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

Examine data from past campaigns (FIRE II, ARM Cloud IOP 2000, SPartICus, etc.)

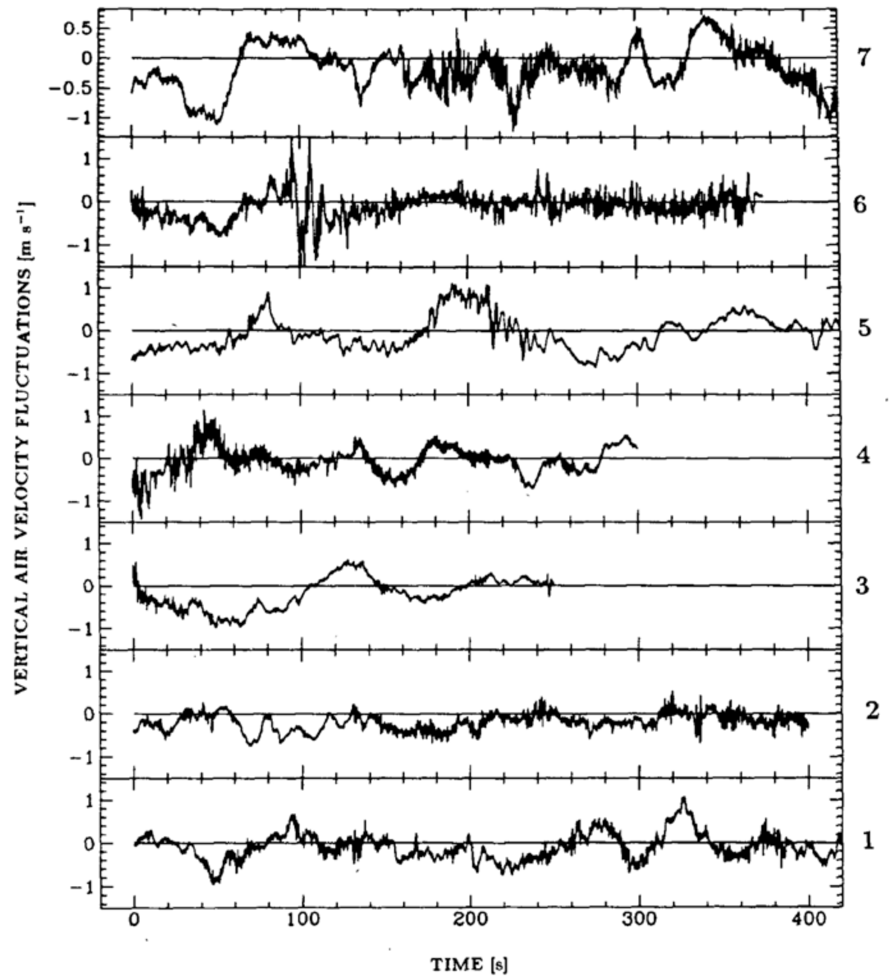
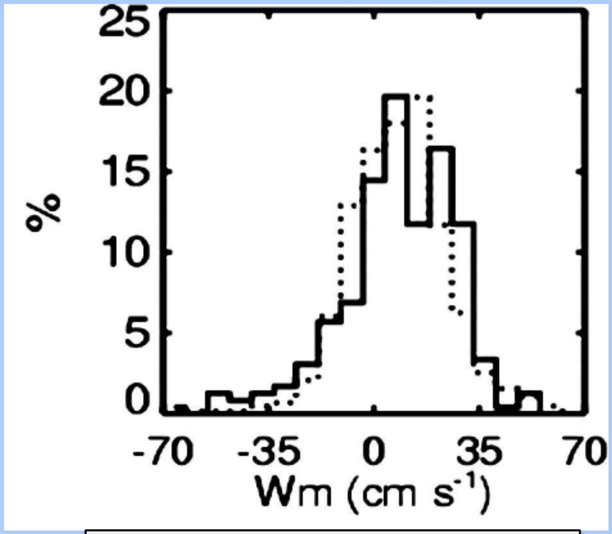


FIG. 13. Time series of vertical air velocity fluctuations for the 6 December case after removing mean and large-scale trend. Leg numbers are shown on the right side of the each box.

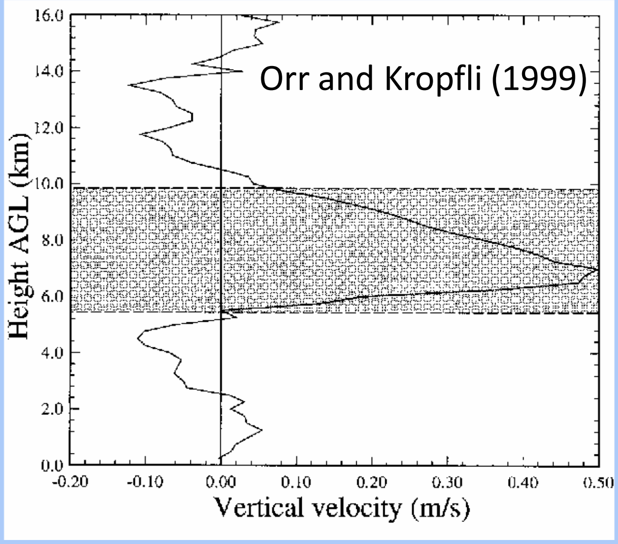
Example: Gultepe et al. (1995) – cirrus measured during FIRE II

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)



Deng and Mace (2006)
Retrieval (solid)
Aircraft (dash)



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

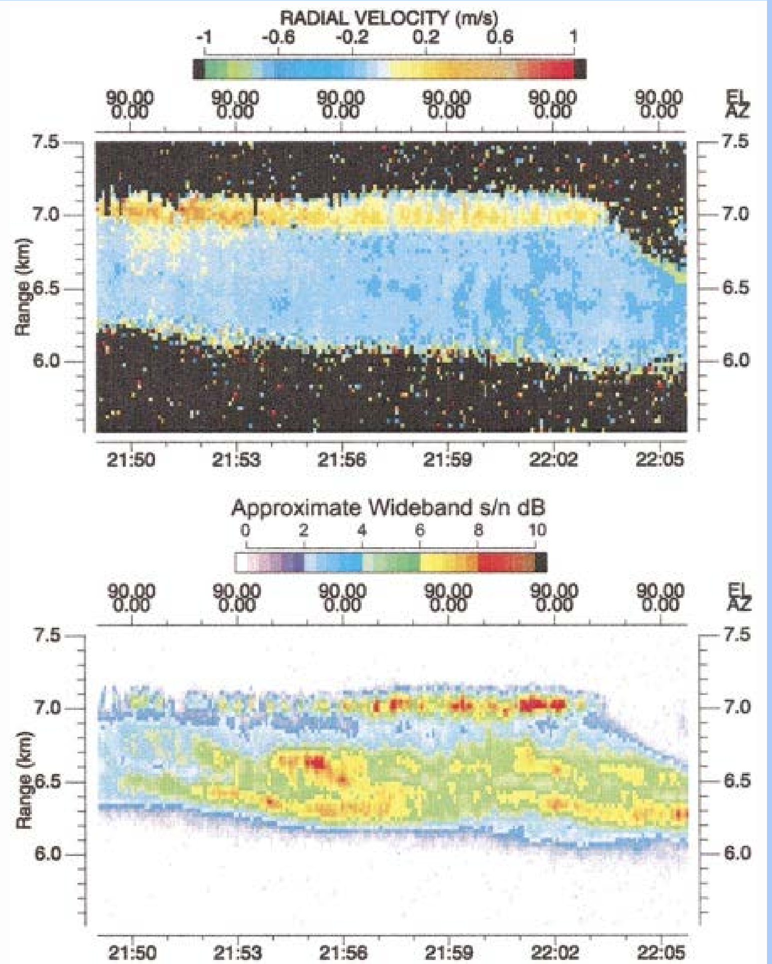


FIG. 10. Range-time display of vertical beam data showing a cirrus cloud as it advects overhead. The *w* structure is shown in the top panel; the backscatter intensity is shown in the lower panel on a log scale. The top of the cloud layer shows the upward motion associated with active generating cells. The remainder of the cloud is composed of ice virga.

Grund et al. 2001 JAOTech

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