Deep and Shallow Mean Meridional Tropical Circulations

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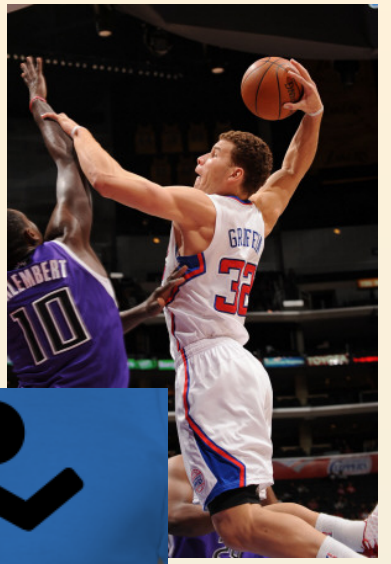
CMMAP Student Colloquium

Summer 2011

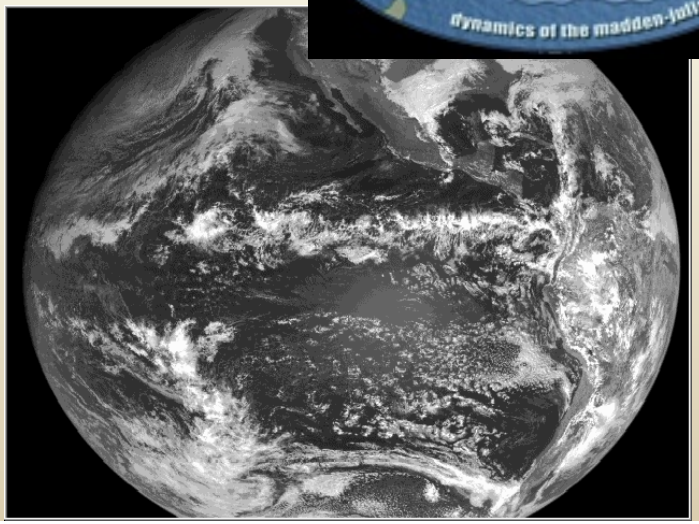
My Hobbies

- Gym
- Running
- Basketball
- Philly sports
- R&B music
- Cooking



Overview of my research

- Finishing M.S. degree
- Working in CGD at NCAR
- Participating in DYNAMO
- Ph.D. topic an continuation of M.S. research

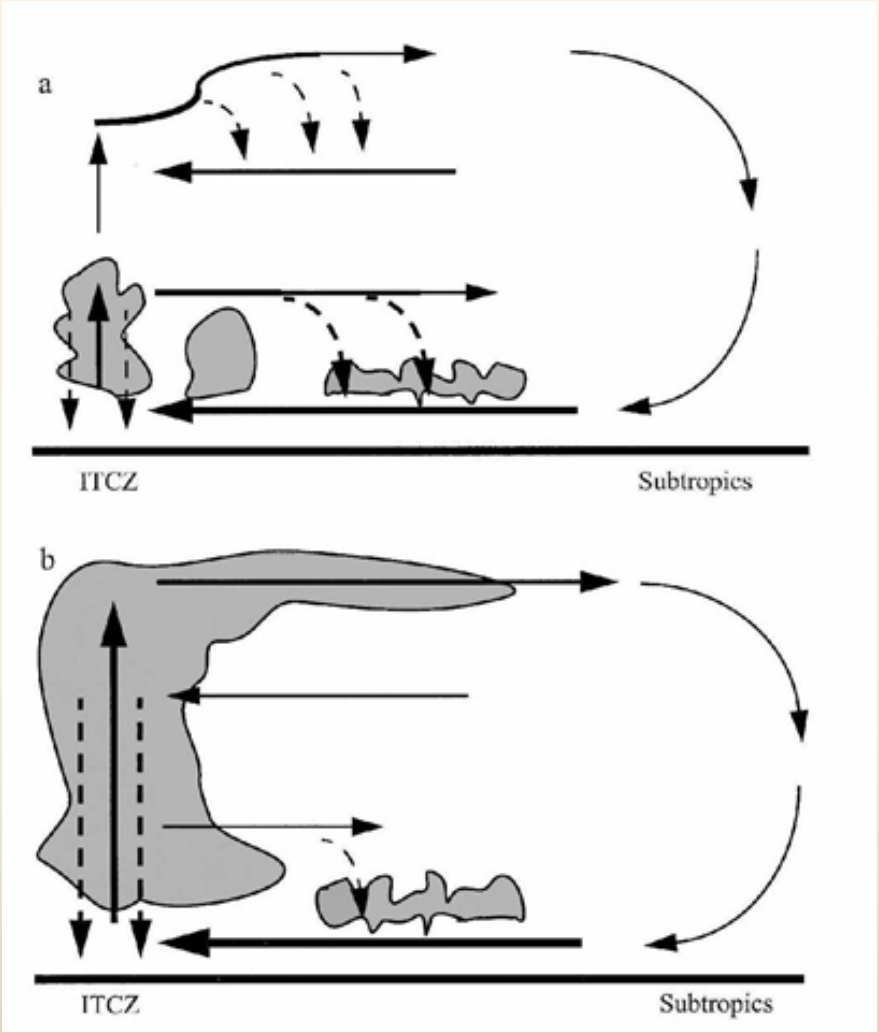


CSU M.S. project – Mean Meridional Circulations (MMCs)

- Two dominant modes of Mean Meridional Circulations (MMCs) – **Shallow and Deep**

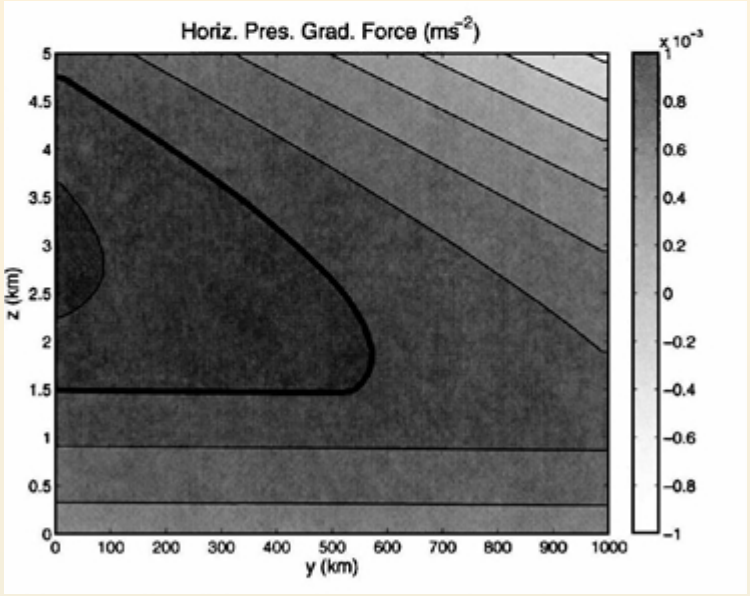
- Zhang et al. (2004) recorded **first observations of SMC**

- Strongest in tropical E. Pacific Ocean, E. Atlantic/W. Africa



SMC Theories

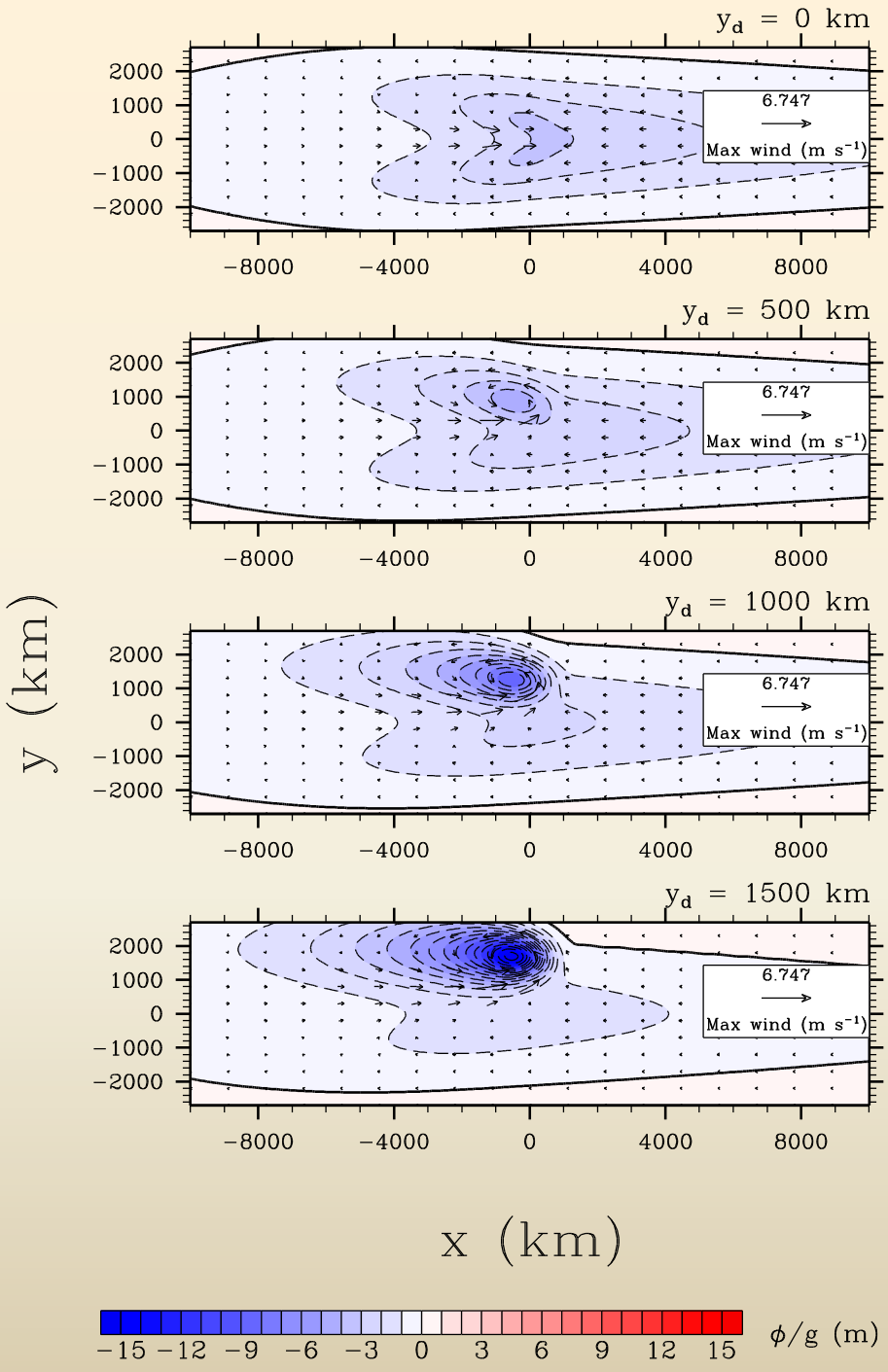
- **Current theory** – large surface temperature gradients
- **Proposed theory** – Tropics have small inertial stability -> large Rossby length -> shallower MMCs
- **Simple model** with diabatic heating and fricitional forcings



$$\mu_n = \left(\frac{C}{A}\right)^{1/2} \frac{n\pi}{z_T}$$

Deep Heating

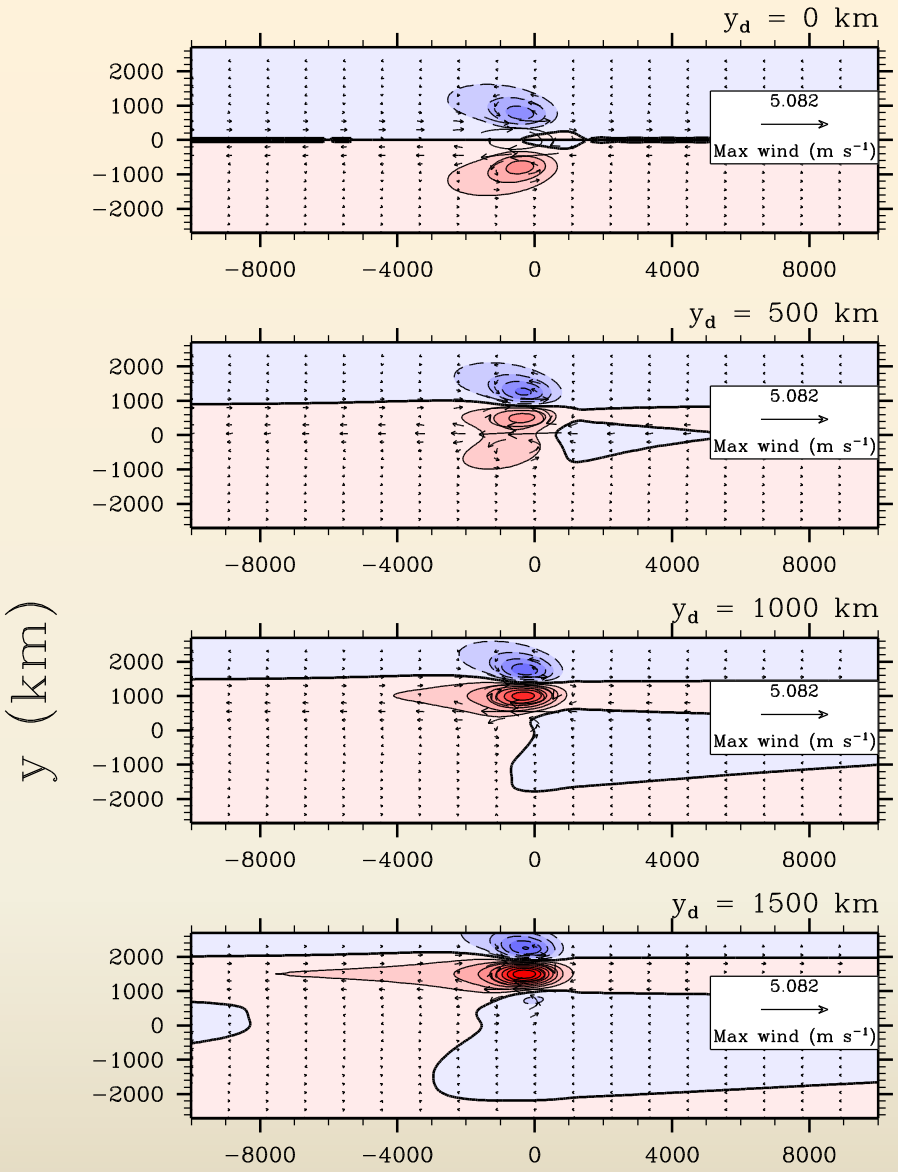
- As heating is displaced farther from equator, meridional wind anomalies increase and geopotential height anomalies become more negative
- ITCZs in E. Atl and E. Pac stay north of equator -> regions where SMCs are present
- Surface wind field has an associated wind stress curl
- Also regions where “cold tongue” is present -> large SST gradients


y_d = 0 km
y_d = 500 km
y_d = 1000 km
y_d = 1500 km
6.747
Max wind (m s⁻¹)
2000
1000
0
−1000
−2000
−8000
−4000
0
4000
8000
y (km)
x (km)
−15 −12 −9 −6 −3 0 3 6 9 12 15
ϕ/g (m)

Frictional Forcing

- Surface wind fields oppose the original wind stress forcing field (positive wind stress curl)

- When frictional forcing is displaced far from the equator there are 3 regions:
  - 1 main region of postitive vorticity
  - 2 regions of Ekman suction

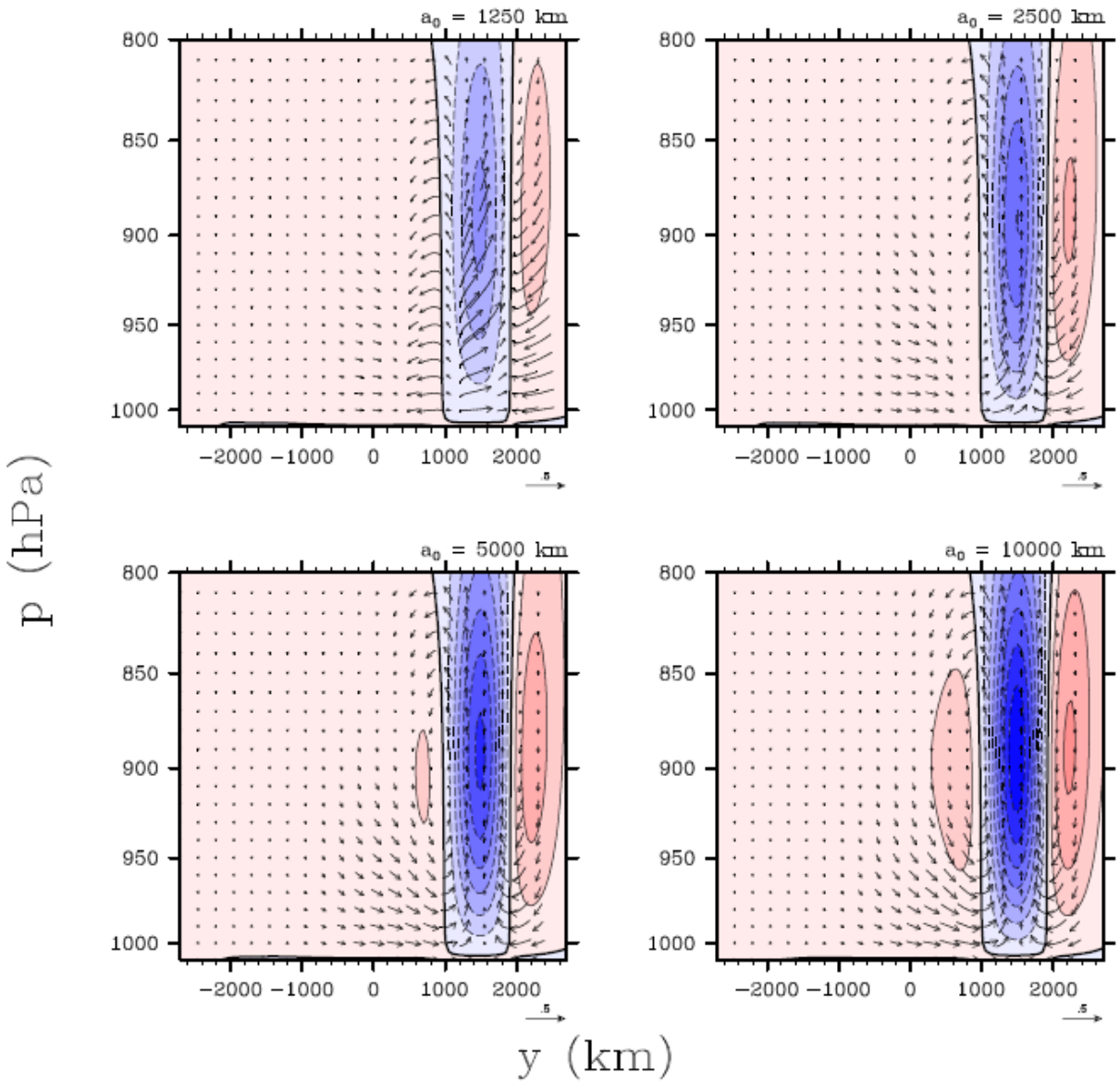

y_d = 0 km
y_d = 500 km
y_d = 1000 km
y_d = 1500 km
5.082
Max wind (m s⁻¹)
2000
1000
0
−1000
−2000
−8000
−4000
0
4000
8000
y (km)
x (km)
−4
−3
−2
−1
0
1
2
3
4
ϕ/g (m)

Vertical Cross Section

- Ekman pumping region is strongest, with weaker Ekman suction to its north and south

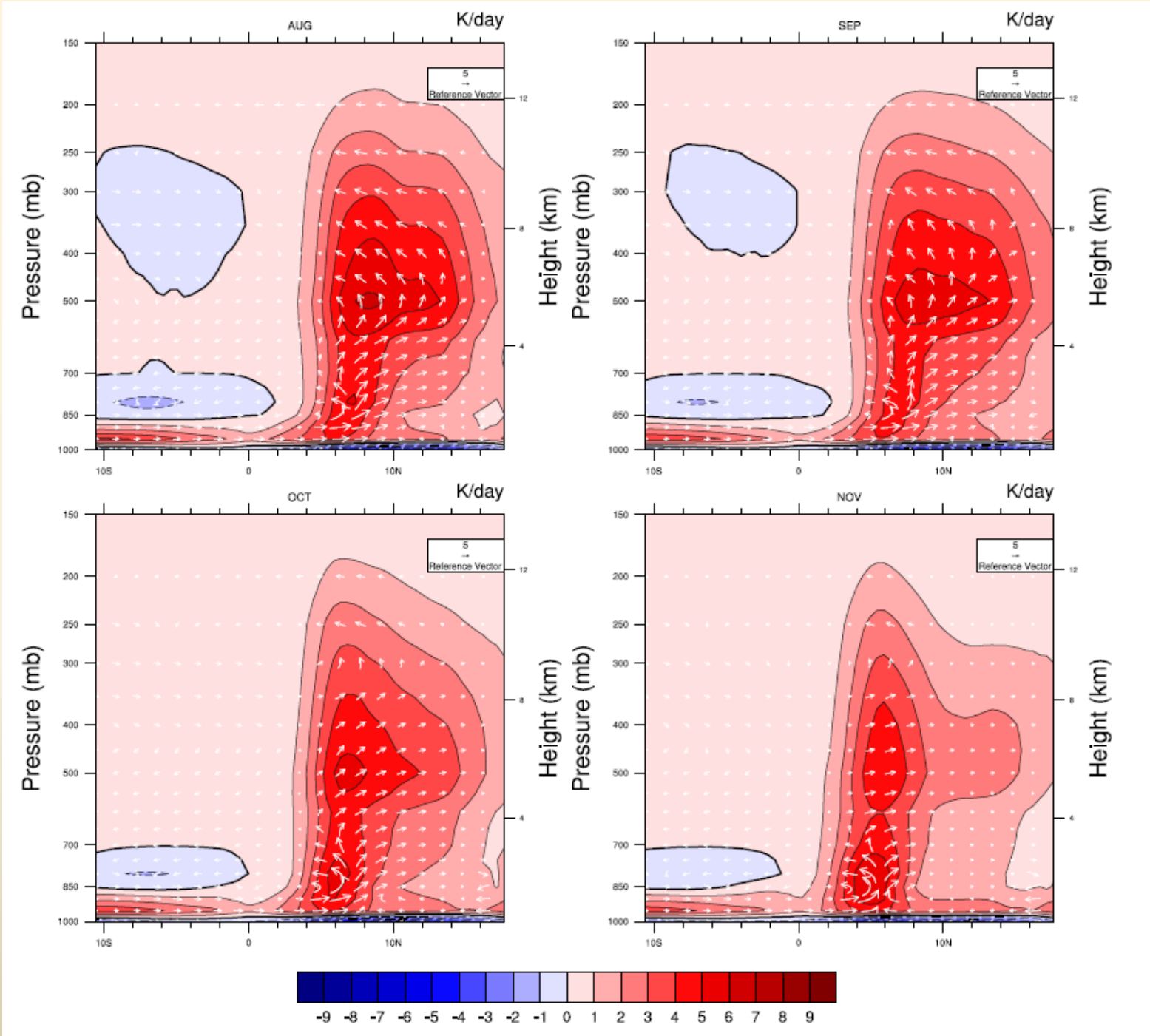
- Rossby length keeps the Ekman suction shallower and weaker near equator

- SMC is present when frictional forcing is zonally elongated


a_0 = 1250 km
a_0 = 2500 km
a_0 = 5000 km
a_0 = 10000 km
800
850
900
950
1000
−2000 −1000 0 1000 2000
p (hPa)
y (km)
−8 −6 −4 −2 0 2 4 6 8
ω (hPa day^{-1})

Continuing Work

- High-resolution coupled CCSM 3.5 produces a robust SMC
- Shallow convection and the SMC are most prominent when cold tongue strongest
- Deep convection is broad and extends farther poleward
- Shallow convection is narrow and stays close to equator


AUG
SEP
OCT
NOV
K/day
Pressure (mb)
Height (km)
Reference Vector
150
200
250
300
400
500
700
850
1000
12
8
4
10S
0
10N
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9

Conclusions and Future Work

- Displacement of ITCZ in E. Pac and E. Atl allows for cold SST anomalies -> larger SST gradient
- Cyclonic wind stress forcing leads to Ekman pumping in BL and SMC when it's zonally elongated
- Frictional forcing has relatively weak vertical motion, but -> not significant enough
- CCSM shows a robust SMC with evidence of concepts of Rossby length
- Both SST gradients and wind stress forcing important features, but which is more important for the SMC?
- A more complex model on SST and frictional forcing influence on buildup of convection

Questions?