



Sensitivity of Tropical Cyclone Convection to the Initial Entropy Deficit

Joshua Alland, Brian Tang, and Kristen Corbosiero
University at Albany, State University of New York



How do varying entropy deficits
affect the evolution of a simulated
TC?



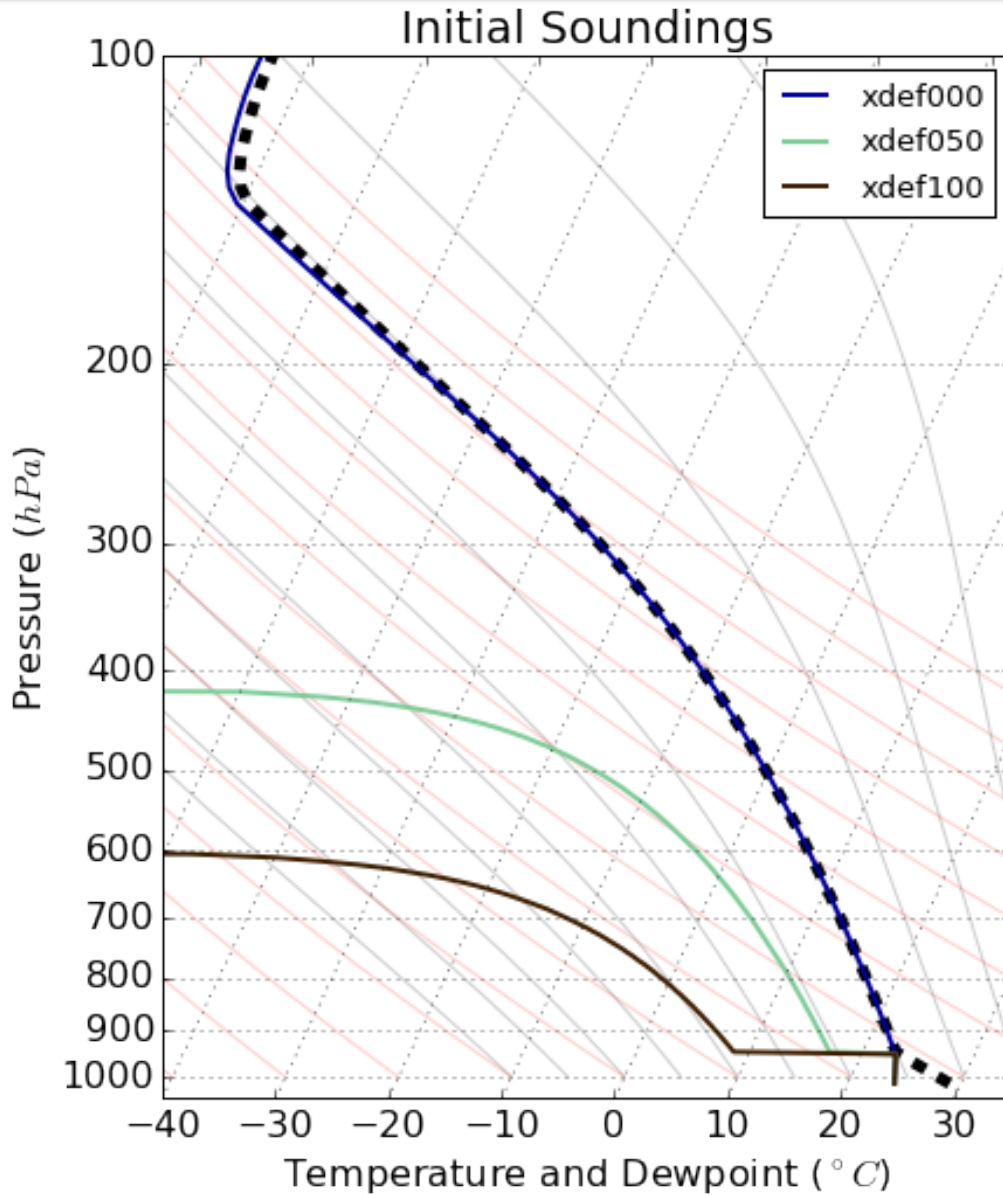
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Motivation

- ❑ Investigate differences in the distribution and strength of convection.
- ❑ Purpose: Gain insight into the role of free tropospheric moisture on the convective evolution and the spinup timescale of a TC.

Three Experimental Profiles

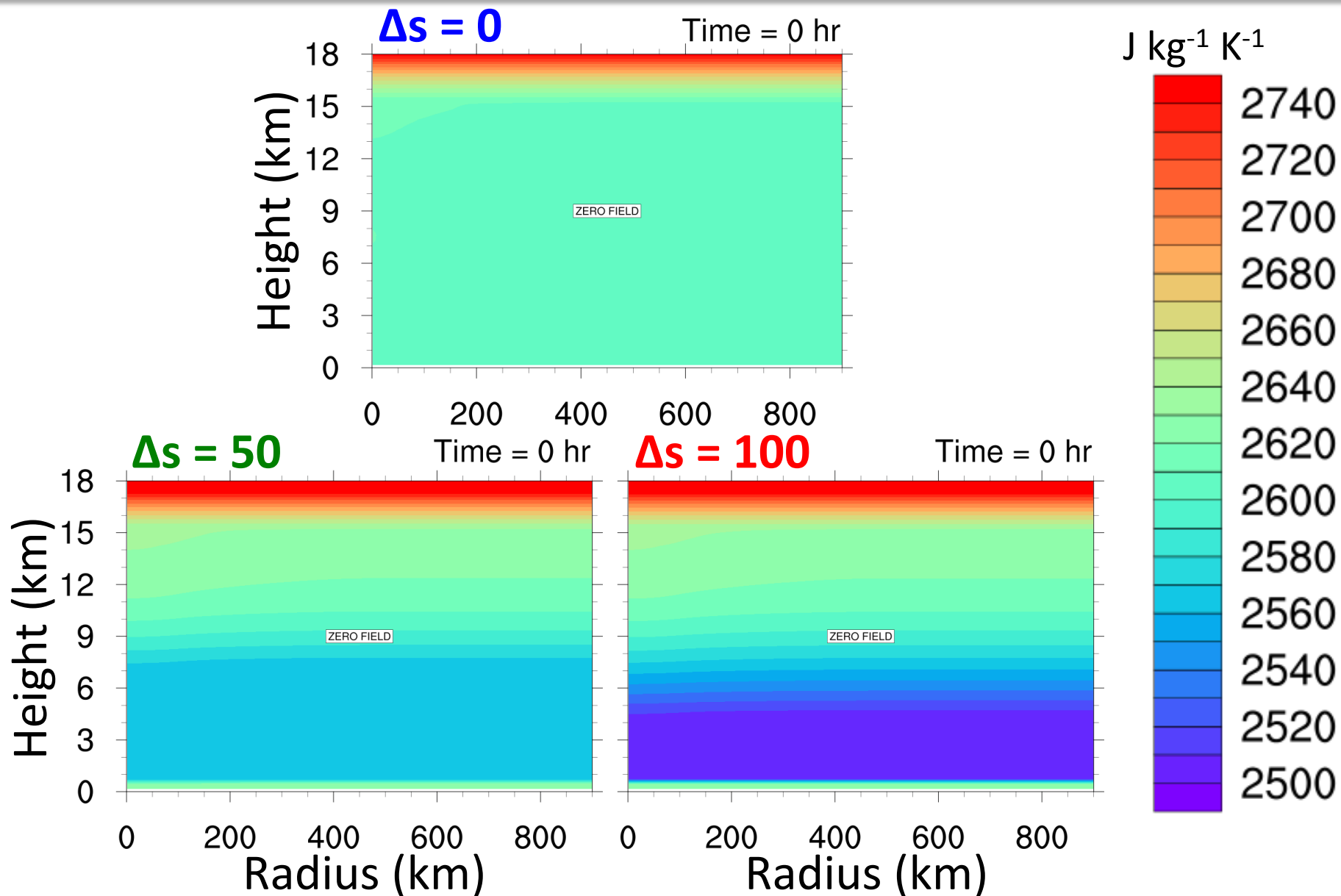


Moist: $\Delta s = 0$

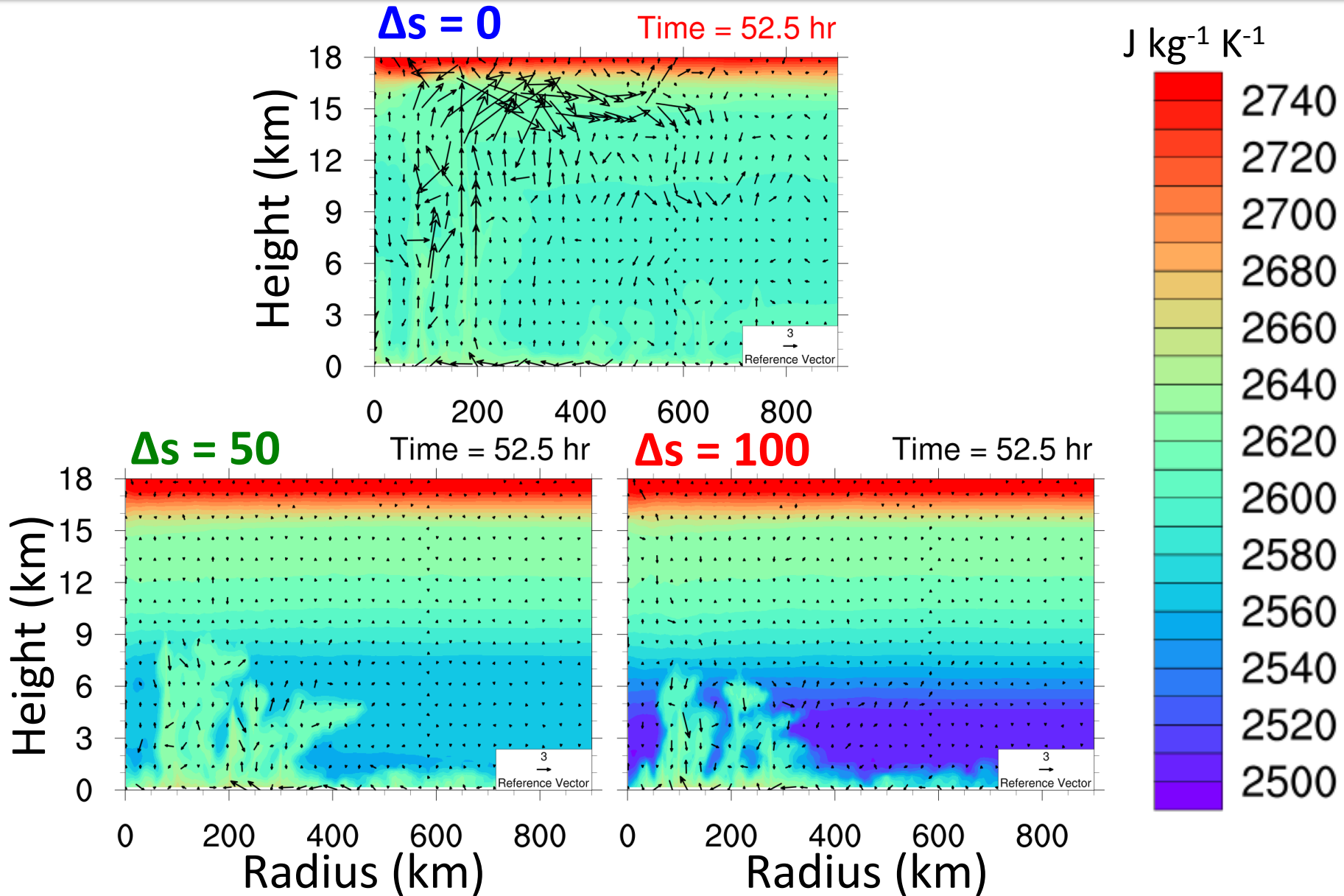
Intermediate: $\Delta s = 50$

Dry: $\Delta s = 100$

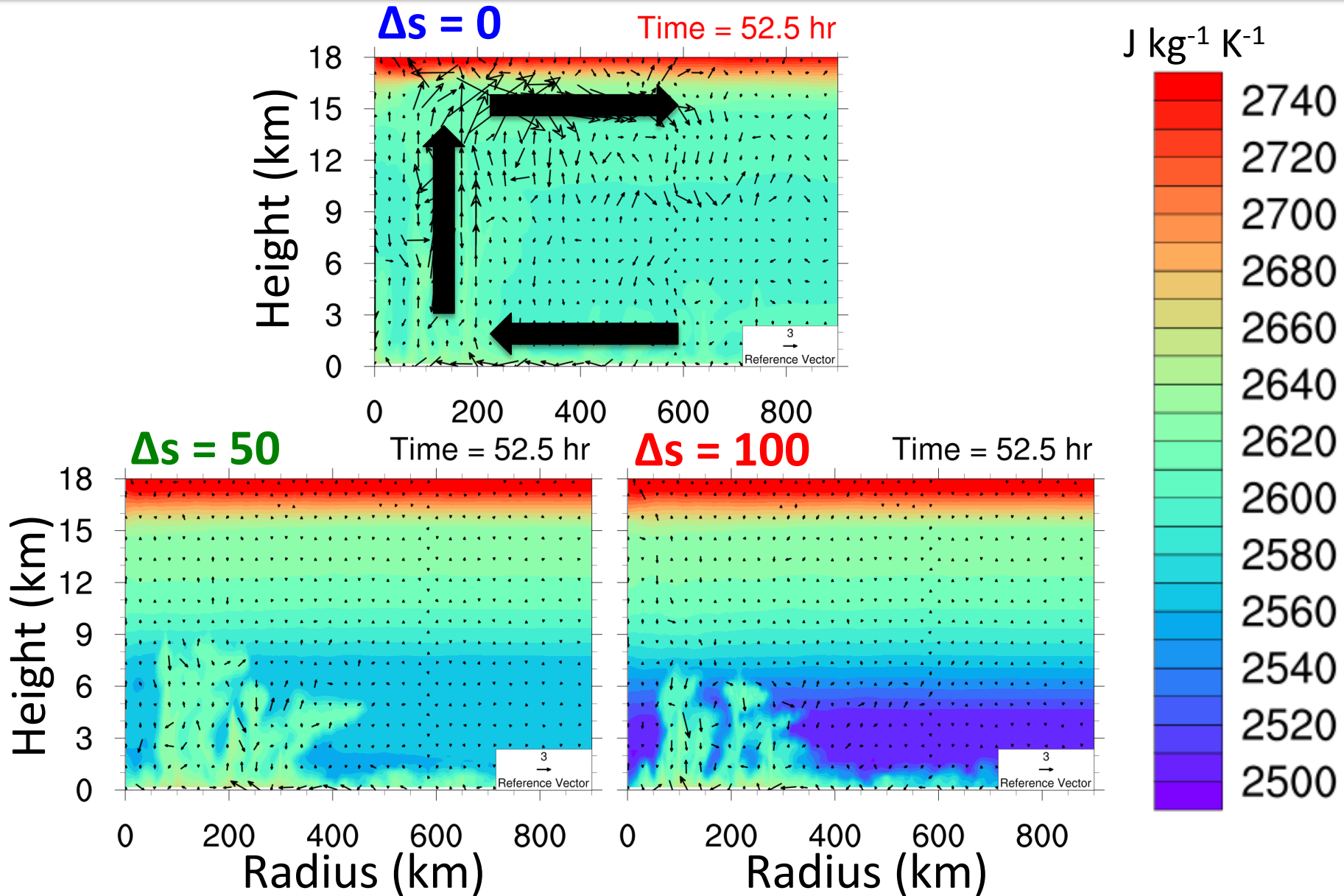
Evolution of the Simulations



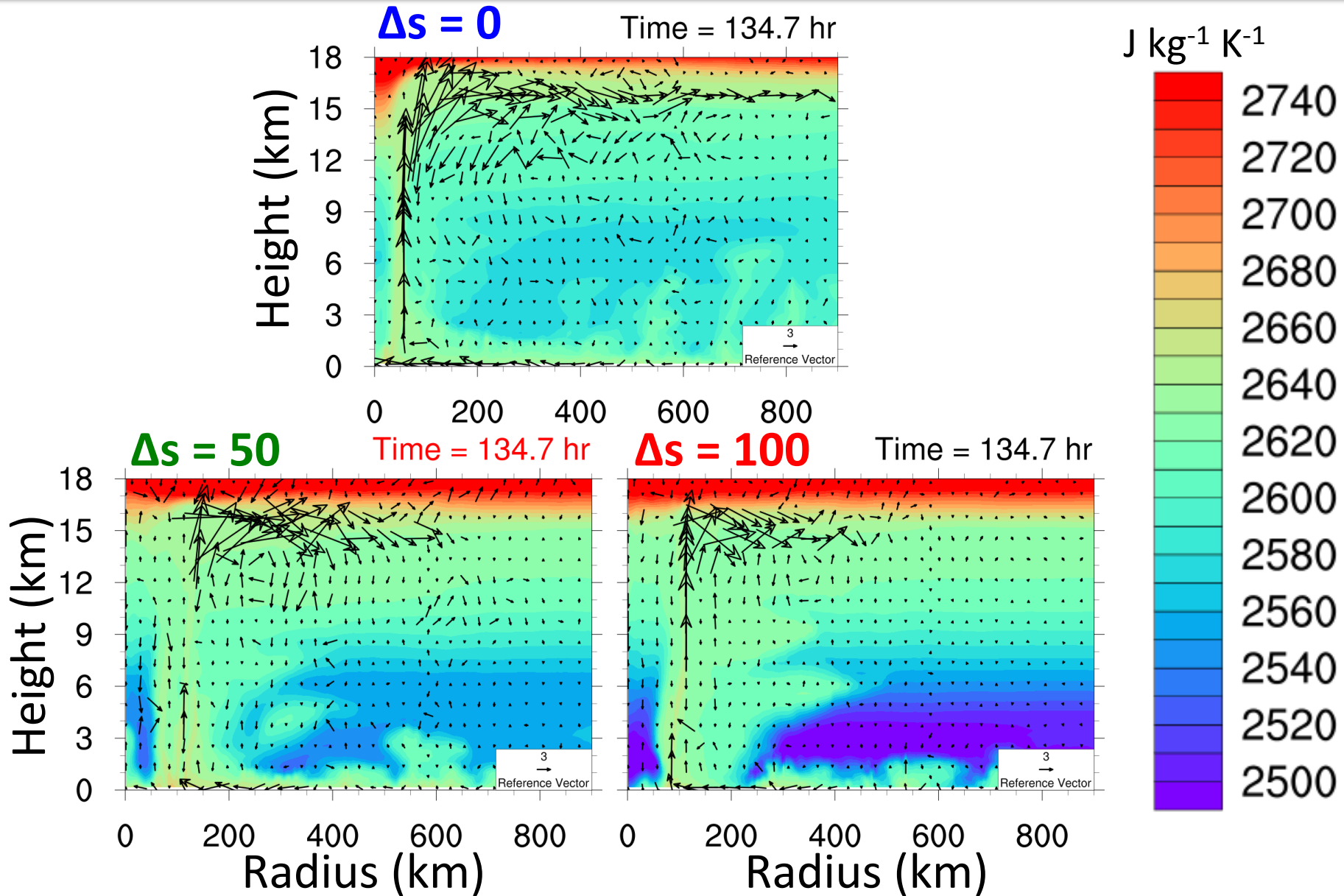
Evolution of the Simulations



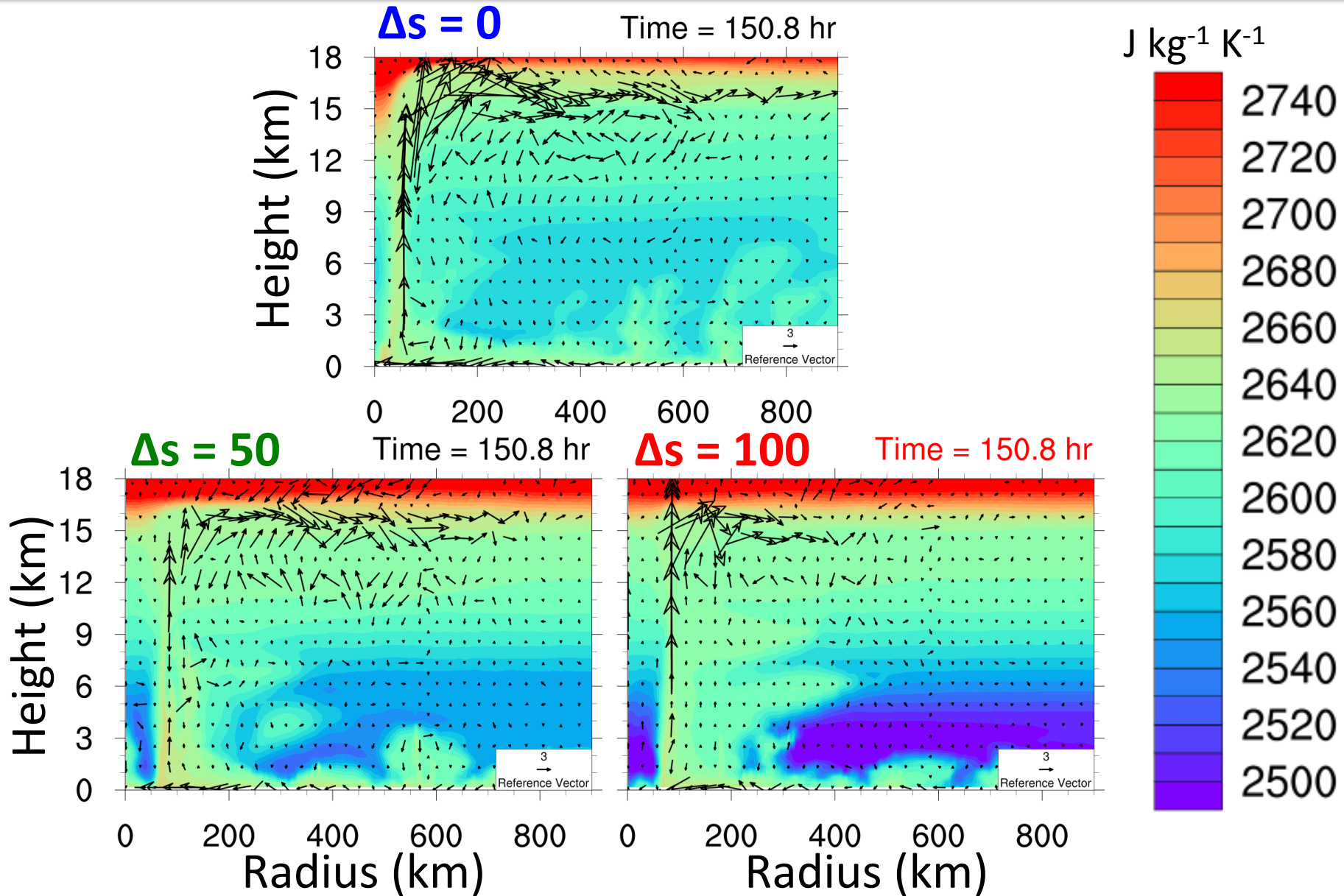
Evolution of the Simulations



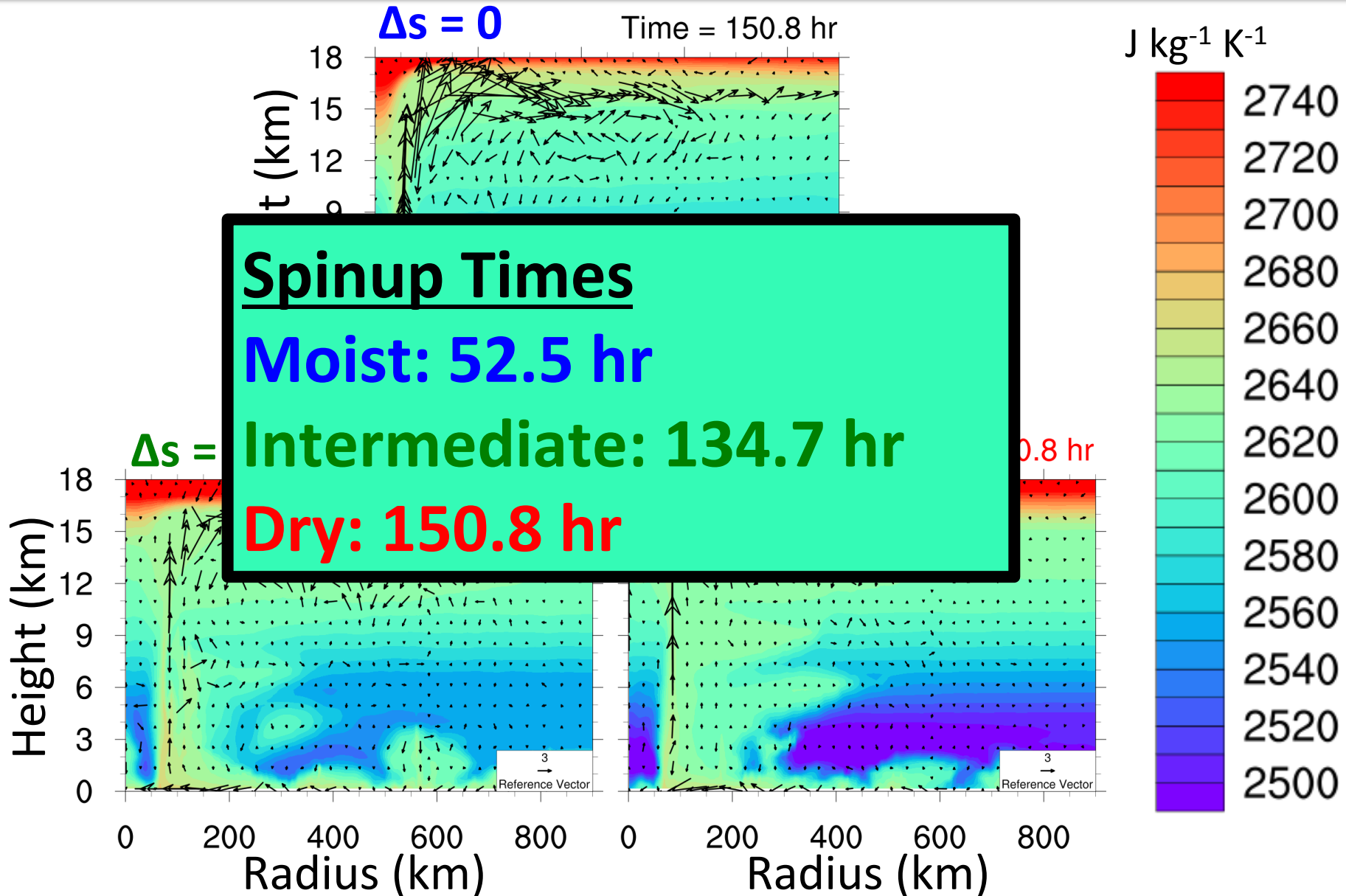
Evolution of the Simulations



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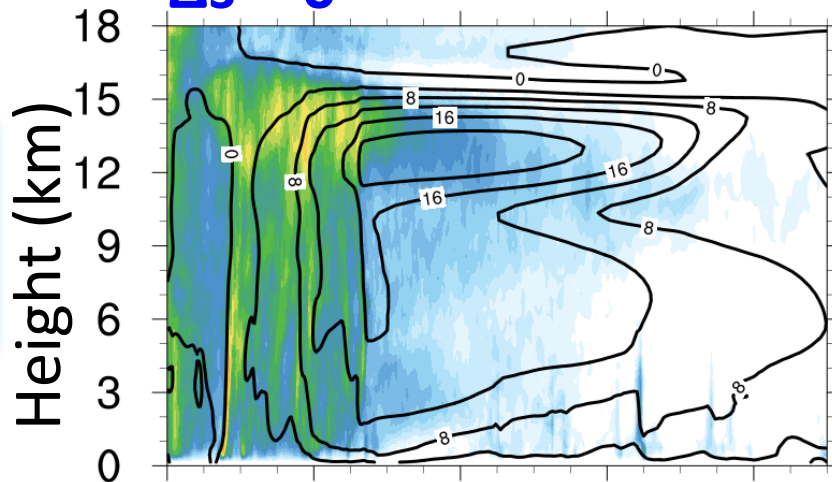
Evolution of the Simulations



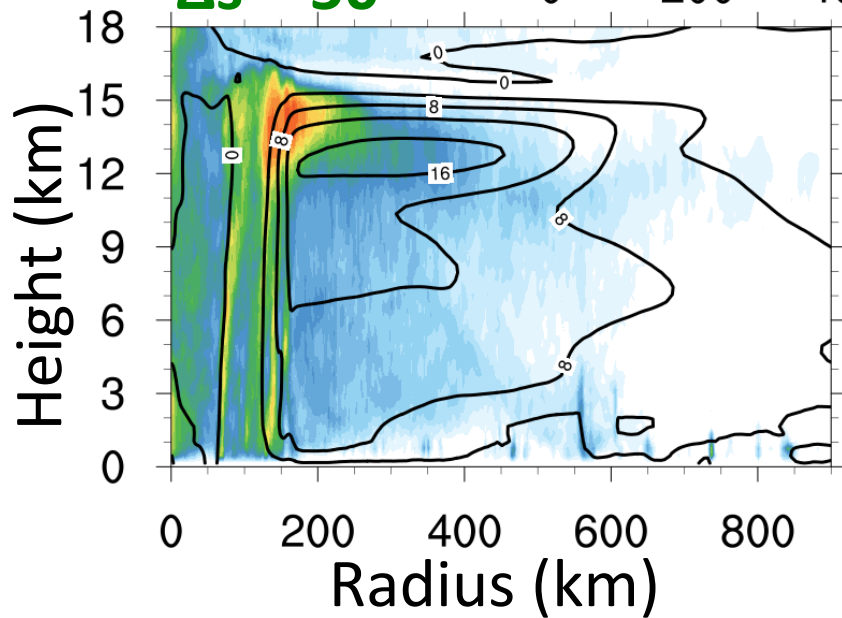
Updrafts and Streamfunction

Time-averaged
24 hours before
spinup

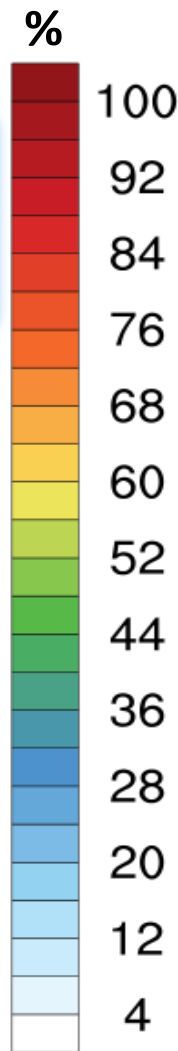
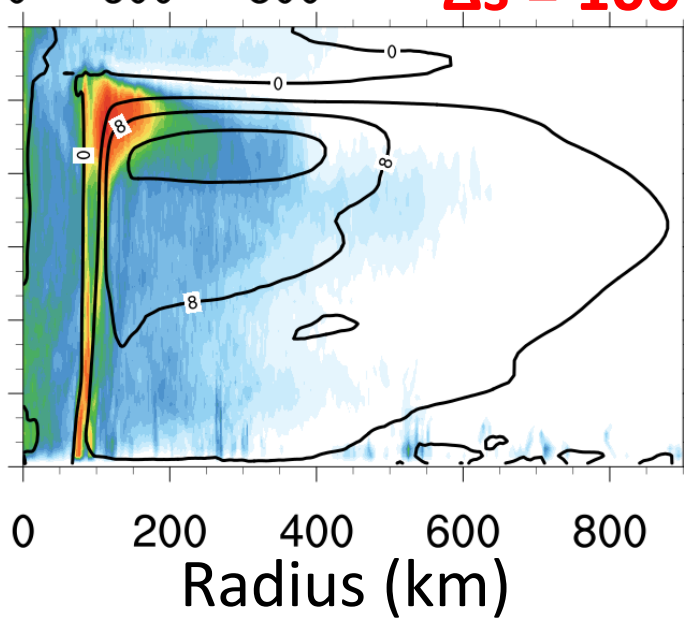
$\Delta s = 0$



$\Delta s = 50$

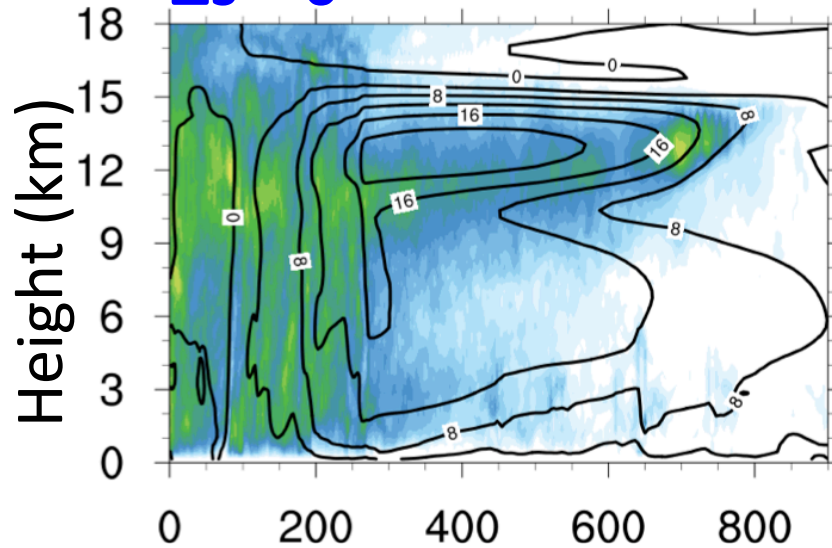


$\Delta s = 100$

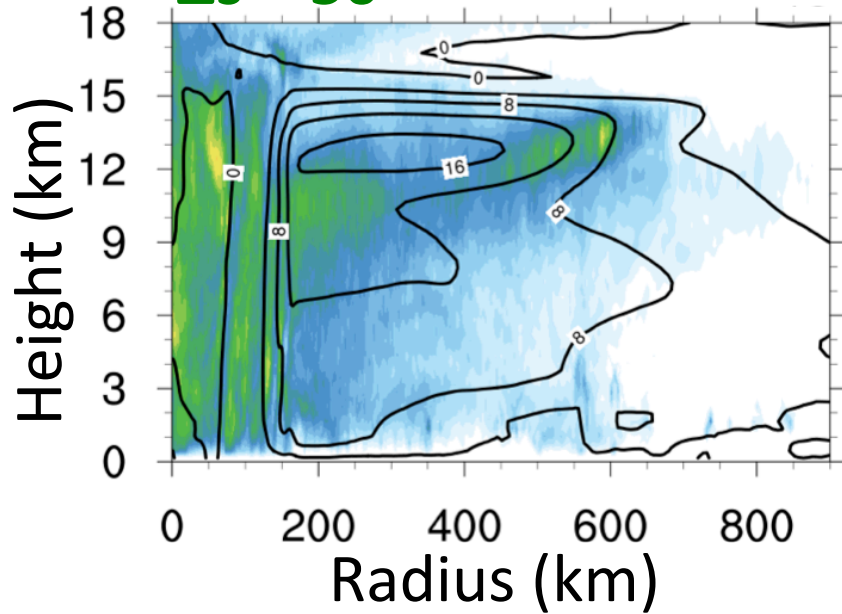


Downdrafts and Streamfunction

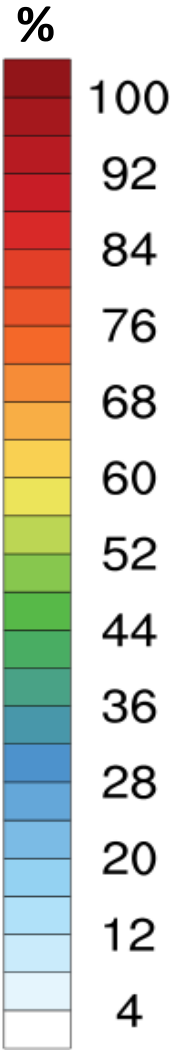
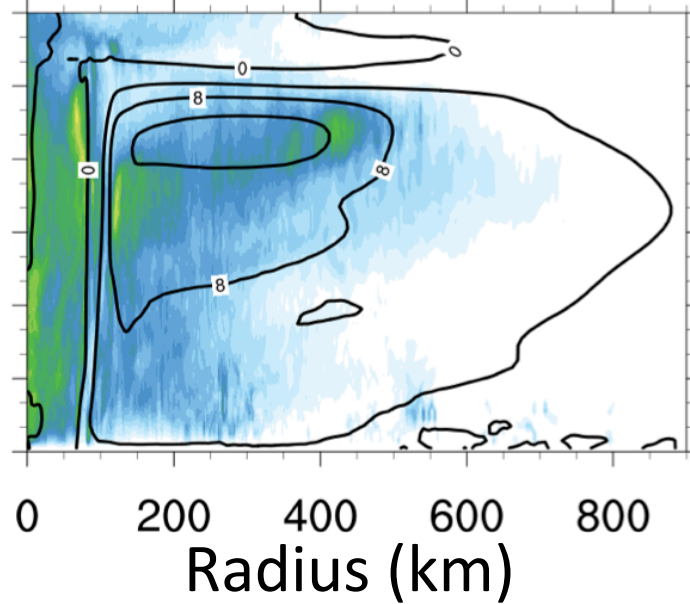
$\Delta s = 0$



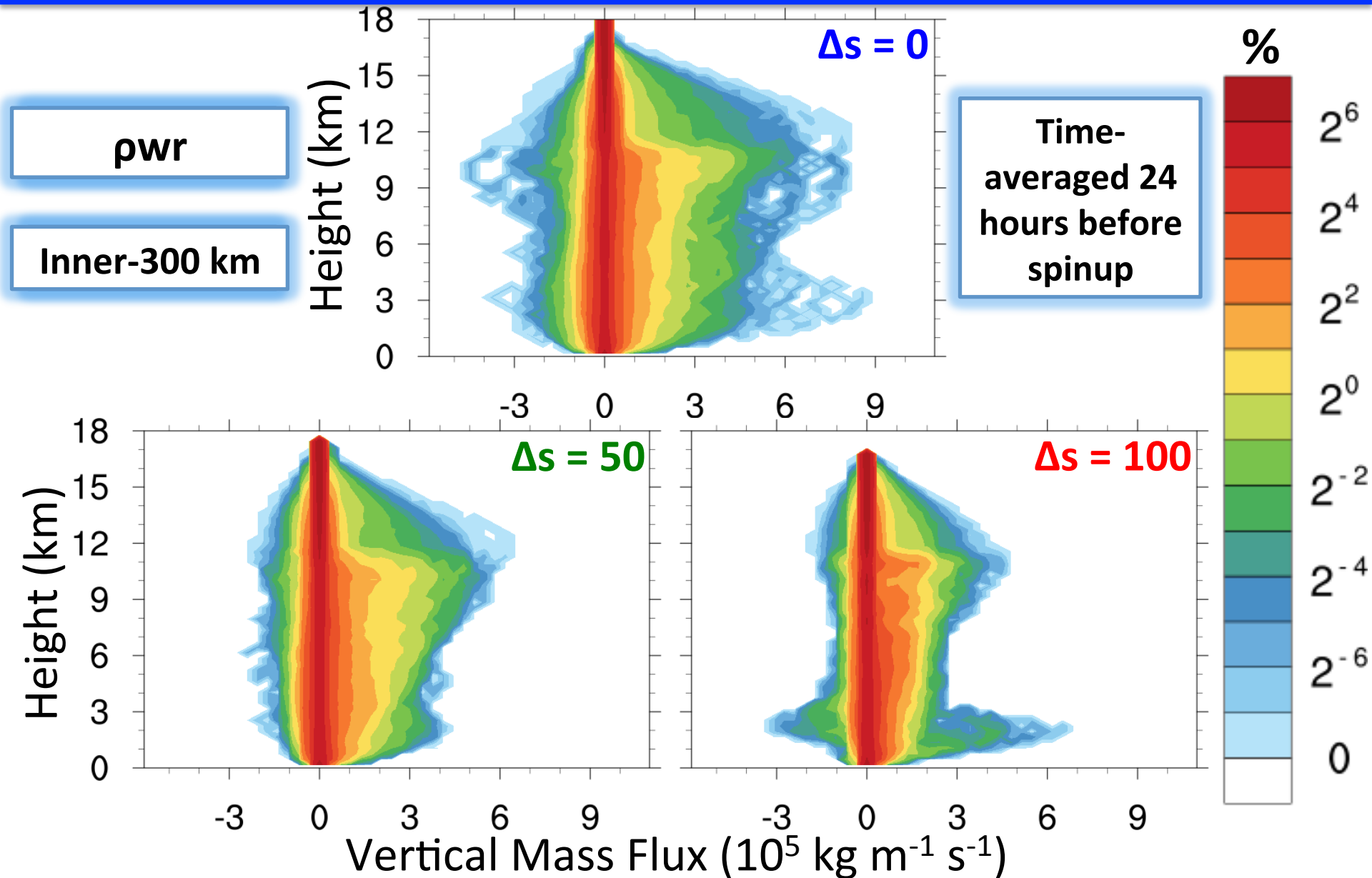
$\Delta s = 50$



$\Delta s = 100$



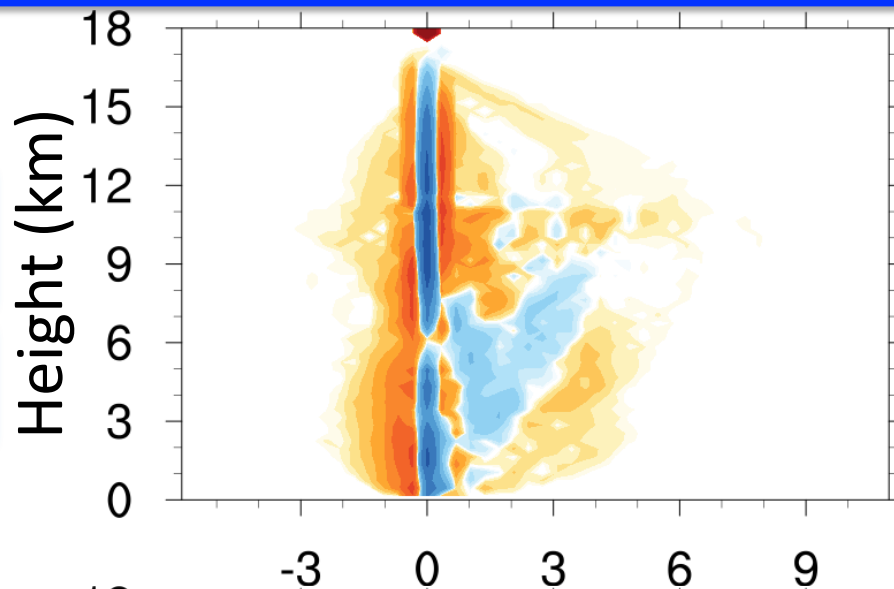
CFAD Diagrams: Vertical Mass Flux



CFAD Differences: Vertical Mass Flux

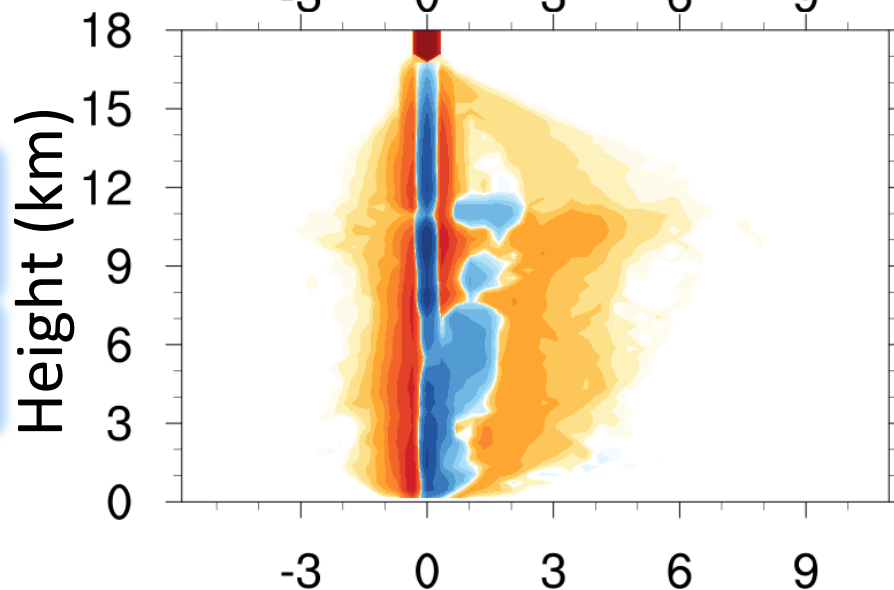
$(\Delta s = 0) - (\Delta s = 50)$

Moist - Intermediate

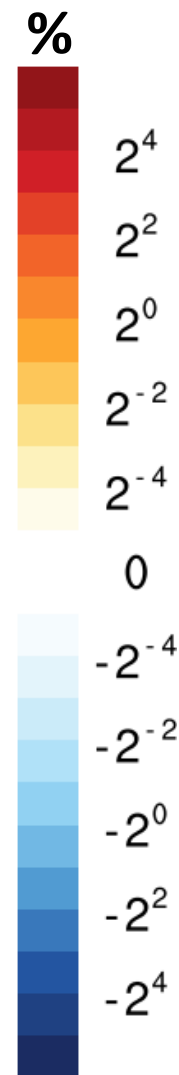


$(\Delta s = 0) - (\Delta s = 100)$

Moist - Dry



Vertical Mass Flux ($10^5 \text{ kg m}^{-1} \text{ s}^{-1}$)

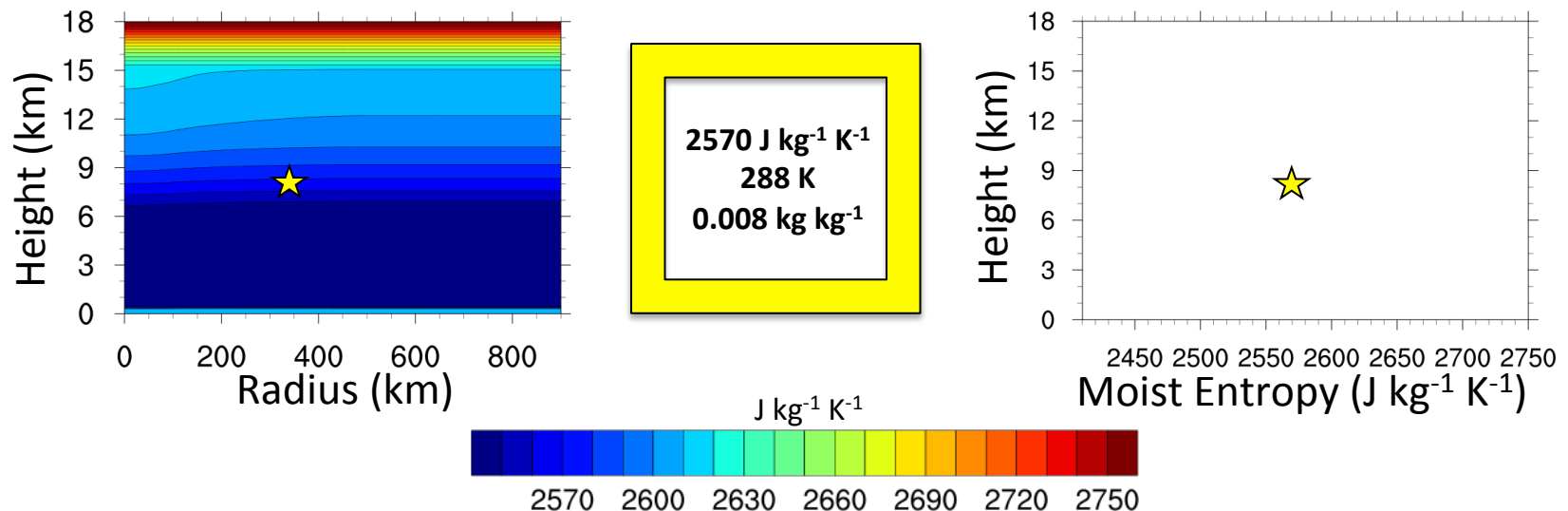


Moist Entropy Framework

- Look at convective motions from a moist entropy coordinate system (as in Pauluis and Mrowiec 2013).
- **Benefits**
 - ❖ Separates high and low entropy streams.
 - ❖ Analyze characteristics of updrafts and downdrafts separately.
 - ❖ Determine diabatic tendency directly.

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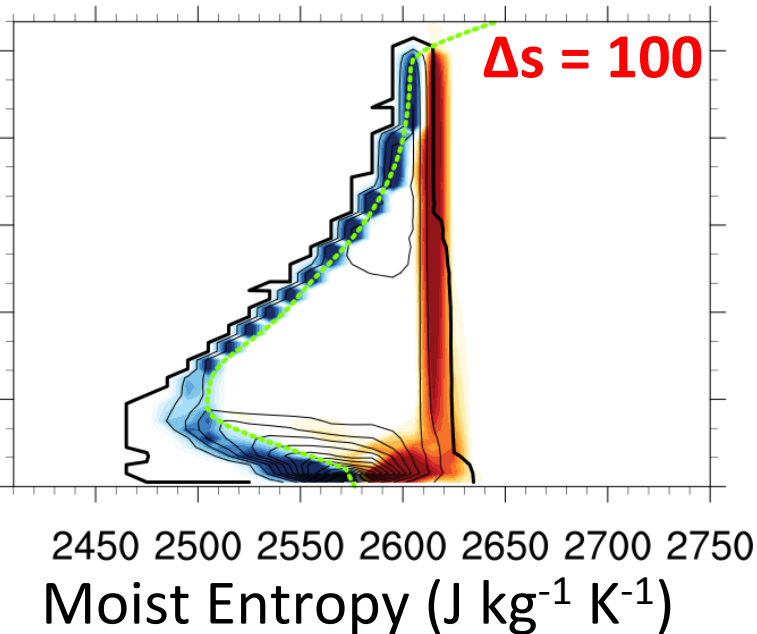
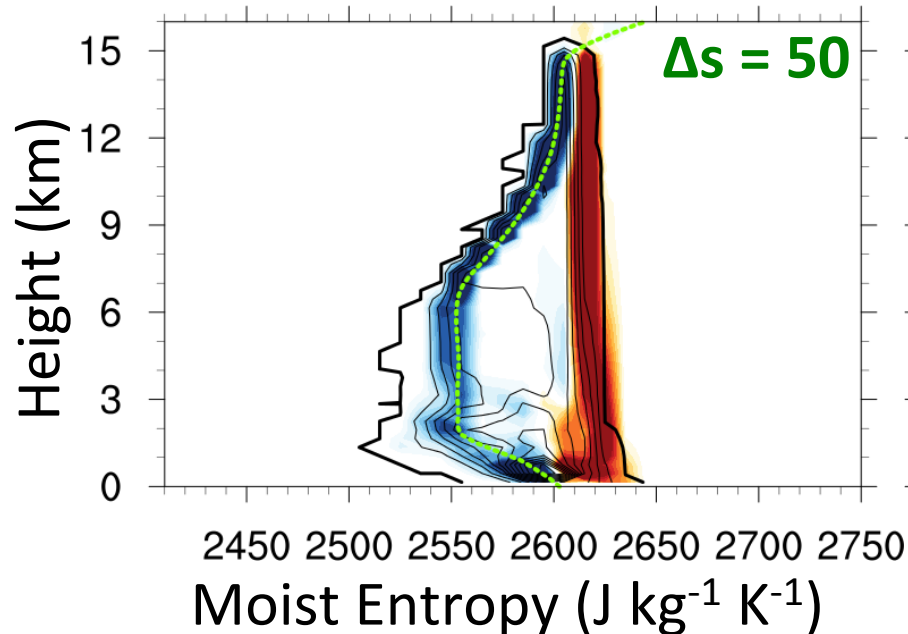
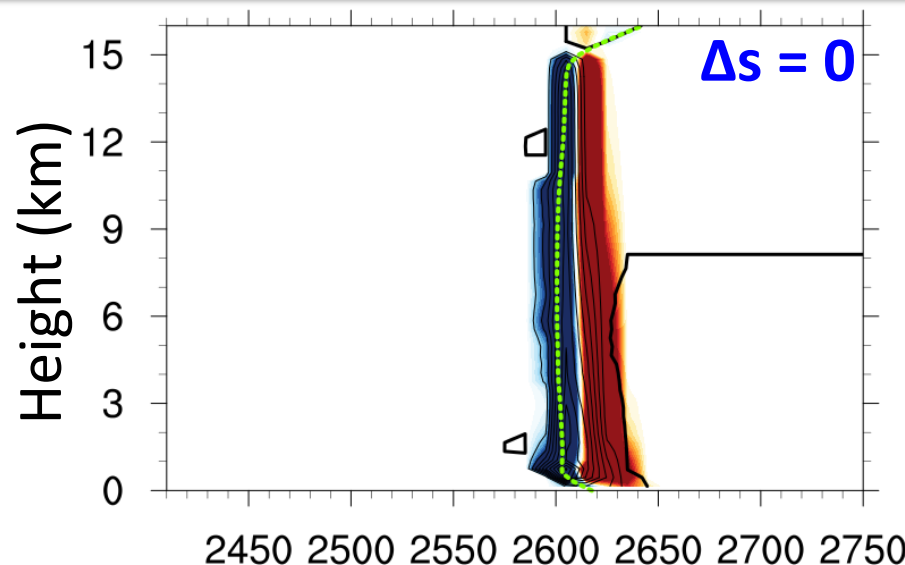


Vertical Mass Flux and Streamfunction

$$\Psi(z, s_p) = \int_{-\infty}^{s_p} (\rho w r dr) ds_p$$

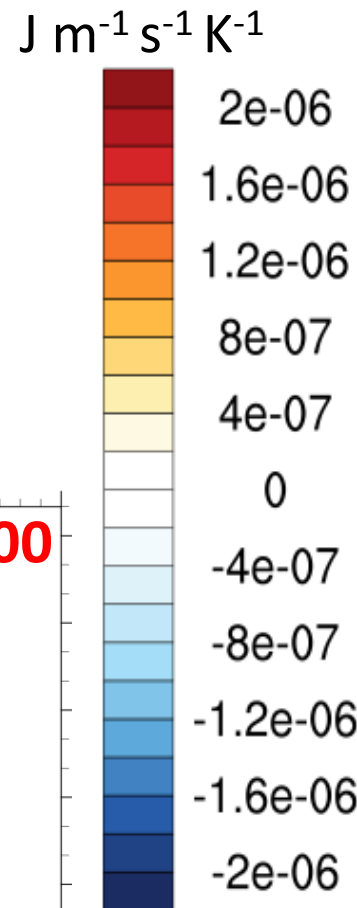
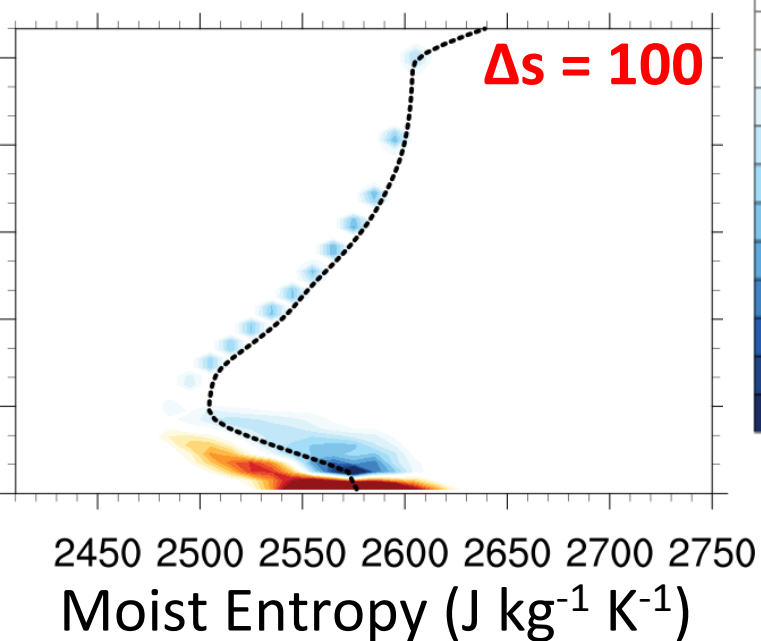
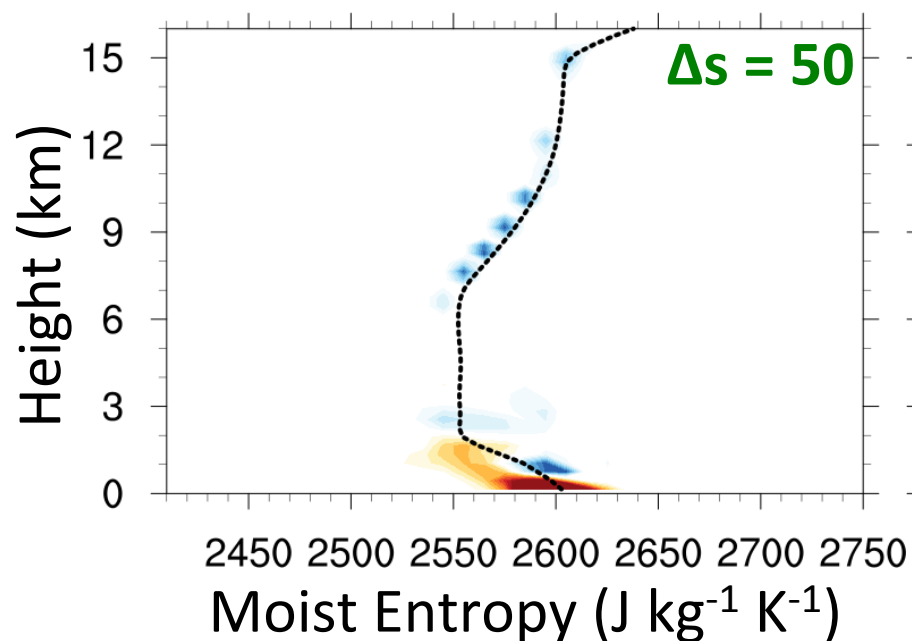
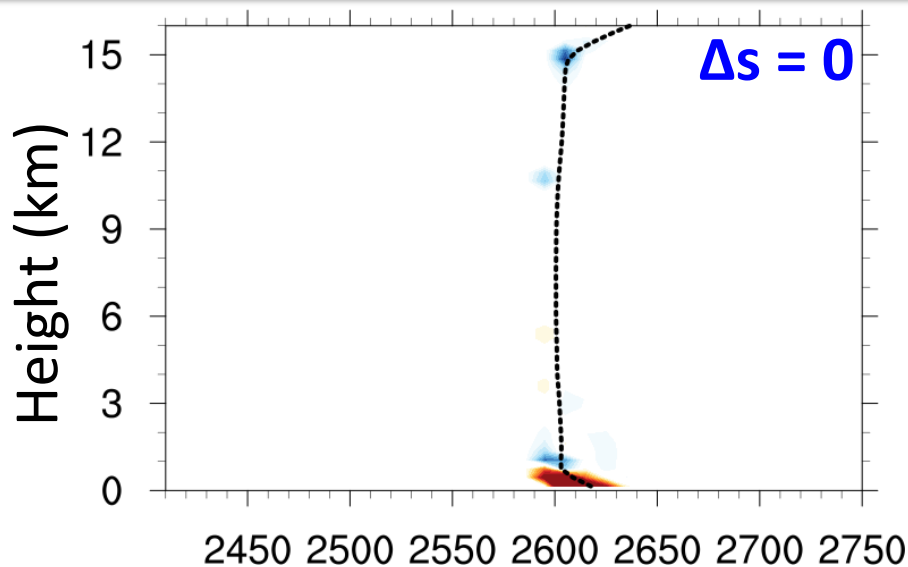
Contours: Streamfunction
(every $0.0002 \text{ J s}^{-1} \text{ K}^{-1}$)

Shading: Vertical Mass Flux
($10^{-4} \text{ kg s}^{-1}$)



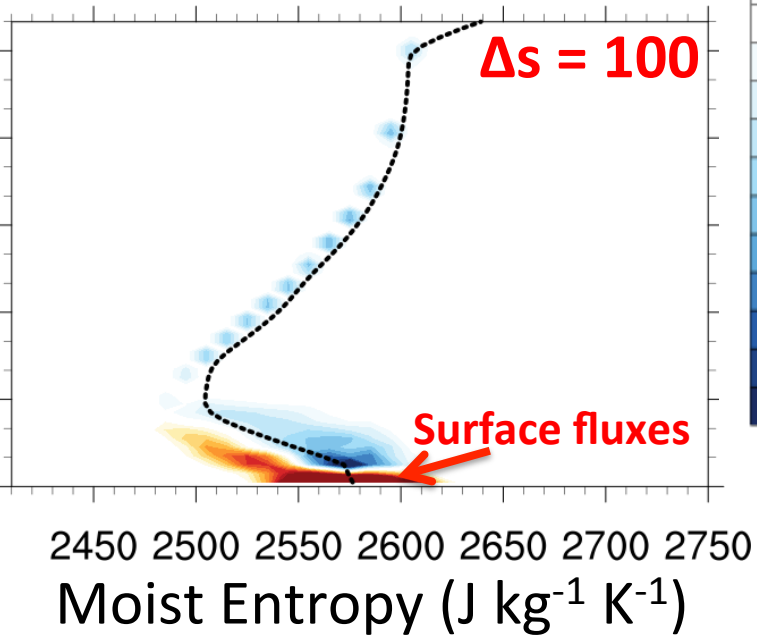
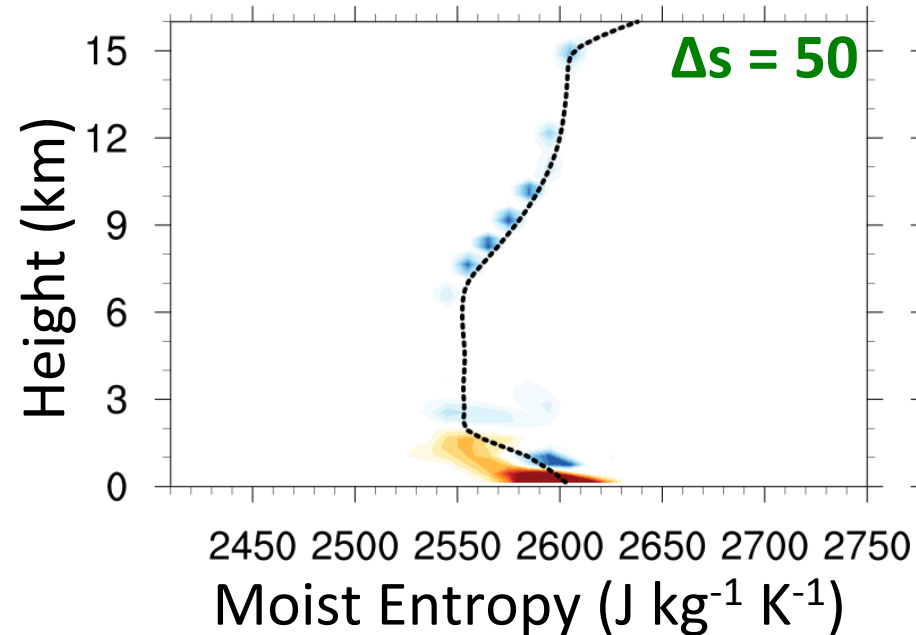
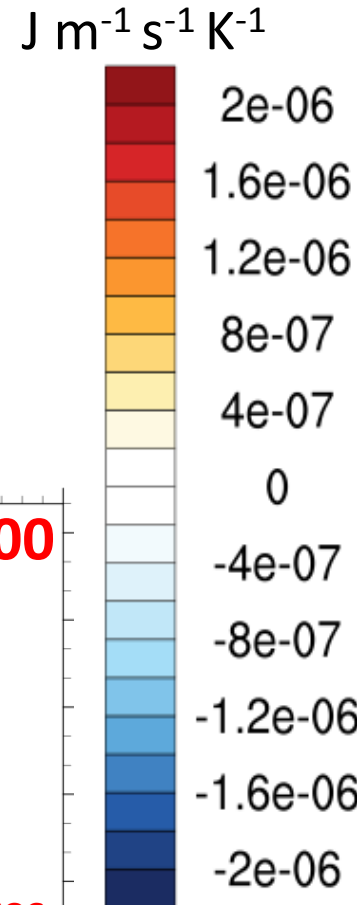
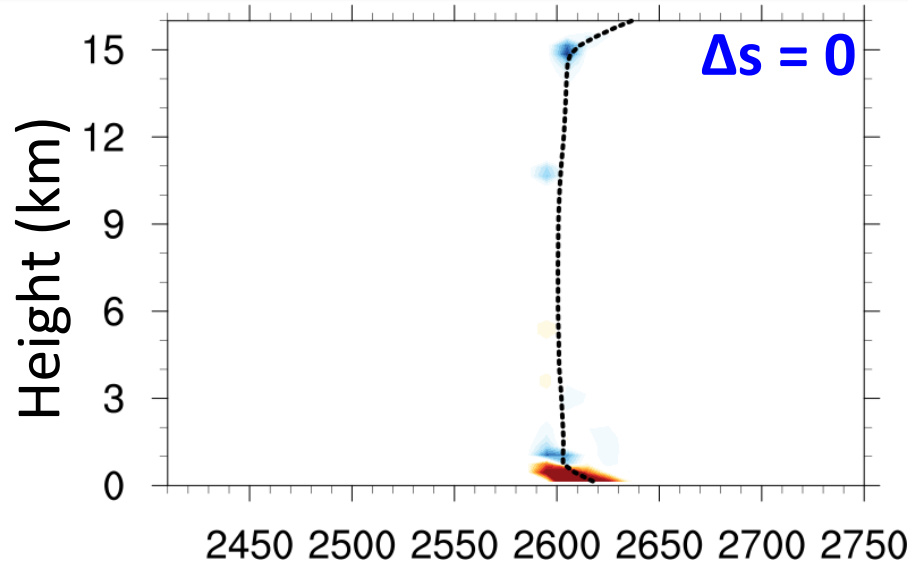
Mass-Weighted Diabatic Tendency

$$\rho \dot{s}_p = - \frac{\partial \Psi}{\partial z}$$



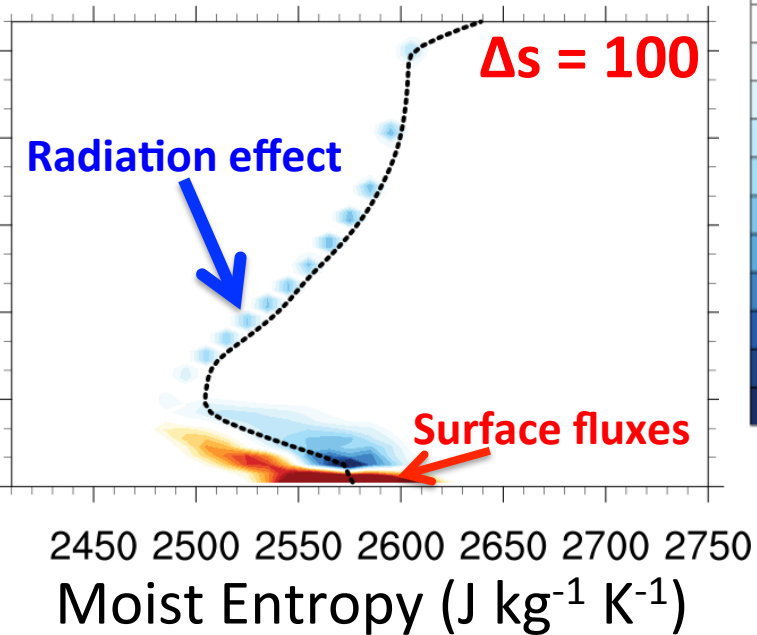
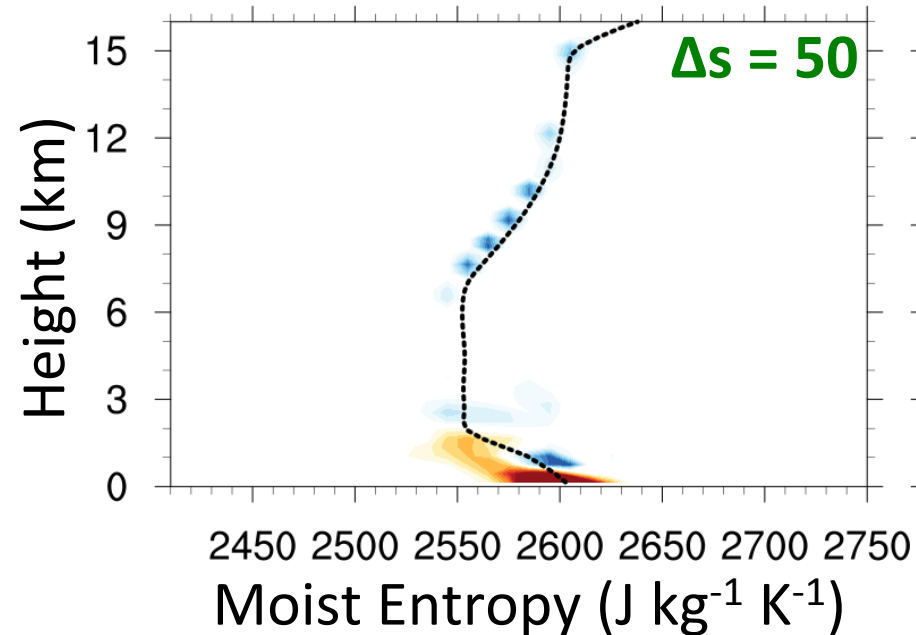
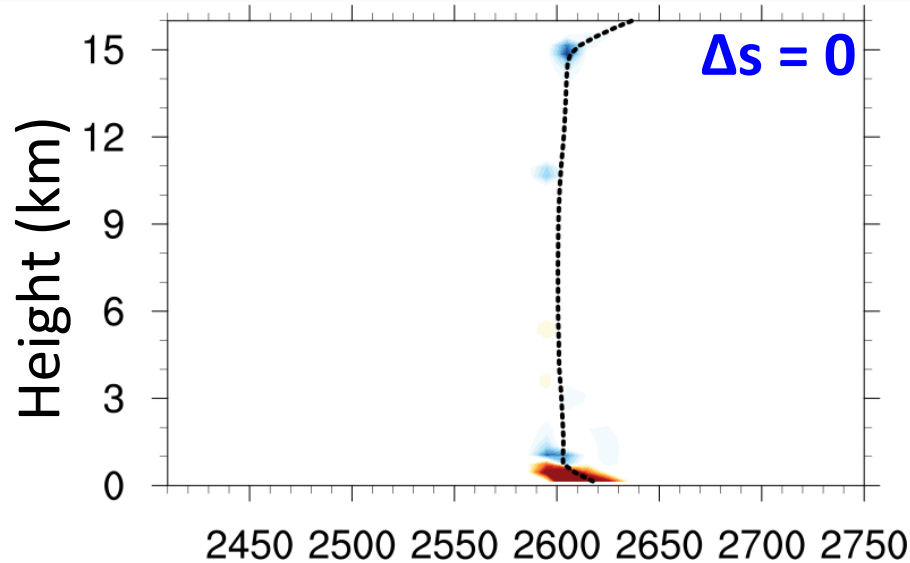
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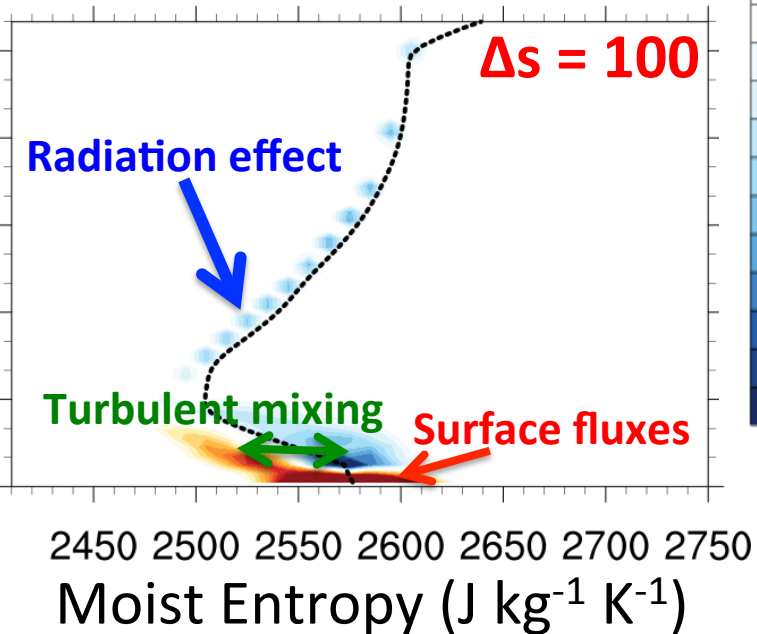
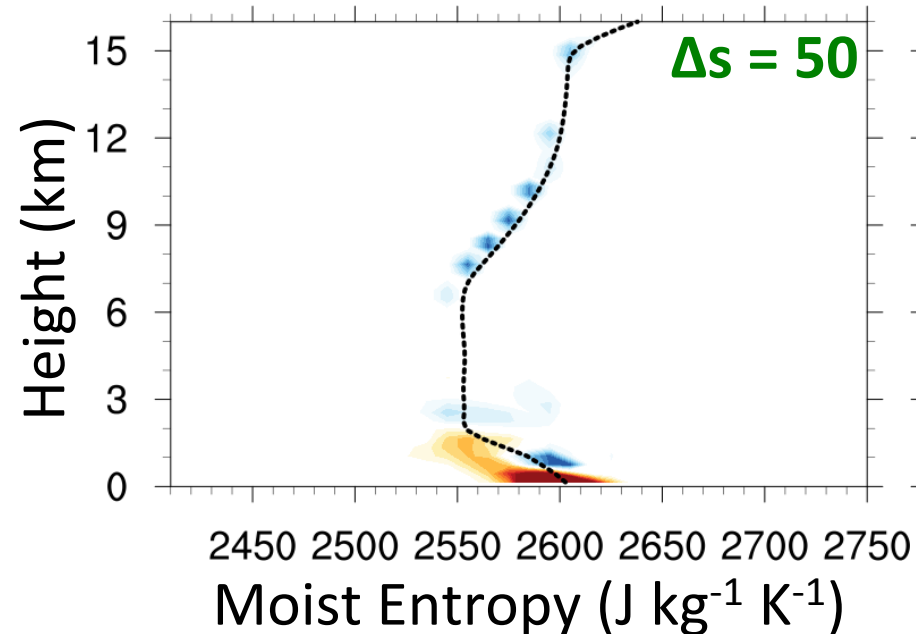
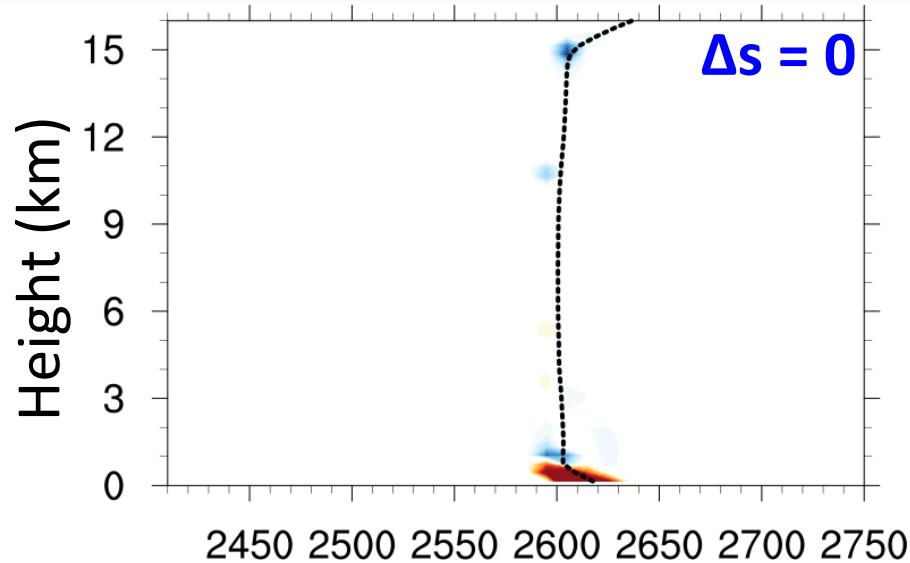
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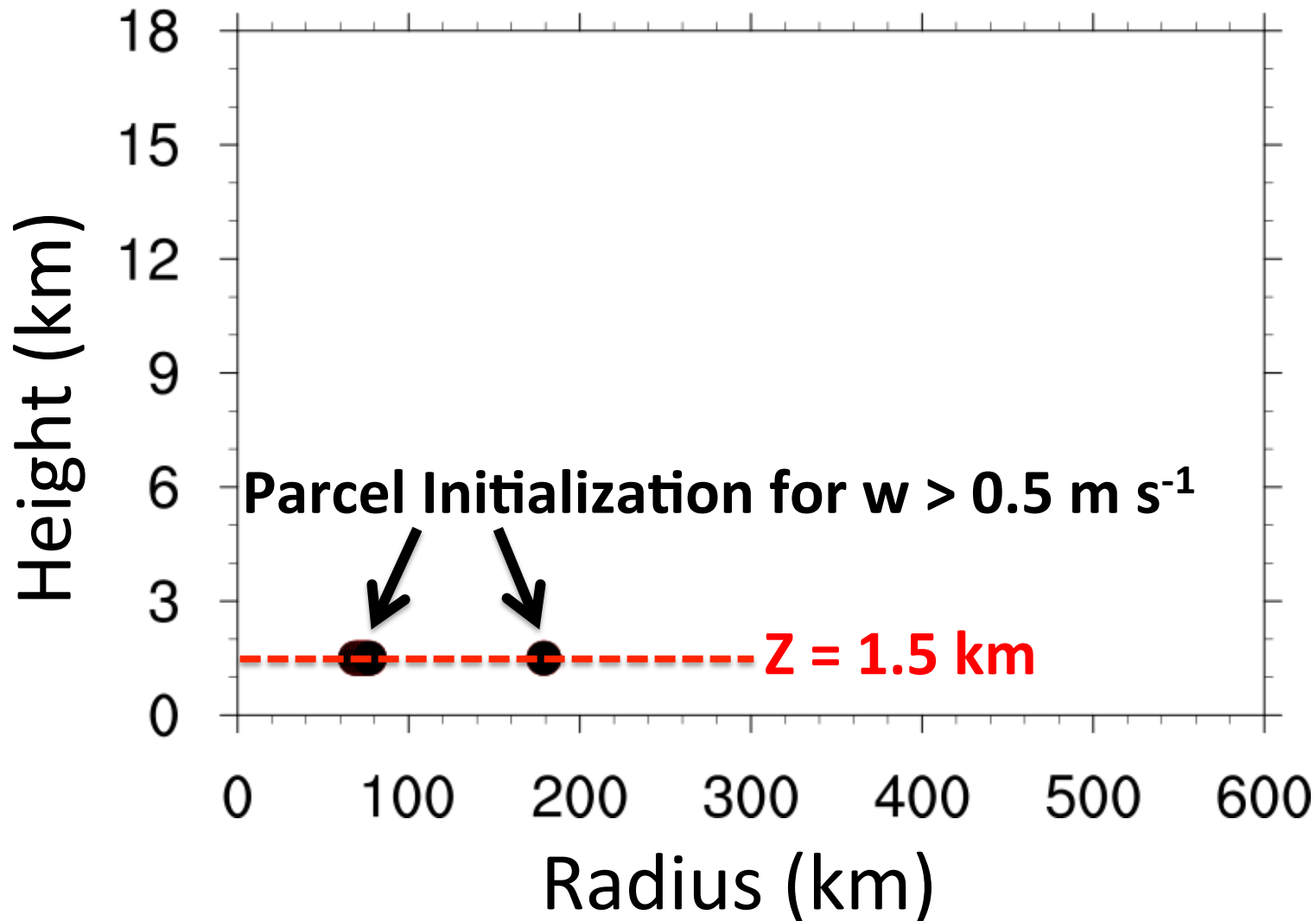


Mass-Weighted Diabatic Tendency

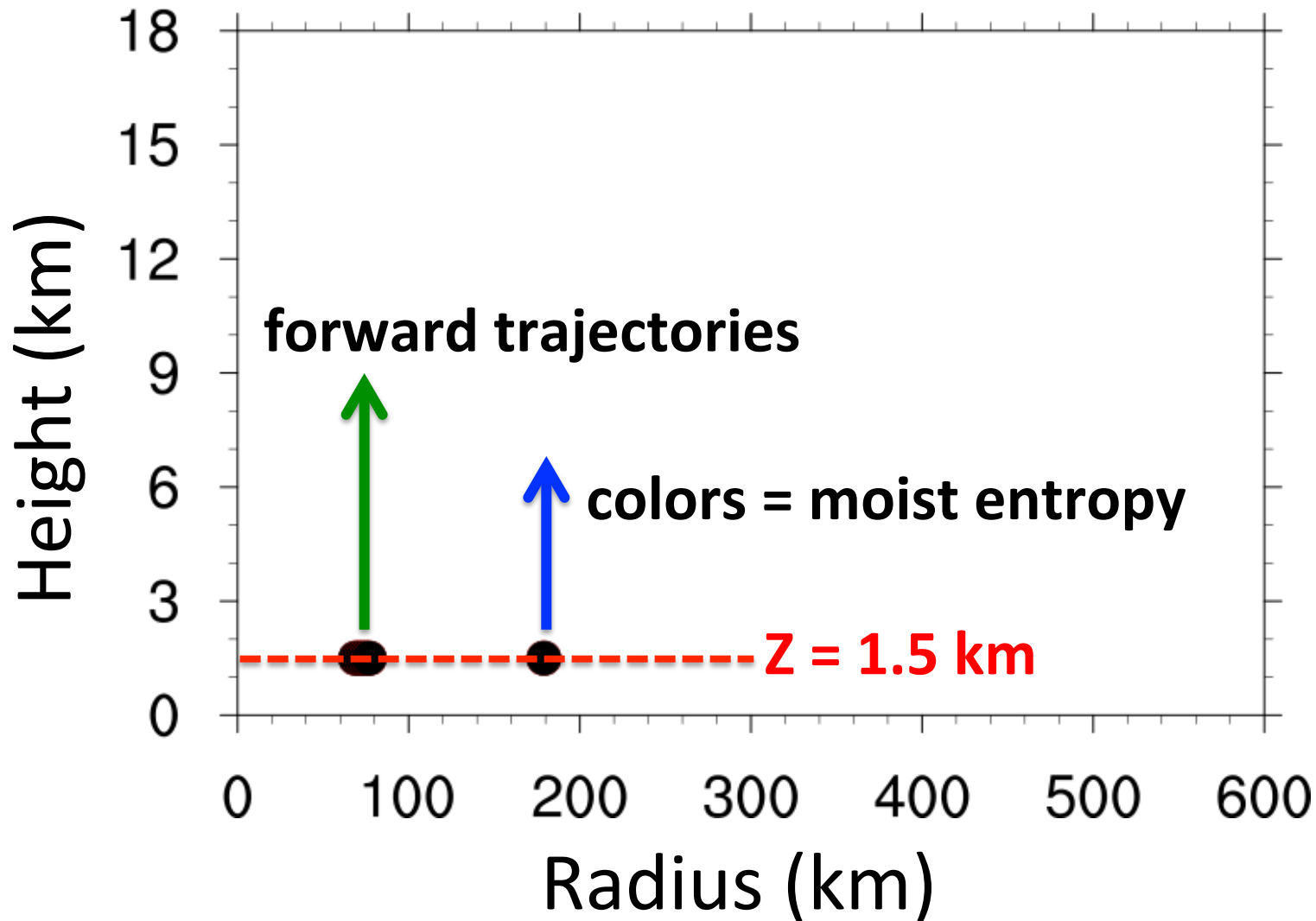
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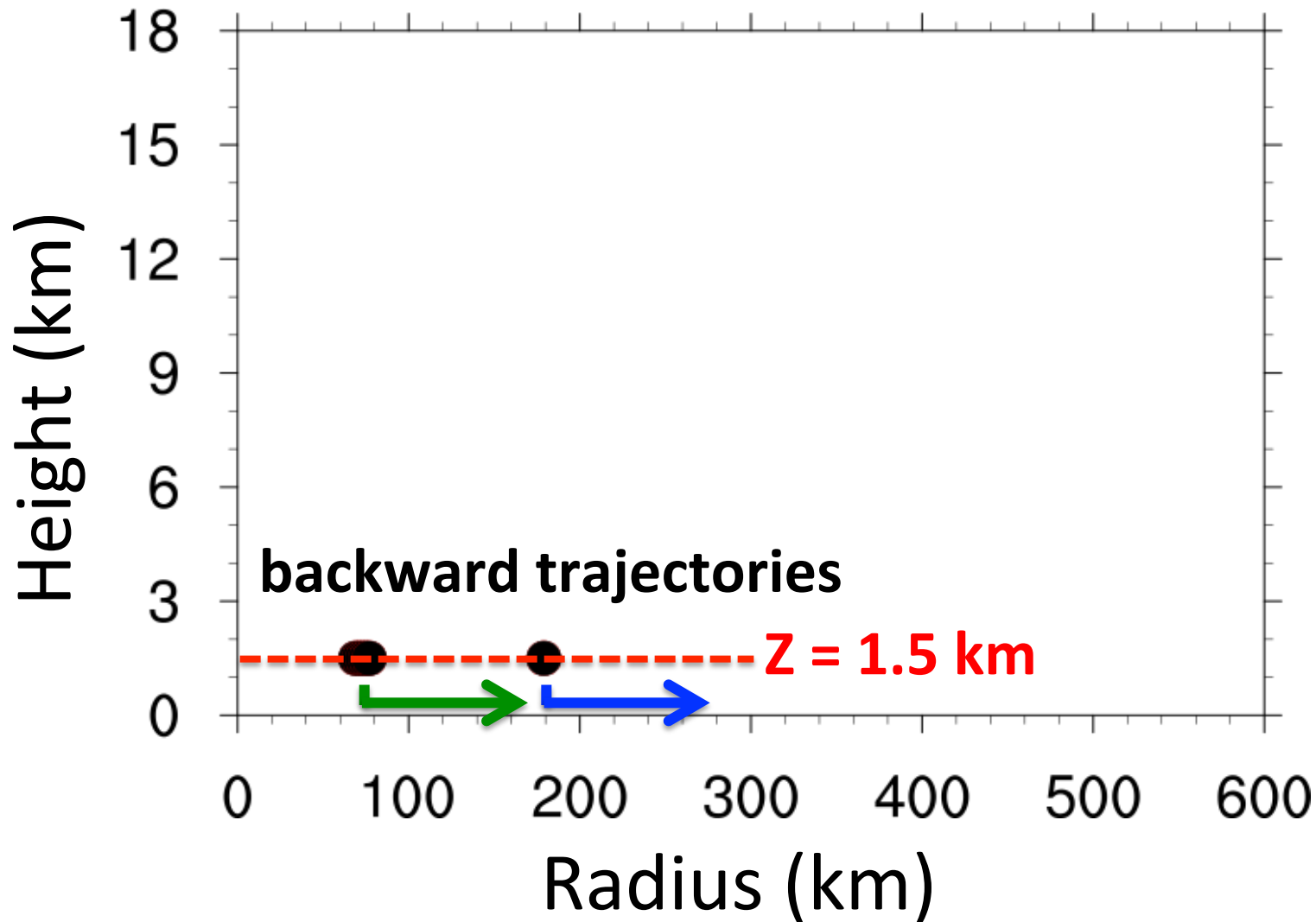
Forward and Backward Trajectories



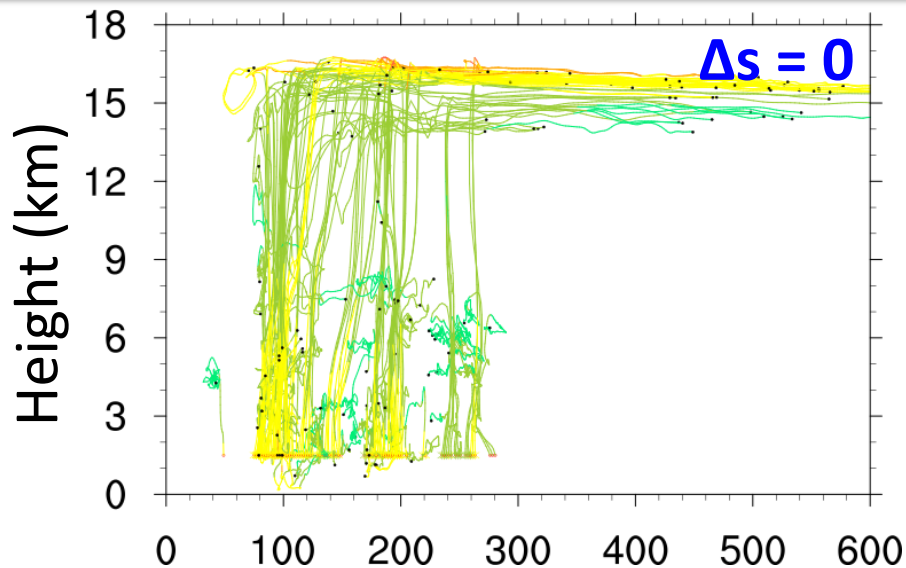
Forward and Backward Trajectories



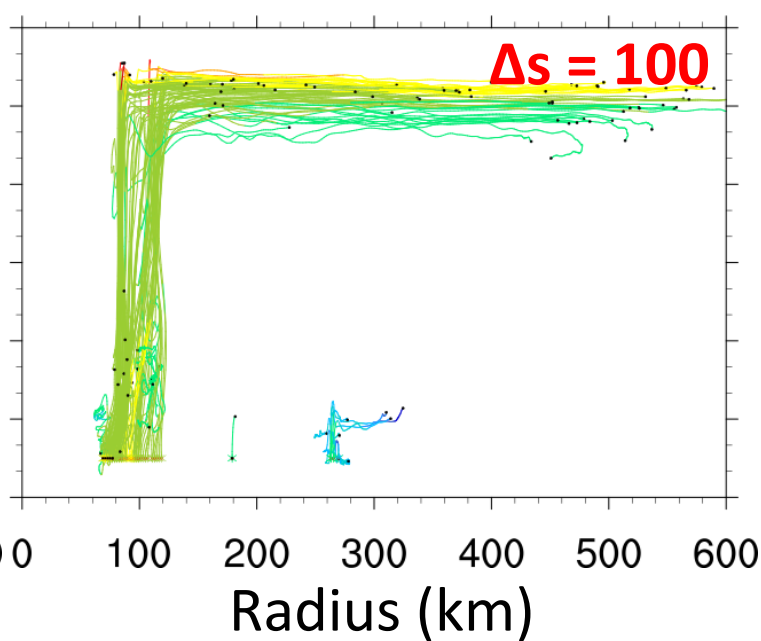
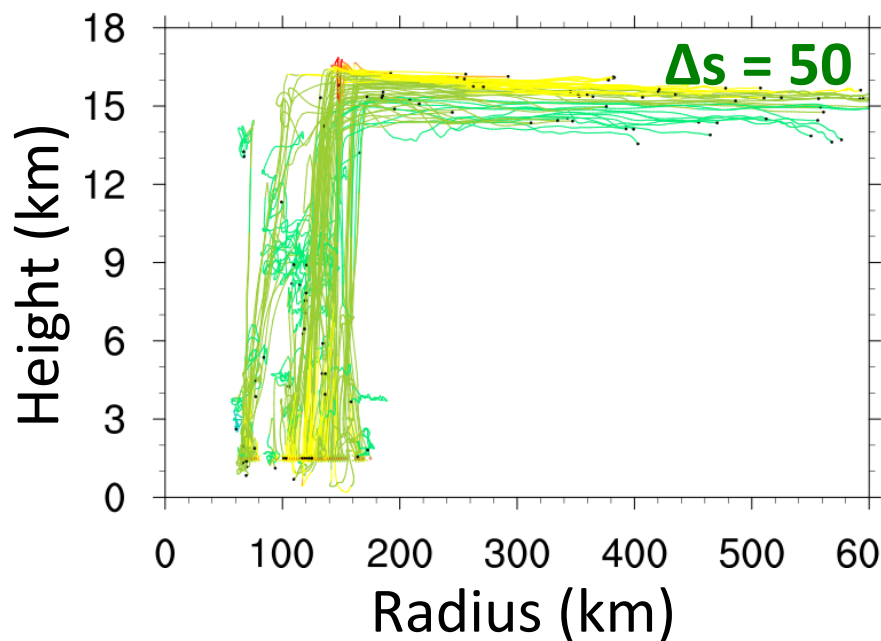
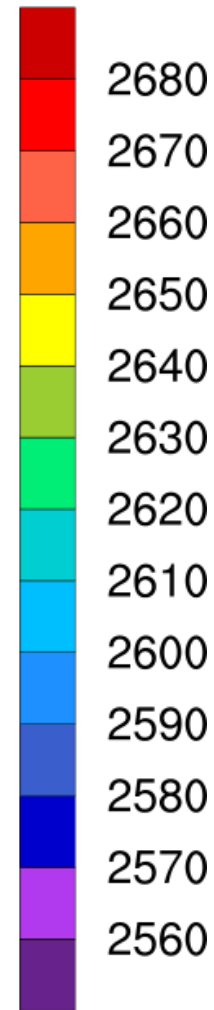
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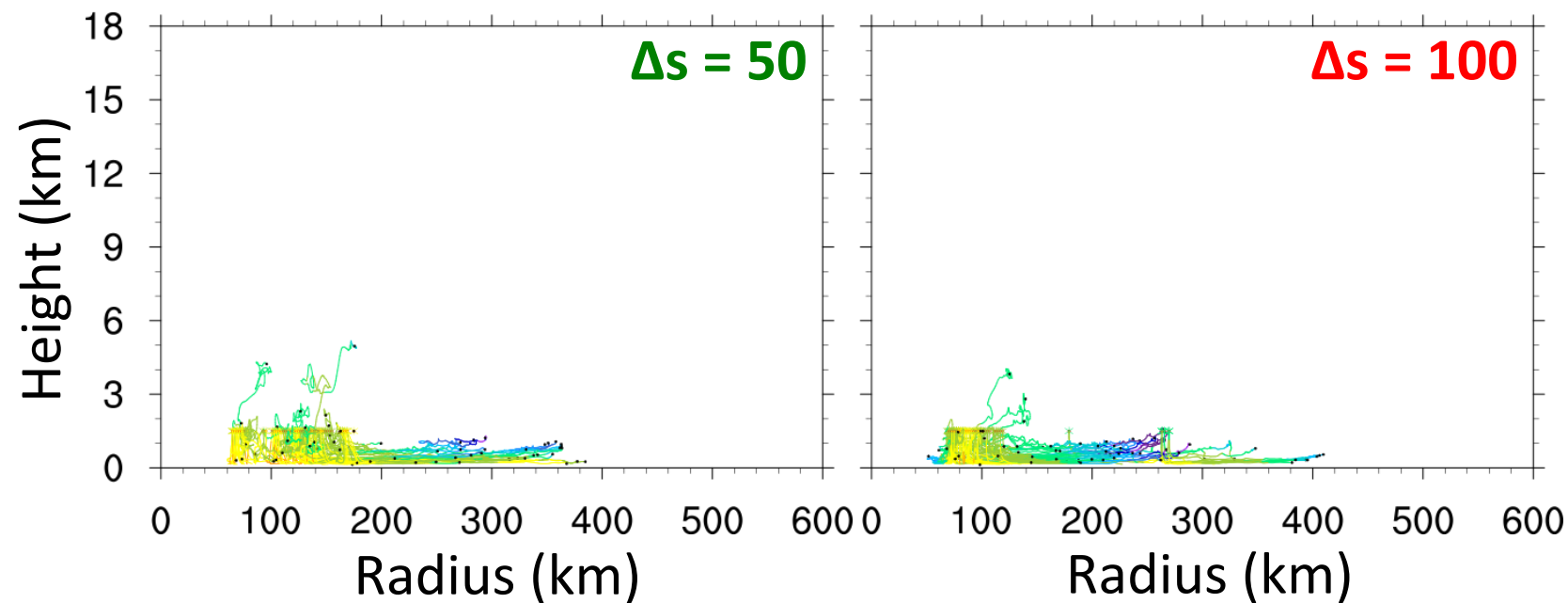
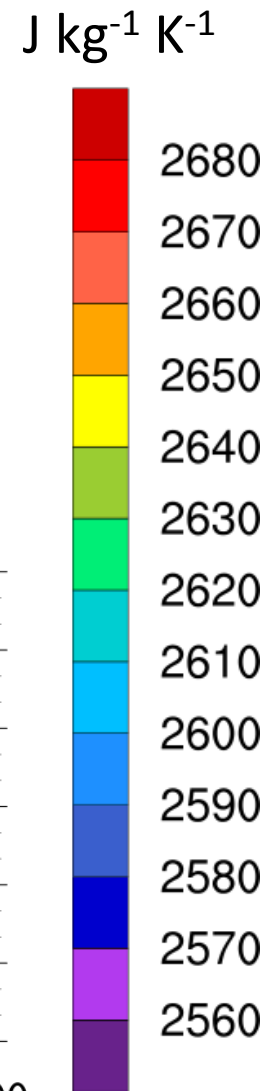
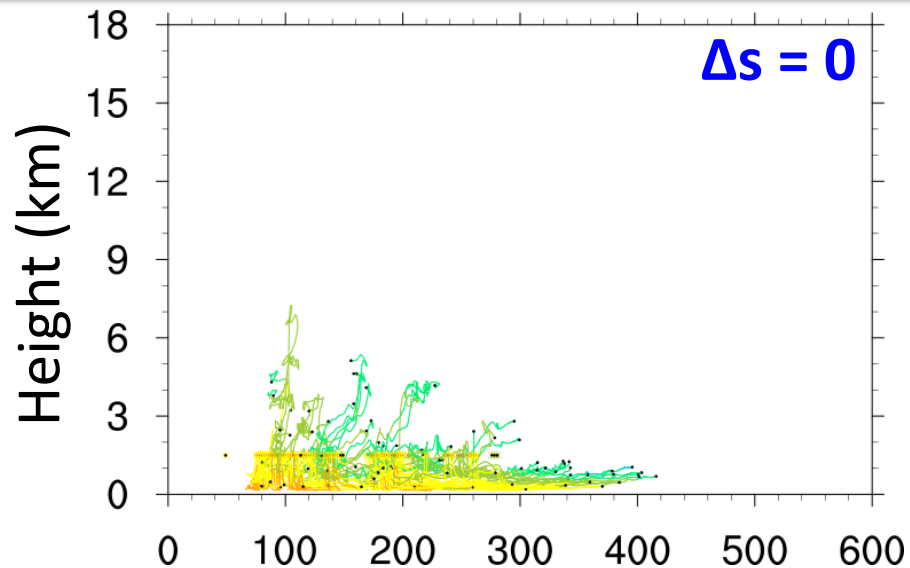
Forward Trajectories



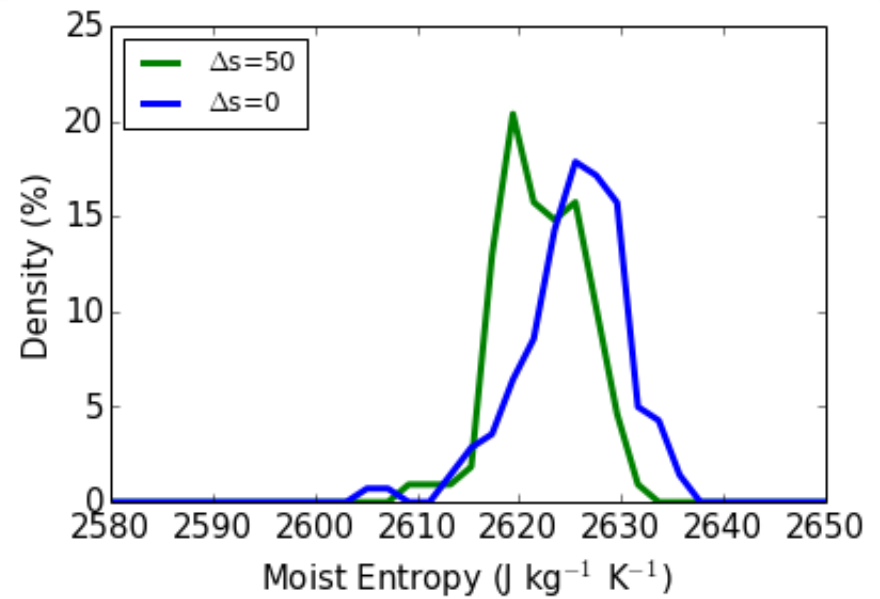
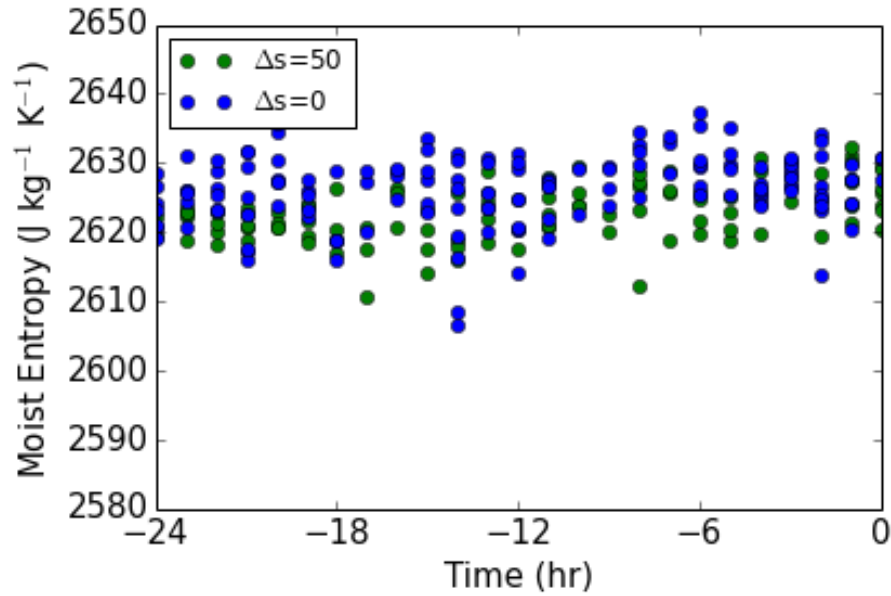
$\text{J kg}^{-1} \text{K}^{-1}$



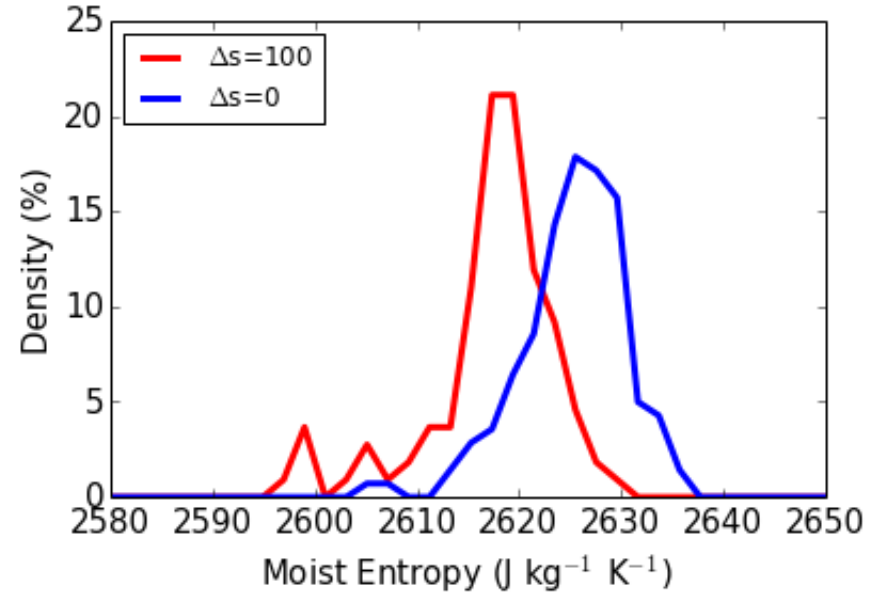
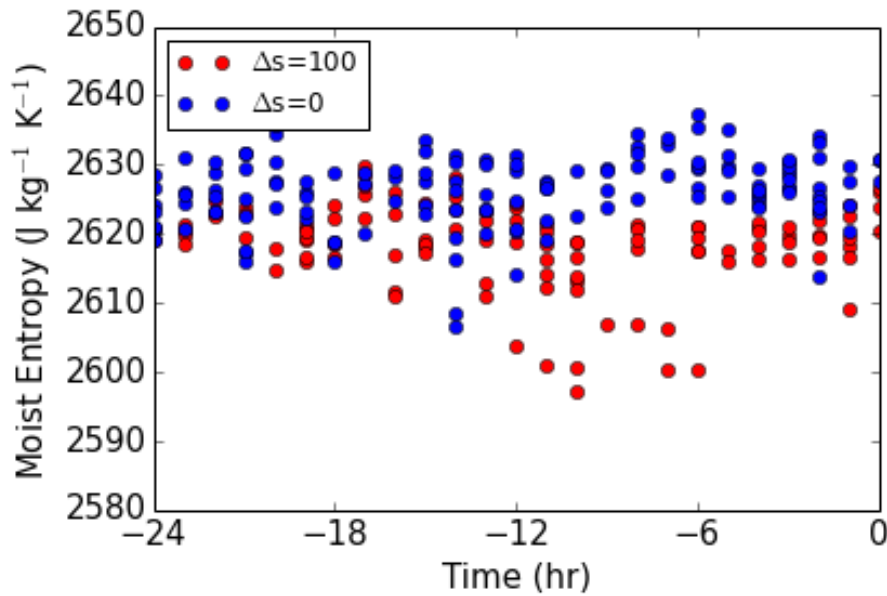
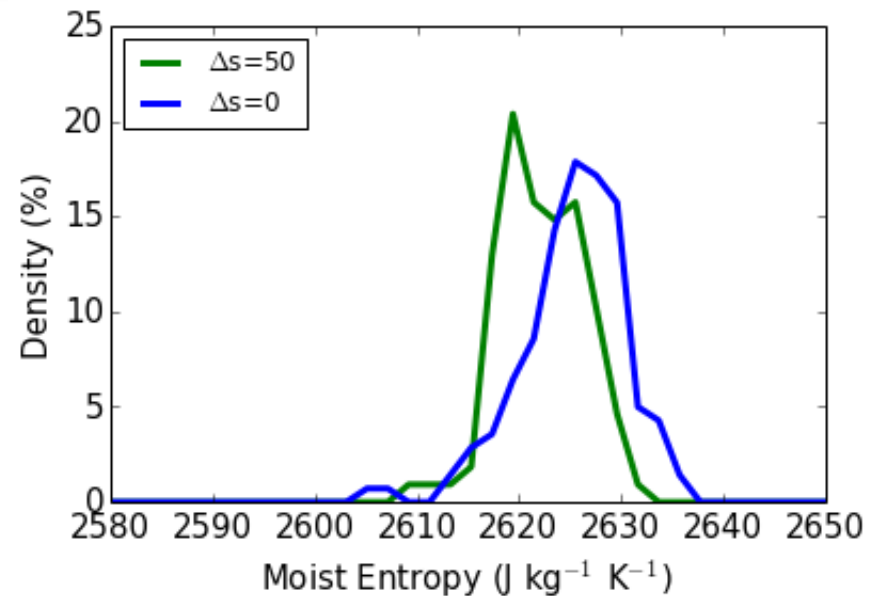
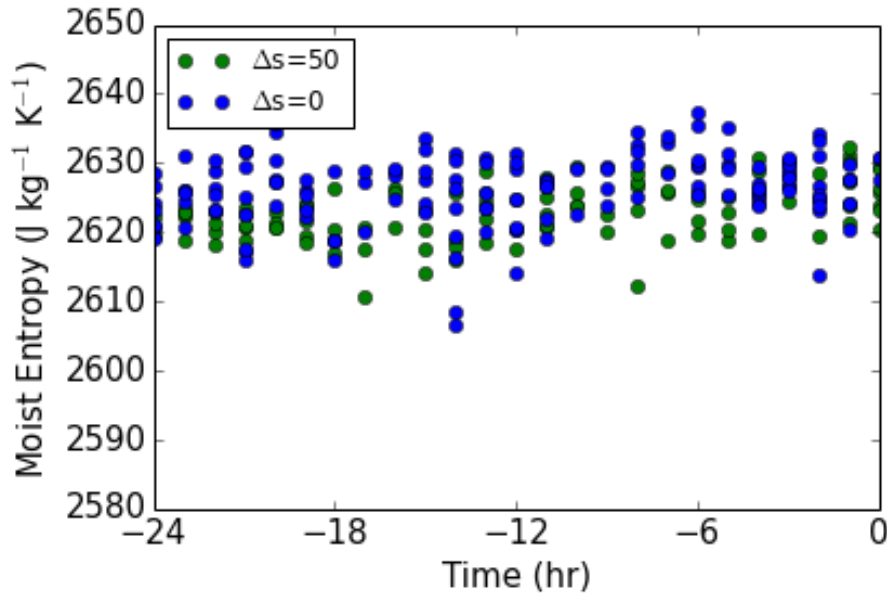
Backward Trajectories



Moist Entropy Comparison



Moist Entropy Comparison



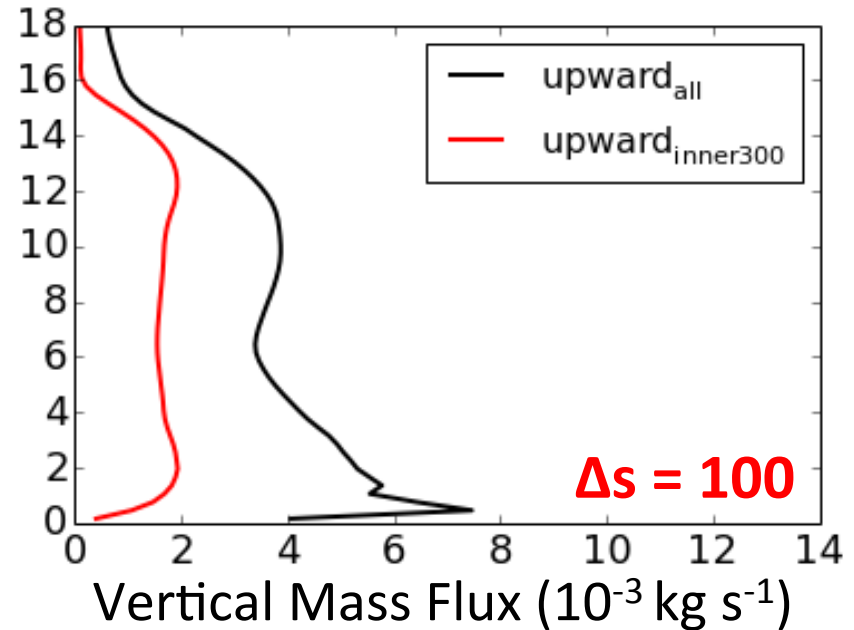
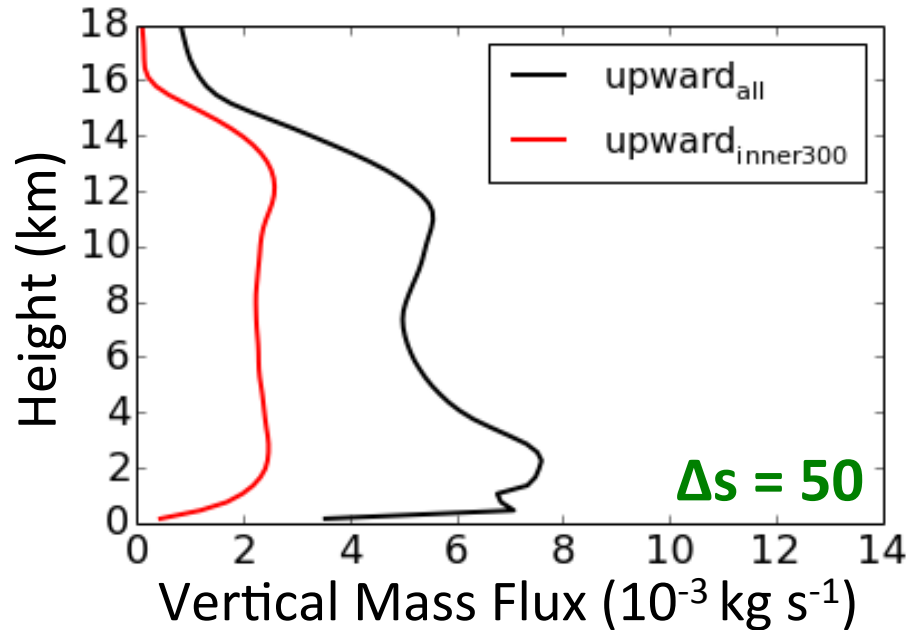
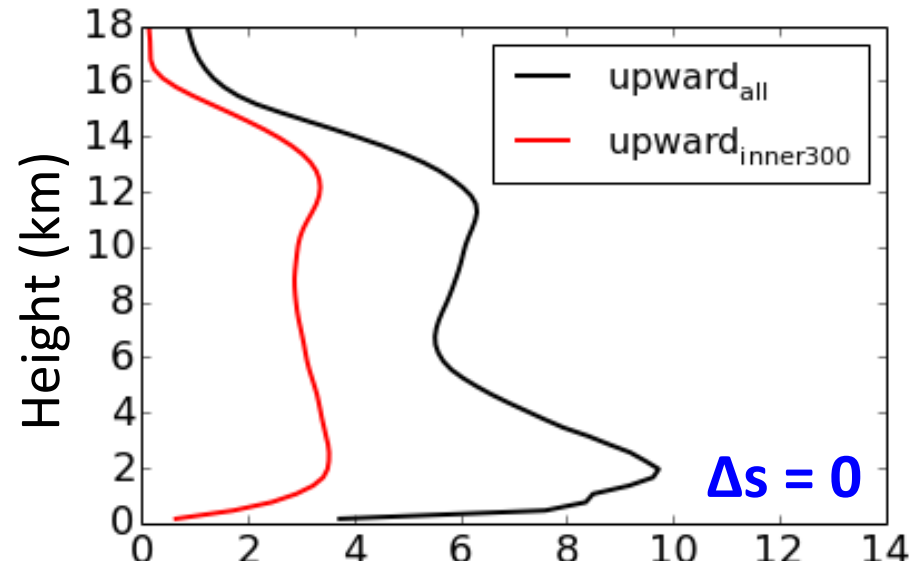
Conclusions

- ❖ Dry air entrainment reduces the mean upward vertical mass flux for drier simulations.
- ❖ This dry air entrainment occurs from low-entropy air entering the PBL.
- ❖ Less buoyant air parcels results in weaker mean upward vertical mass flux and an increased spinup timescale.
- ❖ Future work: What happens with more realistic idealized modeling?
- ❖ This material is based upon work supported by the NSF Graduate Research Fellowship NSF-DGE-1060277.

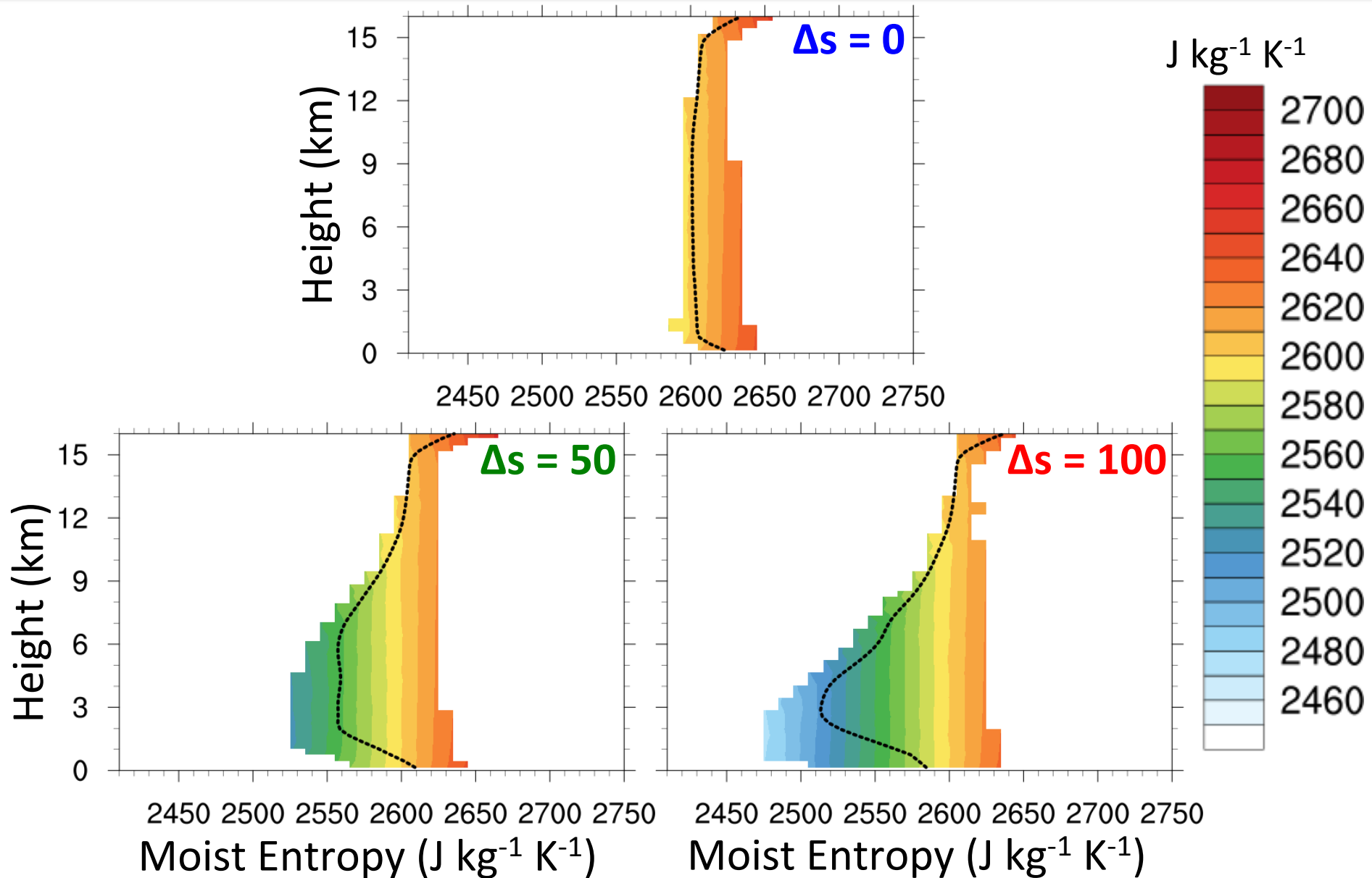
Extra Slides

Two-Stream Approximation

Vertical Mass Flux
 $\rho w r dr$

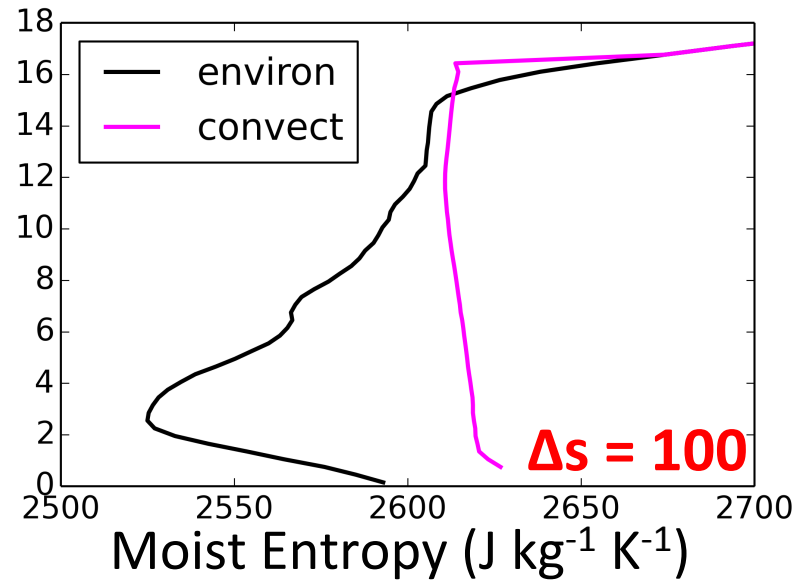
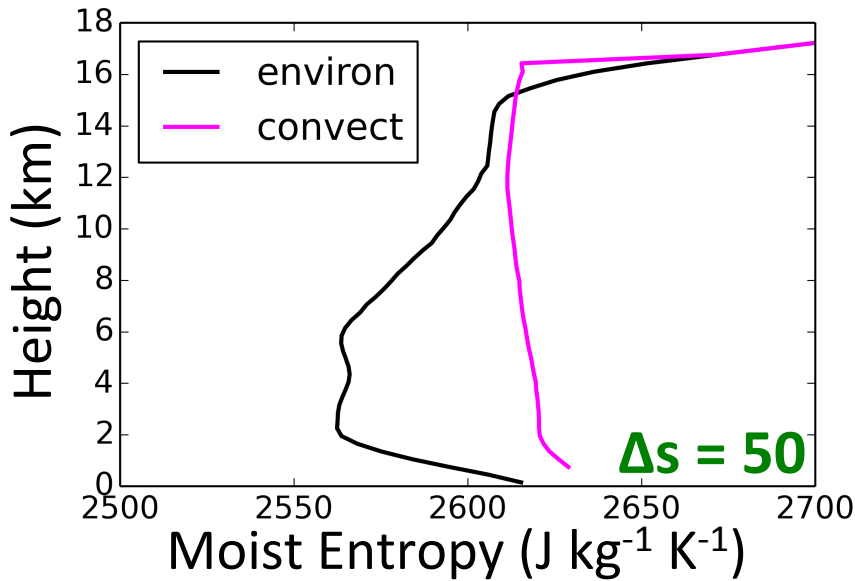
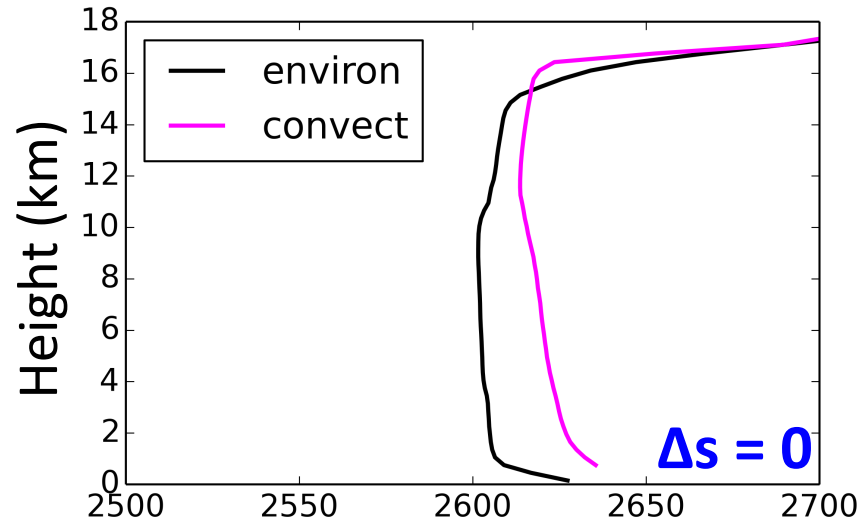


Moist Entropy

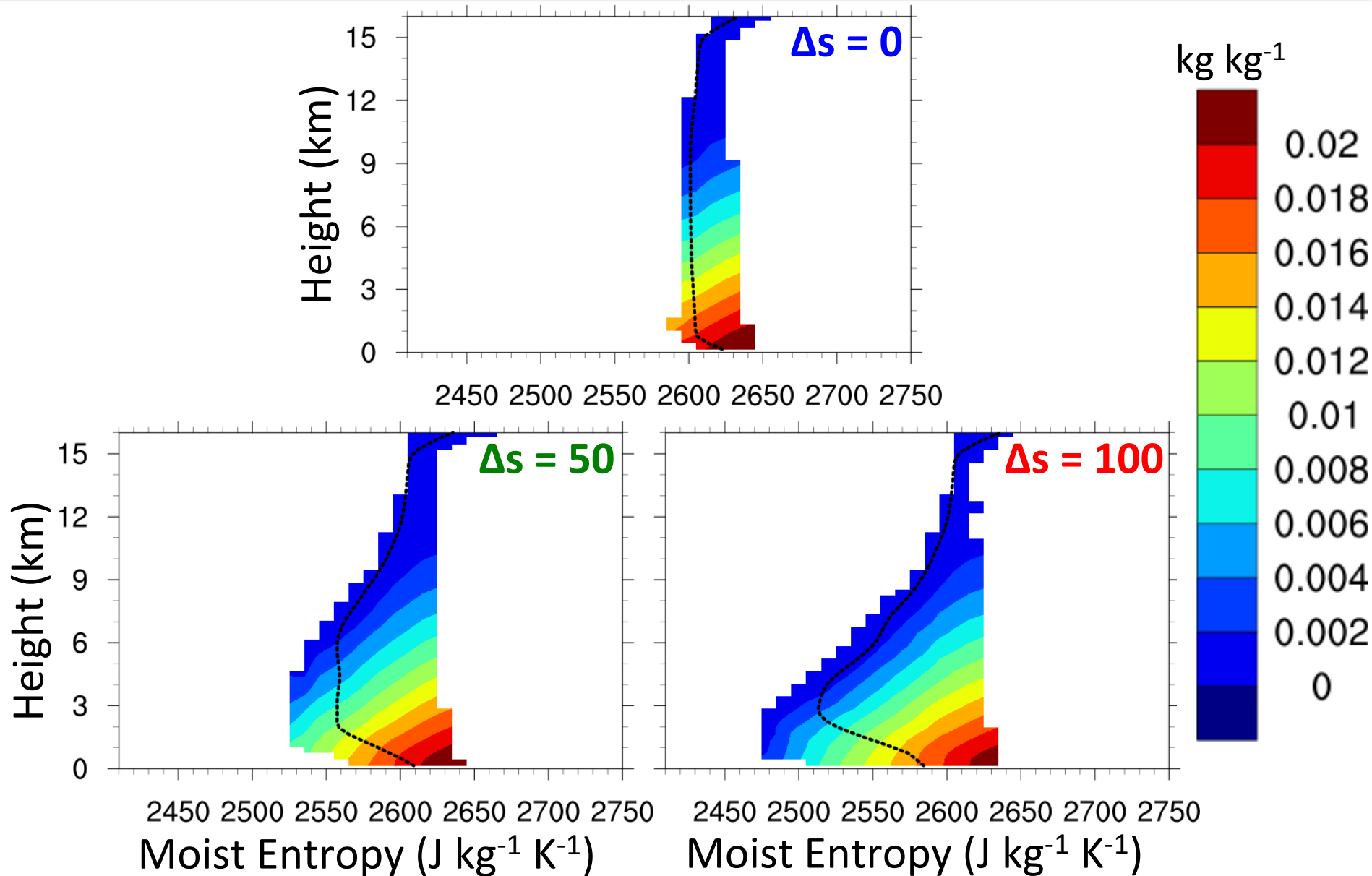


Two-Stream Approximation

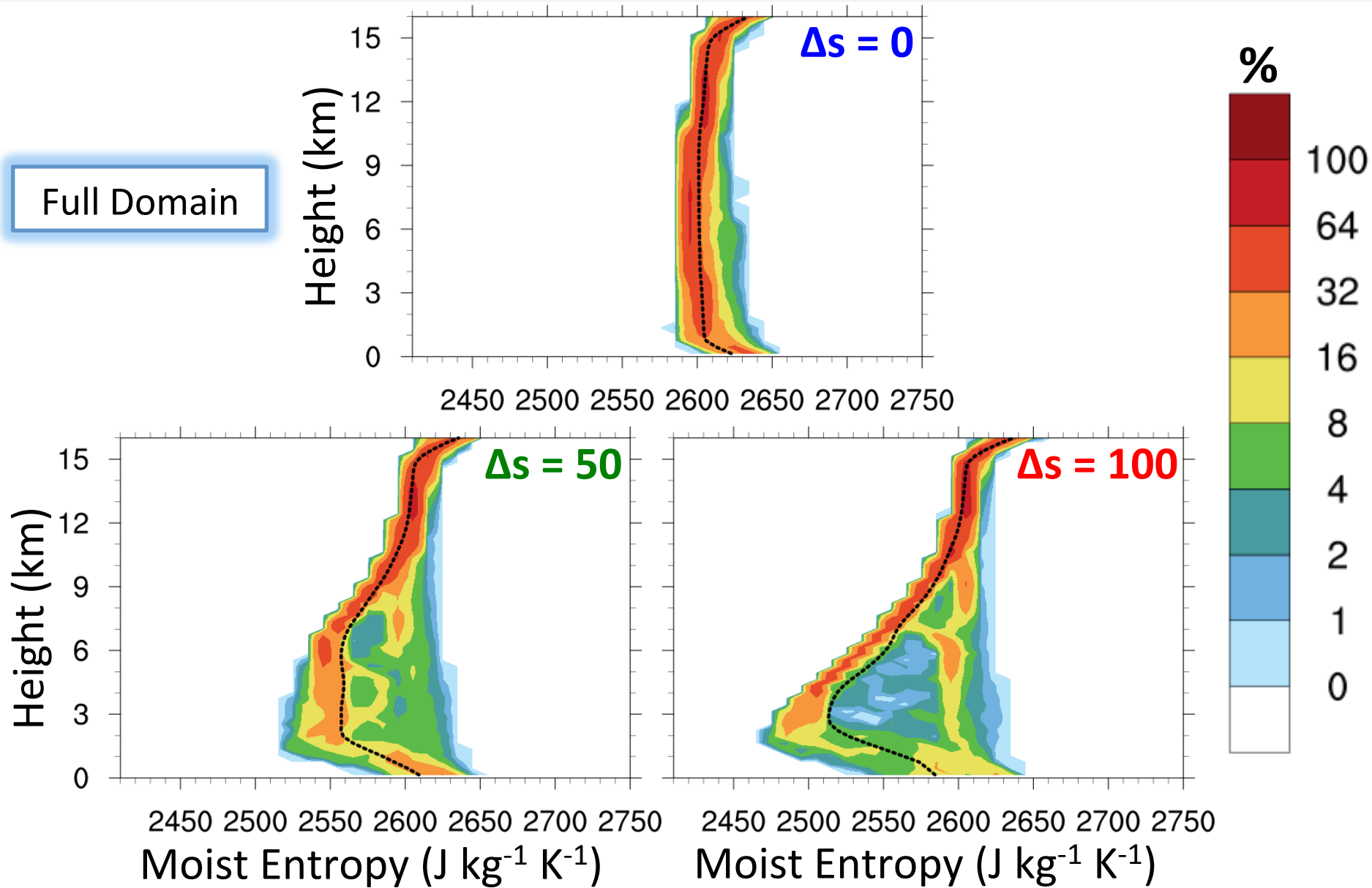
Moist Entropy



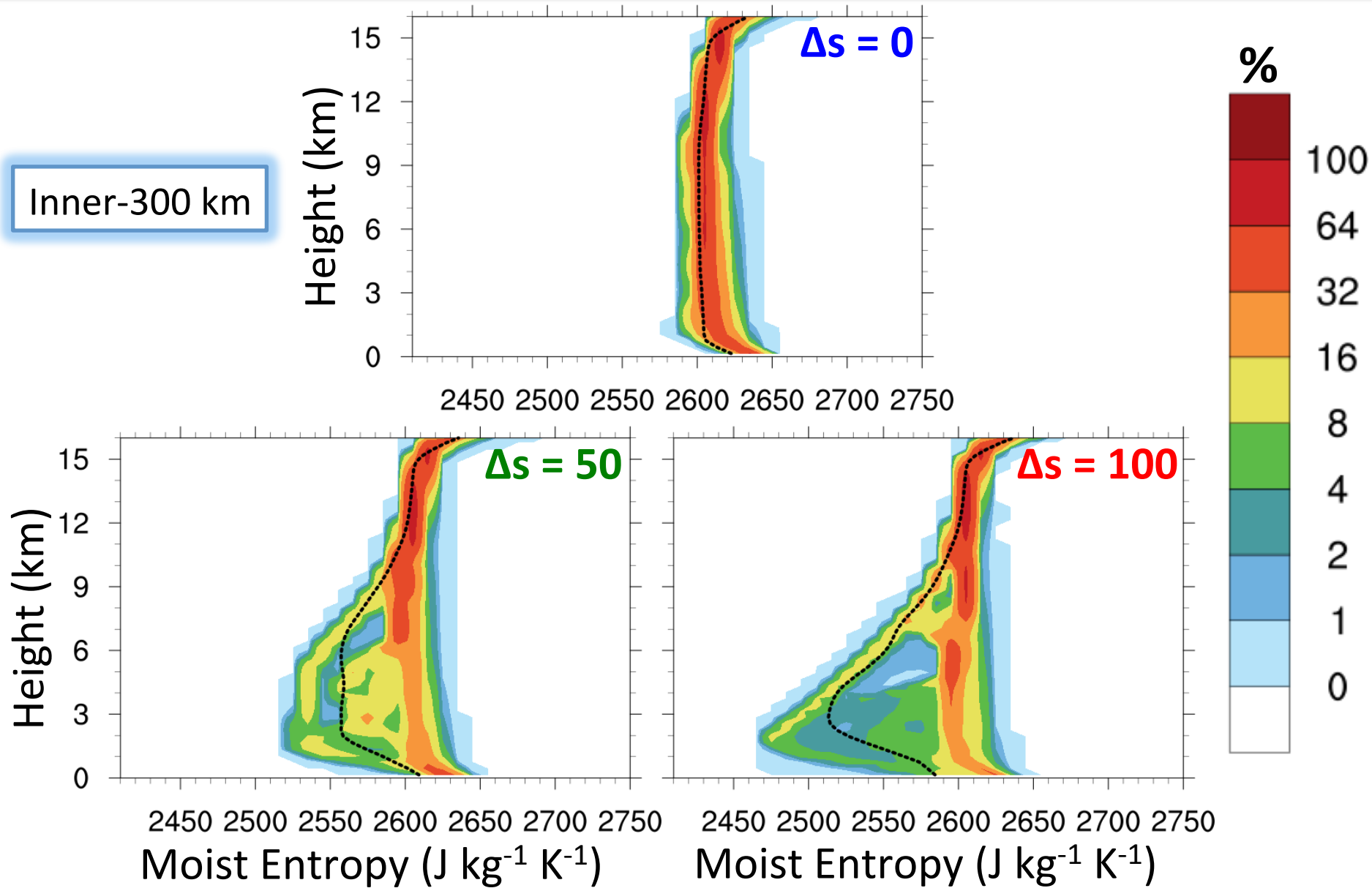
Water Vapor Mixing Ratio



CFADs of Moist Entropy

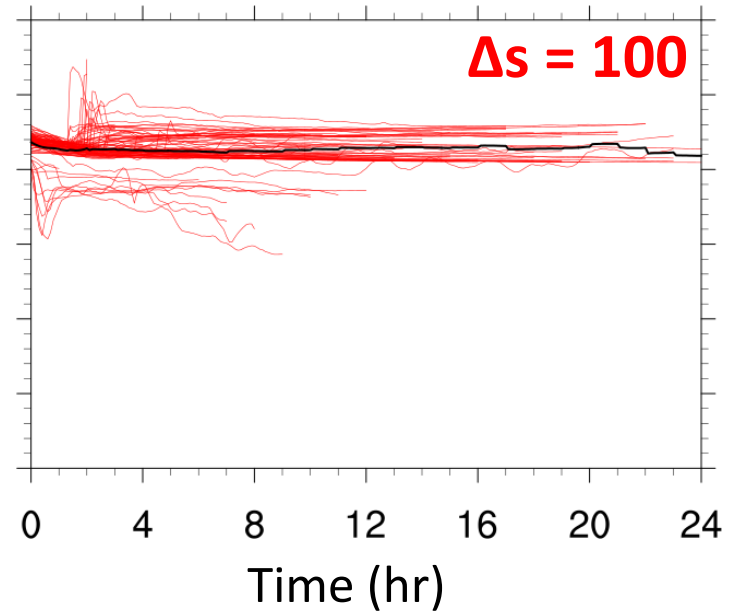
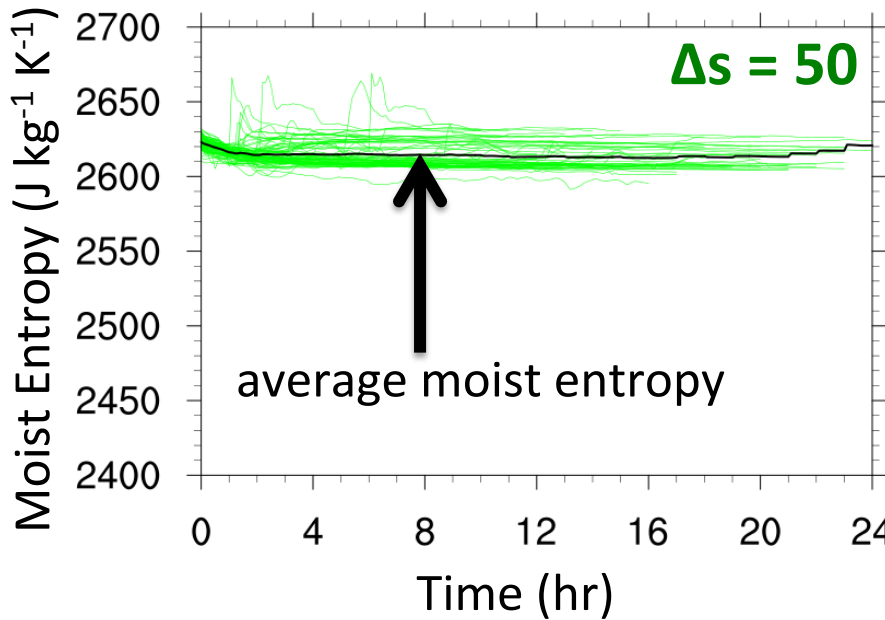
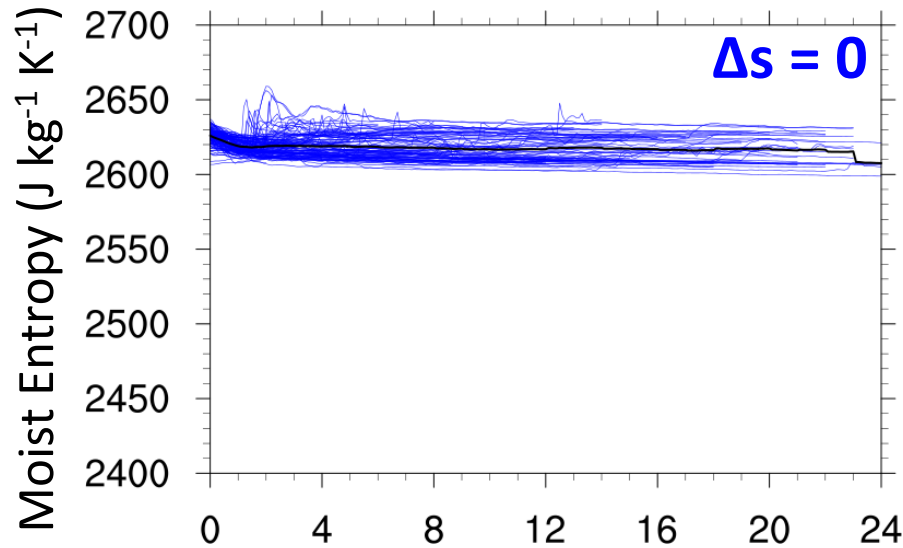


CFADs of Moist Entropy



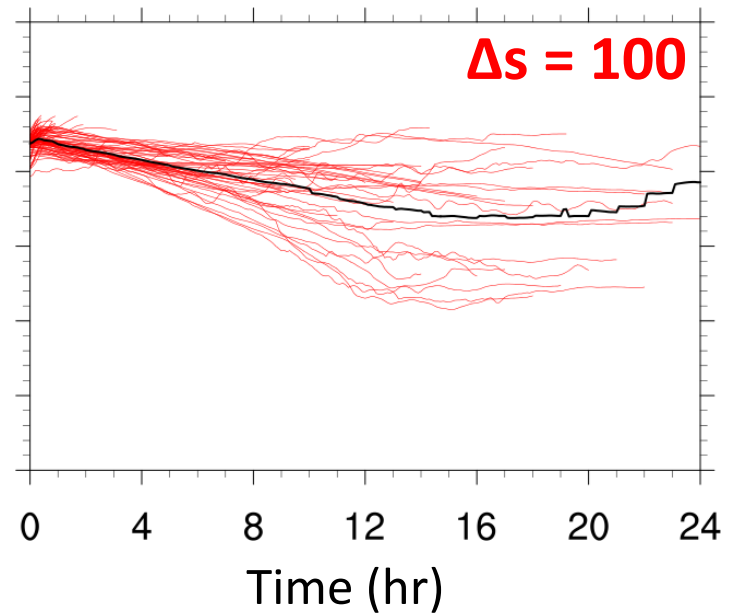
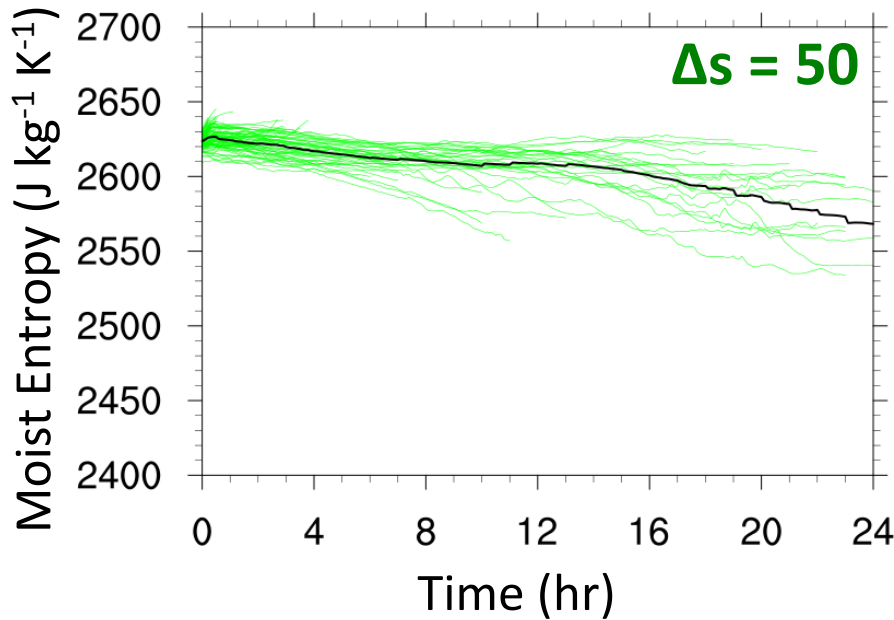
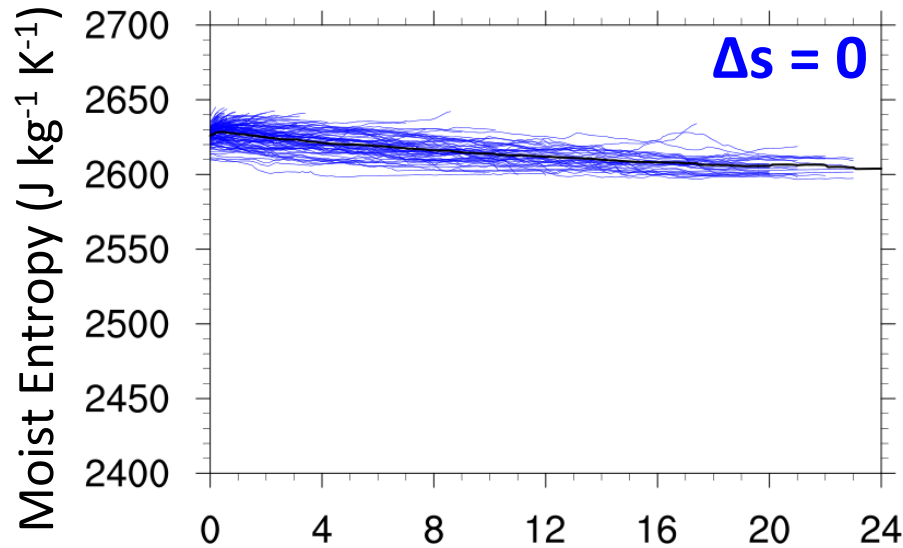
Forward Trajectories

All parcels transformed to begin at t=0hrs

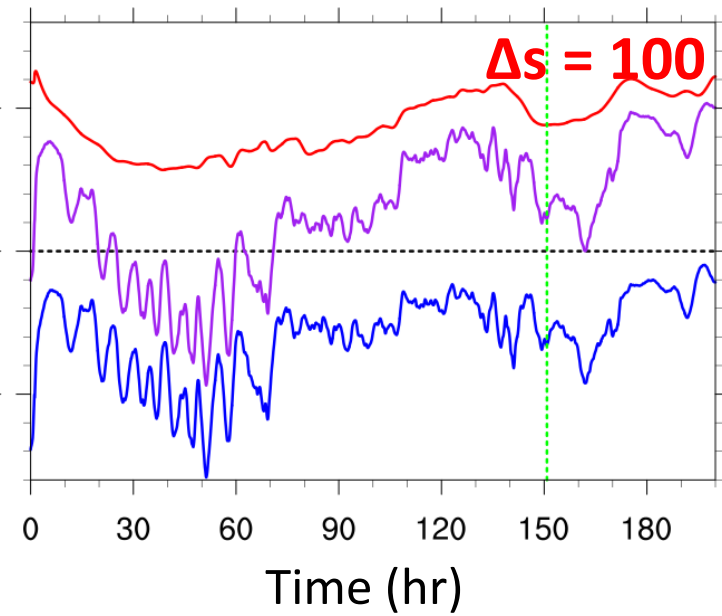
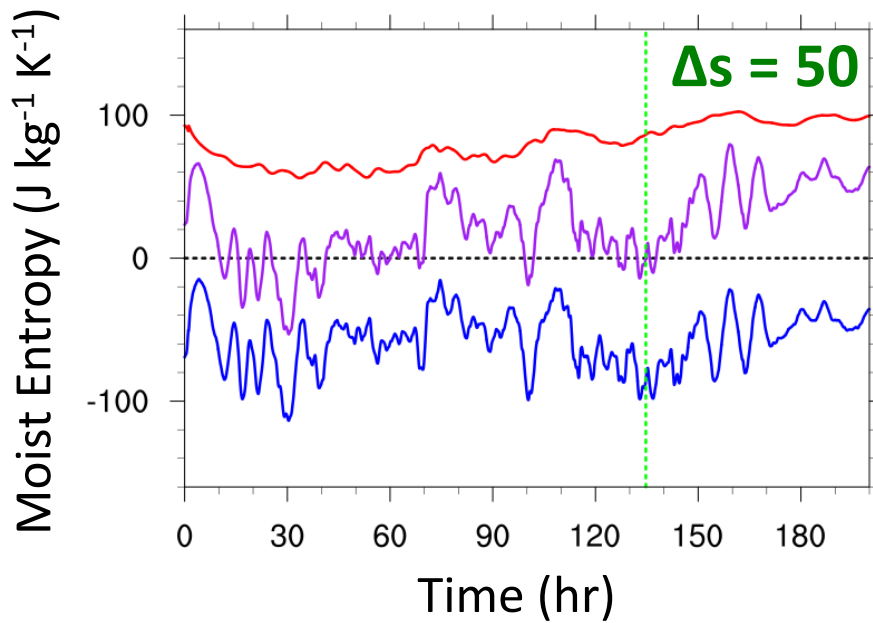
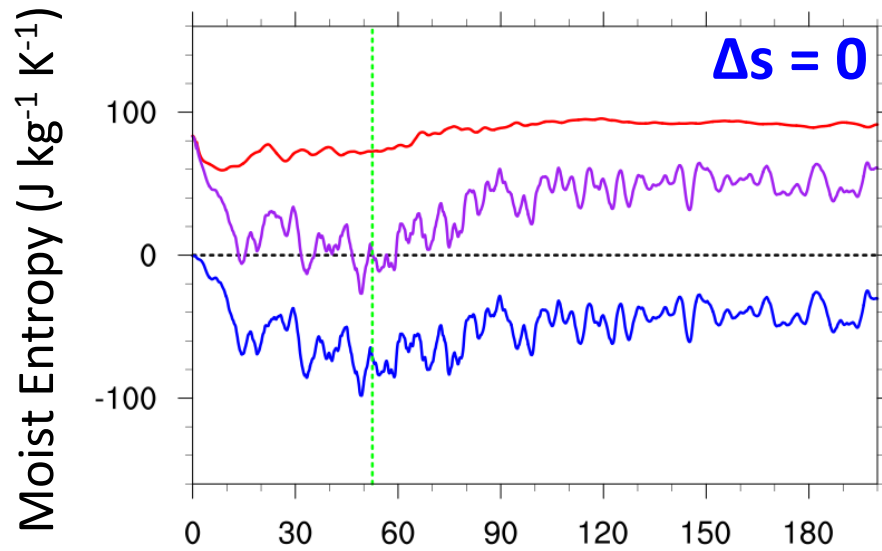


Backward Trajectories

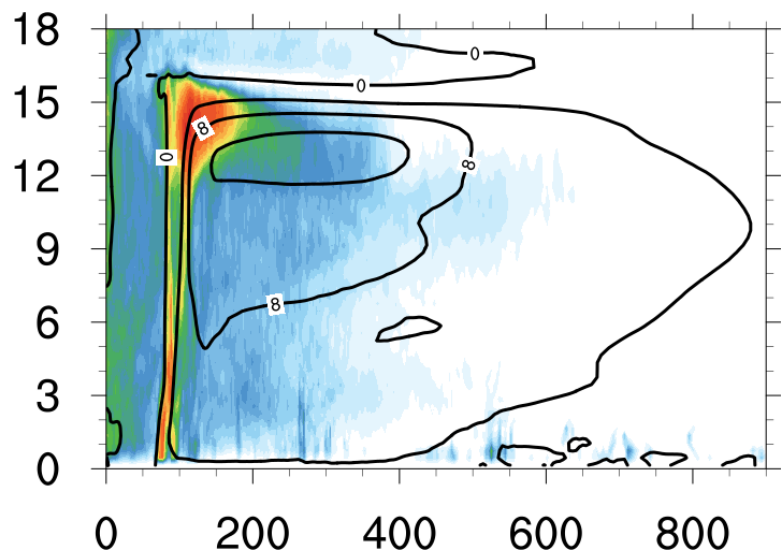
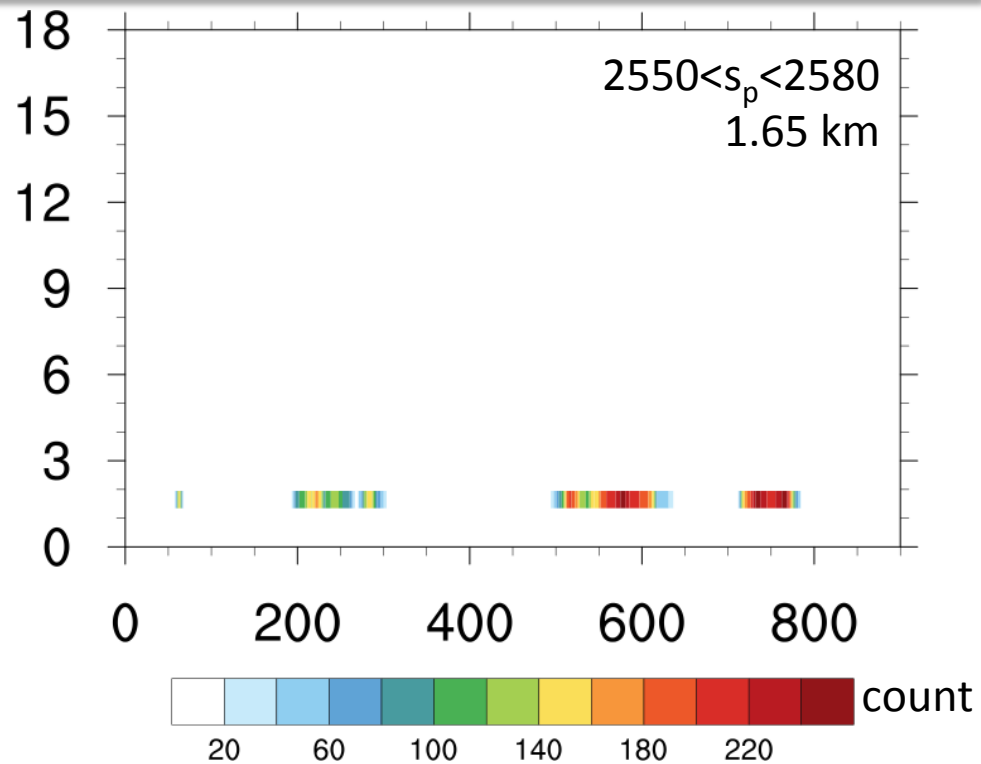
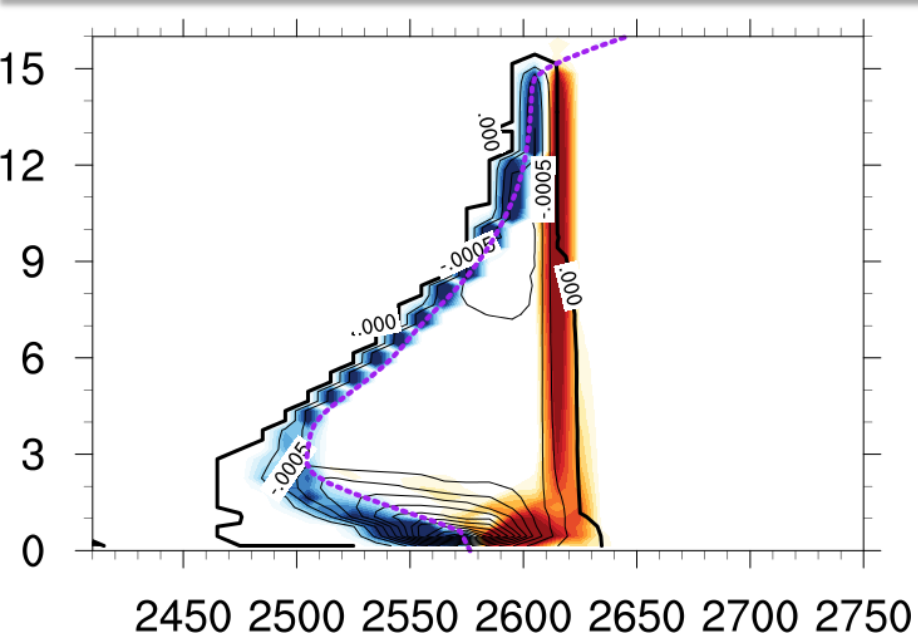
All parcels transformed to begin at t=0hrs



Forward Trajectories

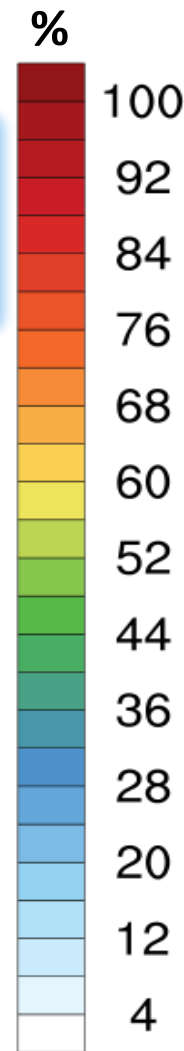
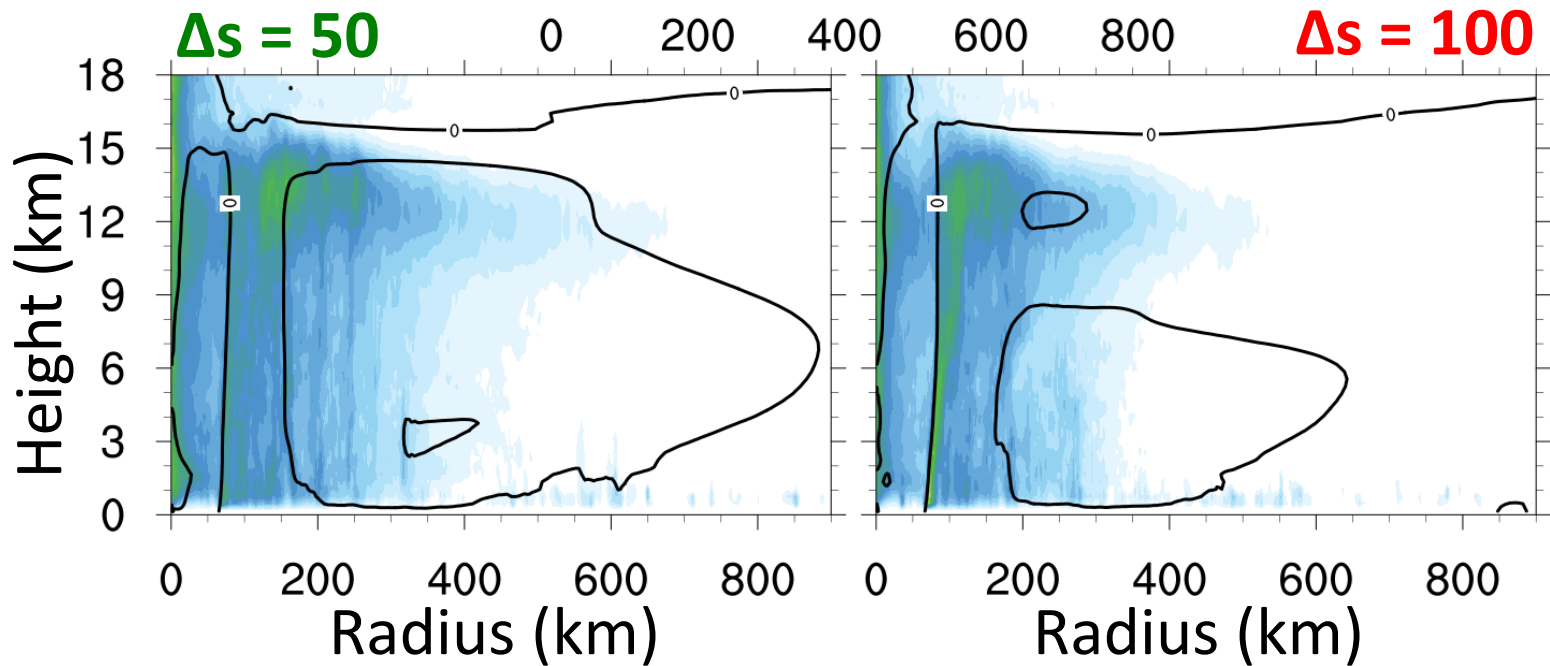
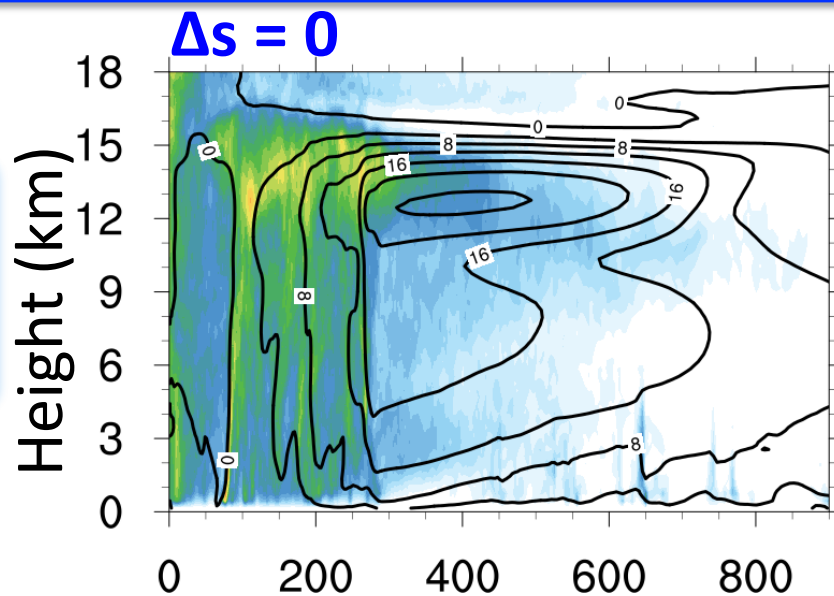


Shallow Convection



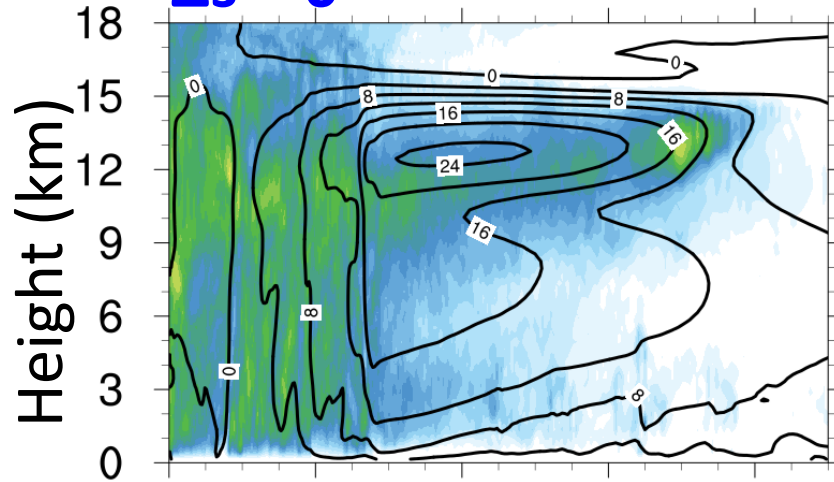
Updrafts and Streamfunction

Time-averaged
24 hours before
spinup time



Downdrafts and Streamfunction

$\Delta s = 0$



Contours: Streamfunction ($\times 10^8 \text{ kg s}^{-1}$)

Shading: Percentage of downdrafts $< -0.05 \text{ m s}^{-1}$

%

100

92

84

76

68

60

52

44

36

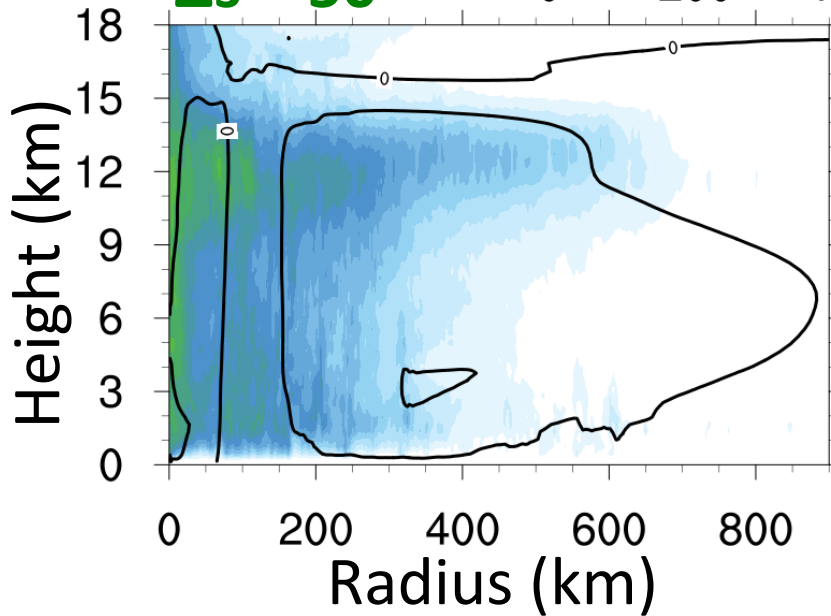
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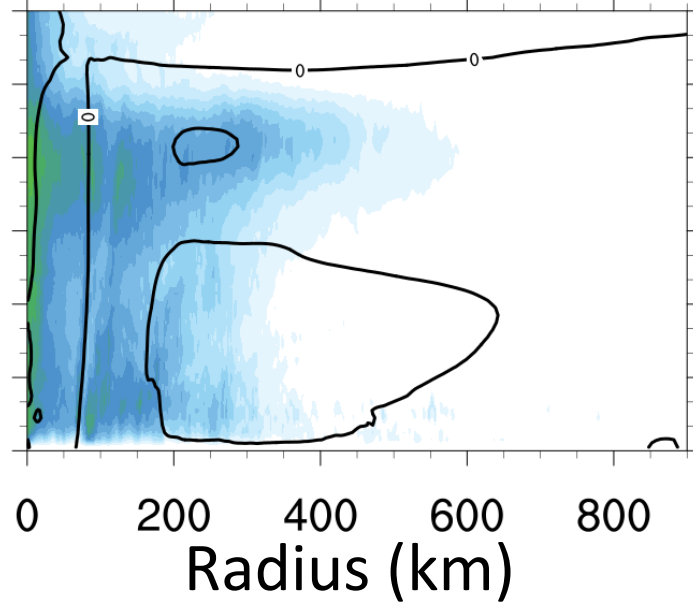
12

4

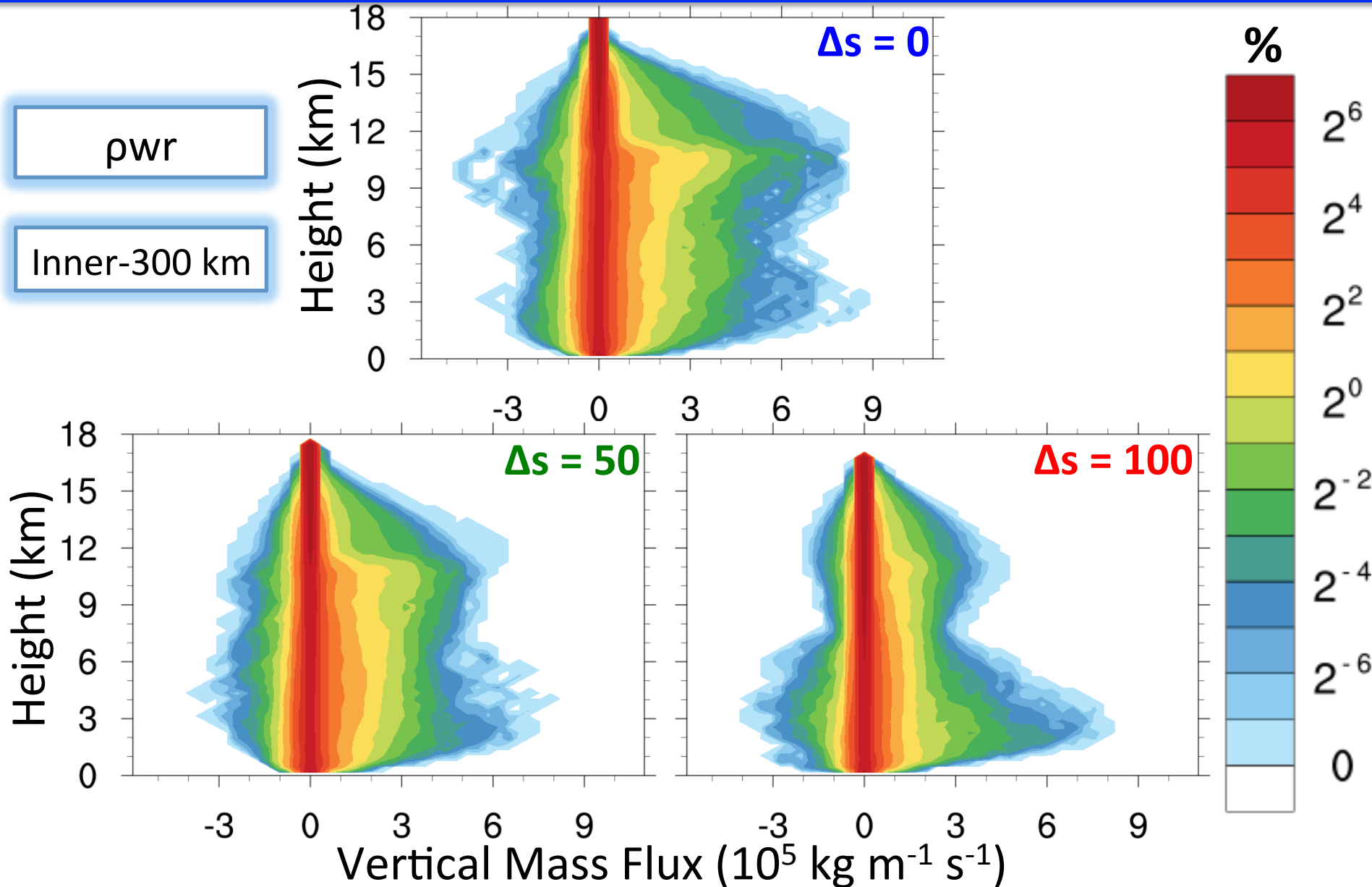
$\Delta s = 50$



$\Delta s = 100$

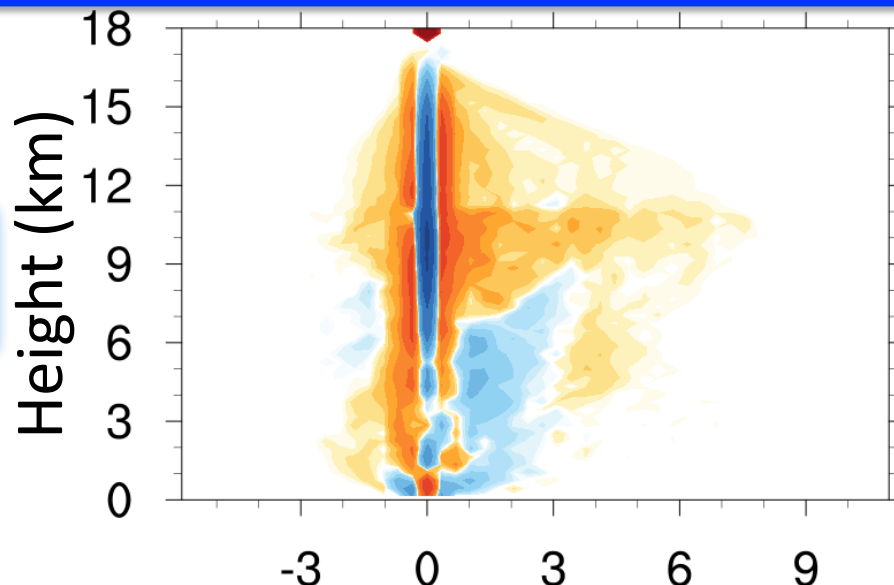


CFAD Diagrams: Vertical Mass Flux

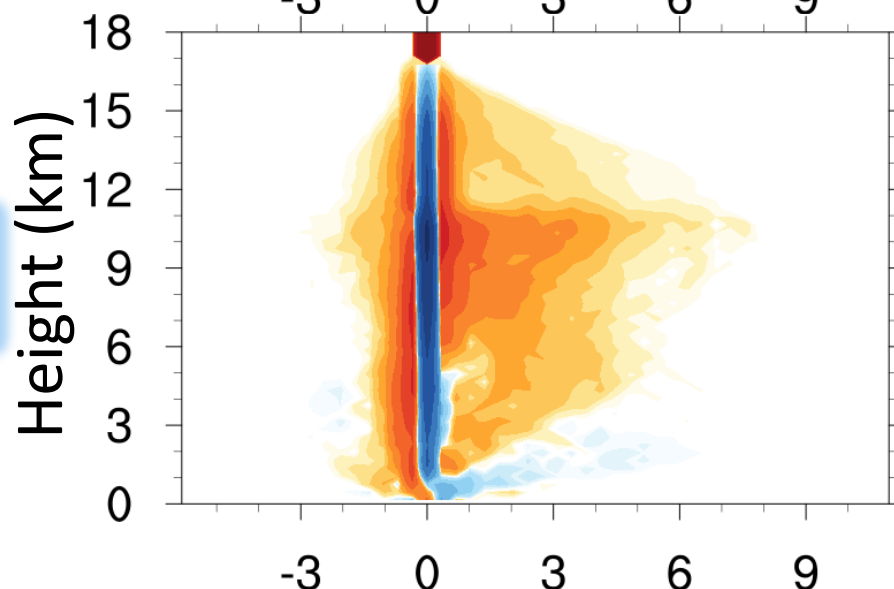


CFAD Differences: Vertical Mass Flux

$(\Delta s = 0) - (\Delta s = 50)$



$(\Delta s = 0) - (\Delta s = 100)$

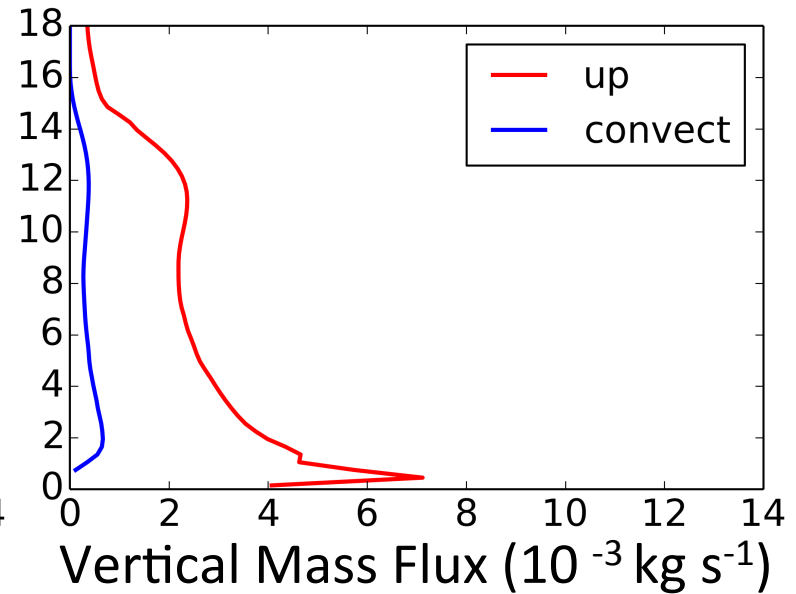
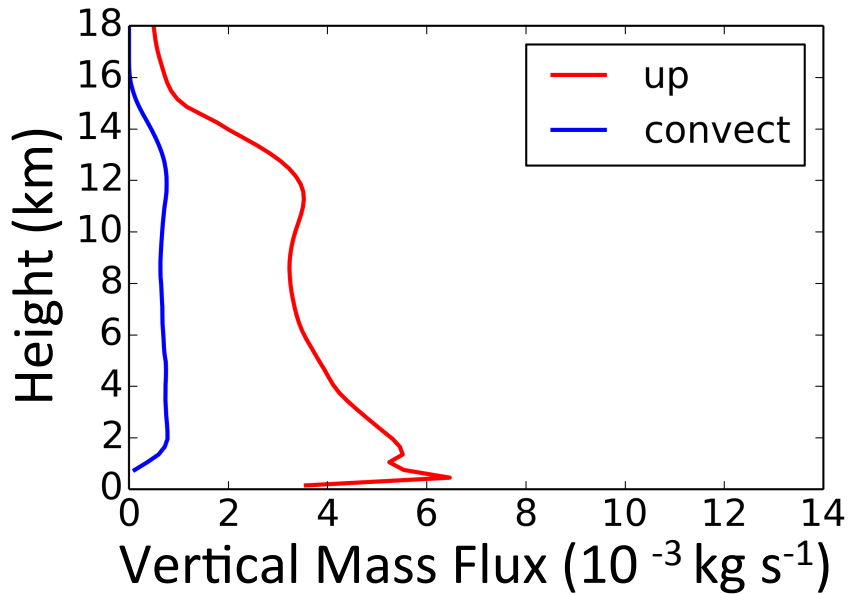
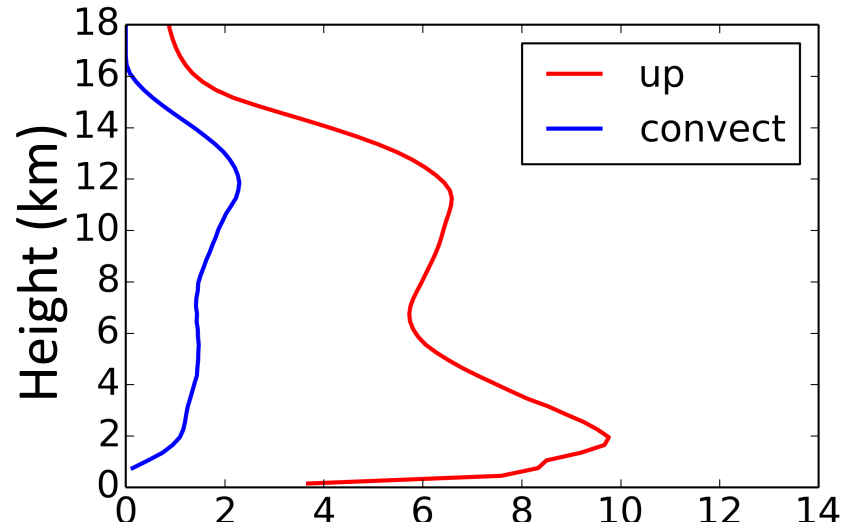


Vertical Mass Flux ($10^5 \text{ kg m}^{-1} \text{ s}^{-1}$)

Two-Stream Approximation

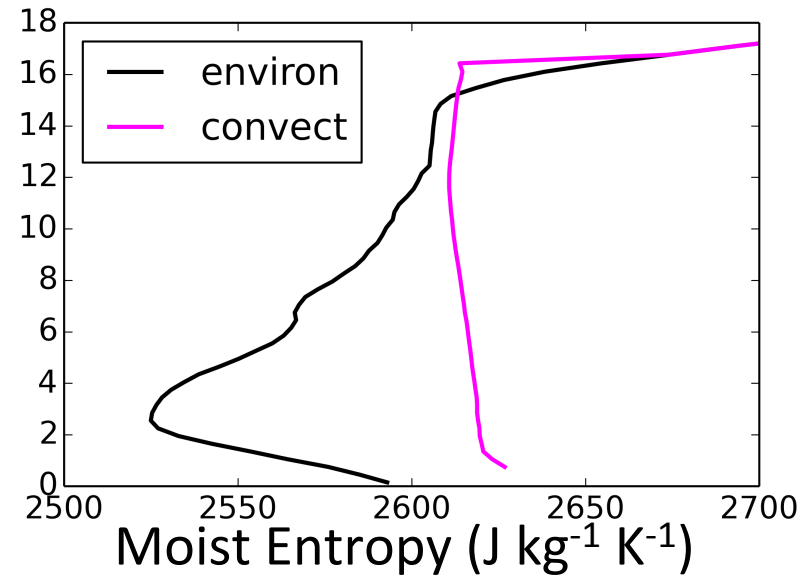
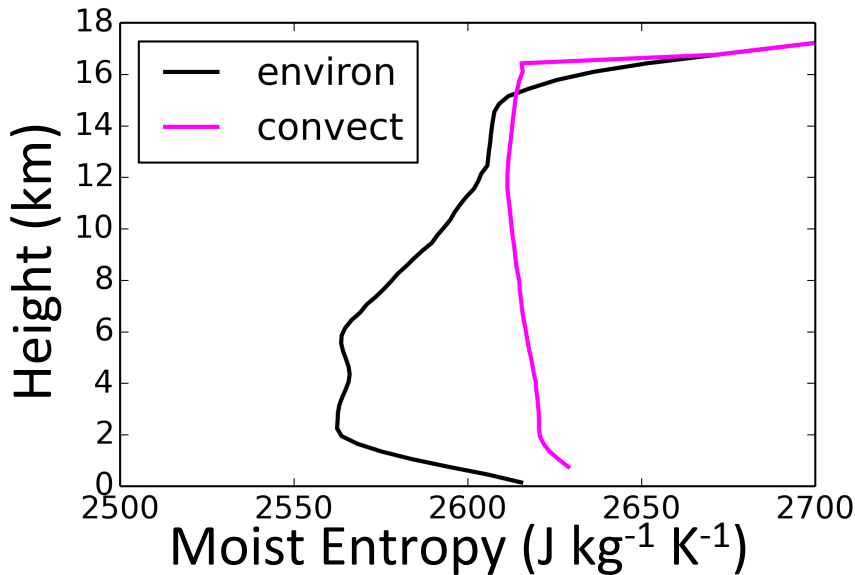
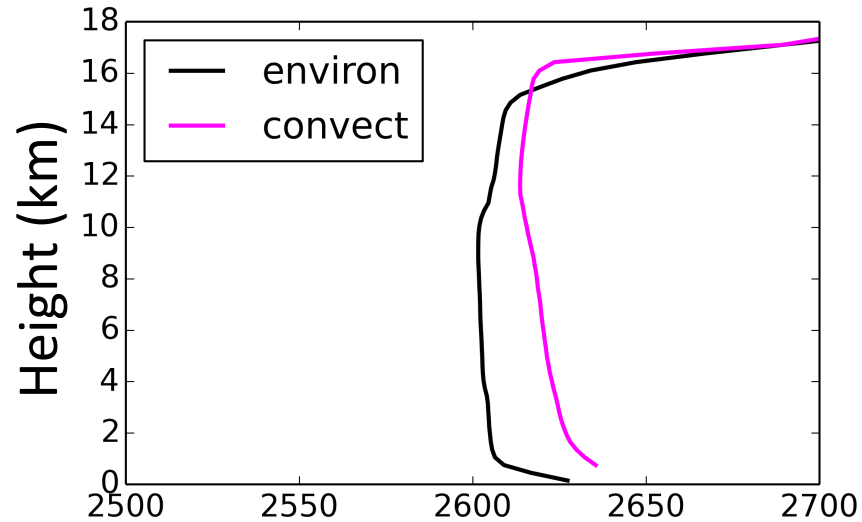
Vertical Mass Flux = $\rho w r dr$

Full domain

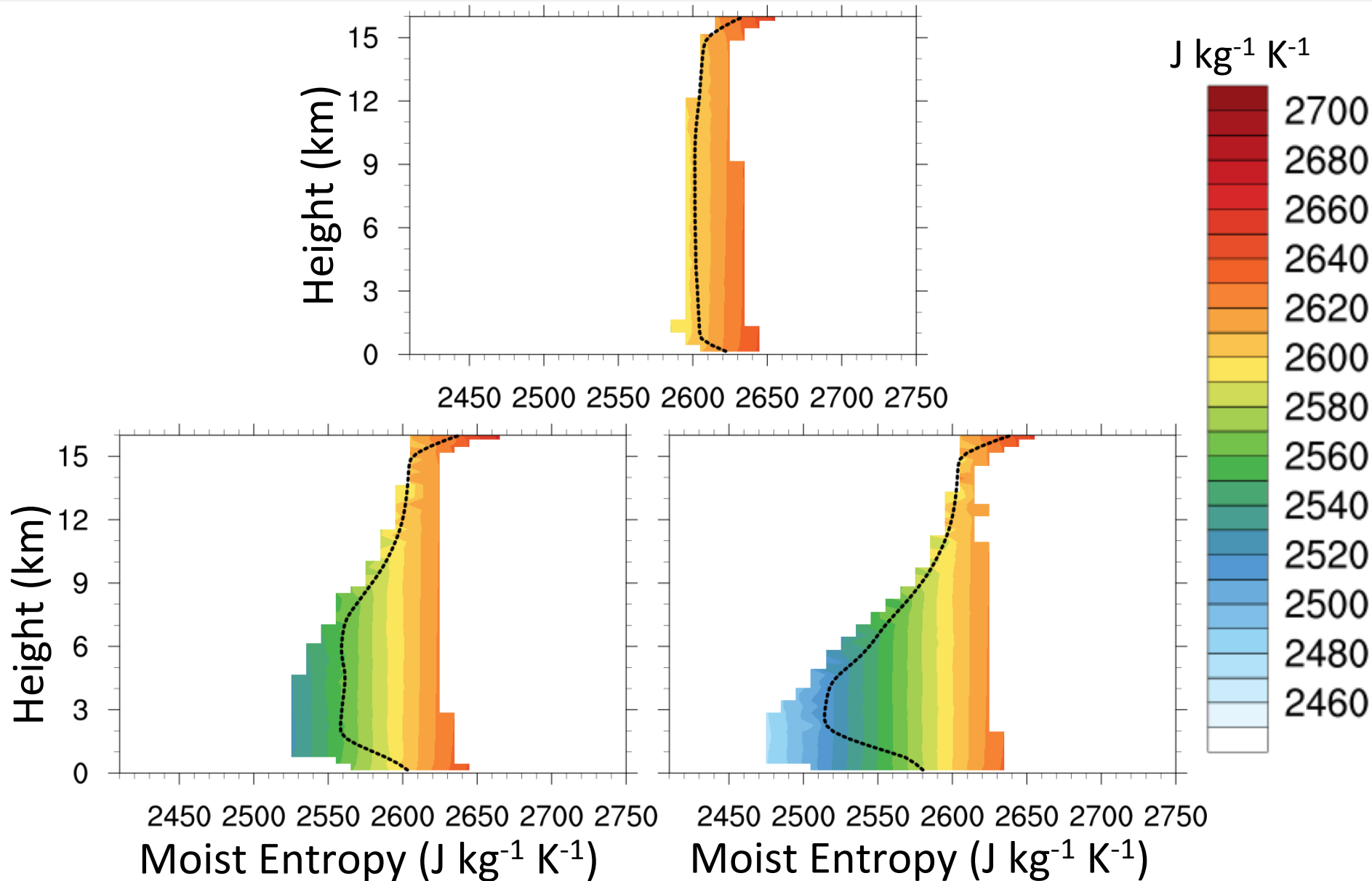


Two-Stream Approximation

Moist Entropy



Moist Entropy

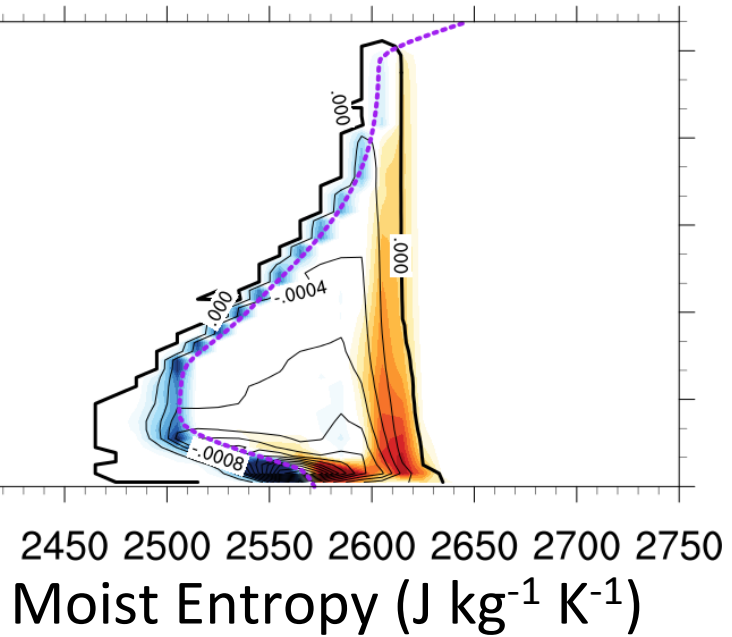
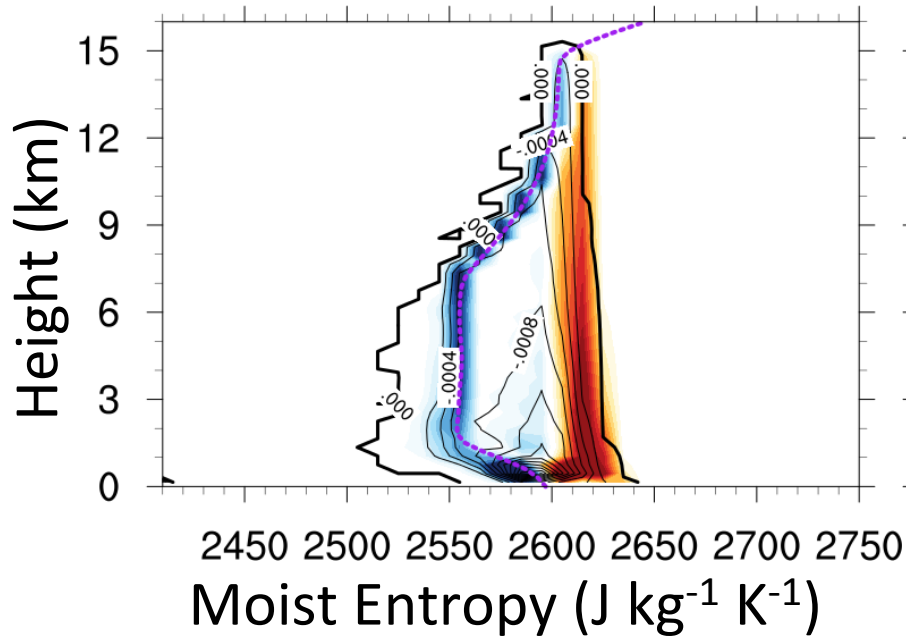
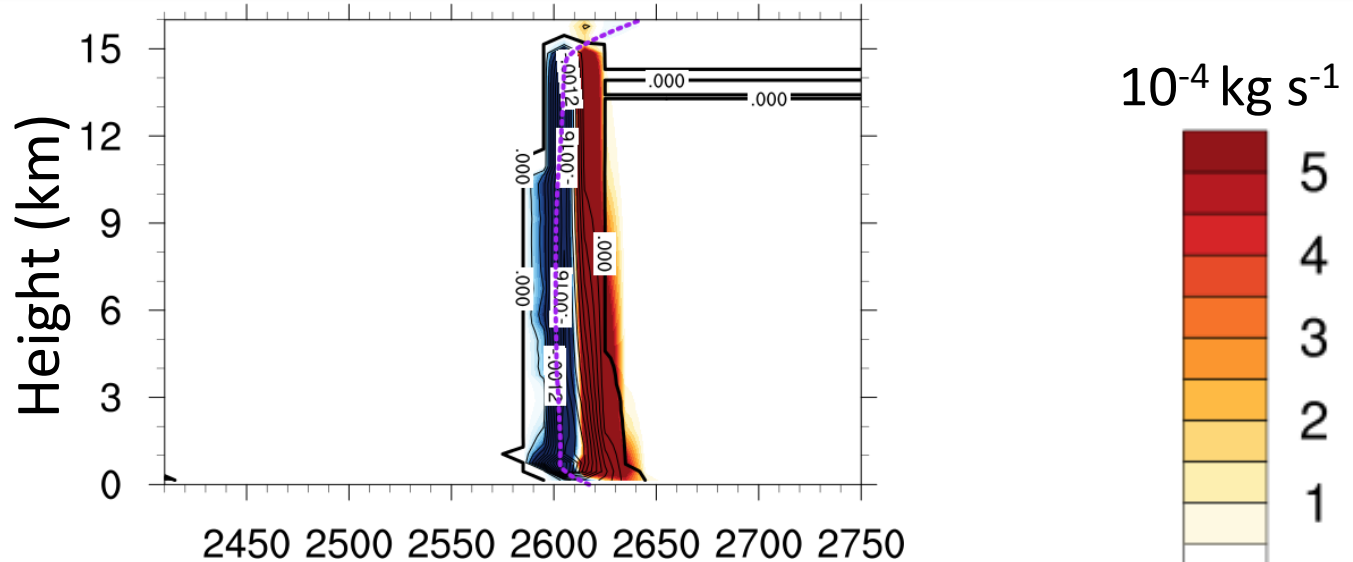


Vertical Mass Flux and Streamfunction

$$\Psi(z, s_p) = \int_{-\infty}^{s_p} (\rho w r dr) ds_p$$

Contours: Streamfunction
($\text{J s}^{-1} \text{K}^{-1}$)

Shading: Vertical Mass Flux
($10^{-4} \text{ kg s}^{-1}$)



Mass-Weighted Diabatic Tendency

$$\rho \dot{s}_p = - \frac{\partial \Psi}{\partial z}$$

