Weather radar data quality enhancement in aeronautical applications through polarimetric measurements

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(Dated: 01 June 2012)

1. Introduction

Weather radar information finds wide use in various aeronautical applications ranging from pilot and air traffic controller briefing to terminal airdrome forecasting and present weather reporting. Because of the high safety requirements in aviation, quality of the final products (weather phenomena map being the main one) and therefore quality of radar data becomes of great importance.

One of the most intensive and evident factor impairing a product quality over wide areas is a non-meteorological echo including ground clutters, anomalous propagation and bio-scatters. Conventional methods developed for non-coherent single-polarization weather radars – used by IRAM’s automatic weather radar system “MeteoCell” and proved their efficiency with weather radars of previous generations – turn out to be not enough effective with modern radars and their high sensitivities. Even use of advanced Doppler filtering techniques adherent to the modern radars with coherency does not help with non-stationary non-meteorological echoes. In order to discriminate and suppress bio-scatter signals a new filter was developed and implemented in “MeteoCell” system. Based solely on reflectivity data it uses intricate detection schemes and requires fine on-site tuning. With an advent of dual-polarization radars, plainer and more robust methods can be used to solve the task of clutter suppression. In this paper, new methods developed to mitigate non-meteorological echoes using polarimetric data are presented and comparison of their performance in aeronautical applications against conventional ones is performed.

2. Minsk radar

The new radar system was installed in Minsk (Belorussia) as a replacement of an airport operational weather radar system “MeteoCell”, which used MRL-5 weather radar as a sensor. Being operated by the airport meteorological center, the primary objective of the system is a provision of aviation with severe weather maps. Also some products are sent to the existing radar network and some local end-users.

The radar itself is sited on the territory of the Minsk International Airport right on the position of the old radar (Fig. 1). It is a METEOR-600C Doppler weather radar with dual polarization produced by SELEX SI GmbH. It uses a magnetron transmitter and operates at C-band frequency. After the primary data processing in GDRX and SP weather data is passed for the secondary processing to “MeteoCell” system situated at the airport.

Minsk radar operates a scanning strategy optimized for simultaneous reflectivity and velocity data retrieval at 10-minutes period, devised earlier by Linev et al. (2008) specifically for Doppler weather radar systems and already used in Pulkovo, Borispol and Almaty airports operationally. The radar works in dual polarization mode with simultaneous transmission and receiving of both polarizations allowing to measure differential reflectivity, correlation coefficient and differential phase in addition to common radar reflectivity, radial velocity and spectral width.

For the seamless transition from the MRL-5 to “Meteor-MeteoCell” both systems were operated in parallel – the new one during the daytime for tests and configuration and the old one overnight.

3. Single polarization systems

“MeteoCell” radar system was developed more than 20 years ago as a solution to automate the MRL-5 dual-band non-
coherent single-polarization weather radars. Beside the automatic radar control the system also performed the automatic weather phenomena and precipitation type classification, based on the spatial characteristics of radar reflectivity, precipitation calculations and nowcasting. Along the years its algorithms were refined and fine-tuned, producing the system compliant with all modern rigorous requirements for meteorological aviation provision.

In 2006 a new generation of the system emerged – “Meteor-MeteoCell” system with Doppler capabilities and, later on, with dual-polarization. After the transition to new radar sensors with higher sensitivity more data became visible. On the one side more subtle and distant clouds can be detected, but on the other side more non-meteorological sources contaminate the picture.

In warm season in the daytime relatively low reflectivity is observed around the radar in the lowest two or three kilometers with the sky absolutely clear (Fig. 2). Flowing with the air these non-meteorological targets couldn’t be discriminated from the light stratiform precipitations with low upper boundary, which are typical for cold seasons, using only reflectivity data. Without dual-polarization data only profile filtering switched on only for warm seasons can help to surmount this. And care should be taken not to miss light low stratiform clouds.

When the vertical gradient of the refractive index exceeds in absolute value the critical one, super-refraction occurs – leading to the intersection of radar beams at low elevations with the orography and appearing of ground clutter at distant ranges. This situation is known as anomalous propagation conditions. And the more radar is sensitive, the more clutter and at farther distances contaminate the picture.

4. Hydrometeor classification

Installation of Minsk radar allowed testing the dual-polarization algorithms for hydrometeor classification of “MeteoCell” system “in vivo”.

As the use of polarimetric radar data allows to discriminate different types of hydrometeors and non-meteorological targets, the first objective of the classification scheme was to identify regions with flying insects and anomalous propagation. The next step was to apply class information to meteorological phenomena and types of cloudiness classification and severe
weather area detection.

The hydrometeor classification algorithm implemented in “MeteoCell” system is a variant of fuzzy logic approach. First implementations of the fuzzy logic schemes were published for the S-band (Liu and Chandrasekar, 2000; Zrnic et al., 2001; Lim et al., 2005) and later extended to C-band (Baldini et al., 2005). As the input parameters radar reflectivity, differential reflectivity, correlation coefficient, specific differential phase and ambient temperature are used. The latter allows us to remove unrealistic results as every precipitation type can be found only in certain temperature range. Since the central system of Minsk radar is sited at the airport meteorological center, it has a reliable source of meteorological data on temperature. For the volume distribution of temperature gridded binary forecast data in GRIB code are used. For the surface temperature synoptic reports from local meteorological stations and airdrome weather station are used.

The set of the output classes is reduced in comparison with original algorithms, namely: bio-scatter, ground clutter, liquid scatterers, frozen scatterers, mixed phase scatterers, graupel, and hail. The choice of the types was conditioned by the existing non-polarimetric classification scheme and the stipulated end products format (Bazlova et al., 2002).

5. Conclusions

During the summer season a wide variety of cases with bio-scatter, anomalous propagation and thunderstorms, isolated and mixed, was recorded. After thorough analysis and tuning the membership functions the hydrometeor classification algorithm allowed sufficiently reliable discriminating of non-meteorological echoes from the weather signal, thus giving the way to effectively eliminate the spurious reflectivity from the total picture.

Nevertheless performance of the algorithm in precipitation phase detection should be further studied during the transitional and cold seasons. Since the non-polarimetric algorithm has a good efficiency when applied to thunderstorm and hail identification, main impact on the accuracy of classification with the addition of dual-polarization capabilities to the radar is expected to become apparent in autumn and spring seasons.

References


