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Stratospheric cirrus clouds related to deep convection over North America observed by satellite measurements

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Cirrus clouds in the stratosphere (SCCs) regulate the water vapor budget in the stratosphere, impact the stratosphere and tropopshere exchange, and affect the surface energy balance. But the knowledge of its occurrence and formation mechanism is limited, especially in middle and high latitudes. In this study, we aim to assess the occurrence frequencies of SCC over North America based on The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) instrument during the years 2006 to 2018. Possible driving forces such as deep convection are assessed based on Atmospheric Infrared Sounder (AIRS) observations during the same time.

Results show that at nighttime, SCCs are most frequently observed during the thunderstorm season over the Great Plains from May to August (MJJA) with maximum occurrence frequency of 6.2%. During the months from November to February (NDJF), the highest SCCs occurrence frequencies are 5.5% over the North-Eastern Pacific, western Canada and 4.4% over the western North Atlantic. Occurrence frequencies of deep convection and strong storm systems from AIRS show similar hotspots like the SCCs, with highest occurrence frequencies being observed over the Great Plains in MJJA (4.4%) and over the North-Eastern Pacific, western Canada and the western North Atlantic in NDJF (~2.5%). Both, seasonal patterns and daily time series of SCCs and deep convection show a high degree of spatial and temporal correlation. As further analysis indicates that the maximum fraction of SCCs generated by deep convection is 74% over the Great Plains in MJJA and about 50% over the western North Atlantic, the North-Eastern Pacific and western Canada in NDJF, we conclude that, locally and regionally, deep convection is a leading factor for the formation of SCCs over North America. Other studies stressed the relevance of isentropic transport, double tropopause events, or gravity waves for the formation of SCCs.

In this study, we also analyzed the impact of gravity waves as a secondary formation mechanism for SCCs, as the Great Plains is a well-known hotspot for stratospheric gravity waves. In case of SCCs that are not directly linked to deep convection, we found that stratospheric gravity wave observations correlate in as much as 30% of the cases over the Great Plains in MJJA, about 50% over the North-Eastern Pacific, western Canada and maximally 90% over eastern Canada and the north-west Atlantic in NDJF.

Our results provide better understanding of the physical processes and climate variability related

to SCCs and will be of interest for modelers as SCC sources such as deep convection and gravity waves are small-scale processes that are difficult to represent in global general circulation models.