Resolution dependence of initiation and upscale growth of deep convection in convection-allowing forecasts of the 31 May—1 June 2013 supercell and MCS

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The Case

- On 31 May—1 June 2013, a tornadic supercell and subsequent quasi-stationary MCS occurred in Oklahoma and led to 21 fatalities: 8 from the tornado and 13 from flash flooding (NWS 2014; Wurman et al. 2014)
- The upscale growth from supercell to heavy-rain-producing MCS was a challenge for both forecasting and warning/communication

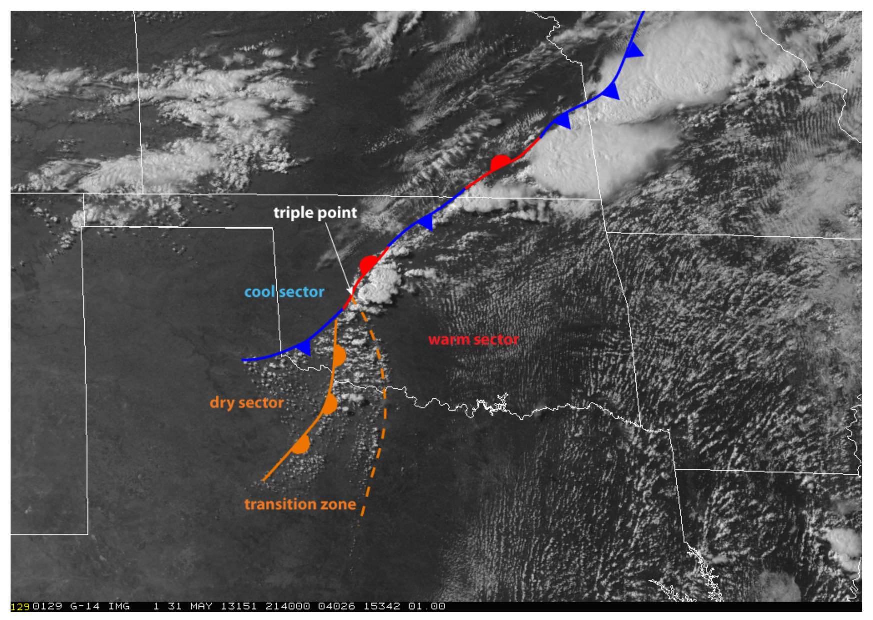

Fig. 1: Visible satellite image from 2145 UTC 31 May with manually analyzed surface boundaries. Convection initiated near a "triple point" intersection between a stationary front and two drylines.

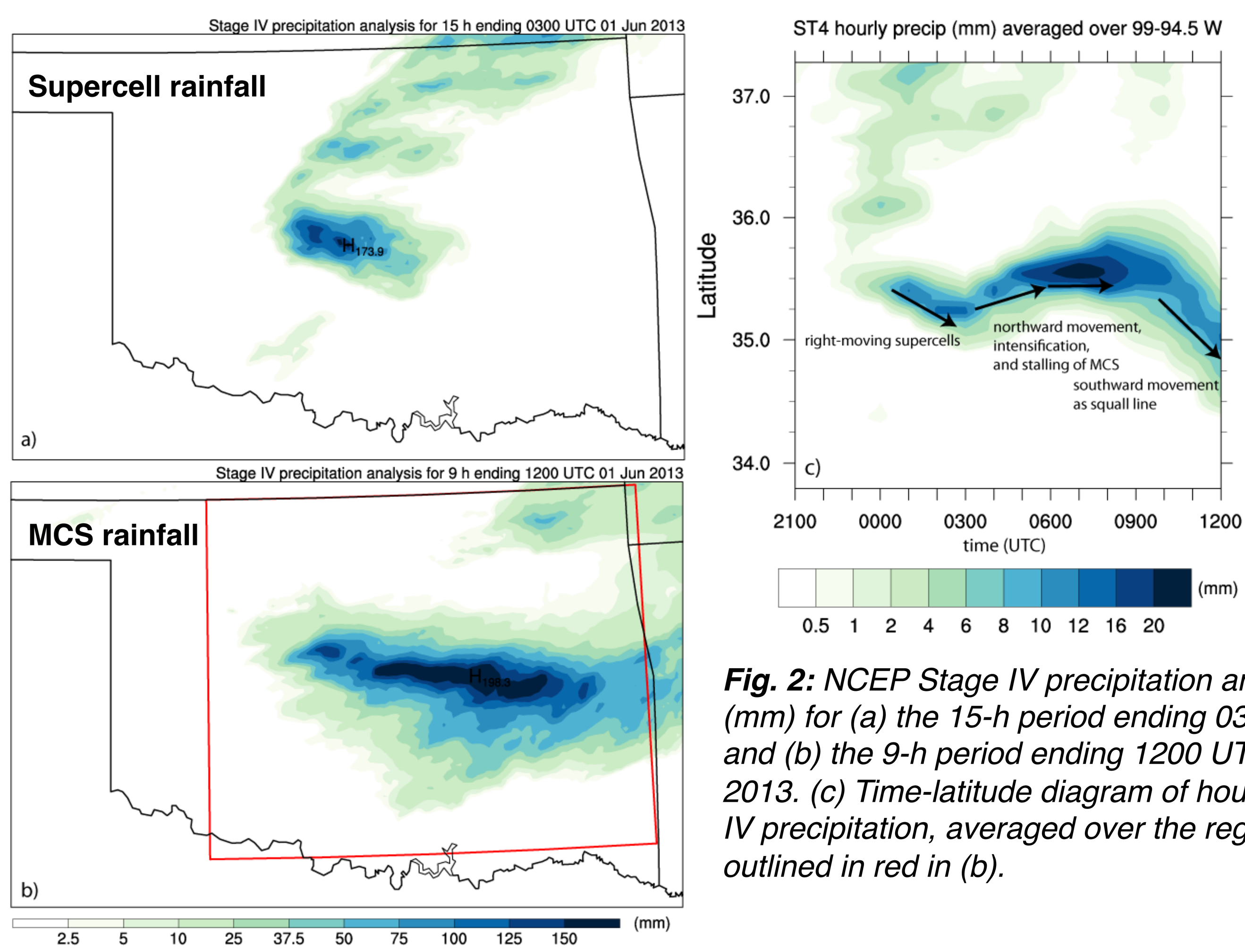

Fig. 2: NCEP Stage IV precipitation analysis (mm) for (a) the 15-h period ending 0300 UTC and (b) the 9-h period ending 1200 UTC 1 June 2013. (c) Time-latitude diagram of hourly Stage IV precipitation, averaged over the region outlined in red in (b).

The Problem

- A real-time convection-allowing WRF-ARW forecast at 4-km grid spacing, run in support of the MPEX field campaign, accurately predicted the location, timing, and evolution of the convection (though the rainfall from the supercell was underpredicted)
- **The same forecast was run at higher resolution to further explore the convective-scale processes in this event, but it turned out completely different! (specifically: much worse)**
- A series of experiments were conducted to understand why, and to illustrate the larger implications of these results

Experiment	Grid points	Timestep
Real-time (4-km)	748 x 600	25 s
5KM	598x480	30 s
3KM	997x800	18 s
2KM	1496x1200	12 s
1.33KM	2244x1800	6 s
444M-nest	1405x1102	2 s

- All simulations initialized at 1200 UTC 31 May with initial/lateral boundary conditions from GFS
- 51 vertical levels, Morrison 2-moment microphysics, single domain covering most of western and central US
- Simulations used the "local" MYJ boundary-layer parameterization

Results of the Experiments

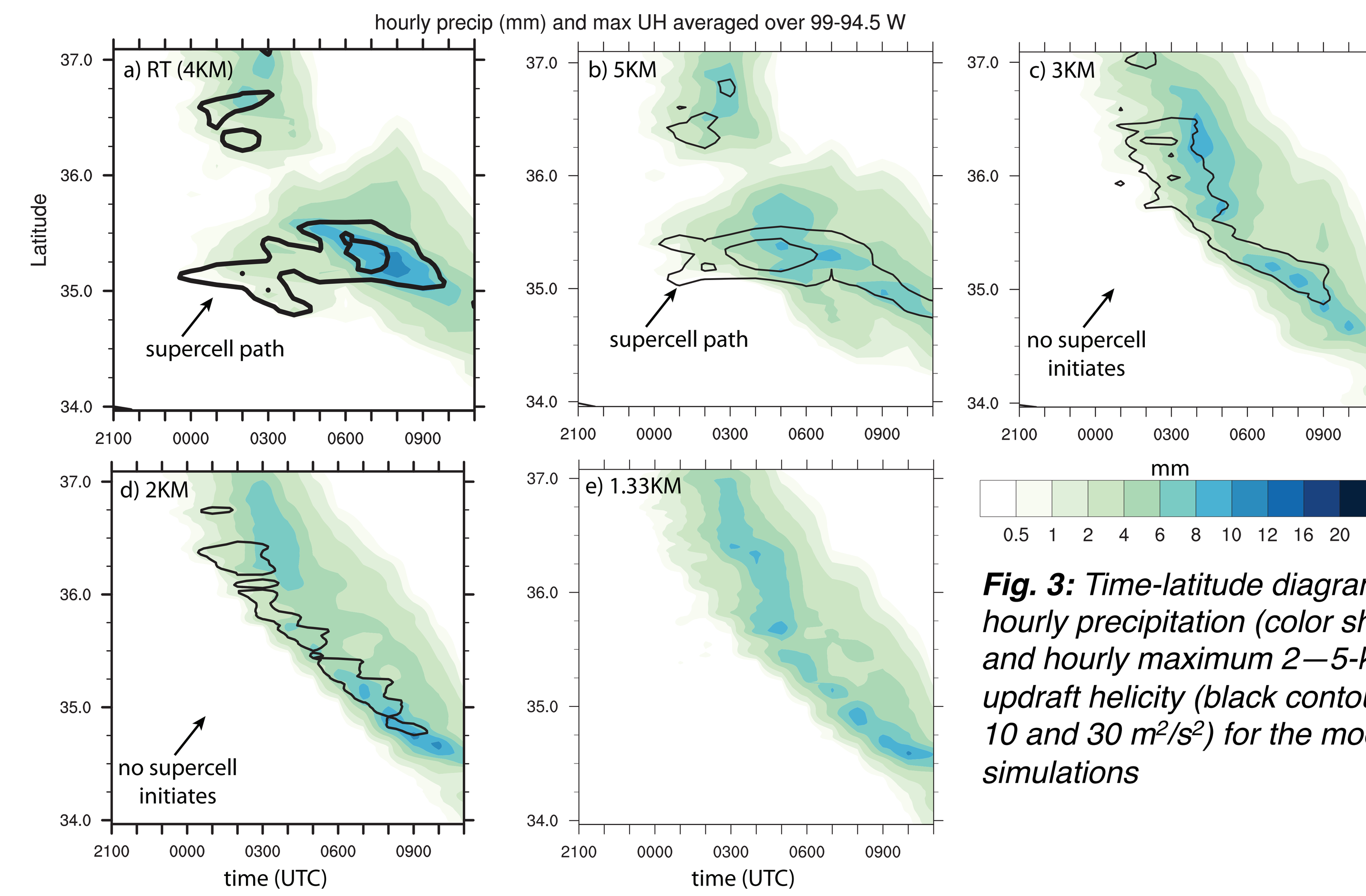

Fig. 3: Time-latitude diagram of hourly precipitation (color shading) and hourly maximum 2—5-km updraft helicity (black contours at 10 and 30 m^2/s^2) for the model simulations

- At 4-km and 5-km grid spacing, a supercell initiates in west-central Oklahoma and evolves into a slow-moving MCSs, similar to observations. But at $\Delta x \leq 3$km, no supercell initiates and a faster-moving line develops

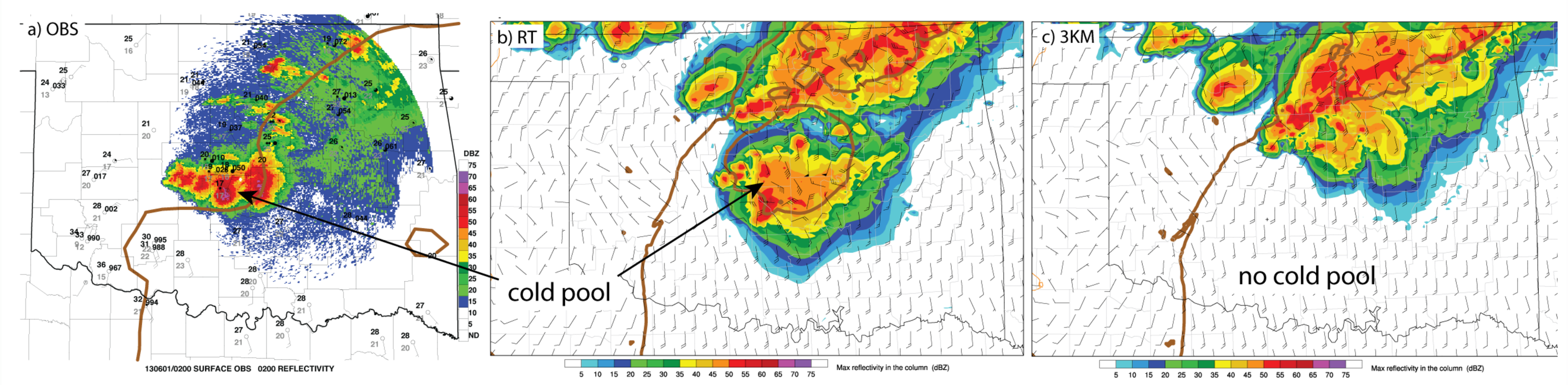

Fig. 4: Composite reflectivity and 20°C dewpoint contour at 0200 UTC 1 June for (a) obs, (b) RT, (c) 3KM

- The supercell in observations and RT produces a cold pool, and new development occurs along and behind the gust front. But with no supercell in the higher-resolution runs, there is no cold pool, and the convection along the front simply moves southward
- Primary difference between the lower- and higher-resolution runs is the moisture in the PBL, and its influence on the movement of the two drylines
- At higher resolution, a region of lower dewpoints originates in west Texas near the dryline, and expands through the dry sector and transition zone through the afternoon: the 2KM run has a broad region with PBL-average dewpoint 2-4 K lower than RT
- In higher-res runs, the dryline has moved past the location where the supercell initiates in the lower-res runs, which inhibits initiation in that spot

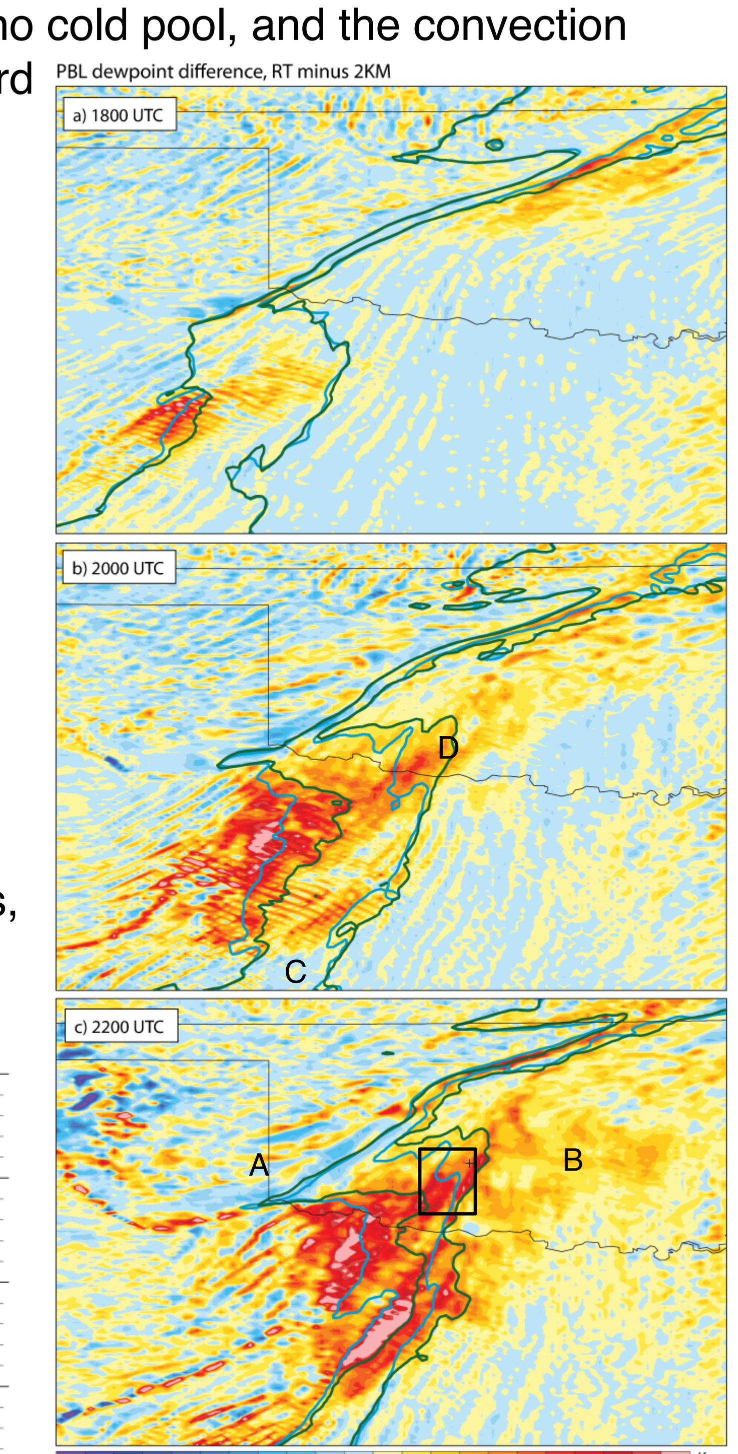

Fig. 5: PBL average dewpoint difference (RT minus 2KM), with the 16 and 20°C dewpoint contours shown in cyan (RT) and green (2KM)

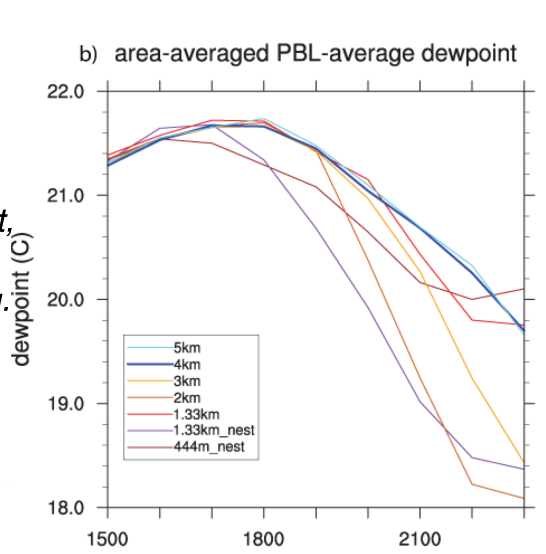

Fig. 6: Time series of PBL-average dewpoint, averaged over the rectangle shown in Fig. 5. In the higher-resolution simulations, the dewpoint drops off after 18-19 UTC but stays higher in the lower-resolution runs.

Reasons for the Differences

- Wyngaard (2004) defined the "terra incognita" for PBL modeling as falling between large-eddy simulation (in which turbulence is explicitly resolved) and mesoscale modeling (for which parameterizations were developed). In between, there is a mixture of resolved and parameterized turbulence, which can lead to poor representation of PBL processes
- Ching et al. (2014) demonstrated that modeled PBL circulations can grow rapidly at higher resolution (especially in schemes with only local mixing), resulting in PBL structures inconsistent with observations
- In our case, gravity waves near PBL top develop in all simulations, but at higher resolution they grow rapidly, leading to vigorous downward mixing of dry air, faster progression of the dryline, and inhibition of convection in western OK. At lower resolution, the PBL remains moister and the wave-dryline intersections support convection initiation.

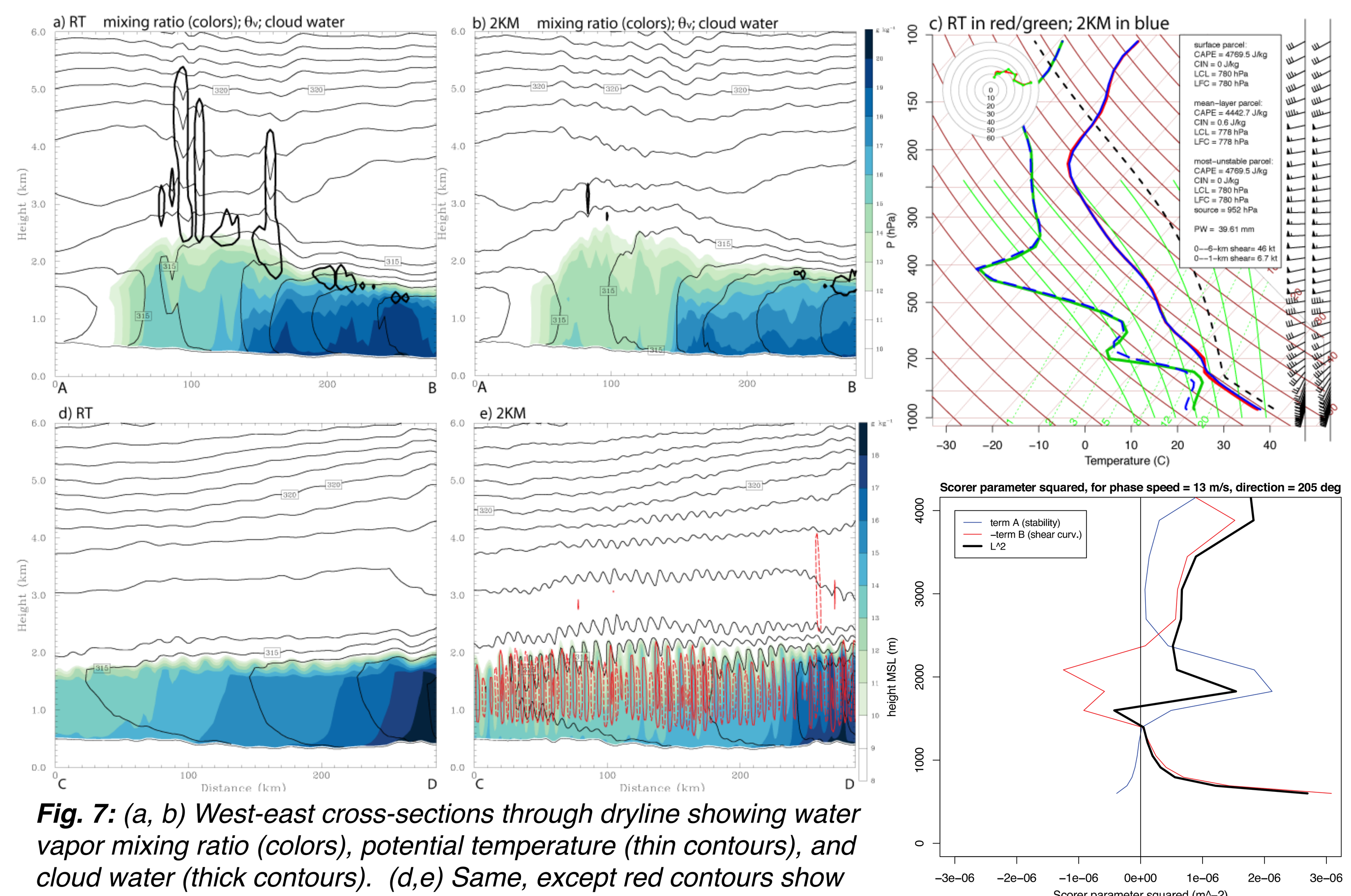

Fig. 7: (a, b) West-east cross-sections through dryline showing water vapor mixing ratio (colors), potential temperature (thin contours), and cloud water (thick contours). (d,e) Same, except red contours show vertical velocity, and section is taken from SW-NE through waves. (c) is SkewT—logp diagram at 2200 UTC. (f) shows vertical profile of Scorer parameter squared. The stable layer with positive L^2 overtopping a layer of negative L^2 near PBL is supportive of wave trapping, and possibly also the amplification of circulations within the well-mixed PBL

- Similar experiments with the non-local YSU PBL scheme show that, although the precipitation forecasts were consistently worse than those with MYJ, there is no difference in PBL moisture or dryline, supporting Ching et al.'s finding that allowing non-local mixing partially mitigates the resolution dependence

Implications

- This study investigated an instance where higher spatial resolution degraded the forecast of a high-impact convective event (in contrast to most past findings that increased resolution was inconsequential or improved forecasts)
- Resolution dependence in the representation of PBL circulations substantially altered the initiation, and subsequent upscale growth, of convection
- Although such large differences are probably unusual and appear limited to "local" PBL schemes, this study provides further evidence that caution is warranted as forecast models move further into the "terra incognita."

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- **For more details, see MWR article in press, or russ.schumacher@colostate.edu**