Vertical velocity in ice clouds
Status report

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Justification for VV measurements in cirrus clouds

• Vertical air motions acting on a wide range of spatial (1-100 km) and temporal scales (seconds to hours) have been suggested as the primary mechanism for reaching ice-supersaturation and subsequently cirrus cloud formation (Kärcher and Ström, 2003).

• Facilitate:
  – microphysical retrievals (actually coupled) and thus help to assess ice clouds radiative properties
  – particle sedimentation rates in cirrus clouds and sensitivity of GCM future climate simulations (Mitchell et al., 2008)
Vertical Velocity in Cirrus

Measured extensively using aircraft observations – though data is not well utilized.

Example: Gultepe et al. (1995) – cirrus measured during FIRE II

Examine data from past campaigns (FIRE II, ARM Cloud IOP 2000, SPartICus, etc.)
Retrievals of Vertical Velocity in Cirrus

- Radar Methods (examples)
  - Averaging Doppler Velocity over long time periods i.e. Orr and Kropfli (1999)
  - Solve explicitly within the sample volume using 3 Doppler moments (Deng and Mace, 2006)

Limitations: Sensitive to larger particles that are typically falling, missing nucleation zones where crystals form
Coherent Doppler Lidar
under-explored for cirrus studies

Example from Grund et al. (2001) using High-Resolution Doppler Lidar

Potential to study vertical velocity in cirrus nucleating zones and crystal fall speeds using zenith lidar or nadir on-board aircraft.

Limitations – limited to optically thin clouds
Challenges

The majority of the available (published) ice cloud remote sensing techniques have focused on ice microphysical retrievals (e.g., IWC and effective radius).

Aircraft-based VV measurement are a great source of in-situ data for vertical air motion and microphysics (SPARTICUS) and future retrieval development efforts should take advantage of such observations.

Straw man suggestions:

Start by analyzing the long record of Doppler measurements at the ARM sites to derive a cirrus clouds “Doppler velocity” climatology (e.g., variance, identification of turbulent/gravity scales of motion)

Revisit the Z-V and Doppler spectra based techniques that could accomplish separation of ice clouds microphysics and dynamics.
Inertial Subscale Slope vs. altitude & time for past 12 years

Before the MMCR upgrade