URSI - RCRS 2022, IIT (Indore), India, 1 - 4 December, 2022

Vertical Structure of Atmospheric Energetics due to Clouds Associated with Walker Cells: Estimations Using a Decade of CloudSat and CALIPSO Observations

Aswathy R S*[(1,2)] and K Rajeev [(1)]
(1) Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram, Kerala
e-mail: aswathy_rs@vssc.gov.in; k_rajeev@vssc.gov.in
(2) Department of Physics, University of Kerala, Thiruvananthapuram, Kerala; e-mail: aswathy_rs@vssc.gov.in

The Walker circulation is the prominent east–west atmospheric circulation cells along the equatorial belt and is tightly coupled to the zonal contrast in sea surface temperature. Globally, the Walker circulation comprises of three prominent ascending limbs, the strongest ascending branch is located in the east equatorial Indian Ocean, while the other two are located at the African and American sectors. It regulates the global exchange of momentum, heat, and water vapour within the tropics through massive overturning motions [1]. The Walker circulation possesses pronounced variability on seasonal, intra-seasonal and inter-annual timescales, especially during the El Niño–Southern Oscillation. The present study based on over a decade (2006-2018) of observations using the spaceborne radar and lidar, CloudSat and CALIPSO investigates the vertical structure of Walker circulation and variabilities on the basis of the global 3-dimensional distribution of cloud occurrence, cloud water content (CWC) and its associated atmospheric energetics. The CloudSat operating a Cloud Profiling Radar at 94GHz, provided the first-ever observations to derive the global three-dimensional distribution of clouds and CWC with high vertical (240 m) and along-track spatial (1.7 km) resolutions [2]. Its minimum detectable signal sensitivity is -30 dBZ, and hence can detect clouds with a water content of >0.4 mg/m^3. However, CloudSat observations have certain limitations: (i) optically thin clouds cannot be detected, and (ii) it makes observations only along the sub-satellite track and hence the across-track spatial resolution and temporal sampling are highly limited by the 16-day orbit cycle. Analysis of the observations made with the spaceborne lidar, CALIPSO, matched to the CloudSat foot-print can provide information on optically thin clouds as well. Due to the limited longitude resolution and temporal sampling of CloudSat and CALIPSO observations, in the present study, the global 3-dimensional distribution of clouds, CWC and atmospheric energetics are investigated on a monthly basis. Notwithstanding this, the observations during 2006-2018 provide a robust data set to make a comprehensive analysis of the global distribution of clouds and its variability.

The zonal variations of the vertical distribution of clouds averaged over the equatorial belt (10^{0}S to 10^{0}N) show the following prominent features: (a) all the three ascending limbs of the Walker cell are clearly manifested in the occurrence of deep convective clouds over the equatorial regions of (i) the eastern Indian Ocean and the western Pacific (80^0 E-180^{0}E), (ii) west-central Africa (10^{0}E-40^{0}E), and (iii) Central American region (80^{0}W-50^{0}W). (b) Subsidence and the least convection (or its absence) associated with descending limb of the Walker cell occurs over the western equatorial Indian Ocean (40^{0}E-60^{0}E), the western Atlantic (30^{0}W-5^{0}E), and the eastern Pacific (150^{0}W- 90^{0}W). (c) Average geographical locations of the ascending and descending branches of the Walker cell are rather steady, but the strength of the branches undergoes substantial annual variations. (d) On average, the largest convection and cloudiness associated with the ascending limb of the Walker cell occurs over the east equatorial Indian Ocean and the western Pacific. This branch attains its peak strength during October-January, while its weakened during March-June. (e) The strongest descending limb of the Walker cell occurs over the western equatorial Indian Ocean, with minimum convective clouds occurring over 40^{0}E – 60^{0}E. However, in terms of the areal extent, the descending limb of the Walker cell is most prominent over the eastern Pacific. (f) Zonal spreading of the cirrus clouds generated from the convective outflow from these cells is substantial over the entire tropics. This long-range spreading of cirrus clouds by upper tropospheric winds is most prominent over the Indian Ocean during northern summer when the spreading extends to >2700 km from 70^{0}E to 45^{0}E.

1. K.-M. Lau and S. Yang, "Walker circulation," *Encyclopedia of Atmospheric Sciences*, pp. 2505–2510, 2003.

2. Marchand, R., Mace, G., Ackerman, T. and Stephens, G., 2008. Hydrometeor Detection Using Cloudsat—An Earth-Orbiting 94-GHz Cloud Radar. *Journal of Atmospheric and Oceanic Technology*, 25(4), pp.519-533.