Operational implementation of the adaptive specific differential phase


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1. Introduction

Specific differential phase (K_{dp}) is a measure of propagation effects of the radar signal in precipitating medium. It is derived from the range evolution of the differential phase (Φ_{DP}), using data that are acquired at the polarimetric weather radar. K_{dp} is a key element to improve quantitative precipitation estimates (QPE) with polarimetric radar. Meanwhile, the propagation effects in Φ_{DP} can be used in constrained corrections to attenuated (differential) reflectivity. Further, Φ_{DP} carries gate level information about back scattering, important in echo identification.

Operational applications of K_{dp} have been obscured by significant and variable sampling noise, as well as other frequent sources of distortion, present in the Φ_{DP} data. The microphysical rainfall relation $R(K_{dp})$ [mm/h] = cK_{dp}^{b} [(degrees/km)^{b}] (Bringi and Chandrasekar 2001) is challenging for K_{dp} based QPE. For example at C-band, K_{dp} needs to be determined at a precision better than 0.2 degrees/km in order to estimate rainfall of 10 mm/h at 50% generic precision. This is only feasible through substantial spatial averaging. However, spatial variability is high in intense rainfall (R>> 100 mm/h), in which the K_{dp} observation is expected to make the most significant impact in QPE.

The K_{dp} generic precision relates to the precision of Φ_{DP} measurements and their spatial resolutions (Bringi and Chandrasekar 2001). Precision of normally distributed Φ_{DP} measurement depends on characteristics of echo scatterers, as well as on the radar system performance. From radar system view point, it is feasible to acquire Φ_{DP} operationally at a precision at the level of, or better than one degree in rain, at spatial resolution of less than 100 m (Moisseev et al. 2010). When non-Gaussian features of Φ_{DP}, such as differential back scatter, are resolved for, K_{dp} can be obtained at a spatial resolution that enables K_{dp} based rainfall estimates in intense convective rain. Similarly, rainfall of lower intensity can be estimated by spanning the procedure over larger spatial scales. Such products are operationally valuable, too, in events and applications of large scale precipitation.

The method of adaptive specific differential phase (Chandrasekar and Wang 2009) is a comprehensive answer to these signal processing needs. Non-Gaussian features of Φ_{DP} are managed. The method adaptively scales the regression errors in estimation of K_{dp}, and responds to momentary needs of variability in spatial resolution. K_{dp} estimates are well behaved over a large range of rain intensities. The method is tested in a variety of environments and is suitable for real-time application (Wang and Chandrasekar 2009).

This is a report on study of feasibility and on implementation of adaptive K_{dp} in a general purpose weather radar signal processing and operating system, which runs the functions of gate data acquisition and of moment data generation. The system also operates the pedestal for antenna and the radio frequency transmitter, generates sweep and volume level data products, and manages the subsequent data dissemination and system monitoring. The commercially available platforms of RVP8 and RVP900 signal processors, operated by the IRIS system are used as a specific case. The summary of implementation is accompanied with examples of operation.

2. Implementation in weather radar data acquisition and operation system

Adaptive K_{dp} are computed from ray moment data. The method fits well in the ray-to-ray processing architectures, such as the RVP8 and RVP900 signal processors. Estimates of K_{dp} are obtained in real-time. Quality controlled differential phase data, conditioned for folding and back scattering, are made available for the corrections to attenuated (differential) reflectivity. The back scattering information of differential phase is preserved separately, and is used as input to polarimetric echo identification, which utilizes the propagation terms (K_{dp}) as well. The integrated real-time approach enables simultaneously the legacy Doppler signal processing, polarimetric echo identification (Keränen et al. 2007) and corrections for attenuated (differential) reflectivity (Panov et al. 2008), with computational and performance advantage.

Experiences in implementing advanced algorithms have driven us to make them available in the mode of post-processing (IRIS), too, with a requirement of identical outcome. This enables robust technical validation. Algorithm properties can be traced back to previous implementations and validations. The mode of post-processing supports continued evaluations in varied conditions and for varied application needs.

3. Examples of operation

The IRIS/RDA radar and signal processing software enhanced with the functionality of adaptive K_{dp} was installed at the C-band polarimetric weather radar (WRM200) at the Vaisala facility in Kerava, Finland (Moisseev et al, 2010). Additional data sets were analyzed from another C-band polarimetric weather radar operated at the Kumpula campus, University of Helsinki (Puhakka et al. 2006). The radars were operated with scanning strategies that included tasks resembling typical operational settings using 32 to 64 pulses, pulse widths from 0.5 to 1 μs, pulse repetition frequencies from 500 to 1200 Hz.

A case of large scale precipitation extending up to radii of 200 km is displayed in Figure 1. It represents relatively shallow precipitation in spring 2010. The 0^{o}C isotherm is located at the height of 700 meters (MSL). Echoes are mostly from measurement volumes beyond 50 km and contain mixed phases of water. Generally, the range evolutions of differential phase are visibly negligible, except in a limited sector south-west, where significant gradients are seen of the order of 60 degrees over intervals of 60 km. Data pose challenges such as vanishing signal-to-noise ratio and mixed water phase.

The adaptive method to specific differential phase appears resolving the data well and produces fields of K_{dp} that meet the qualitative expectation of stability. K_{dp} deviate from zero in regions of non-negligible radial gradients of differential phase and the values obtained match quantitatively with the observed differential phase evolution. As a technical check, the data have been reprocessed with a fully independent procedure. A good agreement is found.

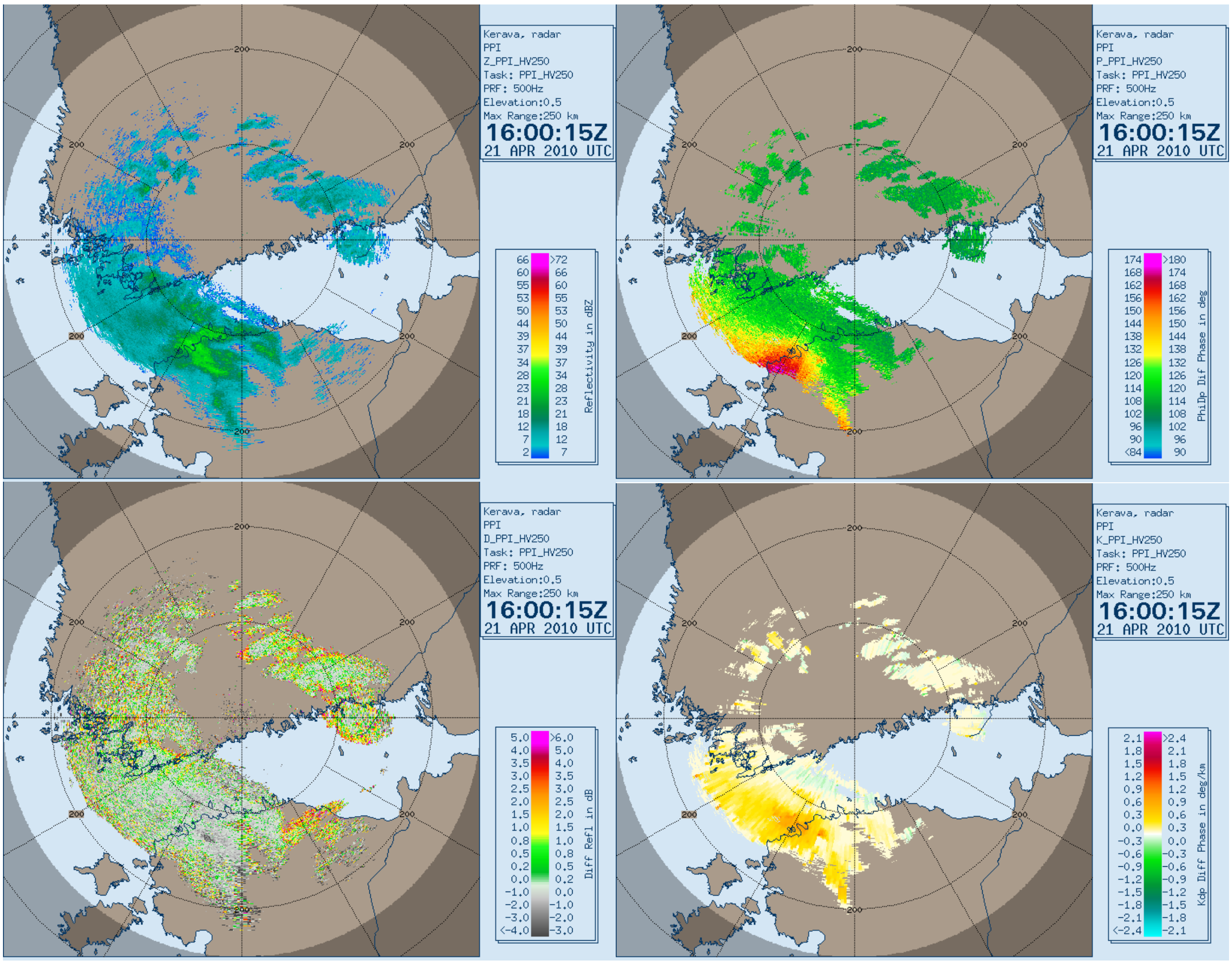

Fig.1. Example of sweep data acquired by the Kerava WRM200 radar in large scale precipitation. All moments are Doppler filtered for ground clutter. Top left: the field of reflectivity, top right: field of differential phase, bottom left: field of differential reflectivity, bottom right: field of specific differential phase computed with the adaptive Kdp method (adaptive scaling factor 0.5).

The second example considers a warm season case of intense rain, occurred in Helsinki region in August the 9th, 2005.

The Kumpula weather radar was operational through the event and observed the rapidly evolving local convection that approached from south. The data are visualized in Figure 2. One observes high values of reflectivity (> 50 dBZ) in proximity of the radar, suppressed rapidly at further distances. Fields of differential phase are available through the convective cell and indicate total evolution of Φ_{DP} in excess of 300 degrees in intervals of a few tens of kilometers. The fields of differential reflectivity suggest, too, that significant attenuation occurred, in particular in directions of the most intense rain. Distinct radio interferences are present. Due to the intrinsic pulse-to-pulse coherence of the klystron radar, data contain components of second range echo, generated by another convective system approaching from south-east (at radii more than 120 km). The 0^{o}C isotherm is located at variable heights more than 3 km (MSL).

The adaptive method is found to perform in stable manner in this intense event. In particular, the convective regions are resolved at high spatial resolution of a few kilometers, in particular the smaller localized cells of convection at distances of 40 km in the south-east. K_{dp} values in excess of 10 degrees/km are obtained; suggesting for rain intensities higher than 100 mm/h. These are consistent with estimates from reflectivity, when comparison is limited to unattenuated parts of data (negligible net evolution of Φ_{DP}). Profiles of negative K_{dp} are seen. They can be associated with underlying second range echoes (low reflectivity) or data at altitudes higher than 4 km consistent with ice clouds. These features are manageable in subsequent applications. Signals of non-meteorological origin are readily suppressed.

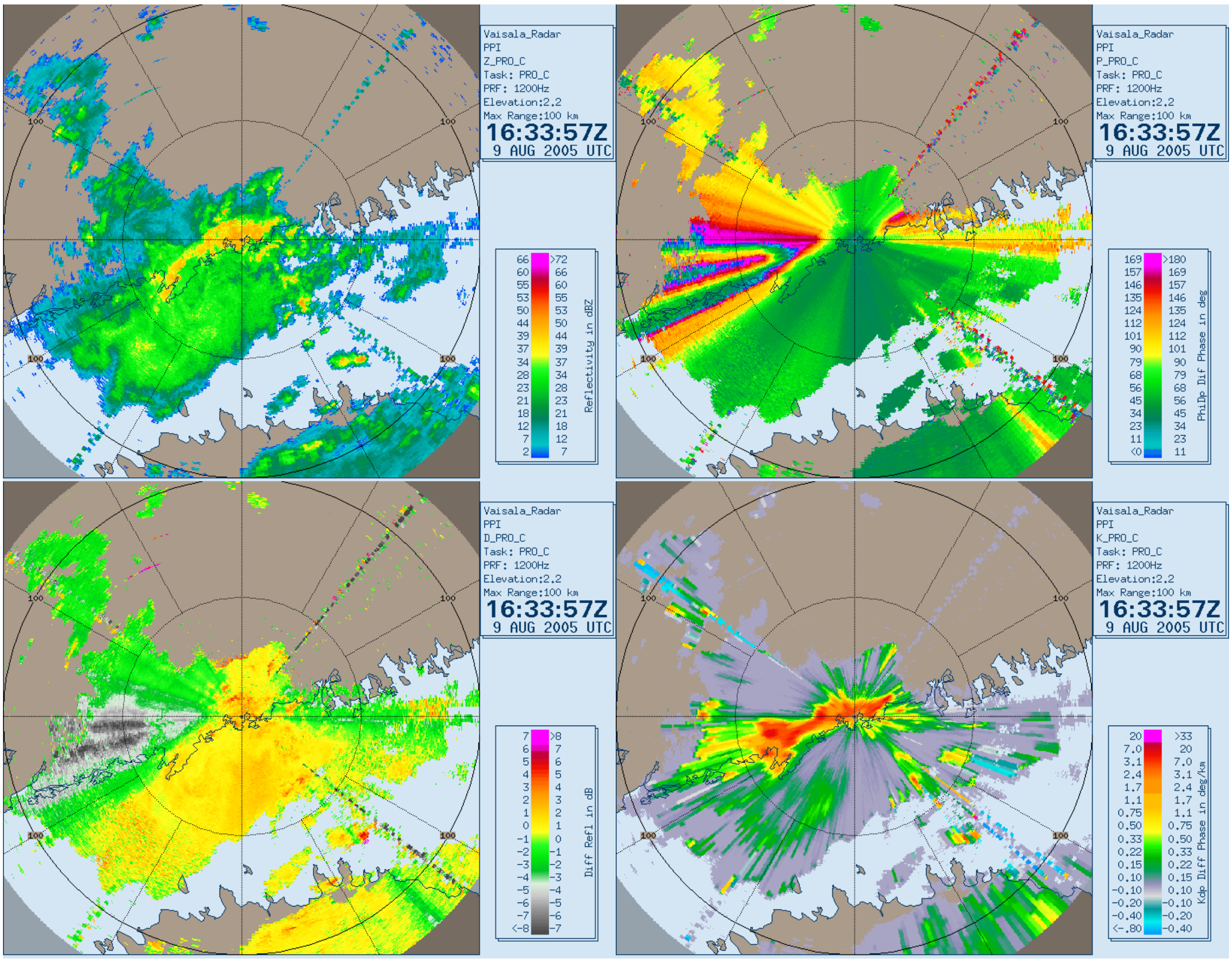

Fig. 2. Example of sweep data acquired by the Kumpula weather radar in event of intense convection. Top left: the field of reflectivity, top right: field of differential phase, bottom left: field of differential reflectivity, bottom right: field of specific differential phase computed with the adaptive Kdp method (adaptive scaling factor 0.5).

5. Conclusions

The adaptive method to specific differential phase is well suited to the real-time signal processing. It has been implemented as an integral part of moment generation and of other polarimetric advanced methods. The results can be readily utilized in corrections to attenuated (differential) reflectivity, and in echo and hydrometeor identification. The K_{dp} data are reported at quality that allows their efficient use in down stream applications, such as rainfall estimates.

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References

Bringi, V.N. and Chandrasekar V. 2001: Polarimetric Doppler weather radar: principles and applications. *Cambridge University Press,* 648 pp.;

Chandrasekar V., Wang Y. 2009: Adaptive Specific Differential Phase at Dual-Polarization Radar *International Application Published under the Patent Cooperation Treaty,* **WO 2009/114864 A1**;

Keränen R., Saltikoff E., Chandrasekar V., Lim S., Holmes J., Selzler J. 2007: Real-time Hydrometeor Classification for the Operational Forecasting Environment, *33rd Conf. on Radar Meteorology,* Cairns, QLD, Australia, Amer. Meteor. Soc.;

Moisseev D., Keränen R., Puhakka P., Salmivaara J., Leskinen M. 2010: Analysis of dual-polarization antenna performance and its effect on QPE, *6th European Conference on Radar in Meteorology and Hydrology,* Sibiu, Romania;

Panov S., Keränen R. and Chandrasekar V. 2008: Assessment of the polarimetric attenuation correction implementation in the RVP8 signal processor, *5th European Conference on Radar in Meteorology and Hydrology,* Helsinki, Finland;

Puhakka, T., M. Leskinen, P. Puhakka, S. Niemi, L. Konkola, N. Tollman, 2006: University of Helsinki research radar setup. *4th European Conf. on Radar Meteorology and Hydrology*, Barcelona, Spain;

Wang Y., Chandrasekar V. 2009: Algorithm for Estimation of the Specific Differential Phase *J. of Atmospheric and Oceanic Technology,* **26**, 2565-2578.