Comparison of Vertical Velocities in Cirrus Derived from Aircraft and Ground-based Radar

Research Highlight

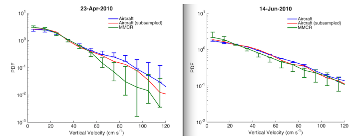
Vertical velocities and turbulence in the upper troposphere are key elements affecting the microphysical properties and dynamical evolution of cirrus clouds. In particular, vertical velocities contribute to the cooling rates in the upper troposphere thereby affecting the values of ice supersaturations, the number concentrations of ice crystals formed by ice nucleation, and the growth rates of ice particles. Adequate parameterizations of the microphysical properties of ice clouds in global climate models (GCMs) require knowledge of the subgrid-scale fluctuations of vertical velocities within a GCM grid box in order to better represent the physical properties and variability of cirrus clouds. Thus, a better knowledge of vertical velocities and their mesoscale variability in the upper troposphere is necessary for advancing our understanding of the relationships between large-scale dynamics and the cloud-scale processes that ultimately affect the microphysical and radiative properties of cirrus clouds.

However, improving our understanding of the statistical distributions of vertical velocities in the upper troposphere and their relationships to the large-scale environmental conditions requires long-term observations. Until a few years ago, the majority of observations of vertical velocities in cirrus clouds have been collected by aircraft and this collection of in situ measurements has served as the basis for our present knowledge about the turbulence and wave generating mechanisms controlling the mesoscale variability of vertical velocities in the upper troposphere. Novel retrieval algorithms are now being used to obtain continuous observations of vertical air motions within cirrus clouds from ground-based profiling Doppler

cloud radar. Due to their long record and continuous ongoing observations, these radar-based retrievals have the potential to provide an unprecedented amount of data for a wide range of conditions. However, a rigorous comparison of vertical velocities retrievals with in situ aircraft measurements is lacking so far but is necessary for building confidence in the observations and better understanding potential limitations of both observational platforms.

This study introduces a statistical comparison of vertical velocity observations within cirrus from aircraft and ground-based cloud profiling Doppler radar. Two cases of midlatitude anvil cirrus forming under very similar environmental conditions are examined. The case studies benefit from simultaneous observations of vertical velocities in cirrus collected at and around the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site during the Small Particles in Cirrus (SPARTICUS) field campaign.

Observations from both platforms suggest that the majority of vertical velocities in the examined case studies of midlatitude anvil cirrus are roughly within 1 m s#1 although higher vertical velocities are occasionally observed. The quality of the vertical velocity comparison between in situ aircraft measurements and ground-based Doppler radar retrievals depends on the case. For the first case on 23 April 2010, the comparison suggests that the radar retrieval may underestimate vertical velocities in the range between roughly 50 cm s#1 and 1 m s#1. For the second case on 14 June 2010, the agreement between radar and aircraft is excellent and the differences are smaller than the observed spatial variability of vertical velocities within cirrus as explained by the spatial distance between the aircraft and the radar. Differences in the spatial scales of vertical velocities and turbulence sampled by the aircraft and Doppler radar, which arise due to differences in the temporal resolution of the observational platforms are not found to fully explain the observed discrepancies. However, for the April 23 case, spatial and temporal variability related to anvil evolution is larger and contributes substantially to discrepancies at large vertical velocities.



Probability density functions (PDF) of absolute values of vertical velocity in cirrus observed by aircraft (blue) and retrieved from MMCR (green) for anvil cirrus on (a) 23 April 2010 and (b) 14 June 2010. The PDF of aircraft data subsampled at the same rate as MMCR is shown in red. Uncertainty range is indicated by vertical bars. Note the scale change of y-axis in the right panel.

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Estimates for the dissipation rate of turbulent kinetic energy agree to within 1 order of magnitude between the two observational platforms. The comparison suggest that retrievals of vertical velocities have considerable potential for providing high-quality continuous observations of vertical velocities in the upper troposphere, but further comparisons and dedicated field campaigns are necessary to further investigate the discrepancies and to better understand the effect of the microphysical assumptions on the vertical velocity retrievals.

Reference(s)

Muhlbauer A, H Kalesse, and P Kollias. 2014. "Vertical velocities and turbulence in midlatitude anvil cirrus: A comparison between in situ aircraft measurements and ground-based Doppler cloud radar retrievals." Geophysical Research Letters, 41, doi:10.1002/2014GL062279.

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Cloud Life Cycle