Vertical Motions in Arctic Mixed-Phase Stratus

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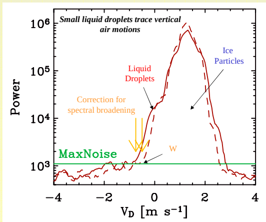
Air Motions from Doppler Spectra

Method

1) Identify regions containing cloud liquid (see E. Luke et al. poster)
2) Determine spectral broadening correction terms due to shear, turbulence, and beam width
3) Vertical velocity is the left edge of the spectrum (w/ correction)

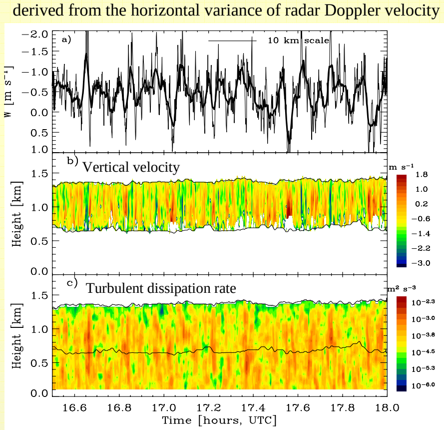
Main assumption: Liquid droplets trace vertical air motions due to their limited size.

A Doppler Spectrum



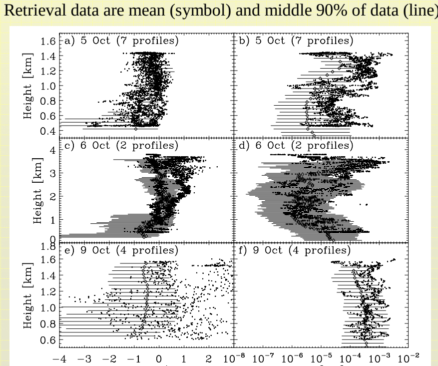
An Example

Layer-averaged & height resolved vertical velocity, and turbulence derived from the horizontal variance of radar Doppler velocity



Aircraft comparisons during M-PACE

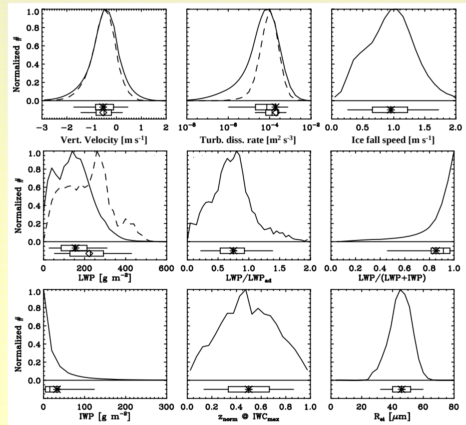
Vertical velocity (W) and turbulent dissipation rates (ε). Retrieval data are mean (symbol) and middle 90% of data (line)

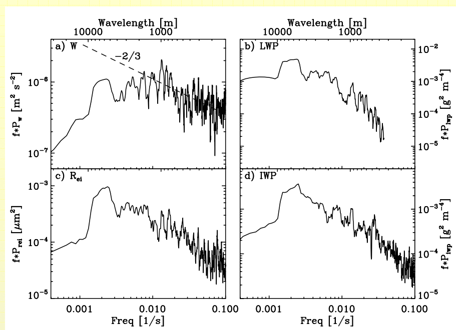


Mixed-Phase Cloud Properties

Retrieved Properties During M-PACE

These distributions of cloud properties are characteristic of single-layer, low-level, autumn mixed-phase stratus observed in Barrow, Alaska. Cloud microphysical properties are derived using a combination of radar and microwave radiometer.





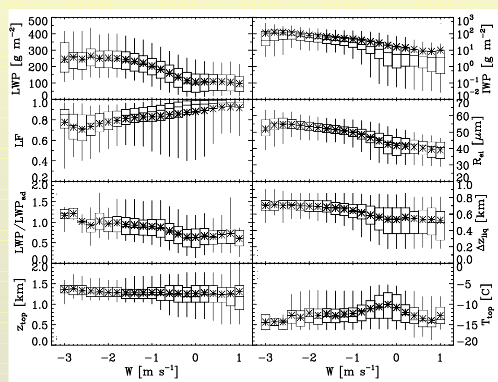
Timeseries Analysis

Cloud microphysical properties and vertical air motions vary on similar scales. Microphysics are dominated by 4 – 10 km motions while vertical motions are dominated by scales from 0.6 – 10 km.

Dependencies

Vertical velocity influences cloud properties. For increasing updraft strength:

- LWP, IWP, R_{ei} increase
- Liquid fraction decreases
- Liquid layer thickness increases
- Adiabaticity increases



Summary

❖ Vertical velocity can be derived from cloud radar; results compare favorably with aircraft observations

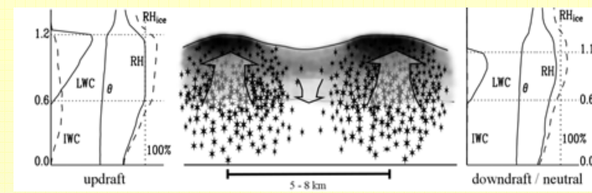
❖ Typical autumn, Arctic mixed-phase stratus:
W = 0.6 m s^{-1}(up), LWP = 150 g m^{-2}, IWP = 20 g m^{-2},
85% liquid fraction, R_{ei} = 45 μm, ice fall speed = 1 m s^{-1}.

❖ Dominant scales-of-variability for vertical motions and microphysics are 0.6 – 10 km.

❖ A conceptual model details the cloud life cycle by relating vertical velocity to other cloud parameters. Limited ice forming nuclei concentrations and ice particle fallout are important for liquid maintenance throughout the cloud life cycle.

A Conceptual Model

relating air motions and microphysics

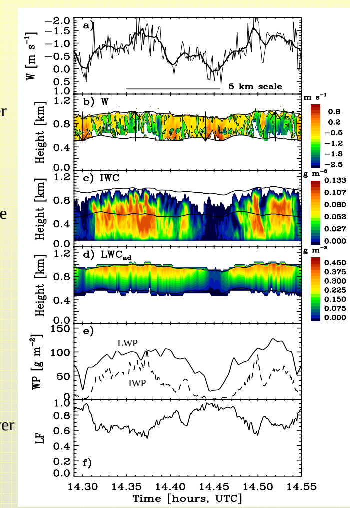


Updraft

- Liquid grows to form a near adiabatic profile
- RH ~ 100% in liquid cloud layer
- Cloud top lifts
- Ice particle nucleation within liquid layer due to high RH_{ice}
- Ice crystals grow to large sizes
- IWC maximizes near liquid base

Neutral/Downdraft

- Liquid evaporates (but not completely) becoming sub-adiabatic
- RH < 100% in cloud layer
- Cloud top descends
- No new ice particle initiation
- Ice crystals fall out of liquid layer (vertical stratification)



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