The Structure, Evolution, and Dynamics of a Nocturnal Convective System Simulated Using the WRF-ARW Model

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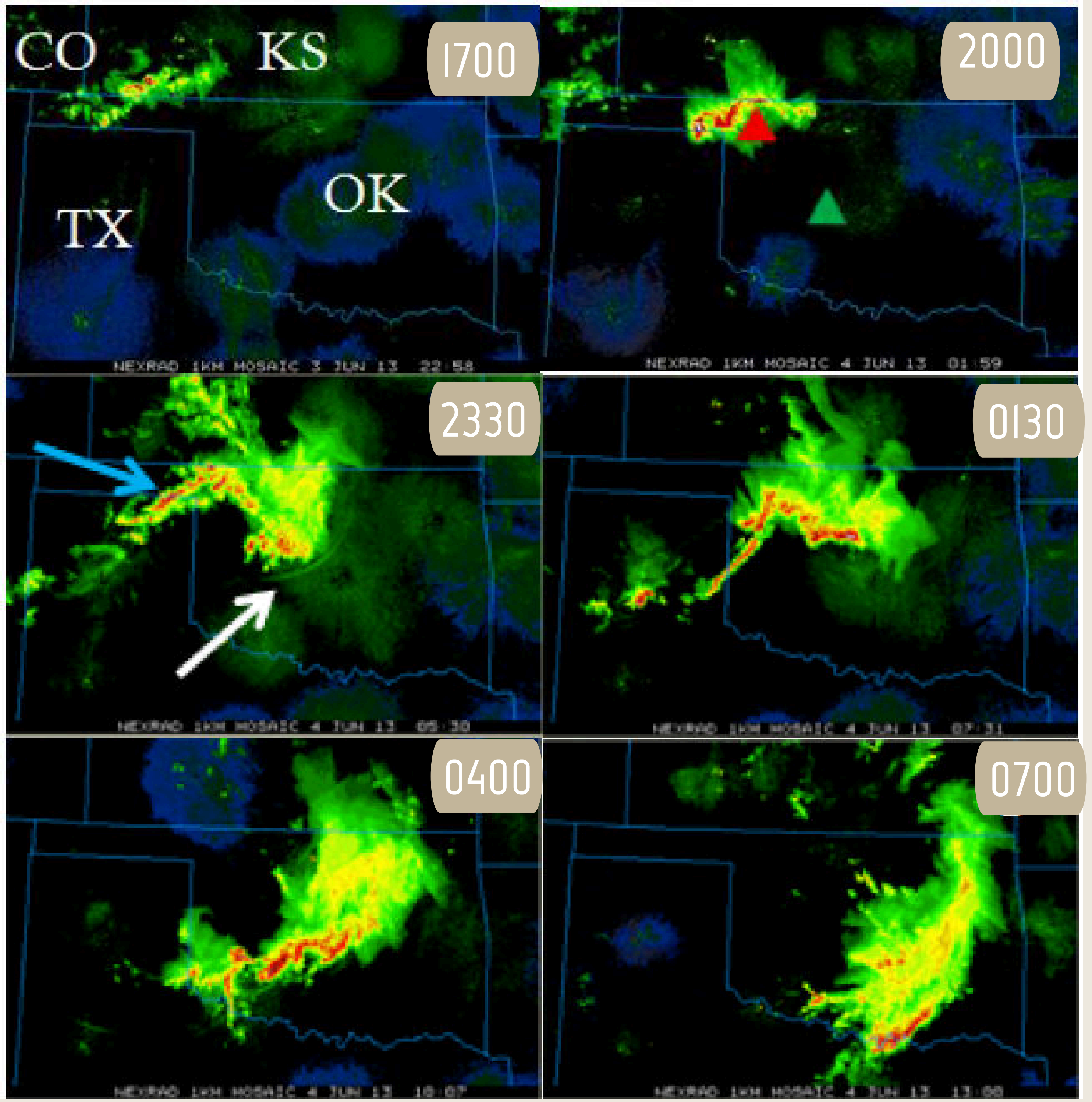
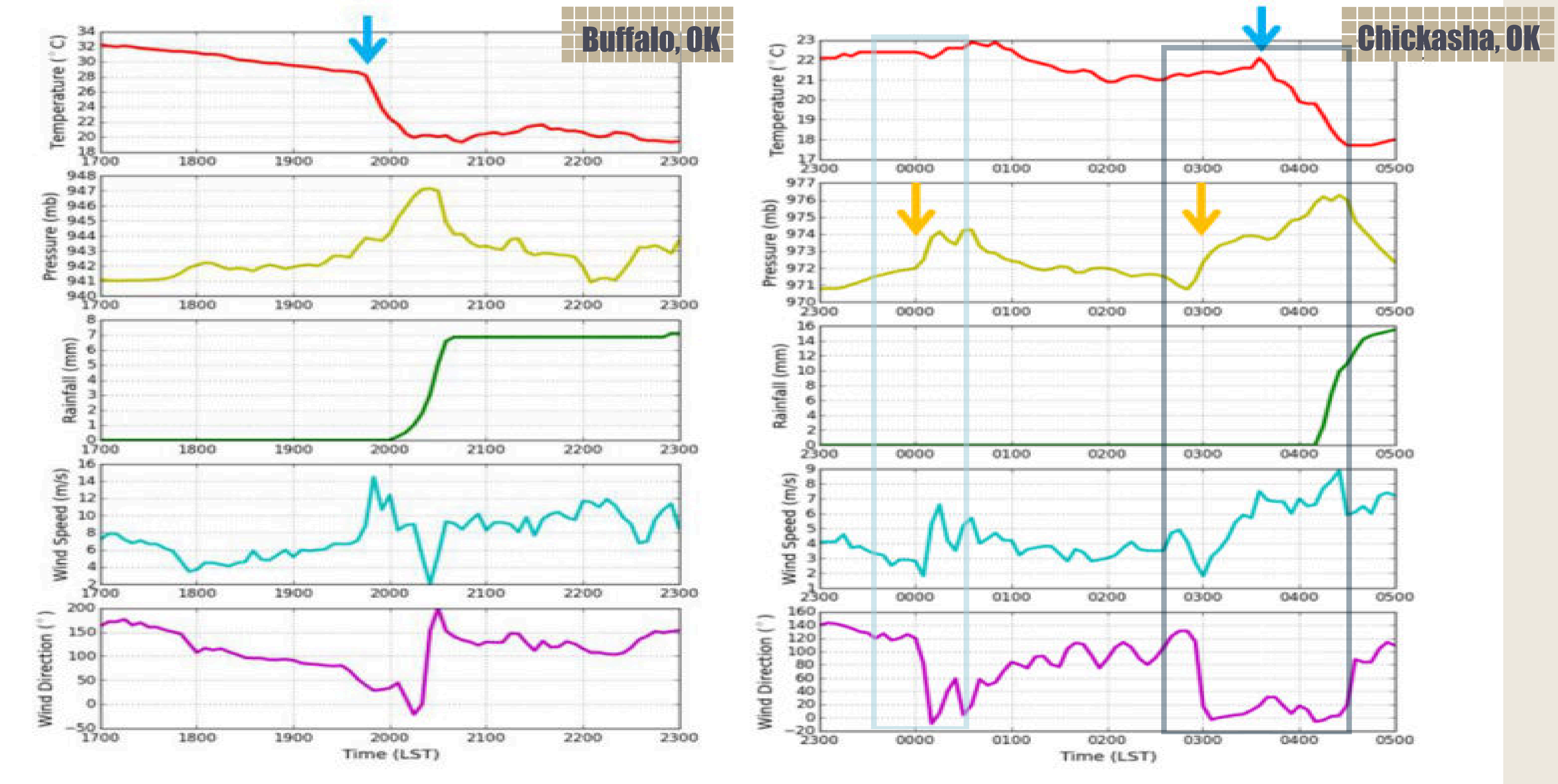
Summary

- WRF-ARW model is utilized to simulate a nocturnal MCS that occurred over southern Great Plains on 3-4 June 2013
- Simulation result enables authors to gain insights on processes that (1) Maintain MCS (2) Controls 3d variation in the convective system's structure along cold pool
- LLJ provided narrow corridor of unstable air above nocturnal boundary layer (NBL)
- Buoyancy bores in prefrontal region assisted in transporting unstable air near LFC (their properties are examined with wave theory)
- MCS structural variations is determined by differing integrated vertical shear
- Storm was associated with a short-wave trough that moved through N OK and a well-defined LLJ over TX/OK
- MCS was located well to the south of a quasi-stationary frontal boundary, therefore frontal ascent does not play a role in the maintenance of this system
- Nocturnal convections developed behind the leading system and quickly grew upscale into an elevated MCS

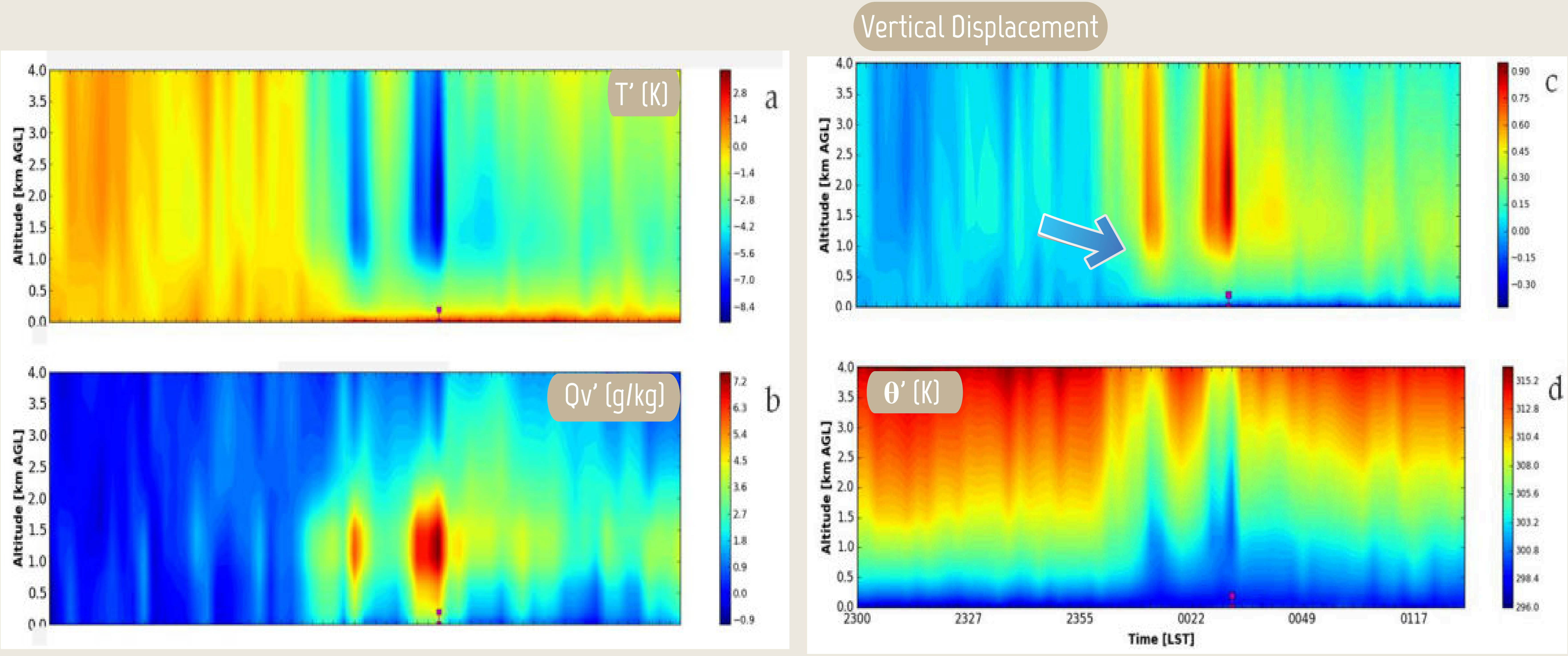
Composited reflectivity (LST)



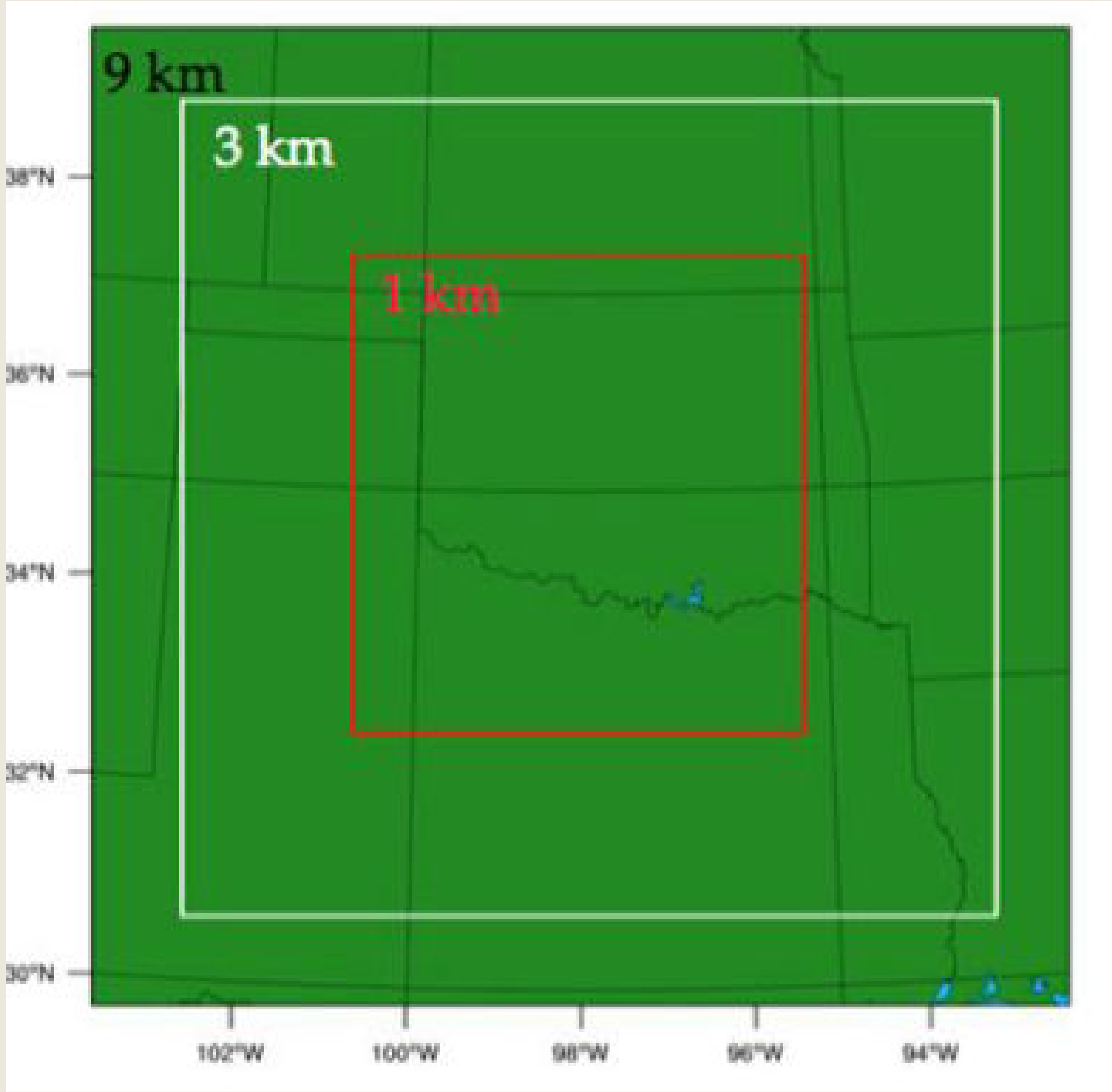
Surface observation



Microwave retrievals



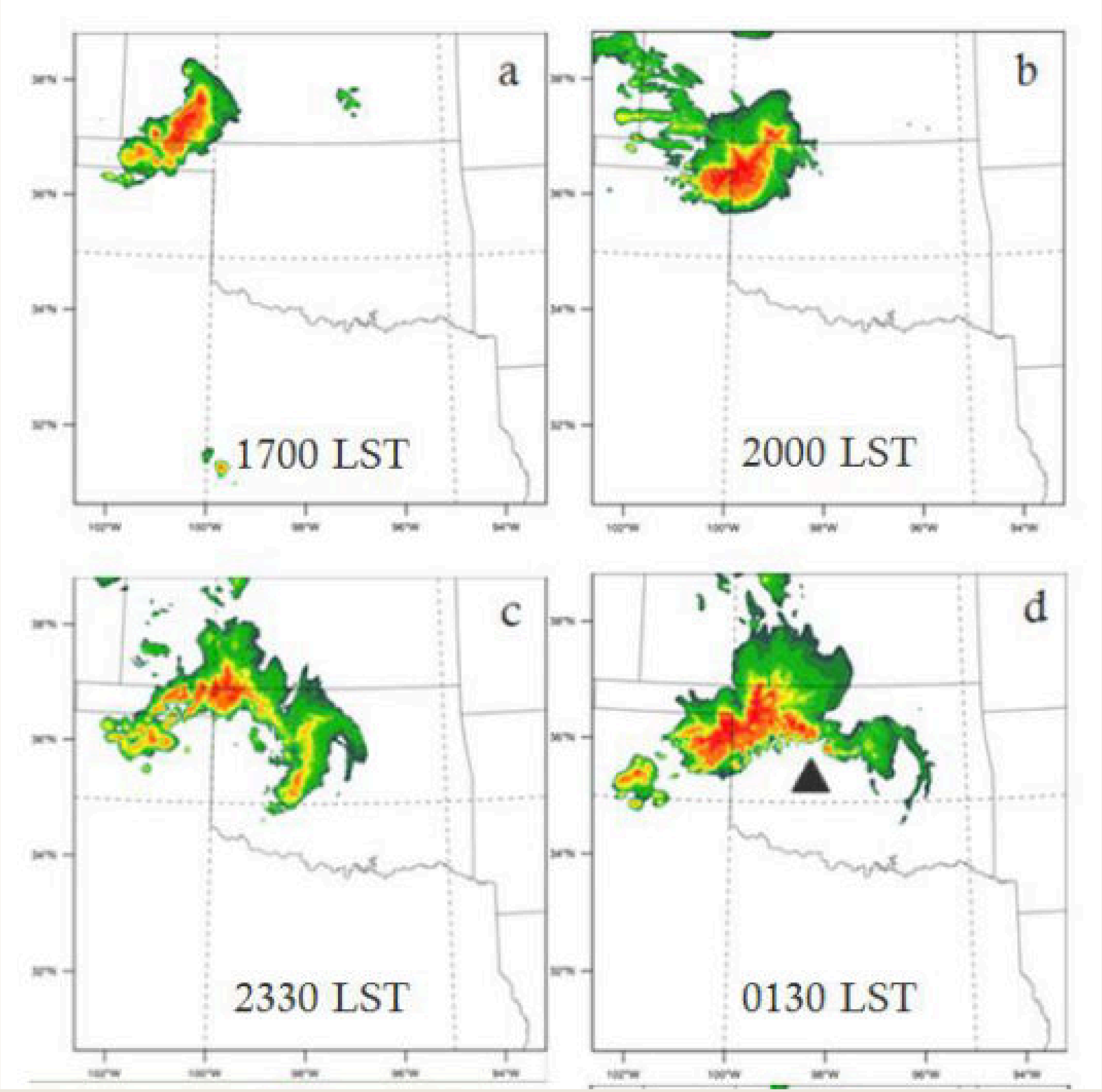
Simulation Design

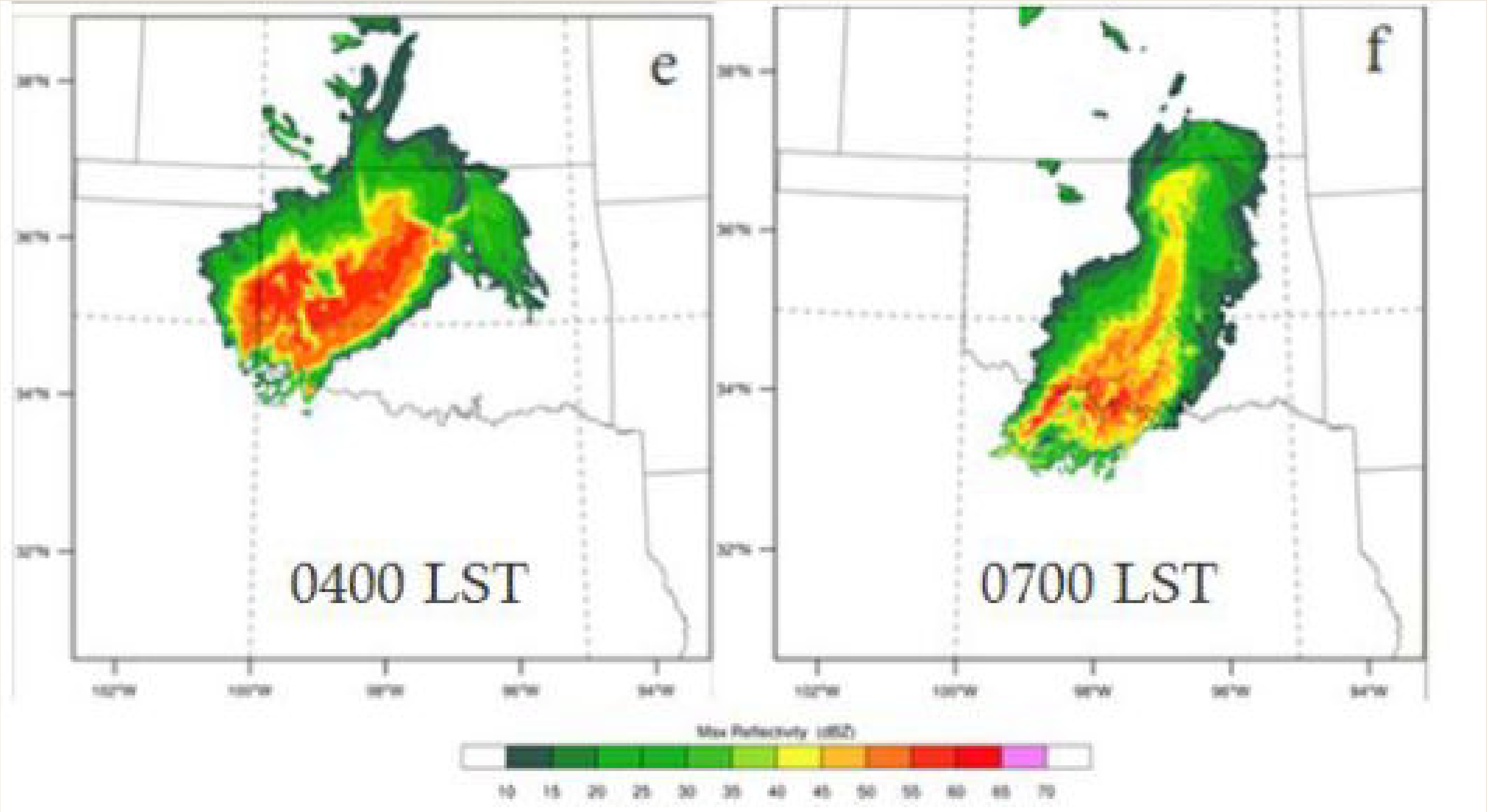


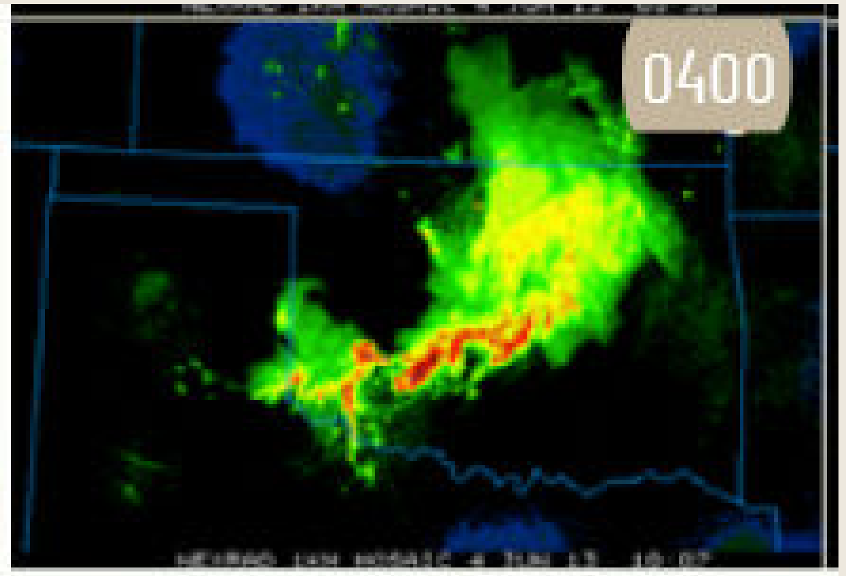
- WRF v3.6.1
- 100 vertical levels for all domains (with stretched spacing)
- Lateral BC: 1hr RAP output+Noah land surface model soil information

Atmospheric Process	Parameterization Scheme	Reference and Notes
Longwave radiation	RRTM	Mlawer et al. 1997
Shortwave radiation	New Goddard	Chou and Suarez 1999
Cloud microphysics	Morrison	Morrison et al. 2009 Double moment scheme
Land surface	Noah	Ek et al. 2003
Convection	BMJ	Janjić 1994 9-km domain only
PBL	MYNN Level 2.5	Nakanishi and Niino 2004
Surface layer	MYNN	Nakanishi and Niino 2004

Simulation Design

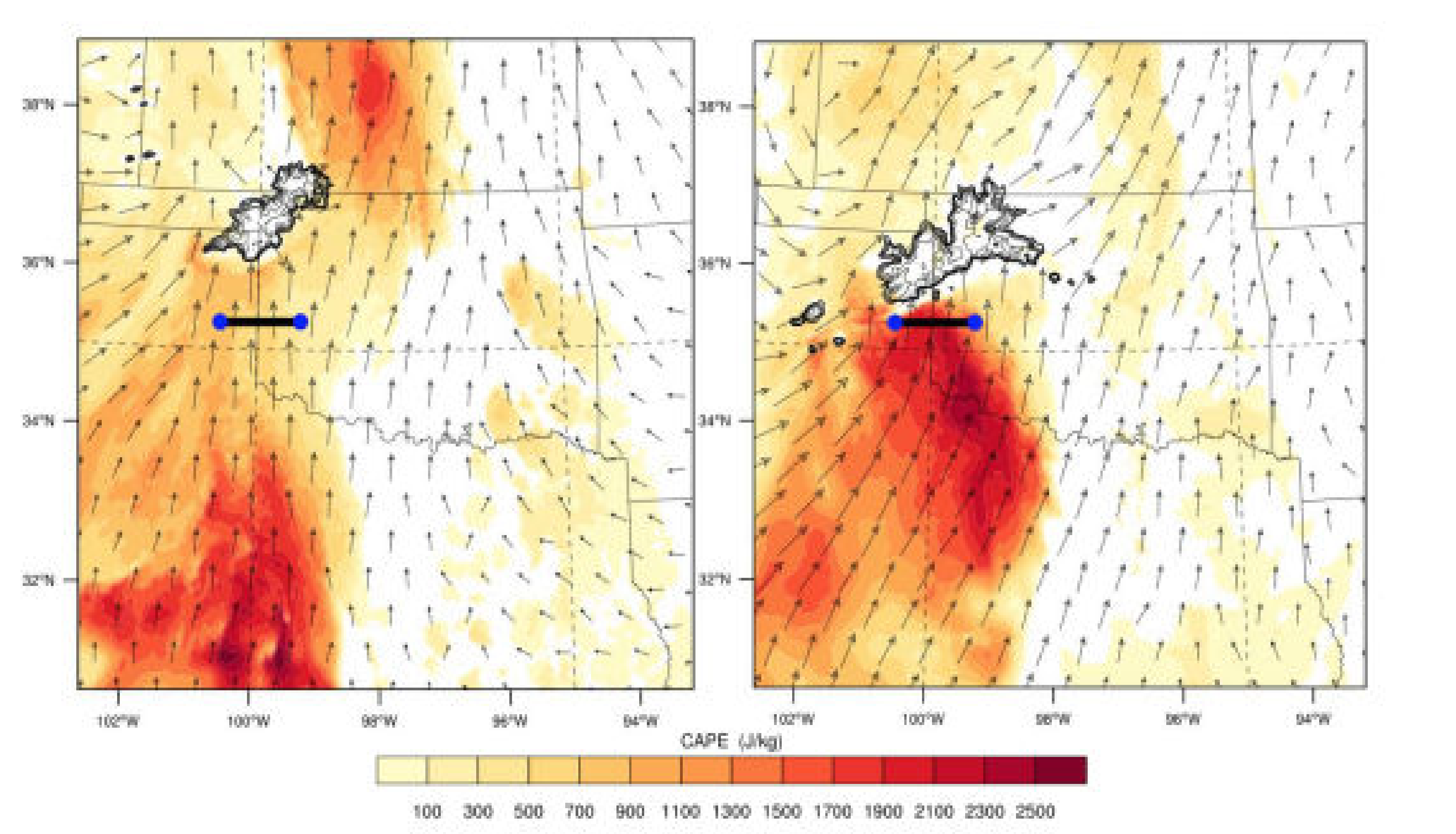




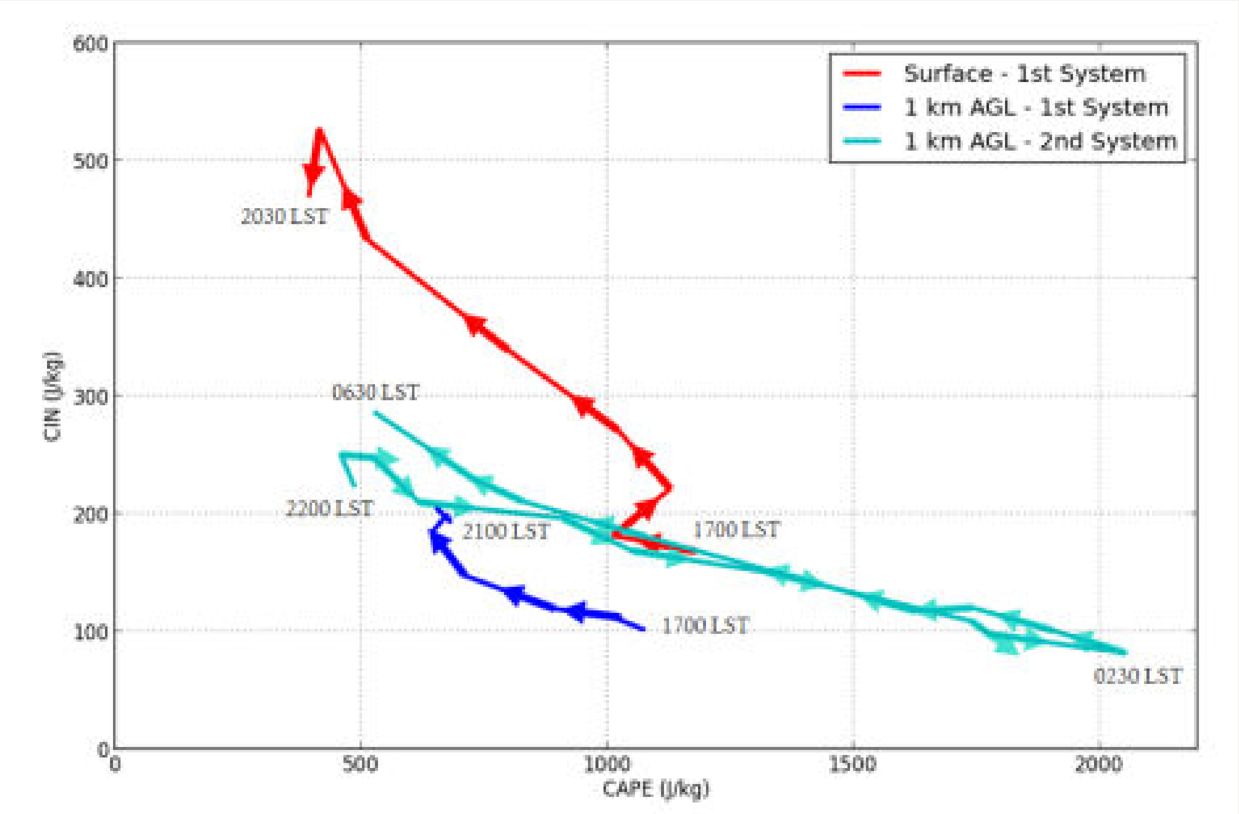


Instability evolution

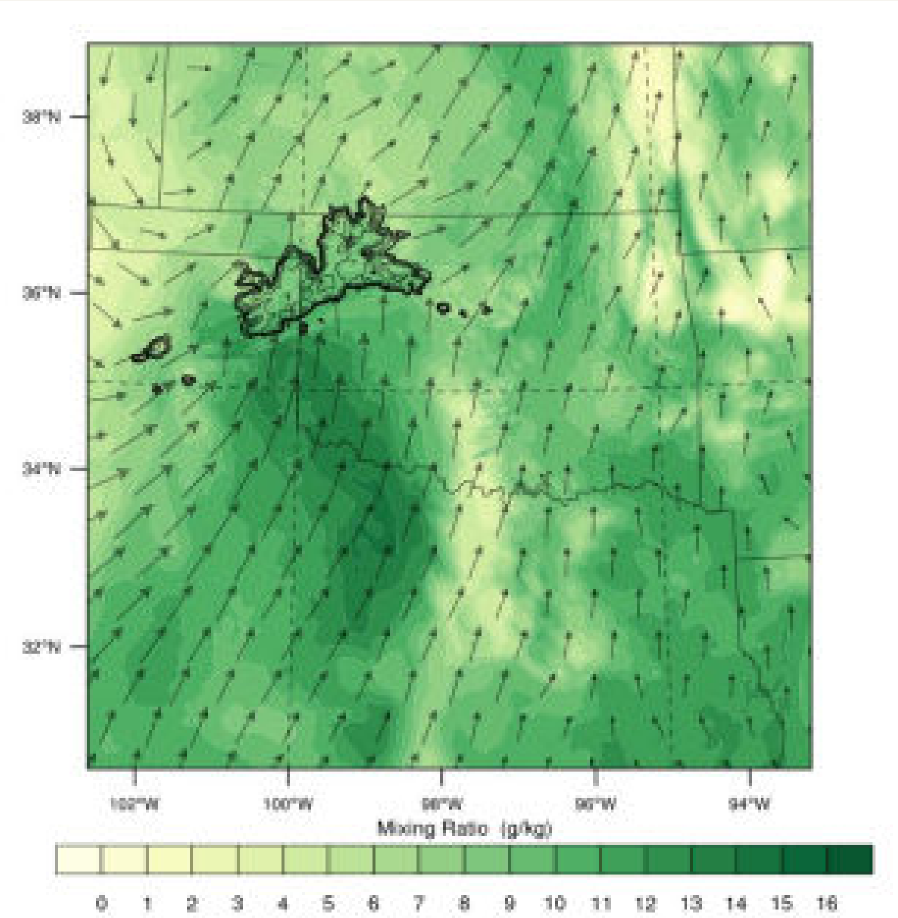
1930 0100



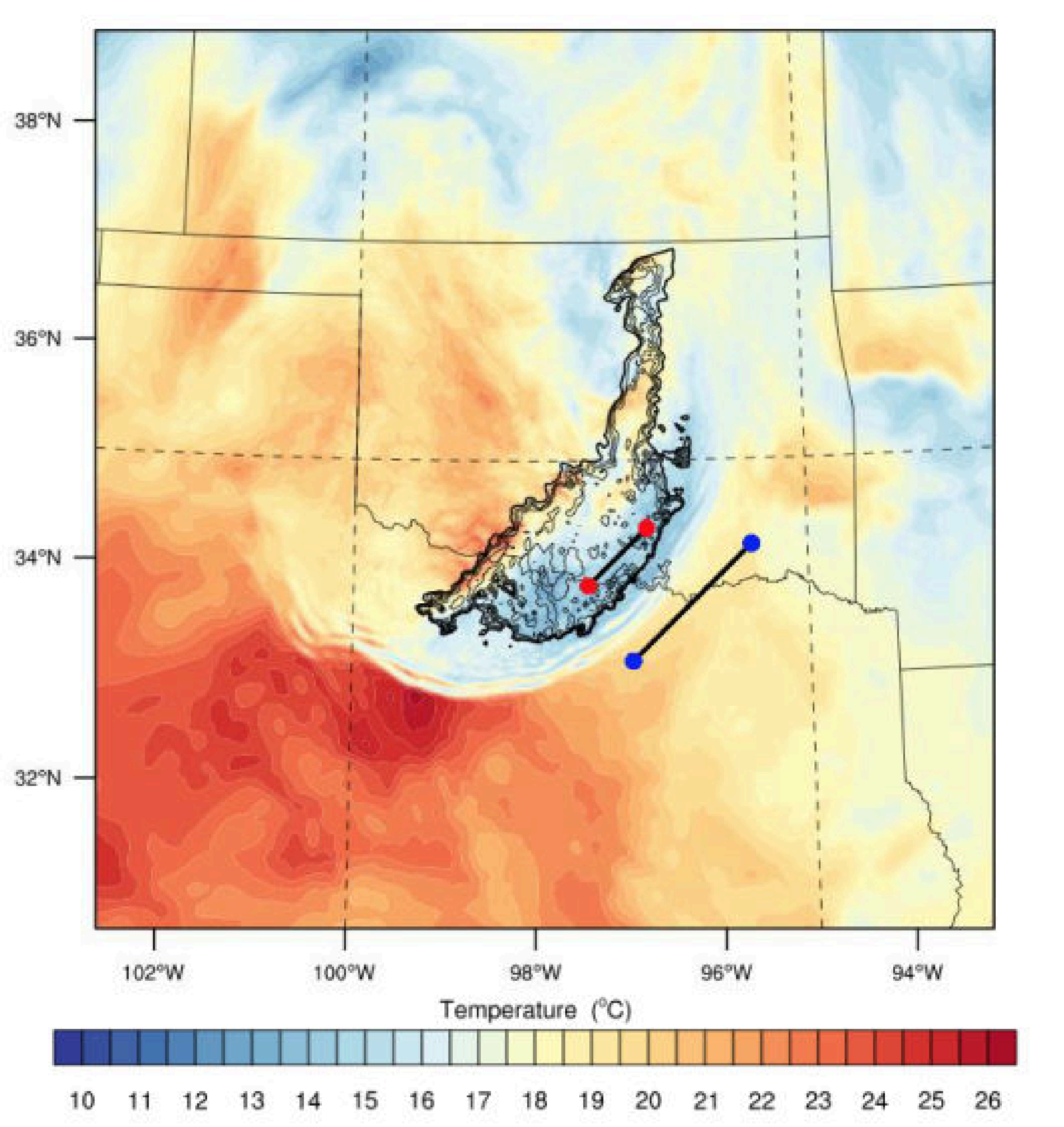
1km CAPE



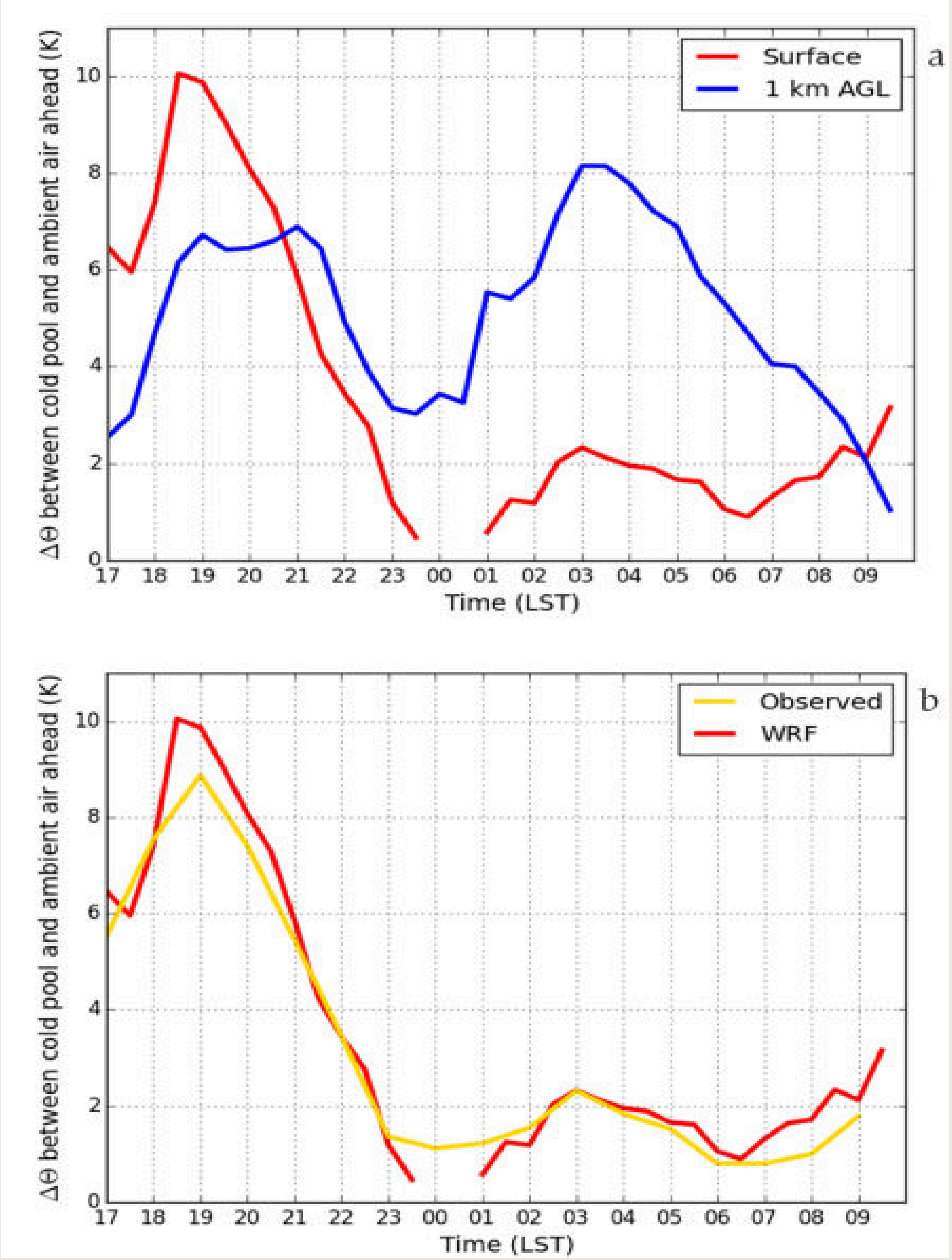
CAPE/CIN evolution



LLJ transport evaluation

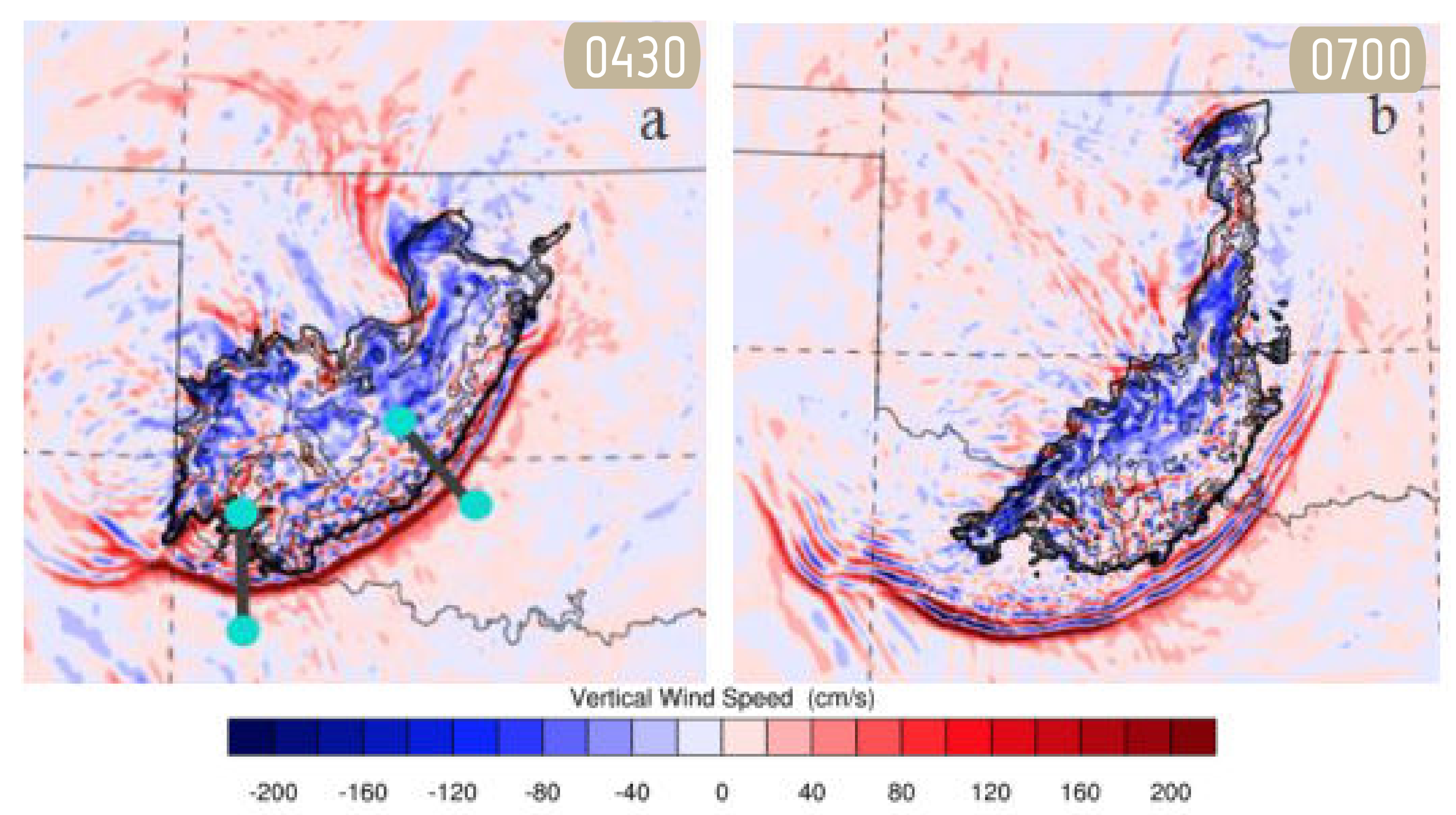


1km Temperature

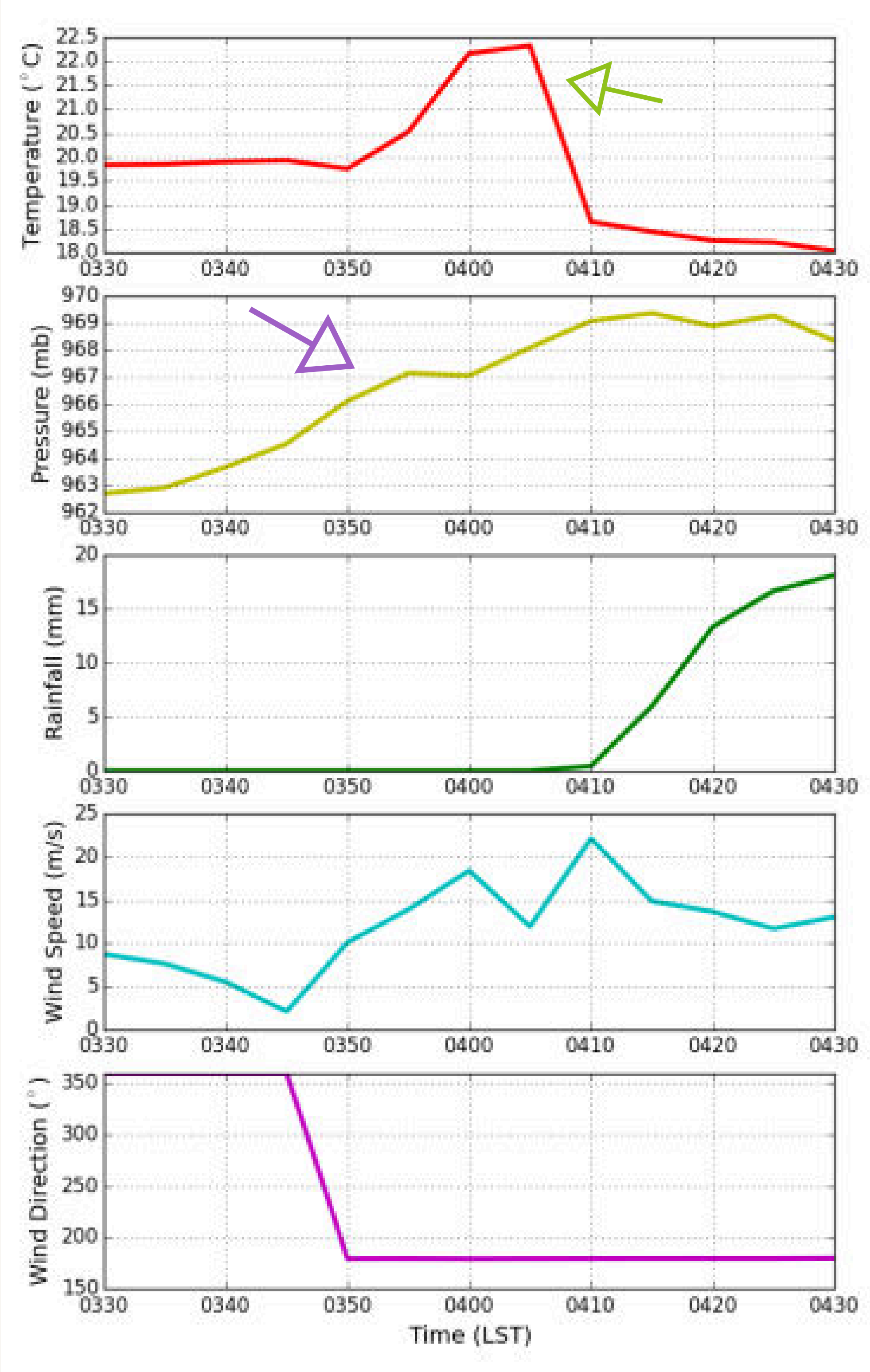


Δθ

Bore evaluation - I. Surface data



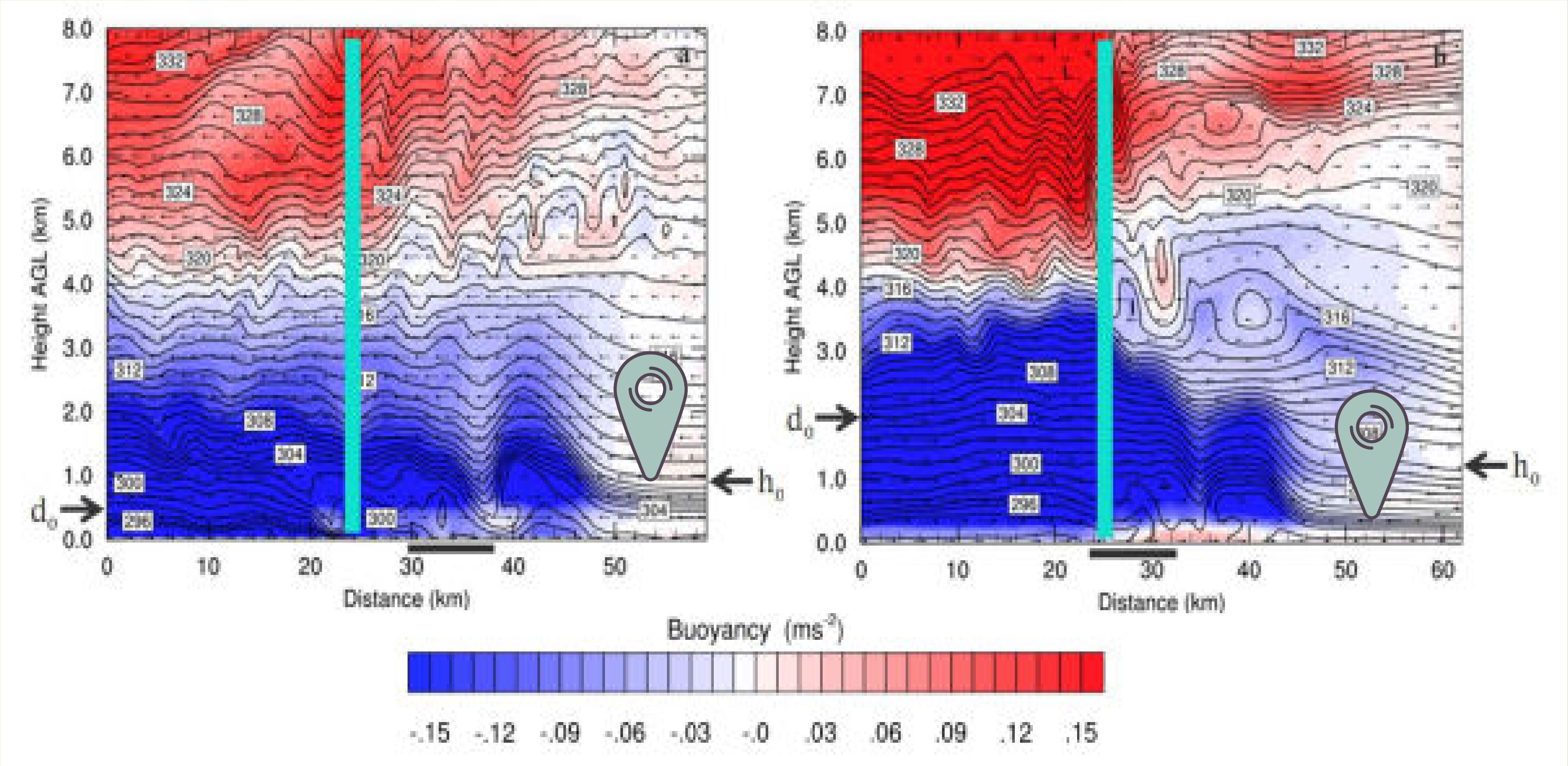
1km Vertical Velocity



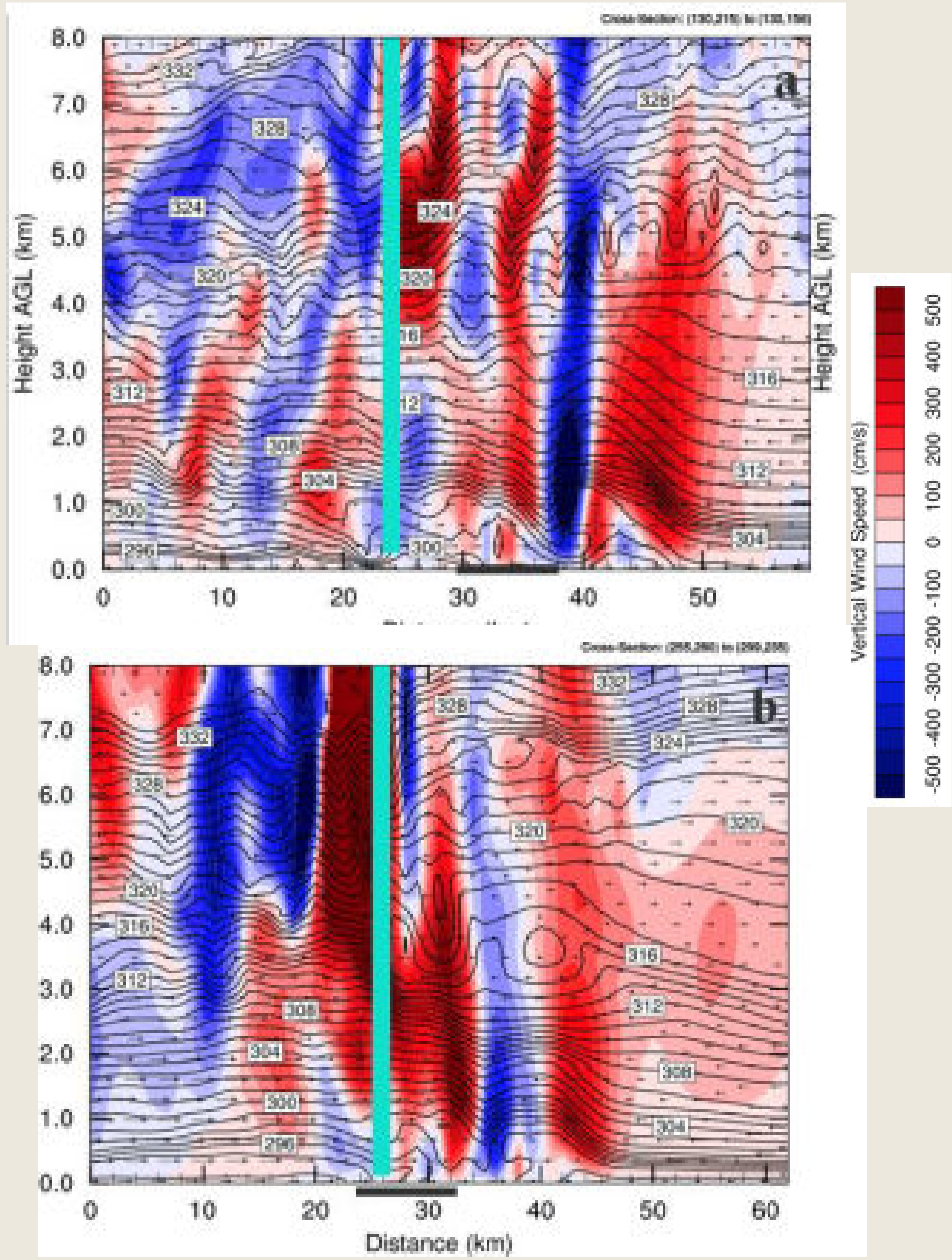
WRF Chickasha surface ob.

Bore evaluation - II. Buoyancy profile

$$B \equiv g\left[\frac{\theta'}{\bar{\theta}} + 0.61(q_v - \bar{q}_v) - q_c - q_r - q_i\right]$$



Buoyancy cross section at 0430 LST(L: N-S, R: NW-SE)

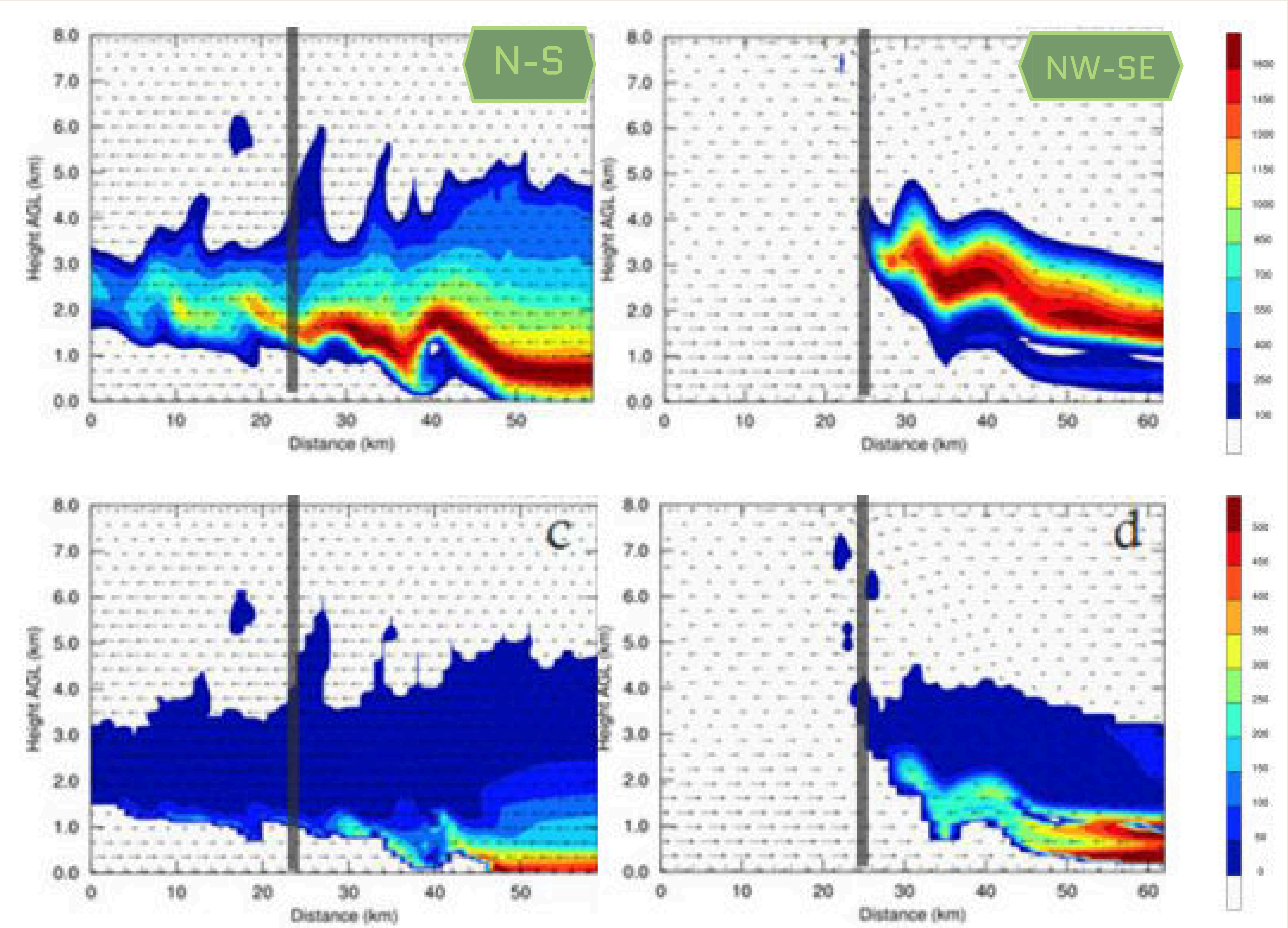


Vertical Velocity cross section

Bore evaluation - III. Implication on instability release

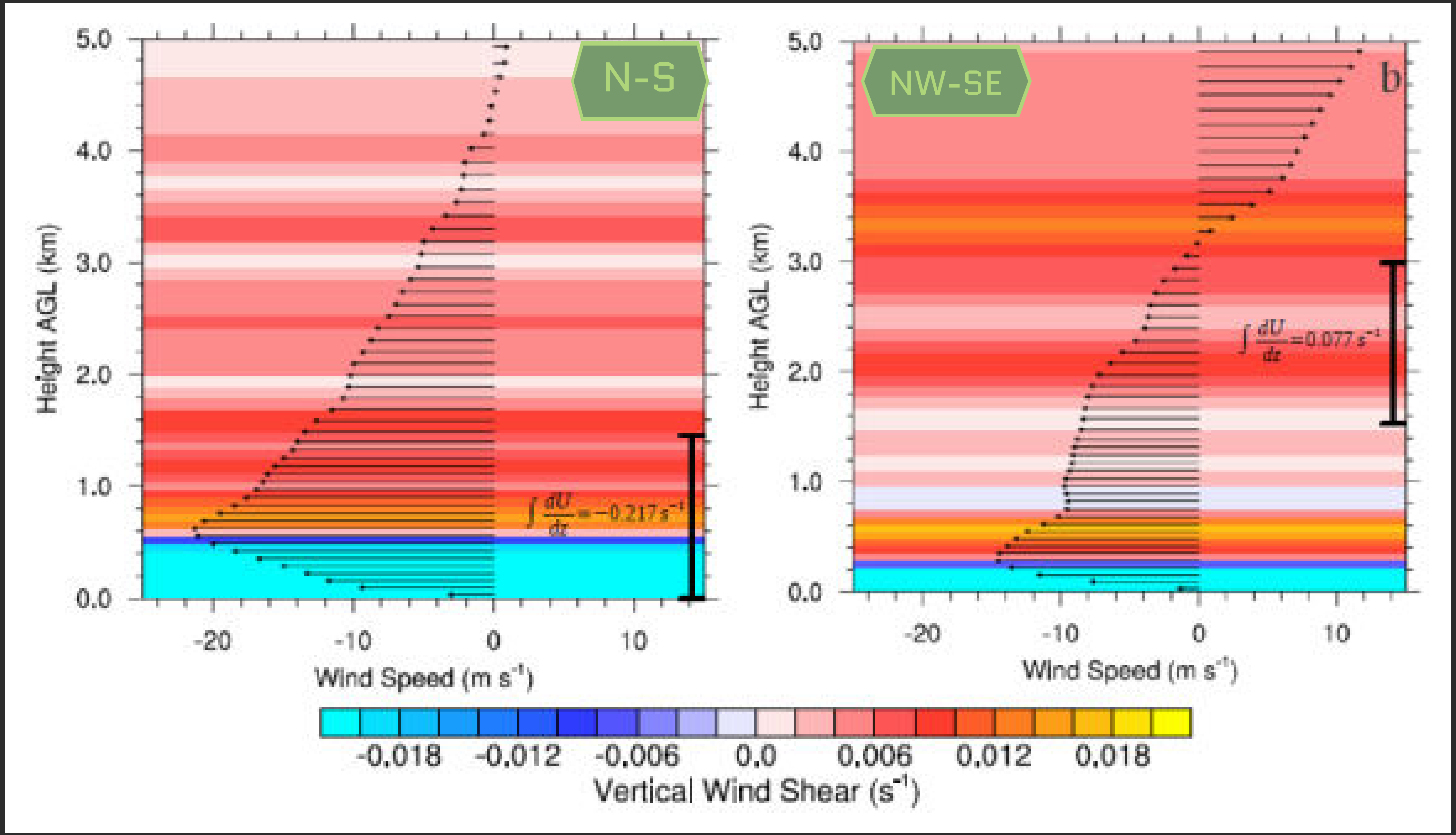
CAPE

CIN

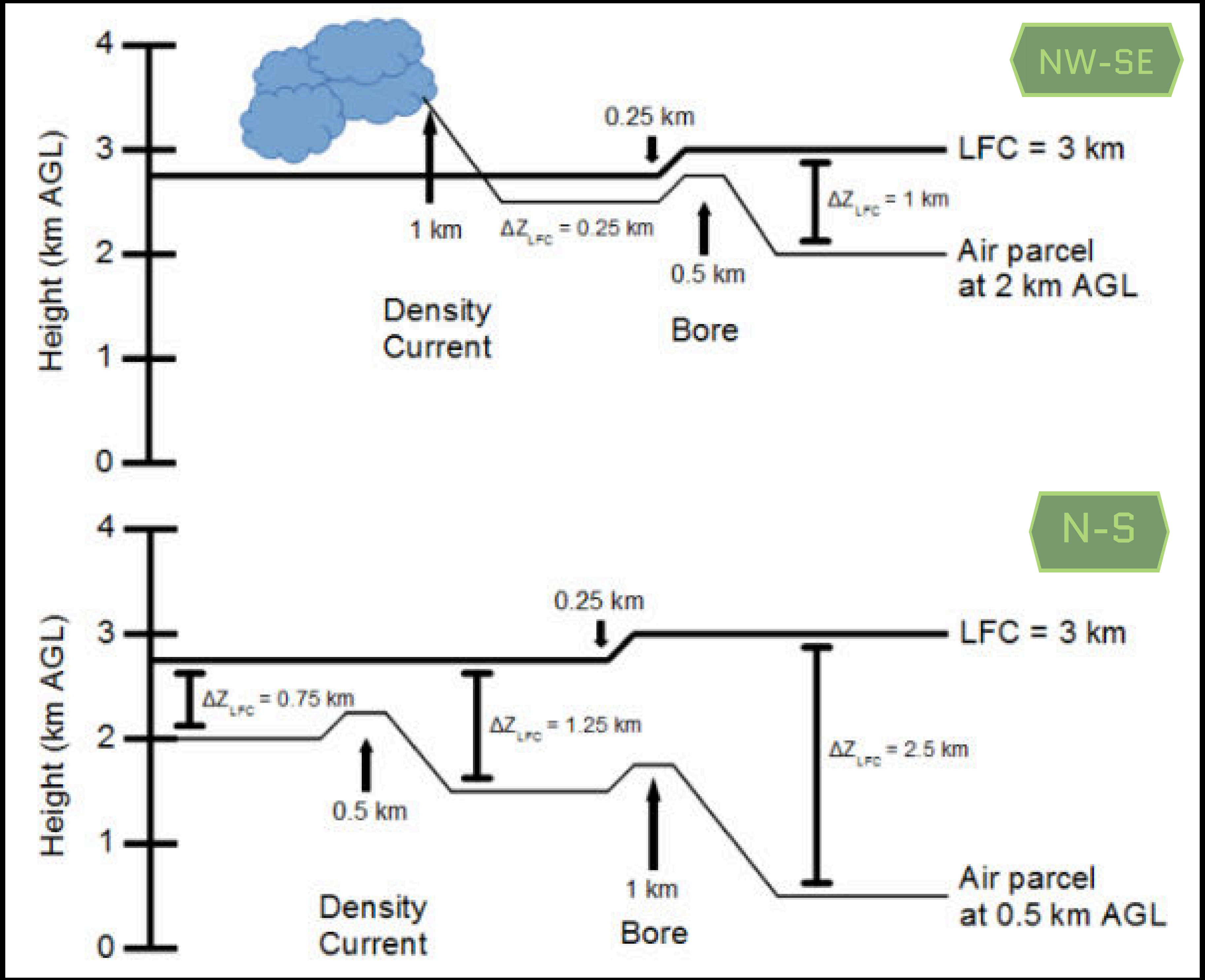


Dynamical inferences - I. RKW analysis

- Rotunno et al. (1988) argues that the optimal conditions for vertically orientated updraft occurs when the negative horizontal vorticity associated with the cold pool is balanced by the positive horizontal vorticity associated with the ambient wind shear
- c/deltaU>0 would produce larger parcel displacement compared to negative c/deltaU ratio (Moncrieff and Liu 1999)
- For convective system encountering a stablizing low troposphere (eg. nocturnal radiative cooling-induced stablization), French and Parker (2010)) argues that the shear profile with the effective inflow layer with high-CAPE, low-CIN is more revelent comparing to the SBL shear



Role of bores in preconditioning the environment

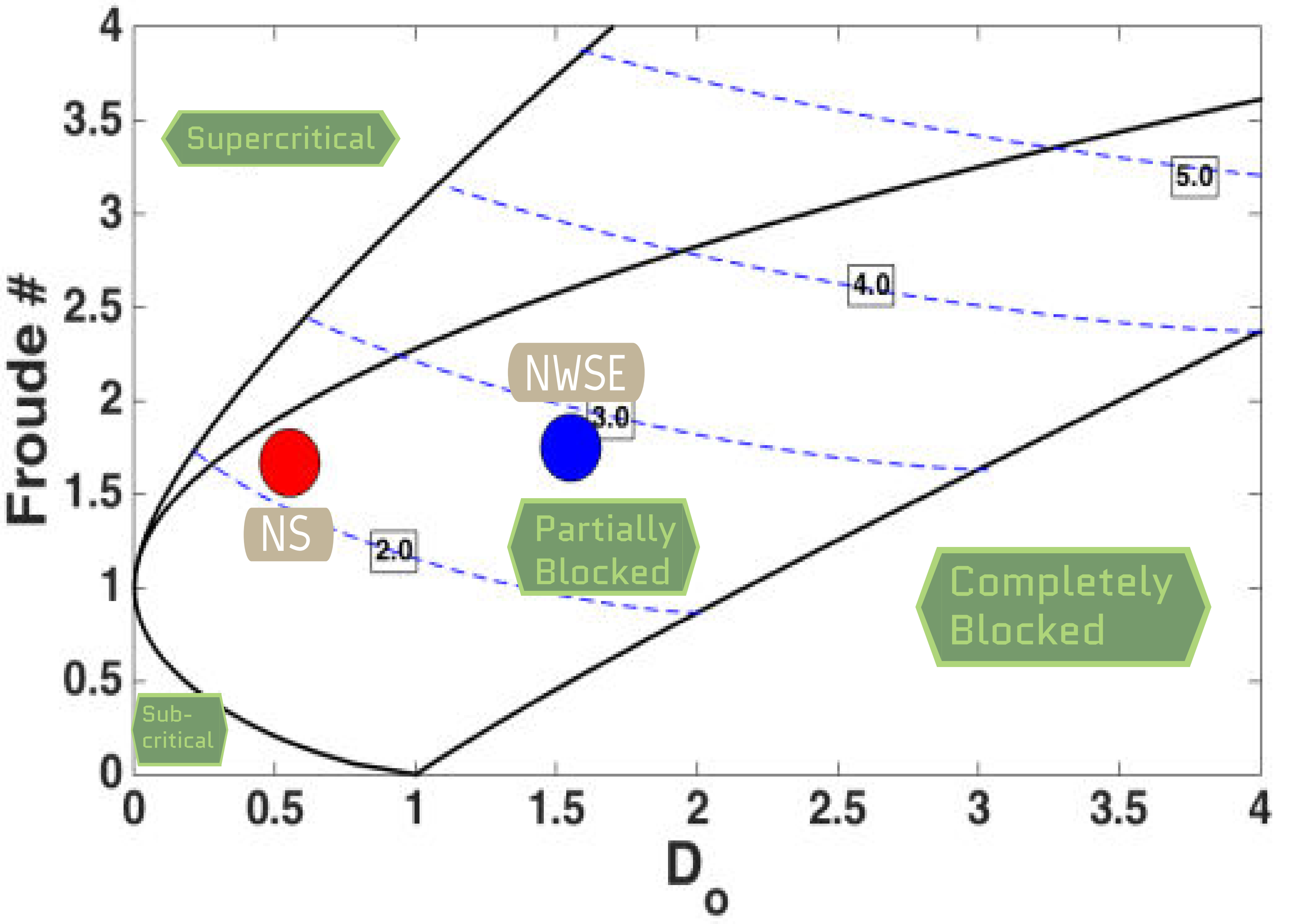


Dynamical inferences - II. Hydraulic Theory

Orientation	N-S	NW-SE
h_o (m)	979.65	1285.81
Inversion Strength (K)	8.6	11.28
Estimated C_{dc} (m s^{-1})	13.33	15.71
Estimated d_o (m)	537.94	1977.32
D_o	0.55	1.54
F	1.67	1.75
Flow Regime (SP,PB,CB,SB)	PB	PB

$$D_o = \frac{d_o}{h_o}$$

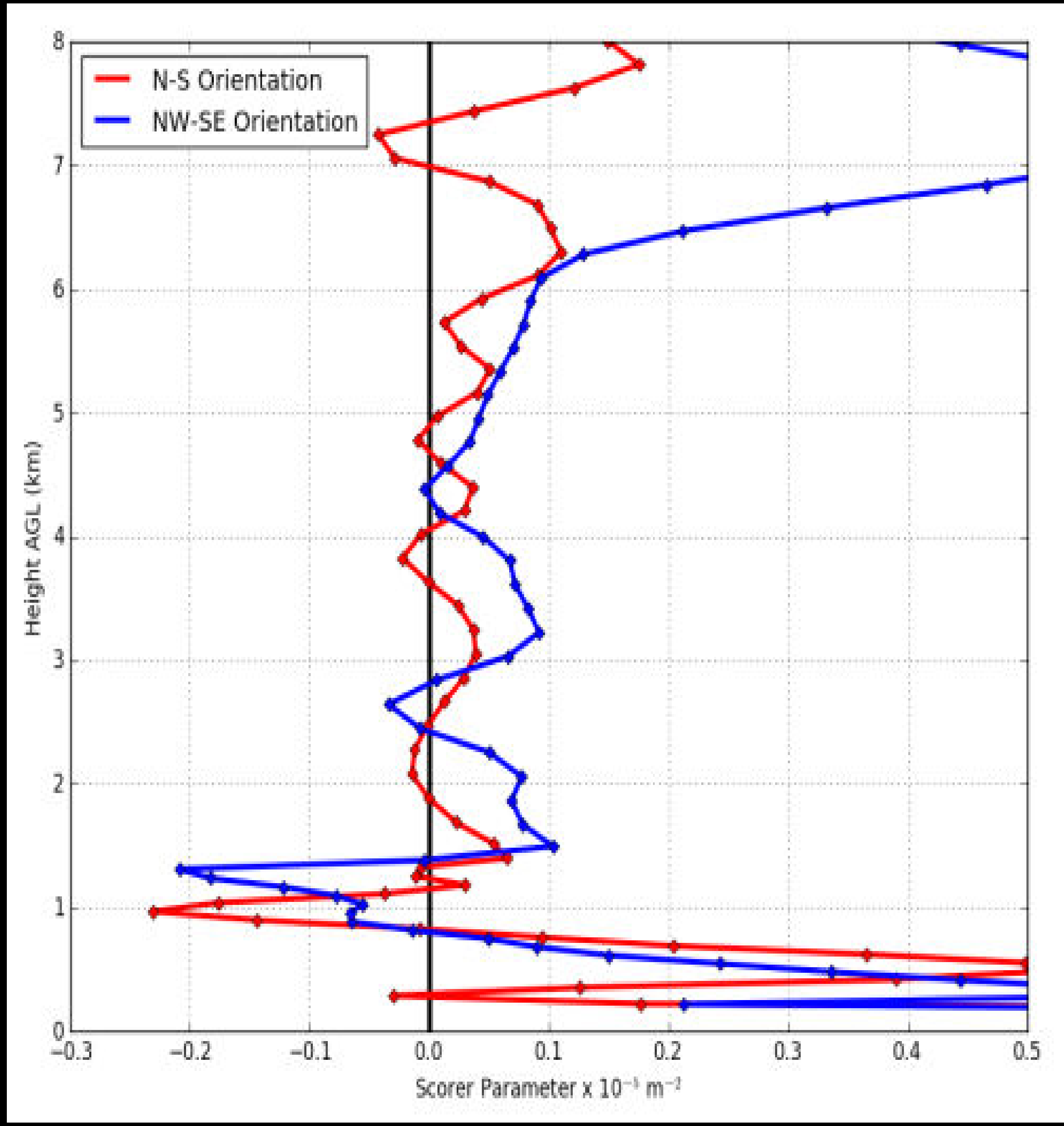
$$F = \frac{(U - C_{dc})}{C_{gw}} = \frac{(U - C_{dc})}{\sqrt{g(\frac{\Delta\theta_{vw}}{\theta_{vw}})h_o}}$$



Dynamical inferences - II. Hydraulic Theory

- (NS) l^2: -0.12x10^-5 - 0.5x10^-5, z1~800m, k~0.4x10^-7 => 10km wavelength trapped
- (NWSE) l^2: -0.09x10^-5 - 0.6x10^-5, z1~800m, k~0.4x10^-7 => 10km wavelength trapped

$$m^2 = \frac{N^2}{(U - C_{bore})^2} - \frac{\frac{\partial^2 U}{\partial z^2}}{(U - C_{bore})} - k^2$$



Scorer Parameter

THE END

Thank you for listening