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What Do We Really Know About Cloud Changes over the Past Decades?

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Abstract. Clouds are a critical component of Earth's climate system. Although satellite-based irradiance measurements are available over approximately the past 30 years, difficulties in measuring clouds means it is unclear how global cloud properties have changed over this period. From the International Satellite Cloud Climatology Project (ISCCP) and Moderate Resolution Imaging Spectroradiometer (MODIS) datasets we have examined the validity of long-term cloud changes. We find that for both datasets, low-level (>680mb) cloud changes are largely a reflection of higher-level (≤680mb) variations. Linear trends from ISCCP also suggest that the dataset contains considerable features of an artificial origin. Despite this, an examination of ISCCP in relation to the MODIS dataset shows that over the past ten years of overlapping measurements between 60°N–60°S both datasets have been in close agreement ($r = 0.63$, $p = 7\times10^{-4}$). Over this time total cloud cover has been relatively stable. Both ISCCP and MODIS datasets show a close correspondence to Sea Surface Temperatures (SST) over the Pacific region, providing a further independent validation of the datasets.

Keywords: Clouds, Remote sensing, ISCCP, MODIS, Sea surface temperatures.
PACS: 92.60.N

INTRODUCTION

A number of studies have suggested that long-term irradiance-based measurements of cloud cover from satellite may be unreliable due to the inclusion of artifacts, difficulties in observing low-cloud, biases connected to view-angles, and calibration issues [1, 2, 3, 4]. Using monthly-averaged global satellite records from the International Satellite Cloud Climatology Project (ISCCP [5]) and the MODerate Resolution Imaging Spectroradiometer (MODIS [6]) in conjunction with Sea Surface Temperature (SST) data from the National Oceanic and Atmospheric (NOAA) extended and reconstructed SST (ERSST) dataset [7] we have examined the reliability of long-term cloud measurements. The SSTs temperatures are used here, with success over certain regions of the globe, as a proxy and cross-check for cloud variability.

LONG-TERM CLOUD DATA FROM ISCCP AND MODIS

The ISCCP data are calculated from intercalibrated radiance measurements operating from the VIS (~0.6μm) to IR (~11μm) spectral range, recorded by a fleet (>40) of instruments on both geostationary and polar orbiting satellite platforms. The ISCCP data utilized in this study are from the D1 dataset, diurnally averaged from 3-hour intervals, at a 2.5° × 2.5° resolution, from the period of July 1983 to December 2009. The MODIS data are from the Terra instrument, collection 5.1, version 3, and give a near-global coverage over a 24-hour period, at a 1° × 1° spatial resolution, operating in 36 spectral bands between 0.620μm and 14.385nm, over the period of March 2000 to December 2011. Seasonal variations in the data have been accounted for by removing the monthly mean climatology from each entire available datasets.

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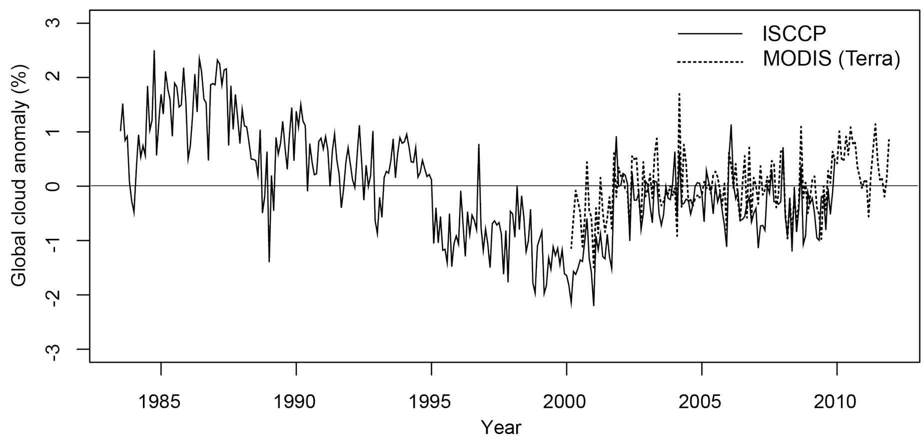

FIGURE 1. Globally averaged daily ISCCP (solid line) and MODIS (Terra) cloud amount (%) between 1983 and 2012.

The monthly time-series of ISCCP and MODIS total cloud anomalies (%) are plotted in Figure 1, which shows that between the years of 1983 to 2000 the amount of cloud detected by ISCCP declined by around 4%. After this time the MODIS data becomes available and both datasets show an increase in cloud (with ISCCP recovering by approximately 2% of the previous long-term decline in a matter of two-to-three years), this is followed by a period of relative mean stability. A detailed geographical comparison between ISCCP and MODIS is discussed in [8].

In relation to claims that the passive irradiance-based cloud estimations from satellites result in low level cloud data that is significantly influenced by overlying clouds [1, 3] we have examined globally-averaged monthly cloud anomalies distinguished into low level (>680mb) and middle+high level (≤680mb) cloud types from ISCCP. These variables are presented in figure 2 over the ISCCP data period: a strong anticorrelation (r = -0.79) is evident between these data. These results support the conclusion that the global low level cloud data is not reliable when derived from irradiance-based estimation methods due to the non-cloud penetrating nature of these measurements coupled with view-angle biases. Interestingly, we note that the trend in high+middle level cloud is only approximately half the magnitude of the trend observed in the low level cloud. The exact same conclusions are reached by examining the MODIS dataset. For ISCCP, however, several significant jumps are clearly evident in Figure 2, connected to a shift in mean cloud anomalies. This suggests that spurious changes exist within the ISCCP data that may have contributed to long-term changes, as suggested by numerous authors [2, 3, 9]. A calibration artifact origin of these changes appears to be highly likely, as can be seen in Figure 3 where geographically-resolved long-term ISCCP trends are shown.

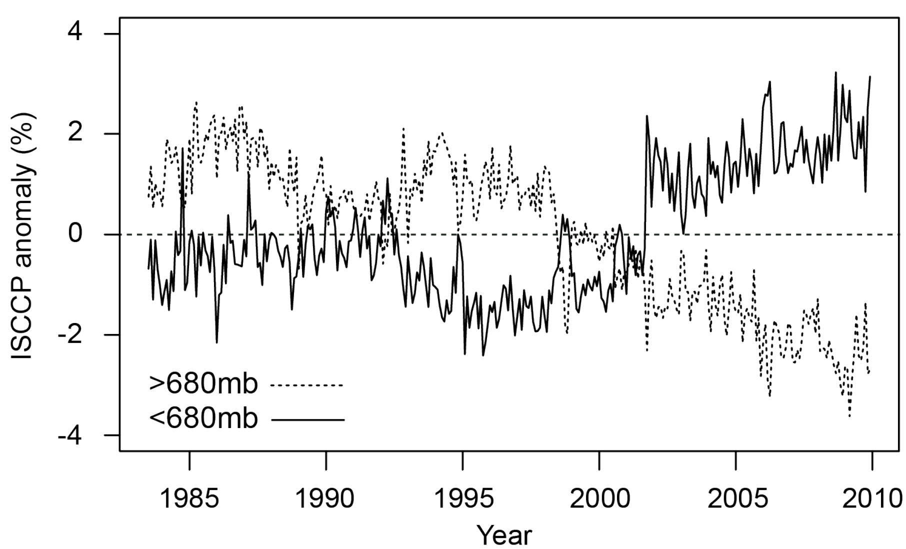

FIGURE 2. ISCCP low cloud (>680mb) anomalies plotted against high + middle (≤680mb) level cloud anomalies.

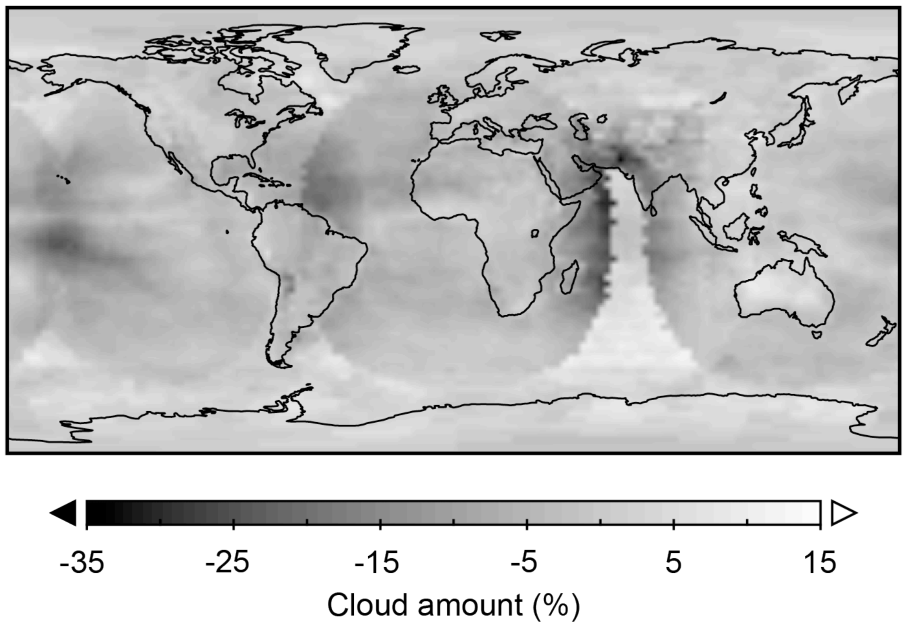

FIGURE 3. Anomalies from linear trend in ISCCP D1 total cloud amount data.

SST–CLOUD VALIDATION OVER THE EQUATORIAL PACIFIC REGION

SST data from NOAA's ERSST version 3b dataset are constructed based on the most recently available (version 2.4) International Comprehensive Ocean-Atmosphere Data Set (ICOADS). ERSST 3b excludes satellite data, using only in-situ ship and buoy data. The data is available globally, at 2° × 2° grid, at a monthly resolution since January 1854 to present. We have deseasonalized and regridded the SST data in an identical method to the cloud datasets, using only the June 1983 to December 2009 months (overlapping with the ISCCP data availability).

Performing a correlation analysis between SST and ISCCP/MODIS total cloud amount we find that overall there is a negative correspondence between cloud at middle latitudes and a positive correspondence at low latitudes. In particular, a strong positive correlation between SST and total cloud is identified over the Equatorial Pacific region (6ºN–6ºS) of r = 0.74 and 0.60 for ISCCP and MODIS, respectively, which is found to be highly statistically significant ($p = 4.5\times10^{-6}$ and 0.03). Other regions over the globe present localized significant positive and negative correlations [8], but this is the more extended region with consistent positive correlations. A time-series of these data is presented in Figure 4. A strong correspondence between SST and total cloud cover is expected over the Equatorial Pacific region as ocean temperatures provide a strong influence the day-to-day formation of convective clouds, but with small impact on the radiation balance. We also expect that at mid-latitudes, the clouds in turn influence ocean temperatures as they provide a negative radiative forcing via their shortwave reflection.

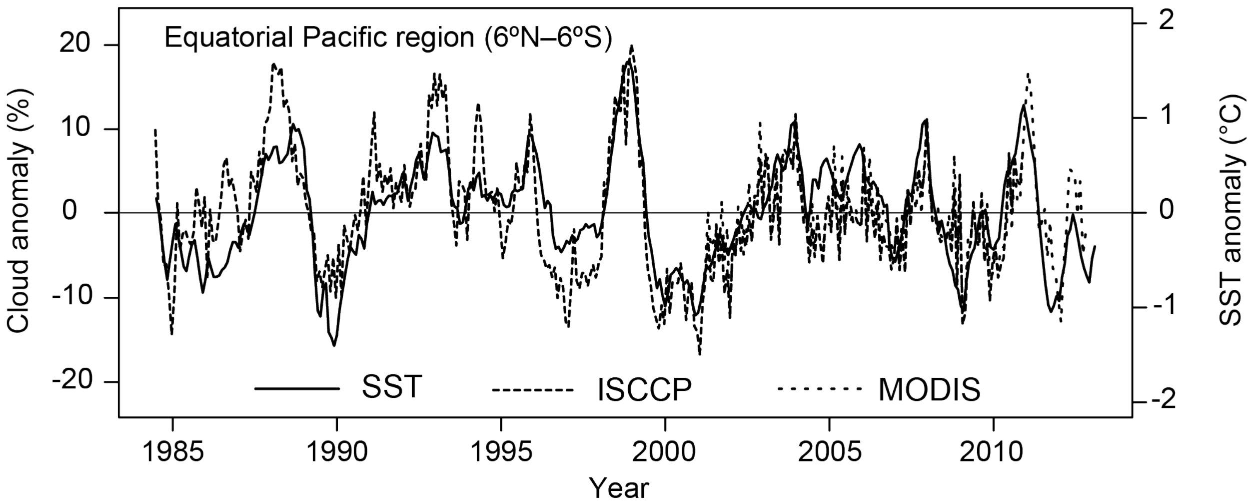

FIGURE 4. Sea Surface Temperature (SST) anomalies (ºC) from NOAAs ERSST v3b (solid line), plotted against both ISCCP D1 (dashed line) and MODIS (dotted line) total cloud anomalies (%). All data is over the equatorial Pacific region only (6ºN–6ºS).

SUMMARY

Despite apparent artificial issues in long-term measurements of cloud from ISCCP, and the lack of reliability in low-cloud data from irradiance-based satellite cloud estimates, we find the ISCCP and MODIS datasets to be in close agreement over the past decade globally. In turn, we find these datasets to correspond well to independent observations of SST, suggesting that some particular regions of the globe are not as affected as others by calibration artifacts. This opens the door to the possibility of using SST temperatures as proxy for past cloud variations.

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