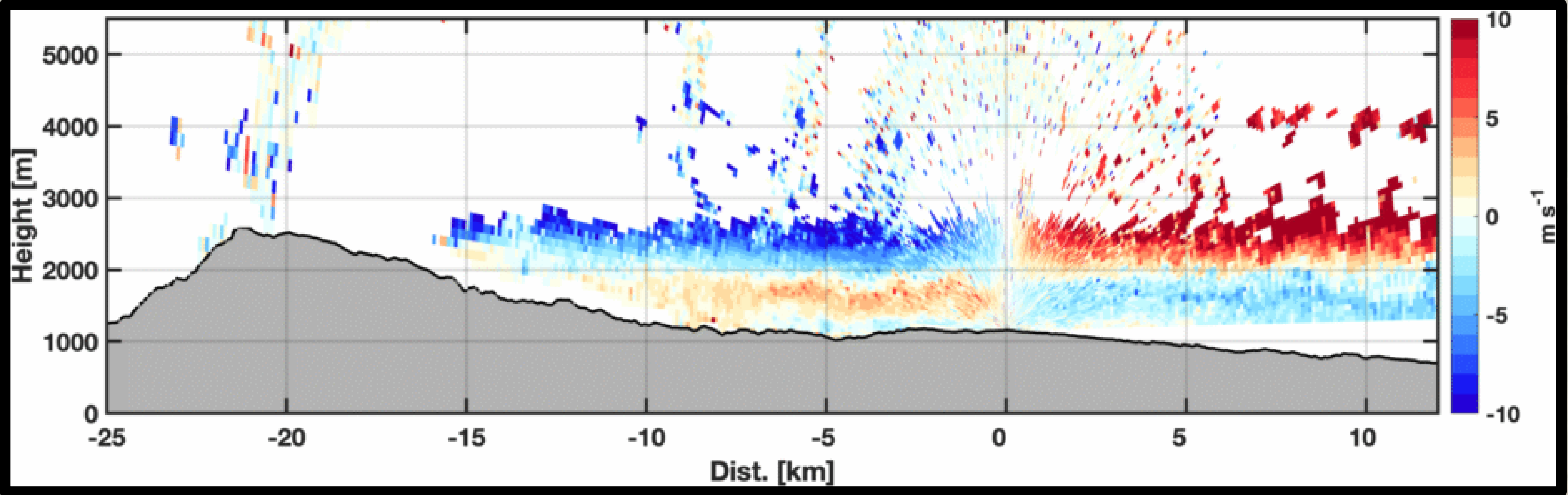
Clear-air radar observations of upslope flow structure and variability during CACTI

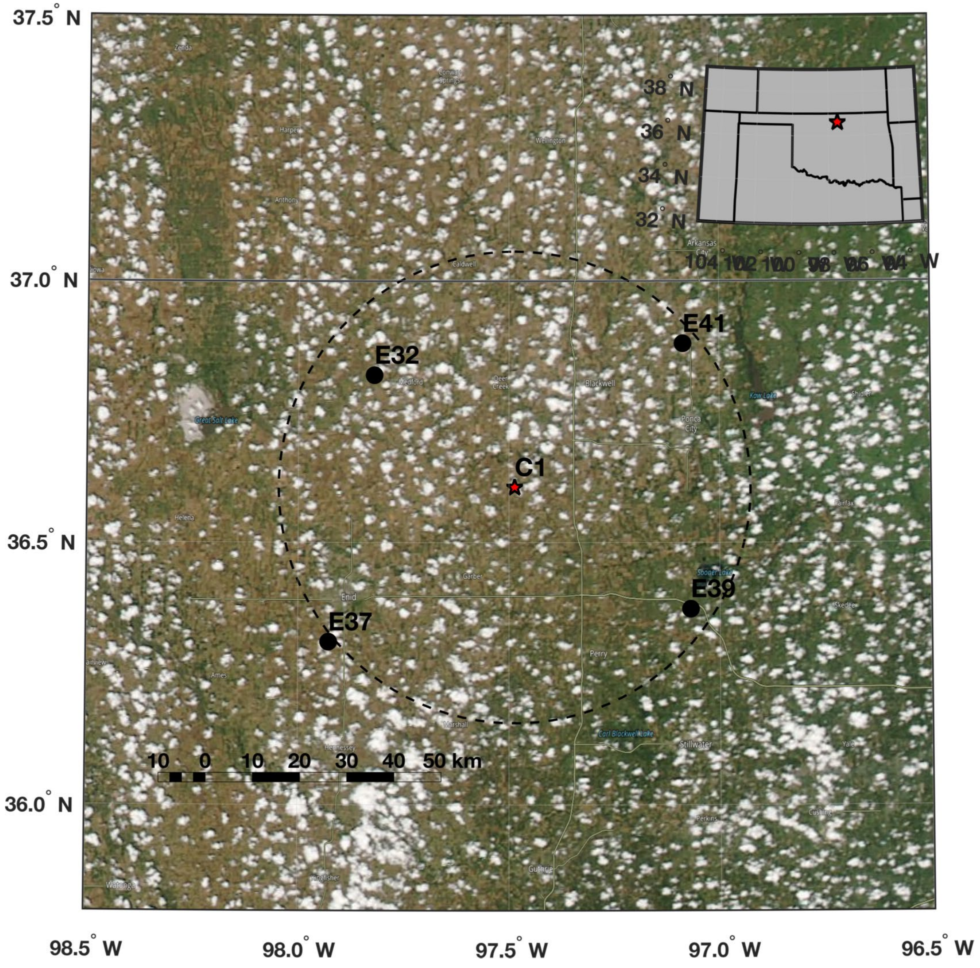


Neil P. Lareau
Department of Physics, University of Nevada, Reno
nlareau@unr.edu

ASR Atmospheric System Research

University of Nevada, Reno

Cumuli Over Flat Terrain



Cumuli Over a Mountain Ridge

Cumulus initiation:

(1) Over flat terrain:
- Coherent Thermals and Plumes
- Convergence zones

(2) Over Complex Terrain
- Coherent Thermals and Plumes
- **Persistent Thermally Driven Circulations**
- **Mechanically forced ascent**

CACTI provides an opportunity to improve our understanding of these orographic processes and how the control/covary wit cumulus convection .

Siebesma et al. 2007

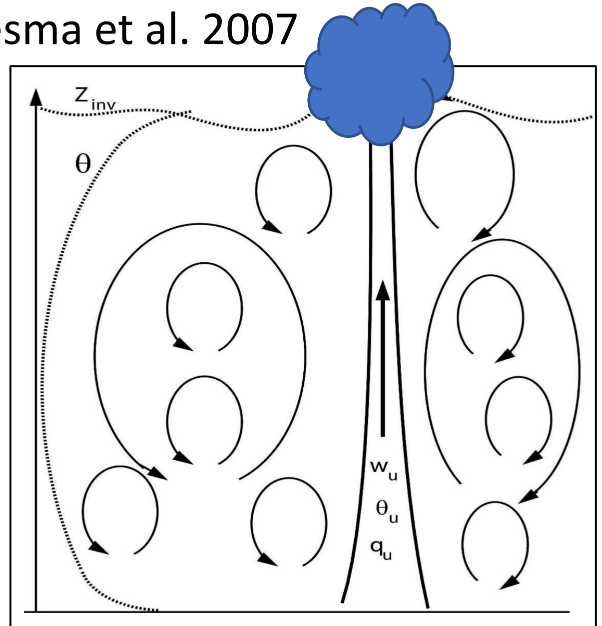


FIG. 1. Sketch of a convective updraft embedded in a turbulent eddy structure.

GEERTS ET AL.

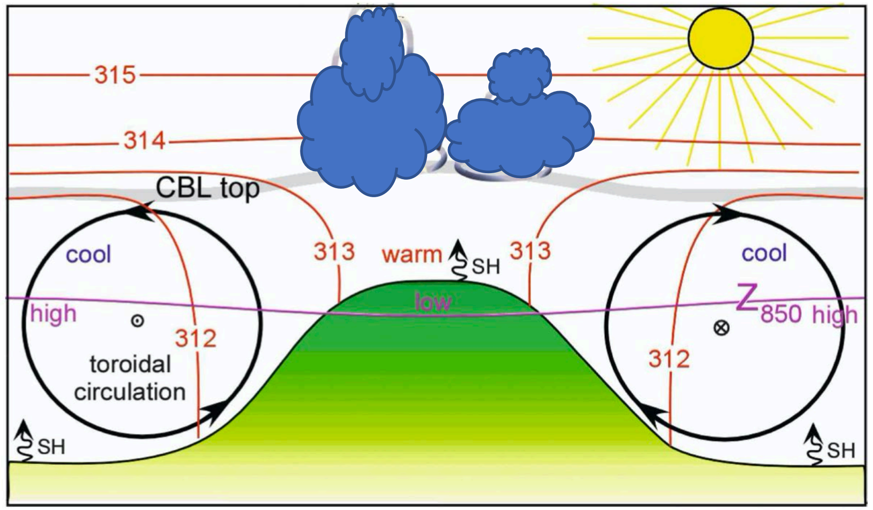


FIG. 1. Schematic depiction of the thermally forced (toroidal) circulation over a heated mountain under quiescent conditions. This depiction includes some isentropes (red lines), one isobar (purple line; Z_{850} is the height of the 850-mb surface), the CBL top (thick gray line), and a positive surface SH flux.

GEERTS ET AL.

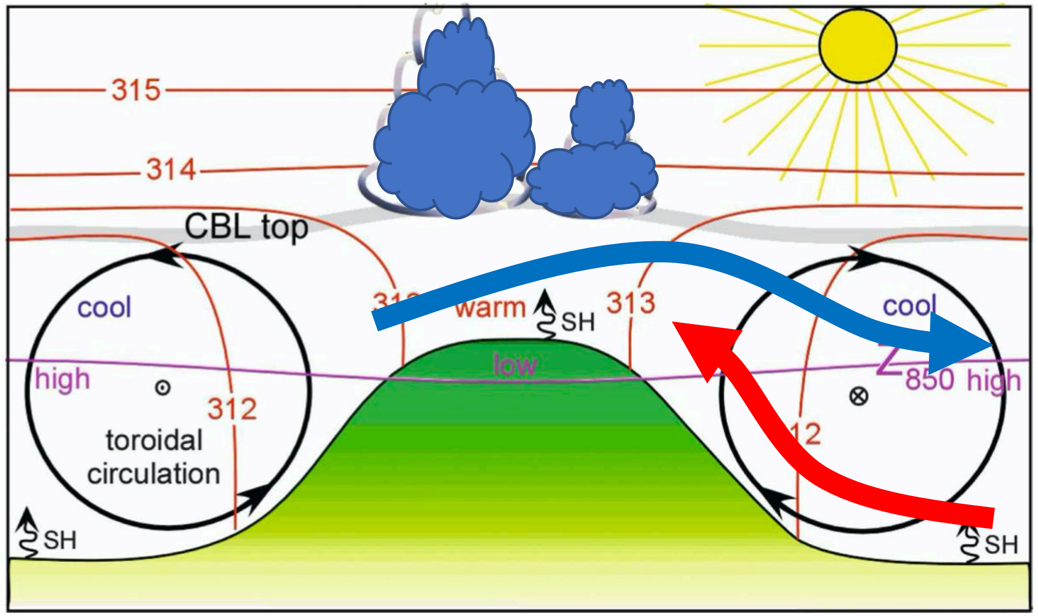
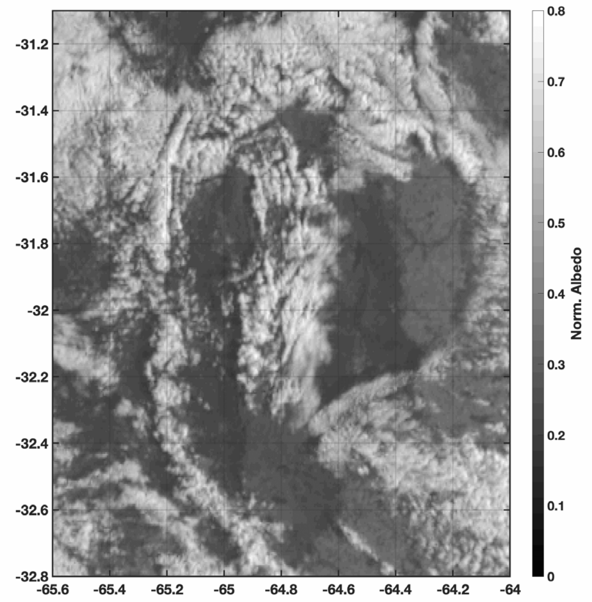
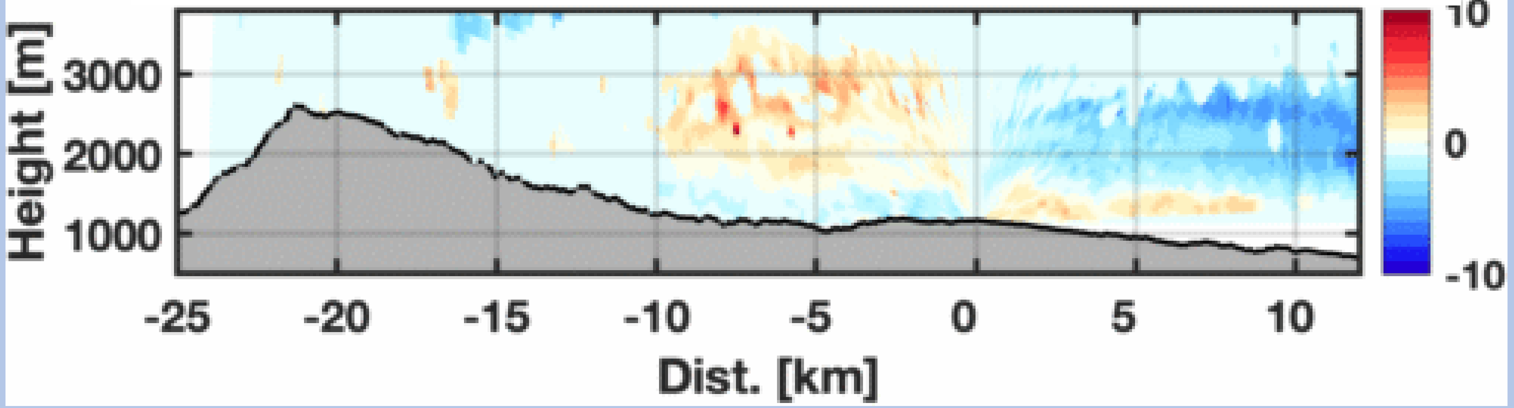


FIG. 1. Schematic depiction of the thermally forced (toroidal) circulation over a heated mountain under quiescent conditions. This depiction includes some isentropes (red lines), one isobar (purple line; Z_{850} is the height of the 850-mb surface), the CBL top (thick gray line), and a positive surface SH flux.

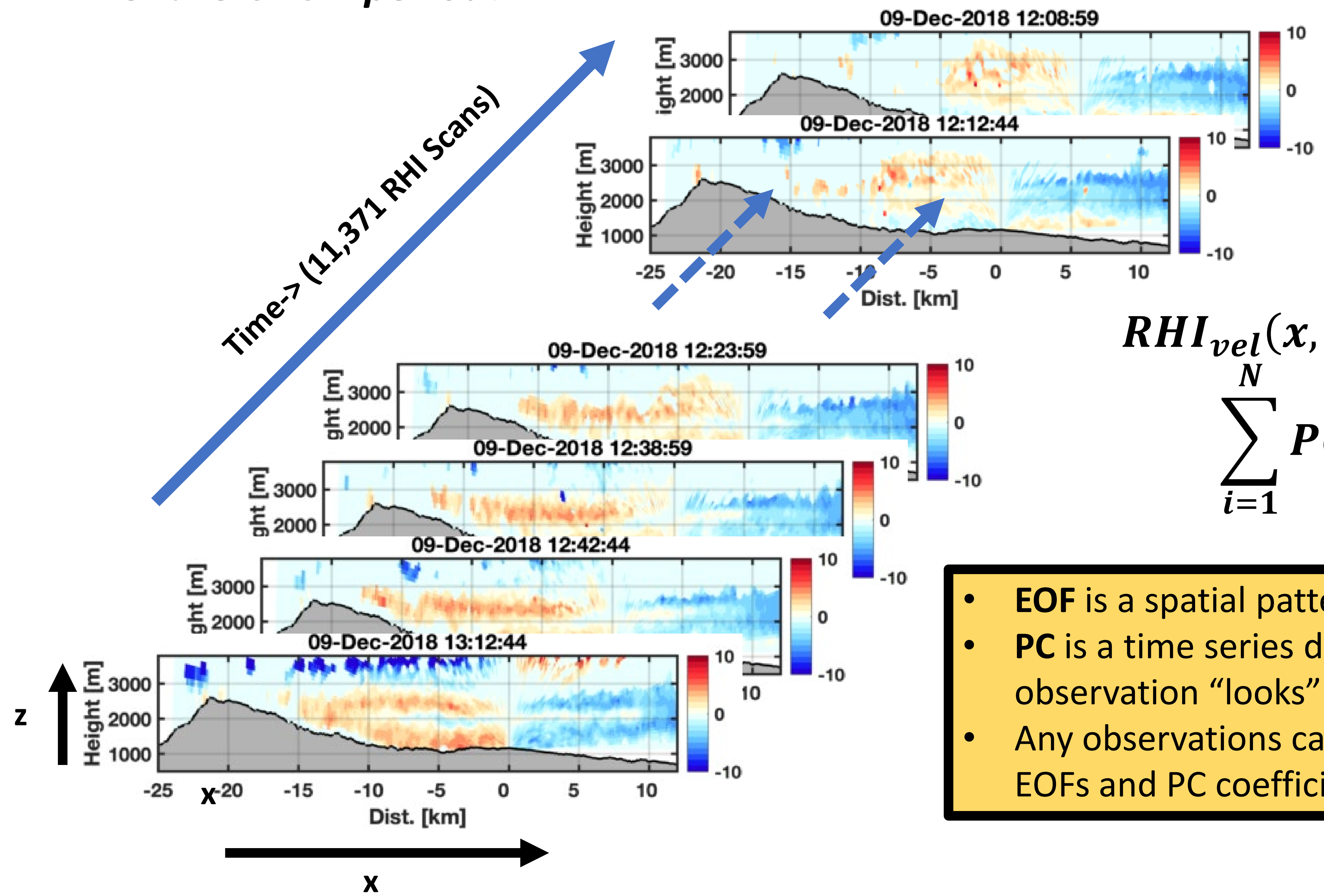
GOES16 Visible



CSAPR clear-air radial velocity observations reveal flow structure



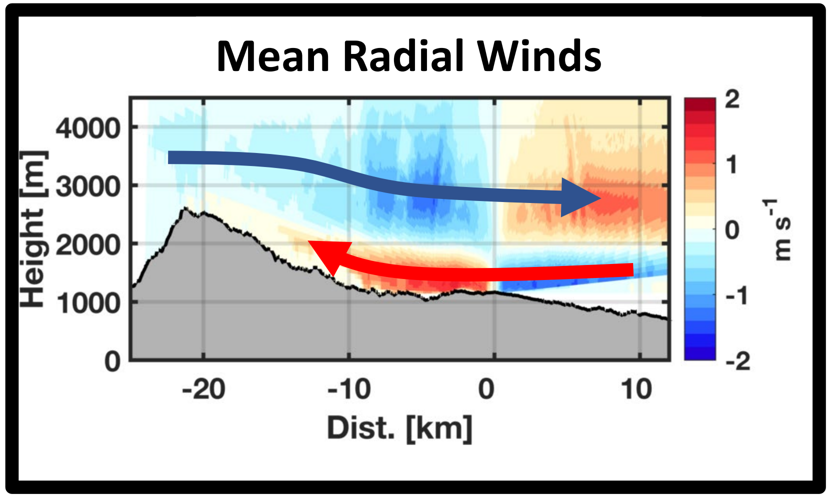
How can we identify modes of variability in the upslope flow structure spanning the entire CACTI period?

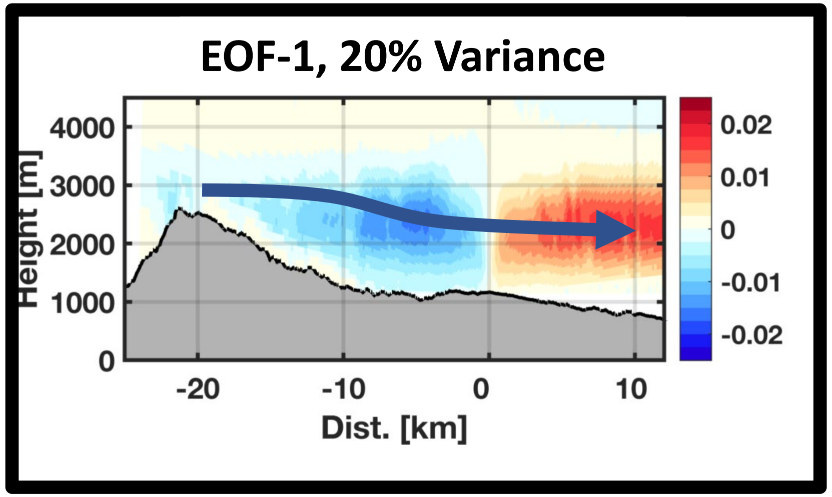


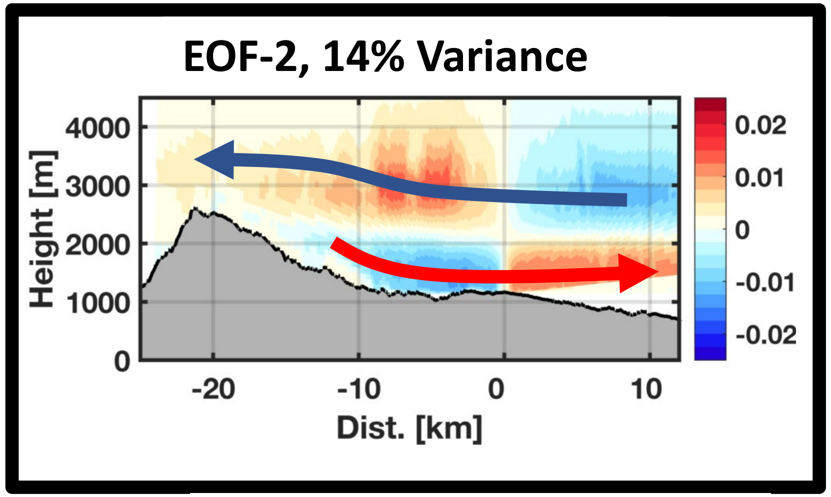
$$RHI_{vel}(x,z,t) = \overline{RHI_{vel}(x,z)} + \sum_{i=1}^{N} PC_i(t) * EOF_i(x,z)$$

- **EOF** is a spatial pattern (x,z) of radial velocity
- **PC** is a time series describing how much a given observation "looks" like the EOF
- Any observations can be reconstructed from the EOFs and PC coefficients

How can we identify modes of variability in the upslope flow structure spanning the entire CACTI period?

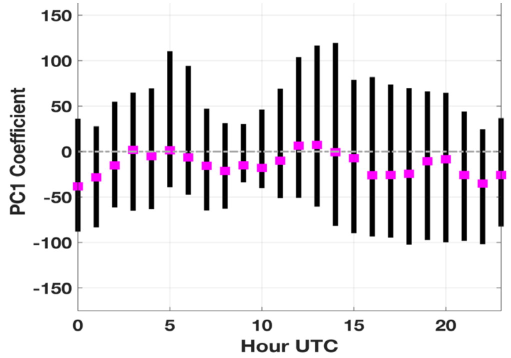




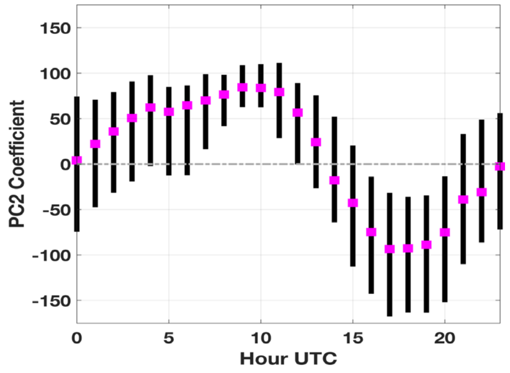


Mean Flow:
- Shallow east-to-west surface layer
- Sloping upslope flow
- Shear and westerly flow aloft

PC-1 Hourly Distribution



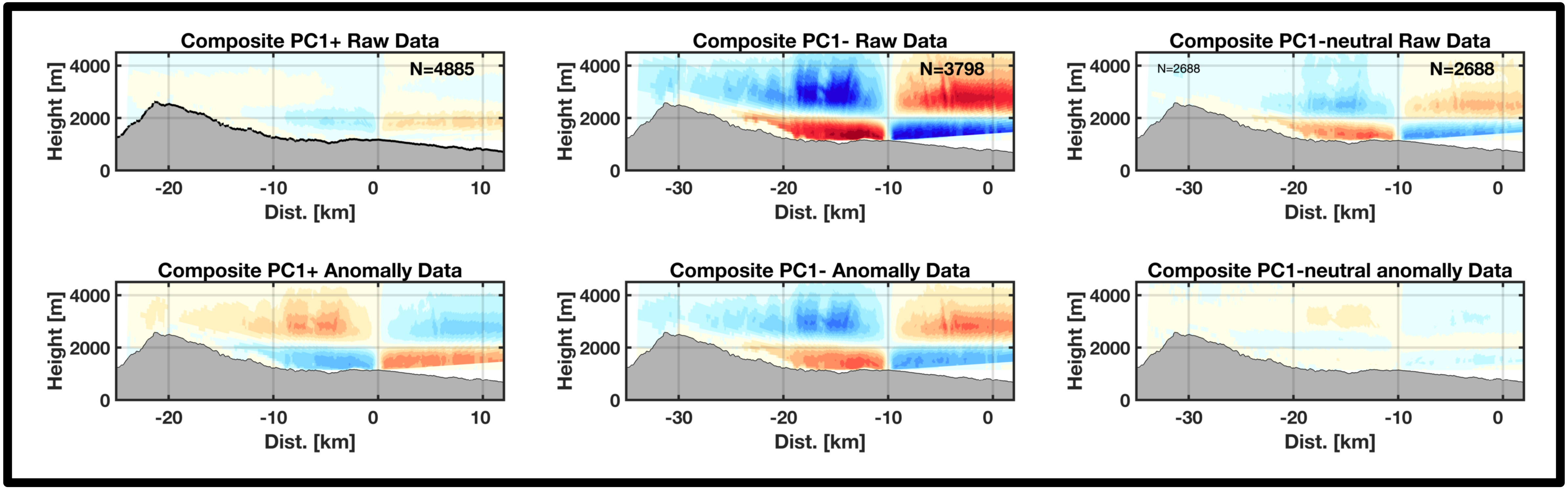
PC-2 Hourly Distribution



EOF-1
- Modulates East-West Flow
- No Diurnal Cycle
- Impact flow depth

EOF-2
- Modulates upslope flow + shear
- Strong Diurnal Cycle

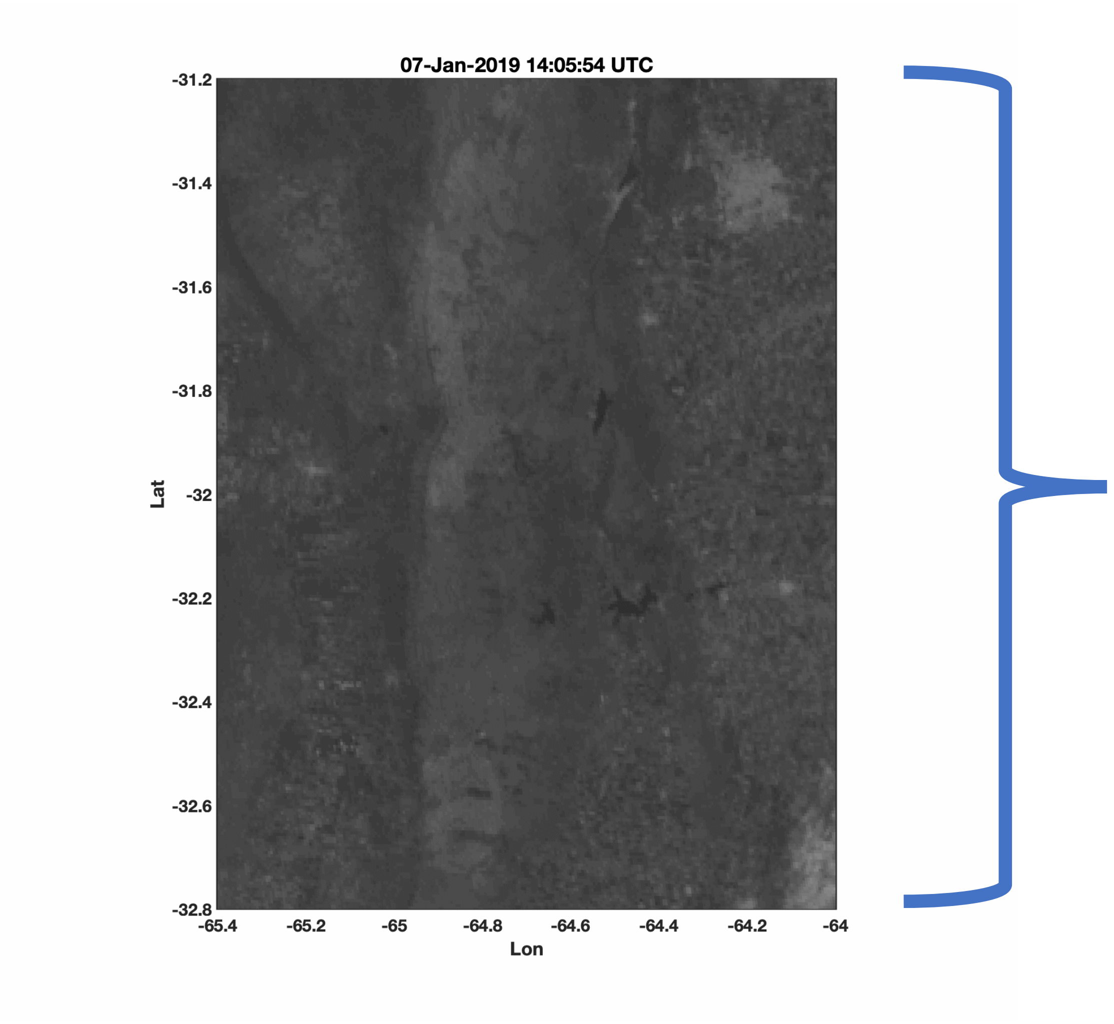
Is EOF-2 a physical pattern? (Yes)

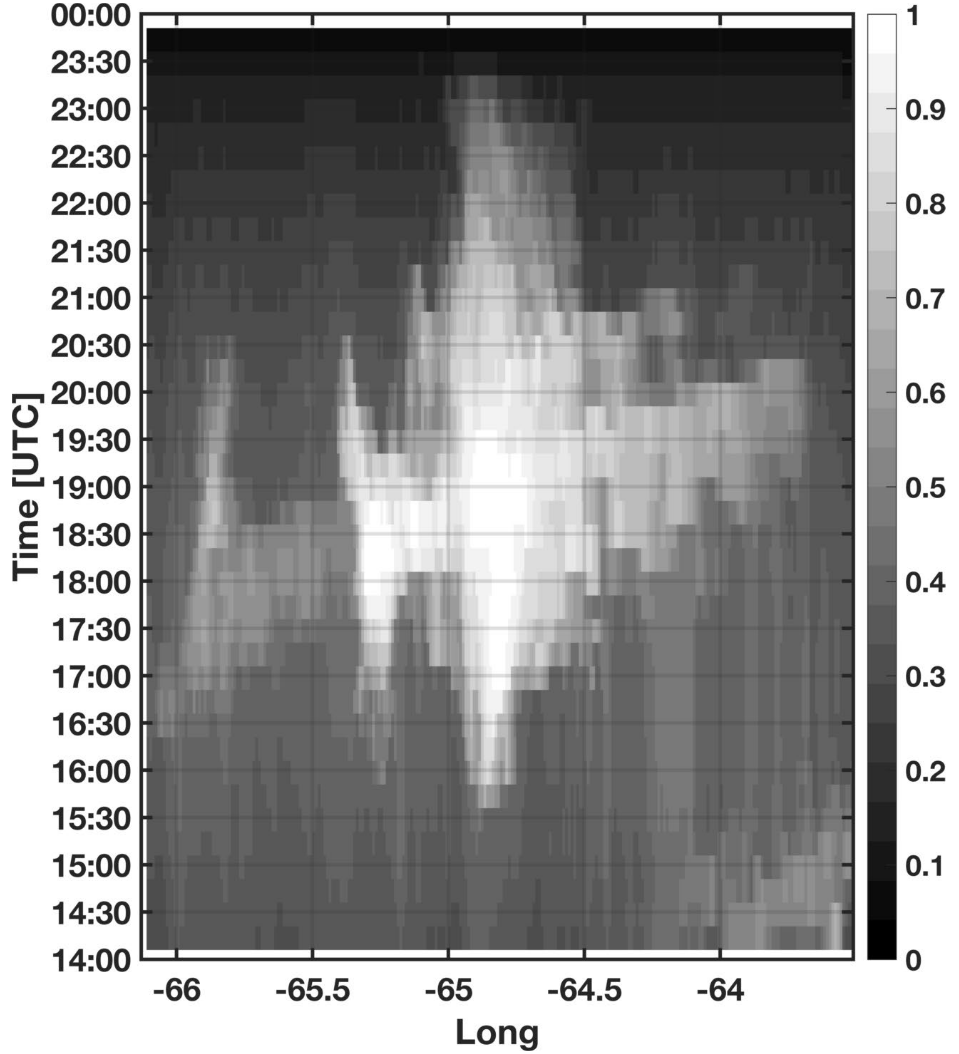


Raw data and anomaly composites for PC2 values that are (a) strongly positive, (b) strongly negative, or (c) near neutral:

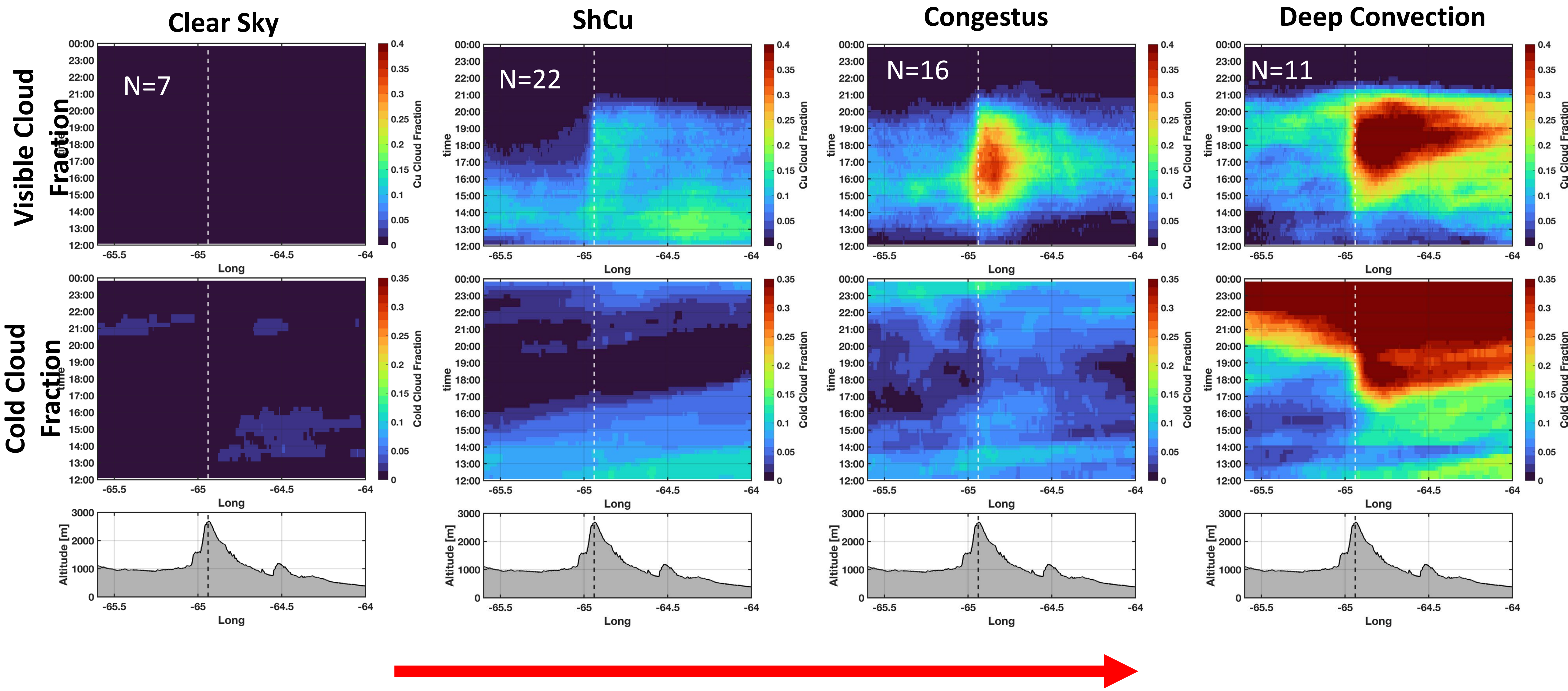
- **Positive mode:** weak overall flow, modest downslope flow.
- **Negative mode:** strong upslope flow layer and a sharp shear layer aloft. Positive superposition of the diurnal slope mode onto the mean state.
- **Neutral Mode:** is similar to the mean state (near zero anomalies).

How can we summarize cloud processes over SDC?

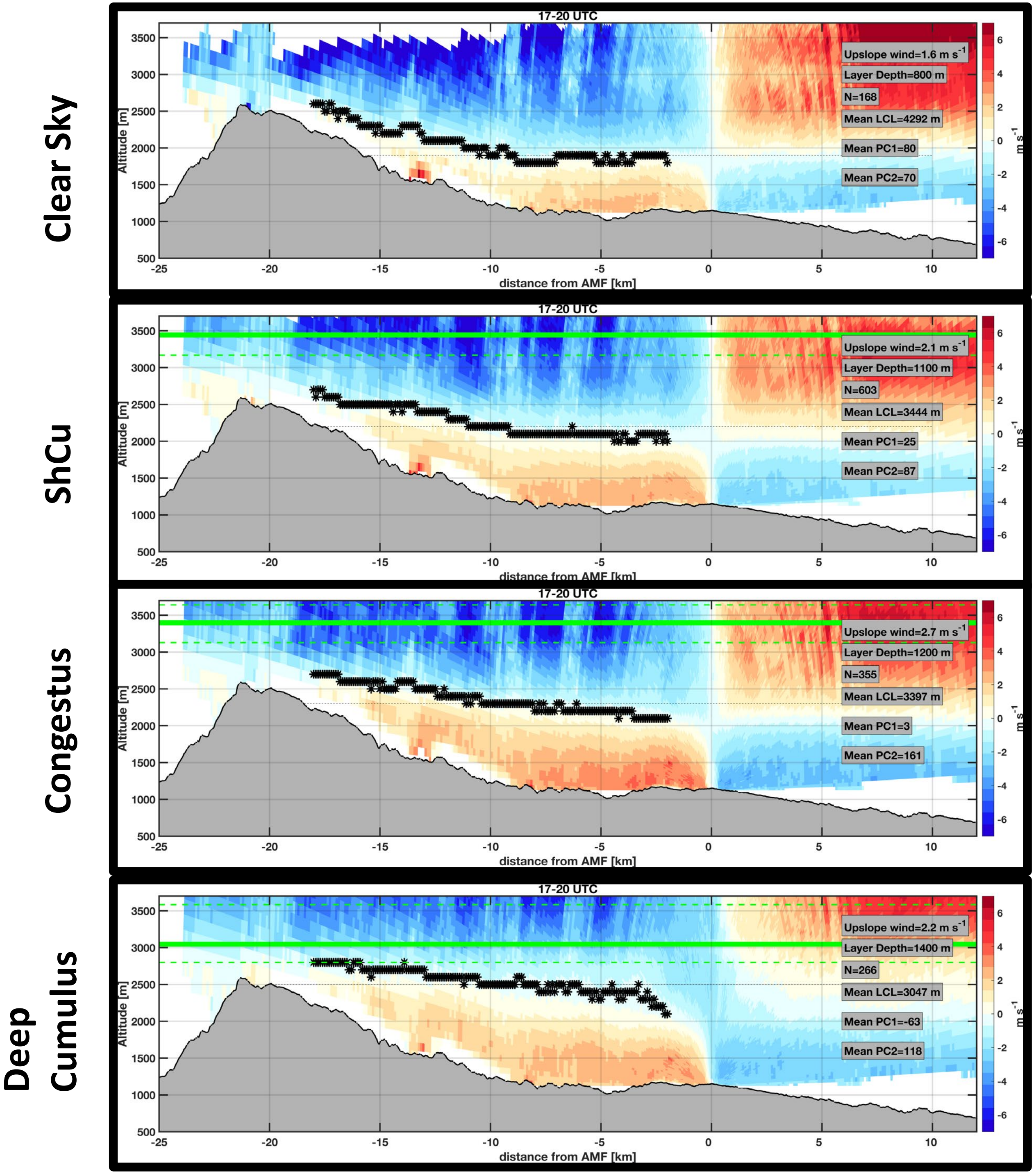




Meridional Cloud Fraction Hovmöller



Increasing Cloud Fraction and Cloud Depth



How does the structure of the upslope flow vary across convective outcomes?

17-20 UTC composites based on cloud categories:

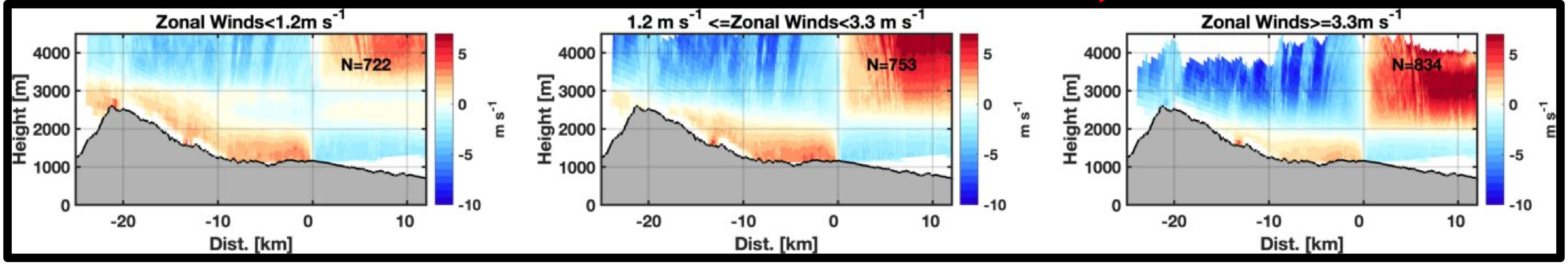
- Upslope flow deepens with increasing cloud development
- LCL lowers with increasing cloud development
    - Mean upslope layer depth is close to the LCL for deep convective days (*ease of initiation*)
- The strength of the flow does not vary much
    - strongest on congestus days

EOF/PC modes and loadings:

- **PC1** decreases from shallow to deep days indicating increasing east-to-west flow in the mid-levels
- **PC2** (*thermal mode*) increases from clear-> congestus mode, then decreases for deep mode.

How does the structure of the upslope flow vary with the strength of the background wind?

Increasing Westerly Flow Aloft

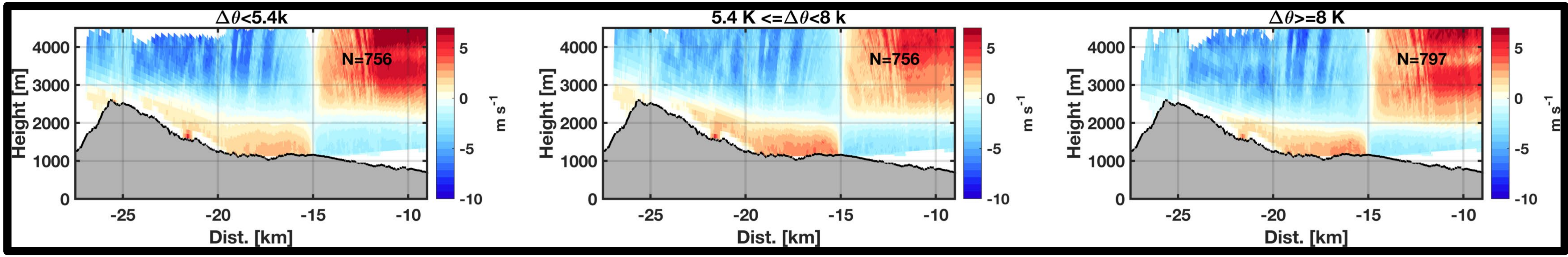


Flow categories based on terciles of winds aloft from the “mergesonde” data set

Increasing westerly winds aloft yield decreasing upslope penetration and decreased upslope layer depth

How does the structure of the upslope flow vary with the strength of the background stability?

Increasing Stability (1000-3000 m)

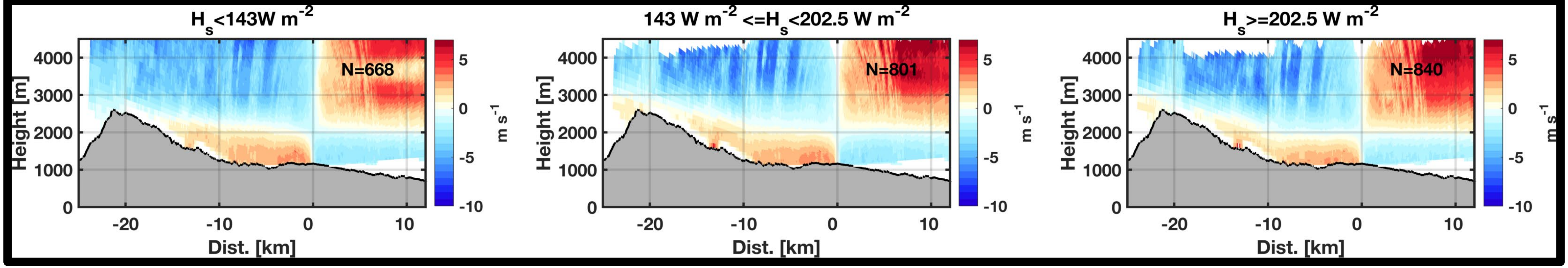


Stability categories based on terciles of bulk potential temp difference (3000-1000 m)from the “mergesonde” data set

Increase stability aloft yields decreasing upslope penetration and decreased upslope layer depth

*How does the structure of the upslope flow vary with the **sensible heat flux**?*

Increasing Flux

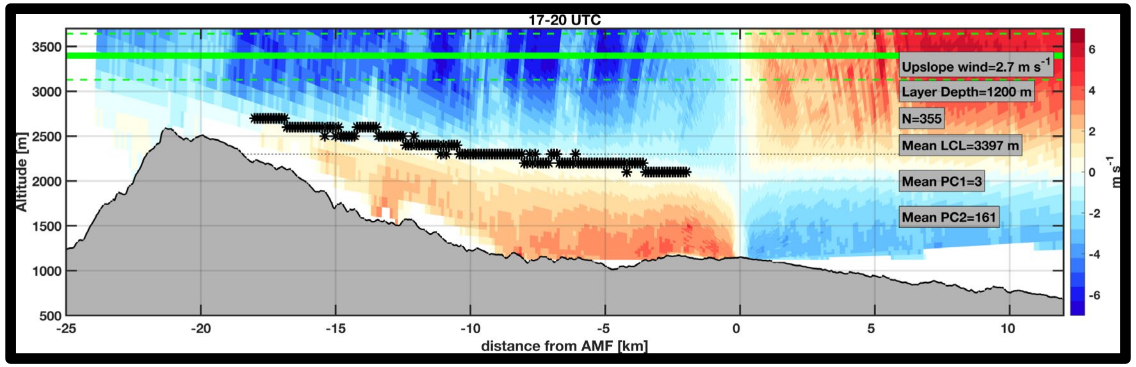


Flux categories based on terciles of ECOR sensible heat flux in the mid-morning period (before deep clouds)

No clear or monotonic response to increase sensible heat fluxes

Summary:

- EOF/PC analysis reveals modes of variability in the upslope flow over the SDC
  - Thermal forcing/diurnal component
  - Non-thermal forcing
- Convective outcomes (*clear->deep*) covary with flow depth and LCL variability
- “Background” wind and stability exert a strong influence on upslope flow depth.

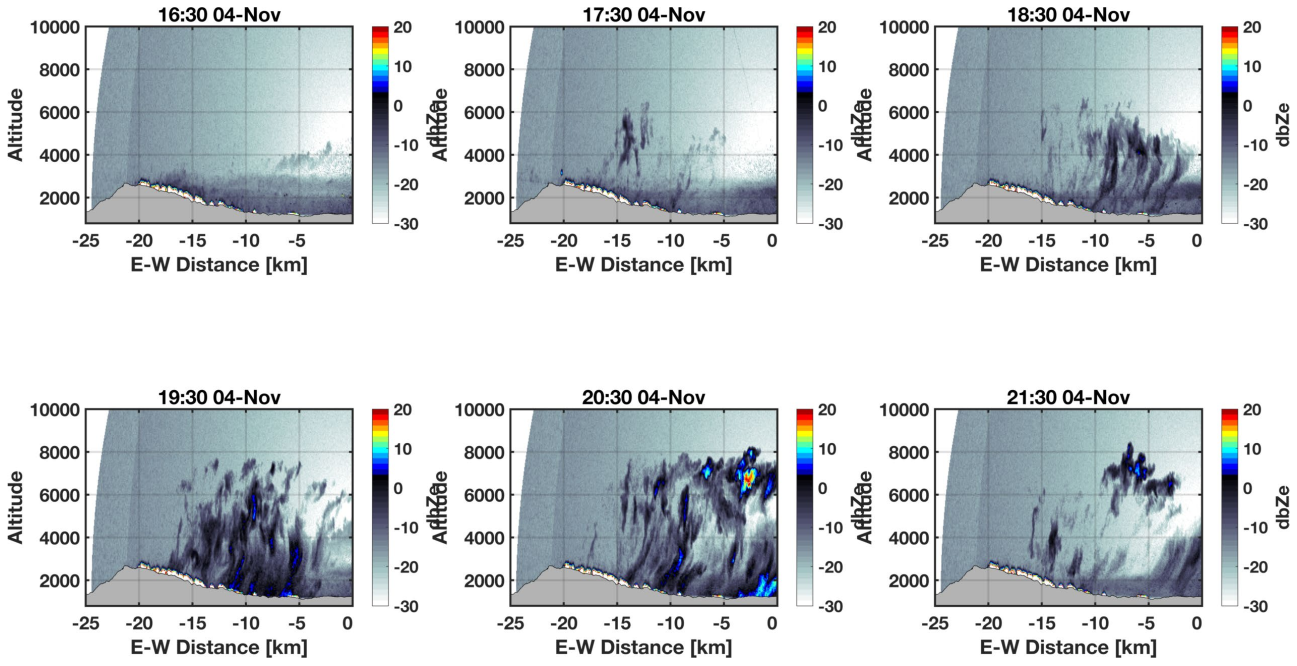


Atmospheric System Research

Questions:
nlareau@unr.edu

What's next?

Cloud development as observed by KASACR RHI scans



Develop "ARSCL"-like cloud masks for RHI data

Linking forcing to PC/EOFs:

-Flux

-Background Flow

-Stability/depth