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Decadal changes in thin cirrus height measured by MISR

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Thin, high cirrus clouds play a key role in Earth's radiation budget. They have relatively low albedos, a strong greenhouse effect due to their high altitudes and low emission temperatures, and tend to warm the climate system. The Multi-angle Imaging Spectroradiometer (MISR) on the Terra satellite has been measuring the altitudes of clouds consistently since 2000, and has detected a reduction in high-altitude cloud over the tropical Pacific Ocean that may indicate a significant response of the climate system to global warming. However, thin cirrus clouds are difficult to detect and the operational cloud-height product from MISR may miss thin cirrus when it overlies thicker, lower-level cloud. To detect thin cirrus over clear skies with MISR, cloud-heights above 10 km were retrieved using a stereo matching technique on the oblique camera pairs and re-projected onto the nadir camera after correction for parallax and winds. The merged datasets from the CERES broadband radiometer, also on Terra, were used to extract Outgoing Longwave Radiation (OLR) measurements and compared to the OLR from a column model of longwave radiative transfer that uses MISR cloud-top heights and reanalysis data as input parameters.

After accounting for uncertainties in modeled OLR of $\pm$ 4 W m^{-2} due to uncertainties in the input properties, especially known high cloud, surface temperature and specific humidity, the average difference of 17 W m^{-2} cannot be directly explained, and is compensated with the addition of thin cirrus of coverage 60%. The additional clouds detected had a mean height $\approx$ 14 km and a maximum height of 20 km in the Tropics. MISR misses thin cirrus of optical depth less than 0.3 with its operational cloud-height product whereas oblique analysis improves detection to an optical depth of 0.1. When applied to all tropical scenes, the coverage of thin cirrus found by oblique-stereo analysis with optical depths in the range 0.1 – 0.3 is 10%. Based on the overall difference between model and the measurement, the remaining coverage of subvisual cirrus with optical depths $<$ 0.1 is 67%. The magnitude of thin cirrus forcing averaged over all tropical cirrus is 19 W m^{-2}for optical depths $<$ 0.3 and 17 W m^{-2} for optical depths $<$ 0.1. Oblique-detected thin cirrus was compared with cloud radar and lidar from Tropical Western Pacific (TWP) Atmospheric Radiation Measurement (ARM) sites to validate the retrievals. The oblique-stereo analysis detects 45% of cirrus-top layer within the uncertainty range, mostly $<$ 1 km in thickness that was undetected by the standard-stereo technique at the ARM sites. The analysis of tropical MISR orbits with standard processing shows a decline in cloud-top height since 2000. Interestingly, the additional cirrus detected over the tropics also shows a decline in cirrus-top height. The spatial and temporal changes in cloud-top height in the tropics would be reported.