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Direct Estimation of the Vertical Velocity distribution in Cirrus and Implications for the Aerosol Indirect Effect

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The representation of vertical wind velocity, W, in atmospheric models constitutes the largest source of uncertainty in the calculation of cirrus formation rates, challenging our understanding of the effect of aerosol emissions on ice clouds. Using global atmospheric simulations with a spatial resolution of 7 km we obtain for the first time a direct estimate of the global distribution of W, P(W), at the scale relevant for cloud formation. It is shown that P(W) varies widely over the globe with the widest distributions resulting from orographic uplift and convection. Combining our results with reanalysis products and the NASA Goddard Earth System Model (GEOS-5), we show that a narrow P(W) at high altitude limits the frequency of cloud formation events driven by high W, and on average leads to lower ice crystal concentration as T decreases. These features are in agreement with a lower frequency of homogeneous ice nucleation than typically predicted by GCMs and suggest that the correct parameterization of P(W) is critical to the correct simulation of cirrus properties, particularly at low temperature. Furthermore, our results show that the susceptibility of cloud properties to aerosol emissions is strongly dependent on the width of P(W), increasing strongly for narrow distributions. Small-scale dynamical forcing thus acts to modulate the aerosol indirect effect in cirrus clouds.