Establishing a Holistic Understanding of the Circulations of Mesoscale Convective System Stratiform Regions

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MOTIVATION:

- The stratiform region of Mesoscale Convective Systems (MCSs) are key components of the global circulation, radiation budget, and hydrologic cycle
- Intra- and extra-system circulations are responsible for stratiform region creation and characteristics (e.g., hydrometeor detrainment from the convective updraft, evaporation within mid-level rear inflow).
- Low-frequency gravity waves generated by diabatic heating are responsible for initiating and modifying these intra- and extra-system circulations, yet…
- We haven't established how stratiform regions change as a result of variations in these waves!

MAIN HYPOTHESES:

- *Poor representation of MCS stratiform regions in model simulations is a result of an incorrect balance between gravity wave, line-end vortex, and environmentally induced flows.*
- *That incorrect balance stems from an incorrectly simulated latent heating profile.*

OBJECTIVES:

1. Identify low-frequency gravity waves generated by midlatitude MCSs observed by the PECAN and MC3E field campaigns.
2. Isolate the impacts of low-frequency gravity waves, line-end vortex, and large-scale environmental flows on the development and characteristics of the observed PECAN and MC3E MCS stratiform regions.
3. Identify potential errors in the stratiform region of LES-simulated PECAN and MC3E MCSs resulting from incorrect circulation causal partitioning compared to (2).

ACKNOWLEDGMENTS

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1) Identify Low-frequency Waves

- Use three well-observed MCS cases each from the PECAN and MC3E field campaigns.
- Identify low-frequency gravity wave modes using multi-Doppler-derived 3D wind fields, interferometer, lidar, profiler, and surface observations.

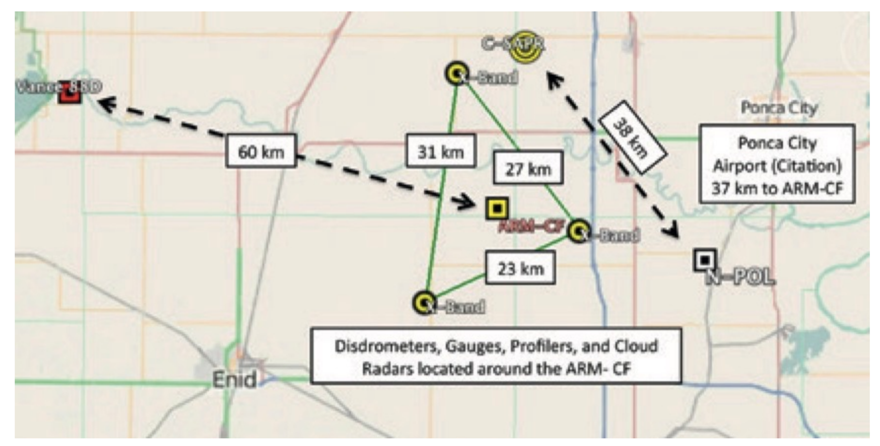

Fig. 1: The Mid-latitude Continental Convective Clouds Experiment (MC3E) central radar network. KSAPR (black and yellow circles, N-POL (black and white square), KVNX (red square), and CSAPR (yellow and black circle) radars. From Jensen et al. (2010).

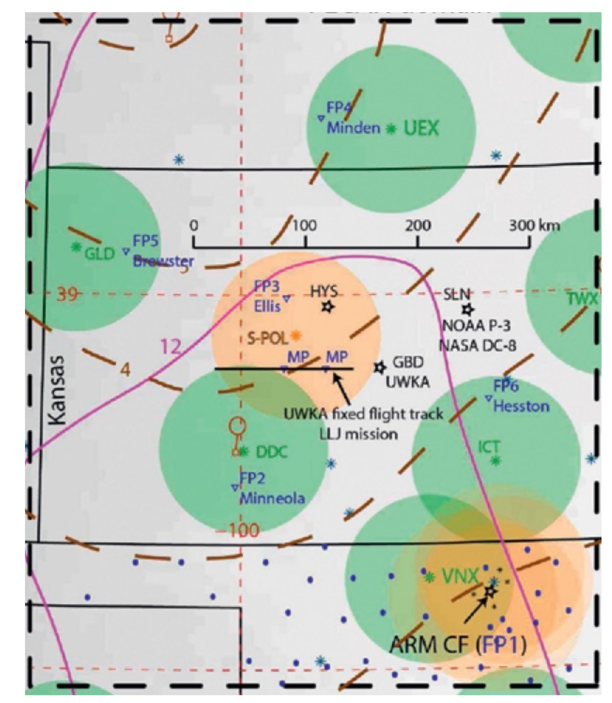

Fig. 2: PECAN (Plains Elevated Convection at Night) campaign domain, including NOAA WSR-88Ds (green), S-POL (orange), and C- and X-band (orange) radars. From Geerts et al. (2017).

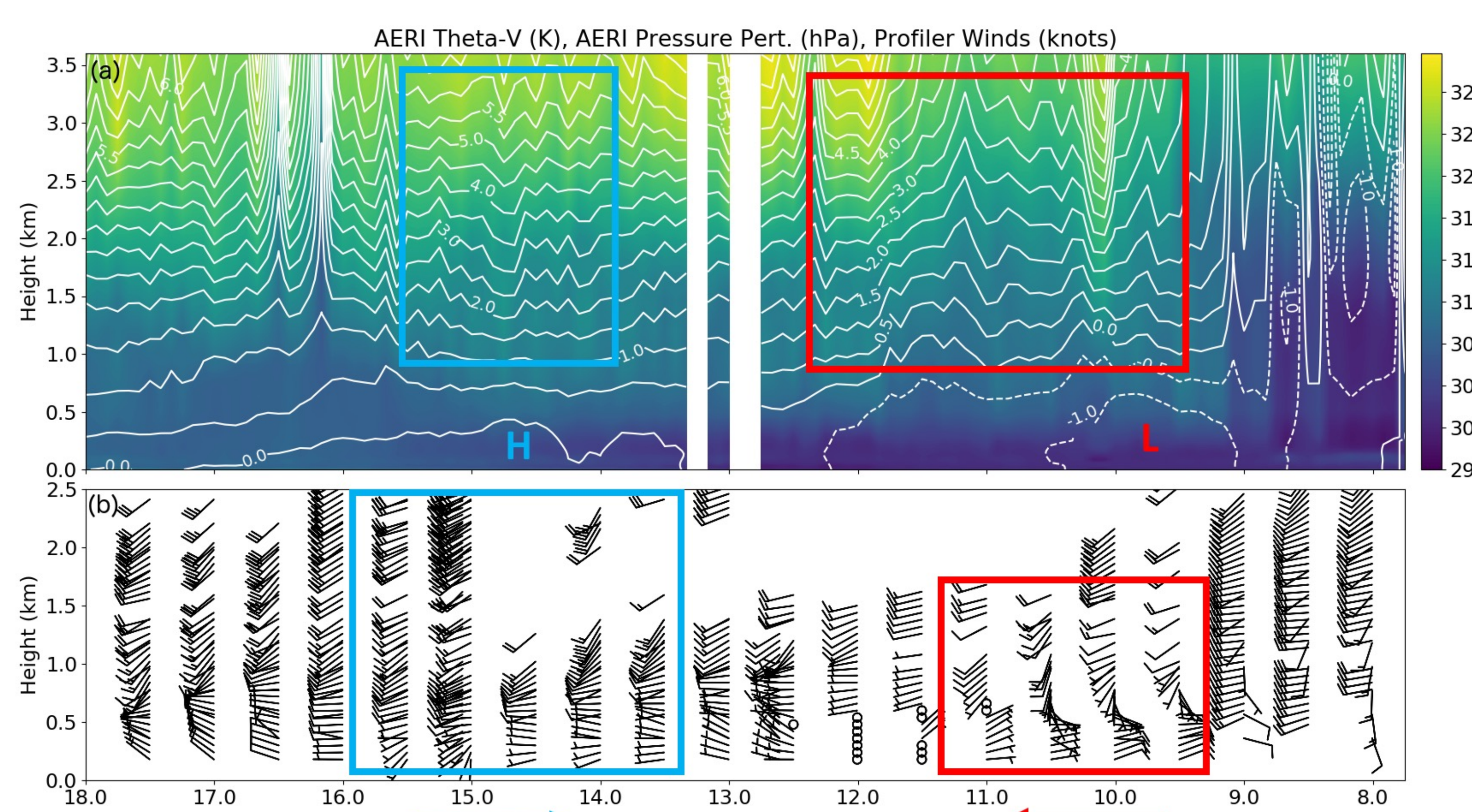

Fig. 3: PECAN IOP 30 on 15 July 2015. (a) FP5 AERI virtual potential temperature (K, color-shaded) and pressure perturbation (white contours every 0.5 hPa, negative values dashed). Time increases to the left. The base-state pressure used to calculate pressure perturbations is defined as average pressure between 0745-0750 UTC, which is after the stratiform region passes but before the analysis begins. (b) Wind barbs from the FP5 NCAR 915 MHz profile.

2) Isolate Gravity Waves, Line-end Vortex, and Large-scale Environmental Flows

- Partition front-to-rear and rear-to-front flows into these three components: $\vec{v}_{total} = \vec{v}_{GW} + \vec{v}_{LEV} + \vec{v}_{env}$ associated with low-frequency gravity waves (GW), line-end vortices (LEV), and the environment (env).
- Which portions of the flow have the largest impact? Do the relative contributions shift over the systems' lifecycles?

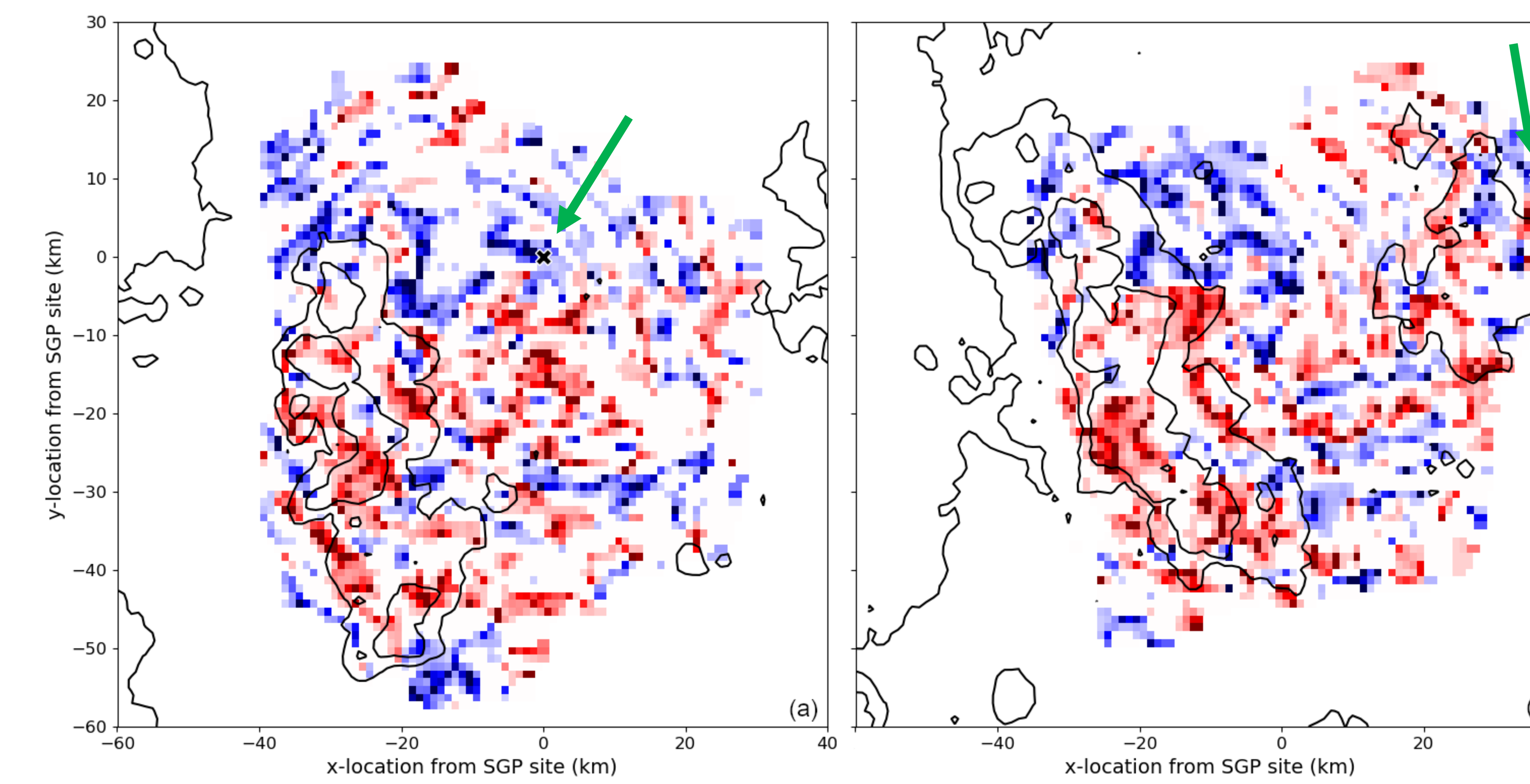

Fig. 4: Value of a n=2 wave mode Fourier decomposition coefficient from (a) 0629 and (b) 0701 UTC 20 May 2011. Blue is negative (corresponding to the typical stratiform n=2 wave mode), and red positive. Coefficients are only shown if the coefficient is determined to be 99% significant per a two-tailed *t* test, and the entire decomposition is determined to be 99% significant per the *F* statistic. The black Xs, highlighted by the green arrow, mark an n=2 wave front's locations; it is at SGP in (a). Black contours are 20, 40, and 50 dBZ composite reflectivity.

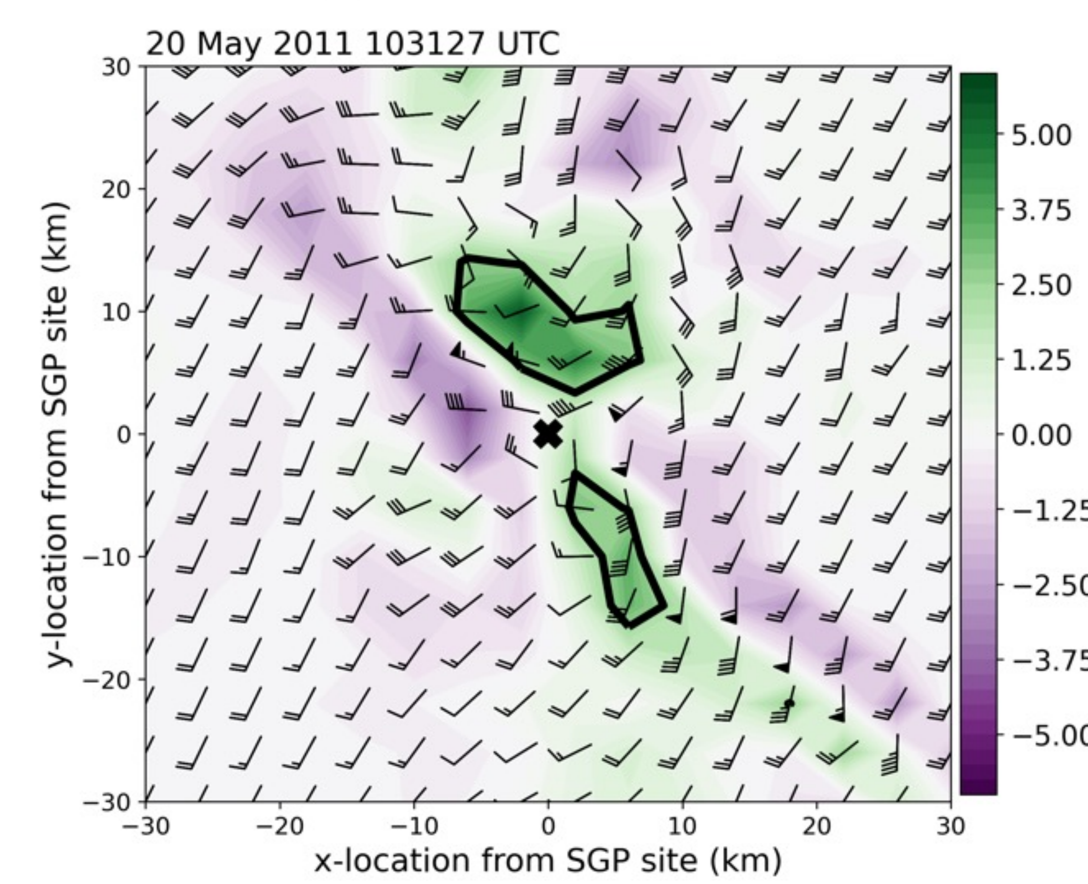

Fig. 5: 2-km relative vorticity (color fill, 10^{-3} s^{-1}; thick black line marks the 2.5×10^{-3} s^{-1} contour) and horizontal wind (half barb: 2.5 m s^{-1}, full barb: 5 m s^{-1}, pennant: 25 m s^{-1}) at 2-km AGL at 10:31:27 UTC 20 May 2011, as derived from the CONVV VAP wind field coarsened to Δx = 2 km. The thick black contours to the north of SGP CF (indicated by the black X) is a line-end cyclonic vortex to which the vorticity-inversion technique will be applied.

3) Identify Potential Errors in Simulated Stratiform Regions due to Incorrect Partitioning

- We theorize that…
  - The horizontal extent of the stratiform region is primarily controlled by low-frequency gravity waves, but its vertical structure is modified by both gravity waves and vorticity-induced flow.
  - Microphysical modifications affect a stratiform region both *directly*, through hydrometeor effects, but also *indirectly*, through changing the gravity waves generated by the system.