Lidar Observations of a Mesoscale Moisture Transport Event and Comparison to Analysis and Forecast Models

Brian Carroll[1,2] *, Belay Demoz[1,2], Ruben Delgado[1,2]

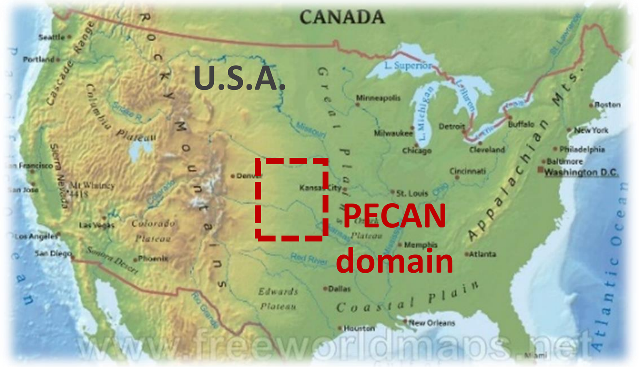
* brian.carroll@umbc.edu

[1] University of Maryland, Baltimore County, Baltimore, MD, USA; [2] Joint Center for Earth Systems Technology, Baltimore, MD, USA

Introduction

- Low-level jets (LLJs) are a major source of moisture for the Great Plains
- Nocturnal mesoscale convective systems (MCSs) are fed by LLJ moisture, momentum, and temperature advection
- Accurate forecasting of MCSs & LLJs remains challenging despite their importance
- Previous studies of LLJ moisture transport rely on radiosondes or reanalysis datasets
- This case study uses lidar observations to resolve mesoscale patterns as well as important smaller features in water vapor and wind

- Data here is from Plains Elevated Convection at Night (PECAN) project, summer 2015
- Models are the Rapid Refresh analysis (RAPa) and forecast (RAPf) and the High Resolution Rapid Refresh (HRRR) operational versions 2 and 1, respectively



Sunset: 0200 UTC
Sunrise: 1115 UTC

FP1: Southern site
FP3: Northern site

Case overview: 11 July 2015

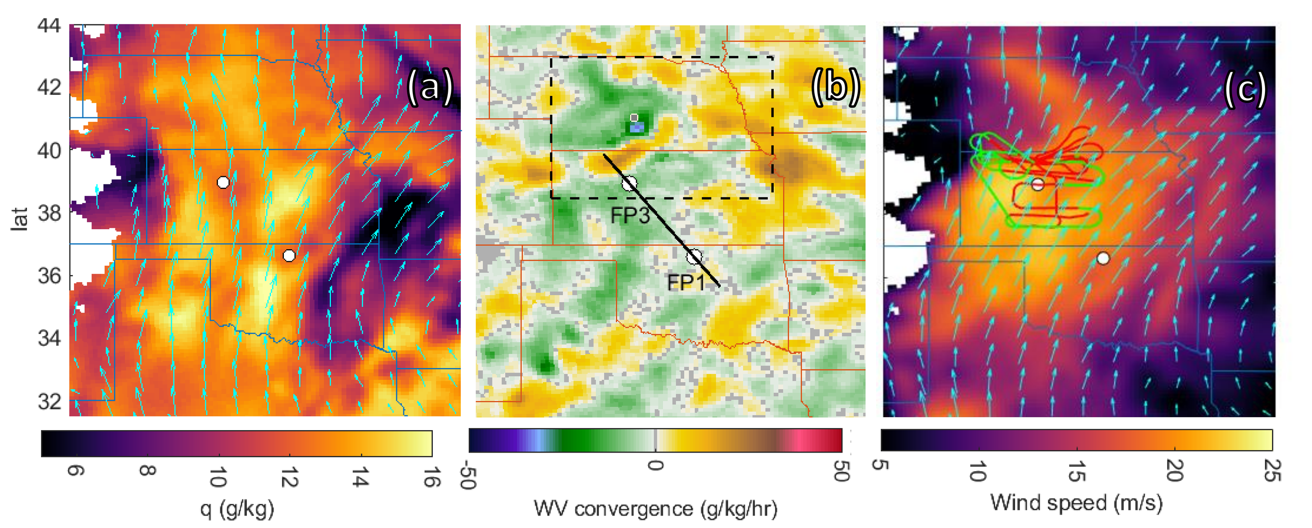


Fig. 1. RAP analysis fields. 850mb q with wind direction arrows at 2 UTC (a), moisture convergence below 800mb (b), and 850mb wind speed and direction at 6 UTC (c).

- Strong southerly LLJ spanned the whole PECAN domain and beyond
- Quasi-stationary warm front along the KS-NE border
- Two nocturnal MCSs grew out of afternoon convection in NE (*see Fig. 2*). Both died out shortly before sunrise.
- A region of moisture convergence south of MCS A was present throughout its lifetime
- The 3 models used in this study produced MCS A (*Fig. 2*), but with a variety of inaccuracies

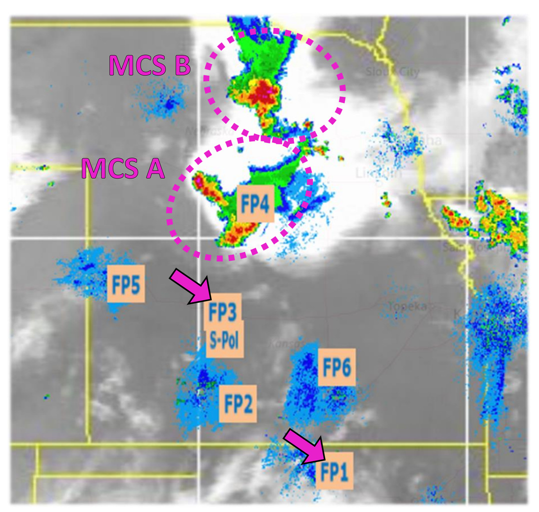


Fig. 2. NEXRAD mosaic at 0615 UTC. Ground sites, including FP1 and FP3, are identified. Grayscale is GOES-13 near-IR.

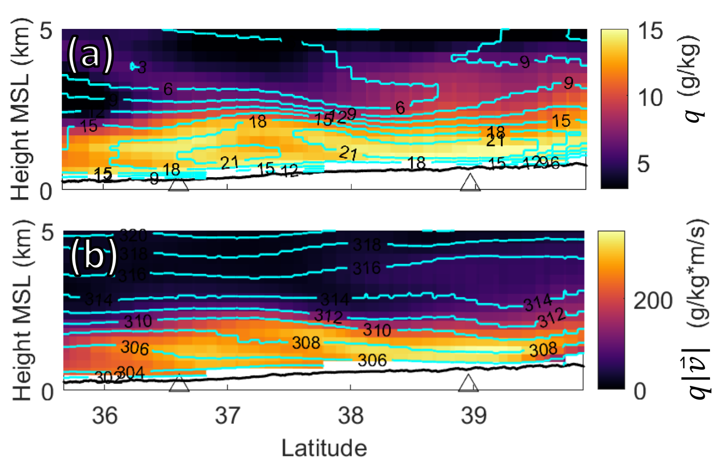


Fig. 3. RAP analysis cross-section along the line shown in Fig. 1(b). Triangles mark FP1 (left) and FP3 (right). q with wind speed (m/s) contours (a) and moisture advection with θ (K) contours (b).

Lidar Instrumentation

		Type	λ (nm)	Vert. Res.	Min. Height	Time Res.
Wind	FP3 Doppler	WINDCUBE®70 (U. Manitoba)	1540	50 m	100 m	15 min
Wind	FP1 Doppler	Stream Line Pro (ARM)	1540	26 m	91 m	15 min
Water vapor	FP3 DIAL	NCAR/EOL	828	75 m	450 m	5 min
Water vapor	FP1 Raman	ARM SGP	355	37.5 m	172 m	70 s
Water vapor (airborne)	DIAL	NASA LASE	817	330 m (avg) native 30 m	350 m	3 min (avg) native 9 s

Water Vapor and Wind: Ground-based Lidar and Models

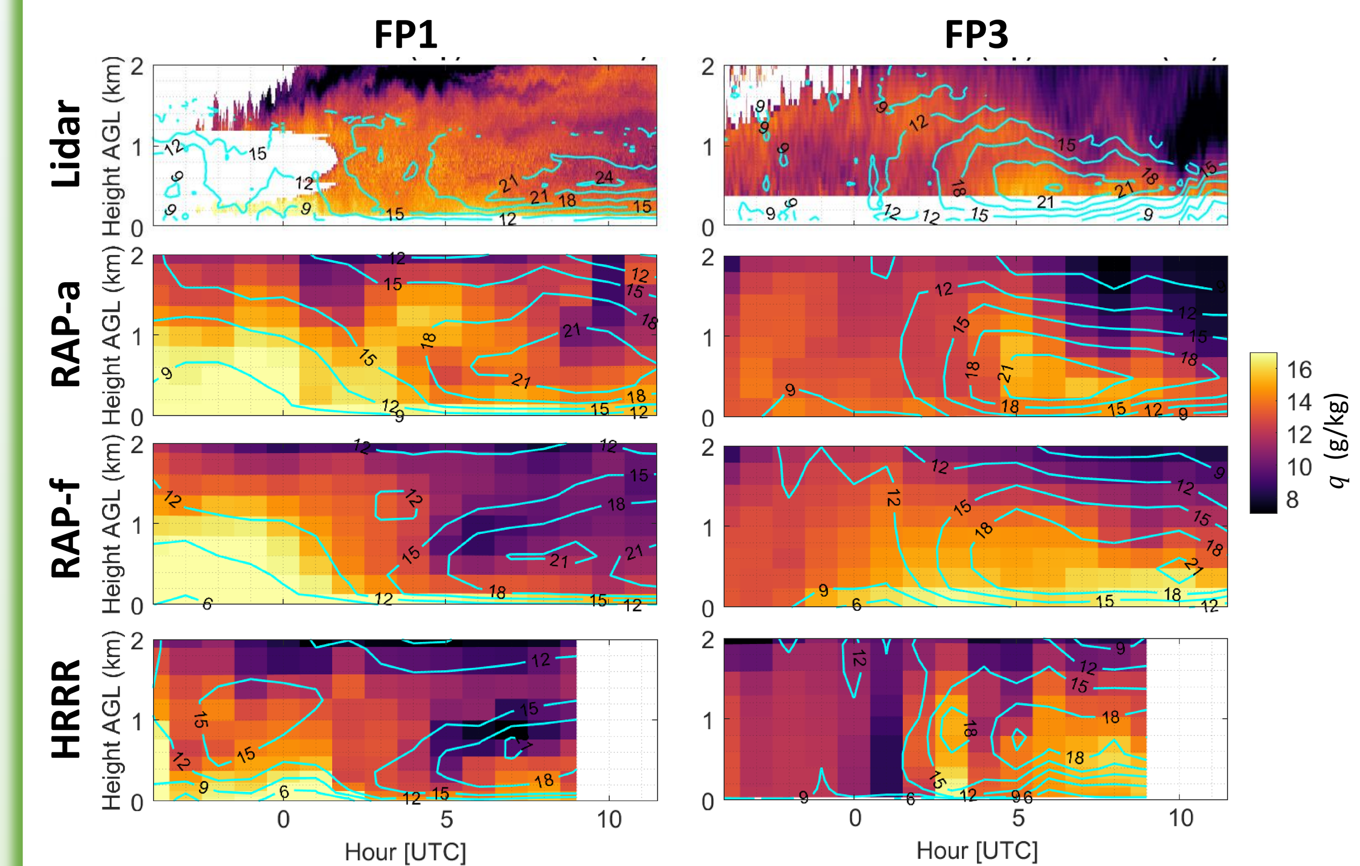


Fig. 7. q with wind speed contours (m/s) at FP1 (left column) and FP3 (right column). Lidar observations are in the top row, followed by the models as labeled on the left.

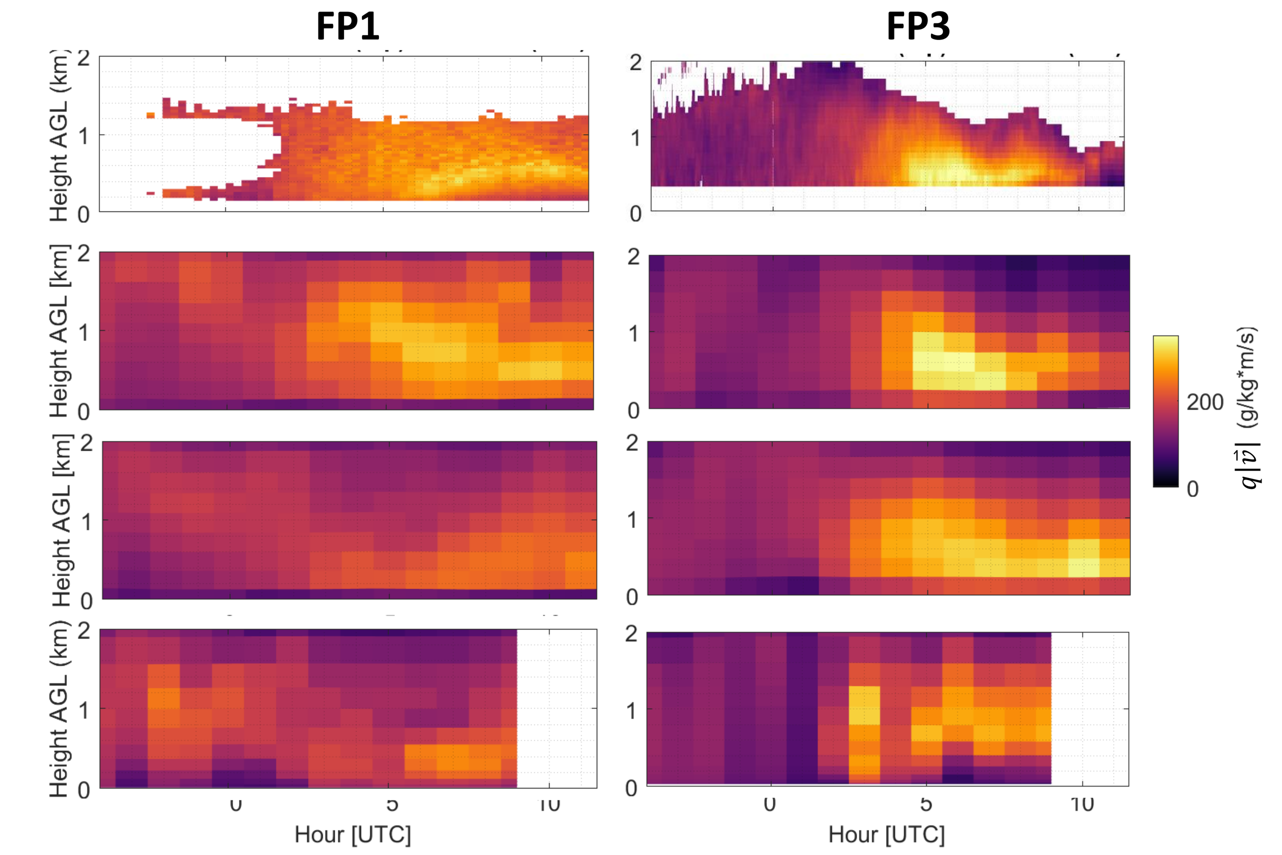


Fig. 8. As in Fig. 7 but plotting water vapor advection.

As the LLJ ramped up throughout the domain, moist boundary layer atmosphere was advected northward from FP1 to FP3

- Moisture advection at FP1 changed gradually with time; little variation vertically
- Moisture advection at FP3 peaked sharply at 0430 UTC, vertically constrained within the LLJ core
- The maximum moisture advection (5-6 UTC) coincided with convective initiation and intensification associated with MCS A ("arrow" of bow-and-arrow structure)
- RAPf and HRRR dried out too much and too quickly at FP1
- Model wind errors at both sites were qualitatively consistent among the 3 models

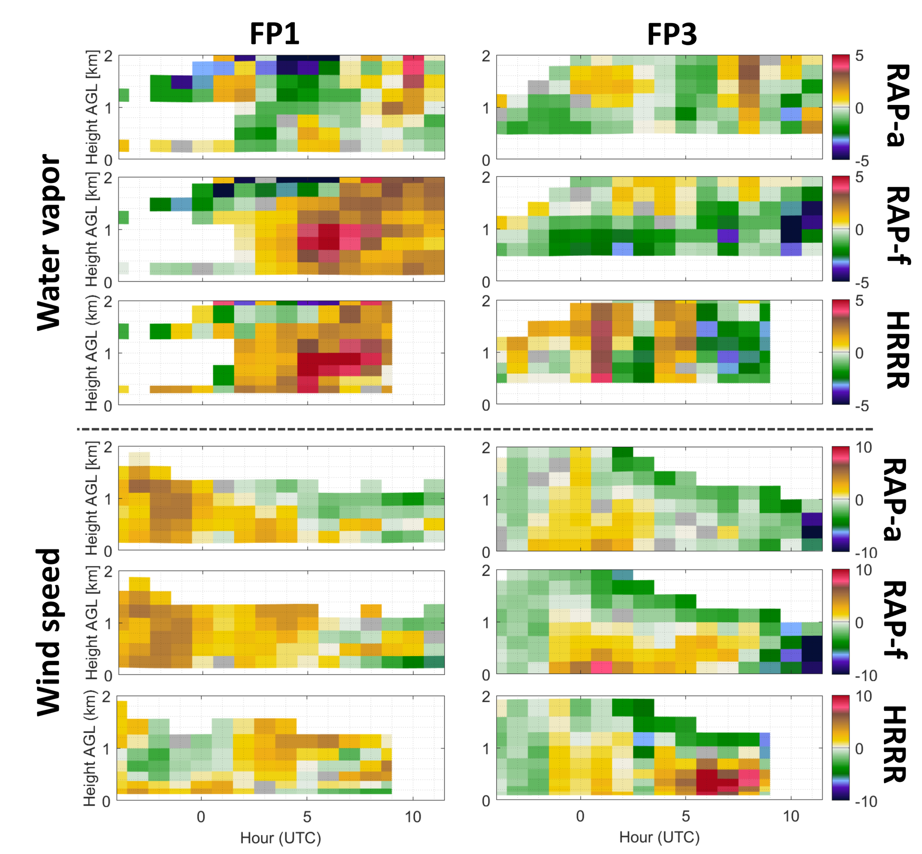


Fig. 9. Differences ([obs] - [model]) between the lidar observations and model output shown in Fig. 7. The FP, model, and variable of each plot are indicated by border text. Water vapor differences are in g/kg and wind speed is in m/s.

Measures of Convective Potential

- At FP1, CAPE at all levels decreased drastically after sunset
- FP3 had minimum CAPE at sunset, but then CAPE increased aloft, maximizing coincident with max moisture advection and formation of MCS A "arrow"
- Moist static energy (MSE) changes were dominated by moisture, with very different pictures at the two sites

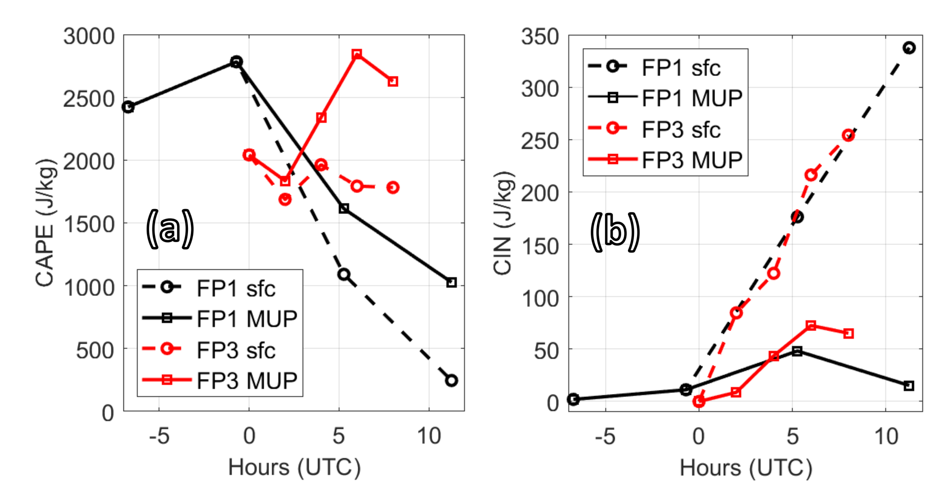


Fig. 10. CAPE and CIN for surface (sfc) and most unstable parcel (MUP) at FP1 and FP3 from afternoon through sunrise.

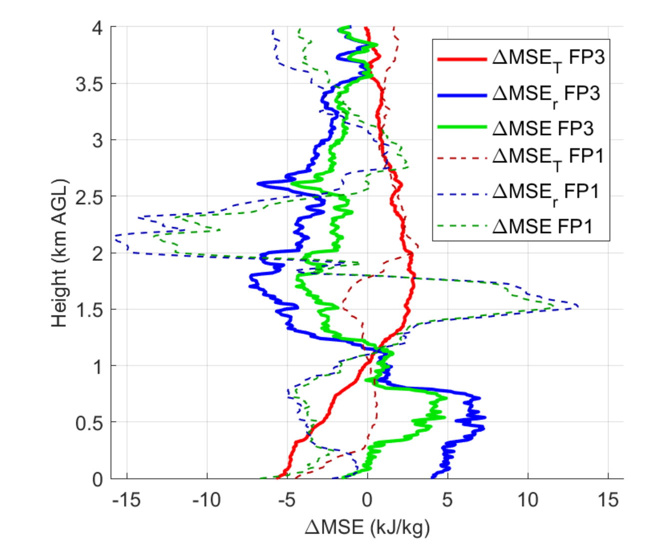


Fig. 11. Temporal change in MSE and MSE components from 0 to 6 UTC.

Airborne Lidar and Model Water Vapor

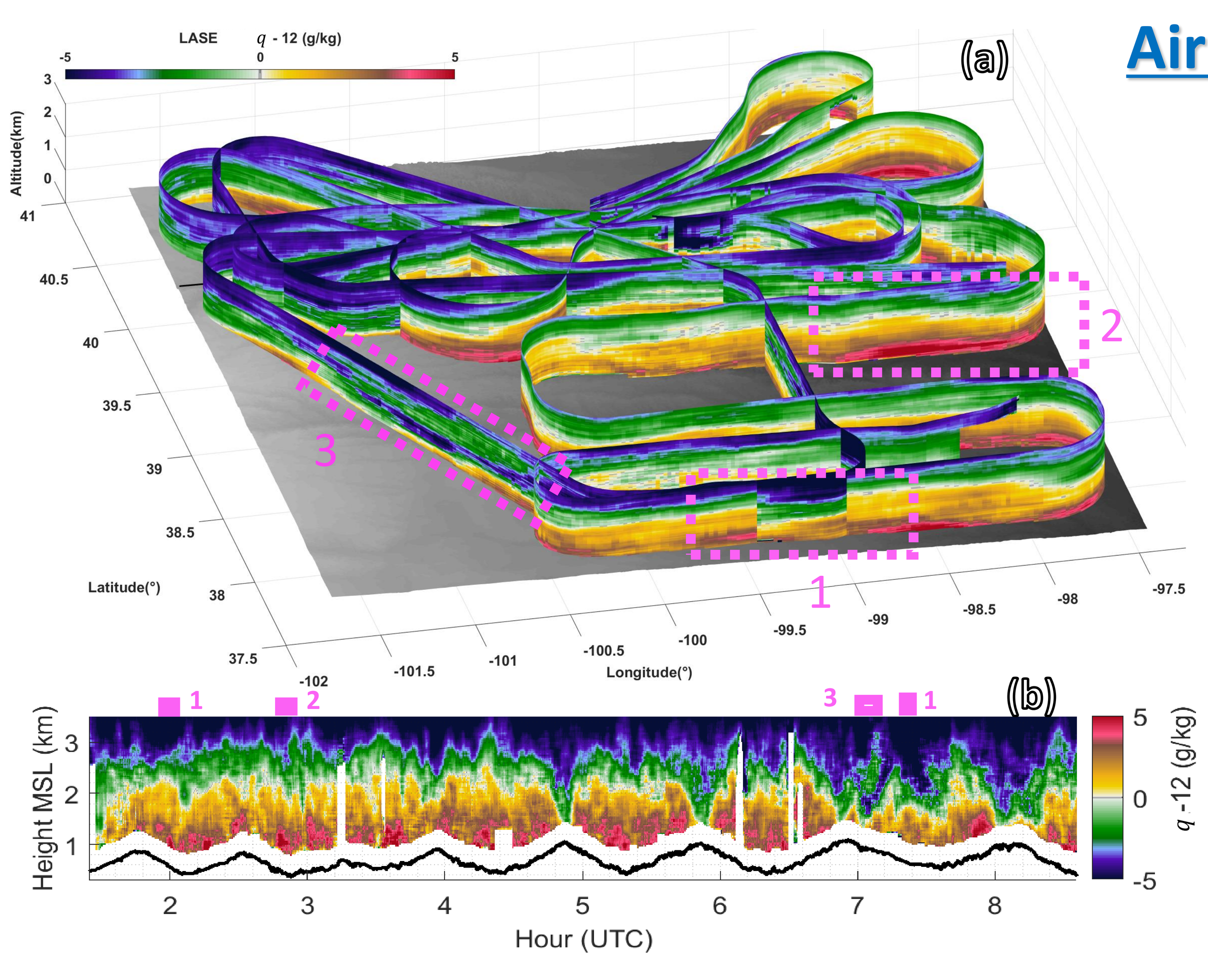


Fig. 4. LASE profiles along the flight track shown in Fig. 1(c). 3-D projection up to 3km MSL is shown in (a); 2-D curtain up to 3.5km is in (b). Pink boxes mark some points of interest.

- Lidar revealed mesoscale patterns and important fine structures in water vapor
  - Southern region dried out over time
  - Thin dry and wet layers (*Fig. 4 Point 3*)
- Model errors often exceeded 2g/kg, manifesting as contiguous wet/dry parcels from tens to over 100km in size

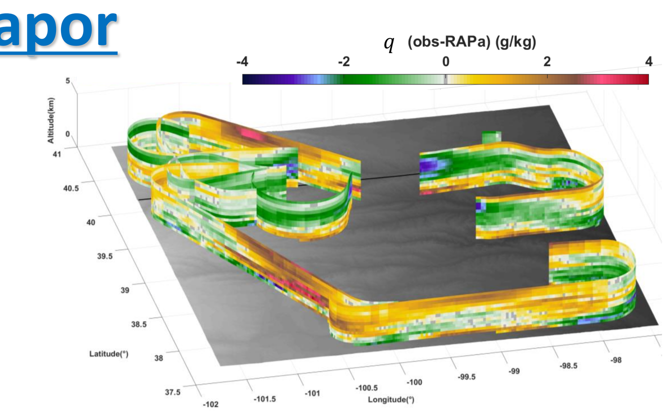


Fig. 5. Water vapor difference, LASE – RAPa.

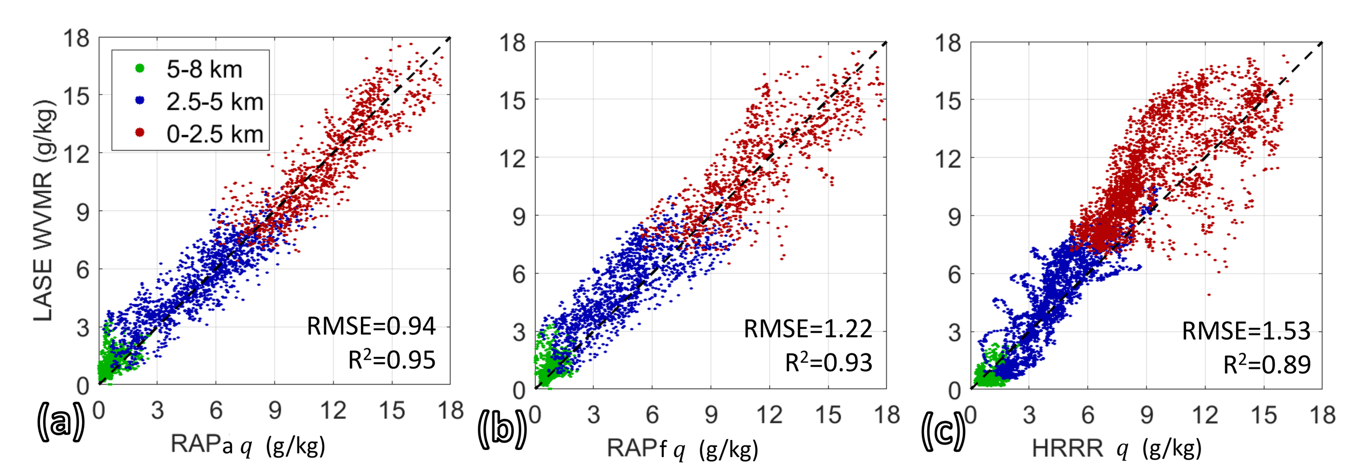


Fig. 6. Comparison plots of LASE measurements and modeled water vapor mixing ratio for RAPa (a), RAPf (b), and HRRR (c). Colors delineate altitudes, with the 0-2.5km approximating the boundary layer.

Summary & Outlook

- The LLJ transported moisture northward, resulting in coincident maxima in CAPE and moisture advection at FP3 that also matched the initiation and intensification of the "arrow" branch of MCS A
- Lidar was able to reveal mesoscale patterns of water vapor transport (northward advection) as well as important smaller-scale features (e.g. thin dry layers above the boundary layer)
- RAPa, RAPf, and HRRR produced MCS A but with various inaccuracies that may be related to errors in water vapor mixing ratio that often exceeded 2g/kg, which manifested as contiguous dry/wet parcels 10s of km to 200km in size
- Future studies can benefit from planned lidar synergy, or assess the impacts of assimilating this data for forecasts
- The work presented here will soon be submitted for publication by the authors

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