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Atmospheric Measurement Techniques Discussions

Interactive comment on "Implementation of Polarization Diversity Pulse Pair Technique using airborne W-band radar" *by* Mengistu Wolde et al.

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We would like to thank the reviewer for these very helpful and constructive comments. Please find our detailed responses to your comments as follows.

1. *EarthCARE CPR is designed for cloud vertical velocity measurements while WIVERN is target for horizontal wind retrieval. Have the author done or planned to do any horizontal wind retrieval based on airborne data?*

The objective of the project was to demonstrate the PDPP technique from a moving platform so our flight profiles were not optimized to do comparison of PDPP derived horizontal winds with vertical profile of horizontal winds. Even for the WIVERN satellite the scope is to measure horizontal winds along the line of sight and the information

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being assimilated by NW models.

However, we did a limited qualitative comparison of the PDPP Doppler velocity with a horizontal wind component obtained from radiosonde at proximity of the flight and the in-situ wind data measured by the aircraft wind system. In Fig. 1 (see attached), we plotted the 12 Z soundings (approximately 2 hours before the PDPP data collection) of the horizontal wind speed and direction obtained from two nearby radiosonde stations. In spite of the time and location differences of the soundings, both the radiosonde and aircraft sounding show a similar horizontal wind profile as the region was influenced by large scale synoptic system. The winds between 2 and 5 km were WNW with speed decreasing with altitude from 25 m/s at the aircraft altitude to nearly 5 m/s at 2 km altitude. Below 2 km, the wind veers with decreasing altitude and becoming light ($<$ 10 m/s) north easterly. In this lower layer, the contributions of the terminal velocity from rain drops cannot be neglected so the Doppler velocity is a combination wind and particle fall velocity. These wind profiles are consistent with the PDPP observations showing a gradual decrease in magnitude from -20 m/s near flight level due to strong westerly winds (aircraft flying towards east) then reverse direction to weak vD of 0-10 m/s in a layer where with winds were north easterly (opposite to aircraft heading).

Figure 1(full caption): Left: vertical profiles of horizontal wind speed obtained during the Convair descent towards Ottawa after the PDPP data collection (black), 12Z upper air sounding from Buffalo (US) and Maniwaki (Canada) and profile of PDPP VD after aircraft motion correction (blue). Right: wind direction corresponding to the aircraft and BUF and WMW soundings. The vertical line correspond to the aircraft heading and the horizontal like is perpendicular to aircraft heading to the WVM sounding.

2. *Figure 17, why the surface velocity estimated by staggered PRT technique (green curve) folded at some antenna position, but not the others?*

The maximum Doppler velocity for the staggered PRT waveform in this case was 26.6 m/s. When the aft antenna was steered to a large slant angle, the Doppler velocity

introduced by the aircraft motion increased (up to over 100 m/s). When the signal radial Doppler (aircraft contribution plus precipitation Doppler) exceeded 26.6 m/s, staggered PRT velocity started folding.

3. *What is the cross-pol isolation of NAWX channels? The SNR in the data case shown in Figure 9 seems high so the surface contamination from cross-pol seems not very significant. Is there any data case with weaker cloud/precipitation layer(s)?*

The cross-polarization isolation of the W-band channels mainly limited by the cross-pol of the antennas which is 30 dB for E-plane and 36 dB for H-plane. We have collected a few data sets where the SNR of cloud layers was low and cross-pol signals were much more significant (see Figs. 2-4). In those cases, Doppler velocities showed large errors or were not available in regions contaminated by cross-pol signals.

Figures 2, 3 and 4: PDPP Z_{hh}, Z_{hv} and retrieval Doppler for the March 29th, 2016 case.

Comment 4-26: We thank the reviewer for pointing these out. The errors/typos have been corrected.

4. *Page 2, Line 79, "94Ghz" to "94GHz".* - corrected as suggested

5. *Page2, Line 105, ". . . a low pair repetition frequency (PRF). . ." to ". . . a low pulse repetition frequency (PRF) . . .".* - corrected as suggested

6. *Page2, Line 129, please spell the full name of "WIVERN".* - WIVERN is spelled out as suggested

7. *Page 3, NAW, NAWX (and later NAX) are used through out of this paper. Please clarify that NAW is W-band alone, NAX is X-band alone in case of confusion.* - We have defined NAX and NAW

8. *Page 3, Line 189, "(Zrnic and Mahapatra, 1985) have . . ." to "Zrnic and Mahapatra (1985) have . . .".* - corrected as suggested

9. *Page 3, Line 204, ". . . ; (assuming a . . ." to ". . . ; assuming a . . .".* - corrected as suggested

10. *Page 3, Line 207, ". . . greater than 0.9 . . .", what greater than 0.9?* - ρ is defined as normalized signal correlation in Eq. 1, so $\rho > 0.9$ means normalized signal correlation greater than 0.9

11. *Page 5, Table 2, "[-40^o -40^o]" to , [-40^o to 40^o]"* - corrected as suggested

12. *Page 5, Table 3, the T_2/T_3 ratio is 3:4, 5:6. But on Page 3, Line 190-194, it states that T_2/T_3 = 2:3 is optimal and the PDPP waveform was also designed for 2:3. Need to be consistent.* - We thank the reviewer for pointing this out. We added text to the revision to make this point clear: "Therefore, the PDPP waveform was designed such that T_2/T_3 is close to 2/3. Additionally, the pulse spacing T_2 and T_3 were set according to the maximum desired measurement range - velocity and the transmitter duty cycle limit of radar."

13. *Figure 4, Has the water vapor and gas attenuation been corrected?* - Gas attenuation and water vapour corrections have not been applied, since the flight in question was performed at a sufficiently low altitude (about 1 km) in clear air condition . As a result, the effects of water vapour and gas attenuation are minimal.

14. *Figure 5, "The NRC Convair . . ." to " (a) The NRC Convair . . .". ". . . show aircraft heading, roll angle, beam incidence angle and aircraft altitude." to ". . . show aircraft (b) pitch, (c) roll angle, (d) beam incidence angle and aircraft altitude."* - corrected as suggested

15. *Page 8, Line 316, "Wivern" to "WIVERN".* - corrected as suggested

16. *Page 8, Line 340-344, PVV and PHH could be different for large rain drops and for surface return at high incidence angle.* - We completely agree with the reviewer. That assumption was used for a calibration case, and does not need for the analysis in this paper. We removed the equation and revised the text accordingly.

17. *Page 10, Line 438, what is "PP10 mode"?* - We added a text in the caption of Fig. 1 that described the NAW PP10 mode.

18. *Page 10, Line 450, 454 (and later in the paper), at X-band dBZ is used instead of* Z_e. - We modified the text for better presentation "Reflectivity from the up and down antennas of the NRC X-band airborne radar . . ."

19. *Page 11, Figure 9 caption, ". . . an V-pulse. . ." to ". . . a V-pulse. . .".* - corrected as suggested

20. *Page 12, Line 505, ". . . (see (Torres et al., 2004) for details)." to ". . . (see Torres et al., 2004 for details)."* - corrected as suggested

21. *Page 12, Line 511, "Wivern" to "WIVERN".* - corrected as suggested

22. *Page 12, Line 512, and Page 14, Line 619, "*V_d*" to "*v_D*" so it will be consistent with the equations.* - corrected as suggested

23. *Page 12, Line 565, delete the sentence "Again it is . . ." (duplication of Line 561).* - corrected as suggested

24. *Page 12, Line 600, "Fig. 13 shows PDPP. . ." to "Fig. 15 shows PDPP. . ."* - corrected as suggested

25. *Page 15, Figure 15, the color table is highly compressed from range -20 dBZe to 68 dBZe. Could use -20 dBZe to 40 dBZe?. Also please change "dBZ" to "dBZe" for W-band reflectivity.* - We updated the color scale as suggested.

26. *Page 15, Figure 16 caption, "(b) estimated velocity of the precipitation along the direction of the antenna beam" to "(b) estimated velocity of the precipitation along the direction of the antenna beam based on PDPP measurements and after removal of aircraft motion".* - corrected as suggested

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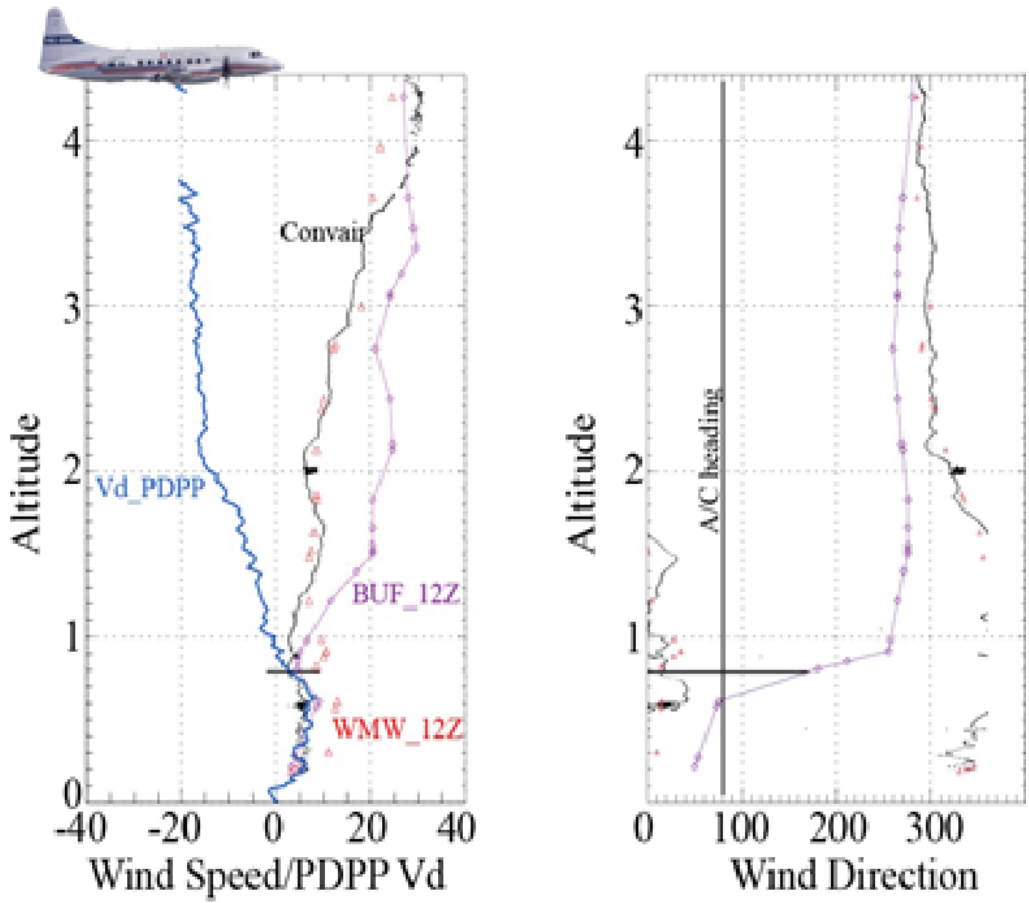

Fig. 1. 12 Z soundings the horizontal wind speed and direction obtained from two nearby radiosonde stations

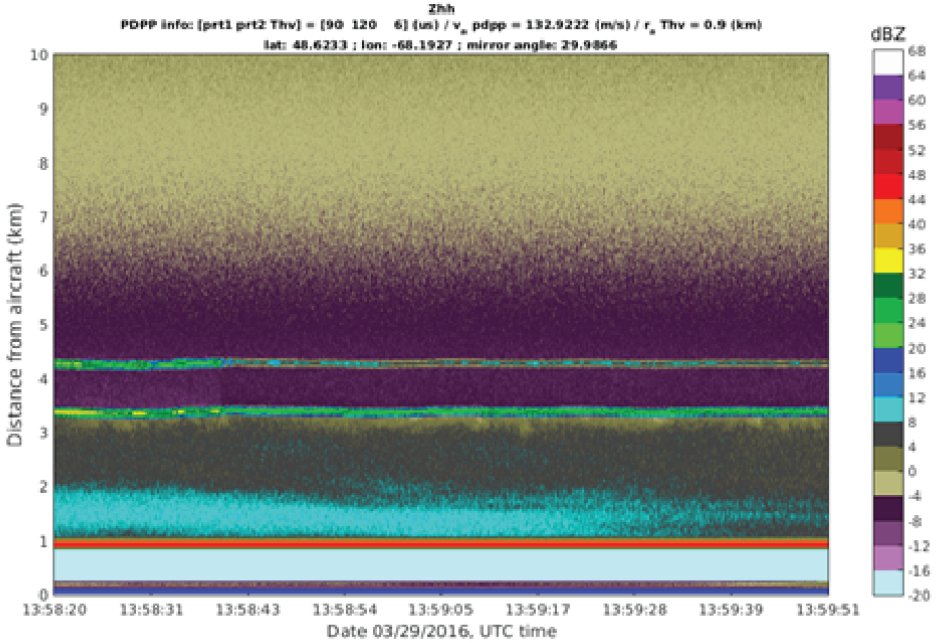

Fig. 2. PDPP Z_hh for the March 29th, 2016 case

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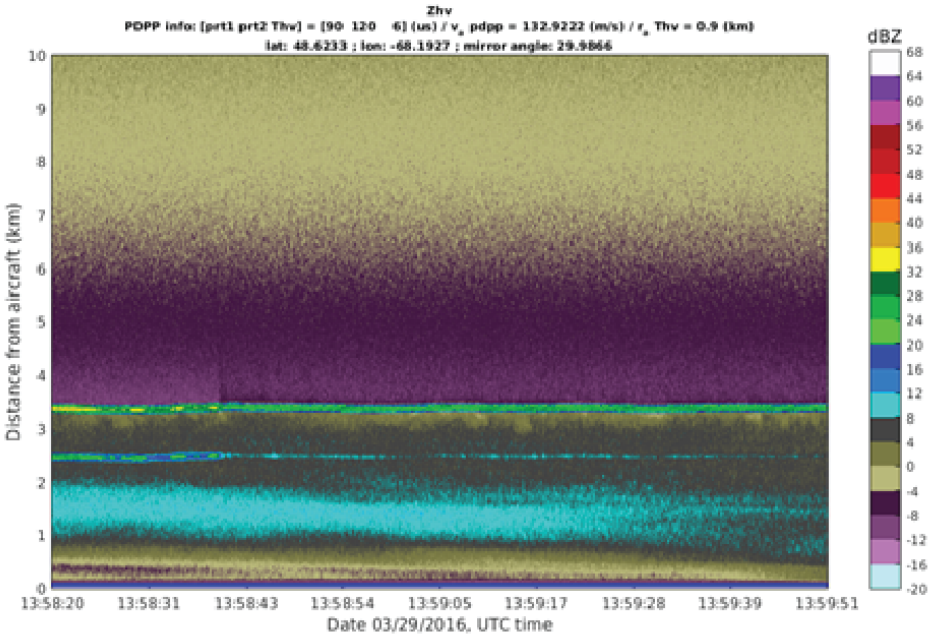

Fig. 3. PDPP Z_hv for the March 29th, 2016 case

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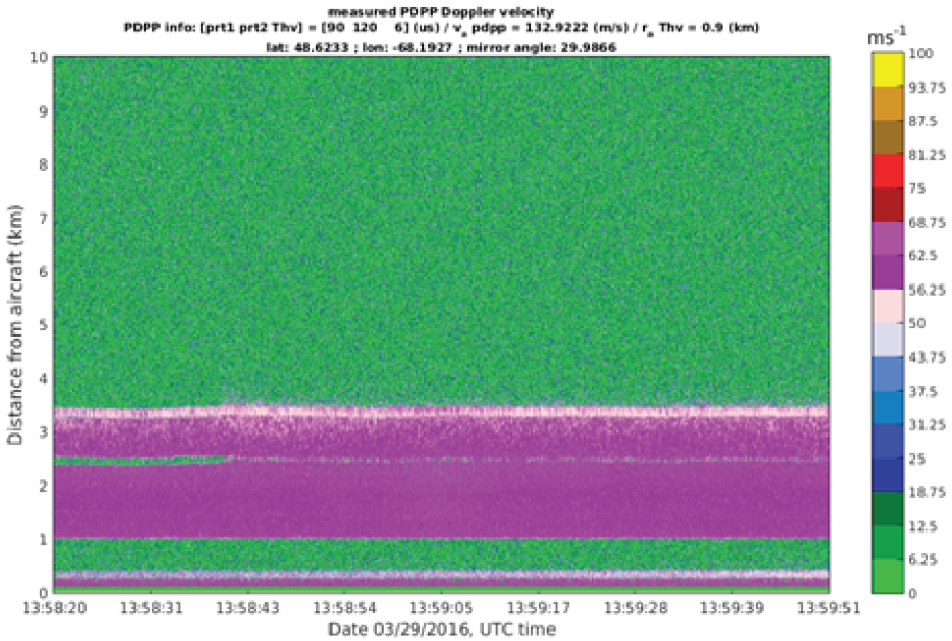

Fig. 4. PDPP retrieval Doppler for the March 29th, 2016 case

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