu), (2) United States (wbrossow@ccny.cuny.edu)

To explore the cloud effects on the radiative heating/cooling rates in the atmosphere, we use the 3-hrly, 2009 radiative profile flux subset (‘PRF’), one of the four global, 3-hrly subsets of the ISCCP-FD flux product, to produce at eight local hours the seasonally-regionally averaged cloud effects (CE) on heating/cooling rates (HCE, in Kelvins/day, K/d) for the seven latitudinal zones, the South Polar (SP, 90˚S–60˚S), the Southern Midlatitudes (MS, 60˚S–30˚S), the Southern Extra Tropics (XS, 30˚S–15˚S), Tropics (TR, 15˚S–15˚N), the Northern Extra Tropics (XN, 15˚N–30˚N), the Northern Midlatitudes (MN, 30˚N–60˚N) and the North Polar (PN, 60˚N–90˚N) zones. We highlight some of the most pronounced features of the cloud effects for LW, SW and total (SW+LW) based on the summer (JJA) and winter (DJF) seasons. The sign of the CE effect is such that positive values indicate relative heating (that is, increase in the flux divergence) and negative values indicate relative cooling (that is, decrease in flux divergence), where the total flux divergence in the atmosphere is generally negative.

Year-round in the Tropical zone, the SW heating rate CE (SW HCE) profiles exhibit heating above ∼400 mb level and cooling below, with a tendency for this dividing level to descend to its lowest level near noon and ascend to its highest level towards nighttime. The largest SW HCE appears near noon (about 0.5 to 0.6 K/d) with a stronger land-ocean contrast in DJF (land effect larger). The LW heating rate CE (LW HCE) is reversed with heating below and cooling above, but the dividing level ascends to near the 200 mb level in late afternoon/evening, especially over land, consistent with deep convective activity. There is less diurnal variation of this dividing line over ocean especially in JJA. The combination of the SW and LW cloud effects produces heating below about 400 mb in the tropics but with a distinctive diurnal variation that shows maximum heating (0.4-0.6 K/d) above the 400 mb level in the afternoon (the ocean maximum is closer to noontime) and maximum heating (0.6-0.8 K/d) below the 400 mb level during the night, especially over land. Therefore, clouds essentially increase heating (decrease cooling) in the tropical atmosphere but with a distinctive diurnal variation with different phases above and below the 400 mb level.

For summer Polar areas, the SW HCE is to increase heating in a layer from ∼700 to 400 mb, except over the North Polar ocean, and decrease heating below and above this layer. In contrast, LW HCE essentially decreases the heating everywhere, most strongly in the same 400-700 mb layer, except over North Polar land areas where the HCE increases, especially at night. The total CE displays a qualitatively similar diurnal cycle, with HCE increasing heating above the 700 mb level near noontime and decreasing heating below but reversing during nighttime to heating below the 700 mb level and cooling above. The magnitudes of the HCE are larger over North Polar land and South Polar ocean areas. The winter Polar HCE is dominated by LW and generally exhibits little diurnal variation with strong heating below the ∼700 mb level and cooling above but the cooling is concentrated in the 400-700 mb layer.

The midlatitudinal zones exhibit a mixture of the features in the other zones. The daytime SW HCE shows the same heating above and cooling below the 700 mb level just after noontime, stronger in the summer hemisphere and roughly similar over land and ocean. The LW HCE shows summer shows heating below and cooling above the 700 mb level, except in the summer hemisphere where there is a weak heating effect in late afternoon-early evening like in the tropics. The combined pattern in summertime midlatitudes shows a strong heating aloft (above 400 mb over land and above the 700 mb level over ocean) and cooling below near noontime, but strong (especially over land) heating below and cooling above 700 mb near midnight. In wintertime, the noontime peak effect is only a weaker cooling than during the rest of the day; however, strong nighttime cooling appears in the 400-700 mb layer, especially over Northern land areas. These features are generally much weaker in the Southern wintertime midlatitudes.

The Extra Tropical zones are largely similar to the tropical zones but also with minor features similar to midlatitudinal zones.

In summary, clouds tend to heat the upper atmosphere and cool the lower atmosphere during daytime but produce the reverse effect during nighttime. Seasonal variations are generally larger over higher latitude land areas. The consequences for the atmospheric circulation from the diurnal and seasonal variations of the total cloud effects on radiative heating/cooling rates need further exploration.