

The moist static energy budget and wave dynamics around the ITCZ in idealized WRF simulations

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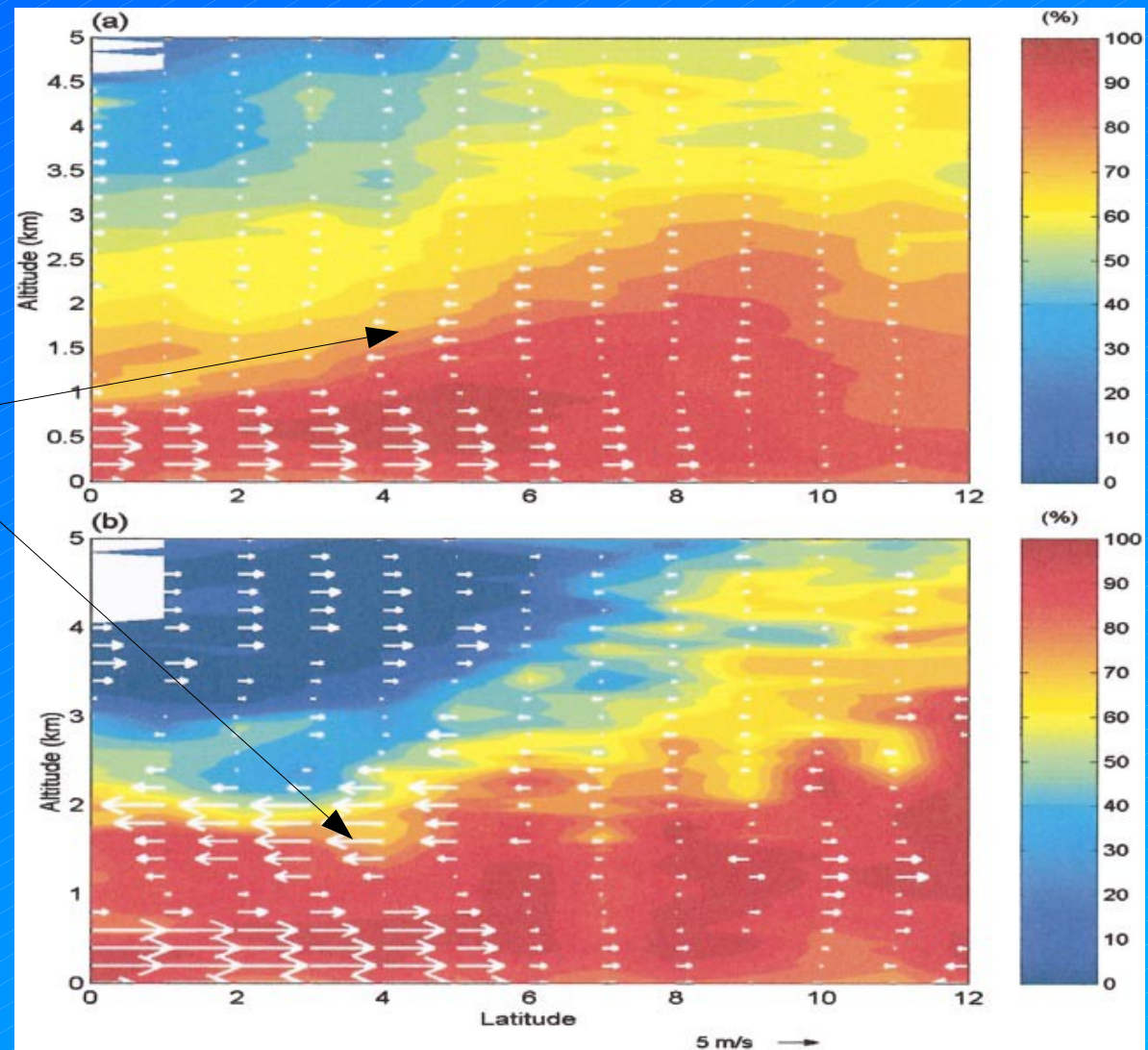
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A shallow meridional circulation (SMC) in Eastern Pacific

- EPIC (2001) field program

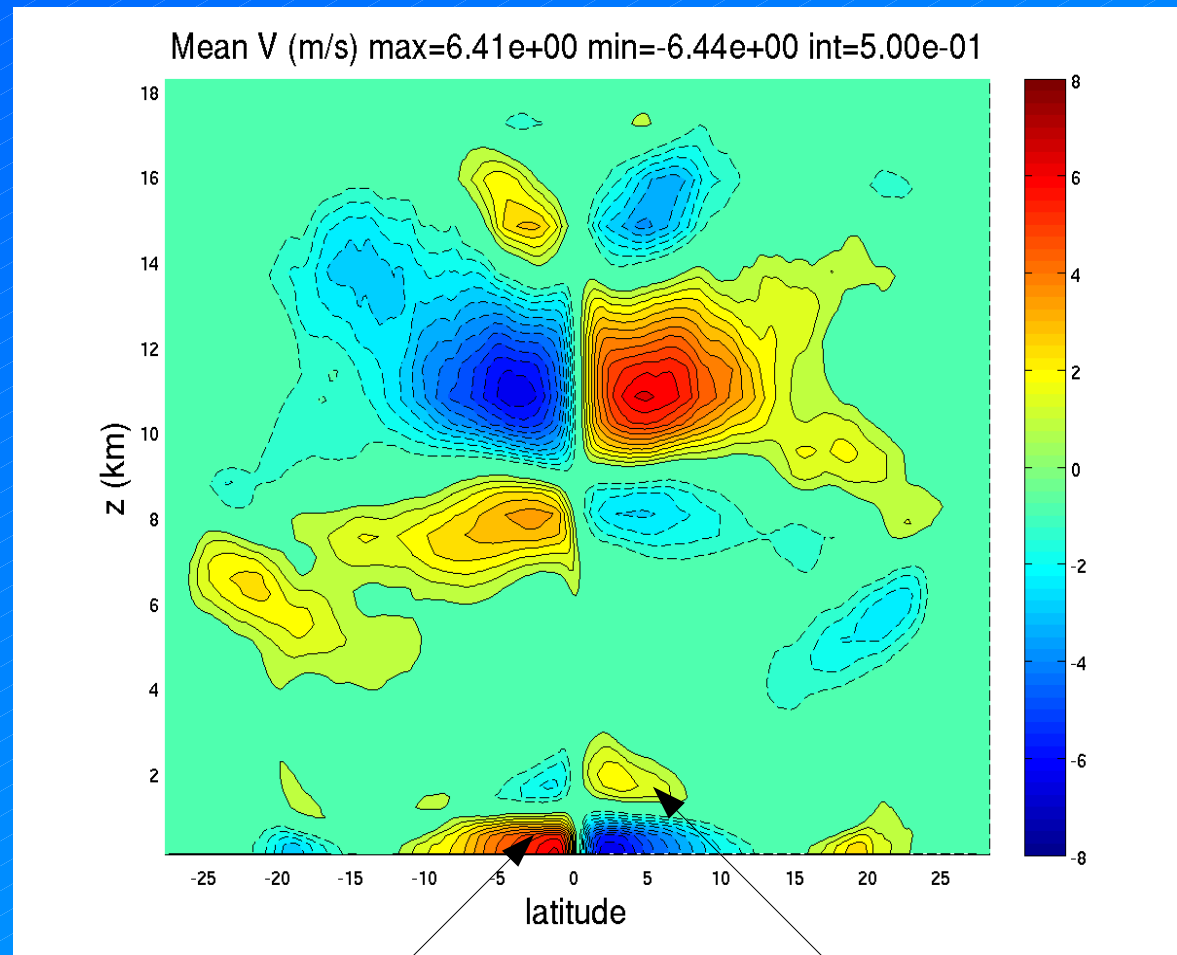
- Zhang, et al. (2004) indicates that a meridional flow out of the ITCZ was present in observational data.



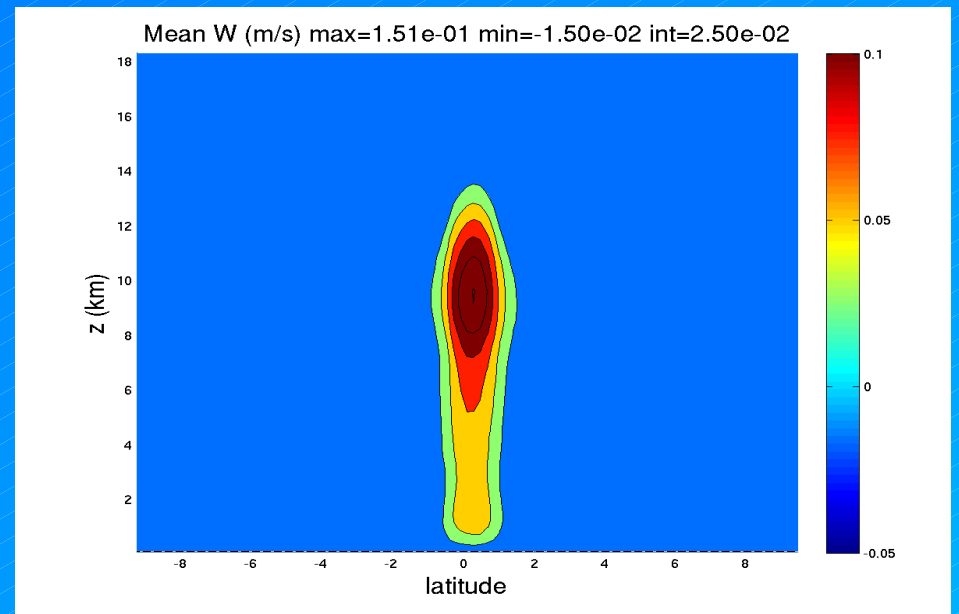
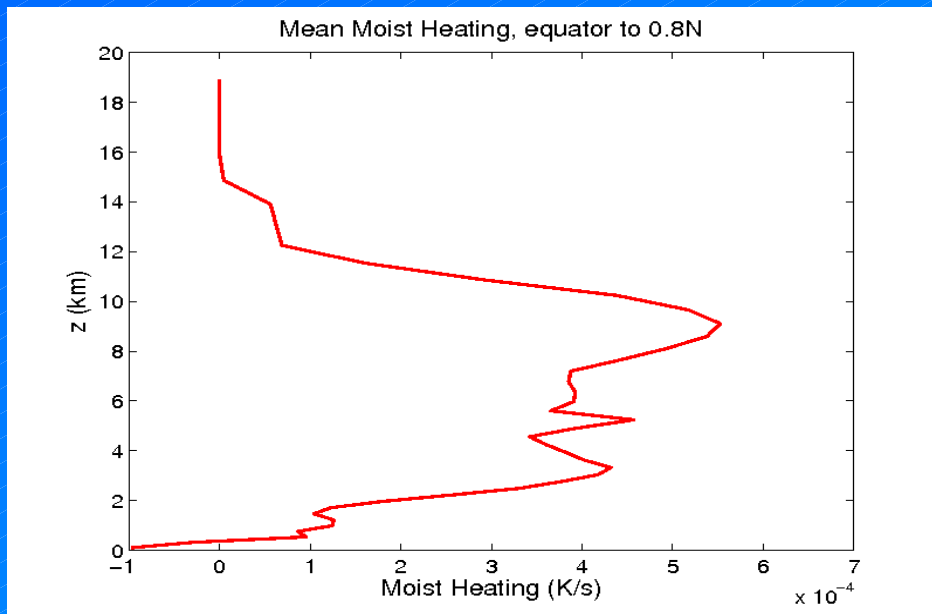
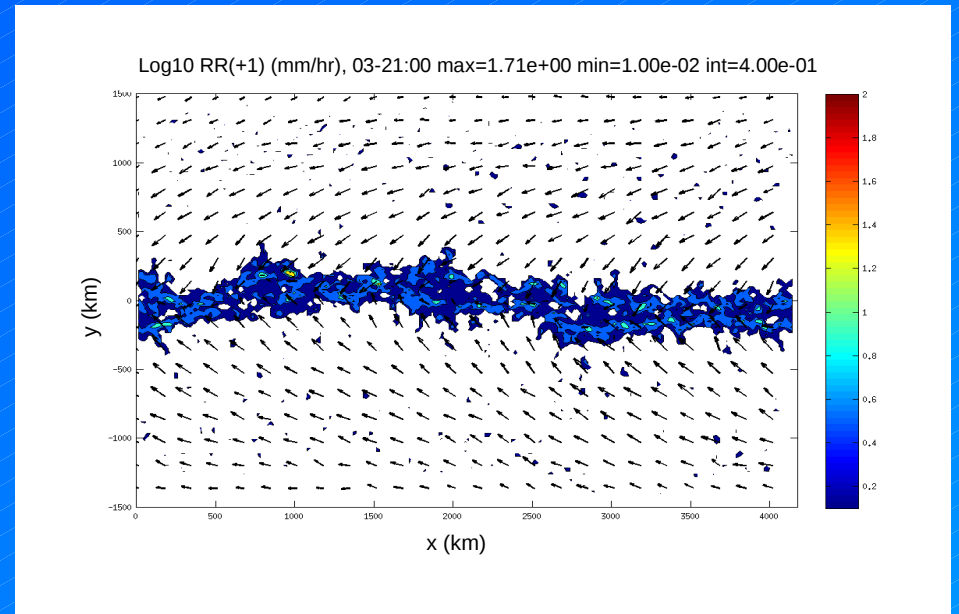
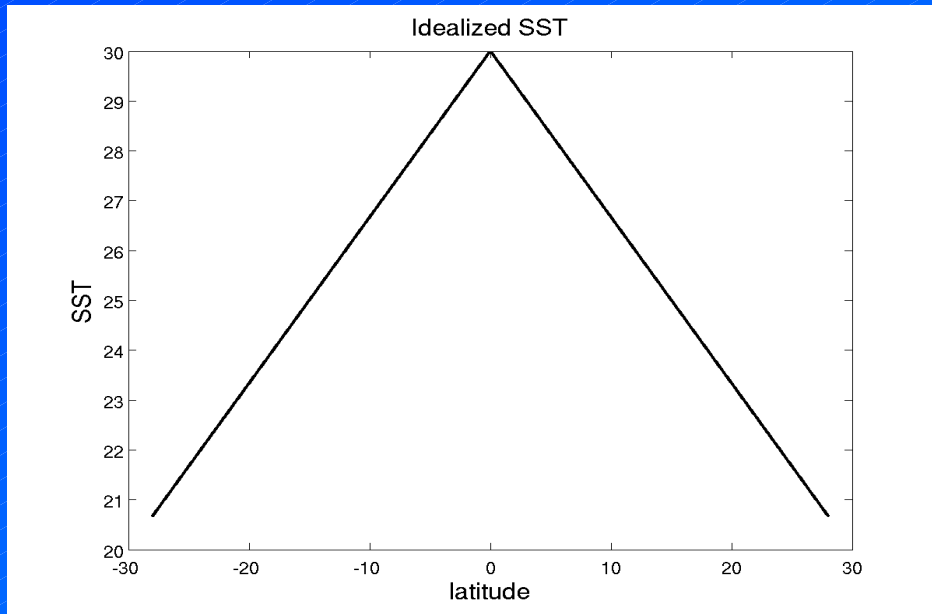
a) Eight-flight mean
b) Oct. 2, 2001

A shallow meridional circulation (SMC) in Eastern Pacific

- Nolan, et al. (2007) used a full physics model to show such a circulation in a tropical half-channel.
- Newer simulations with linear and hyperbolic temperature profiles on a full channel.



Linear temperature profile across equator



Moist static energy (MSE) budget

Moist static energy: dry static energy plus the product of the latent heat of vaporization and water vapor mixing ratio:

$$s = C_p T + \Phi + L_v r,$$

C_p = specific heat of air at constant pressure

T = absolute temperature

Φ = geopotential

L_v = latent heat of vaporization

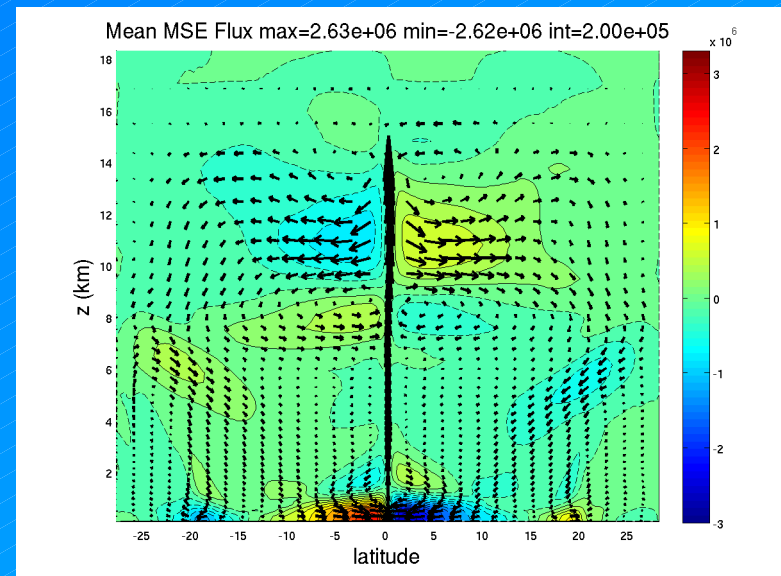
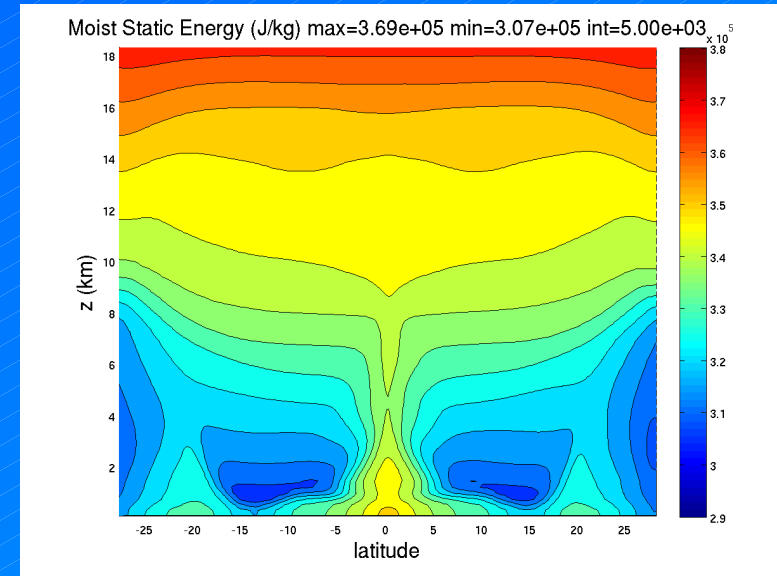
r = mixing ratio

MSE Flux due to Advection:

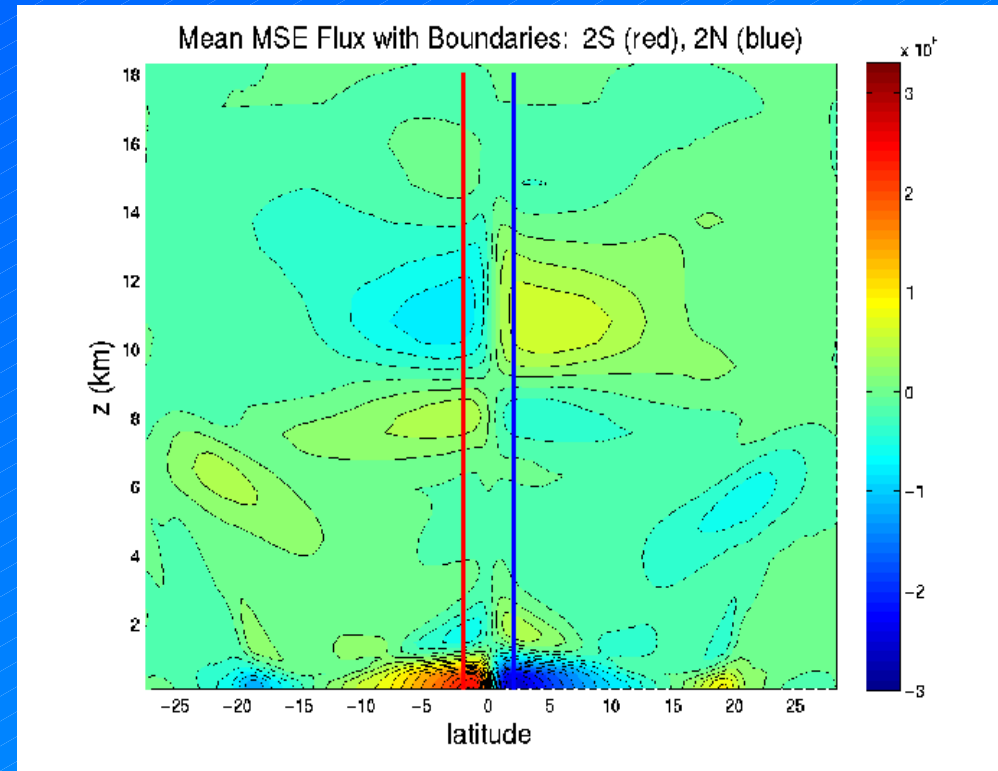
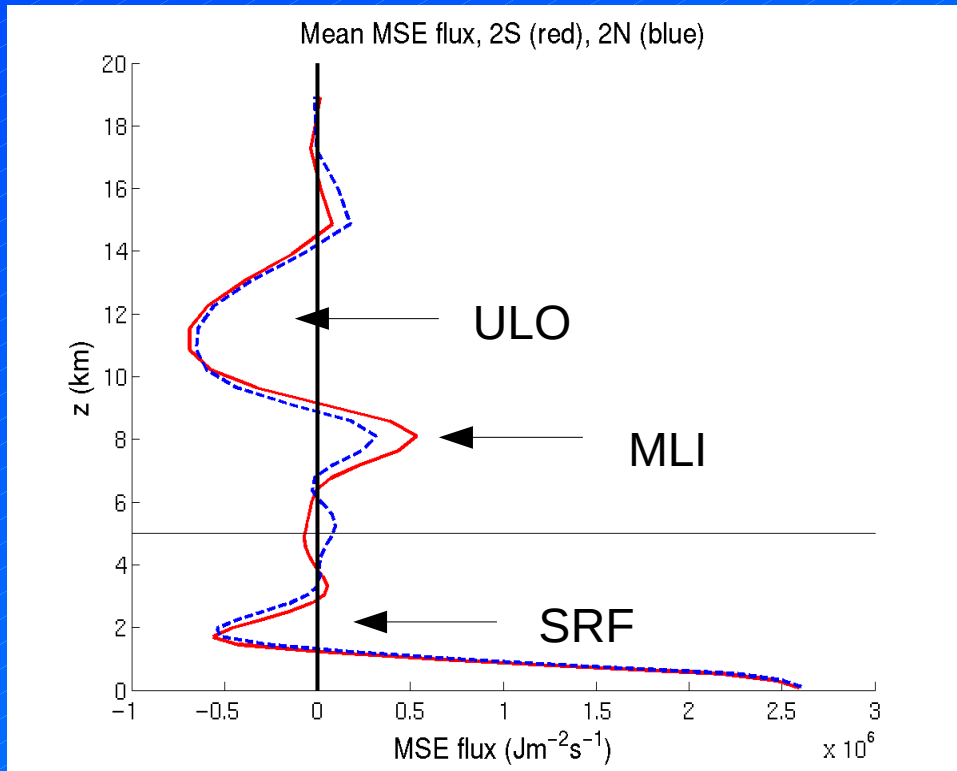
$$\Phi_{\text{MSE}} = \rho * v * s,$$

ρ = density

v = meridional wind velocity



Calculation of the MSE budget: Advection



SMC Level	MSE Flux*: 2S	MSE Flux*: 2N
Upper level return flow	-2.26E+9	-2.05E+9
Mid-level inflow	7.50E+8	4.42E+8
Shallow return flow	-5.04E+8	-5.21E+8
Boundary Layer inflow	1.98E+9	2.10E+9
Total	-3.10E+7	-1.67E+7

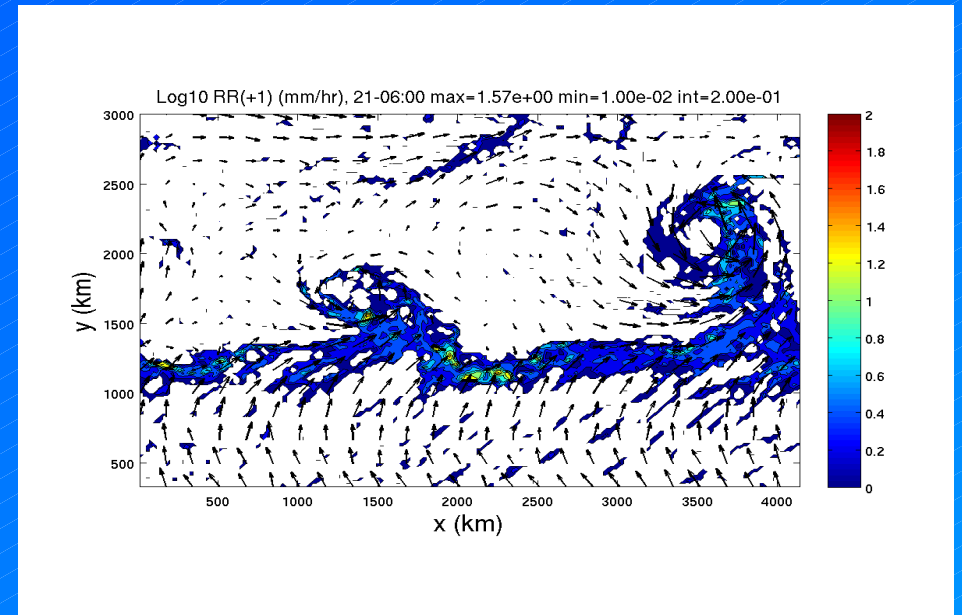
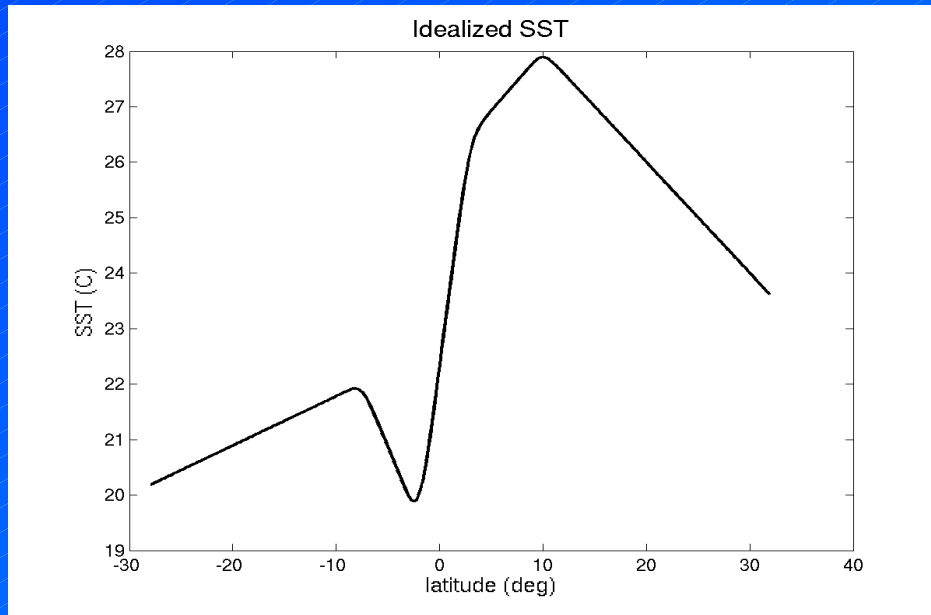
*Fluxes in units $\text{J}\cdot\text{m}^{-1}\cdot\text{s}^{-1}$.

Complete Calculation of MSE Budget

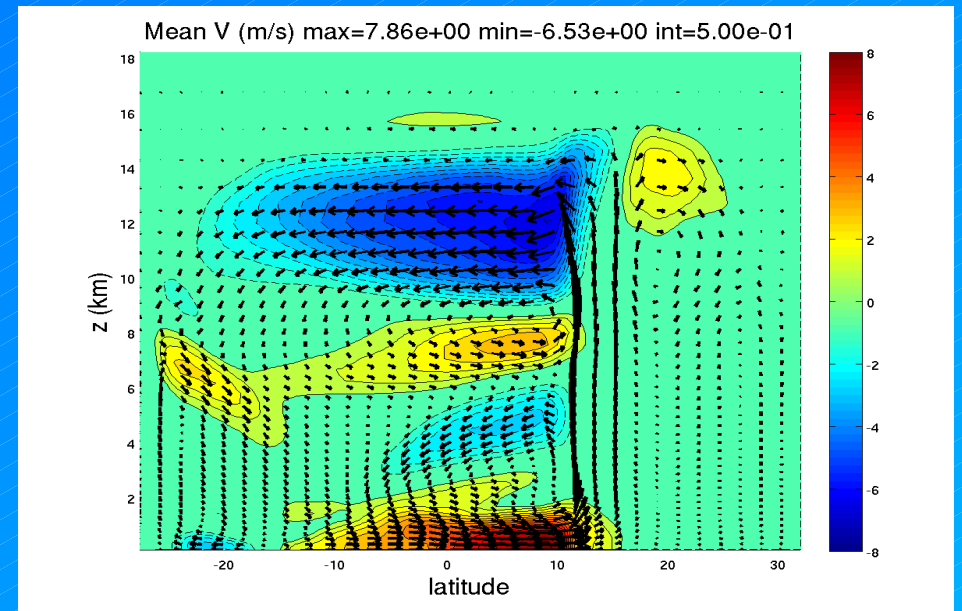
- Shortwave and longwave radiation
- Latent and sensible surface heat fluxes
- Advective terms dominate MSE budget.

Component	Advection: 2S	Advection: 2N	Outgoing Longwave Radiation	Incoming Shortwave Radiation	Latent Heat Flux	Sensible Heat Flux	Total
MSE Flux ($\text{J}\cdot\text{m}^{-1}\cdot\text{s}^{-1}$)	-3.10E+7	-1.67E+7	-7.26E+7	3.90E+7	7.21E+7	9.88E+6	7.66E+5

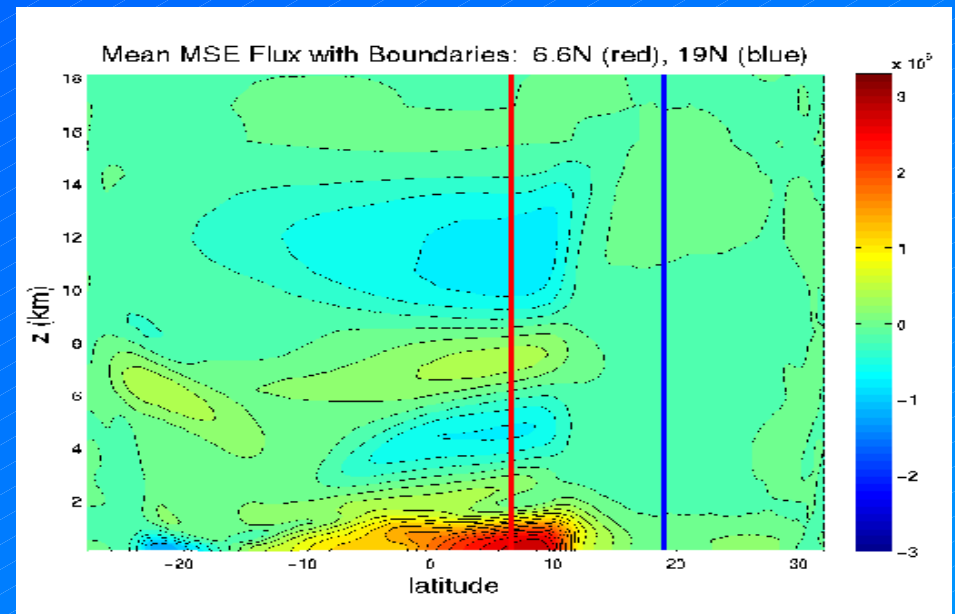
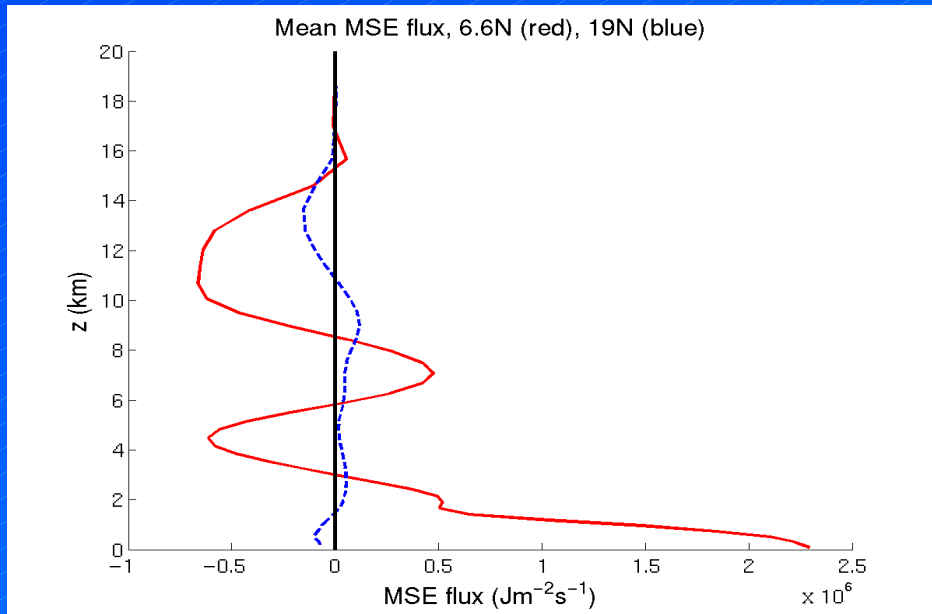
Idealized temperature profile



- Cold tongue region of EPAC.
- Tropical cyclones develop with ITCZ now off equator.
- More robust circulation and mid-level inflow at slightly lower level.



Advected MSE

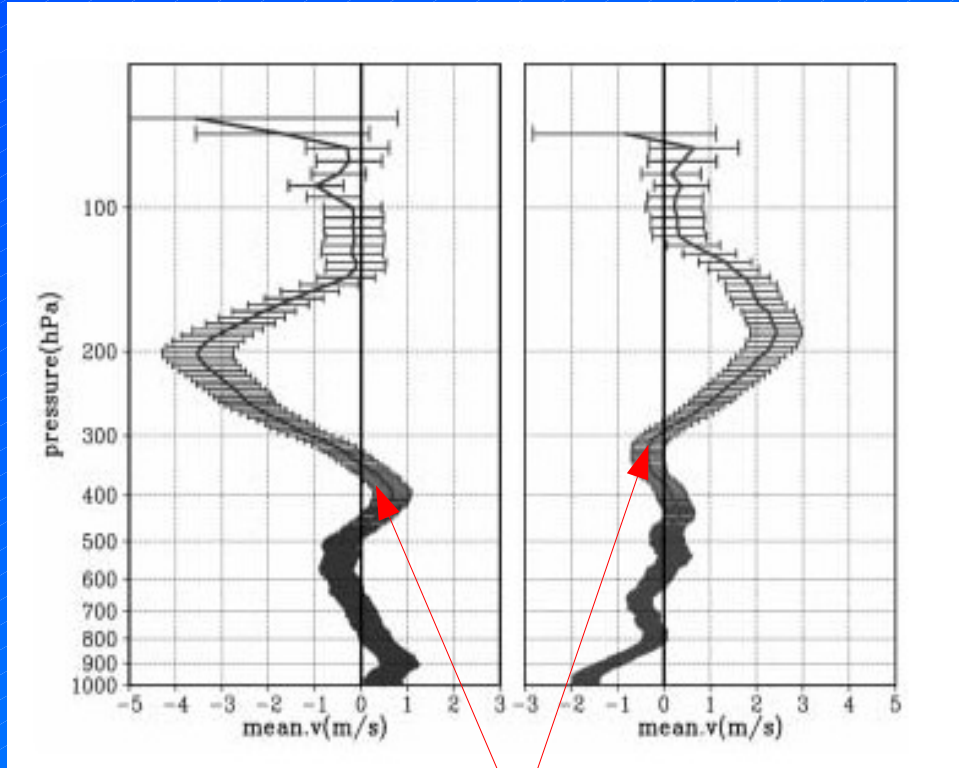


SMC Level	MSE Flux: 6.6N
Upper level return flow	-3.26E+9
Mid-level inflow	7.76E+8
Shallow return flow	-1.17E+9
Boundary Layer inflow	3.57E+9
Total	-8.40E+7

Comparable to upper level and boundary layer flow.

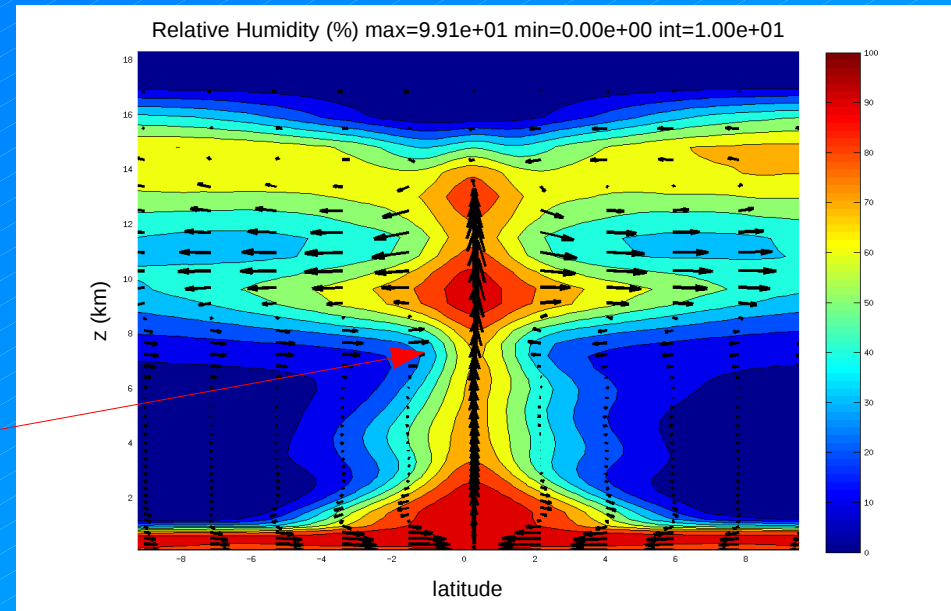
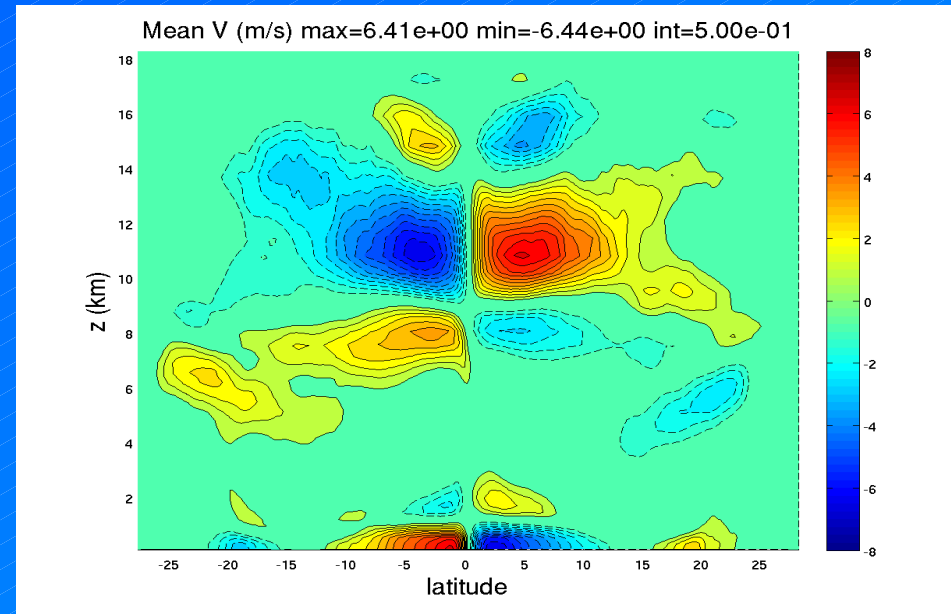
A mid-level inflow

Takayabu, et al. (2006)



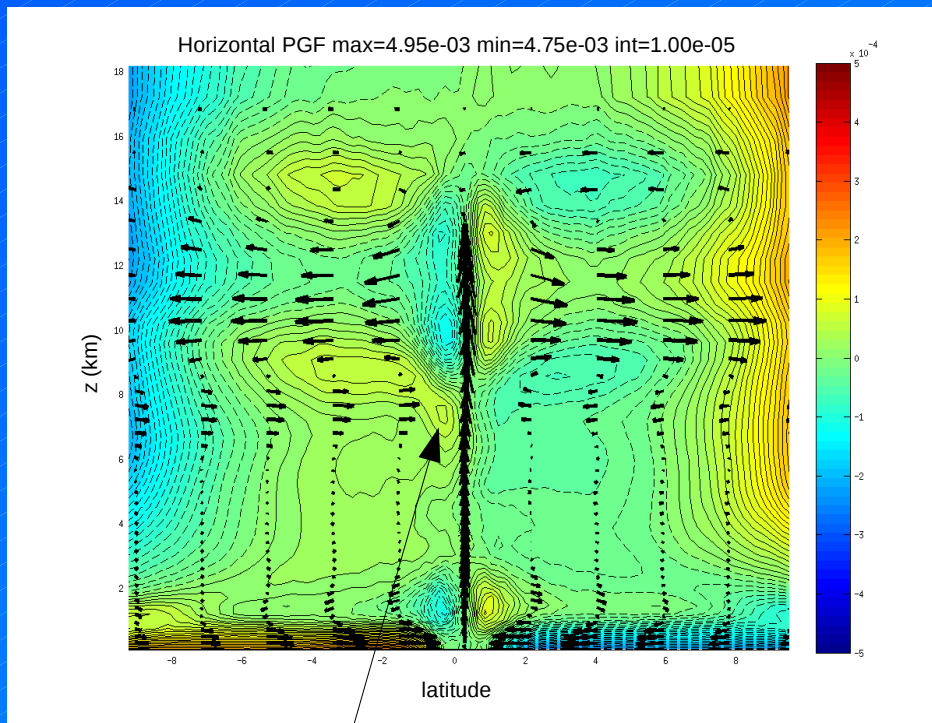
MLI

Dry mid-level inflow

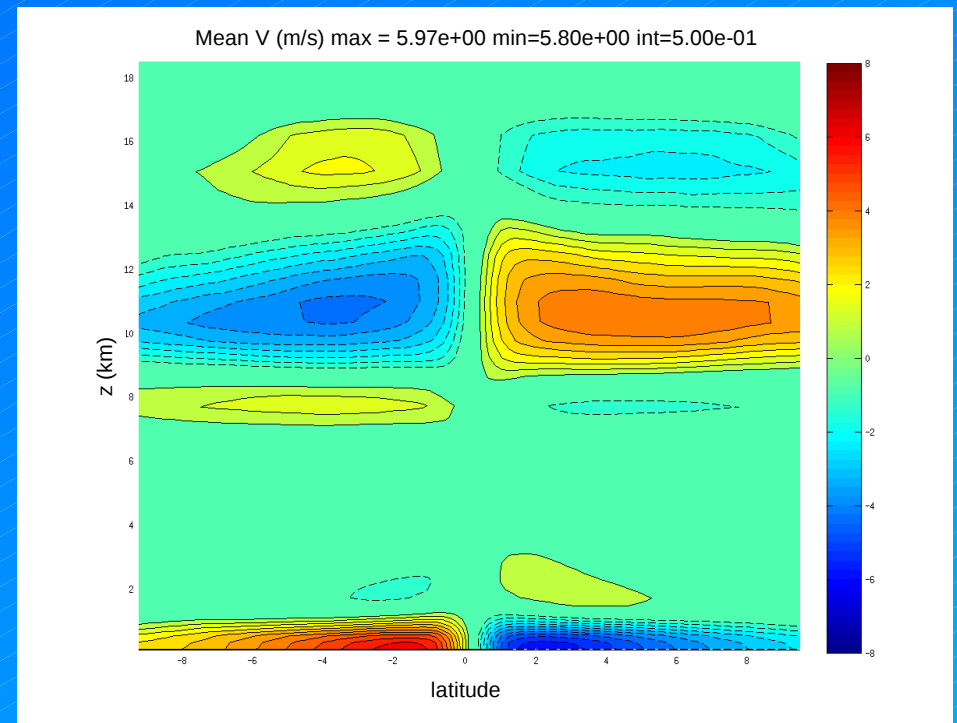


What drives a mid-level inflow?

- Forcing near ITCZ drives mid-level inflow below 8km.
- Evaporative cooling
- MLI not completely eliminated; large scale forcing also driving inflow?



Strong forcing near ITCZ.

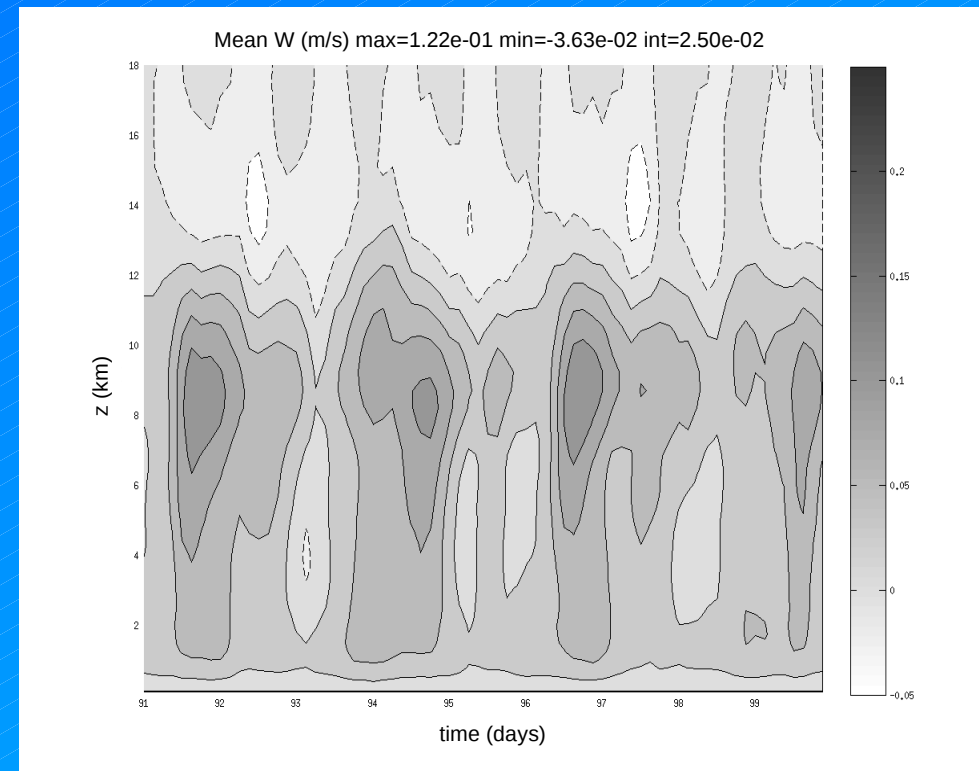
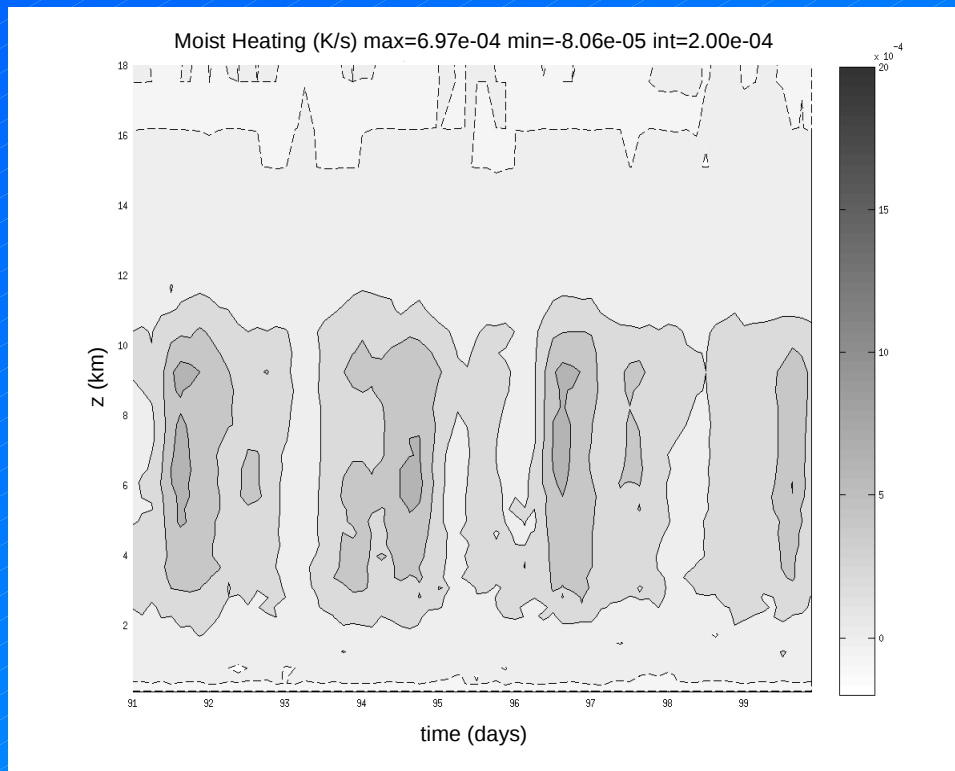


Latent heat of freezing reduced to 1 percent of real value.

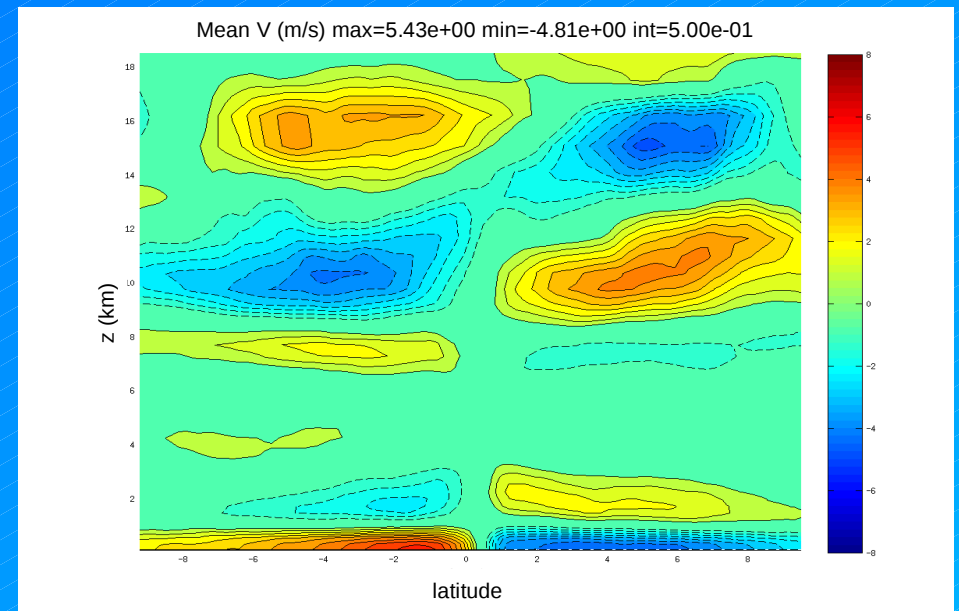
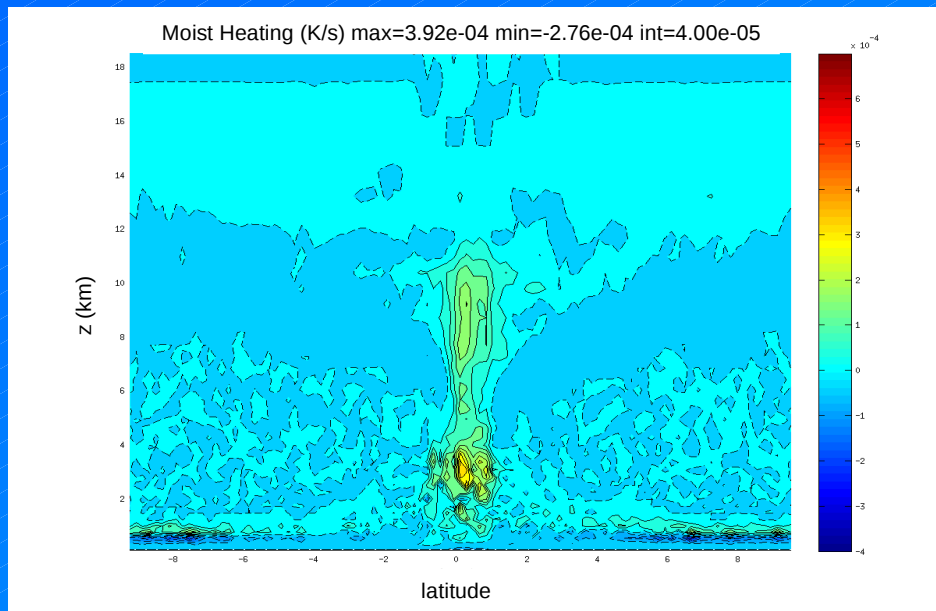
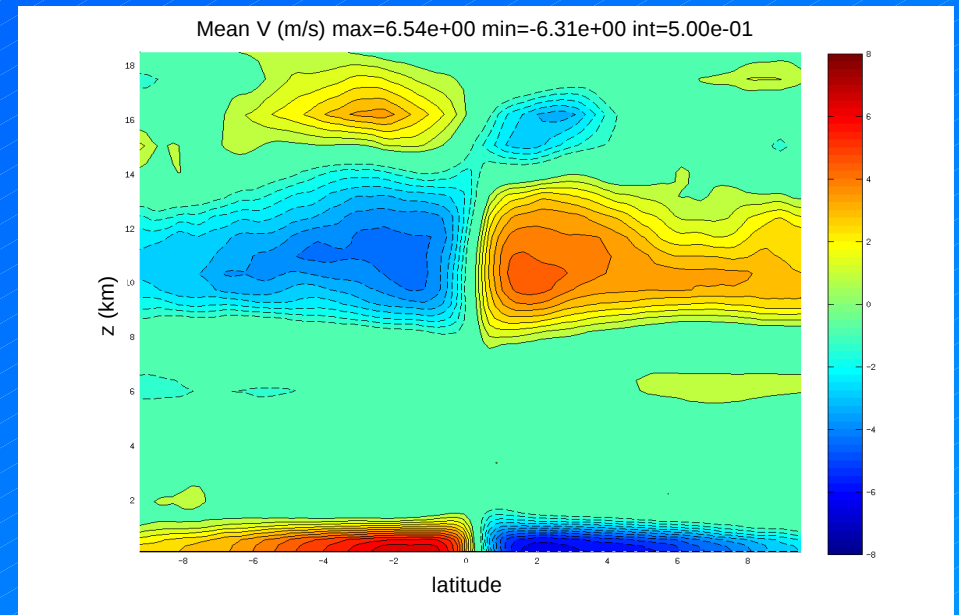
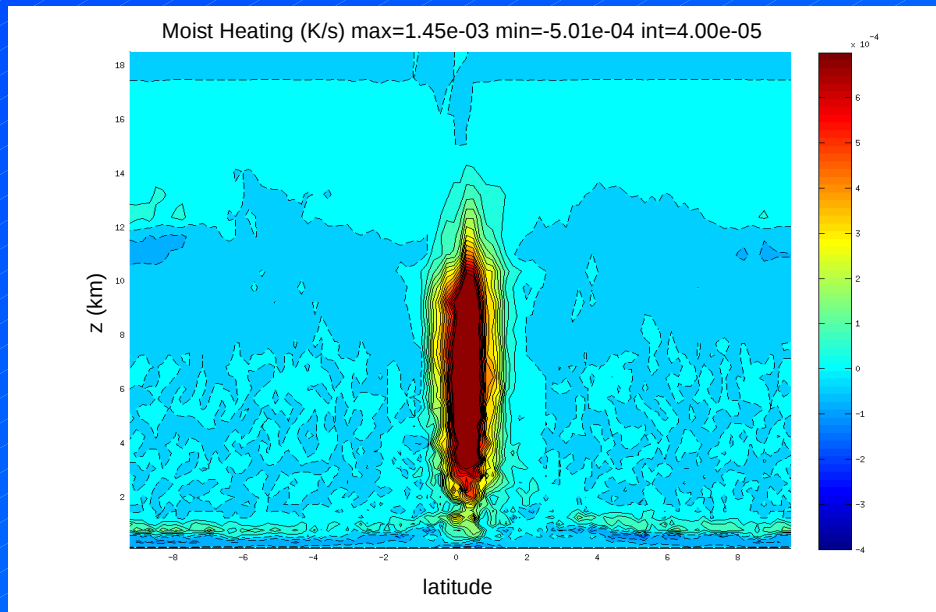
Periodic convection

- Period of about 2.5 days

Nolan, et al. (2007) suggested equatorial Kelvin wave with period of about 2.25 days causing fluctuations in moist heating and convection.



Convection negatively correlated with SRF



Summary

- Advection in shallow return flow and mid-level inflow significantly contribute to the MSE budget and are important enough to be considered when describing the larger Hadley circulation and calculating other budgets near the ITCZ.
- SRF and mid-level inflow only present in the absence of convection; in these simulations; convection likely controlled by westward propagating equatorial wave.
- Evaporative cooling appears to contribute to forcing of mid-level inflow, but further work is needed to determine possible large-scale mechanisms that also contribute to causing a dry mid-level inflow.