Satellite observations of cirrus clouds in the lower stratosphere

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While cirrus cloud are frequently observed by ground-based lidars in the lowermost stratosphere, evidence from satellite observations is less conclusive. Following previous studies, we extracted information on stratospheric cirrus clouds from the latest version of Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) data (V4) and the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) data to investigate their global distribution and occurrence frequencies. The detection of stratospheric cirrus with MIPAS is particularly challenging because of the broad field-of-view of the instrument and presented here for the first time.

For the identification of stratospheric cirrus clouds, precise information on both, the cloud top height (CTH) and the tropopause height are crucial. The tropopause heights we derived from ERA-Interim using the WMO criterion for the first thermal tropopause. As tropopause from ERA-Interim show ~0.3km bias with GPS data and CALIPSO data are reported on a ~0.2 km vertical grid, we considered cirrus clouds with CTHs 0.5 km above the tropopause as being stratospheric. We focus on nighttime CALIPSO measurements because of their higher sensitivity. MIPAS measurements are known to overestimate CTHs of optically thick clouds and underestimate the CTHs of optically thin clouds. For the detection of stratospheric cirrus, we started 0.75 km above the tropopause, which is the average CTH overestimation by MIPAS found in previous studies. The comparison with the CALIPSO statistics showed that in the tropics the MIPAS stratospheric cirrus cloud occurrence frequency were slightly larger than for CALIPSO. Assuming that this is due to MIPAS overestimating the CTH, for MIPAS we increased the minimum distance of the CTH to the tropopause until the occurrence frequencies of both measurements agreed.

In the tropics, a four-year mean global analysis of stratospheric cirrus clouds from CALIPSO showed high occurrence frequencies (max. >32%) over the western Pacific Ocean, South Africa, and South America. Stratospheric cirrus clouds were more often detected in December-February than June-August in the tropics. At middle (40-60°) and higher latitudes (>60°), CALIPSO observed about 2% stratospheric cirrus clouds. MIPAS observed about twice as many stratospheric cirrus clouds at northern middle latitudes (>3%) and southern middle latitudes (4%). The maximum differences of nighttime stratospheric cirrus clouds between MIPAS and CALIPSO data were 4-6% over the northern Pacific and 6-8% over the Drake Passage.
Further sensitivity tests with higher average distance to the tropopause for MIPAS resulted in lower occurrence frequencies at middle latitudes. However, they were still larger than the occurrence frequencies derived from CALIPSO data. Hence, we consider the finding of higher stratospheric cirrus cloud occurrence frequencies at middle latitudes by MIPAS as robust. One possible explanation for MIPAS finding more stratospheric cirrus clouds at middle latitudes is that MIPAS is more sensitive towards thin cirrus clouds than CALIPSO (nighttime measurements), because of the satellite limb measurement geometry.