A Study of Convective Initiation Failure on 22 Oct 2004

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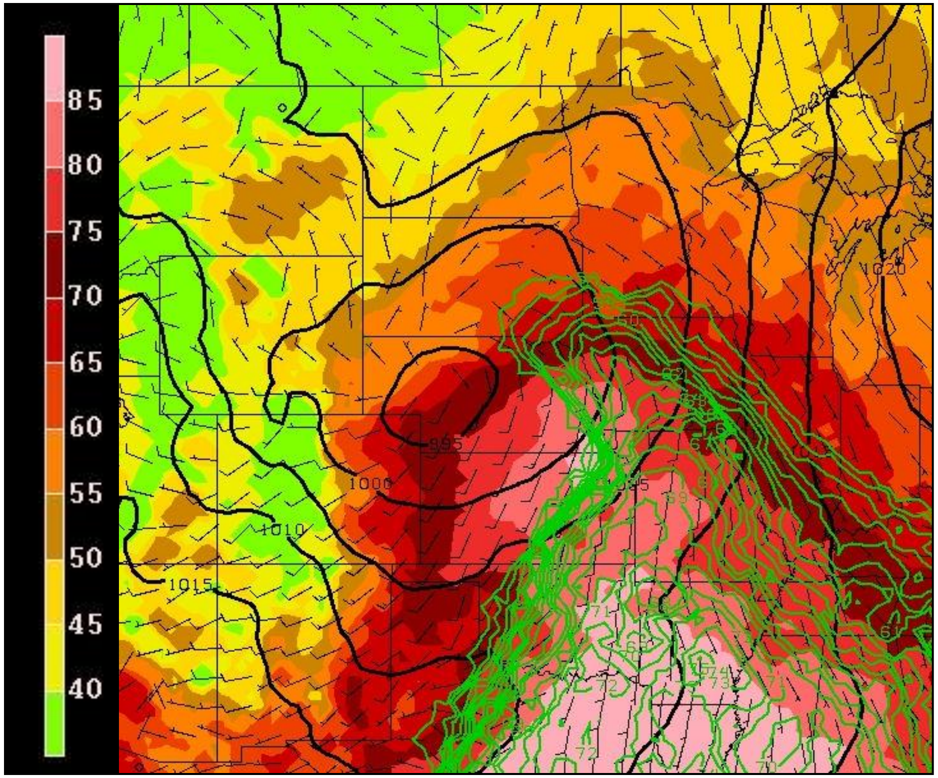
Introduction

- **Forecasting challenge**: strong forcing for ascent and large convective inhibition
- Conditional probability of severe weather is high with initiation the limiting factor
- Models often indicate the likelihood of convection when initiation does not occur
- Need to develop an understanding of how convective initiation occurs in models

Case Study

- 22 October 2004: Dryline in eastern Nebraska with surface low moving through northern NE



1800 UTC: 2 m TMPF, 2 m DWPF, PMSL, 10 m wind

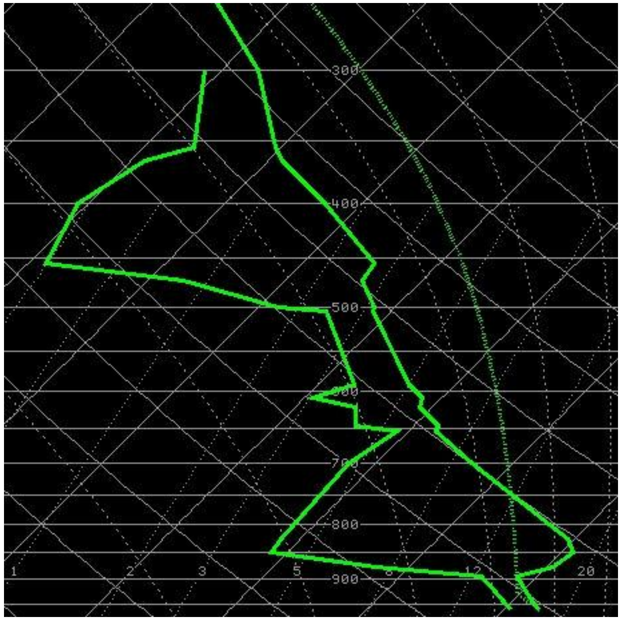
= DWPF > 56° F, contoured at 1° intervals

= PMSL in hPa, contoured at 5 hPa intervals

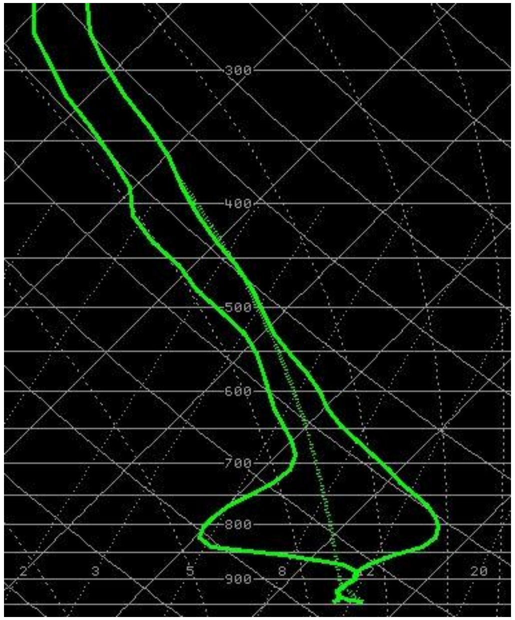
= Wind barbs in knots

Case Study

- Morning sounding and model soundings resolving a significant capping inversion ahead of the dryline



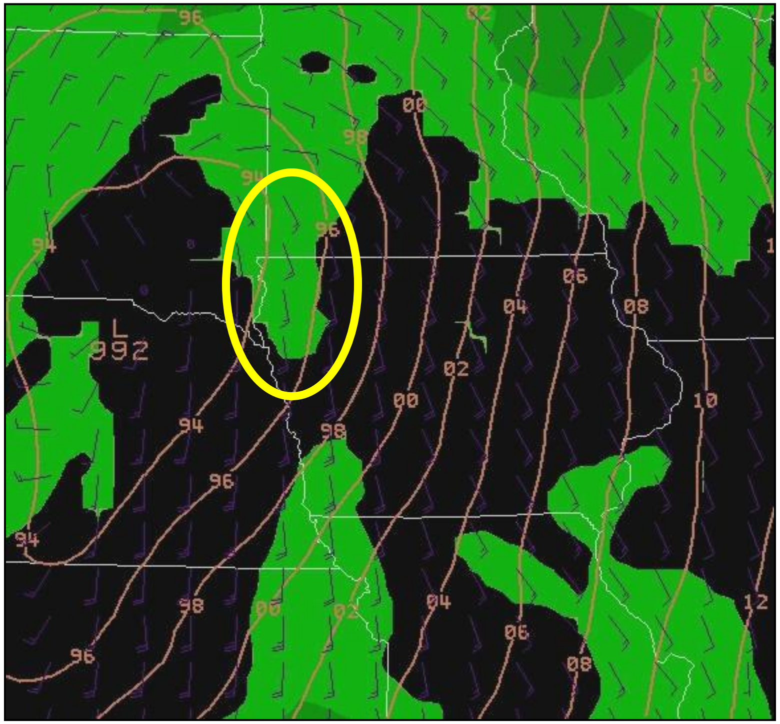
12 UTC sounding
from KOAX



18 UTC NAM sounding
from Spencer, IA

Case Study

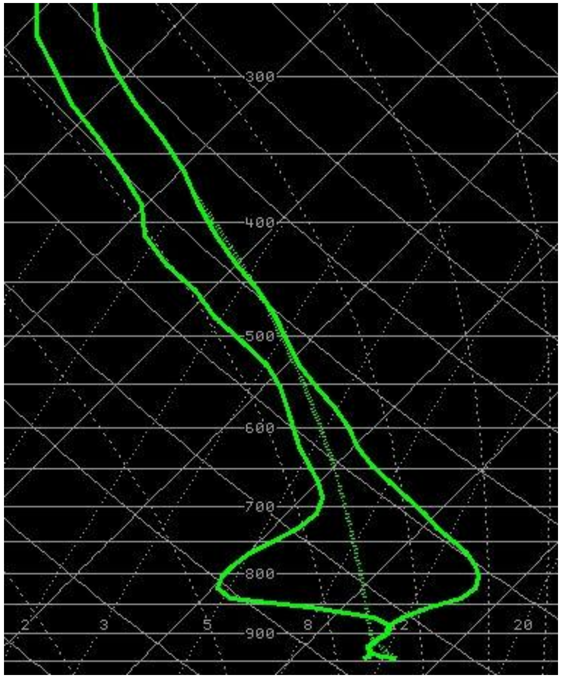
- All operational models forecast convection to initiate along the boundary by 00 UTC 23 October
  - Meso-ETA
  - GFS
  - RUC20



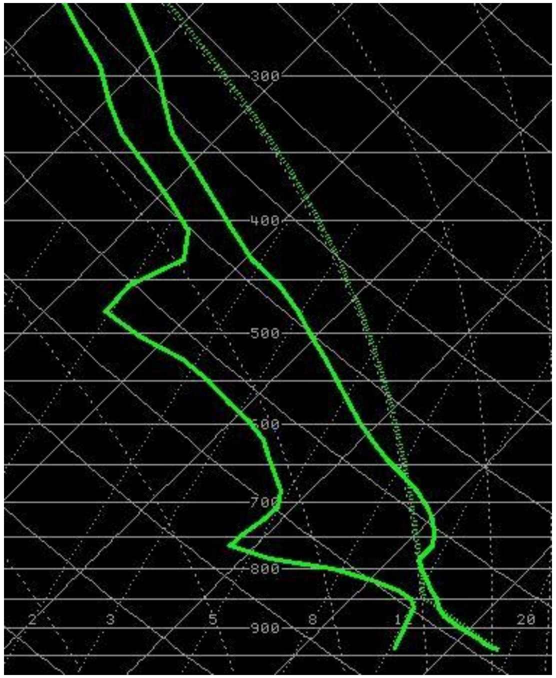
NAM20 precipitation (shaded), wind, and MSLP at 00 UTC 23 October

Case Study

- Models eroded cap throughout the day, decreasing values of CIN and creating the anticipation of severe weather



18 Z NAM sounding (left) and 22 Z NAM sounding (right) from Spencer, IA



Parameterization

- Convective Parameterization (CP): Simulating the effects of moist convection in terms of processes that can be resolved by the model
- Model triggers convection when a list of conditions are met; used because:
  - Time scale of convection is smaller than that of circulations resolved in large-scale models
  - Convective clouds are complex, subgrid-scale phenomena
- Necessary at grid spacing > 4 km

Parameterization

- Once triggered, what does the CP do?
  - Calculates the vertical distribution of cumulus heating and moistening in terms of:
    - Vertical mass flux through clouds
    - Mass entrainment/detrainment from clouds
    - Thermodynamic properties of detraining cloud air
  - In English: adjusts lapse rates of temperature and moisture to simulate effects of convection

- Shallow CP changes temperature/moisture profiles before precip is produced

Methodology

- Varying CPs (with varying shallow CPs) used by models
- This study: Five simulations using the WRF-ARW
  - 27 km with Kain-Fritsch
  - 27 km with Betts-Miller-Janjic
  - 27 km with Grell
  - 9 km with Grell
  - 3 km with explicit convection (no CP)
- Convective initiation (CI) may be more dependent on effect of parameterized convection than a specific scheme

Methodology

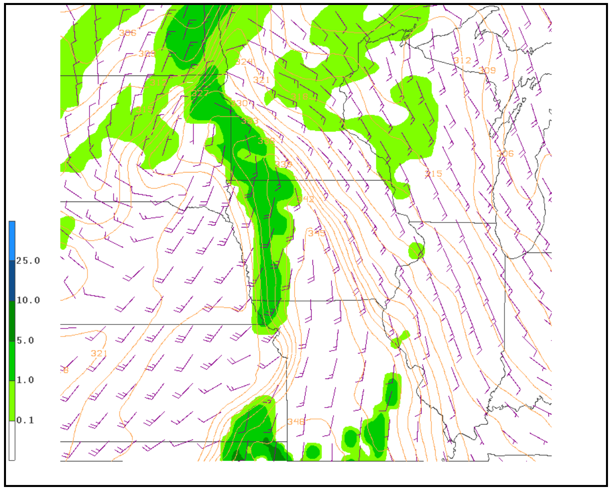
- Simulations are initialized with NARR data
- Run for 36 hours, which allows 18-24 hours for model adjustment before convection initiated in forecast models
- All other model physics and dynamics are set at the default values for the WRF-ARW
  - YSU PBL scheme
  - Lin et al. 1983 microphysics scheme (1 moment, 5 class: 3 phase ice)
  - Noah Land Surface Model

Methodology

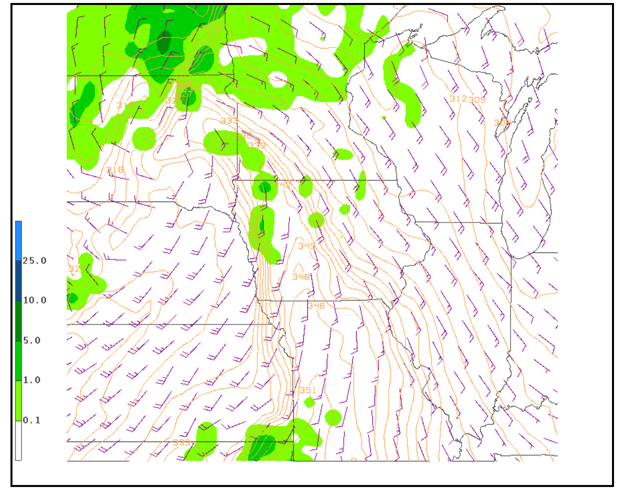
- Model output analysis:
  1) Synoptic standpoint to verify
     - Consistency between simulations
     - Similarity to the evolution of the case study
  2) Total precipitation accumulation and model-derived convective precipitation to determine whether or not deep CI occurs
  3) MUCAPE and SBCIN are plotted for each simulation to analyze of the favorability for CI
  4) Model soundings to inspect the evolution of the thermodynamic profile (atmospheric stability)

Results

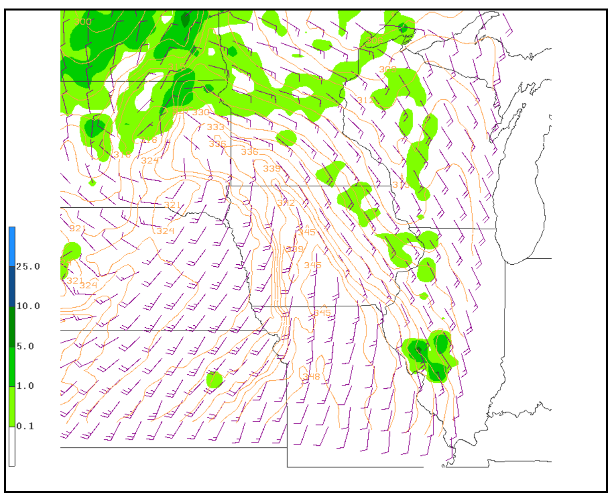
27 km KF



9 km Grell



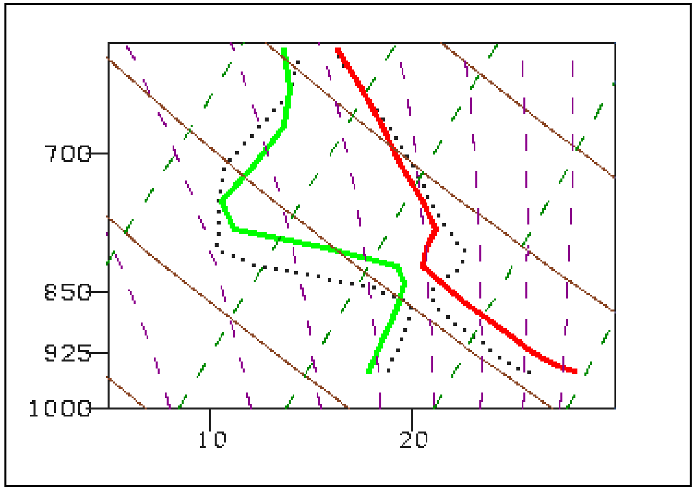
3 km explicit



1 hr precipitation accumulation (shaded), θ_e, and wind barbs in knots at 20 UTC

Results

27 km KF



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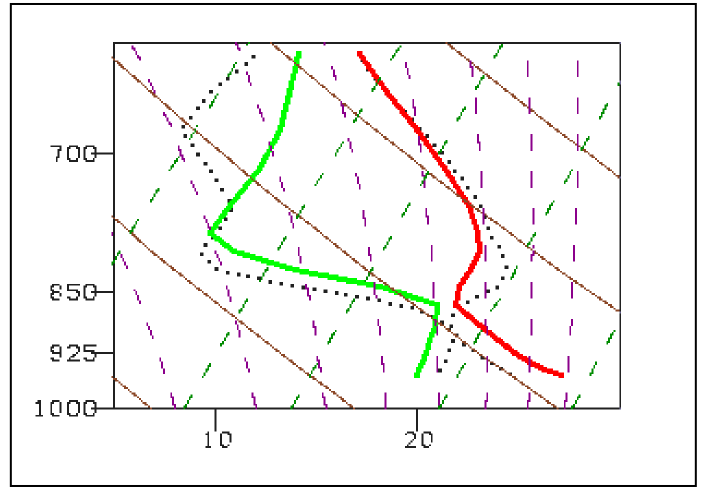

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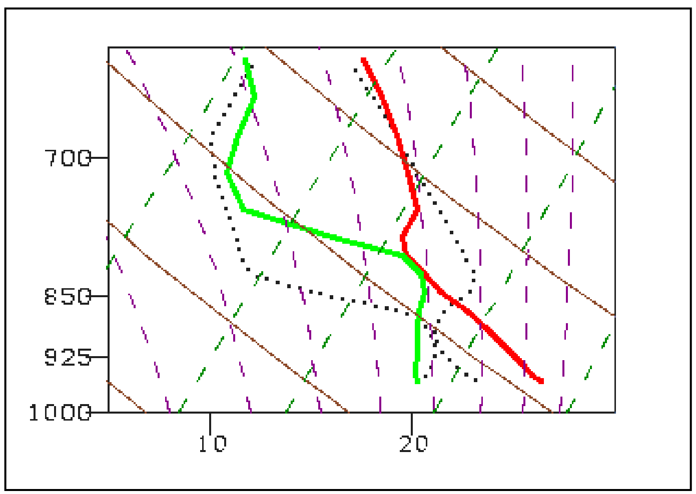
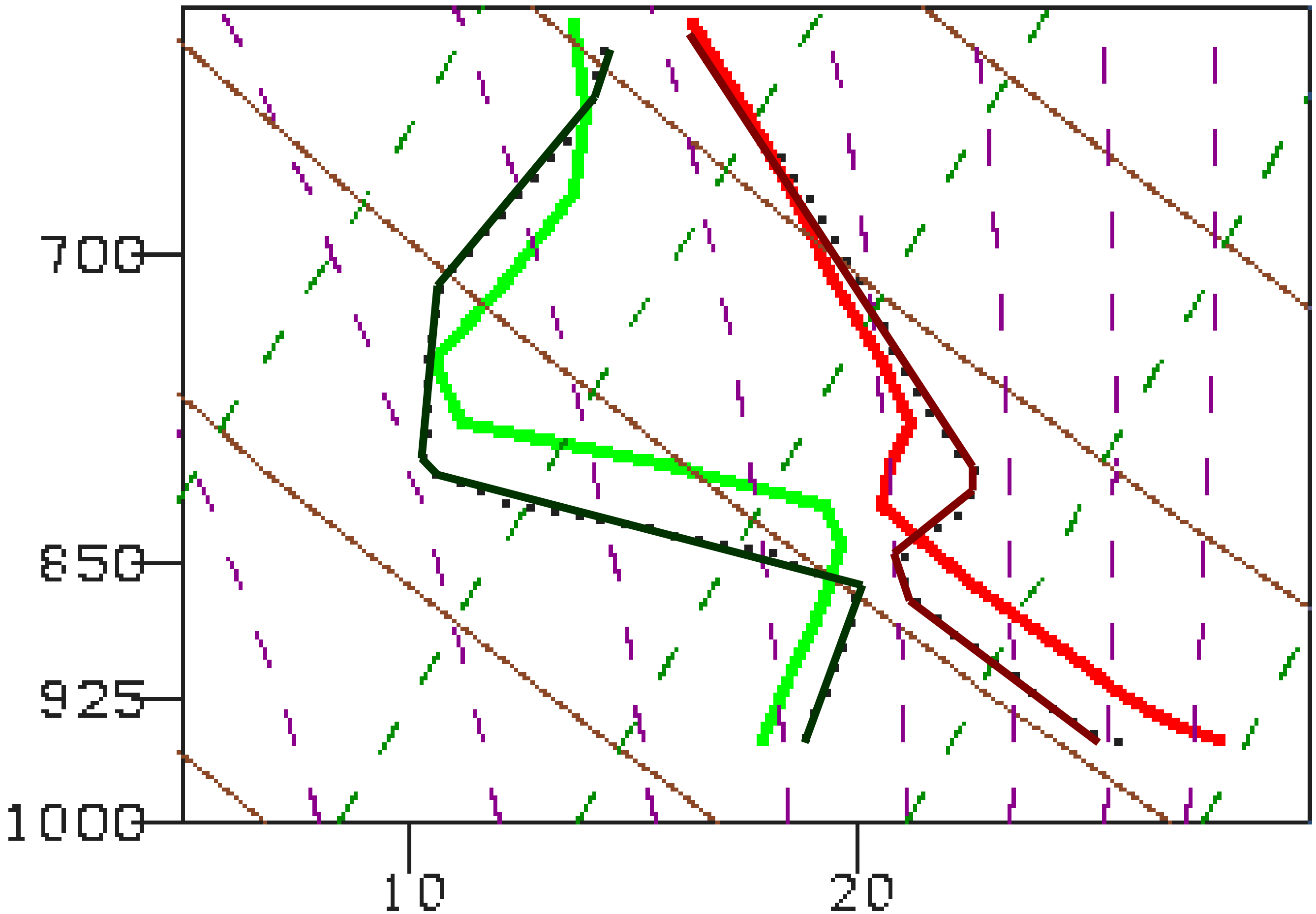


Environmental soundings for 18 UTC (dotted) and 19 UTC (solid colored)

Results

27 km KF



Results

- Deeper analysis of how the capping inversion responds to convective parameterization from the temperature tendency and stability tendency equations:

$$\frac{\partial T}{\partial t} = -v \cdot \nabla_p T + \omega\sigma\frac{p}{R}$$

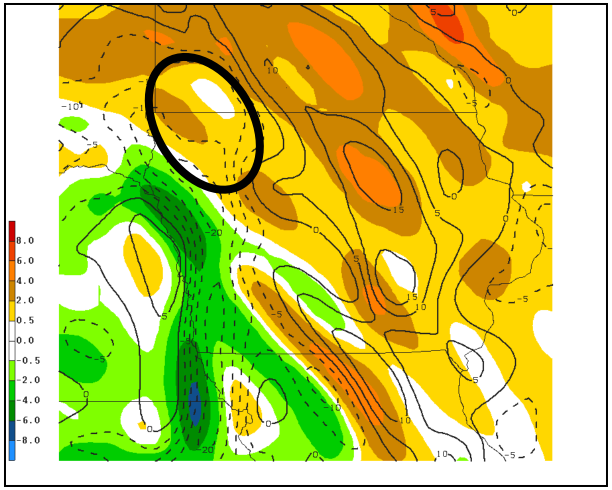
Horizontal advection *Vertical motion*

$$\frac{\partial}{\partial t}\left(-\frac{\partial \theta}{\partial p}\right) = -\frac{\partial}{\partial p}(-v \cdot \nabla_p \theta) - \omega\frac{\partial}{\partial p}\left(-\frac{\partial \theta}{\partial p}\right) - \delta\frac{\partial \theta}{\partial p} - \frac{\partial}{\partial p}\left(\frac{\theta}{C_p T}\frac{dQ}{dt}\right)$$

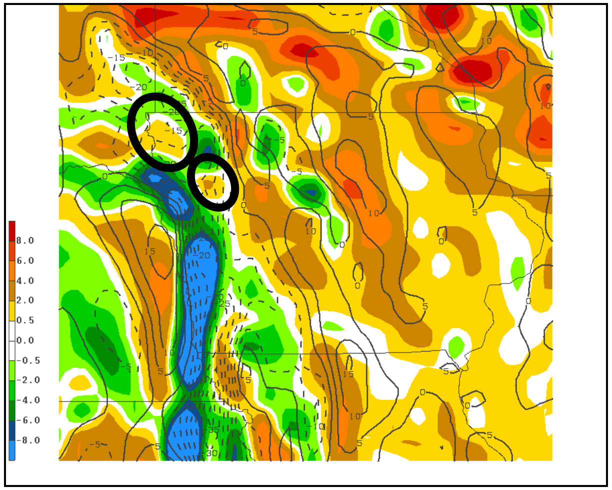
Differential horizontal advection *Differential vertical advection* *Diver-gence* *Diabatic term (ignored)*

Results

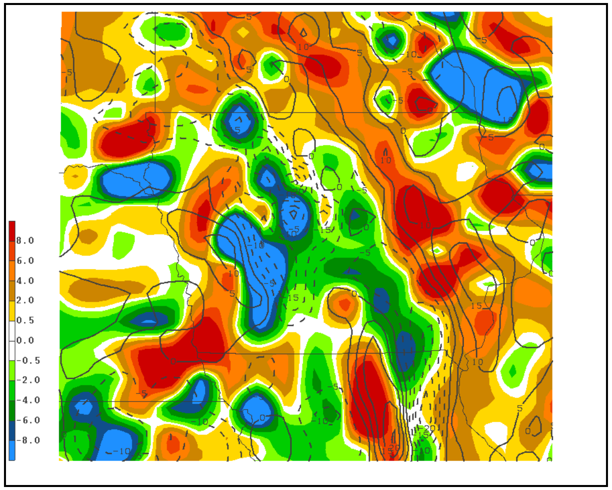
27 km KF



9 km Grell



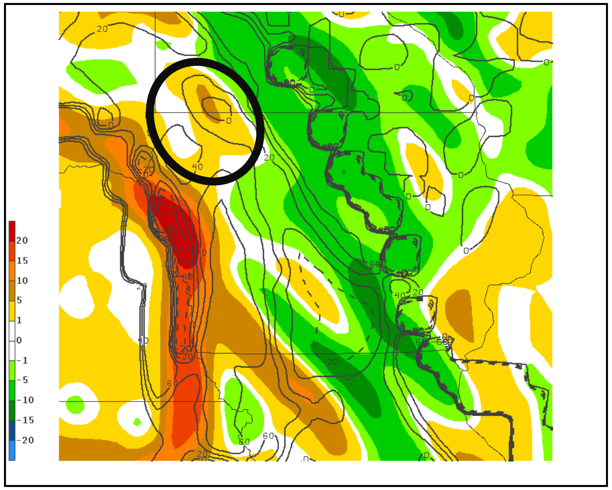
3 km explicit



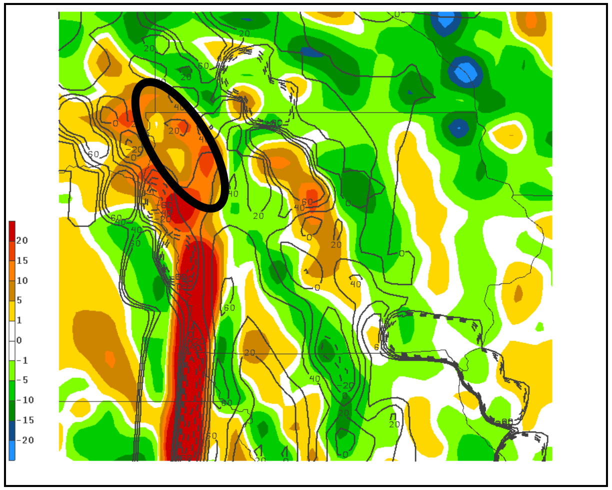
Instantaneous temperature tendency (shaded) and ΔT from 18 UTC to 19 UTC (contours)

Results

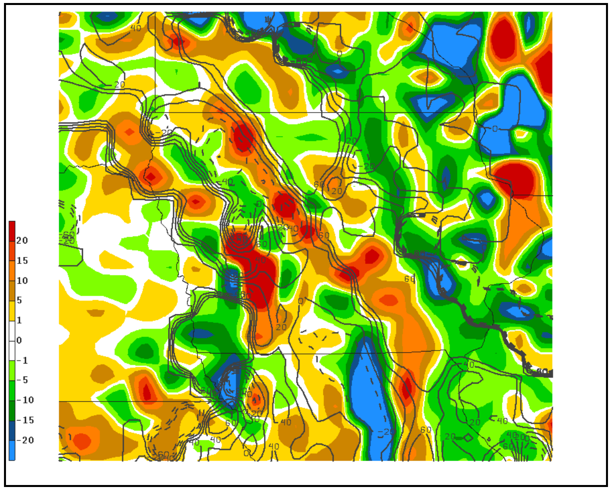
27 km KF



9 km Grell



3 km explicit



Instantaneous stability tendency (shaded) and ΔCIN (contours) from 18 UTC to 19 UTC

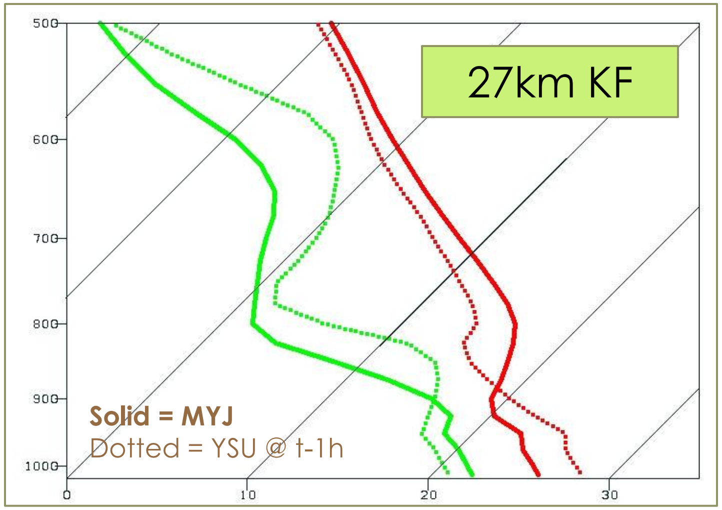
Results

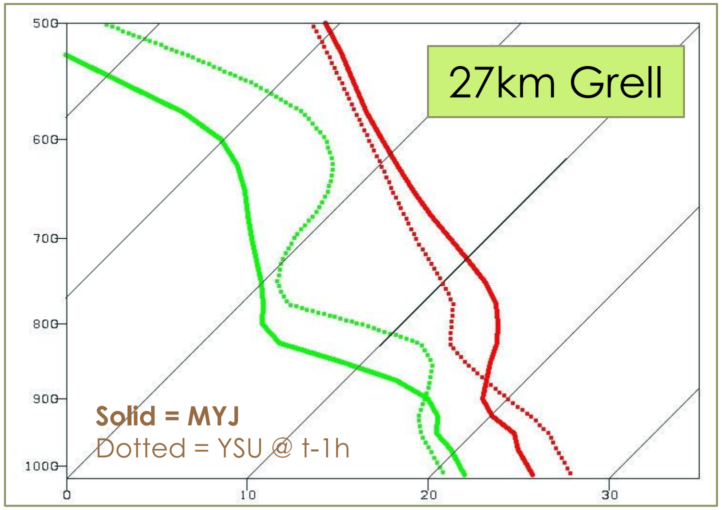
- Temperature tendency at Rock Rapids, IA (43.5;-96):
  - Advection = 1.04 °C/h
  - Vertical motion = 4.54 x 10^{-6} °C/h
  - Total = 1.04 °C/h   Actual ΔT = -1.163 °C
- Stability tendency at Sioux Center, IA (43;-96):
  - Differential horizontal thermal advection = -9.35 x 10^{-9}
  - Differential vertical advection = 2.527 x 10^{-8}
  - Convergence = -4.219 x 10^{-9}
  - Total = 1.170 x 10^{-8} Actual ΔCIN = -47.13 -J kg^{-1}

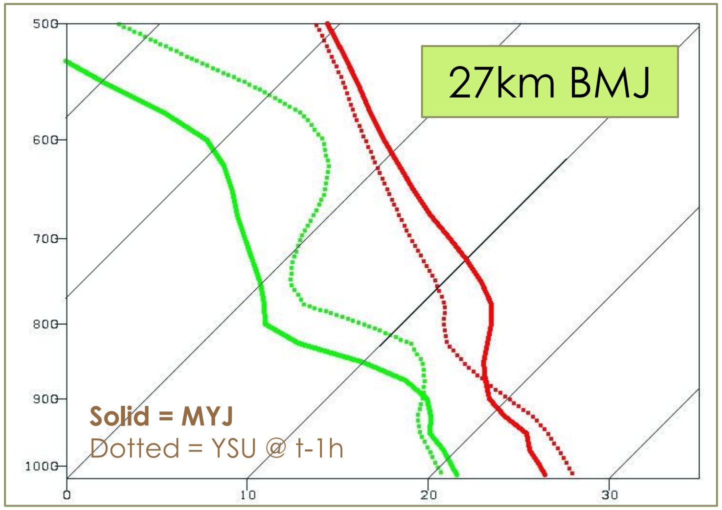
Boundary Layer

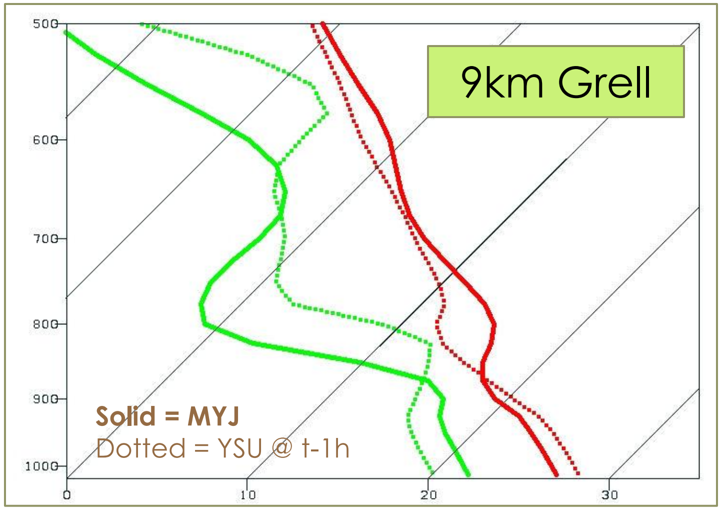
- Simulations were re-run with **MYJ** PBL scheme
- Two of the simulations failed to initiate convection (as in reality)
  - 27 km Kain-Fritsch
  - 9 km Grell
  - Very isolated CI with 27 km BMJ
- Hu et al. 2010: Too much mixing with YSU, not enough with MYJ → any PBL scheme cools and moistens the boundary layer too much
- Specific to this case (?)

Boundary Layer









Discussion

- Appears that the effect of parameterized convection is to decrease CIN
  - Cooling the inversion
  - Moistening at the level of the inversion
- YSU PBL scheme also promotes cooling and moistening in the inversion
- Tendencies indicate a strengthening cap, but the opposite occurs → effect that is not accounted for by tendency equations

Conclusions

- Inclusion of a CP in model simulations may produce deep convection more often than observed in highly capped environments
- Utility of a high-res model with explicit convection is important in operations
- Forecasters should be wary of model-produced decreases in temperature and increasing moisture within shallow cloud layer
  - Consider the plausibility of the model solution
  - Examine temperature & moisture advection
  - Compare different model solutions (different CPs)

Acknowledgements

- WFOs Sioux Falls
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- Conference attendees at the 24th SLS

Models

	Meso-ETA	GFS	RUC
PBL Scheme	MYJ	MRF (YSU)	MYJ
Convection	BMJ	Grell	Grell
Microphysics	Ferrier	Zhao	RUC/MM5