Examining Extratropical Cyclone Sensitivity to a Range of Environmental Conditions

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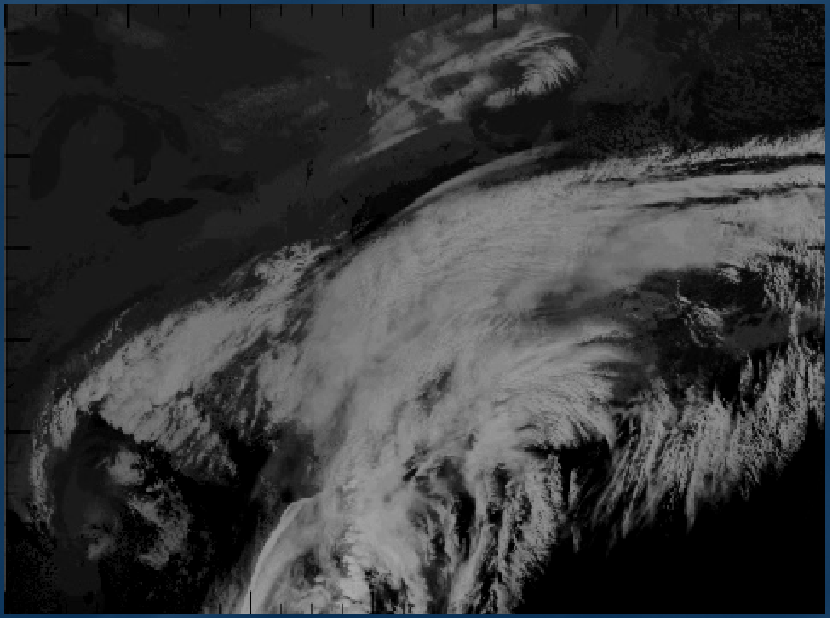
Motivation – Opposing Influences

- The implications of a changing climate extend beyond changes to temperature.
- Atmospheric properties crucial to extratropical cyclone development will also be affected
  - Baroclinicity, Stability, and Moisture Content
- Effects of a warming climate do not exhibit unidirectional influence, in theory.



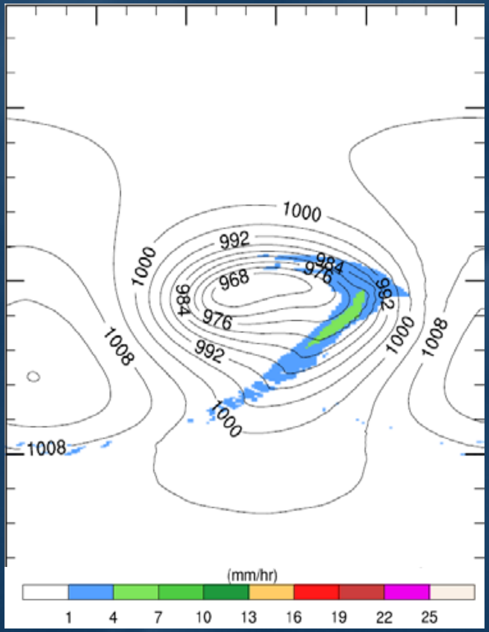
How might extratropical cyclones respond to varying environmental conditions?

An Idealized Framework for Sensitivity Analysis

Model Configuration

- Idealized channel model
  - East-west periodic boundary
- Ocean surface throughout model
- Initialized at 80% relative humidity
- Initialized as in Booth et al. (2012)
  - Specify jet profile and “anchor” temperature at southern boundary leads to initial domain temperatures via thermal wind balance

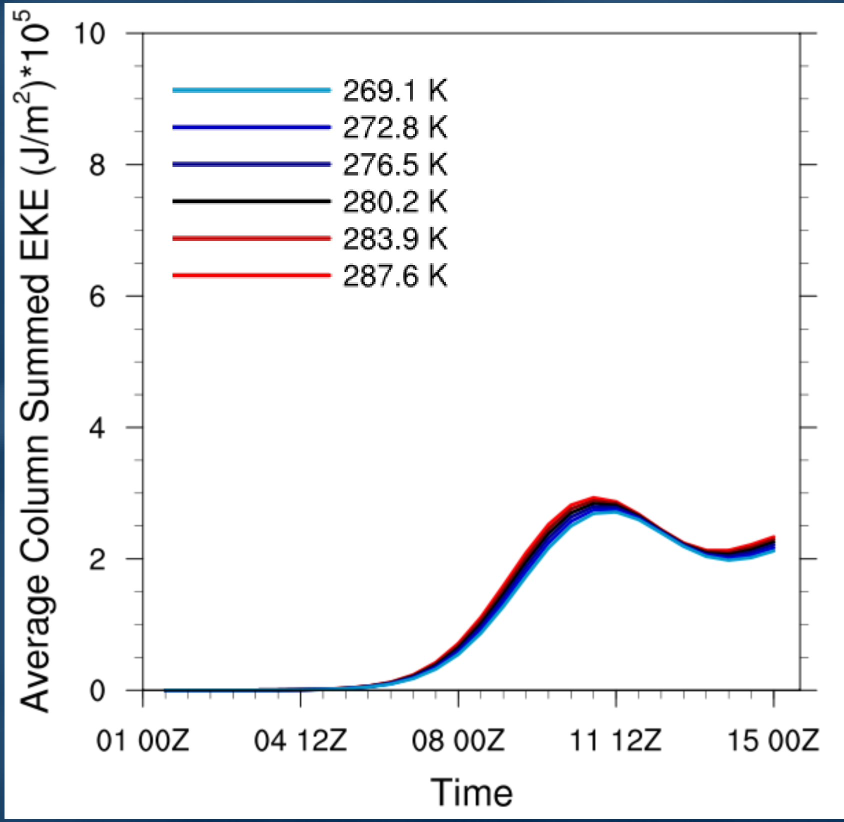
Model Version	WRF V 3.5.1
Grid Spacing	25 km
Domain Size	160 pts E-W, 360 pts N-S 50 vertical levels
Output Frequency	3 hours
Run Duration	14 Days
Microphysics	Morrison Two-Moment
Boundary Layer Scheme	YSU
Cumulus Scheme	Kain-Fritsch
Radiation Scheme	None

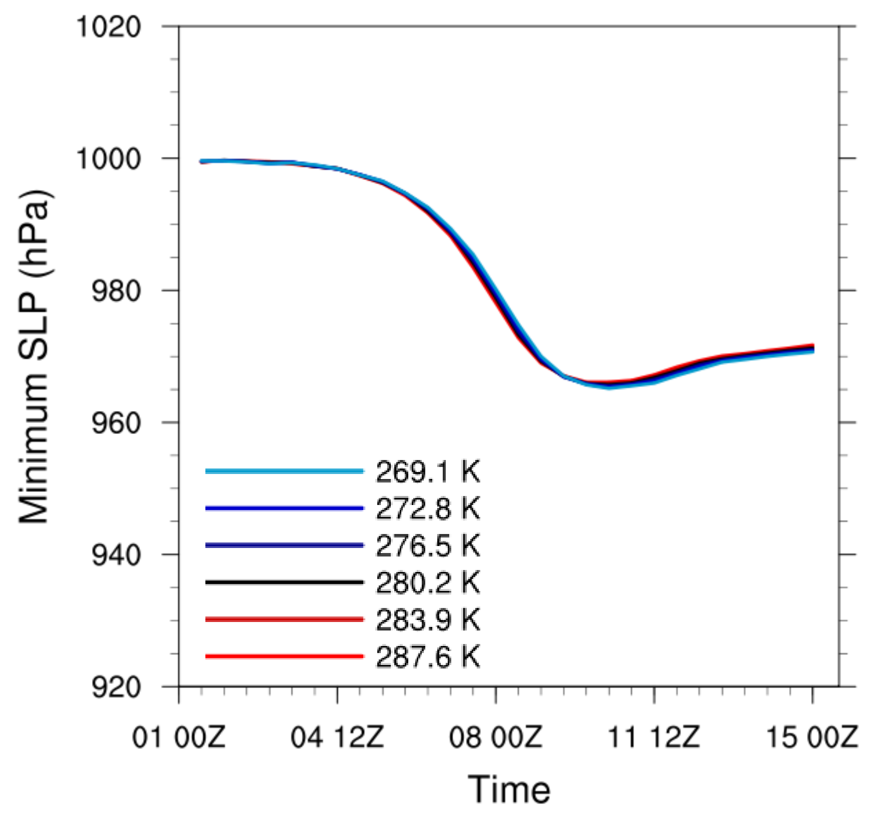


Sensitivity Analysis Framework

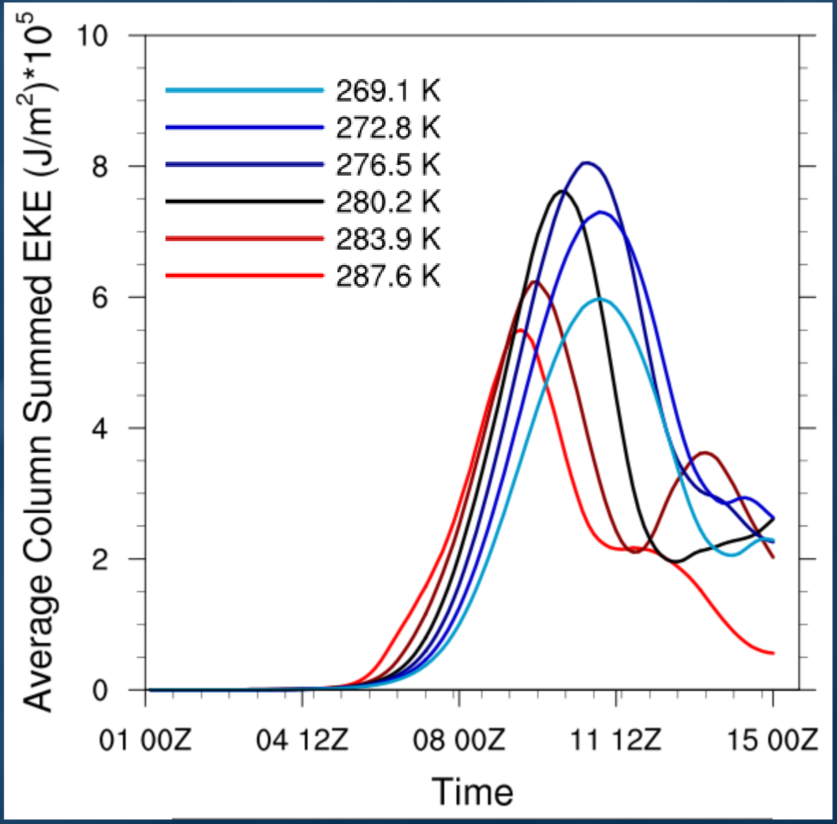
- Tested range of “anchor” temperatures
  - 288 – 308 K, stepped by 4 K
  - Results in domain centered temperatures between 269.1 K – 287.6K
- For each run, the baroclinicity and vertical lapse rates are nearly identical.

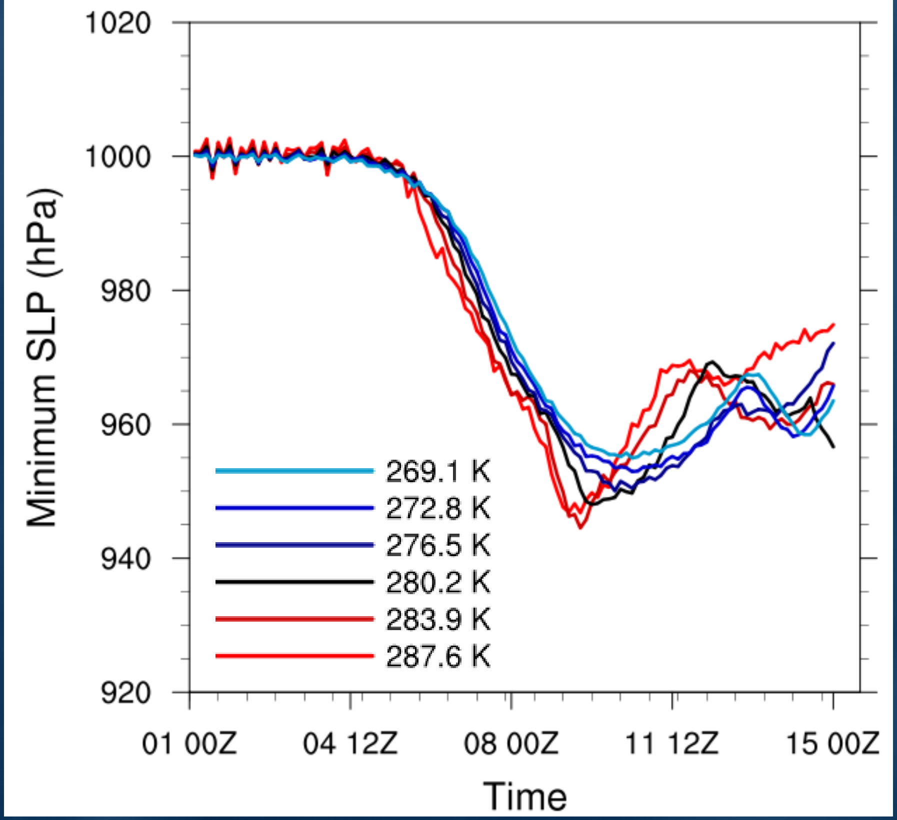
No Latent Heating ΔT Results – EKE & Minimum Sea Level Pressure





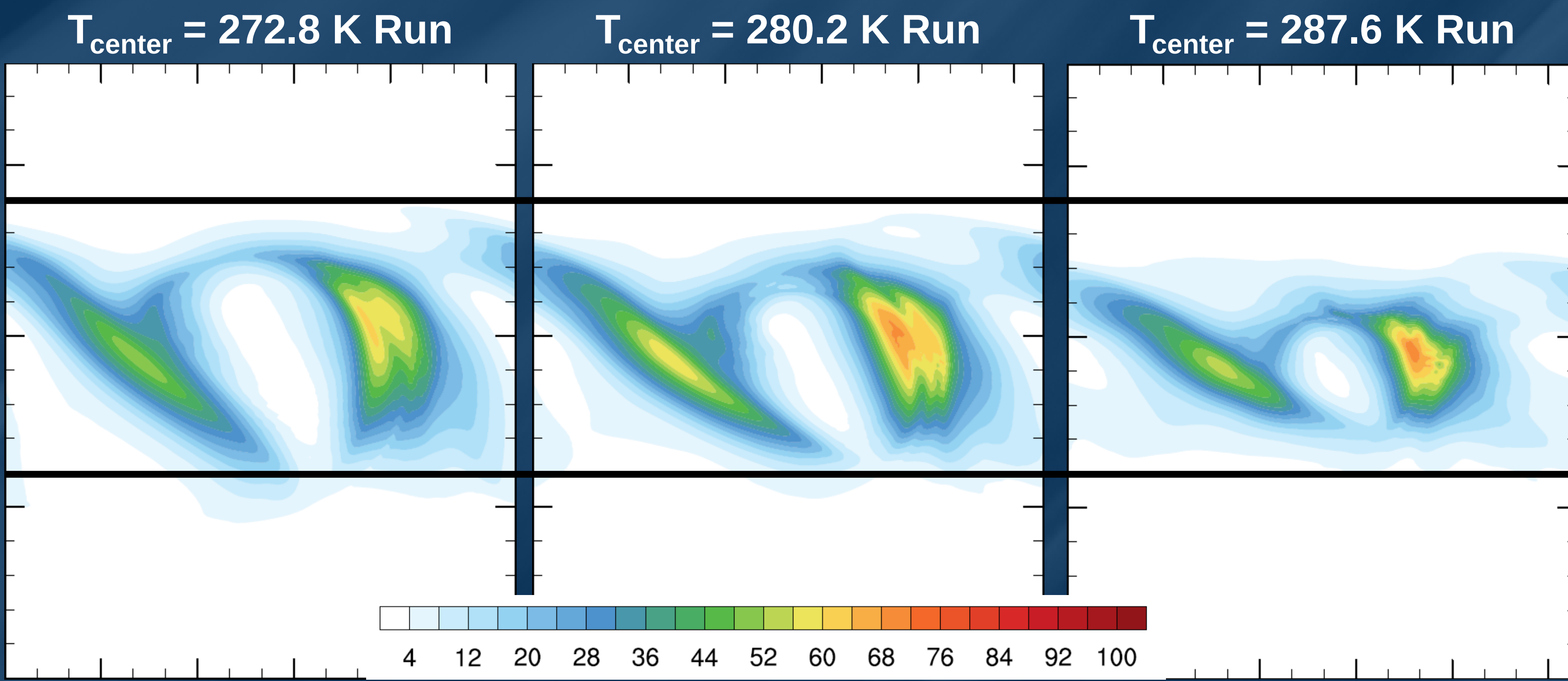
Moist ΔT Results – EKE & Minimum Sea Level Pressure





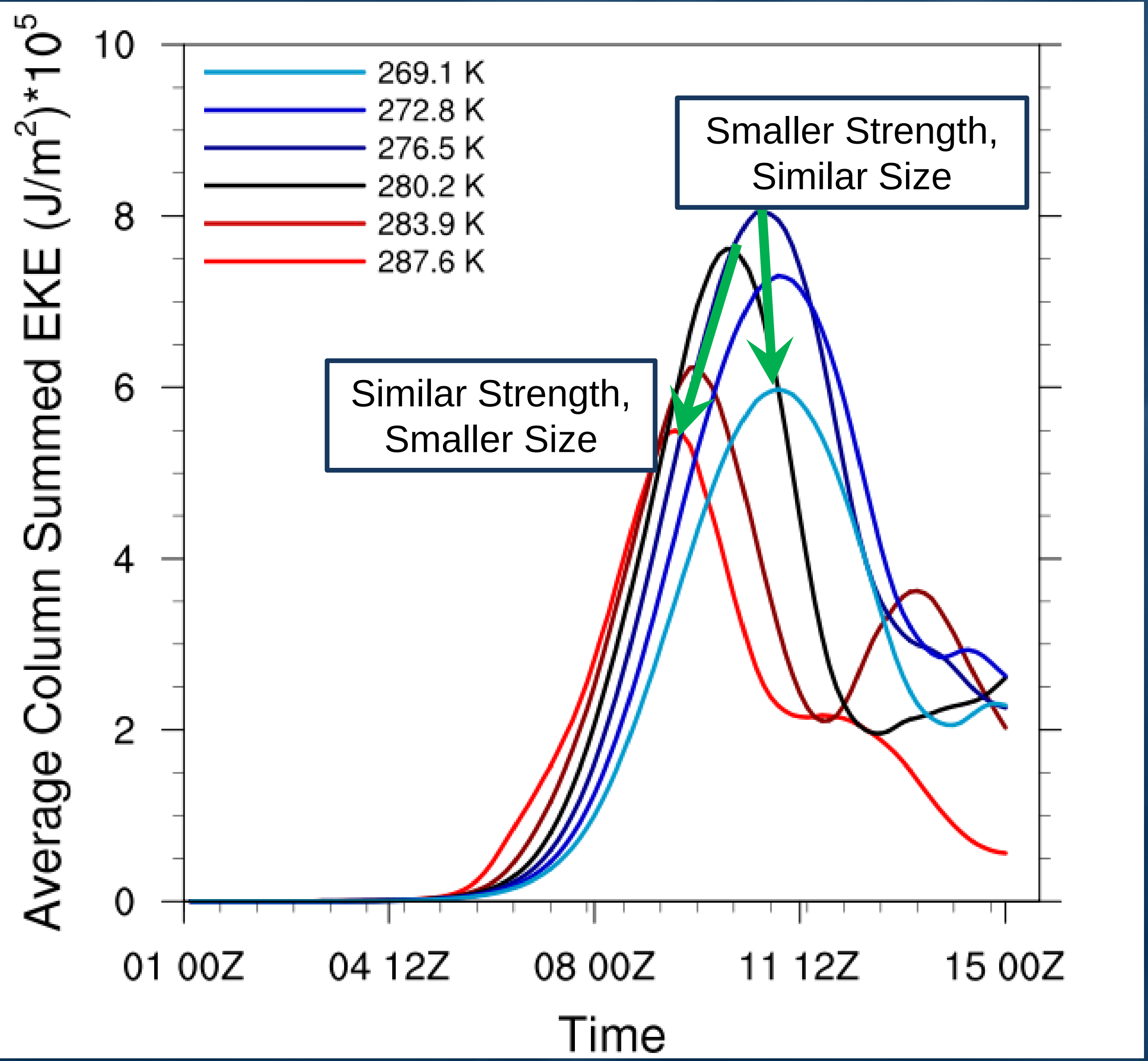
Similar to results of Booth et al (2012), who varied moisture content synthetically

Moist ΔT Results – EKE Map at $t_{Max\ EKE}$

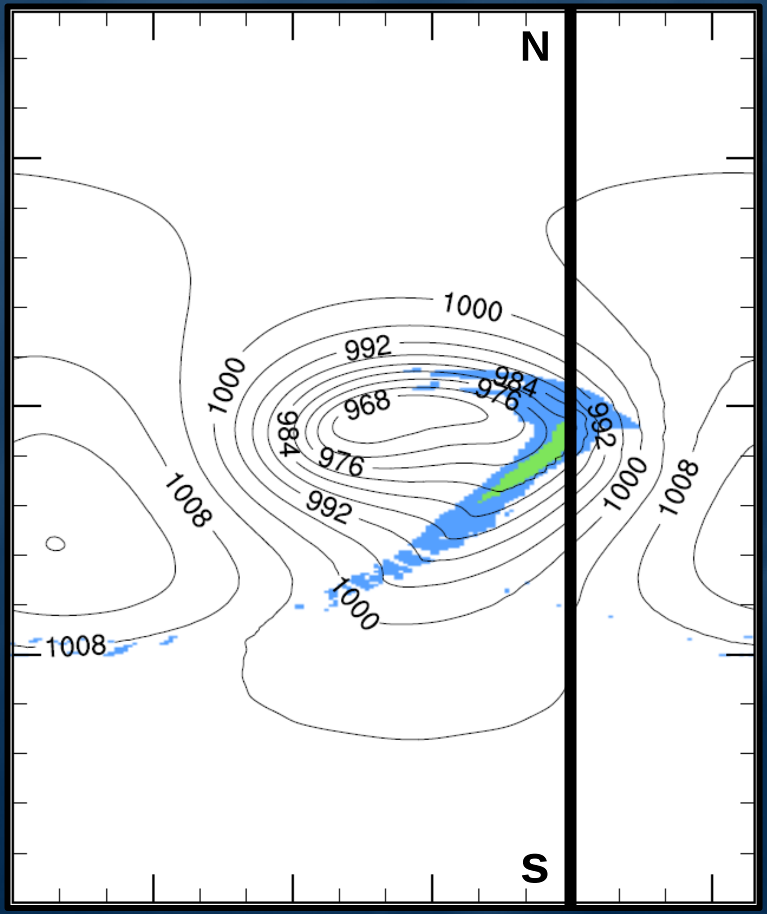


Column-Summed EKE [(J/m²)*10⁵]

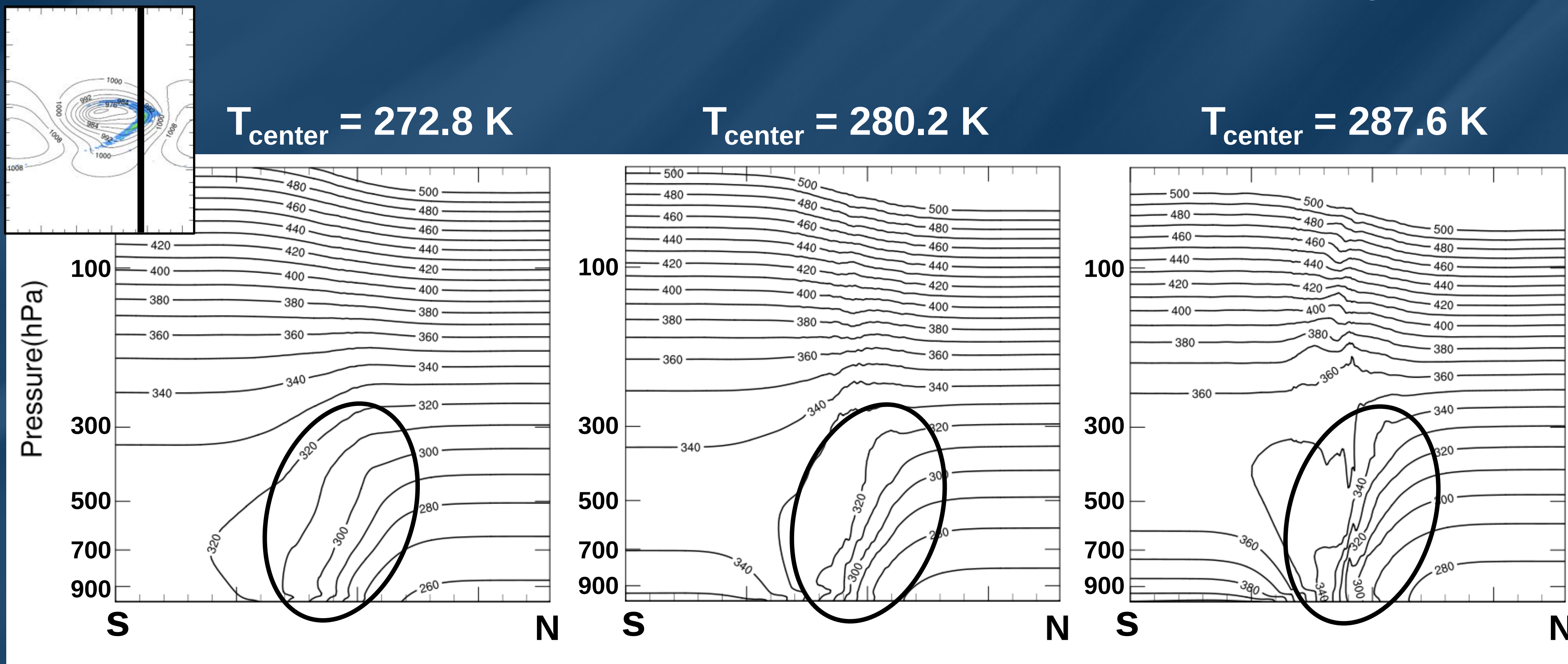
Storm size decreases with warming environment!


Average Column Summed EKE (J/m^2)*10^5
10
8
6
4
2
0
269.1 K
272.8 K
276.5 K
280.2 K
283.9 K
287.6 K
Smaller Strength,
Similar Size
Similar Strength,
Smaller Size
01 00Z
04 12Z
08 00Z
11 12Z
15 00Z
Time

Moist ΔT Results – Θ_E Cross-sections 48 hrs prior to $t_{Max\ EKE}$



Moist ΔT Results – Θ_E Cross-sections 48 hrs prior to $t_{Max\ EKE}$

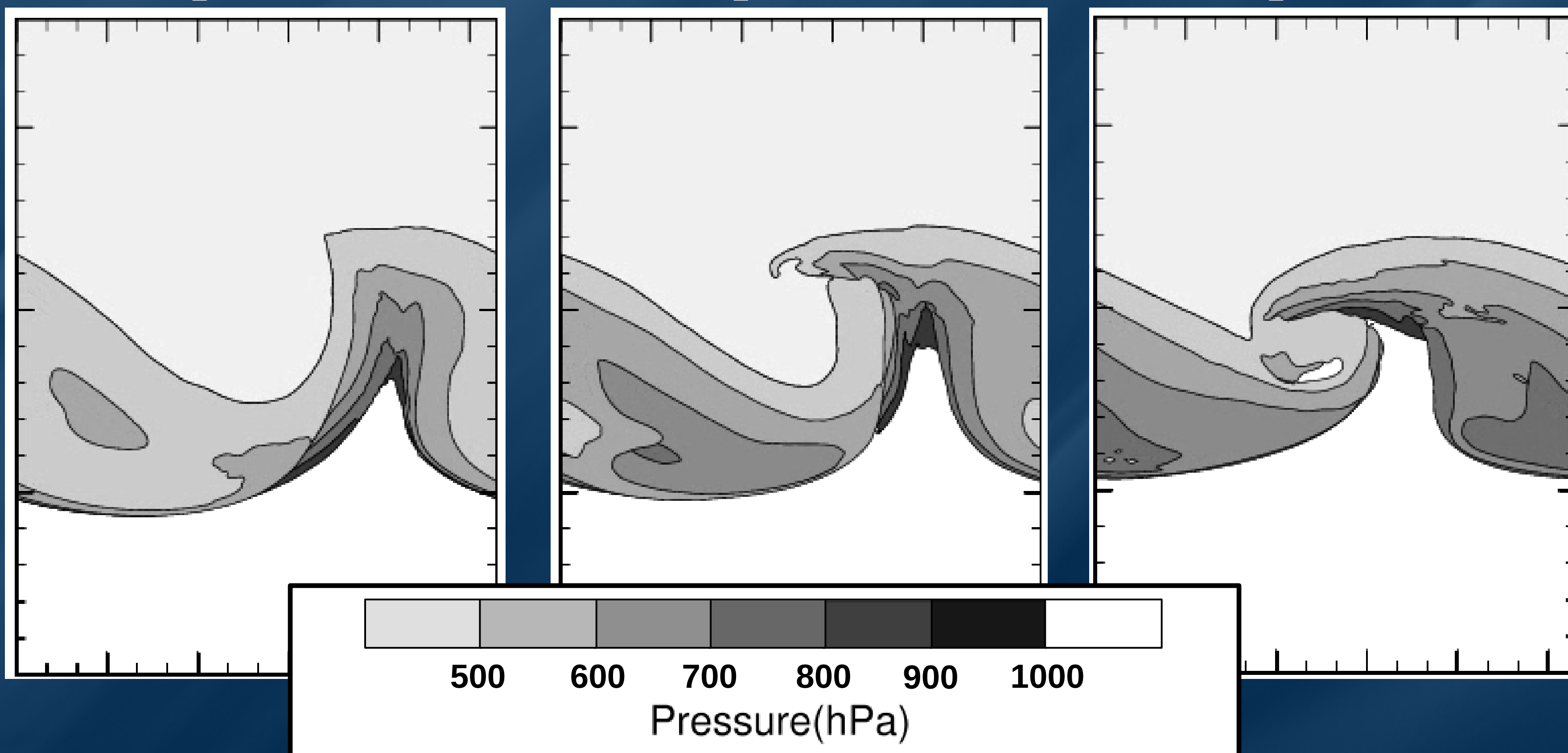


Increasing role of convective processes as compared to stratiform!

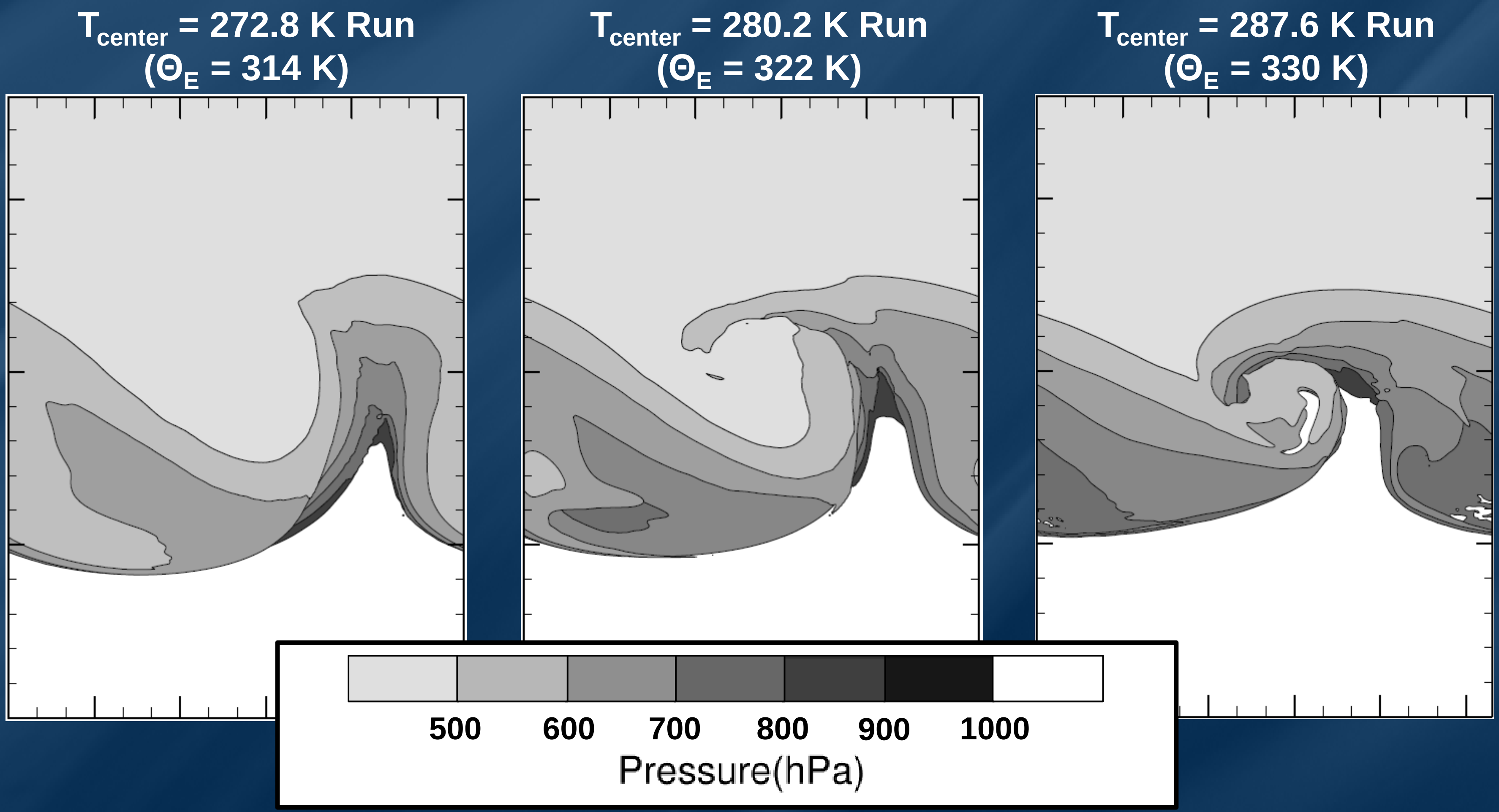
Moist ΔT Results – Isentropic Surface Map

(Depiction of Frontal Surfaces)

T_{center} = 272.8 K Run (Θ_E = 314 K) | **T_{center} = 280.2 K Run (Θ_E = 322 K)** | **T_{center} = 287.6 K Run (Θ_E = 330 K)**



Moist ΔT Results – Isentropic Surface at $t_{Max\ EKE}$



Mechanism Summary

Warmer Temperatures

↓

Increased Isentropic Lift in Warm Conveyor Belt

Increase in Convection and Latent Heat Release

Column heating and vortex stretching

Smaller cyclone via conservation of angular momentum

↓

Non-monotonic maximum values of EKE

Future Work

- Exploration of the multivariate parameter space – what happens when temperature and baroclinicity are perturbed simultaneously?
- Movement to finer grid spacing – remove dependency on convection schemes
  - Requires exponentially more computing power, as well as increased data storage
- Introduction of radiation into the framework
  - In preliminary tests, our conclusions still hold

Summary

- Care must be taken in defining exactly what a “stronger” storm in a future climate.

- The vast majority of sensitivity to changes in temperature are a result of moist processes.

- With increasing temperatures, our results indicate:
  - Decreasing Minimum Sea Level Pressure
  - Non-monotonic maximum EKE values, with a tipping point between 276 – 280 K

- There is still work to be done in exploring the interplay between baroclinicity and temperature changes, as well as increasing our model resolution.

For a copy of these slides, links to previous work, and contact information:

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