In-situ measurements of upper tropospheric vertical velocities: Applications, value and limitations

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Introduction

Motivation:

Vertical velocity (VV) measurements are critical for model evaluation and improvement (e. g., PDF-based cloud parameterizations)

Overview:

- VV measurements collected during DOE Small Particles in Cirrus (SPARTICUS, Jan-Jun 2010) campaign
- Comparison between in-situ aircraft measurements and Doppler radar retrievals (collaboration with Heike Kalesse and Pavlos Kollias)
- Application 1: GASS Cirrus Model Intercomparison Project
- Application 2: Regime-based analysis of VV measurements and relationships to cirrus microphysics

SPARTICUS vertical velocity measurements

- Instrument developed by Aventech Research Inc.
- Primarily developed for measuring **horizontal** wind speeds. Application as airborne measurement system for agriculture and forestry (e. g., determination of spray transport, dispersion and deposition)
- Absolute accuracy: 0.5 m/s (U,V), **0.75 m/s** (W)

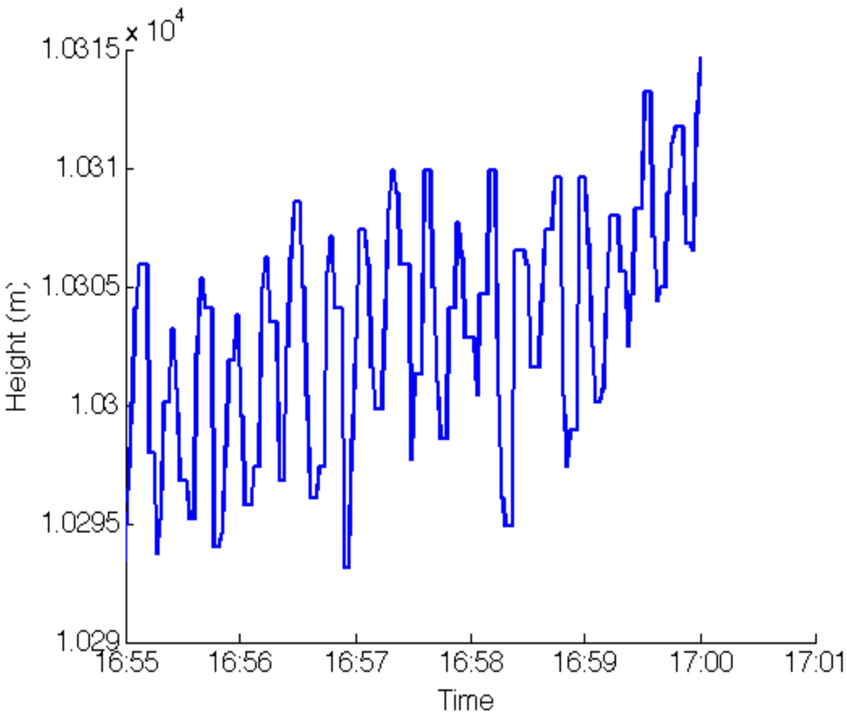
SPARTICUS data and corrections

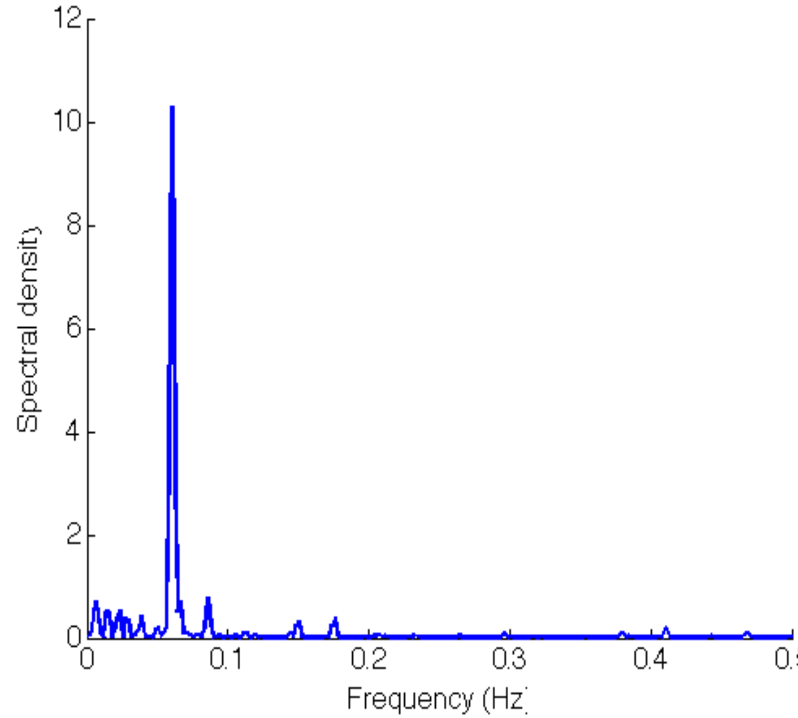
VV measurements can't be used "out-of-the-box" but need corrections:

"Accurate wind measurement on an airborne platform poses a set of challenging problems given the fact that the aircraft is moving many times faster than the wind being measured. As a result, the wind signal of interest is only a small portion of the measured air motion data that is dominated by the dynamic motion of the aircraft itself." (AIMMS-20 flyer)

- Level 1 (L1): Bias correction
- Level 2 (L2): Bias correction + detrending (Gultepe and Starr, 1995, JAS)
- Level 3 (L3): Bias correction + detrending + aircraft harmonics removed

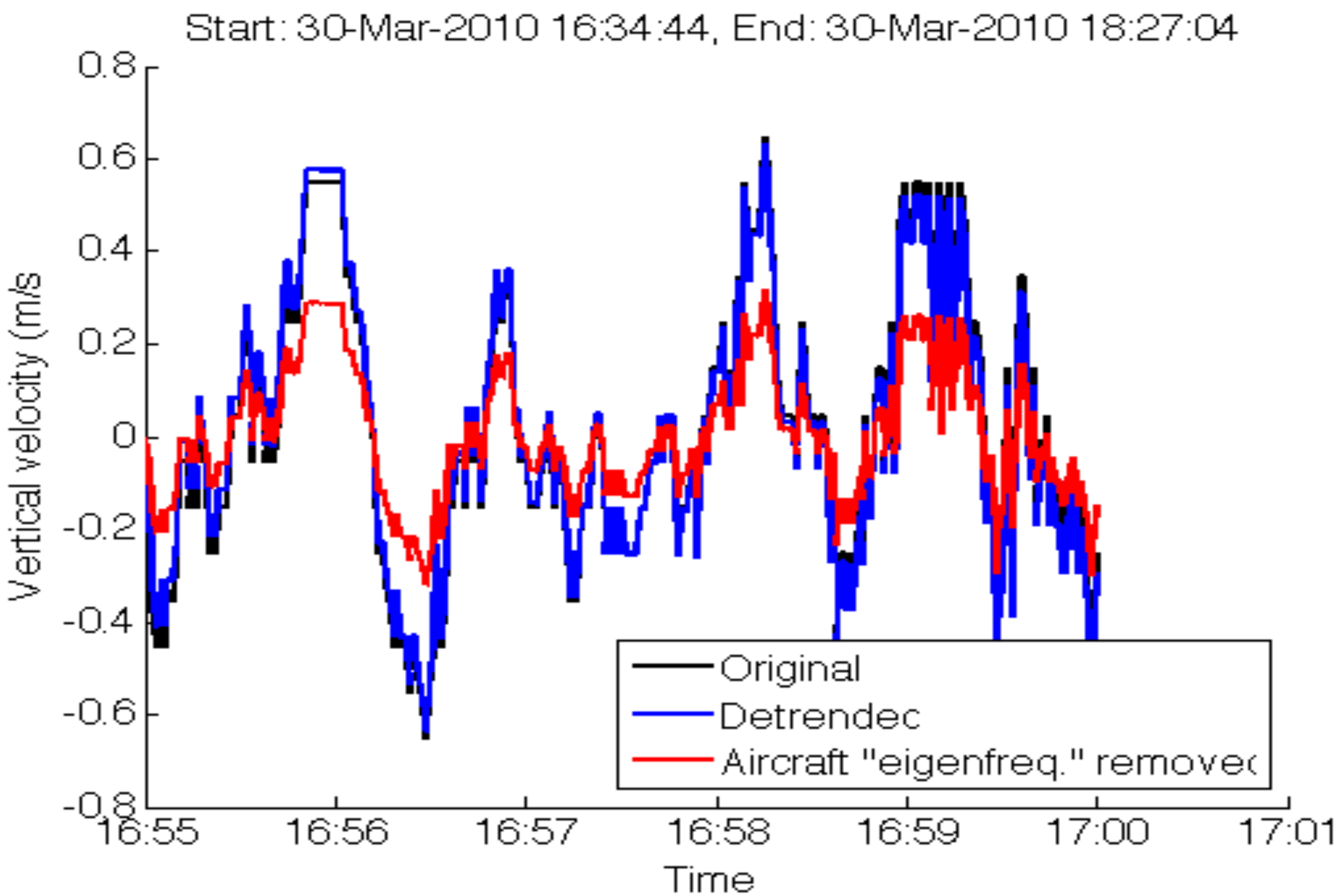
Example of aircraft "eigenmotion"



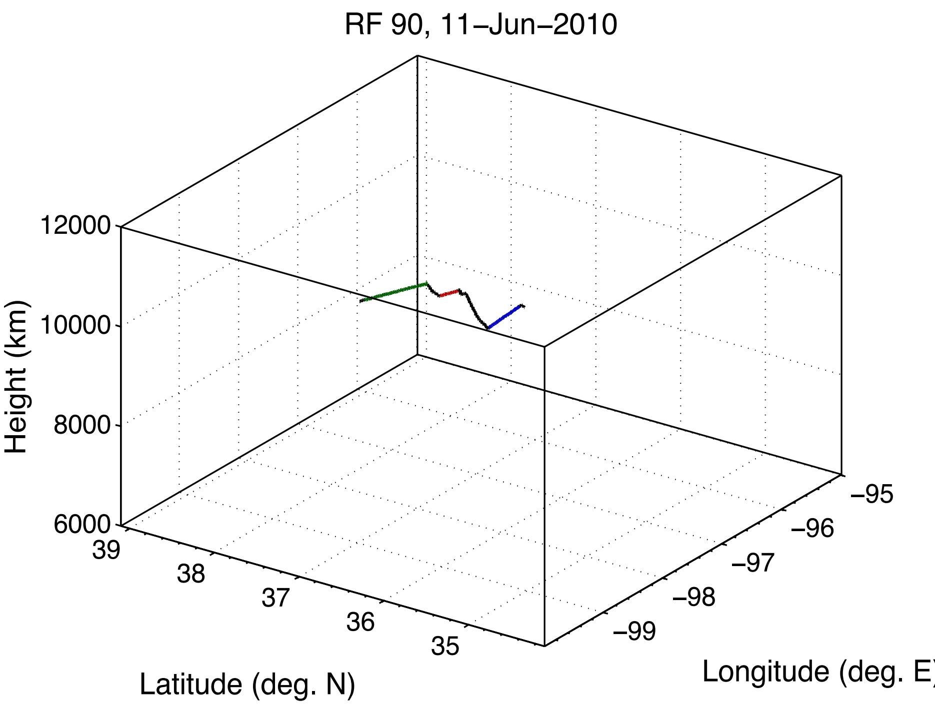


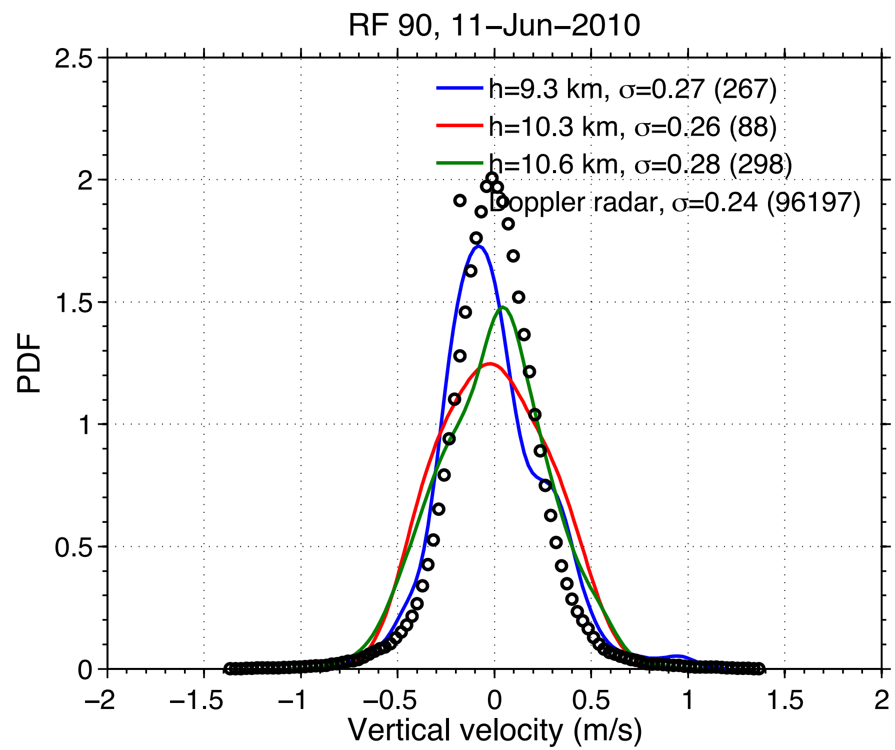
Aircraft vibrations lead to 60 mHz signal in height and VV (2-5 km wavelength). Artifact?

Effect of L1-3 corrections

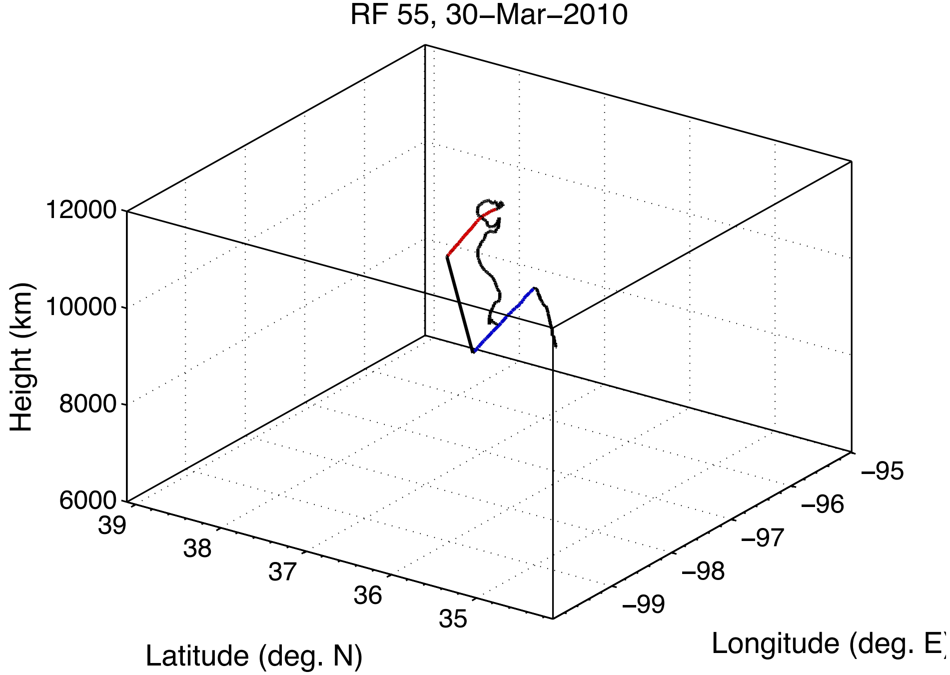


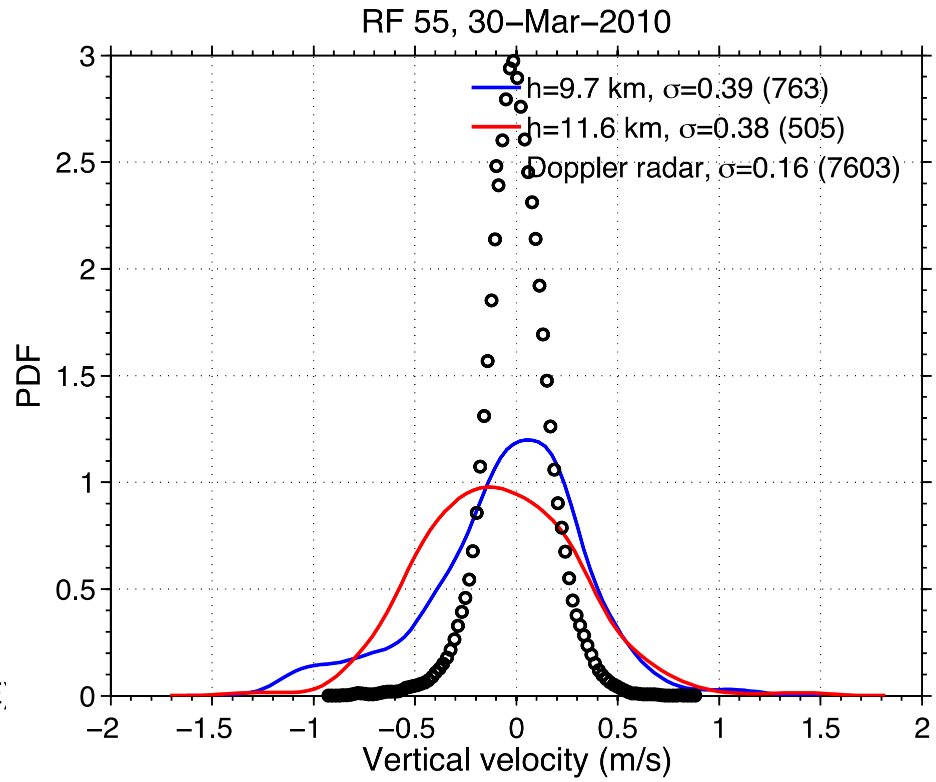
Doppler radar comparison: RF 90, Jun 11



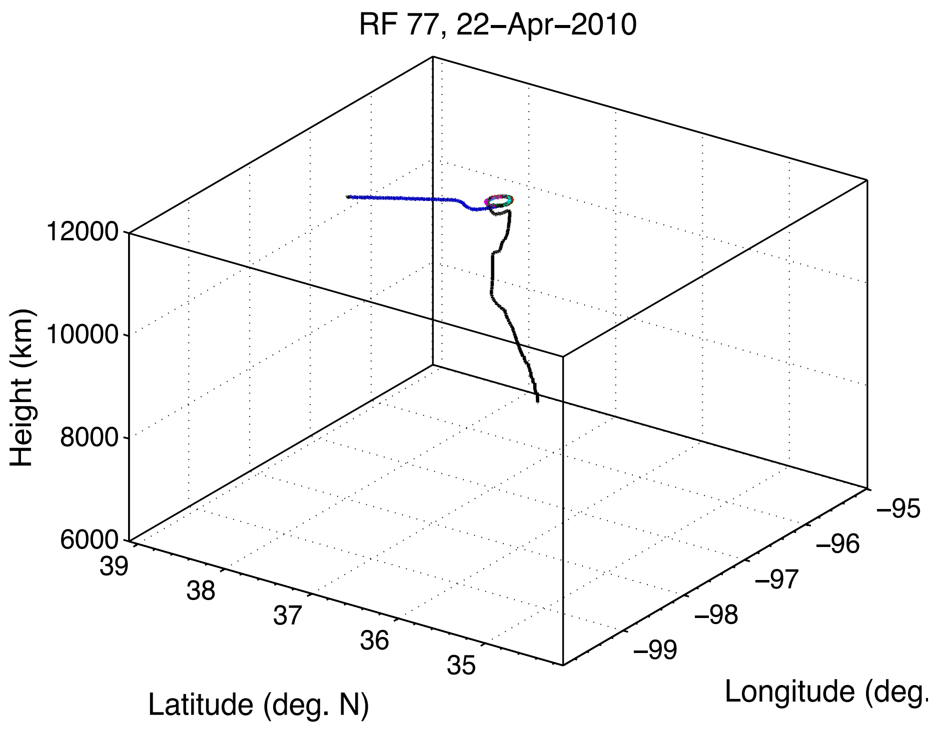


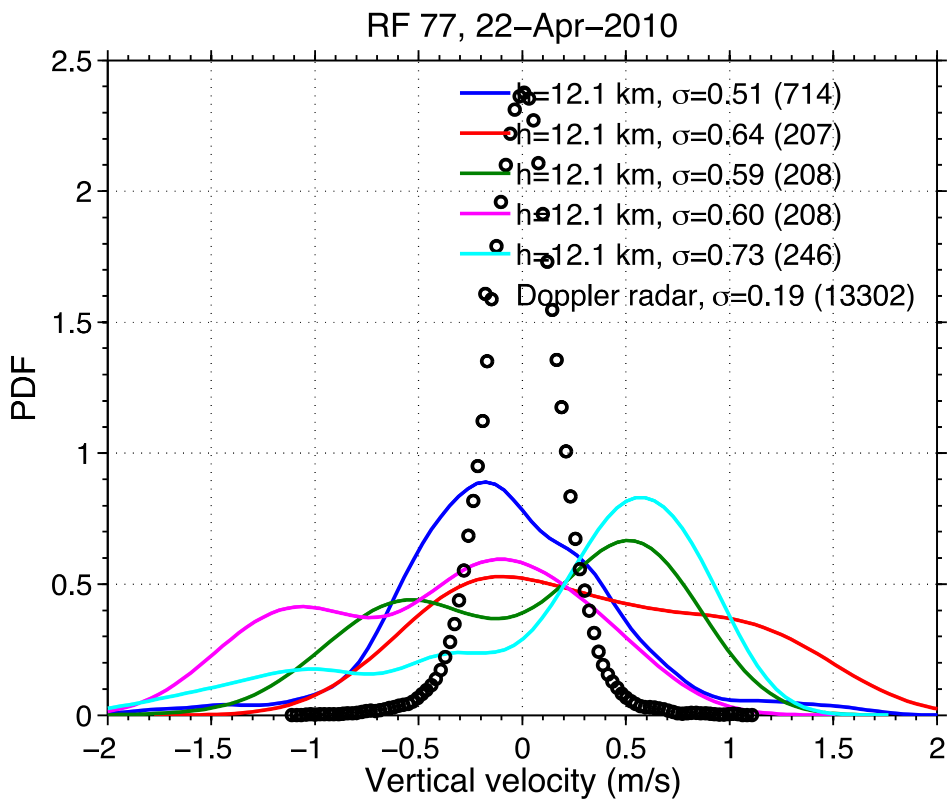
Doppler radar comparison: RF 55, Mar 30



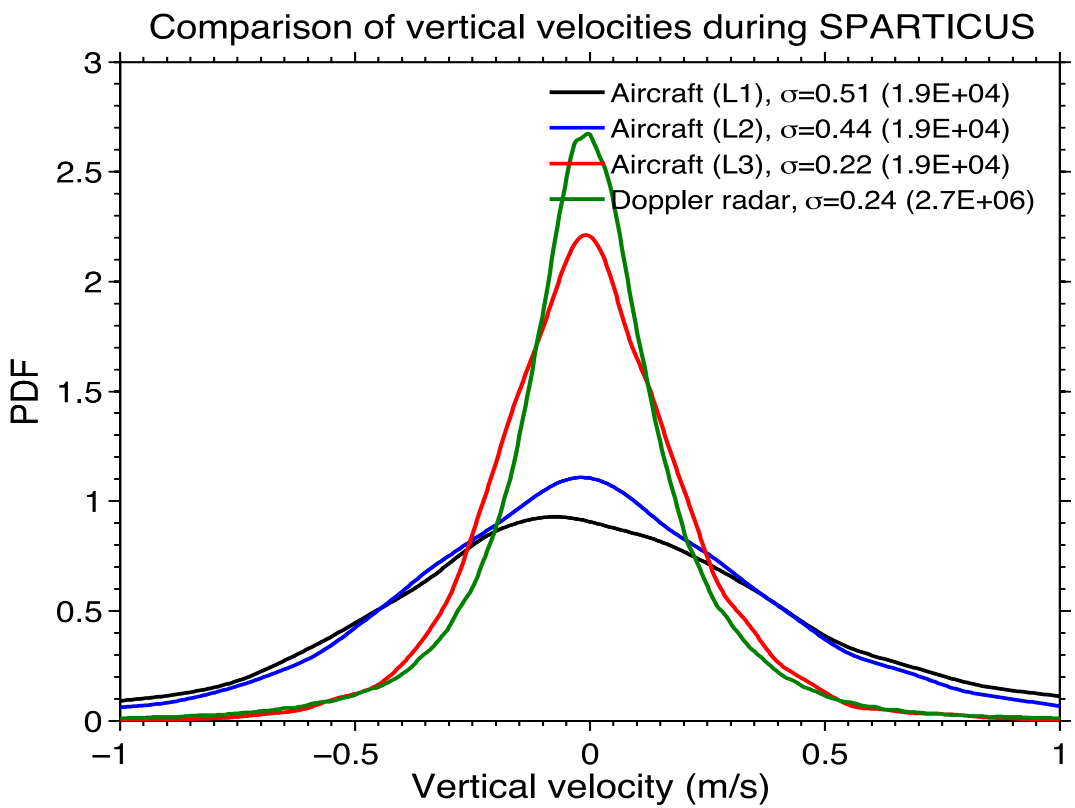


Doppler radar comparison: RF 77 Apr22





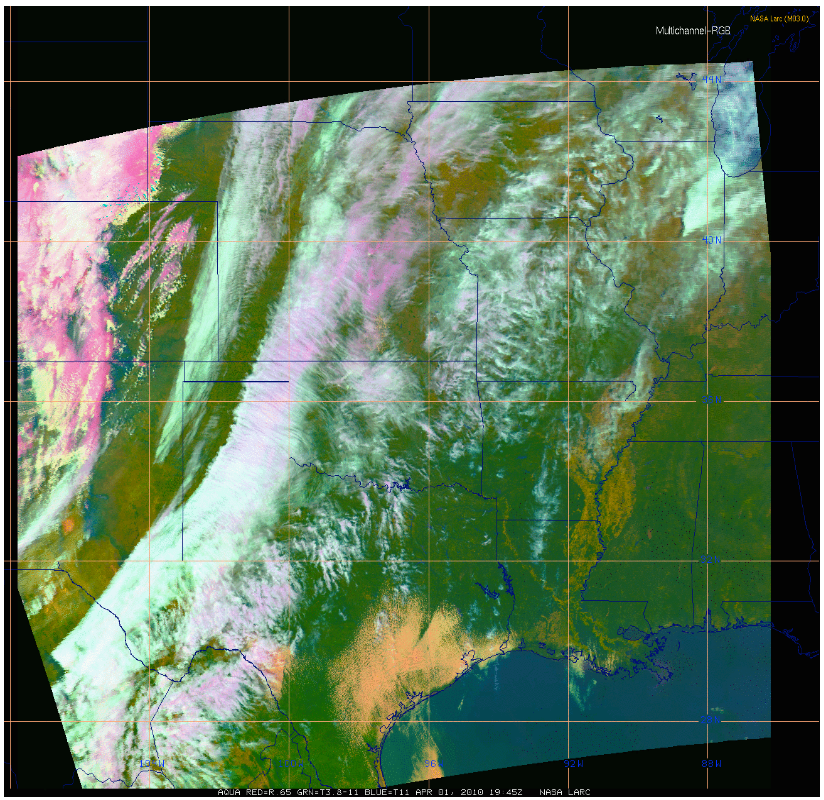
Aircraft vs. Doppler radar

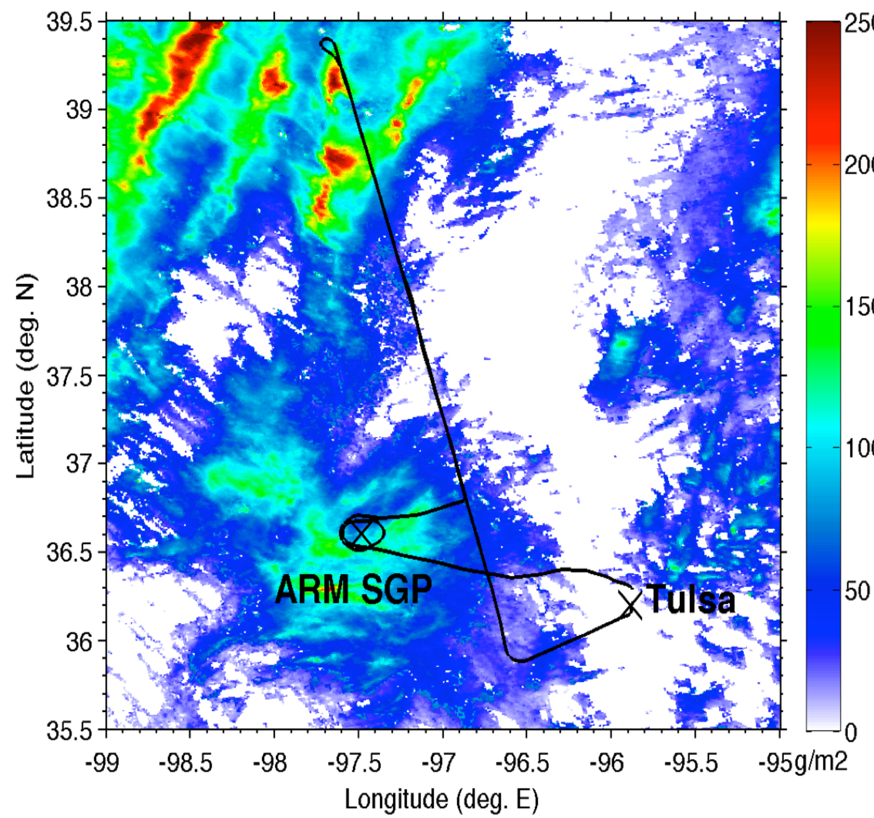


- Aircraft VV PDFs are (2x) broader than VV PDFs from Doppler radar
- Good comparison of VV PDFs if aircraft measurements are corrected for "eigenfrequencies" (L3 correction).

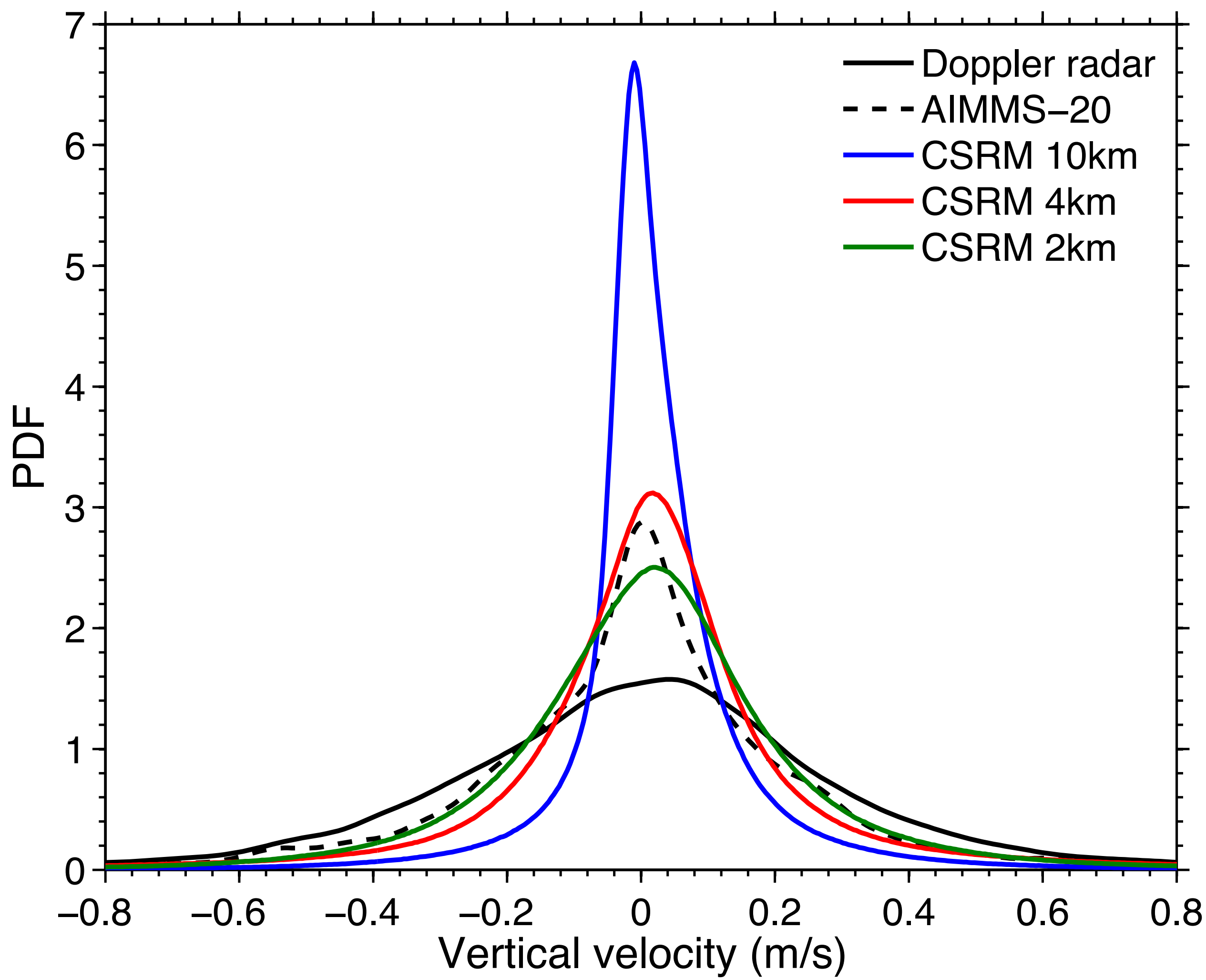
Application 1: GASS Cirrus Model Intercomparison Project

Based on SPARTICUS April 1 case (http://www.gewex.org/gass_panel.html)



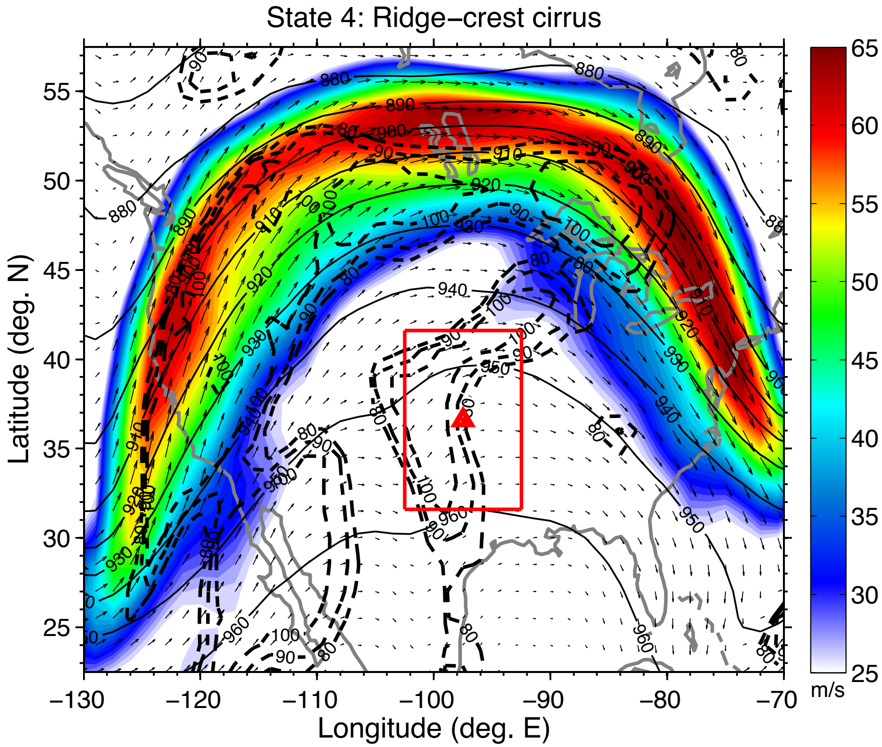


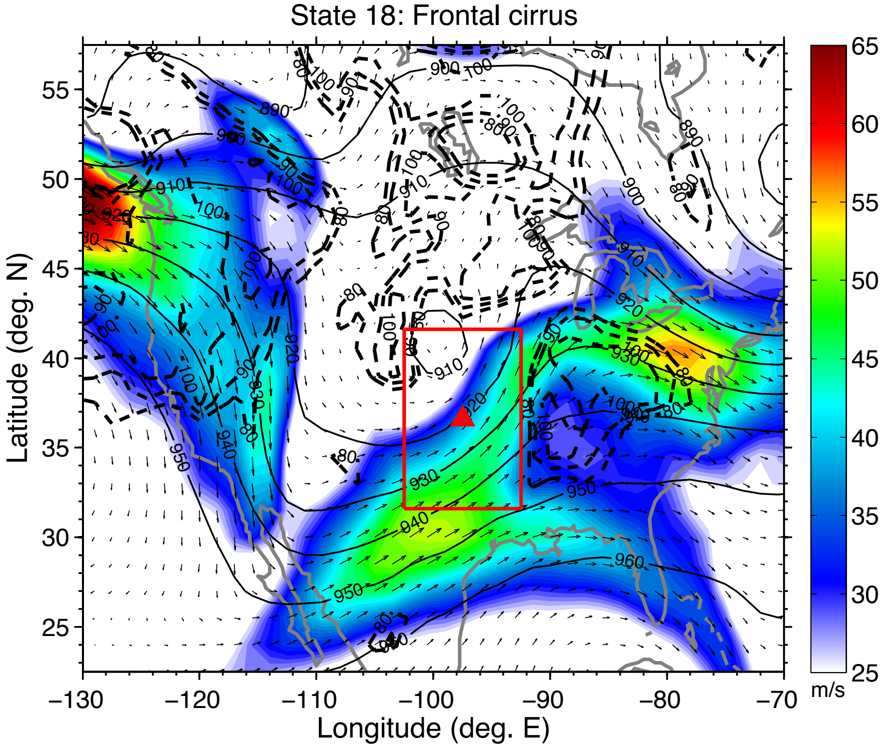
Vertical velocity comparison



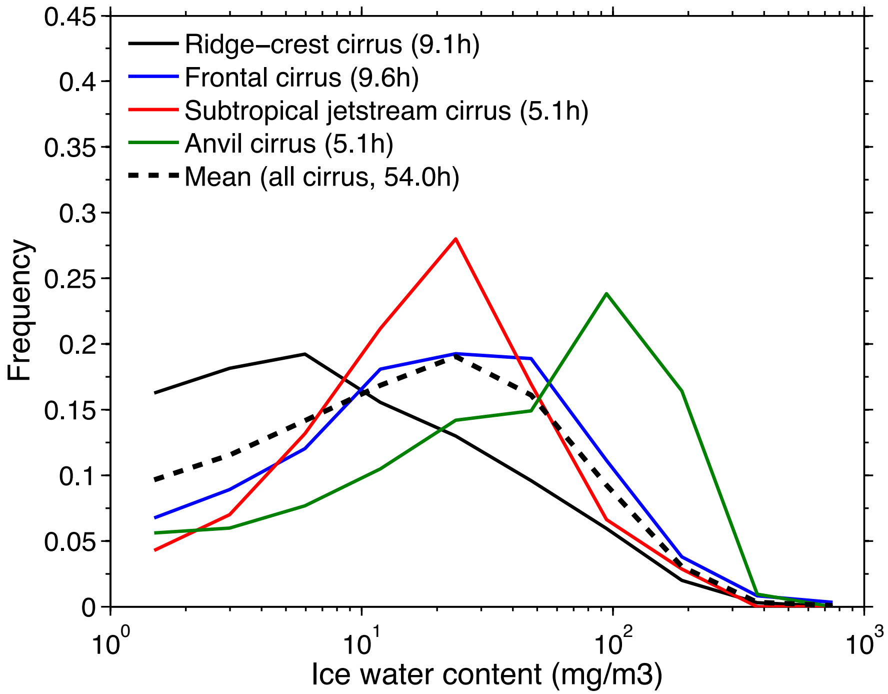
Application 2: Atm. state analysis

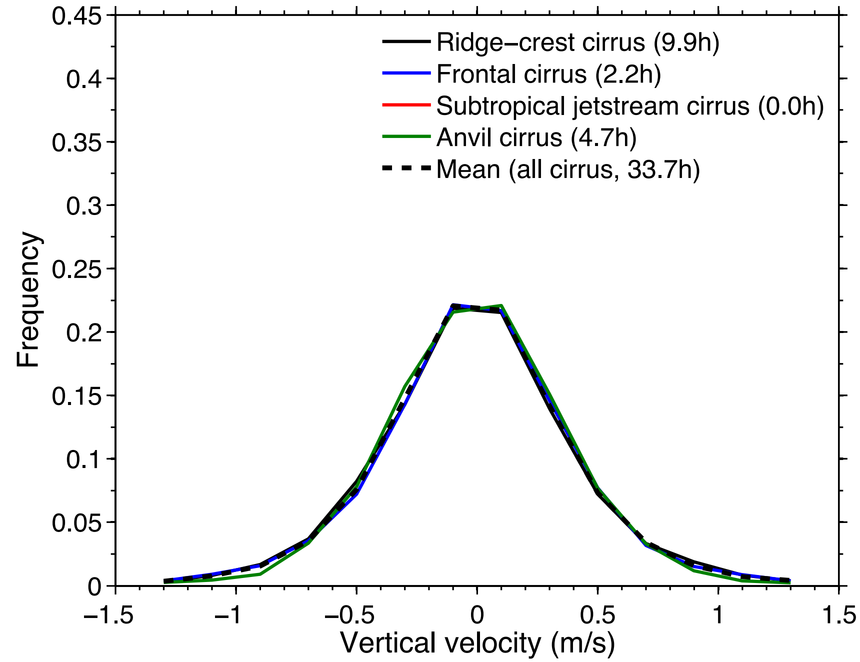
- Atmospheric state analysis at ARM SGP site (Clustering meteorology according to MMCR cloud profiles)
- Composition of SPARTICUS aircraft observations by atmospheric state
- 2 examples: Ridge-crest cirrus category vs. frontal cirrus category





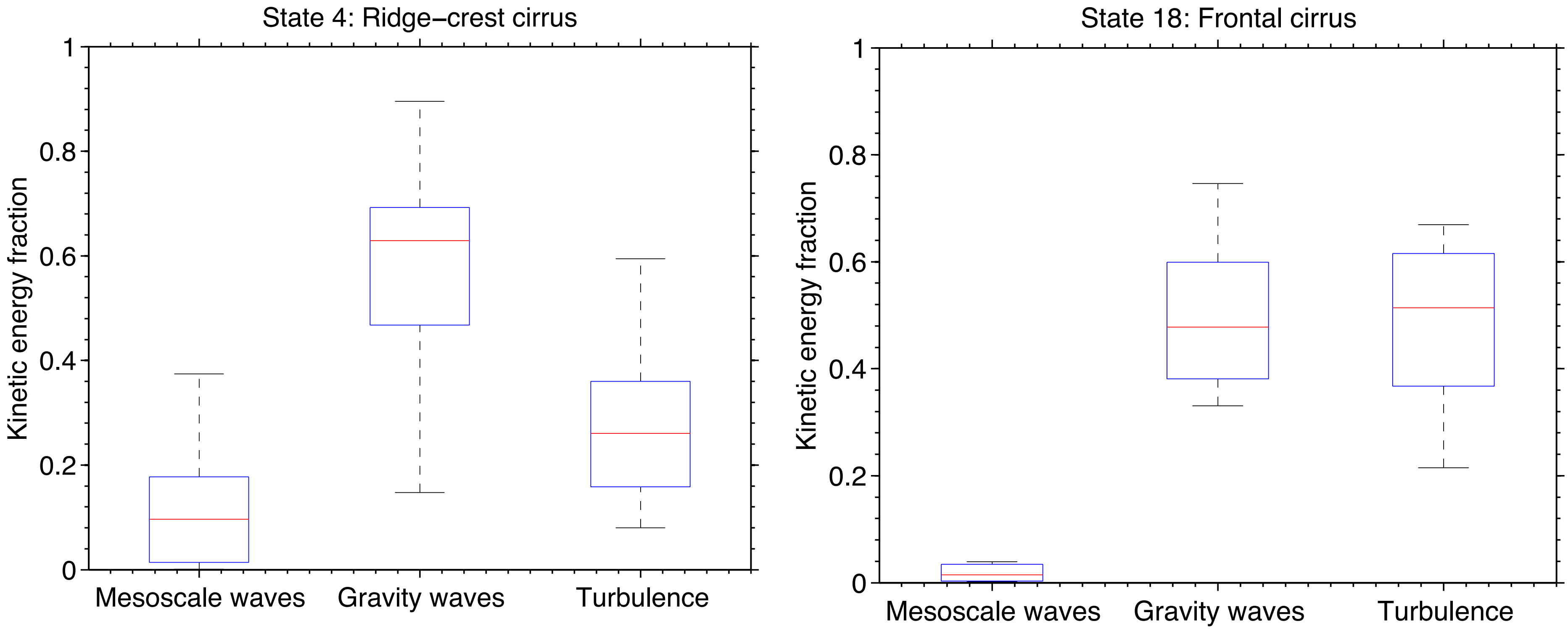
Composites of SPARTICUS obs.





- Striking contrasts in cirrus microphysics among different categories but virtually no differences in vertical velocities

Composites of SPARTICUS obs.



- Ridge-crest cirrus: Contributions to kinetic energy is dominated by wave activity rather than turbulence/embedded convection
- Frontal cirrus: Equal partitioning of kinetic energy between turbulence and gravity waves

Conclusions

Summary:

- Role of aircraft vibrations on airborne VV measurements still unclear and needs further investigation
- Aircraft VV measurements agree with retrievals from Doppler radar within roughly a factor 2
- Comparison between VV from Doppler radar/aircraft show good agreement with high resolution CSRM simulations
- Cirrus microphysical properties are rather insensitive to vertical velocity variations
- Contributions from wave activity vs. turbulence dependent on large-scale dynamics. Kinetic energy spectrum is dominated by gravity modes (ridge-type cirrus category) and turbulence/ embedded convection (frontal cirrus category)

Value:

Vertical velocity (VV) measurements are critical for model evaluation and improvement as well as for improving the fundamental understanding of dynamics-microphysics interactions

Limitations:

- Poor absolute accuracy of instruments limits application to “perturbation vertical velocity”
- Higher time resolution (e. g., 0.1 Hz) for aircraft platforms is desirable (1 Hz sampling with 200 m/s TAS equals 400 m spatial “resolution”)
- Detection of mesoscale waves requires long flight legs (> 15 min.)
- Dedicated instrument intercomparison projects would be desirable

Thanks!

Questions???