Convective-scale data assimilation of high-resolution wind and thermodynamic observations during PECAN and VORTEX2

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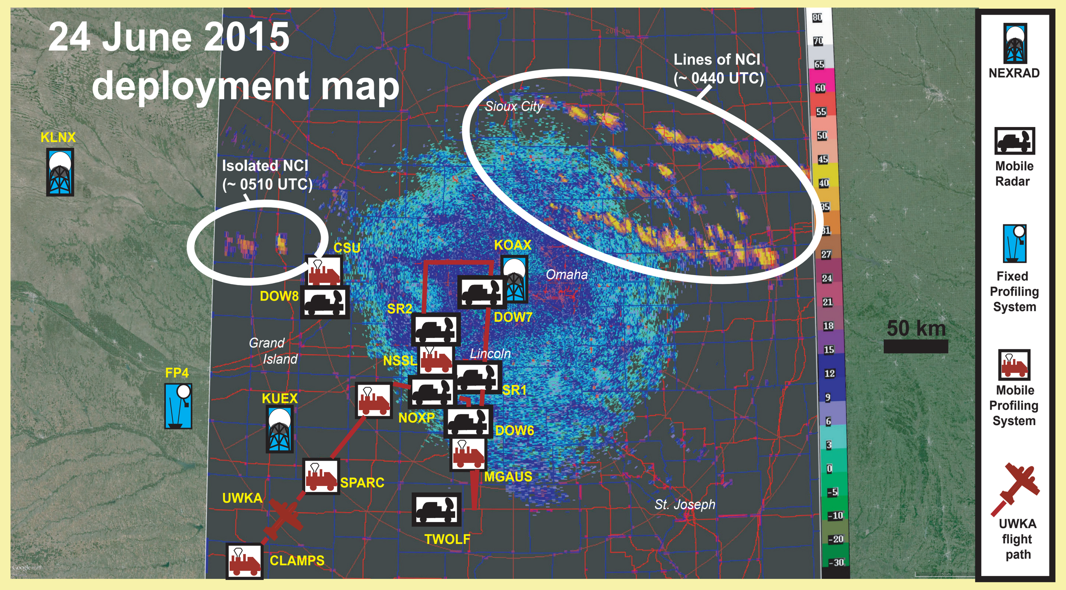
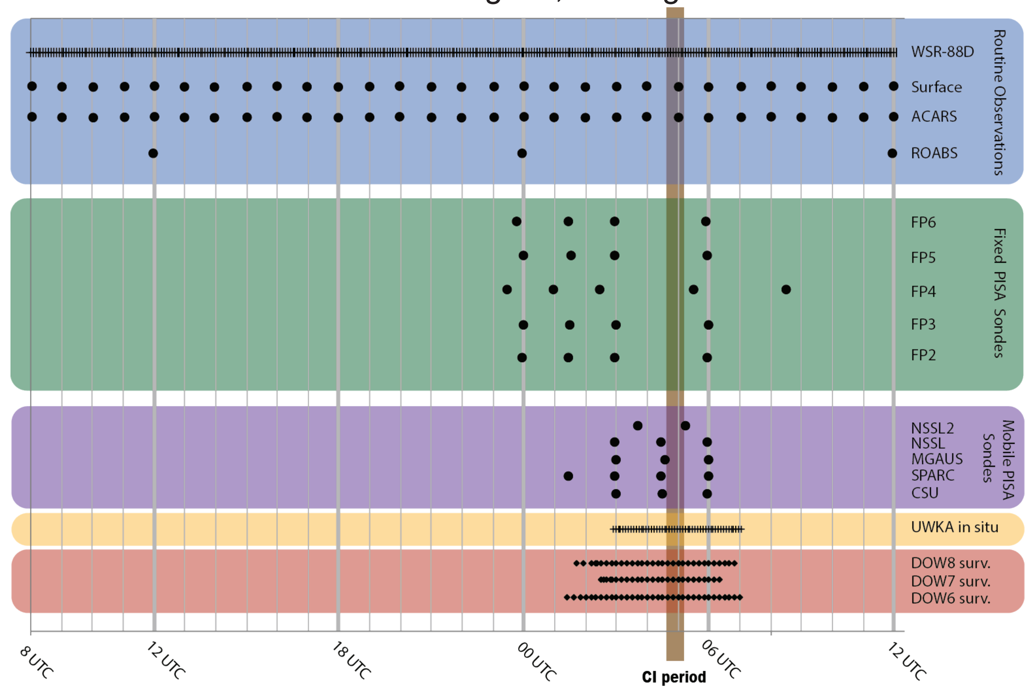
Introduction: Two research projects are underway to explore improvements in numerical representation of environments supportive of nocturnal and daytime convection by assimilating a variety of unique observations to mesoscale and storm-scale ensembles using the WRF model and Data Assimilation Research Testbed (DART) software with the Ensemble Kalman Filter (EnKF) technique.

Goals: Our first project (left) assimilates stationary and mobile radar, aircraft, sonde, and profiler data collected during PECAN to nested domains with 3-km and sub-1-km grid spacing to accurately reproduce detailed environments of nocturnal convection initiation (NCI). Resulting fine-scale EnKF analyses will be used to evaluate environments and triggers dictating specifc locations of NCI, including understanding the roles of nocturnal low-level jets (LLJ), surface boundaries, and influences from previous convection. Analyses also will be used as intitial conditions for forecast sensitivity studies to understand impact of novel high-resolution observations on the predictability of NCI.

Method: Initial EnKF work has begun on the 23-24 June 2015 PECAN case. This was a combined LLJ-NCI mission in SE Nebraska, sampling the LLJ along its forecasted axis. NCI occured just NE and W of Omaha.



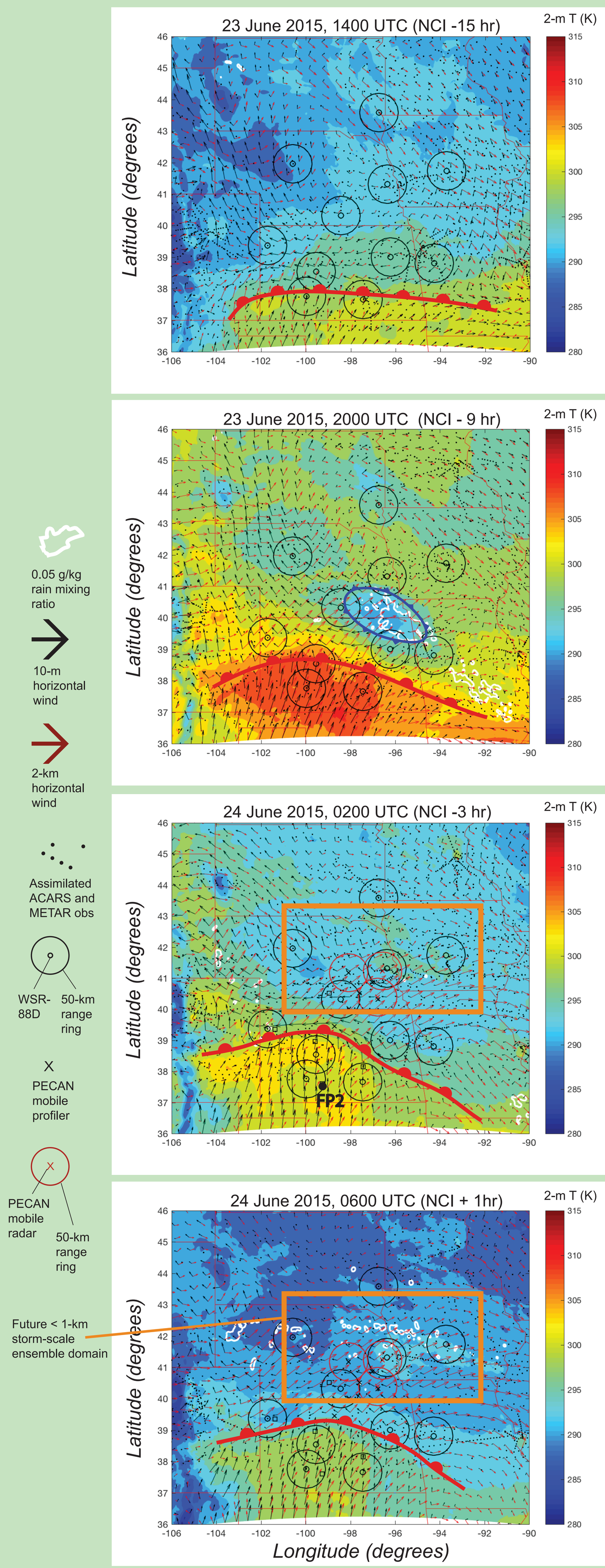
Availability of routine and PECAN observations for assimilation to the mesoscale and storm-scale grids, starting 12 UTC on 23 June.



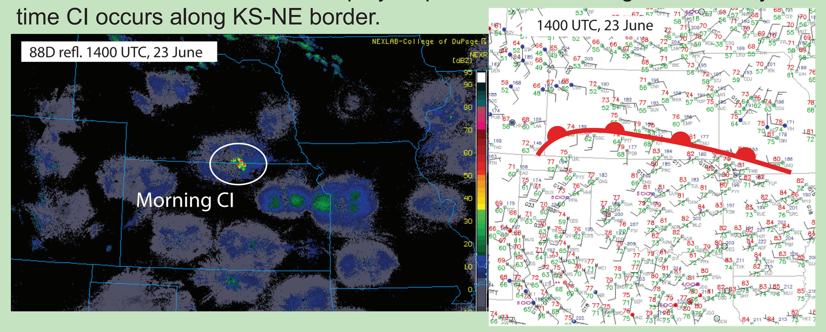
WRF Specs:
- 3-km grid spacing, 733x433x50 grid points, dt = 10s,
- 50 ensemble members,
- Initial conditions from GFS 12 UTC 23 June 2015 (0.25°-res)
- Boundary conditions from GFS analyses,
- *Parameterizations*: No convective param, MYJ PBL, Thompson MP, RRTMG SW & LW radiation, NOAH land-sfc

DART specs:
- Gaspari & Cohn (1999) localization,
- Observations smoothed/thinned prior to assimilation,
- Adaptive Inflation

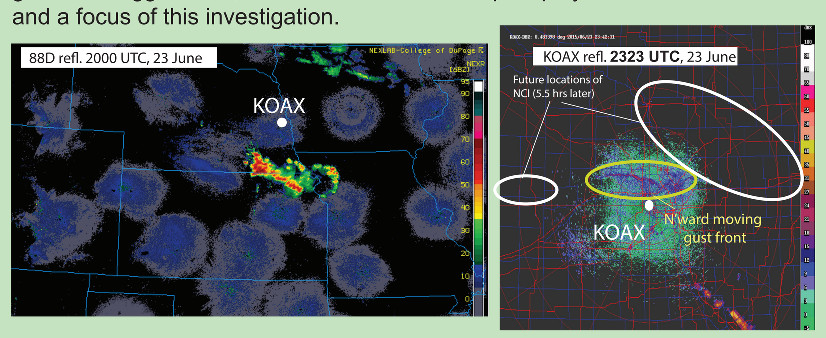
Early Results: Preliminary EnKF analyses assimilate MADIS surface, radiosonde, and commercial aircraft in situ observations (small black dots) hourly to a 3-km mesoscale ensemble. Select posterior analyses are shown below, next to corresponding WSR-88D and other observations. Upcoming analyses will assimilate 88D (black circles) reflectivity, clear-air velocity data (typical coverage extends ~50 km from each radar, large black circles), and PECAN fixed PISA sondes (black squares) leading up to the IOP.



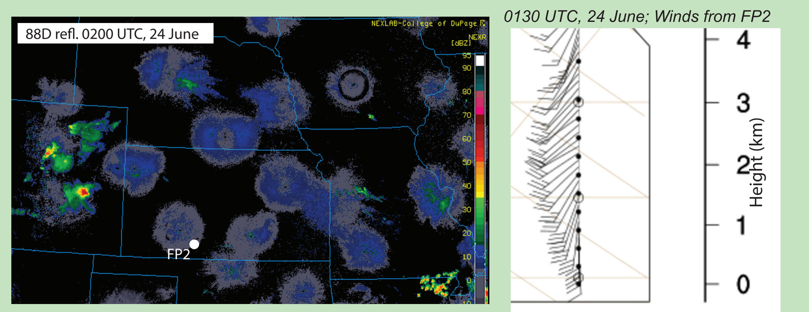
With only MADIS observations assimilated, the mesoscale analyses, starting the morning prior to NCI, develops mesocale/synoptic-scale features observed on 23 June, including a northward-moving warm front in central KS. It is believed this warm front plays a pivotal role in forcing the NCI. Daytime CI occurs along KS-NE border.



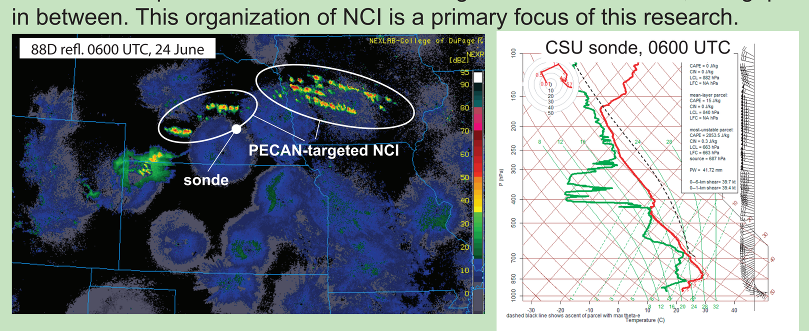
The morning convection develops into a disorganized MCS that moves eastward into Missouri. This convection produces a cold pool that moves northward into the target area for NCI that night. It is not obvious that the surface gust front triggers NCI, but the role that the cold pool plays in NCI is unknown and a focus of this investigation.



No neighboring convection exists by the time of NCI. The warm front continues northward. Southerly flow at z = 2 km is enhanced north of the front, though less so south of it. Wind veers in the LLJ south of the front accurately, but analyzed winds aloft are slightly weaker than observations (e.g., at FP2). Assimilation of PECAN and radar are expected to improve the analyses.

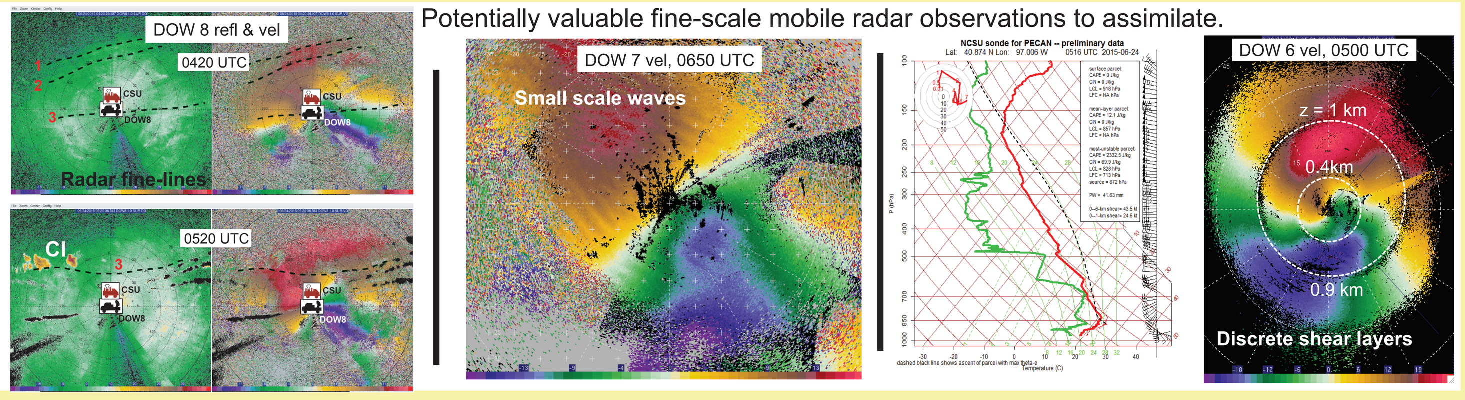


Convection initiates in broken bands north of the warm front within the broad convergence zone leading the LLJ and over-riding flow at approximately 0500 UTC on 24 June. Proximity soundings suggest unstable air originates from elevated sources (above ~700 mb). It is not yet clear why the convection forms in three parallel bands in Iowa and single bands in Nebraska, with gaps in between. This organization of NCI is a primary focus of this investigation.



Future Work: Nested sub-1km-grid centered on IOP and NCI (orange box in panels to the right). Assimilate routine in situ observations, nearby WSR-88D observations, mobile PISA sondes and profilers, and mobile radars at 10-min intervals from 0200 UTC throughout the NCI event. Evaluate origins of convection with parcel trajectory analysis and 4-D mapping of thermodynamic and flow fields. Explore the value of assimilating SPOL refractivity, DIAL, and AERI data. Begin similar work on 3-4 July 2015 case.

Potentially valuable fine-scale mobile radar observations to assimilate.



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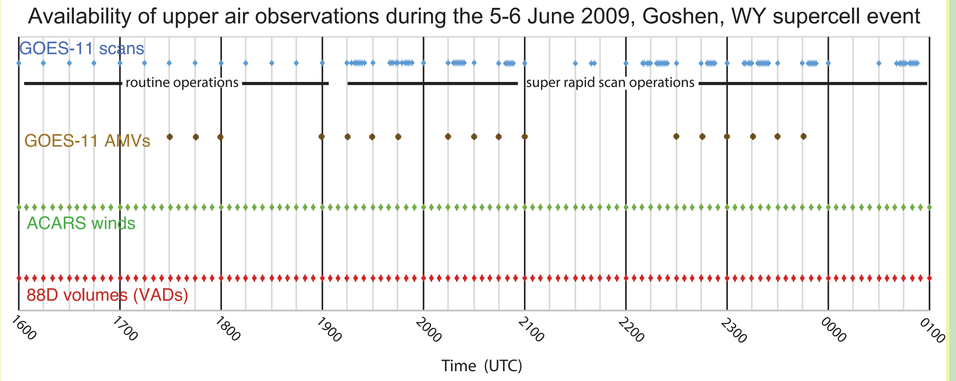
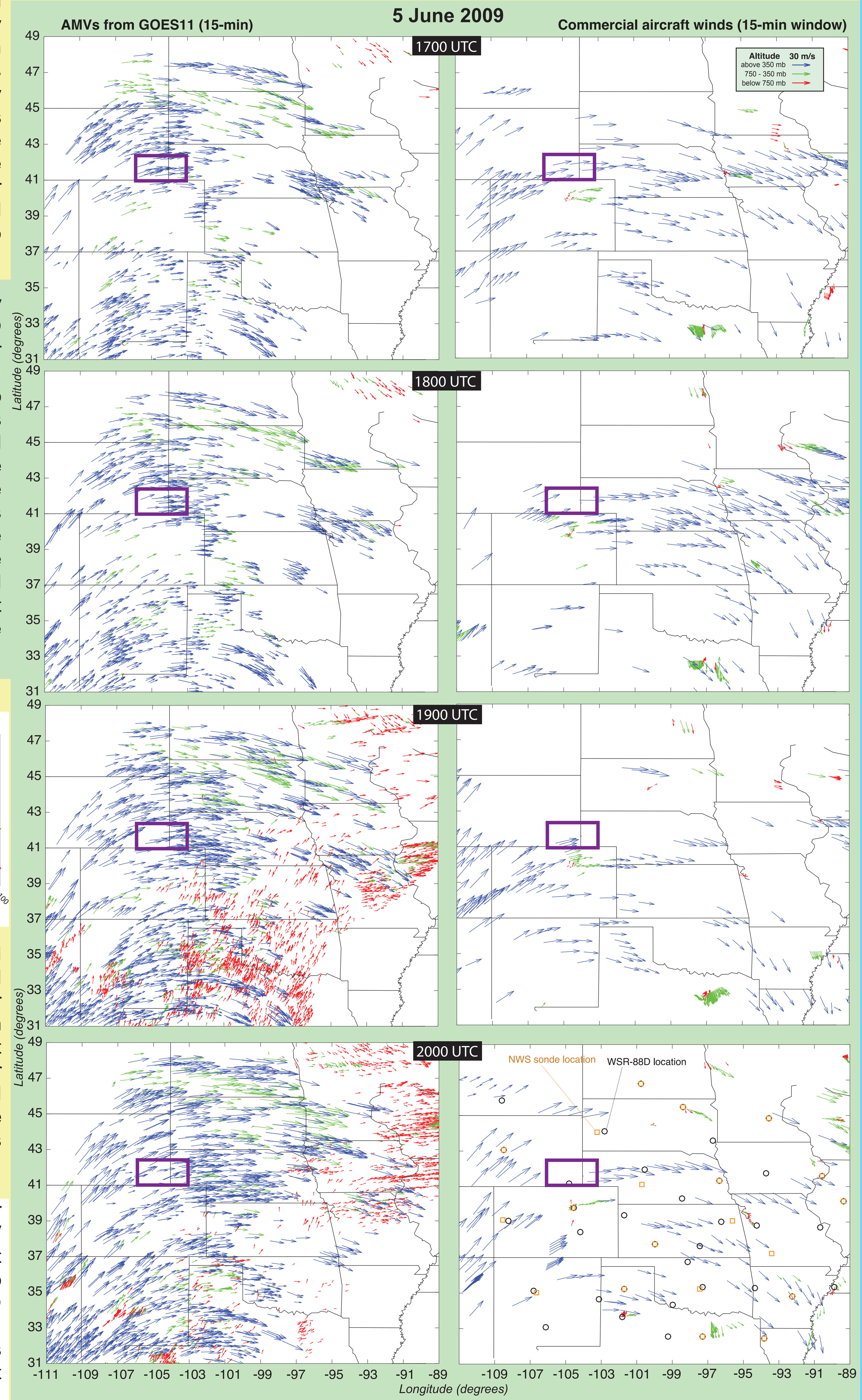
Goals: Our second project (right) assimilates different combinations of routine radar, sonde, and commercial aircraft data, and atmospheric motion vectors (AMVs) derived from super-rapid-scan GOES operations to determine the relative impact of high-resolution satellite observations on the mesoscale shear field surrounding tornadic supercells. Principle data for tests was collected during the second VORTEX project, and will advise upon operational utility of AMVs from the upcoming GOES-R. Fine-scale simulations (<1-km grid spacing) of supercells that employ initial conditions produced with and without AMVs will indicate storm-scale sensitivities of potentially more detailed environments.

Method: Production of a preliminary set of AMVs, derived from GOES-11 imagery on 5 June 2009, is calculated by tracking visible, infrared, and water vapor objects at 15-min intervals (3-min for visible). Super-rapid-scan operations were conducted on 5 June 2009 starting at approximately 1900 UTC (scans at variable time increments, as small as 1.5-min); although, sufficient data were available to produce AMVs prior to this time in routine operation mode. A sample of the AMVs is compared to contemporaneous upper air commercial aircraft (ACARS) data, WSR-88D locations, and routine sondes (only at 0000 and 1200 UTC) in the figure to the **right.**

Early Results: There are significantly higher density mesoscale wind observations resulting from SRSO GOES-derived AMV calculations than from routine upper air observations (e.g., ACARS, 12-hourly sondes, and spatially-limited 88D-derived VAD profiles). Owing to upper-level cloud cover, many AMVs over the high plains are limited to high altitudes (above 350 mb); thus, mid- and low-level observations are generally distant from the VORTEX2-observed storm (located in purple box on the right). However, assimilation of these AMV observations over much of the plains may radically increase details of the boundary layer flow in the TX-OK-KS region, and the upper-level flow in the CO-NE-WY-SD region, which could improve details of the mesoscale and synoptic environment moreso than by only using traditionally-assimilated routine observations.

Availability of upper air observations during the 5-6 June 2009, Goshen, WY supercell event





Experiments: Using a similar cycled mesoscale (3-km grid spacing) data assimilation system as the PECAN-focused project (left), we will evaluate changes in mesoscale shear and its effect on storm morphology and evolution when AMVs are assimilated at 15-min intervals, when they are not assimilated, and when they are assimilated at coarser temporal/spatial resolution commensurate with routine and past satellite observations. Results will inform upon the utility of routinely assimilating new GOES-R AMV data sets for the use of convective-scale operational NWP.

Future Work: Perform similar mesoscale experiments for more GOES and upcoming GOES-R SRSO-derived AMV data sets to understand common impact of different observed cloud layers on storm development. Also, to quantify expectations for coverage and utility of SRSO AMVs over the U.S. Plains for convective events.

Perform storm-scale (sub-1km) resolution simulations with AMV and non-AMV analyses as initial conditions to test impact of improved mesoscale flow (shear) fields.

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