An analysis of Dynamical and Microphysical Characteristics of Deep Convective Clouds During CACTI Using CSAPR2 Observations

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Introduction

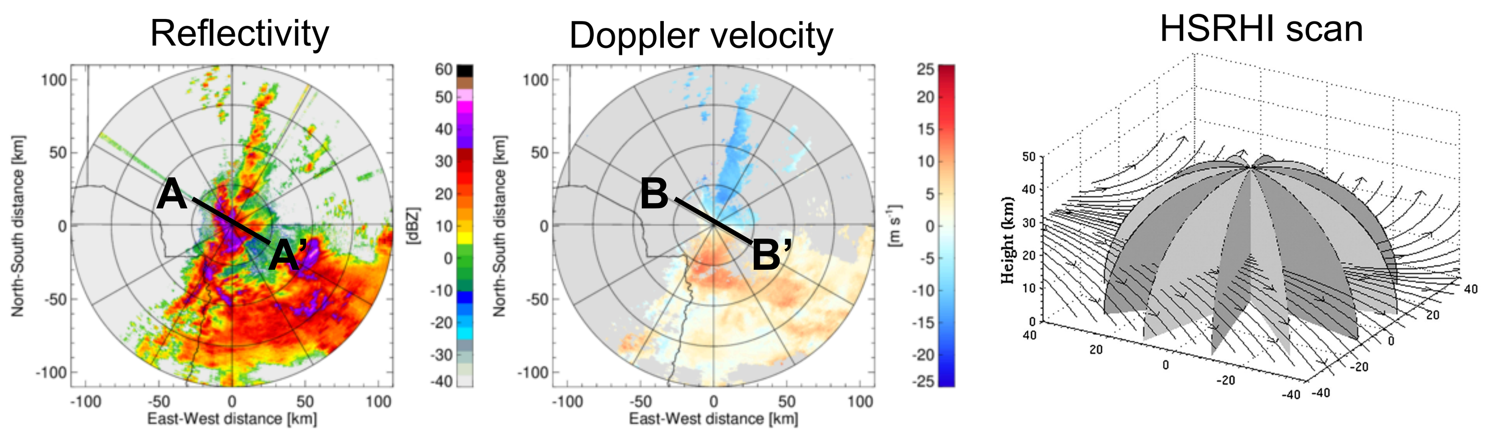
Deep convective cloud systems serve as a primary mechanism for the transfer of heat, moisture and momentum through vertical air motion and entrainment/detrainment processes. However, impacts of vertical transport on redistribution of mass and water at higher altitudes are still unclear. The present study investigated convective core characteristics, and upper-level microphysical characteristics in deep convective clouds, using C-band scanning ARM precipitation radar (CSAPR2) measurements during the Cloud, Aerosol, and Complex Terrain Interactions (CACTI) field campaign.

CSAPR2 can perform high resolution, rapid scan, and full polarimetric measurements. We mainly used Hemi-Spheric Range-Height Indicator (HSRHI) measurements to estimate vertical air motion and track polarimetric variables of deep convective clouds.

Estimation of Vertical Air Motion Using CSAPR2 HSRHI

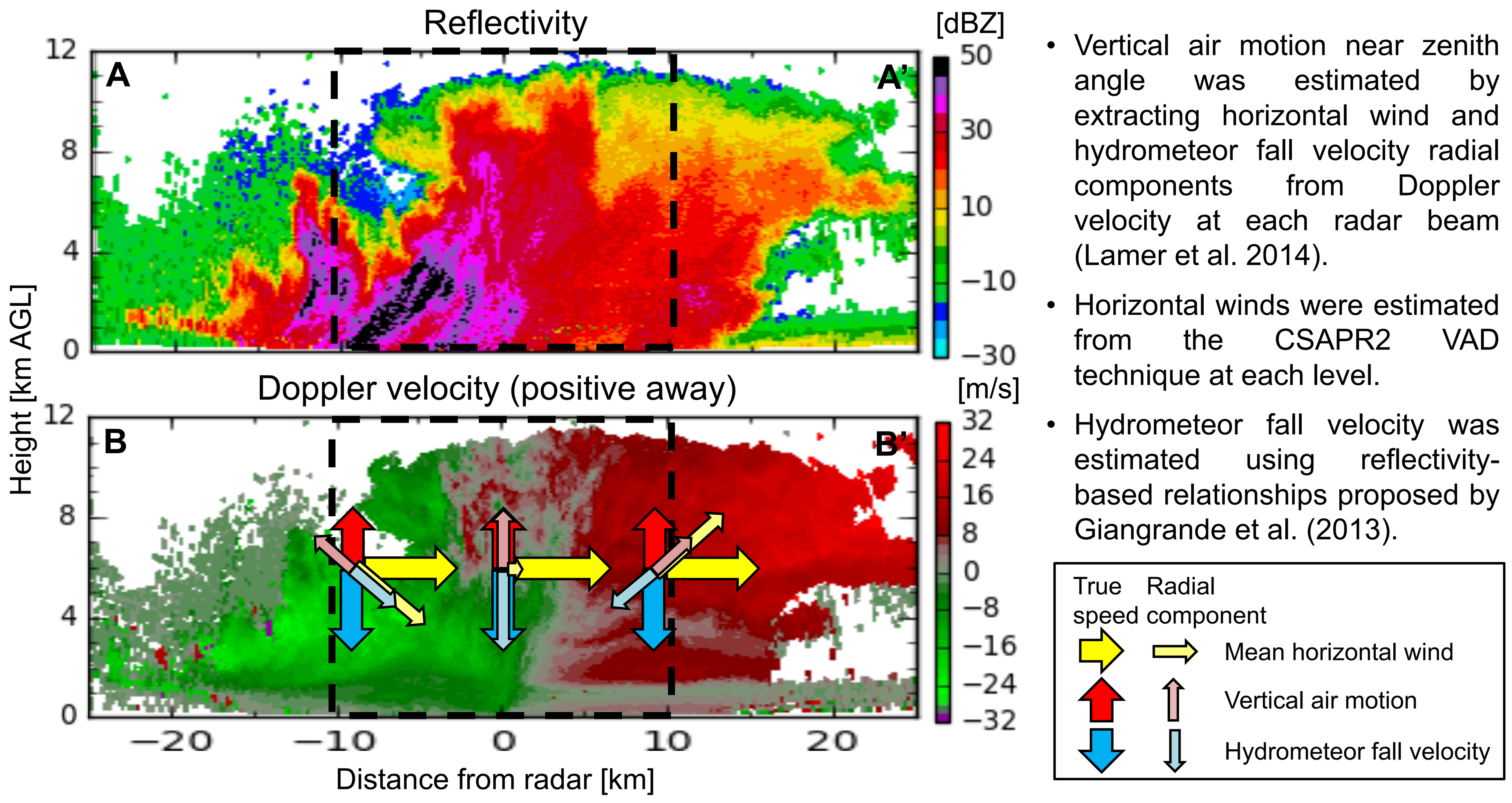
CSAPR2 measurements on Nov. 27, 2018

PPI at Elevation=1.5°

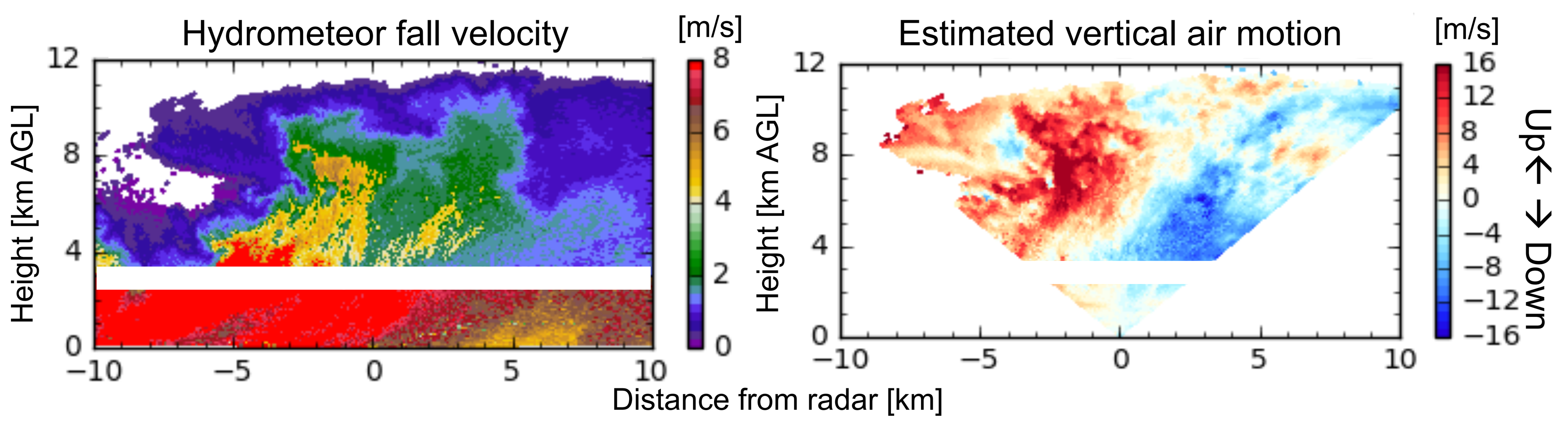


CSAPR2 performed Hemispheric Range-Height Indicator (HSRHI) scans at azimuth angles of 0, 30, 60, 90, 120, and 150° during CACTI.

CSAPR2 HSRHI 0311 UTC, Azimuth=120°

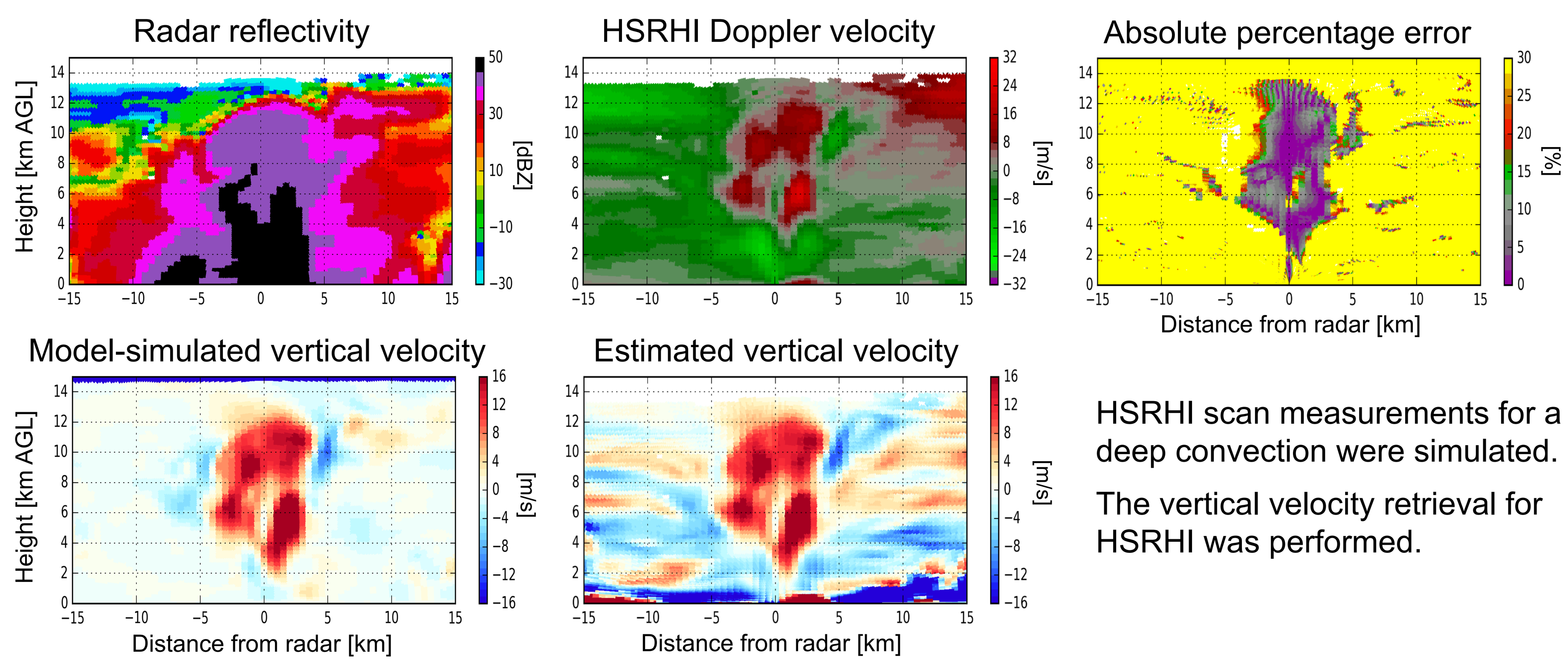


- Vertical air motion near zenith angle was estimated by extracting horizontal wind and hydrometeor fall velocity radial components from Doppler velocity at each radar beam (Lamer et al. 2014).
- Horizontal winds were estimated from the CSAPR2 VAD technique at each level.
- Hydrometeor fall velocity was estimated using reflectivity-based relationships proposed by Giangrande et al. (2013).



- HSRHI can be used to estimate vertical air motion in deep convective clouds passing through the radar.
- CSAPR2 HSRHI measurements revealed a complex structure of vertical velocity in convective clouds.

Evaluation of Vertical Air Motion Estimate Using Radar Simulator



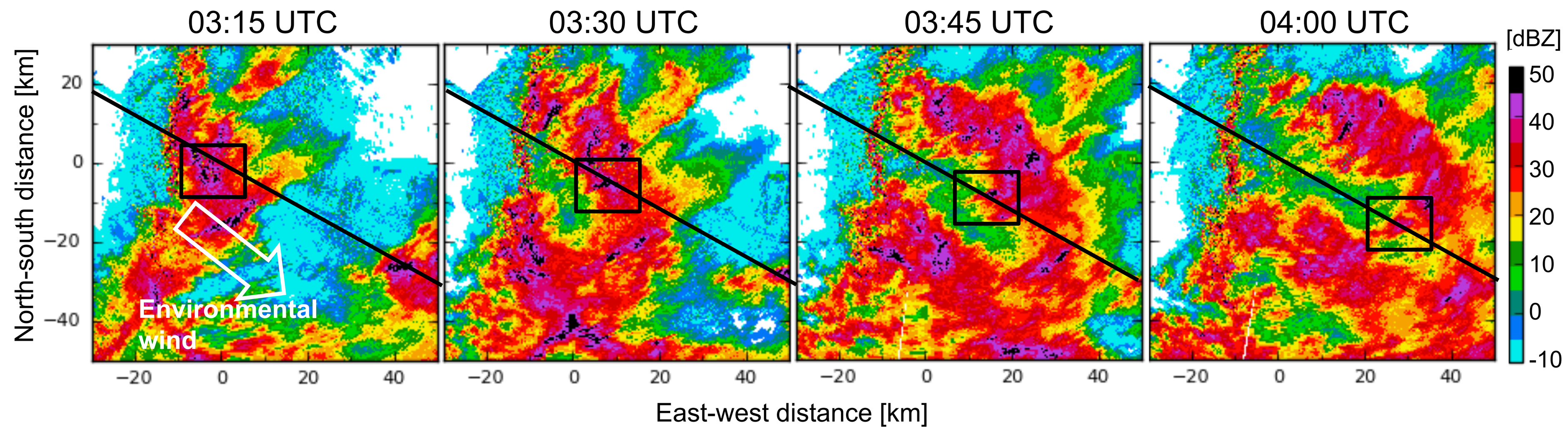
HSRHI scan measurements for a deep convection were simulated.

The vertical velocity retrieval for HSRHI was performed.

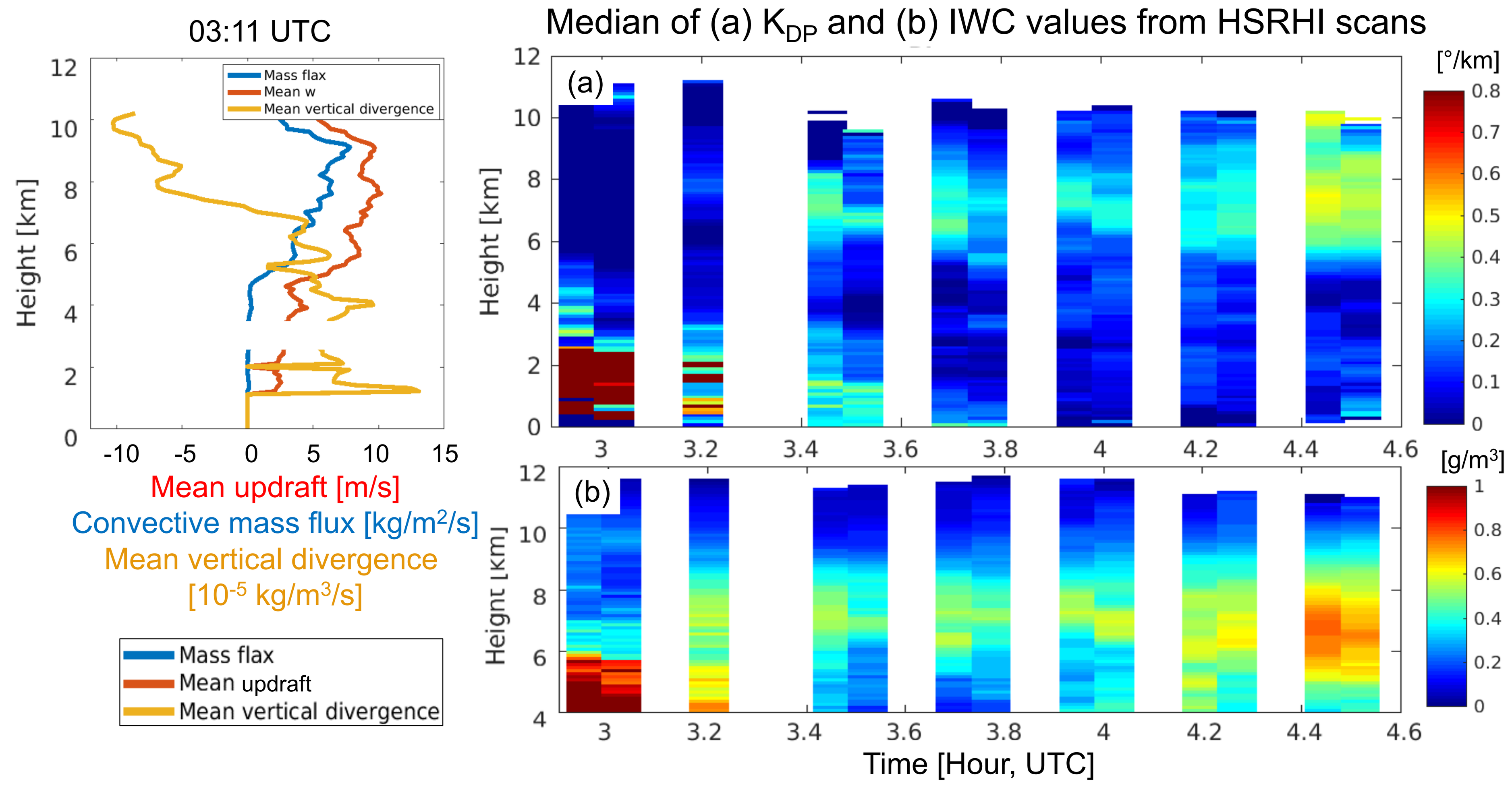
The absolute percentage errors of the HSRHI-based vertical velocity estimate were <10% for stronger vertical velocity regions within zenith angle ~45°.

Polarimetric Parameter Tracked by HSRHI

Tracked convective cloud in CSAPR2 PPI at Elevation=1.5°



Convective core properties and tracked K_{DP} and IWC from HSRHI scans at Az=120°



- K_{DP} and IWC were tracked using HSRHI scans at azimuth angle of 120°, which was consistent with the environmental wind direction.
- Convective core properties were estimated from HSRHI measurements for a deep convective cloud when it passed through the radar.
- Mass flux and mean updraft (w) were estimated for updraft region with updraft > 2 m/s.
- Mean vertical divergence was estimated using $\frac{\partial(\rho * w)}{\partial z}$ (Mullendore et al. 2013).
- IWC was estimated from $\mathrm{IWC} = 0.71(K_{DP}/1.82)^{0.65} Z^{0.28}$ (Z is in linear scale) proposed by Bukovcic et al. (2018, adjusted for C band).

- Vertical convergence found in the upper-level suggested upper-level detrainment.
- The vertical convergence region corresponded to larger K_{DP} regions.
- K_{DP} could be an indicator of upper-level detrainment and be used for IWC estimate and budget analysis.

Summary

- CSAPR2 HSRHI measurements can be used to estimate vertical velocity and convective core characteristics (e.g., mass flux and vertical divergence).
- CSAPR2 HSRHI measurements can also be used to track microphysical characteristics.
- The vertical convergence region corresponded to larger K_{DP} regions, suggesting that K_{DP} could be an indicator of upper-level detrainment.
- Most of deep convective cases from CACTI were associated with northwesterly to north-northwesterly winds at low and upper altitudes. HSRHI scans at azimuth angle of 120° were used to track convective clouds.

Future Work

- Analyze all convective clouds tracked by HSRHI and PPI scans during CACTI.
- Estimate vertical velocity and convective core characteristics associated with cloud evolution using HSRHI and PPI measurements.
- Estimate IWC using the radar measurements, and analyze water budget.

References

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