Parameterization of Ice Fall Speeds in Climate Models

Sanderson et al. (2008) used the Hadley Centre atmospheric model (HadAM3) and performed a linear analysis using a multi-thousand member perturbed physics ensemble to relate climate sensitivity [defined as the equilibrium response of global-mean surface temperature to a CO_2 doubling] to atmospheric GCM model parameters. Based on this study they found that 70% of the variance in the global feedback parameter was due to two leading factors, the entrainment coefficient and the mass weighted ice fall velocity (V_m). The ice fall-velocity has a strong impact on radiative forcing and climate feedback due to its influence on cirrus cloud coverage and upper troposphere water vapor (Mitchell et al. 2008; Mitchell and Finnegan 2009) which is very important for determining climate sensitivity (Sanderson, 2010). Earlier studies have shown that the sensitivity of GCMs is highly dependent on the way clouds are parameterized (Fowler and Randall 1994; Ma et al.1994).

In spite of its importance, V_m in climate models is highly uncertain due in part to its dependence on the ice particle size distribution (PSD), which has been plagued with measurement uncertainties from small ice particles produced by shattering. Historical measurements of ice crystal concentrations, mass and area have been erroneous owing to the presence of large concentrations of small (< 60 μm) ice crystals produced due to the shattering of large ice crystals on inlets of cloud probes. A decrease in ice crystal number concentration for a given amount of ice water content would increase the ice mass (more mass per ice crystal), and thereby increase the mass weighted V_m resulting in shorter cloud lifetime. As thin and sub-visual cirrus present a net positive forcing on Earth's radiation balance, a reduction of these clouds may result in a net negative forcing potentially capable of a significant adjustment of the global radiation balance (Mitchell and Finnegan 2009). Hence proper understanding of ice processes (e.g. ice nucleation, ice multiplication and ice growth) is essential to correctly parameterize and evaluate ice fall speed. Recently, data processing techniques used in conjunction with new probes in recent field campaigns appear to have significantly reduced the artifact concentration of small ice particles (Lawson, 2011). The focus of this research is to improve the parameterization of V_m in GCMs by using data from the new and improved 2 Dimensional-Stereo (2D-S) cloud probe. The parameterization of V_m is achieved by relating it to temperature (T) and ice water content (IWC). V_m is also related to the effective diameter (D_e). It is shown that the relation of V_m to D_e is better for parameterization purposes than the relation of V_m to (T and IWC).

Fall speed parameterization in mid-latitude cirrus (both anvil and synoptic cirrus) will be presented and compared to the fall speed parameterizations in the Tropics and the Arctic.