Critical Evaluation of the ICARUS Portion of the ISCCP Simulator Using ARM Data

Research Highlight

The International Satellite Cloud Climatology Project (ISCCP) was initiated in the early 1980s by Bill Rossow and collaborators with a goal of understanding the role of clouds in the climate system. This level of foresight is clearly a credit to these scientists because, more than a quarter-century later, ISCCP remains a flagship description of the cloudy atmosphere. By analyzing visible and infrared radiances produced by geostationary and polar orbiting meteorological satellites and applying assumptions regarding the layering of clouds in the atmosphere, their thermodynamic phases, and their properties, ISCCP describes a cloudy satellite pixel with the column visible optical depth and cloud-top pressure of the highest cloud layer in the column.

ISCCP is an excellent tool for evaluating the veracity of cloud parameterizations in climate models. However, this is not straightforward, as a bridge must be built between the observations (ISCCP) and the model output. This bridge is an algorithm known as the ISCCP simulator that takes model output and converts it into a cloud top pressure and optical depth that ISCCP would retrieve given the properties of the simulated column. The ISCCP simulator has gained wide use across the community. However, it had not been well validated.

Because ARM measures the vertical profiles of cloud properties with radar, lidars, radiometers, and soundings, the ARM data is potentially an excellent tool for validating the ISCCP simulator algorithm. To accomplish this, we made the assumption that if ARM-derived cloud properties were passed through the ISCCP simulator, they should reproduce the ISCCP retrievals. This seems straightforward. However, the exercise becomes complicated quickly because of the spatial and temporal inhomogenity of cloud fields. Therefore, we applied a very stringent set of criteria and identified several hundred events where the cloud fields were uniform in space and time. For these, we derived the cloud properties, passed them through the ISCCP simulator, and then compared them to nearby ISCCP retrievals.

We found that the ICARUS portion of the ISCCP simulator does indeed facilitate comparisons between observed and simulated cloud top pressures by adjusting some portion of the simulated high-topped and low-topped clouds into the middle-troposphere (Figure 1). In particular, optically thin cirrus that are transmissive in the infrared are found by ISCCP to occur at pressures higher (lower in height) than what is observed by the millimeter-wavelength cloud radar (MMCR). This feature is correctly characterized by the simulator algorithm and causes the comparison in Figure 1 to significantly improve.

However, we found that the optical depth derived (and observed by the multifilter rotating shadowband radiometer [MFRSR]) did not agree with ISCCP (Figure 2 lower row, center). While there is significant scatter in the comparisons, we found that very often the optical depths reported by ISCCP are less than that retrieved from remote sensing data and derived from MFRSR data. This result is not new. Also shown are similar comparisons to ISCCP done by Qilong Min and collaborators in 1996 (lower left plot) and by Howard Barker (lower right plot) in 1998. This optical depth bias results in additional uncertainty in comparisons between ISCCP and any simulations of ISCCP by the ISCCP simulator algorithm. A more careful evaluation of the discrepancies show that were a model to predict the actual occurrence of clouds with the same accuracy as a cloud radar and then the model made reasonable diagnostic interpretations of the column radiative properties, agreement with satellite derived results after applying the ISCCP simulator would be successful in only approximately 1/2 to 2/3 of cases, depending on the cloud type.

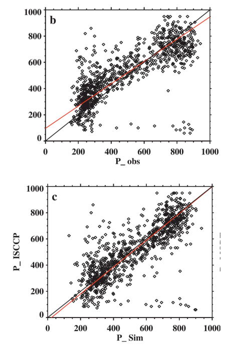

Figure 1. Comparison of actual cloud top pressure from ARM remote sensors compared to ISCCP (top) and after the ICARUS algorithm has been used to convert the measured cloud top pressures to ISCCP-like quantities (bottom).

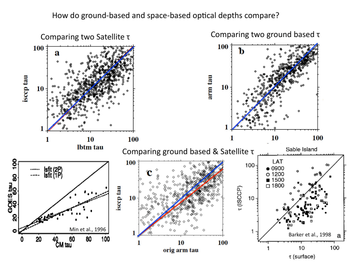

Figure 2. Comparison of various measures of optical depth. Top left shows ISCCP compared to another satellite product generated by Pat Minnis, the upper right shows a comparison of ground-based optical depths, and the bottom row shows comparisons of ground-based optical depths(MFRSR versus MMCR-derived) with satellite-derived optical depth.

Additional work to investigate the source of this bias seemed to point at the variability in the cloud field resulting in potentially biased satellite retrievals of optical depth. In essence, the more variable the cloud field, the lower the satellite-retrieved optical depth becomes relative to the actual mean optical depth of the pixel due to nonlinearities between radiance and optical depth.

We conclude that, given a profile of thermodynamics and cloud properties, the ICARUS algorithm in the ISCCP Simulator accurately simulates the cloud top pressure that ISCCP would retrieve from satellite data. However, the optical depths retrieved from satellite reflectances, especially for larger pixels and high optical depths, are subject to bias due to inhomogeneities in the cloud fields. Our recommendations are that models should be compared to ground-based measurements of optical depth as well as satellite measurements. Additional work will be needed to devise a means of simulating the ISCCP optical depth based on assumed, measured, or modeled cloud field statistics.

Reference(s)

Mace GG, S Houser, S Benson, SA Klein, and QL Min. 2011. "Critical evaluation of the ISCCP simulator using ground-based remote sensing data." Journal of Climate, 24(6), doi:10.1175/2010JCLI3517.1.

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Working Group(s)

Cloud Life Cycle