The Role of the Mid-level Vortex in Tropical Cyclogenesis

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Workshop on Tropical Dynamics and the MJO

Introduction

- Observations: Mid-level vortex precedes genesis.
- Mid-level vortex aids low-level vortex intensification.
- Vortices at different levels are not directly related with vorticity equation;
  $\rightarrow$ How the mid-level vortex facilitates the low-level spin up?
  Thermodynamics: changes the tropospheric stability to moist convection!

Introduction

Raymond and Sessions (2007):

Different tropospheric stratification $\rightarrow$

Different convection $\rightarrow$

Different dynamics!

Data and Methods

- Dropsonde data from PREDICT (24 cases);
- Dropsonde data from GRIP (6 cases);
- Dropsonde and doppler radar data from TCS08 (7 cases).
- All data quality controlled by Earth Observing Laboratory (thank you!).
- 3D-Variational analysis (Carillo and Raymond, 2011).

- Saturation fraction:

$$SF = \frac{precipitable\ water}{saturated\ precipitable\ water}$$

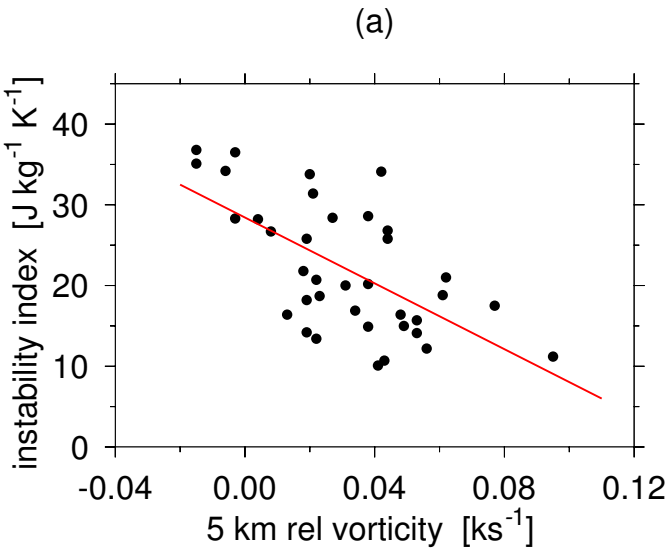
- Instability index:

$$\Delta s^* = s^*_{1-3km} - s^*_{5-7km}$$

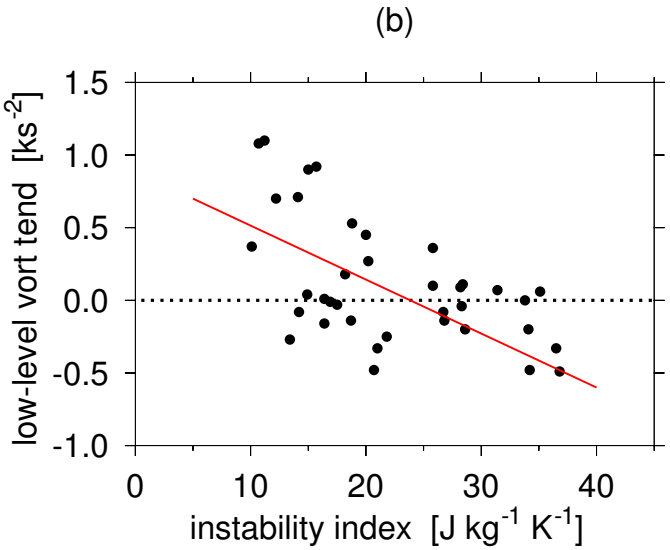
- Vorticity tendency (Haynes and McIntyre (1987) vorticity equation):

$$\frac{\partial \zeta_z}{\partial t} = -\nabla_h \cdot (advection + tilting + friction)$$

Results
Possible correlations

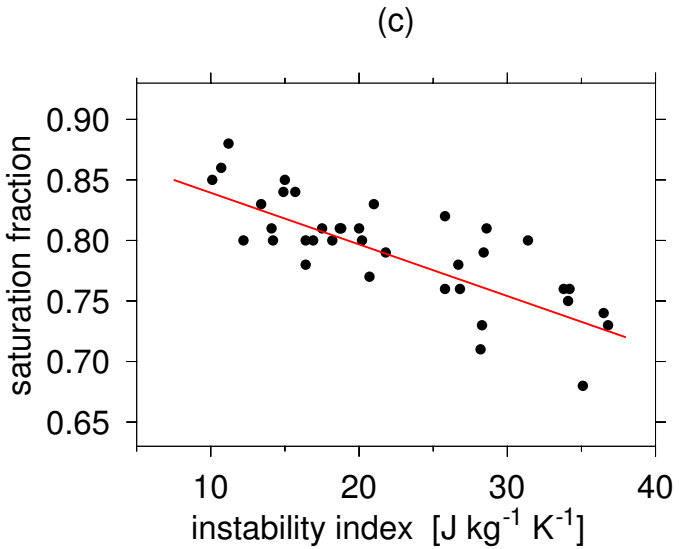


Stronger mid-level vortex $\rightarrow$ more stable atmosphere! (thermal wind balance)



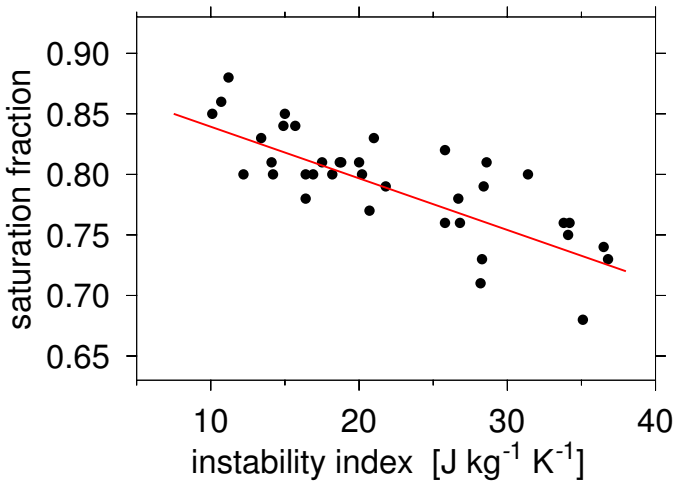
More stable atmosphere $\rightarrow$ larger vorticity tendency near the surface!

Results
Possible correlations

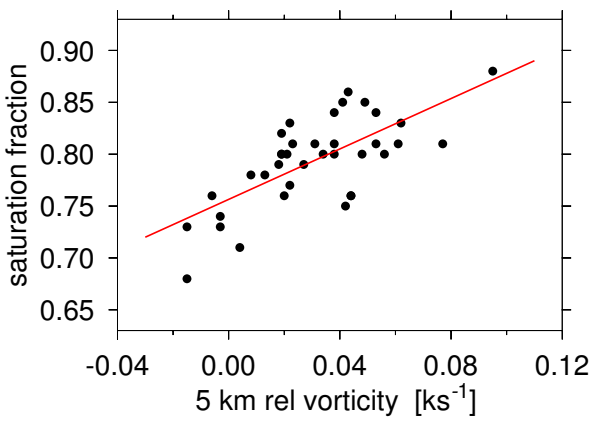


Results
Possible correlations

(c)



(a)



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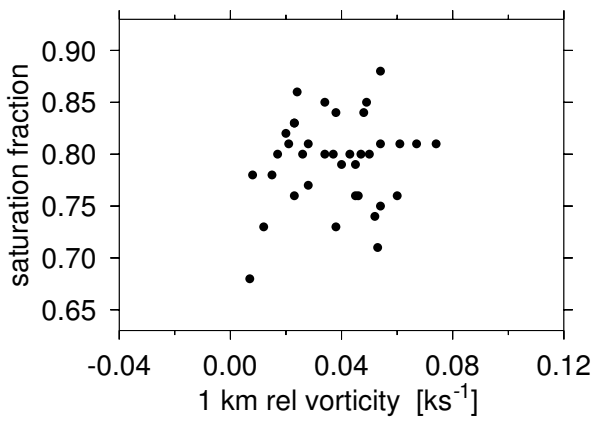


Results

Mid-level vortex $\rightarrow$

more stable thermodynamic stratification $\rightarrow$

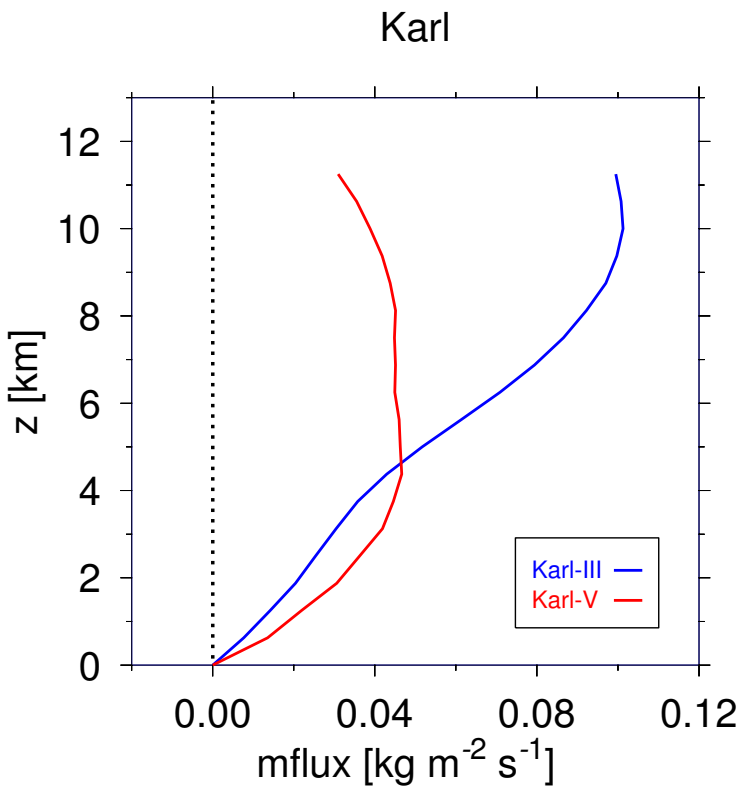
Convection?? $\rightarrow$

low-level vorticity convergence, moisture convergence.

Results
Convection??

Raymond and Sessions (2007): More stable troposphere → more bottom-heavy vertical mass flux.

Observations: $\Delta s^* = 28.4$ J/kg/K; $\Delta s^* = 15.7$ J/kg/K.

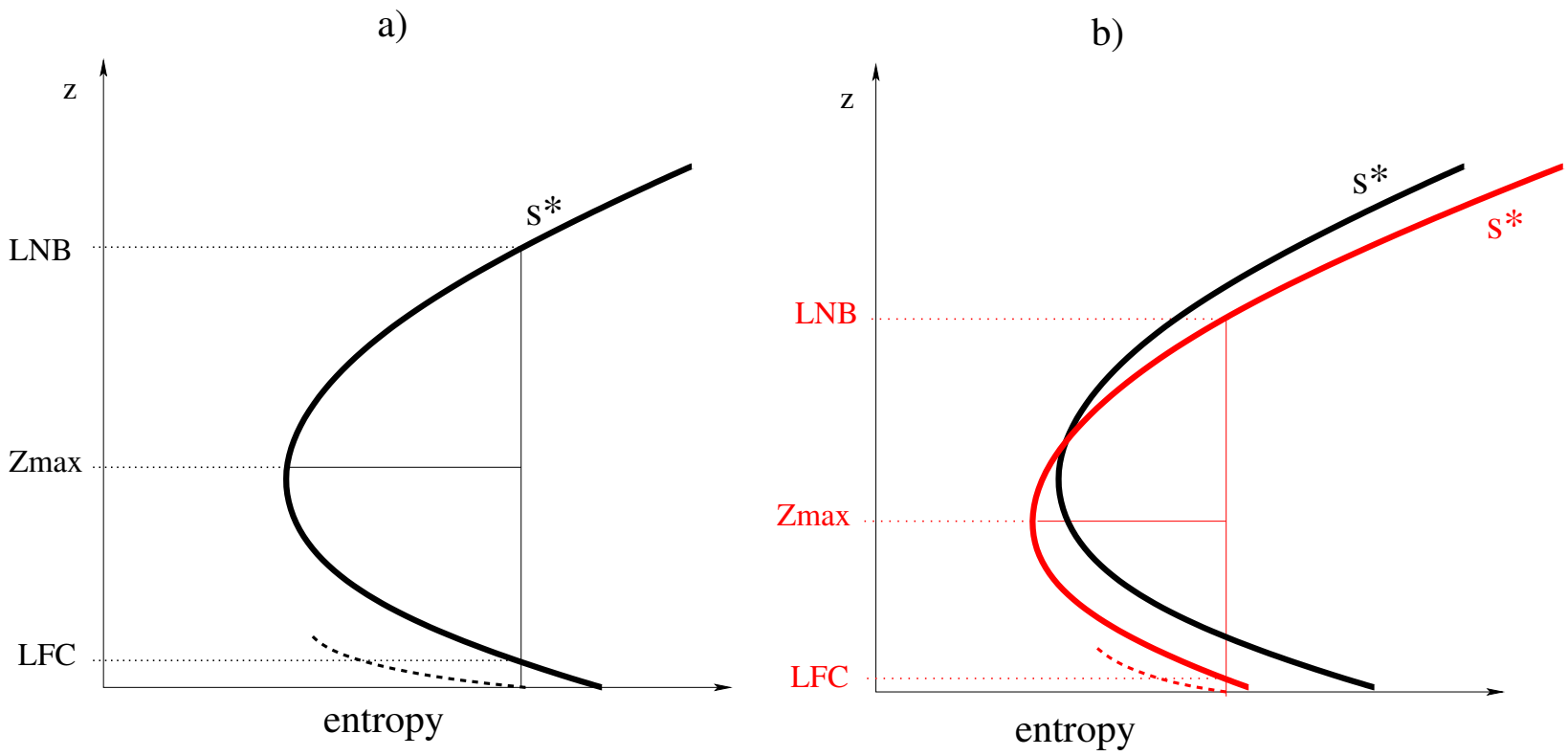


Discussion

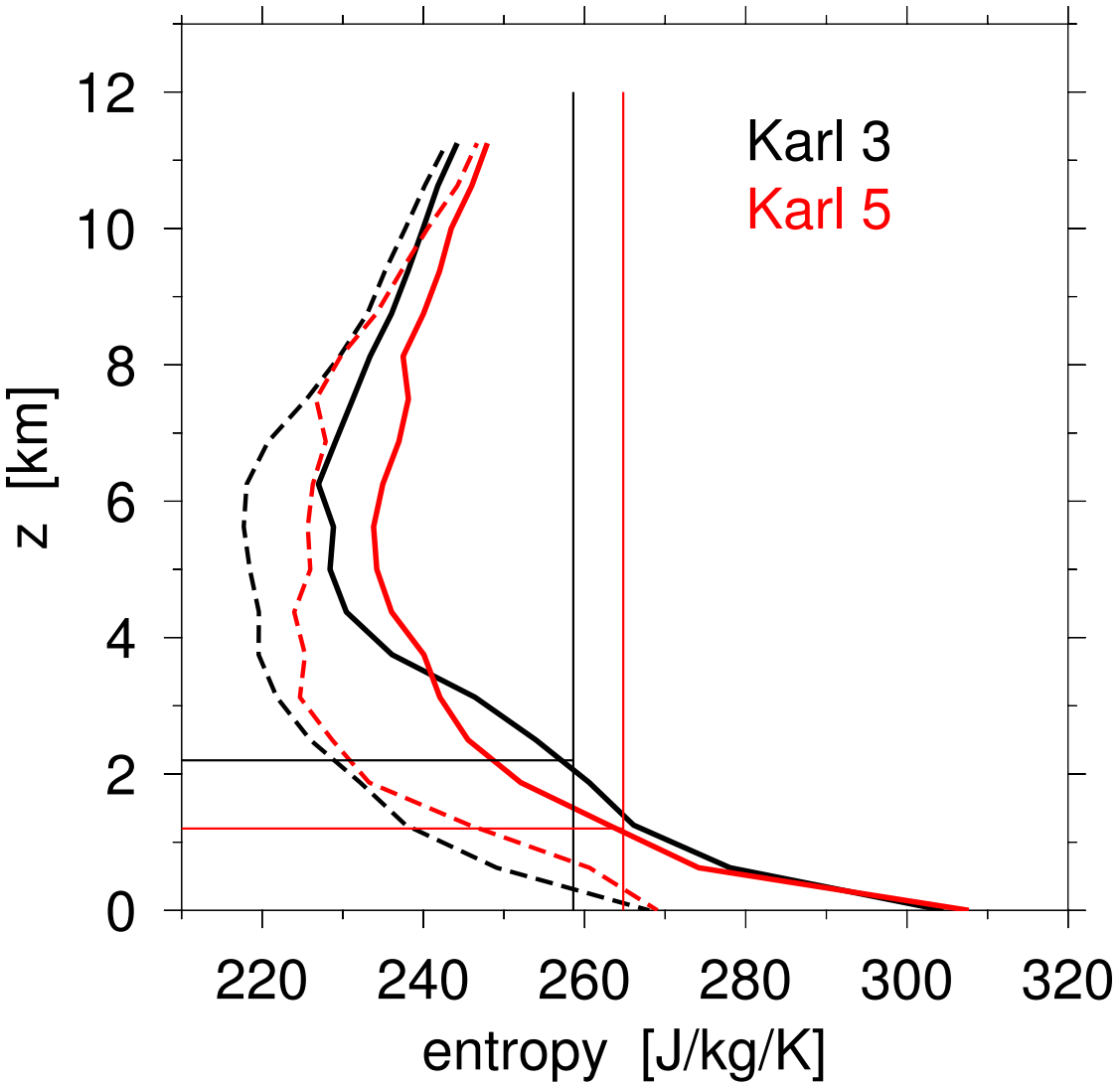
Why is more stable troposphere conducive to more bottom-heavy mass flux profile?

Discussion
Thought experiment

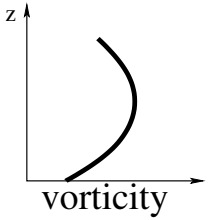
$$s = C_p \ln(\theta / T_r) + L r / T_r \qquad s^* = C_p \ln(\theta / T_r) + L r_{sat} / T_r$$



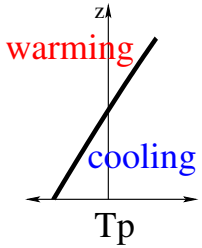
Discussion
Thought experiment



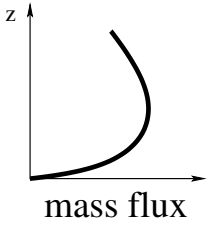
Theory
The pathway to cyclogenesis



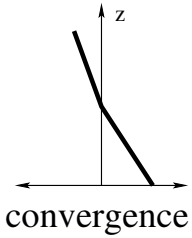
Mid-level vortex



More stable thermodynamic stratification



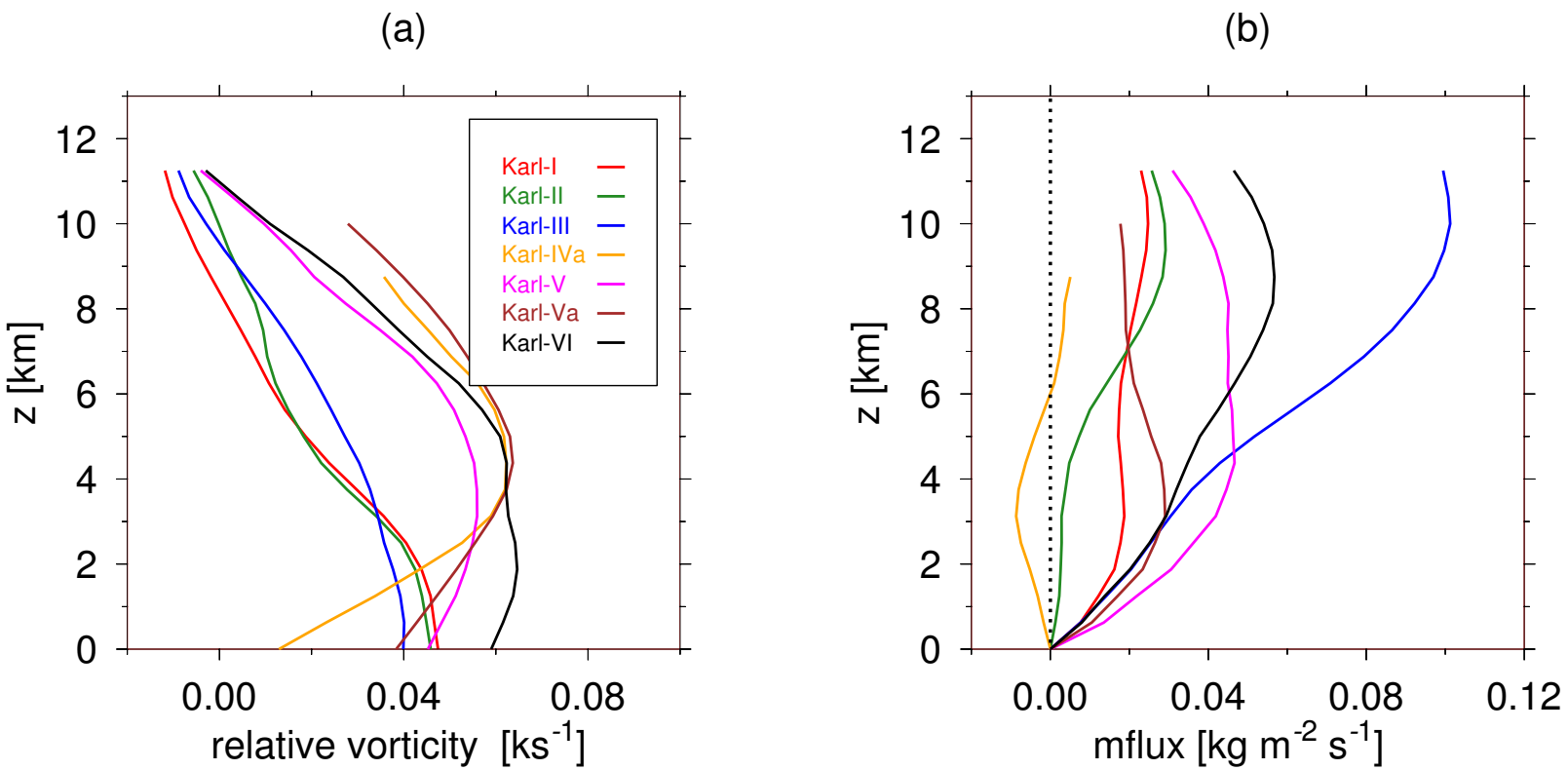
Bottom-heavy mass flux



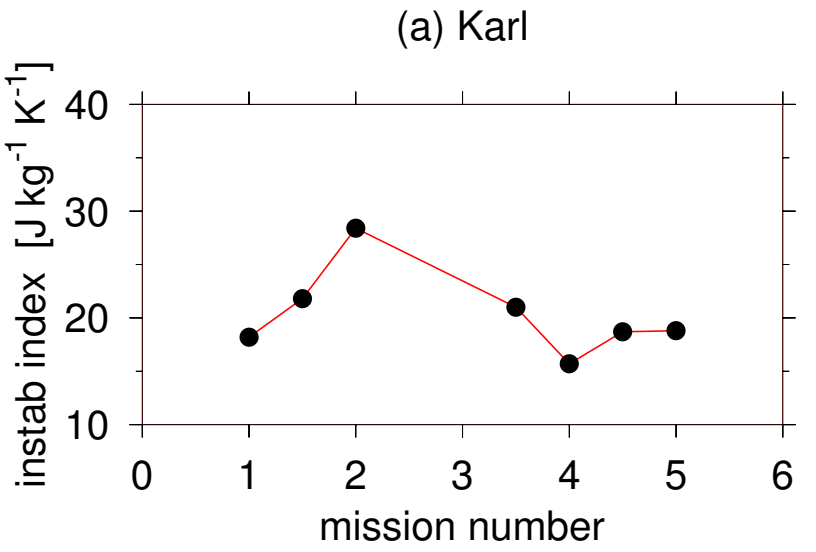
Vorticity convergence, moisture convergence

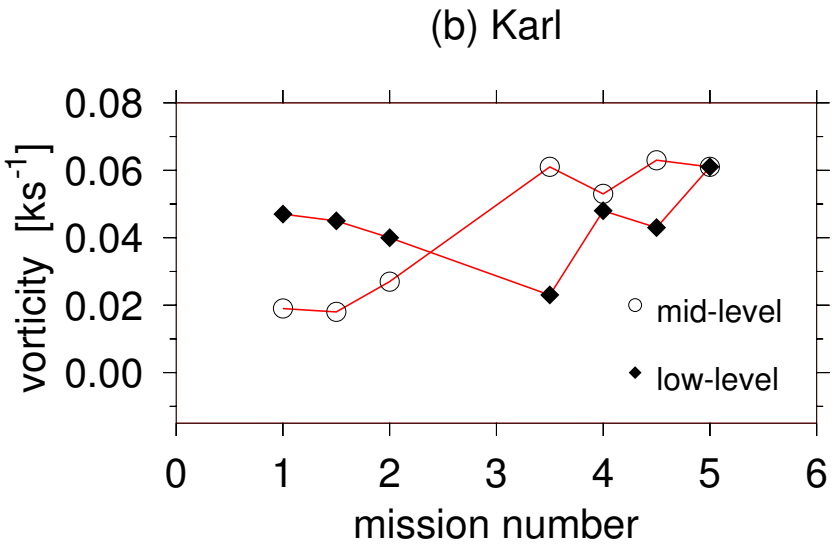
Tropical cyclogenesis.

Results
Karl

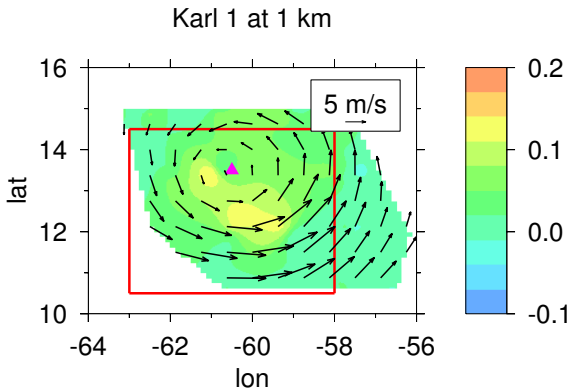


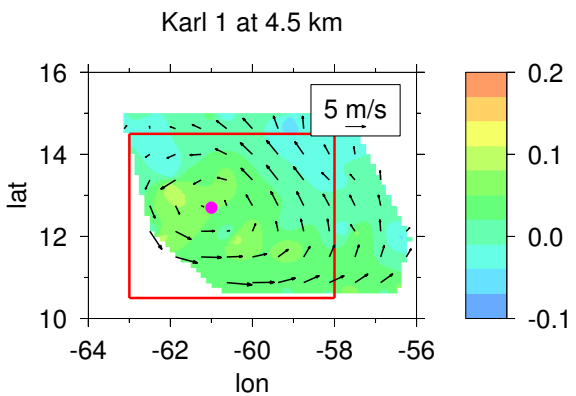
Results
Karl

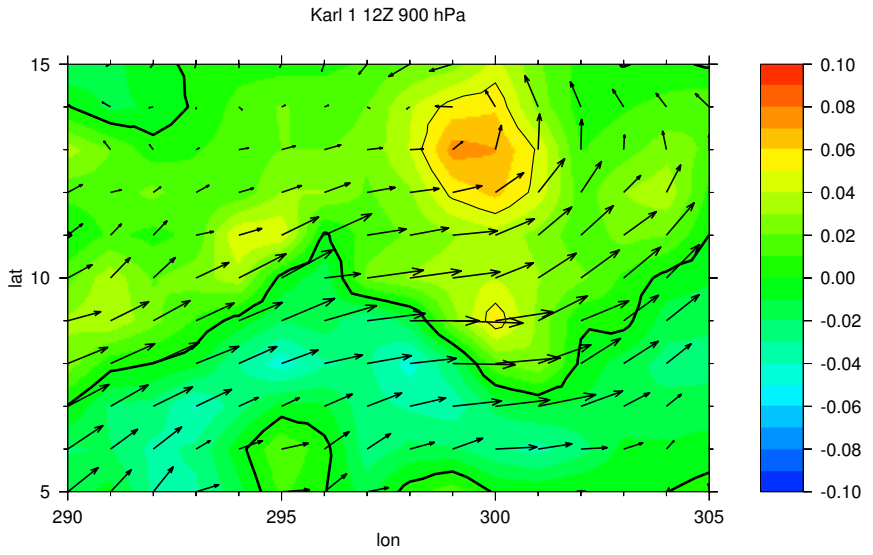


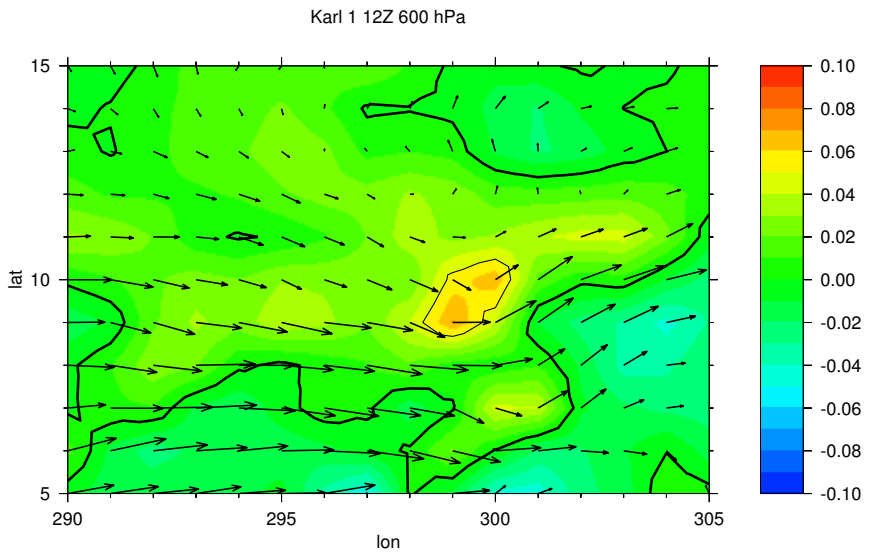


Results
Karl 1









Results
Karl 4a