K_{dp} signatures of precipitating clouds as a proxy for vertical velocity and possible use in precipitation nowcasting

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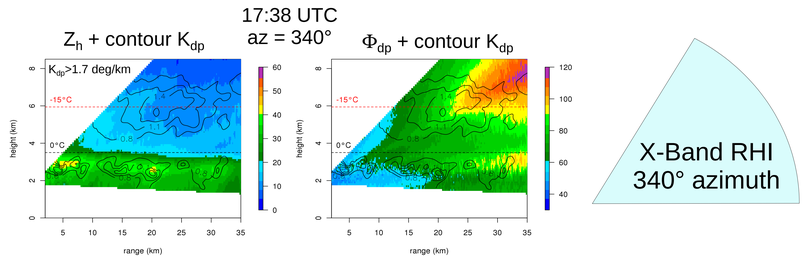
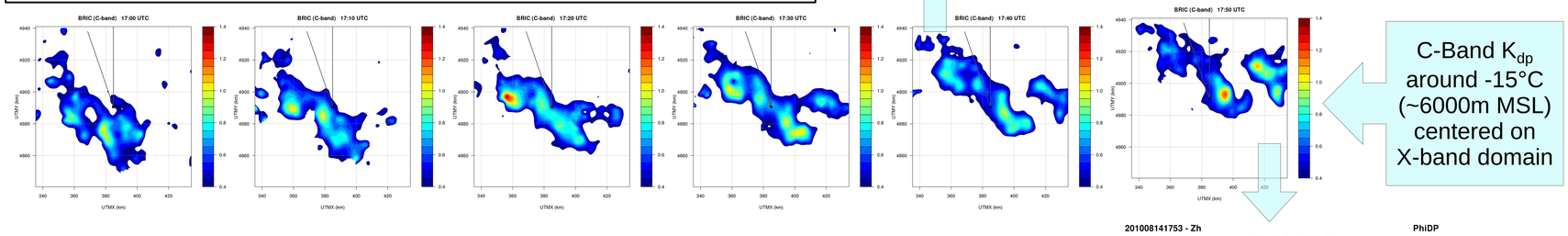
Abstract

Vertical motions play a central role in the formation of precipitation, for both warm and cold rain processes. Radar retrieval of the vertical component of the wind field by means of multiple Doppler techniques is in general only feasible when the vertical velocity is of the same order of the horizontal components (shallow and deep convection) and is limited to a portion of the overlapping area. More often the vertical motions are considerably weaker than the horizontal counterpart and Doppler retrievals are not viable due to large uncertainties.
The potential of radar polarimetry for microphysical retrievals is well established. The identifiable microphysical species and processes are often directly related to the cloud dynamics, specifically to the vertical component of the wind field. This study aims at investigating the potential of polarimetric signatures of microphysical processes related to updraft regions. Notable examples are the vertical columns of Z_{dr} in convective storms and the enhanced K_{dp} values observed in the ice region of stratiform precipitating systems. The latter observations are considered in this work, through a comparison of co-located C-band K_{dp} estimates and X-band vertical pointing Doppler measurements in Italy. The K_{dp} signatures may be used to estimate the IWC or as a proxy for vertical velocity for assimilation in numerical models.



X-Band RHI 340° azimuth

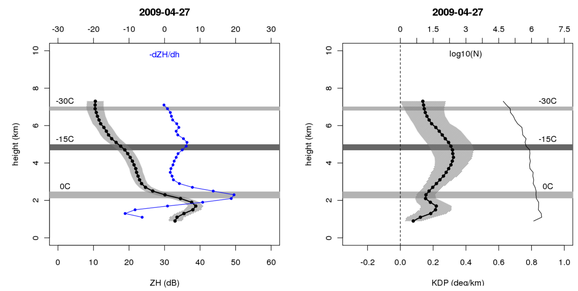


C-Band K_{dp} around -15°C (~6000m MSL) centered on X-band domain

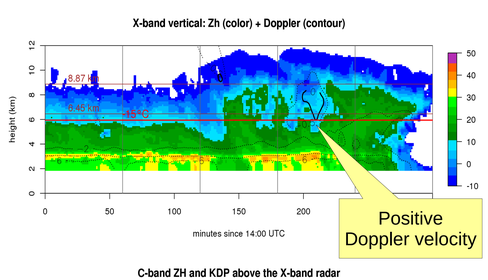
Case Study 2009-04-27

- Widespread precipitation: 24 hours average accumulation of 76 mm over the plains, with peak values up to 140 mm
- Vertical-looking observations from X-band
- K_{dp} fields in the ice from C-band
- Comparison with rain-gauges (Kriging interpolation)

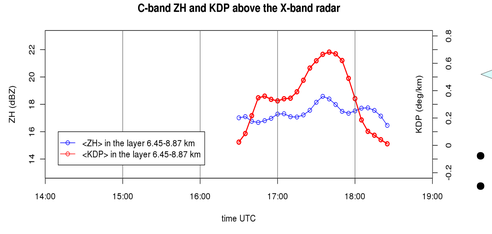
Average C-band vertical profiles (9h)

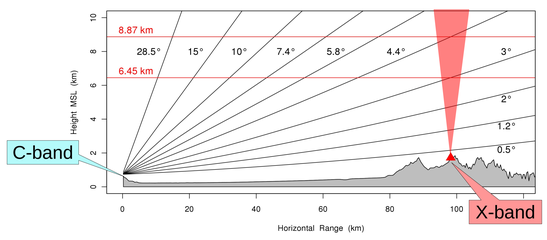


Case Study 2010-08-14



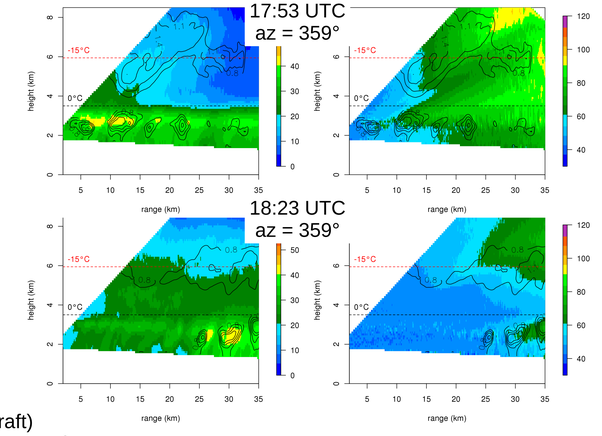
Positive Doppler velocity

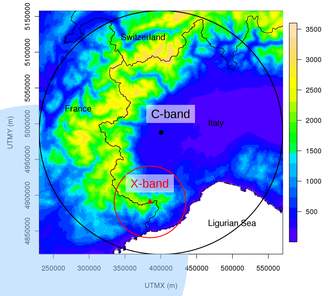




Time-series of reflectivity (Doppler contour) from vertical looking X-band radar (top) and C-band Zh and K_{dp} values from overlooking elevations (bottom)

- K_{dp} increase corresponding to the positive vertical Doppler (weak updraft)
- Reflectivity also shows an increase, but less pronounced

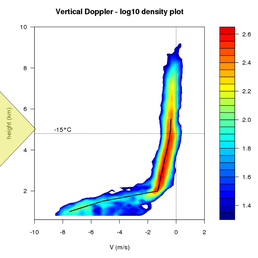




Vertical incidence Doppler velocity

The dominant Doppler velocity is taken as representative of the particle fall speed w(z):

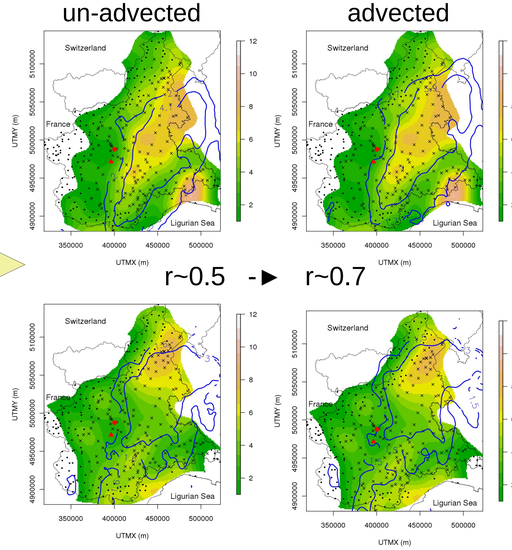
$$\Delta T = \int_{4.8\,km}^{1.0\,km} \left(\frac{1}{w(z)}\right) dz \approx 3800\text{s}$$



Interpolated rain-gauges + contour C-Band K_{dp} around -15°C (~4800m MSL) -1h

01-02 UTC

02-03 UTC



Conclusions

- Marked K_{dp} signatures in stratiform precipitation around -15C level are observed at both C- and X-band
- The coincident K_{dp} estimates (scanning C-band radar) and vertical pointing Doppler measurements (X-band) support the hypothesis of ice crystal growth by vapor deposition, enhanced by weak updraft.
- K_{dp} measurements may allow improvement of the Ice Water Content estimates and provide better input for numerical model assimilantion

References

Kennedy, P. C., S. A. Rutledge, 2011: S-band dual-polarization radar observations of winter storms. J. Appl. Meteor. Climatol., 50, 844–858.
Wang, Y., and V. Chandrasekar, 2009: Algorithm for the estimation of specific differential phase. J. Atmos. Oceanic Technol., 26, 61–78.