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Cirrus cloud radiative forcing on surface-level shortwave and longwave irradiances at regional and global scale

JC Dupont (1), M Haeffelin (2), and C. N Long (3)

(1) Ecole Polytechnique, Laboratoire de Météorologie Dynamique, Le Mans, France (jean-charles.dupont@lmd.polytechnique.fr, +33 1 69 33 51 08), (2) Institut Pierre-Simon Laplace, Paris, France, (3) Pacific Northwest National Laboratory, Richland, USA

Cirrus clouds not only play a major role in the energy budget of the Earth-Atmosphere system, but are also important in the hydrological cycle. According to satellite passive remote sensing high-altitude clouds cover as much as 40% of the earth's surface on average and can reach 70% of cloud cover over the Tropics. Hence, given their very large cloud cover, the relatively small instantaneous radiative effects of these cirrus clouds can engender a significant cumulative radiative forcing at the surface. Precise calculations of the cirrus cloud radiative forcing are obtained from the difference between measured radiative fluxes downwelling at the surface in the presence of cirrus clouds (broadband flux measurements) and computed clear sky references (parametric models with RMS error < 5 W m-2). Overcast and clear sky period identification is obtained from a combined analysis of lidar and broadband flux measurements.

In this study, we analyze two datasets: ground-based and satellite measurements. The firsts corresponds to solar and infrared irradiance measurements, cloud and aerosol Lidar backscattering profiles, microwave radiometer brightness temperatures, radiosonde profiles, and sun-photometer extinctions monitored at four observatories located in the midlatitudes (SIRTA Observatory and ARM SGP Lamont), the Tropics (ARM TWP Nauru) and the Arctic (ARM NSA Barrow). This dataset permits us to estimate the Cirrus cloud Radiative Forcing (cloud base altitude above 7 km) on surface-level shortwave (CRFSW) and longwave (CRFLW) irradiances. The sensitivity of CRFSW to Cloud Optical Thickness (noted CRFSW*) is established and ranges from 100 W m-2 to 200 W m-2 per unit of cloud optical thickness. The important variability of aerosols and water vapor content obtained in studying the 4 observatories allows us to quantify the combined influence of aerosol optical thickness and integrated water vapor on CRFSW* : 10 to 20 % CRFSW* range for turbid and pristine atmosphere. Moreover, the sensitivity of the CRFLW to both cloud emissivity and cloud temperature (noted CRFLW*) is established and the influence of integrated water vapor on CRFLW* quantified: partial infrared opacity for arctic site (dry atmosphere) and quasi-total infrared opacity for tropical site (wet atmosphere), respectively 20% and 97% of opacity. Cirrus cloud radiative forcing parameterizations are hence developed starting from the ground-based collocated measurements. They relate CRFSW or CRFLW to cirrus cloud macrophysical properties, atmospheric humidity, aerosol content and solar zenith angle.

Satellite measurements are used next as input parameters to the cirrus cloud radiative forcing parameterizations to calculate CRFSW and CRFLW at global scale. CALIOP provide aerosol and cirrus cloud properties and AIRS the integrated water vapor. Meridian distribution are shown and discussed. They reveal a positive cirrus cloud net radiative effect (CRFSW + CRFLW) from 30°N poleward during boreal winter and from 45°S during austral winter. The cumulative cirrus cloud net radiative effect reaches +1.5 W m-2 for these two winter cases and -8 W m-2 near the equator.