Evaluating the effect of mass continuity, smoothness, and resolution constraints on thunderstorm wind fields using Dual-Doppler 3DVAR wind retrieval

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OBJECTIVE

To retrieve and analyze the 3D wind structure of thunderstorms using a dual-Doppler variational approach with C-band and X-band radar data, assess the sensitivity to resolution and cost function weights, and validate results with LiDAR observations to improve wind field accuracy and understanding of thunderstorm dynamics. This study is part of the Italian Ministry of University and Research project PRIN-2022- "WIND-RISK: Thunderstorm outflows measurement and modeling for strong–WIND nowcast and RISK mitigation", awarded in 2022 to the University of Genoa and ISAC-CNR [1].

INTRODUCTION

- Situated within the dynamic Mediterranean environment, the Piedmont region is highly susceptible to localized storms, frequently accompanied by sudden and destructive downburst [2].
- Weather radar serve as a crucial tool for nowcasting and is widely used worldwide for real-time monitoring and prediction of convective weather systems [3]. Moreover, variational techniques have been developed to enhance wind field retrievals by applying weak constraints that minimize a cost function based on deviations from physical laws and observation data.

STUDY AREA AND DATASET

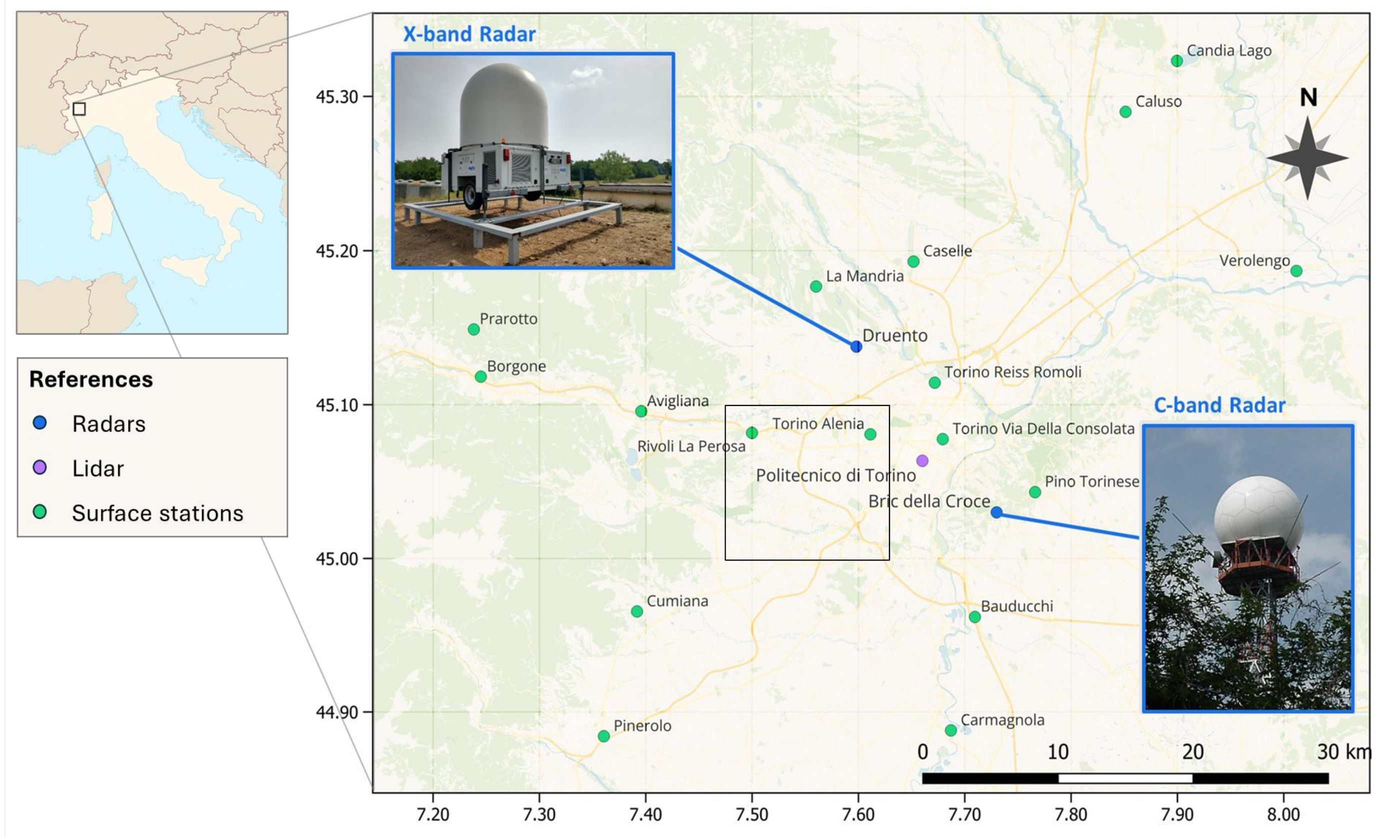


Fig. 1: Map of the study area, showing the location of the radars [Bric (C-band) and Druento (X-band)], the LiDAR, and surface stations.

Table 1: Characteristics of radars and LiDAR.

	C- band radar	X-band radar	LiDAR
Latitude	45.034 N	45.137743 N	45.06352 N
Longitude	7.733 E	7.598067 E	7.660155 E
Altitude	773 m a.s.l.	272 m a.s.l.	248 m a.s.l.
Location name	Bric della Croce	Druento	Politecnico di Torino
Spatial resolution	340 m	150 m	50 m
Temporal resolution	5 min	2.5 min	12 min
Maximum range	180 km	80 km	4.5 km
Nyquist velocity	23.373 m/s	19.2 m/s	30 m/s

METHODOLOGY FLOW CHART

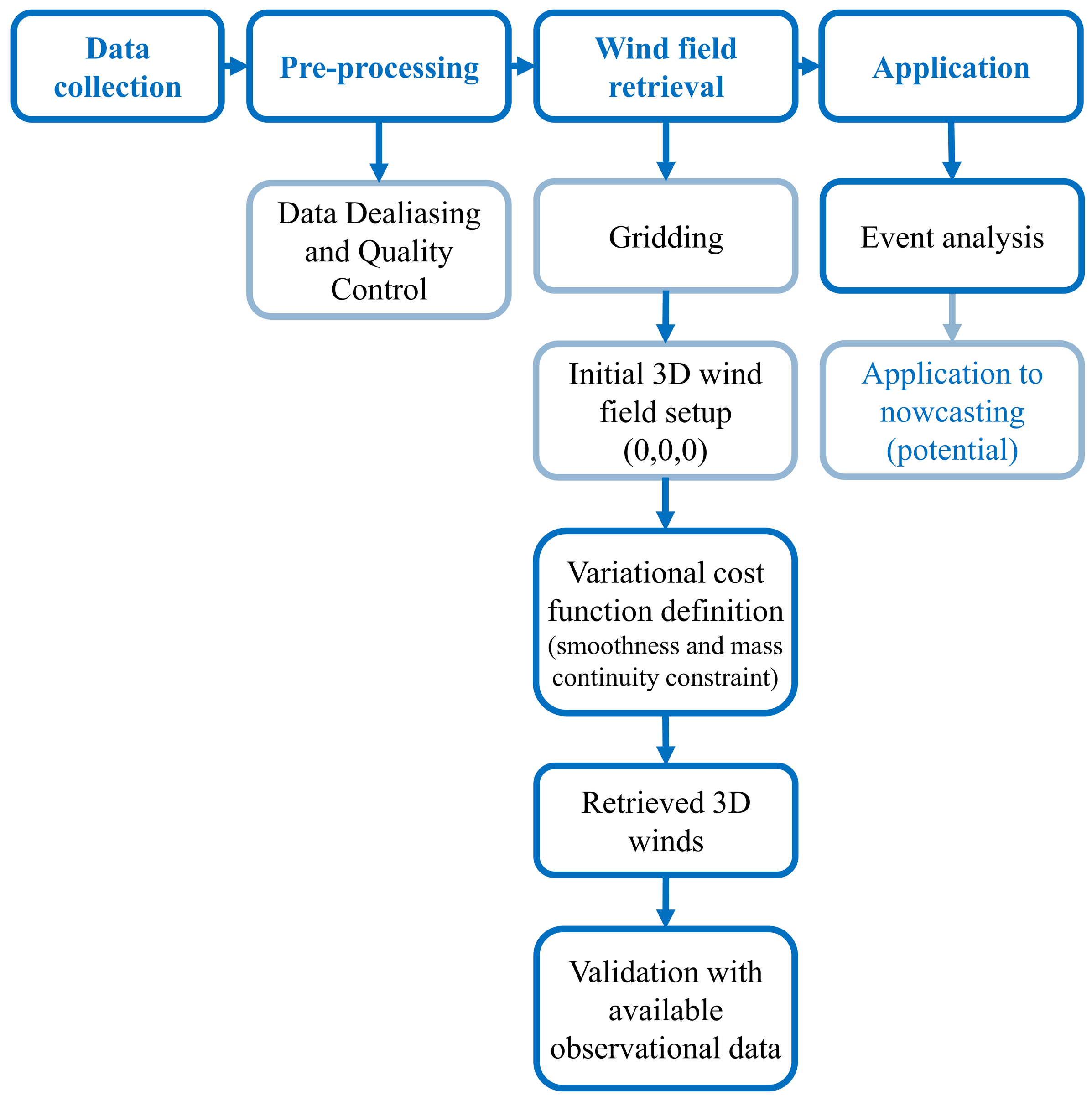


Table 2: Parameters considered in the sensitivity test.

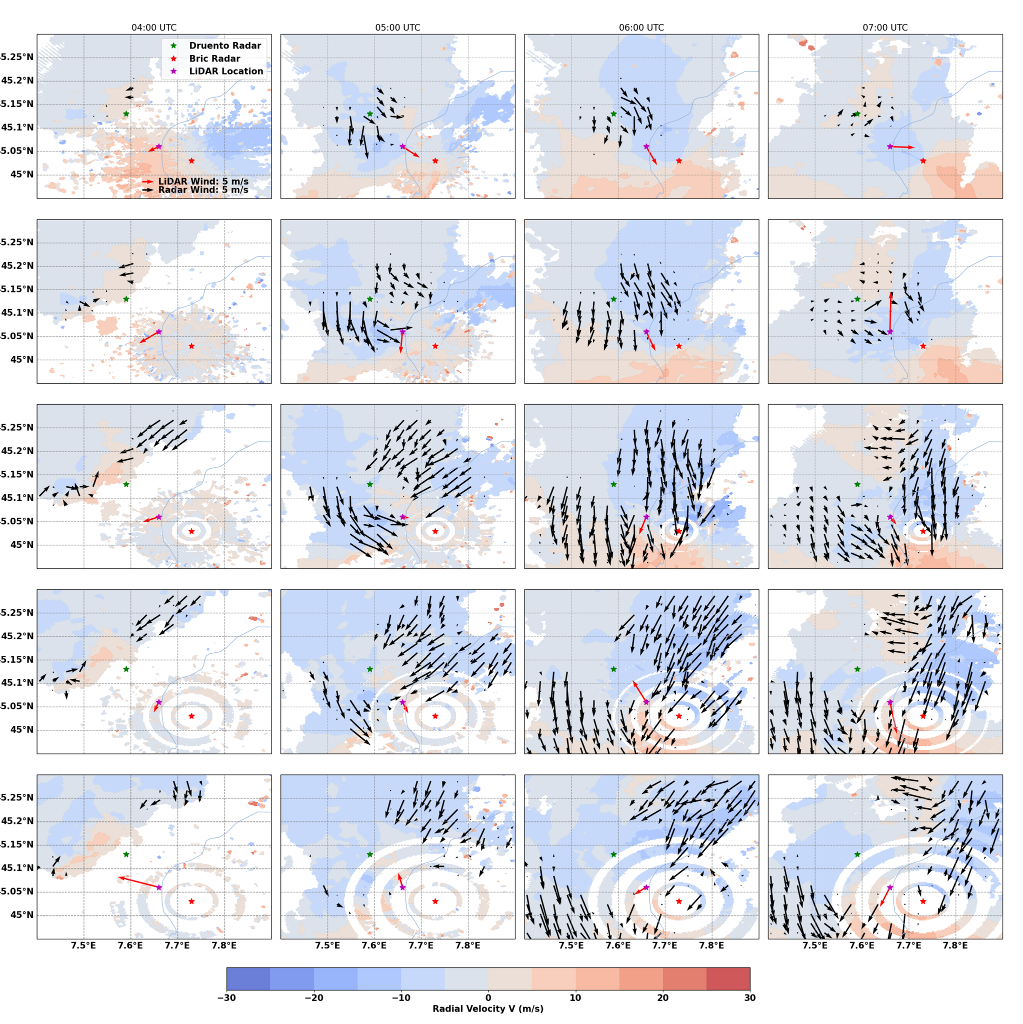
Parameter	Default Value	Tested Values
Horizontal resolution		150, 200, 300 m
Vertical resolution		25, 55, 100 m
Mass continuity weight	1500	0, 500, 1000
Smoothness weight	0	1, 500, 1000, 1500

RESULTS

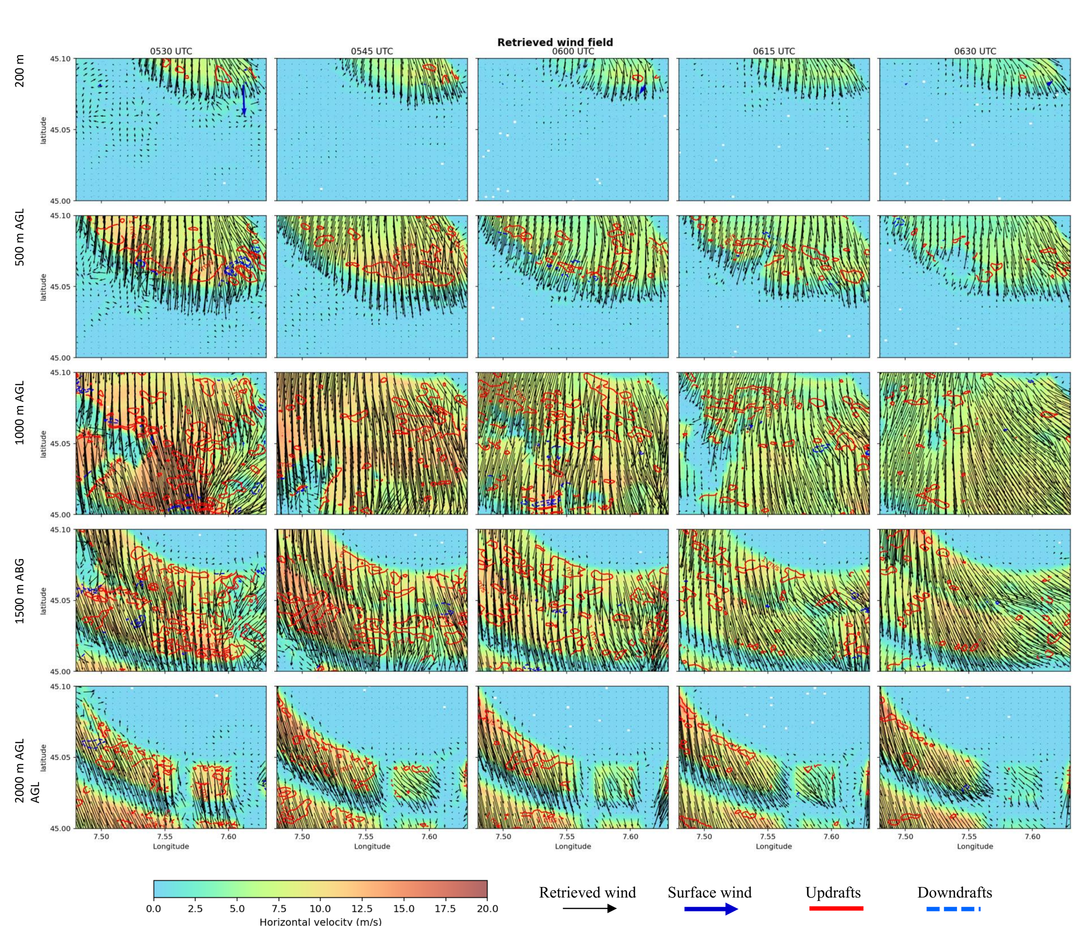
Case event description

September 23, 2023.
Using efault model configuration, resolution 150 m, 55 m.

- **Wind field in the whole domain**



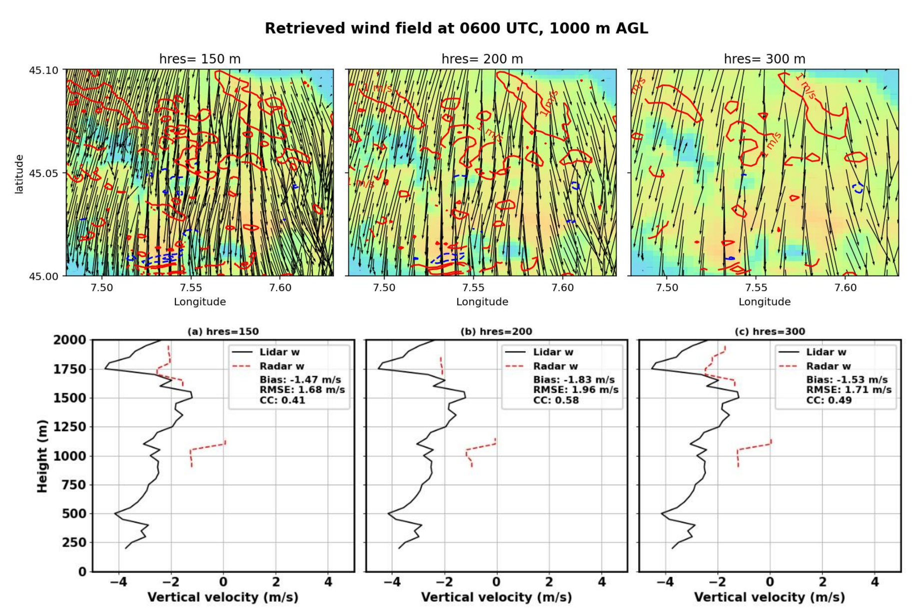
- **Wind field in reduced domain**



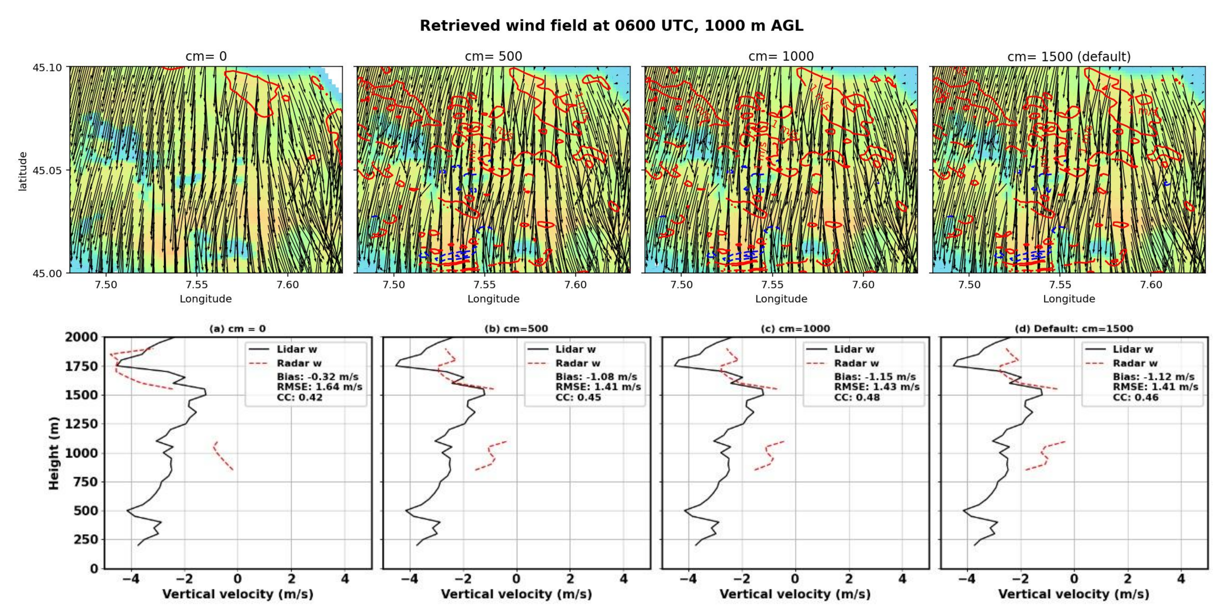
Parameter sensitivity test

Showed: Horizontal slices at height 1 km AGL, vertical profiles of vertical component of wind over Politecnico di Torino, and performance measures with respect to LiDAR data at 06:00 UTC.

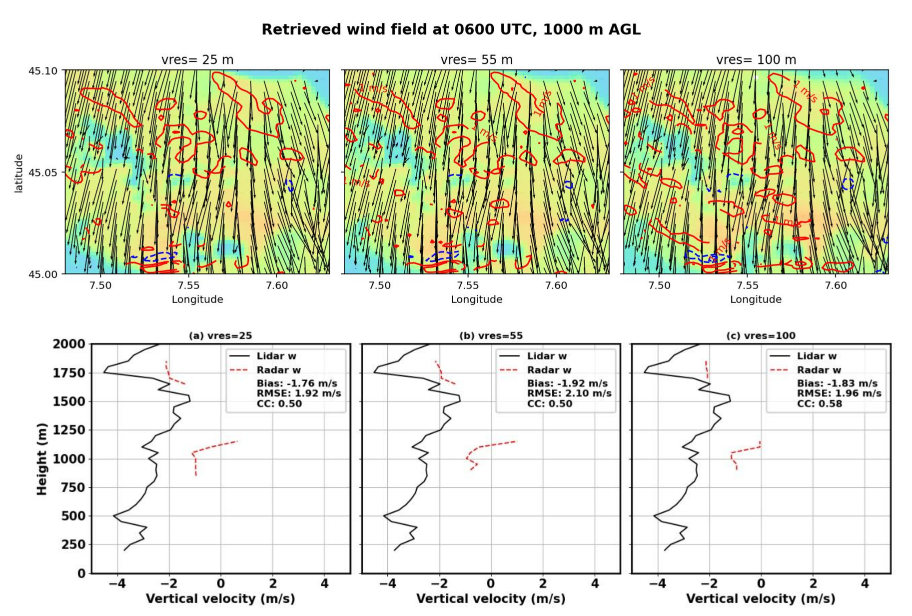
1. **Horizontal resolution (vres= 100 m)**



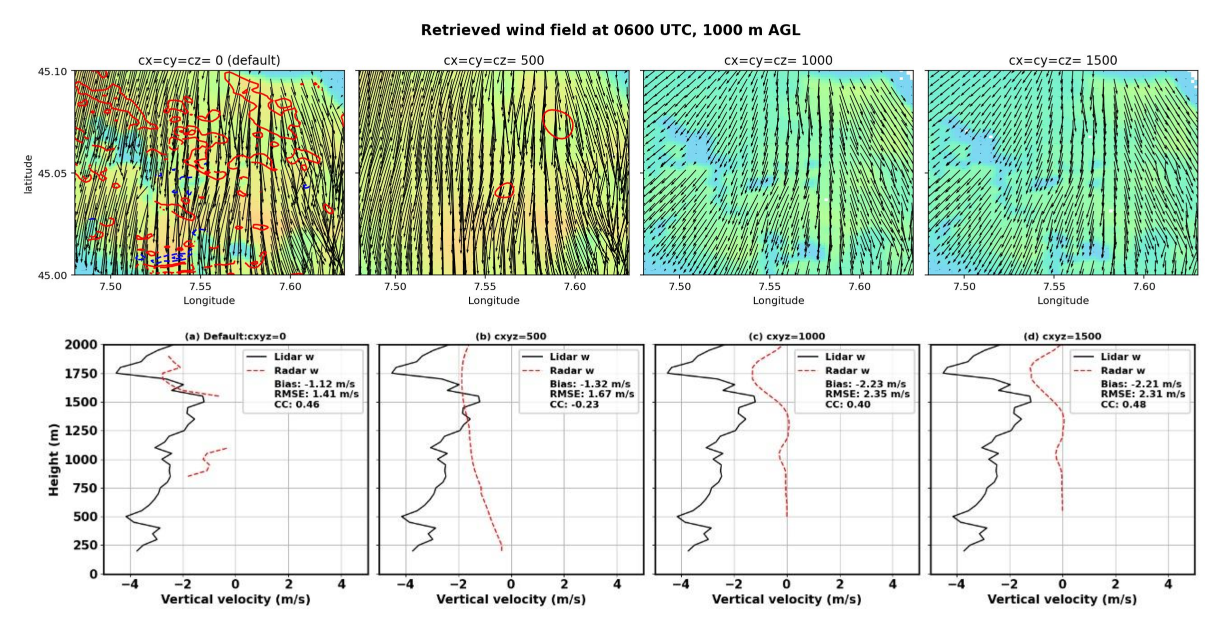
3. **Mass continuity constraint weight (150,55)**



2. **Vertical resolution (hres= 200 m)**



4. **Smoothness constraint weight (150, 55)**



CONCLUSION

- Dual-Doppler retrievals captured 3D wind structures, revealing convergence below 1 km and divergence above 1.5 km, characteristics of strong updraft regions.
- LiDAR comparison verified structural consistency but exposed underestimated downdraft.
- Sensitivity tests identified that hres= 150-200 m, vres= 25-100 m, cm= 1500-1000 and cxyz= 0 exhibited lower error and higher correlation with lidar data, reinforcing the importance of parameters tunning in convective storm analysis.

REFERENCES

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