A Multivariate Analysis of Extratropical Cyclone Environmental Sensitivity

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Extratropical Cyclone Ingredients

Baroclinicity

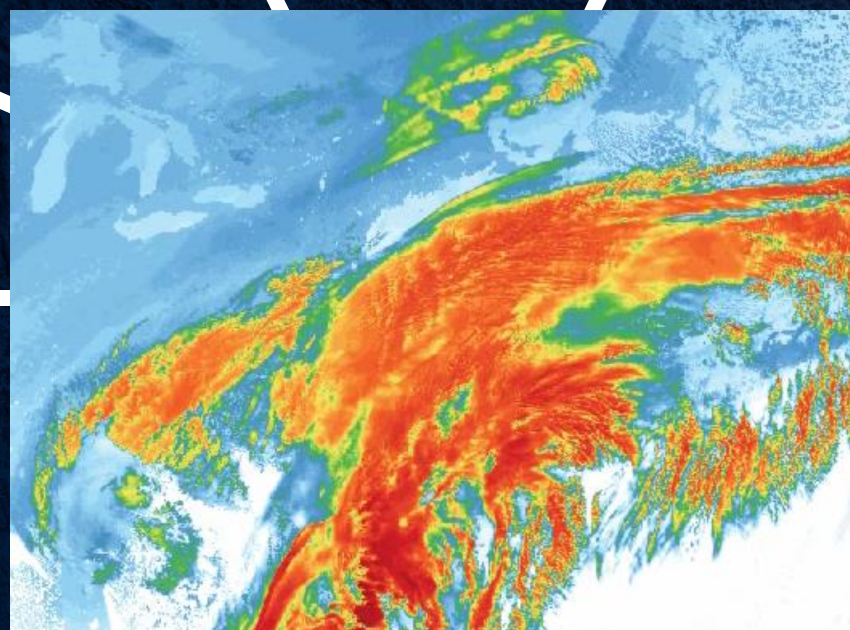
Sea Surface Temperature

Temperature

Moisture Content

Latent Heat Release

Stability



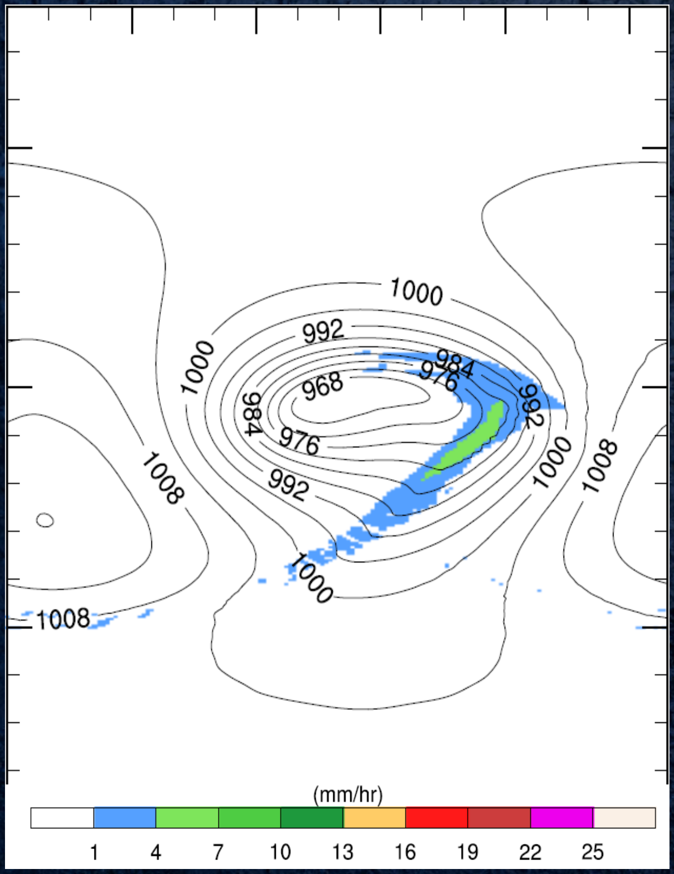
How might extratropical cyclones respond to varying environmental conditions?

An Idealized Framework for Sensitivity Analysis

Model Configuration

- Idealized channel model
  - East-west periodic boundary
- Ocean surface throughout model
- Initialized as in Wang and Polvani (2011)
  - Specify jet profile and “anchor” temperature at southern boundary leads to initial domain temperatures via thermal wind balance
- Initialized at 80% surface relative humidity, with profile as in Booth et al (2013)
- SSTs – static & set at initialization as -.5 K less than temperature above model level.

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
Radiation Scheme	None



An Idealized Framework for Sensitivity Analysis

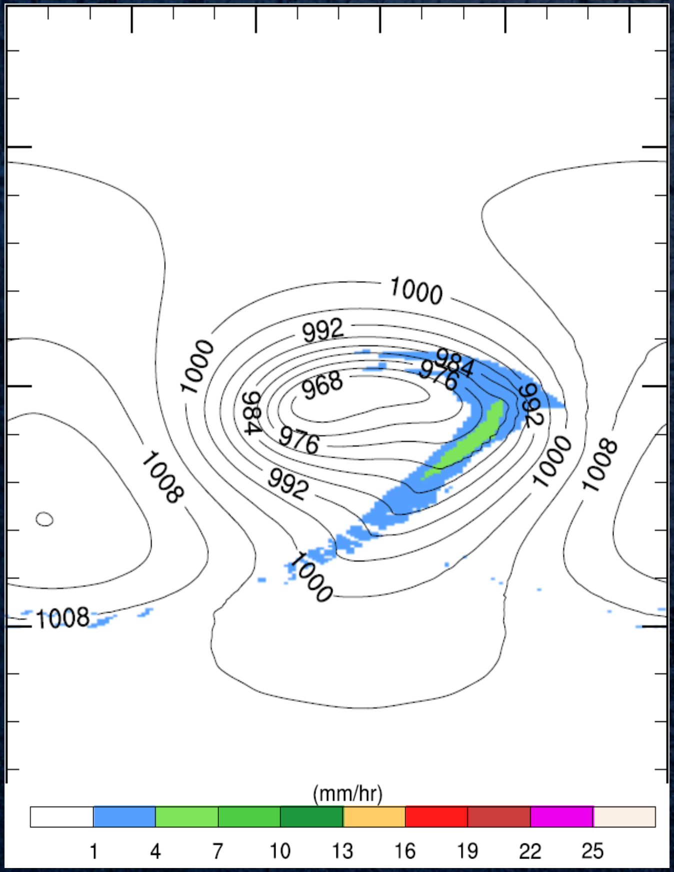
<u>Temperature Sensitivity Framework</u>

- Tested range of "anchor" temperatures
  - 288 – 308 K, stepped by 4 K
  - Results in domain centered temperatures between 269.1 K – 287.6K

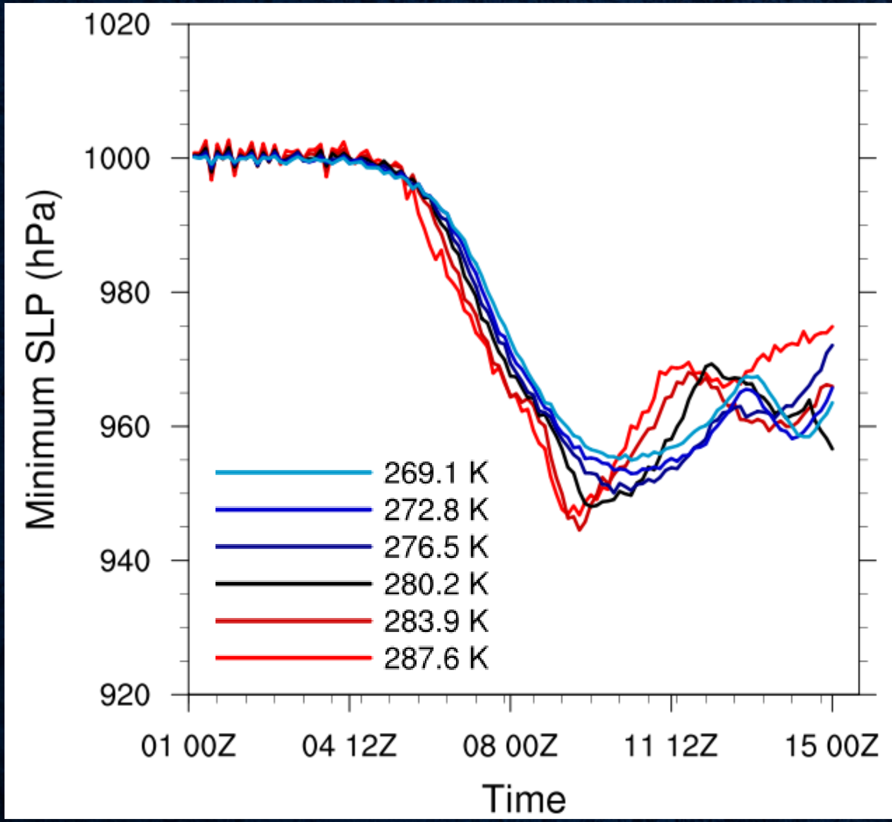
- Allows us to change the moisture and LHR effects via a more familiar method, rather than scaling LHR with a coefficient.

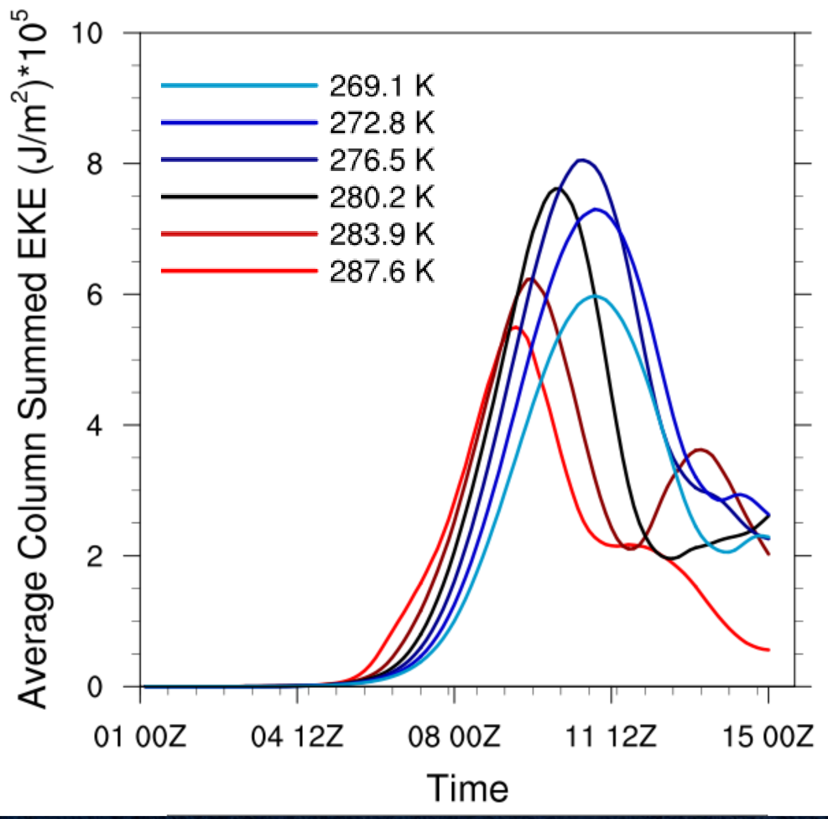
- The temperature of the <u>entire atmosphere</u> is increased, not just the surface temperature.

- **For each run, the baroclinicity and vertical lapse rates are nearly identical.**



Moist ΔT Results – EKE & Minimum Sea Level Pressure

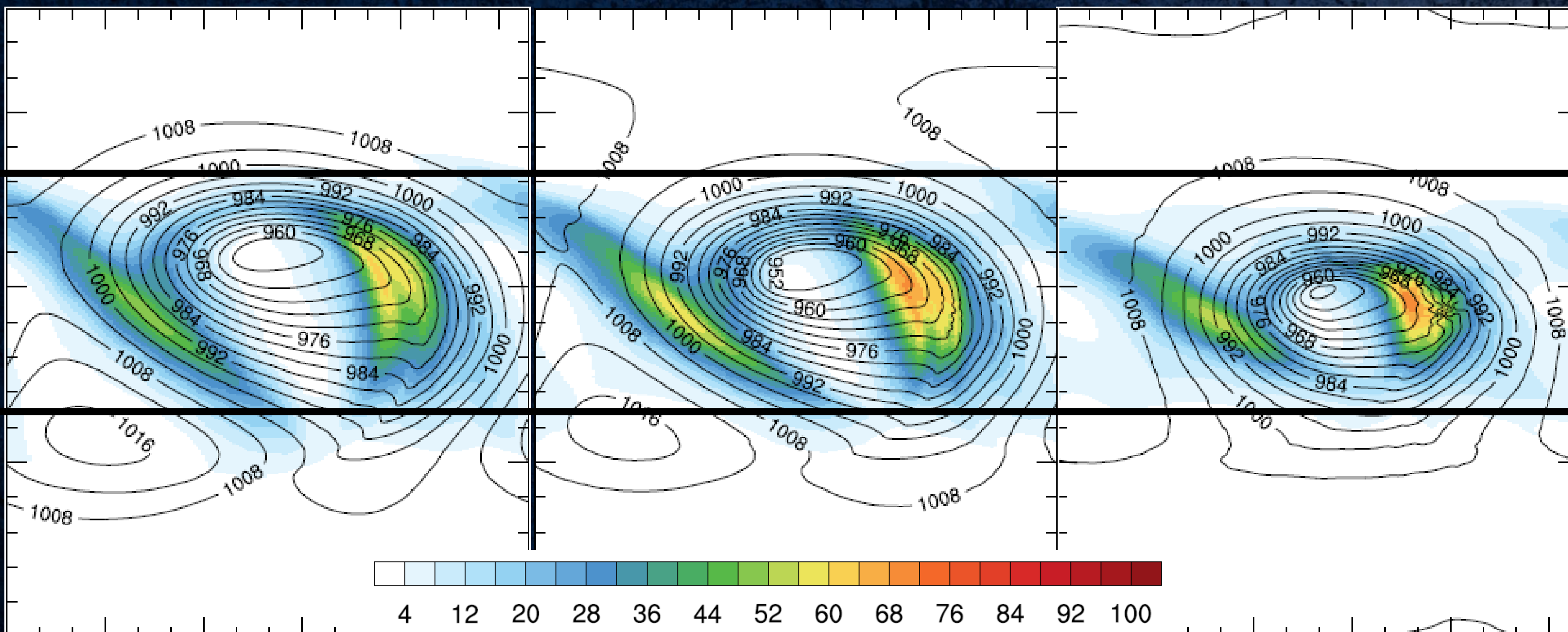




Similar to results of Booth et al (2013), who varied moisture content synthetically

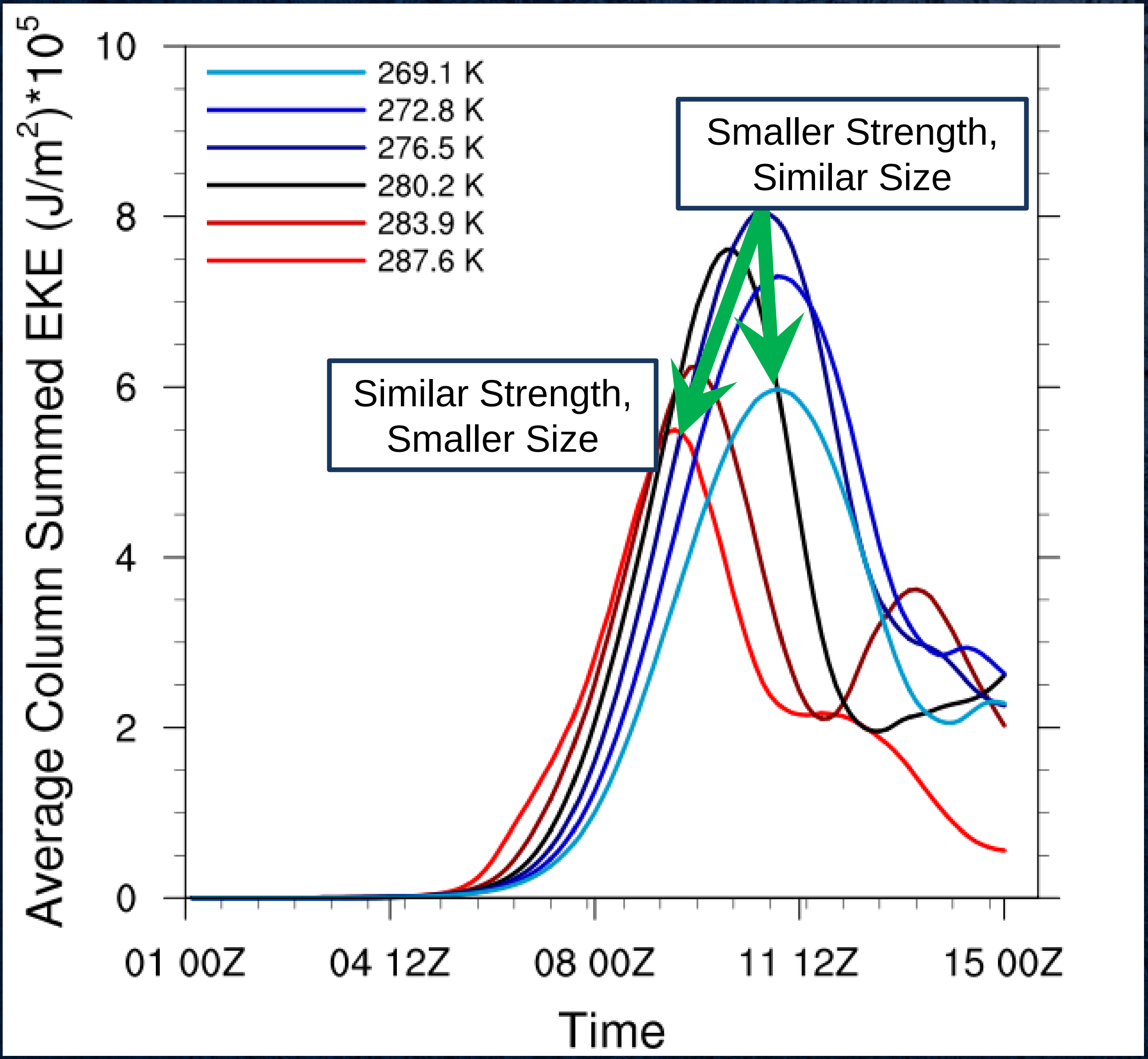
Moist ΔT Results – EKE Map at $t_{Max\ EKE}$

T_{center} = 272.8 K Run | **T_{center} = 280.2 K Run** | **T_{center} = 287.6 K Run**



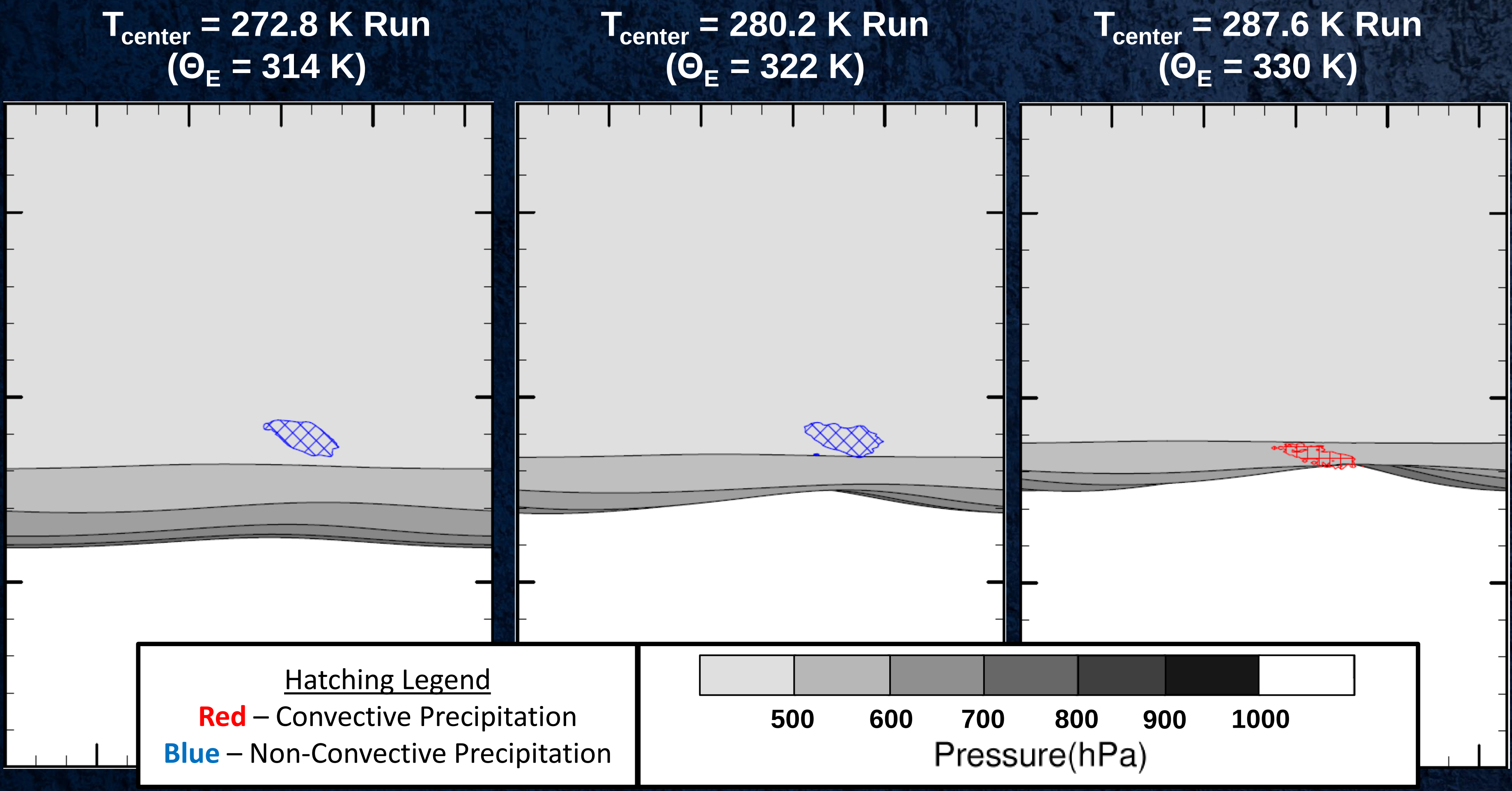
Column-Summed EKE [(J/m^2)*10^5]

Storm size decreases with warming environment!

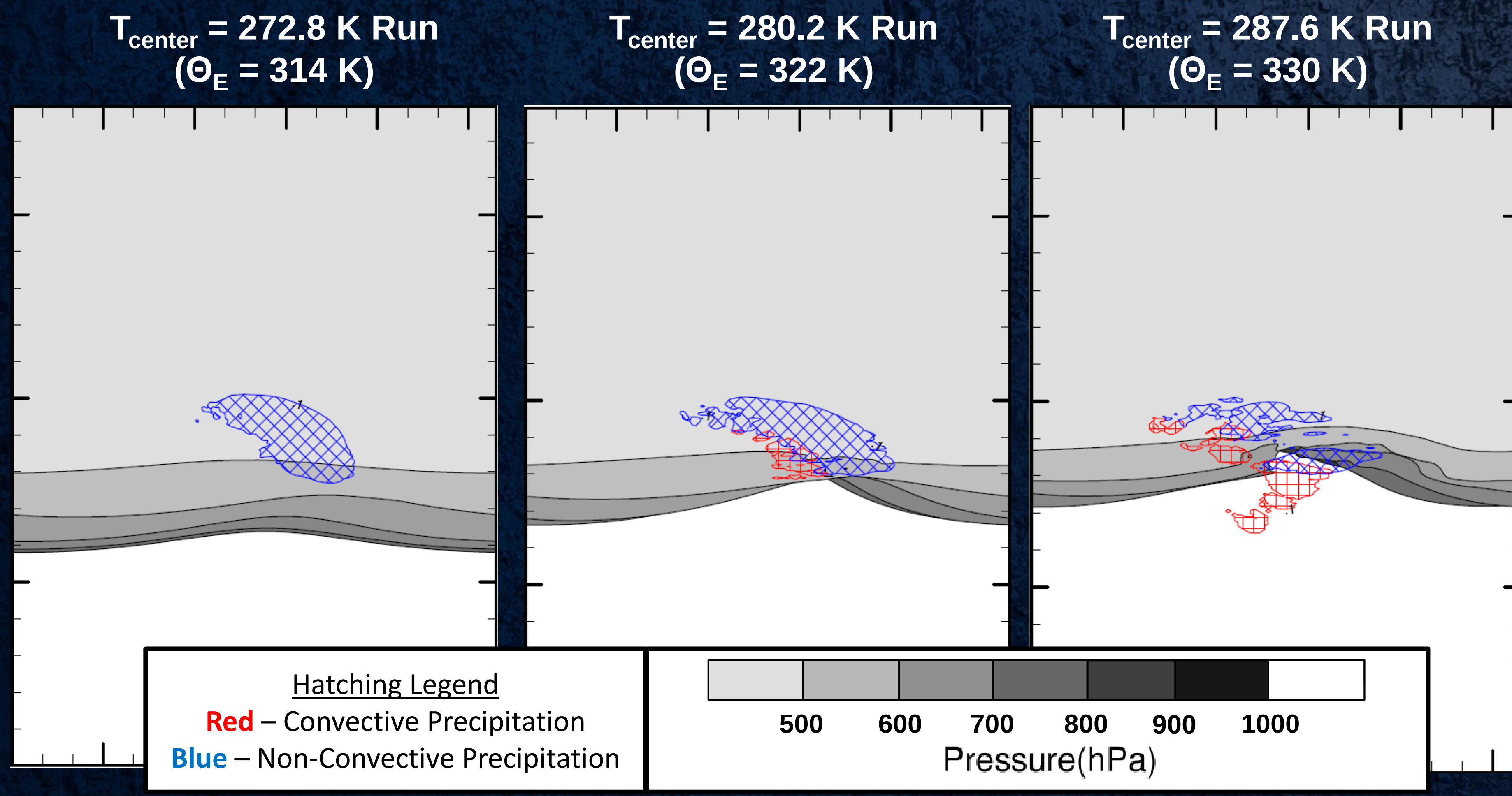


269.1 K
272.8 K
276.5 K
280.2 K
283.9 K
287.6 K
Smaller Strength,
Similar Size
Similar Strength,
Smaller Size
Average Column Summed EKE (J/m^2)*10^5
10
8
6
4
2
0
01 00Z
04 12Z
08 00Z
11 12Z
15 00Z
Time

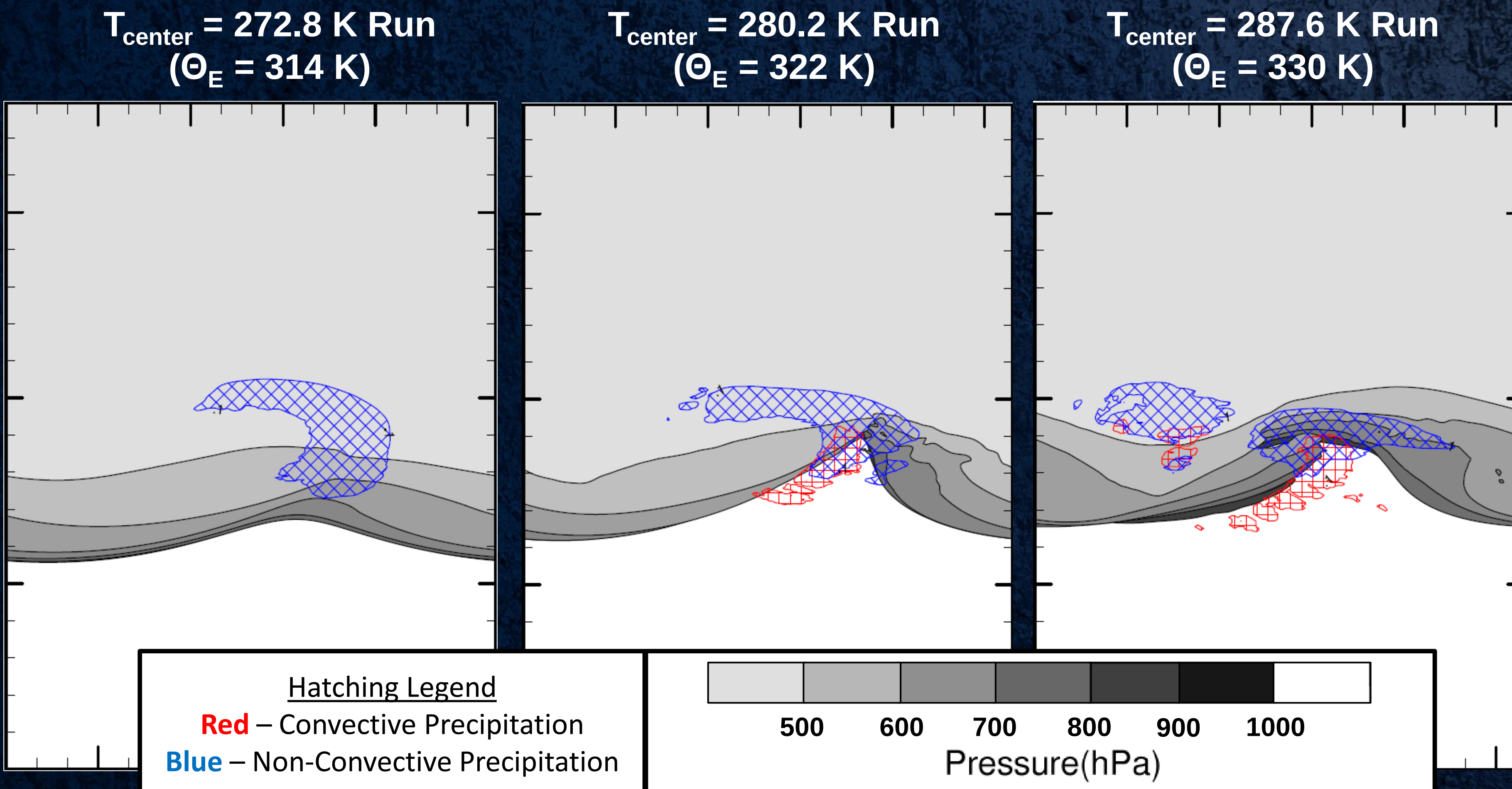
Moist ΔT Results – Isentropic Surface at $t_{\text{First Precip + 00hrs}}$



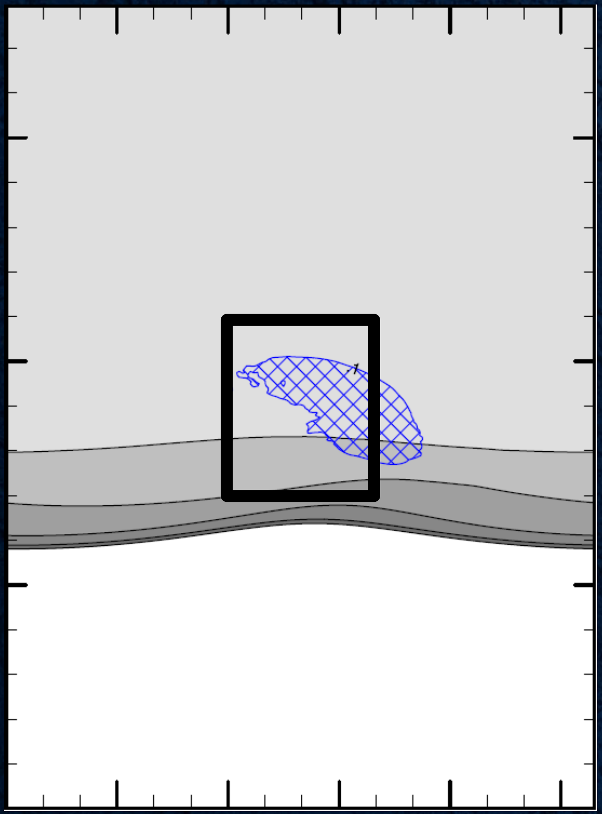
Moist ΔT Results – Isentropic Surface at $t_{\text{First Precip + 24hrs}}$

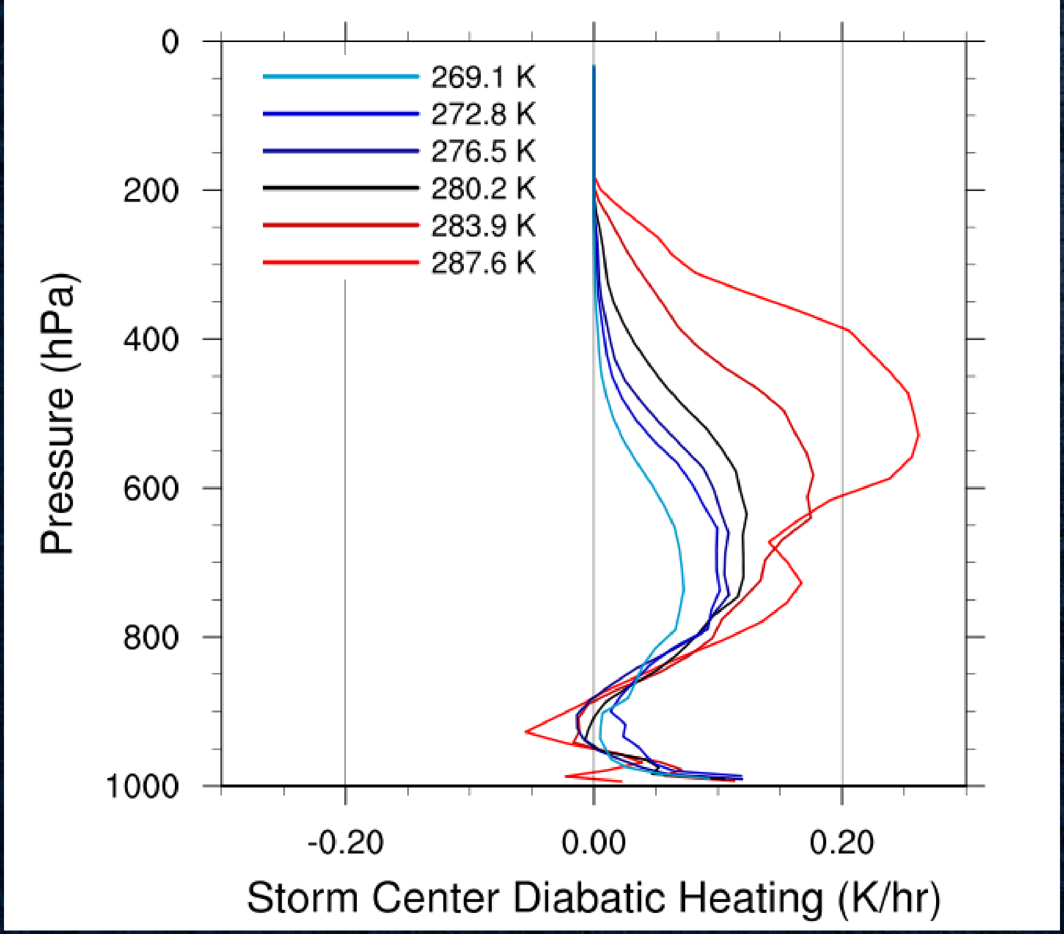


Moist ΔT Results – Isentropic Surface at $t_{First\ Precip + 48hrs}$



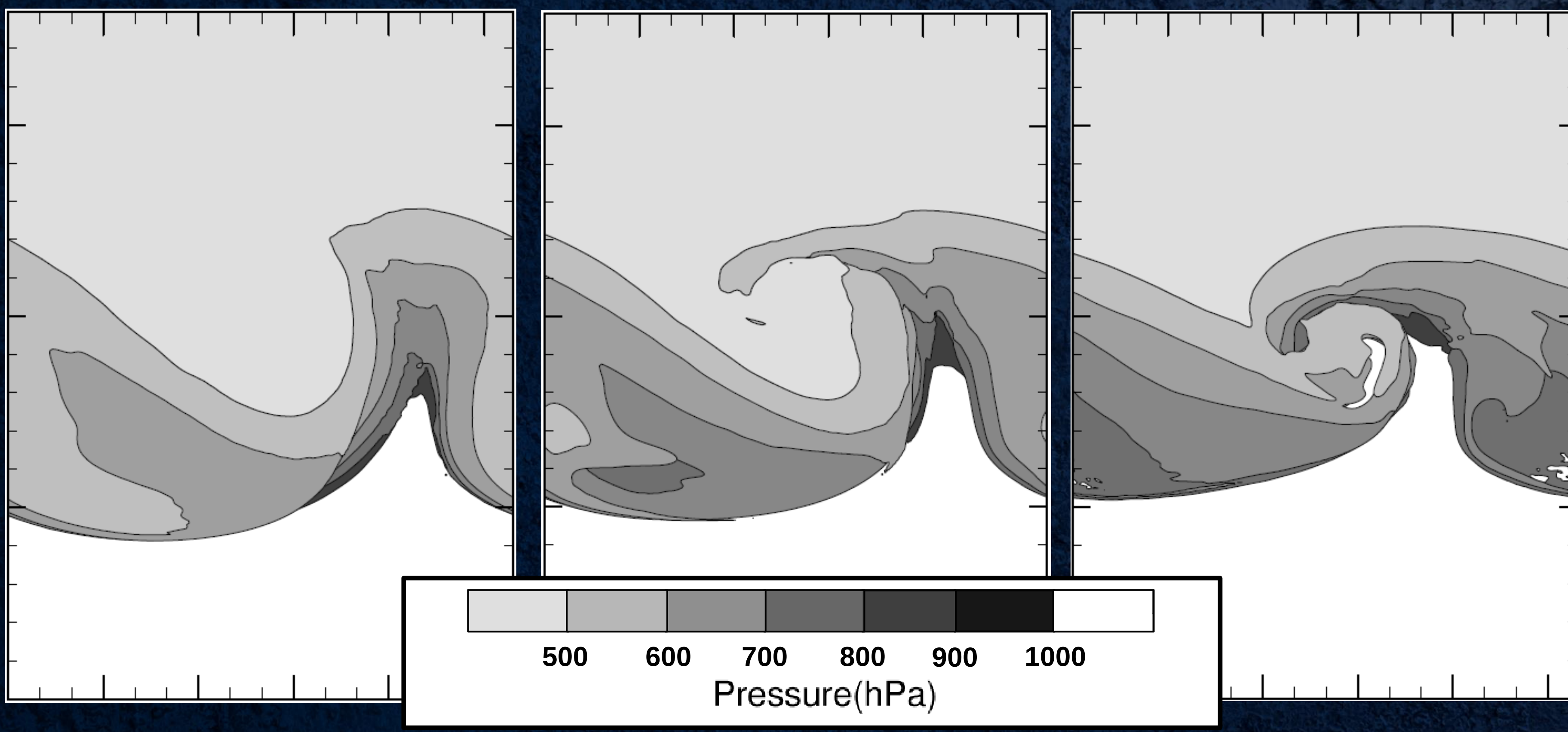
LHR Profile – Storm Center 72-48 hours before $t_{Max\ EKE}$





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

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)**



Mechanism Summary

Warmer Temperatures

↓

Increased Isentropic Lift in Warm Conveyor Belt

↓

Increase in Convection and Latent Heat Release

↓

Column heating and vortex stretching

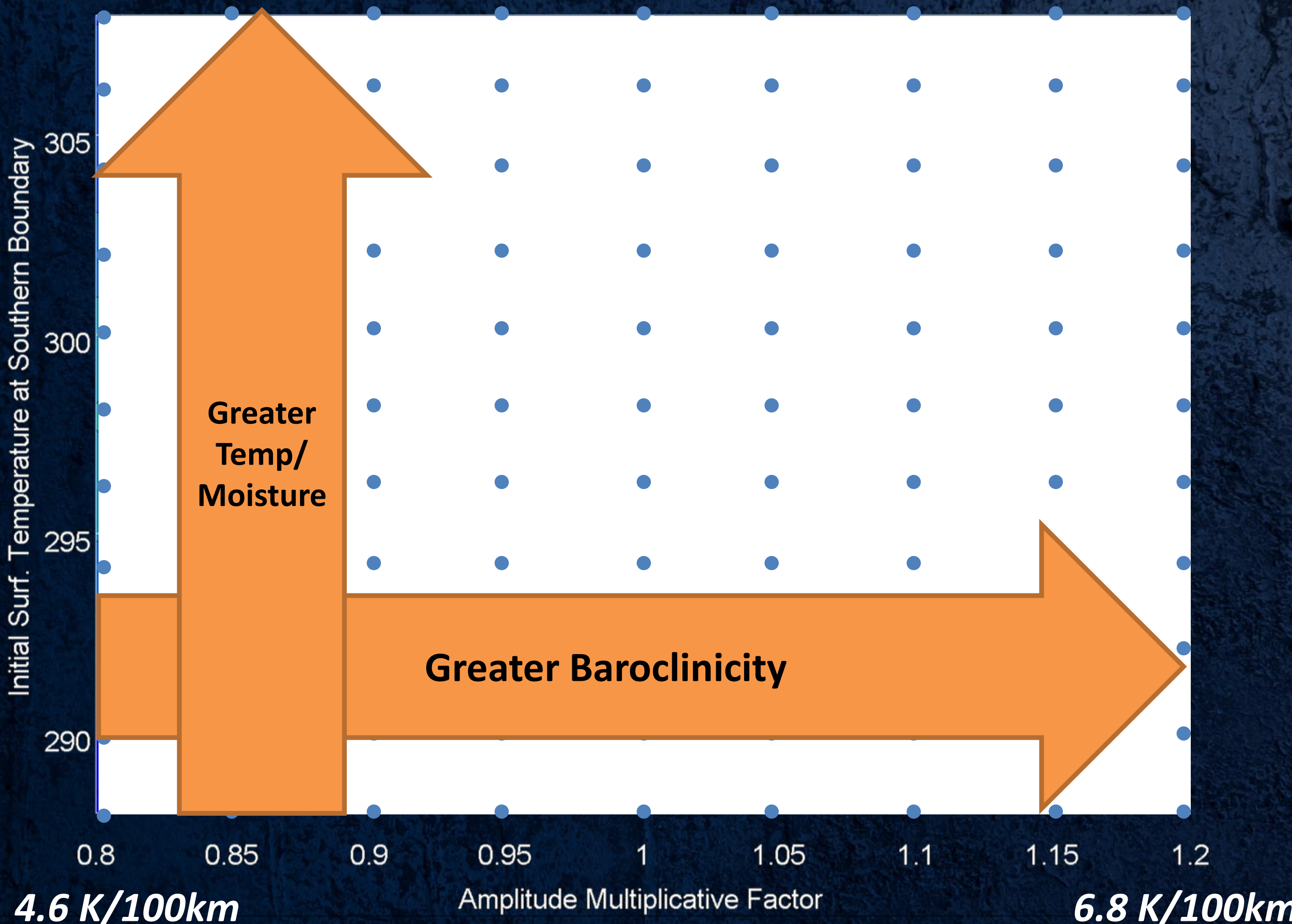
↓

Smaller cyclone via conservation of angular momentum

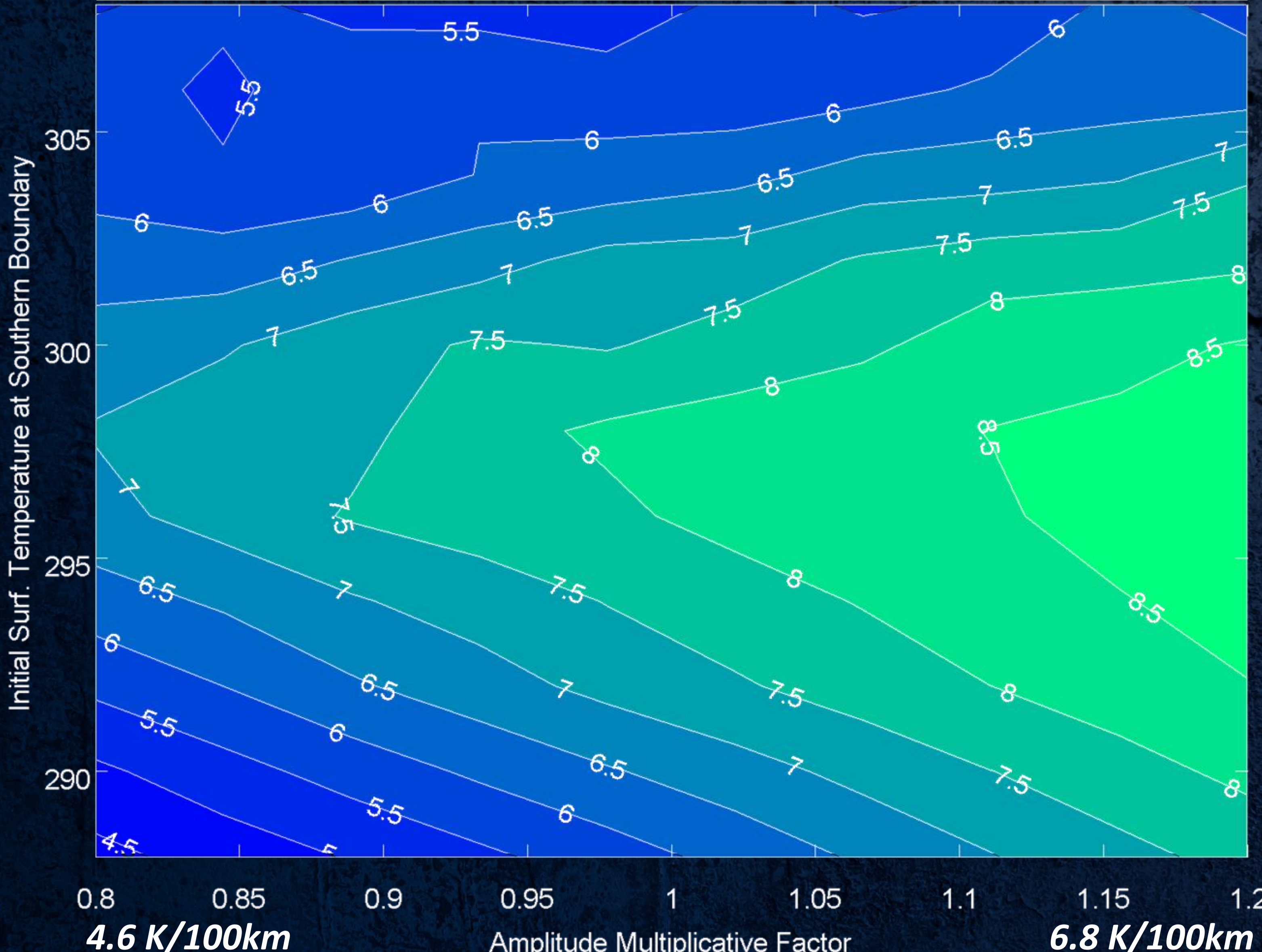
↓

Non-monotonic maximum values of EKE

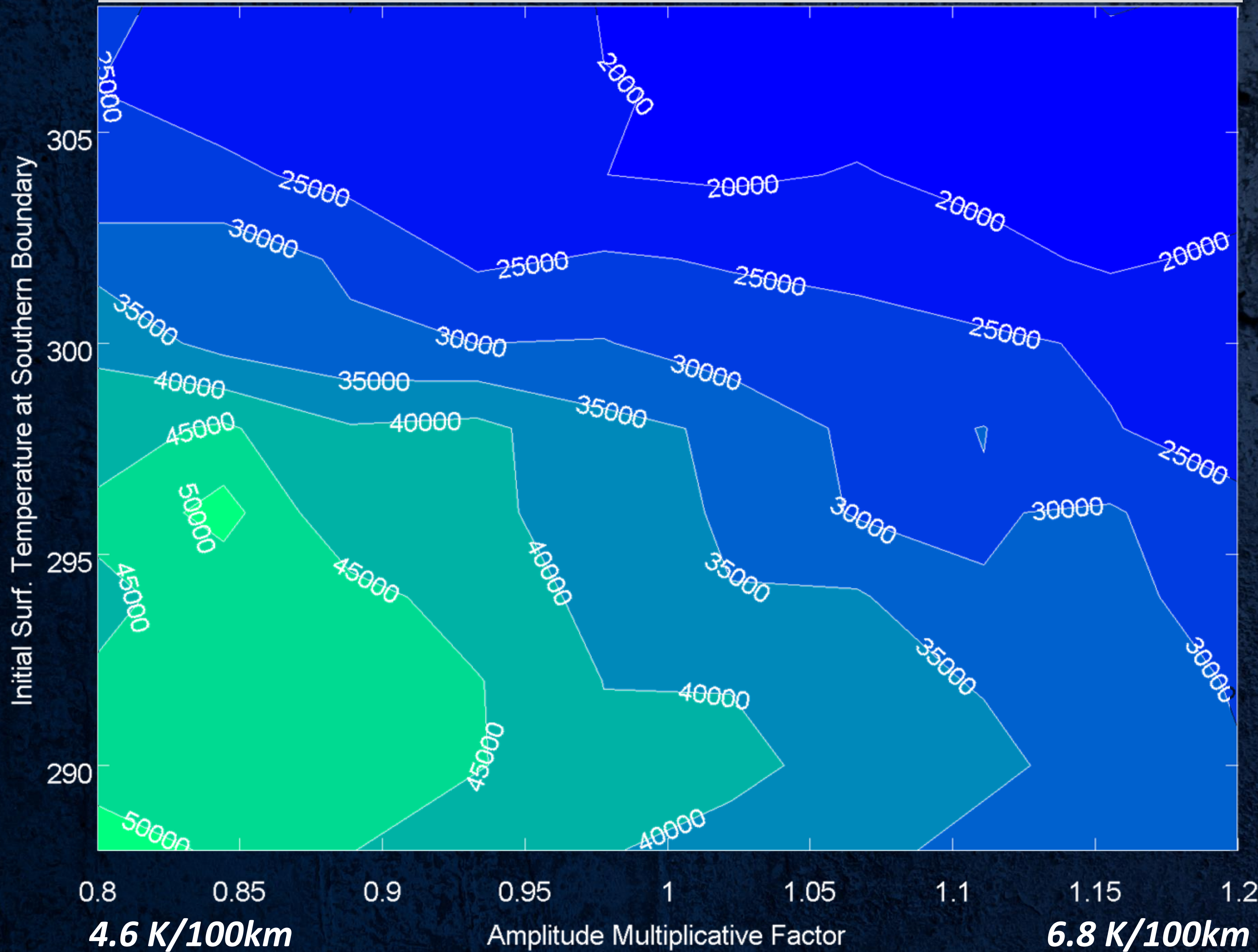
Bi-variate Parameter Space



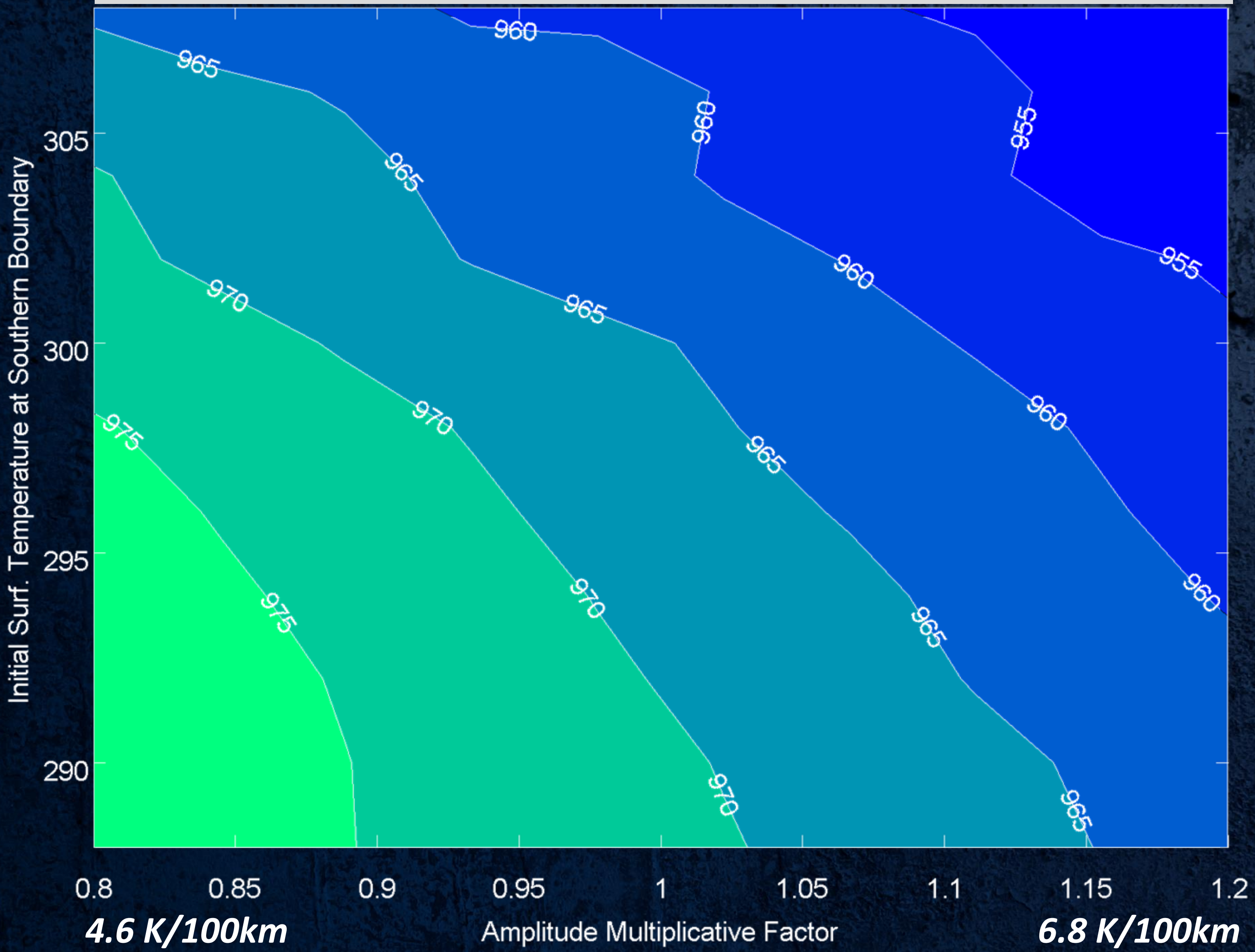
Maximum Average Column-Summed EKE $(J/m^2)*10^5$



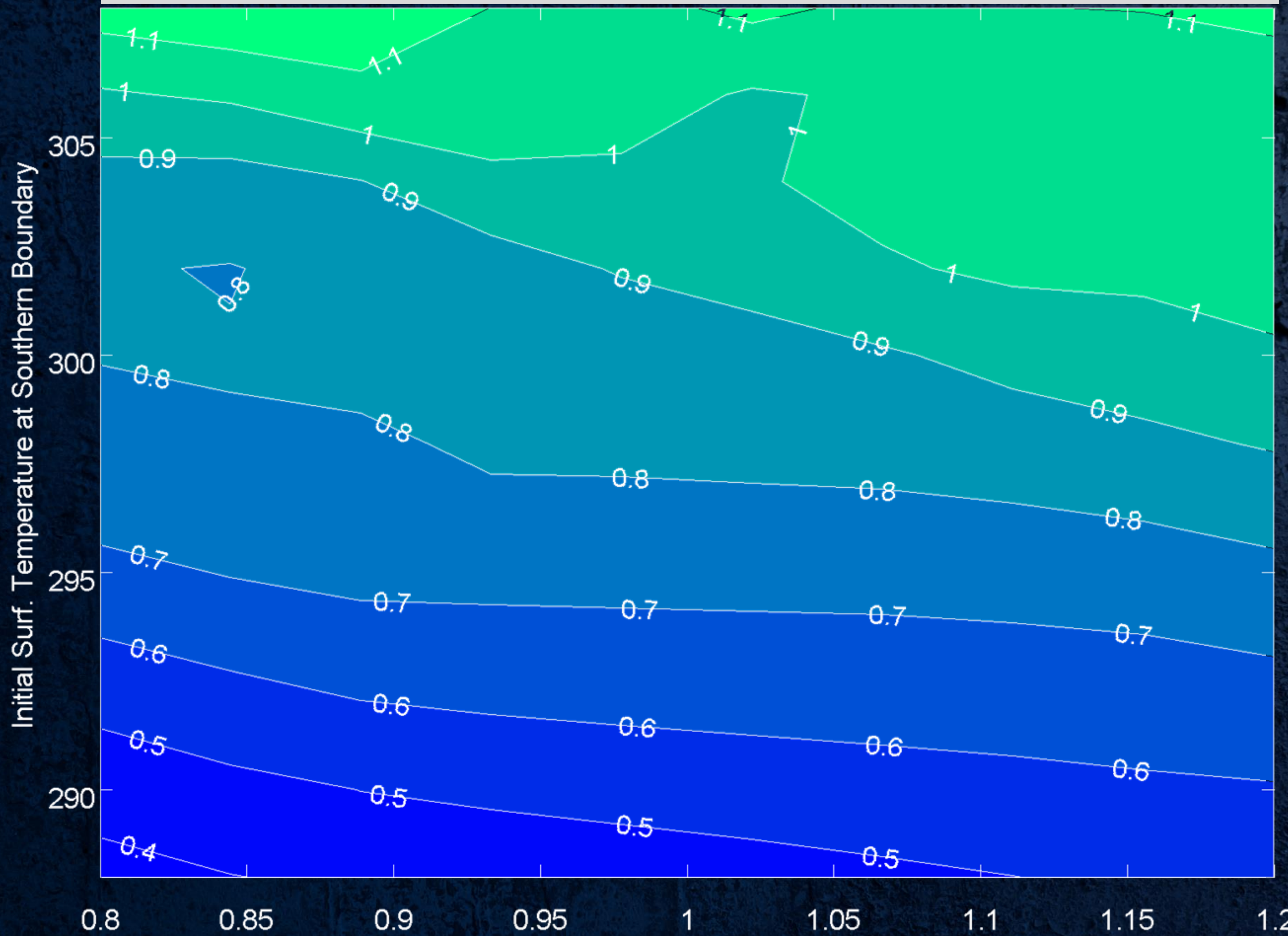
Approximate Area Inside (MinSLP + 30hPa) Contour (km^2)



9 Point Average Minimum Sea Level Pressure (hPa)

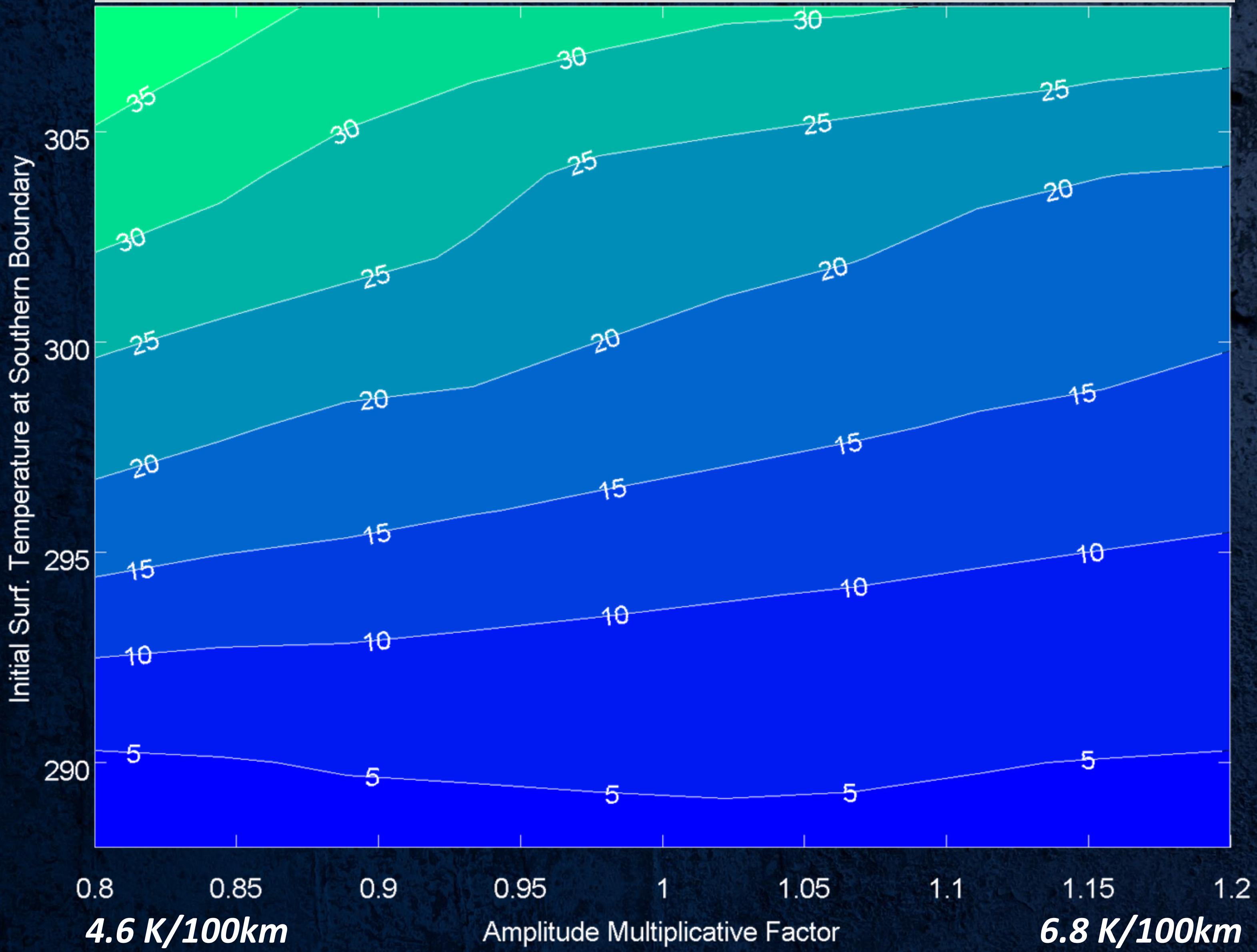


Average Total Precipitation (mm/day)



4.6 K/100km ***6.8 K/100km***

% of Total Precipitation from Convective Processes

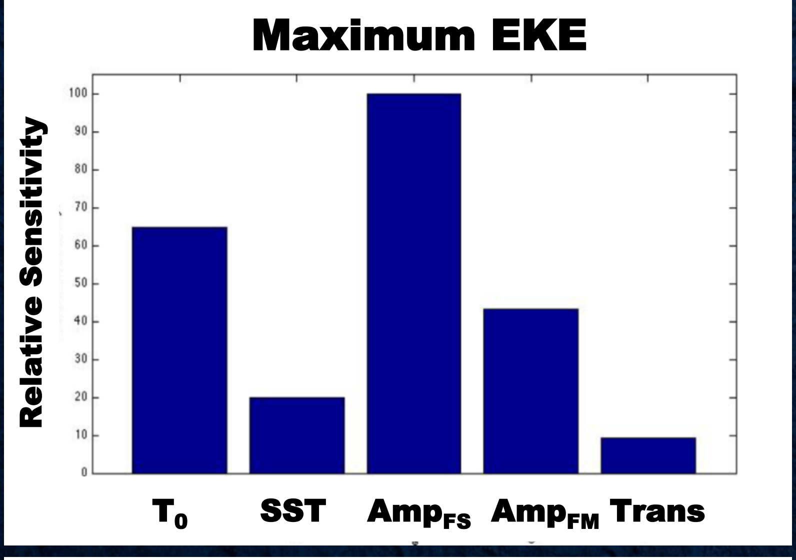


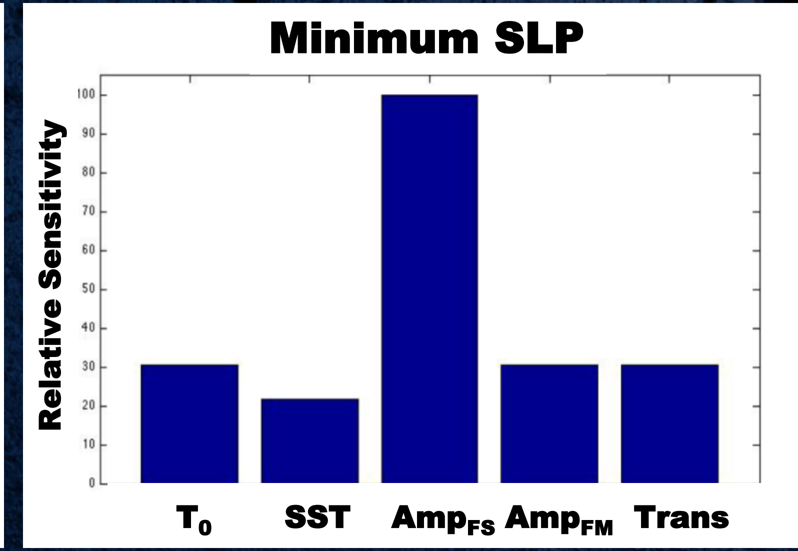
Future Work: To a Multivariate Space

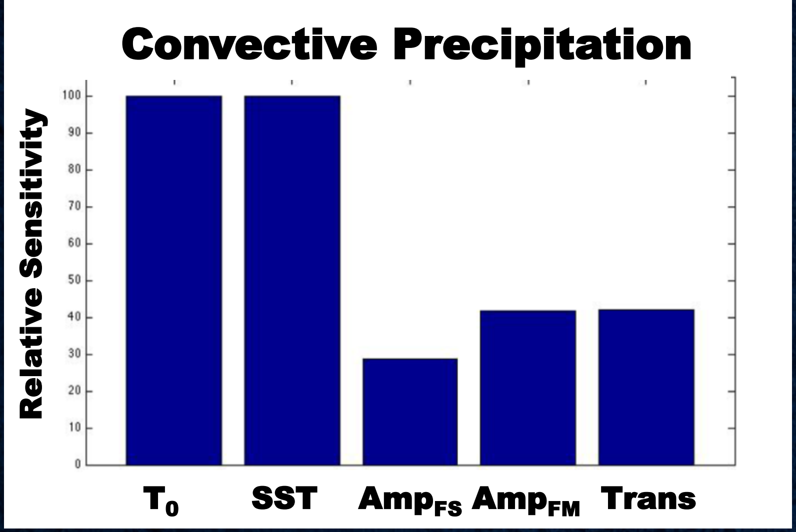
- Pilot experiment: 5D parameter space spanned by 100 model runs.
  - Latin Hypercube used to gain consistent coverage

- 5 Parameters
  - Bulk Temperature
  - Baroclinicity (Jet Profile Adjustment - Fixed Surface)
  - Baroclinicity (Jet Profile Adjustment - Fixed Maximum)
  - Shear Profiles (Jet Profile Adjustment - Translation)
  - Sea Surface Temperatures

Future Work: To a Multivariate Space







Can start to rank influences of input parameters on output metrics – very preliminary!

Additional Future Work

- Run at convection-permitting grid spacing (4km), removing possible impact of convective parameterizations
- Running the ensemble with radiation
  - Partially tested → Minimum SLP & Maximum EKE results do hold for temperature sensitivity.

Summary

- We can successfully reproduce the results of synthetic moisture variations by using more "natural" temperature changes.

- Increases in temperature (and thus moisture) led to deeper, more compact storms, as convection plays an larger and earlier role in the cyclone life cycle.

- An increased evolutionary role of convection is observed at a wide range of baroclinicities, even as other changes in precipitation and cloud properties are observed.