5A.2 SINGLE-DOPPLER WIND RETRIEVAL OF A SQUALL LINE DURING THE WET AMC AND TRMM LBA FIELD EXPERIMENT CAMPAIGN

Augusto J. Pereira F°.* and Leonardo Calvetti
University of São Paulo, São Paulo, Brazil

1. INTRODUCTION

The Amazon Region has been the focus of many environmental studies in the past few years aimed to understand its contribution to the equilibrium of the global system. Recently, the government of Brazil has deployed the Amazon Surveillance System (SIVAM) to monitor the entire Amazon Basin. It also includes a network of automatic weather stations and Doppler weather radars. Particularly, the radar network will be very useful for short-term weather forecasting. Thus, radar-based information such as the wind field at constant elevations is relevant operationally.

The present study applies the Zhang-Gal-Chen single-Doppler velocity retrieval (ZG) method (Zhang and Gal-Chen 1996) to the 26 January 1999 squall line monitored by the S-POL and TOGA weather radars (Fig. 1) during the WET AMC and TRMM LBA field experiment campaign in Rondônia, Brazil (Pereira Filho et al. 2002). Sensitivity analysis are performed for variable area sizes and weights of the cost function that conserves the reflectivity and the radial wind field in both stationary and moving frame of reference. The retrieved wind fields by the ZG method are compared to the ones retrieved by the above two weather radars.

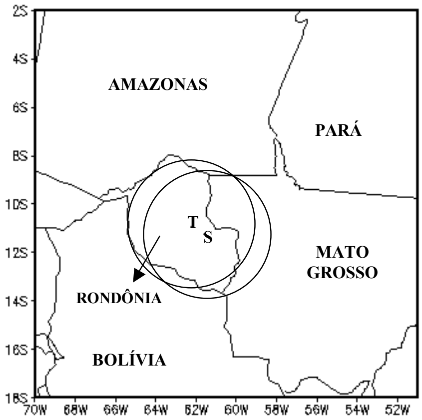

Figure 1: Map of Northwestern Brazil centered at the WET/AMC TRMM-LBA experiment in Rondônia, Brazil, carried out between January and February 1999. Boundaries of Brazilian States and Bolivia are indicated. Circles of 150-km radius indicate the surveillance area of the TOGA (T) and the S-POL (S) weather radars. Latitudes (left) and longitudes (bottom) are indicated in degrees.

2. METHODOLOGY

The ZG method assumes that the reflectivity field of a single weather radar is conserved during short time intervals.Thus, advection speeds (U,V) can be estimated:

$$J(U,V,W) = \int_{\Omega} \alpha_Z \left[Z_t + UZ_x + VZ_y + (W + W_t)Z_z \right]^2 dxdydzdt \quad (1)$$

where Ω = 4D domain; Z = reflectivity; Z_t, Z_x, Z_y e Z_z = time and spatial derivatives of Z; W_t = terminal velocity; and α_z = reflectivity weight. The cost function J is minimized to get the 3D basal wind field. The stationary frame of reference is changed to a moving one such that advection speeds are zero. The total wind field is *(u,v,w) = (U+u',V+v',w'),* where *(U,V)* = advection speeds; W = mean vertical speed; (u',v',w') = perturbation speeds. Then, the conservation of the reflectivity field: $Z_t + uZ_x + vZ_y + (w + W_t) Z_z = 0$. On the other hand, radial velocities can be written as:

$$Vr = u\frac{x - p_1}{r} + v\frac{y - p_2}{r} + (w + W_t)\frac{z - p_3}{r} \quad (2)$$

where (x,y,z) and (p_1, p_2, p_3) are Cartesian coordinates of a grid point and of the radar, respectively; r = distance from the radar. Time tendencies of the reflectivity field are minimized in relationship to (u,v,w) and radial winds:

$$J(u,v,w) = \int_{\tau} \int_{\omega} \alpha_Z \{ \left[Z_t + uZ_x + vZ_y + (w + W_t)Z_z \right]^2 + \alpha_{vr} \left[V_r{}^m - V_r{}^e \right]^2 \} d\omega dt \quad (3)$$

where α_{vr} = radial velocity weight; *m* and *e* refer to measured and estimated radial velocities, respectively. The reflectivity field is not conserved in this stationary frame of reference. Then it is changed to a moving one using the basal speeds and the procedure in Eq. 3. More details found in Zhang and Gal-Chen (1996).

3. RESULTS

Several tests were performed with reference frames, radial wind weights, area sizes and spatial resolutions. Below are shown results only for area and times in Fig. 2.

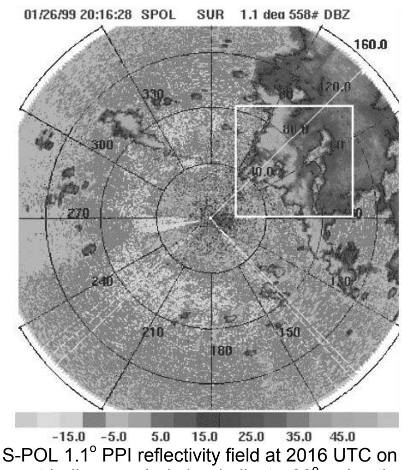

Figure 2: S-POL 1.1° PPI reflectivity field at 2016 UTC on 26 January 1999. Concentric lines and circles indicate 30° azimuth angles and 40-km distances from the radar, respectively. Reflectivity intensities (dBZ) in grey scale (bottom). Square indicates the area within the squall line where the ZG wind retrieval was performed.

* *Corresponding author address*: Augusto J. Pereira Fo., Univ. de São Paulo, Rua do Matão, 1226, Cidade Universitária, São Paulo, SP, Brazil, CEP 05508-900;
e-mail: apereira@model.iag.usp.br

Fig. 3 shows 2-km altitude retrieved winds by the ZG method and by S-POL and TOCA radars together. The ZG retrieval was performed with α_{vr} = 1 (Eq. 3) at 0.5 km horizontal resolution using volume scans between 2000 UTC and 2015 UTC. The estimated advection speed is (U,V) = (-4,-1) m s^{-1}. The gust front in the leading edge of the system was retrieved by both methods though wind intensities are smaller for the ZG method. A rear to front low level jet is apparent on the Northeast region of the squall line in the retrieval with two radars (Fig. 3). Weak Easterly winds are prevailing for the ZG method. Both methods were able to retrieve a convergence zone where reflectivities are above 50 dBZ.

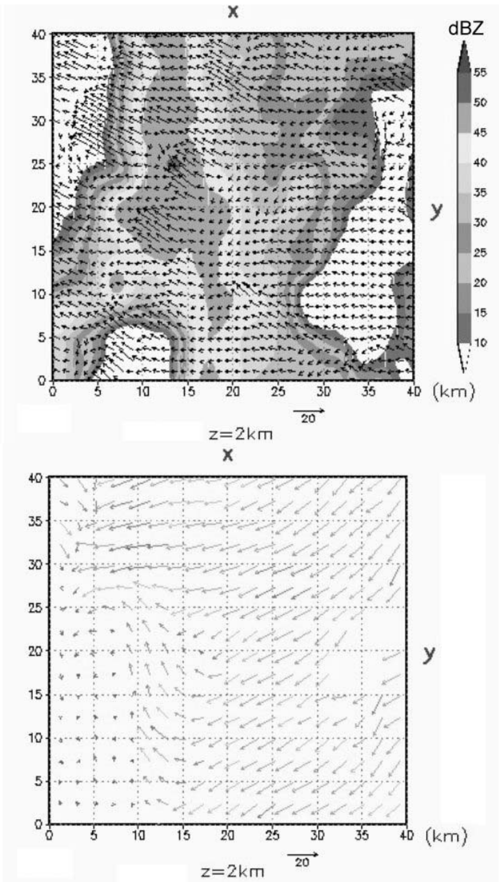

Figure 3: Retrieved wind fields within the convective region shown in Fig. 2 using only S-POL and the ZG method (top) and both S-POL and TOCA radars (bottom). Radial winds were measured between 2000 UTC and 2015 UTC on 26 January 1999 Arrows indicate wind intensity (m s^{-1}) and direction. Reflectivity intensities (dBZ) in grey scale (top-right).

A sensitivity analysis of radial wind weights and reference frames with altitude is shown in Fig. 4. Best results are associated with the moving frame of reference and α_{vr} = 1 between 4 km and 9 km altitude. Above these levels, range-height effects reduce the spatial resolution of the reflectivity field. On the other hand, close to the surface, reflectivity gradients (Fig 2) are high and also ground echoes contaminate measurements. In general, rms errors are higher for the meridional wind (not shown) retrievals. Error magnitudes are similar to those obtained by Lazarus et al. (1999) for a much smaller area.

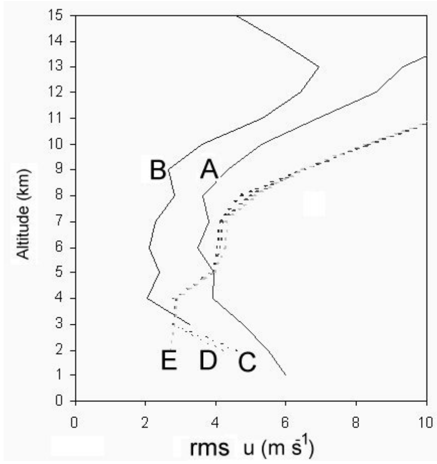

Figure 4: Root mean square errors of the retrieved zonal wind as a function of altitude within the square shown in Fig. 2. Letters A and B indicate a moving frame of reference for α_{Vr} = 10 and 1, respectively, and letters C, D, and E indicate a stationary frame of reference for α_{Vr} = 10, 1 and 0.1, respectively.

4. CONCLUSION

The ZG method was applied to a significantly larger area and height of retrieval than previous experiments performed with the same technique. Overall, results were much better for radial wind weight close to 1. That means the reflectivity and wind fields are both important. Results also improve with the increase of the spatial resolution. The vertical component of the wind were not adequately retrieved in all experiments, but in most instances the wind direction were coherent with those obtained with two-radars. Other constraints can be applied to the cost function (Eq. 3) such as rotation and convergence and alternative methods of estimating terminal velocities (Lazarus et al. 1999). The LBA data are being used to carry out further analysis with the ZG method since it is more cost effective computationally.

ACKNOWLEDGMENTS

The authors are thankful to Dr. Zhang for her kind assistance with the ZG computer code. This research was sponsored by Fundação de Amparo À Pesquisa do Estado de São Paulo - FAPESP under grant number 00/00119-8 and by Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq under grant 302419/2002-0.

REFERENCES

Lazarus, S., A. Shapiro, and K. Droegemeier, 1999: Analysis of the Gal-Chen-Zhang single-Doppler velocity retrieval. J. Atmos. and Oceanic Technol., 16, 5-18.

Lutz et al, 1995: NCAR's S-Pol: Portable Polarimetric S-band Radar, 9th Conf. on Meteorological Observations and Instrumentation. Charlotte, NC. AMS.

Pereira Filho, A. J., M. A. F. Silva Dias, R. I. Albrecht, L. G. P. Pereira, A. W. Gandu, O. Massambani, A. Tokay and S. Rutledge, 2002: Multi-sensor analysis of a squall line in the Amazon Region. J. of Geophys. Res., 107, D20, 8084, 52-1,12.

Zhang, J. and T. Gal-Chen, 1996: Single-Doppler wind retrieval in the moving frame of reference. J. Atmos. Sci., 53, 2609-2623.