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

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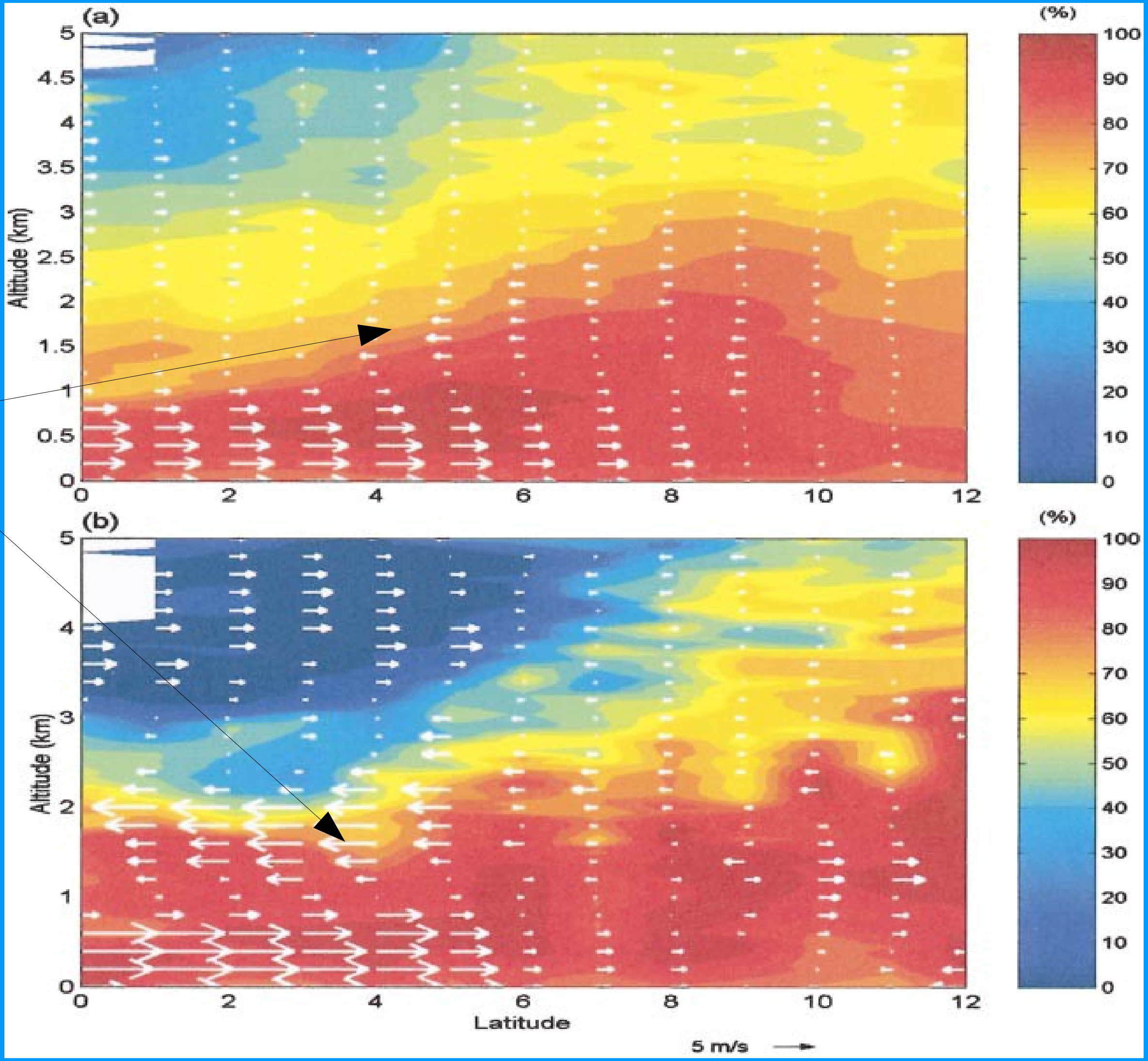
A shallow meridional circulation (SMC) in Eastern Pacific

- EPIC (2001) field program

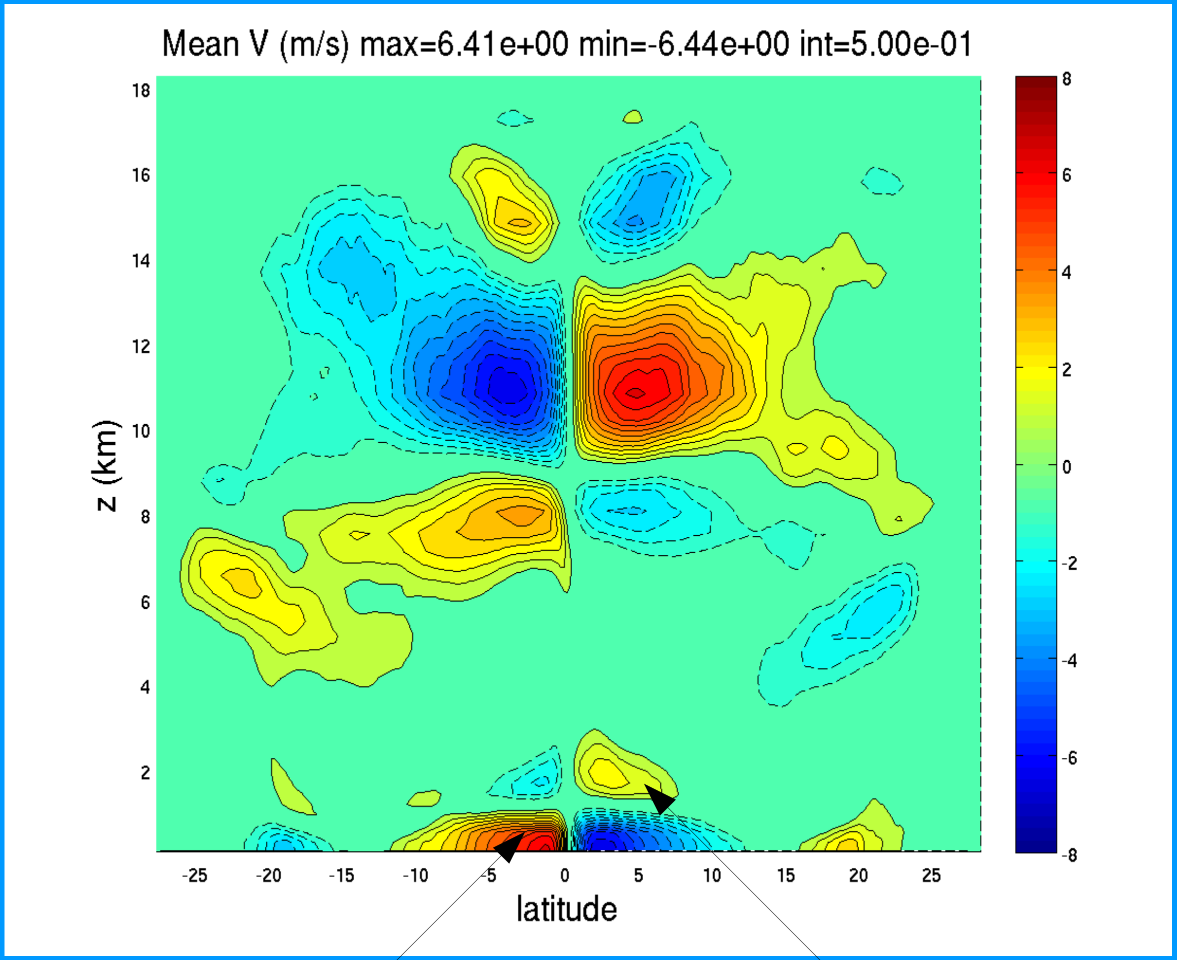
  - Zhang, et al. (2004) indicates that a meridional flow out of the ITCZ was present in observational data.



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

A shallow meridional circulation (SMC) in Eastern Pacific

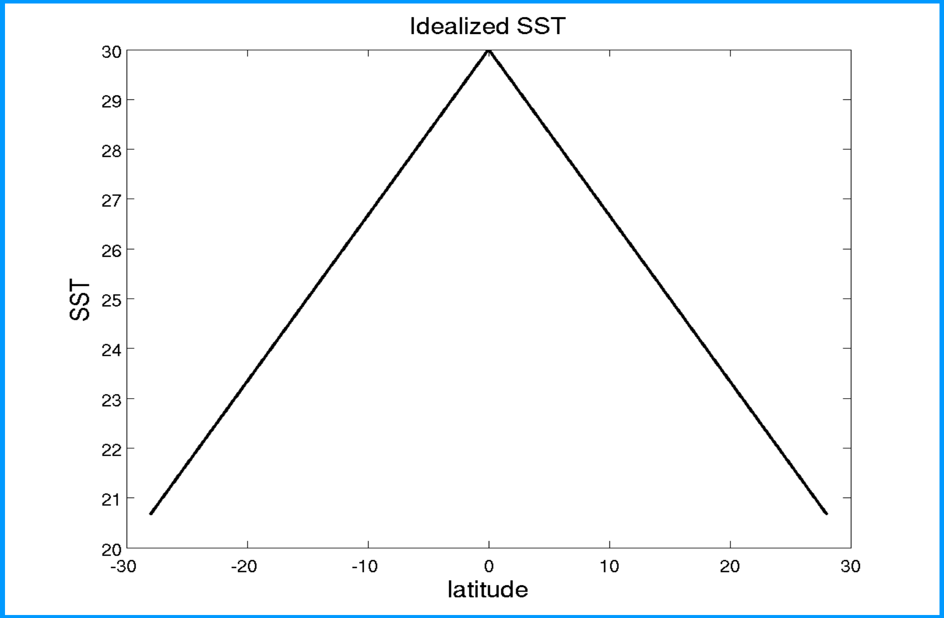
- Nolan, et al. (2007) used a full physics model to show such a circulation in a tropical half-channel.
- Regional model by Wang, et al. (2005) and radiative cooling
- “Sea-breeze” circulation
- Newer simulations with linear and hyperbolic temperature profiles on a full channel.

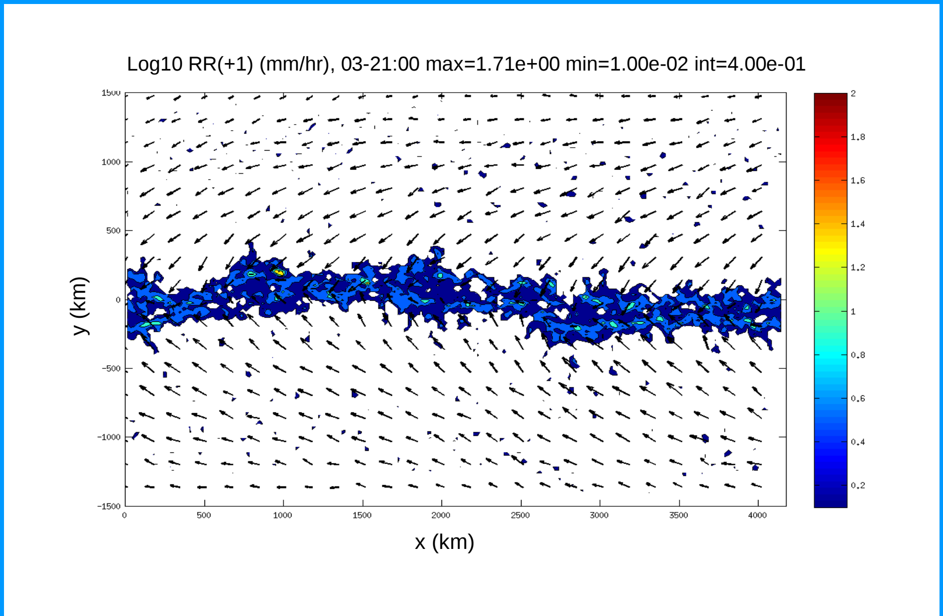


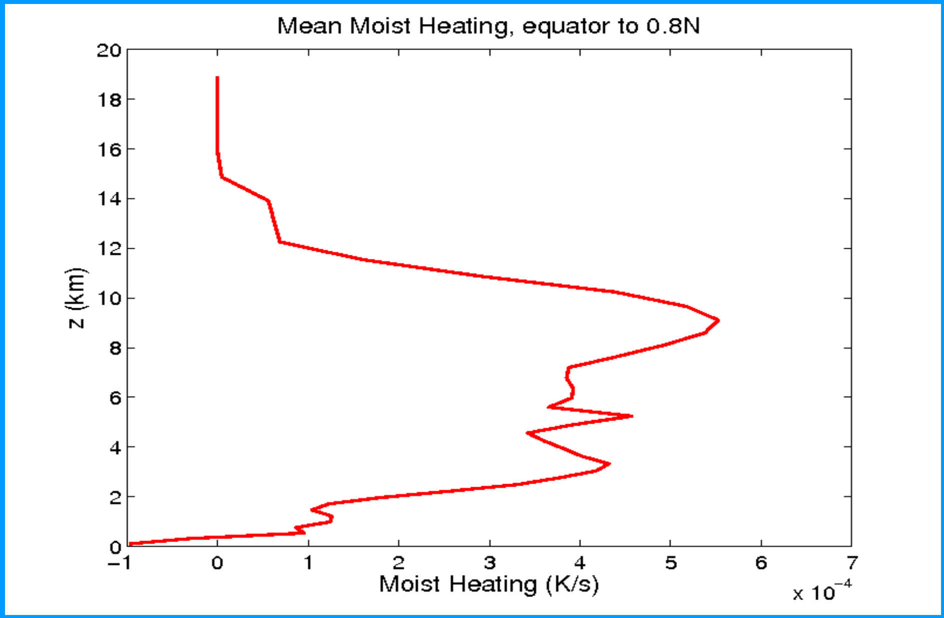
Boundary layer inflow

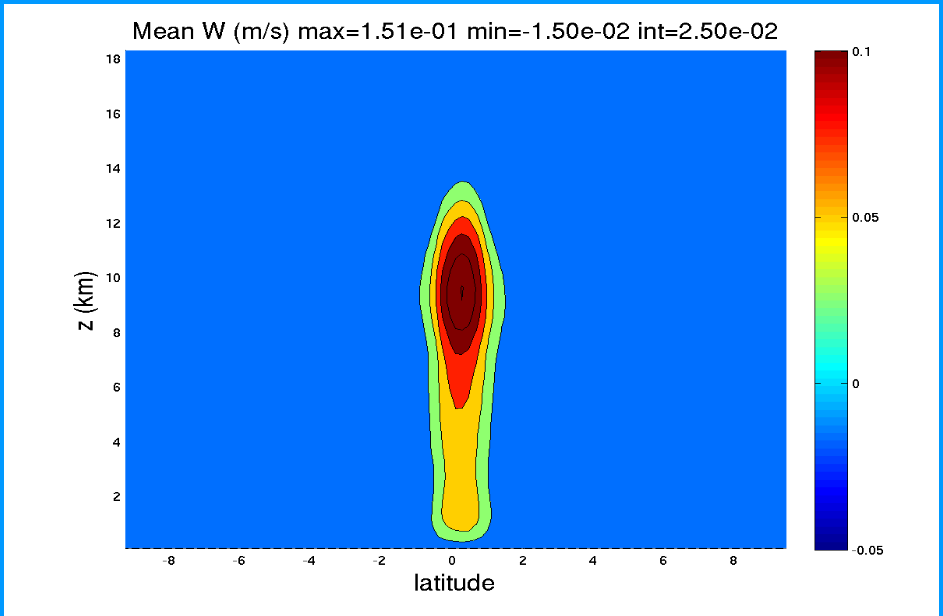
SRF above boundary layer

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:

$$\mathbf{s = C_pT + \Phi + L_vr},$$

C_p = specific heat of air at constant pressure

T = absolute temperature

Φ = geopotential

L_v = latent heat of vaporization

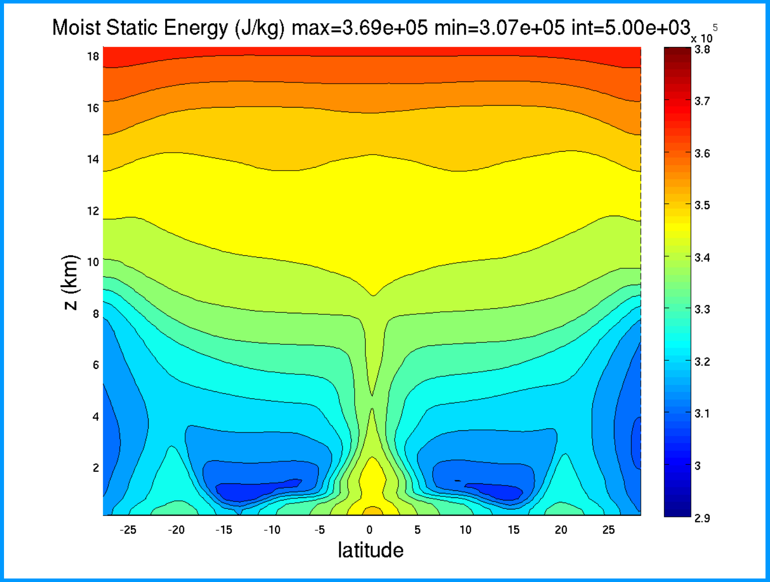
r = mixing ratio

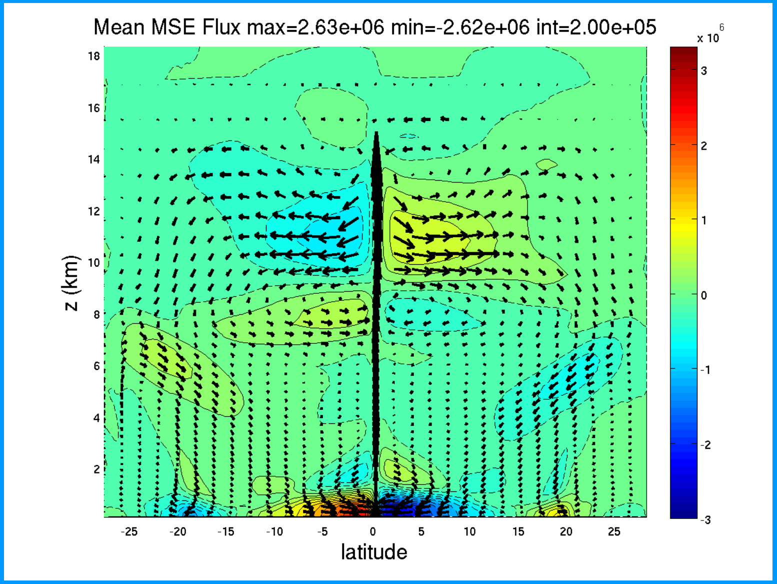
MSE Flux due to Advection:

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

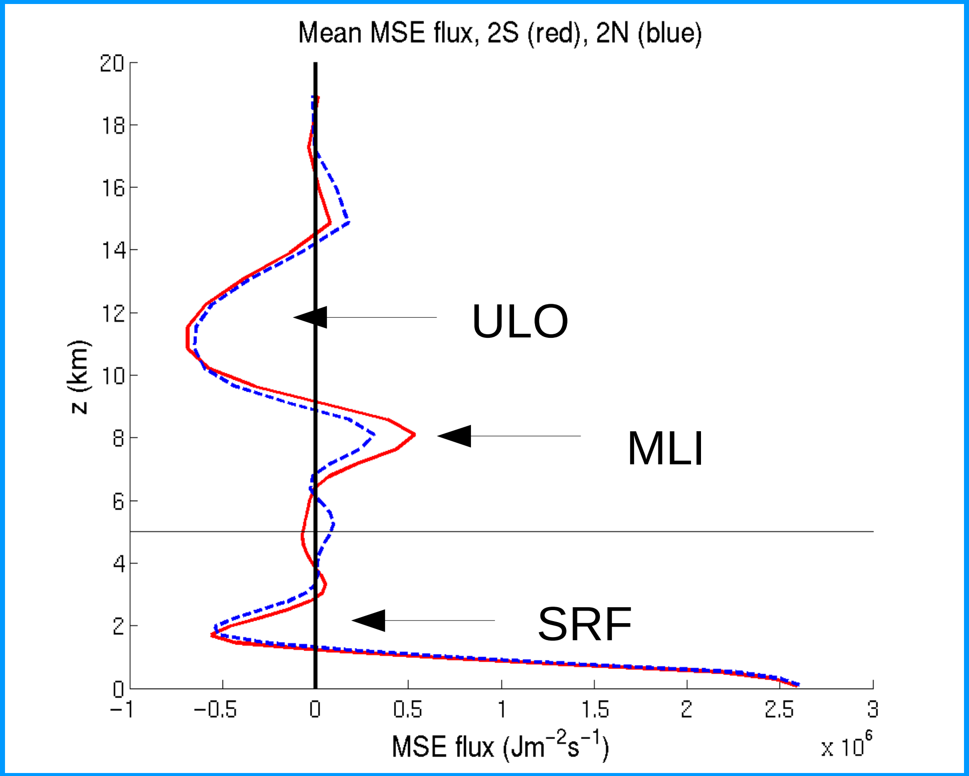
ρ = density

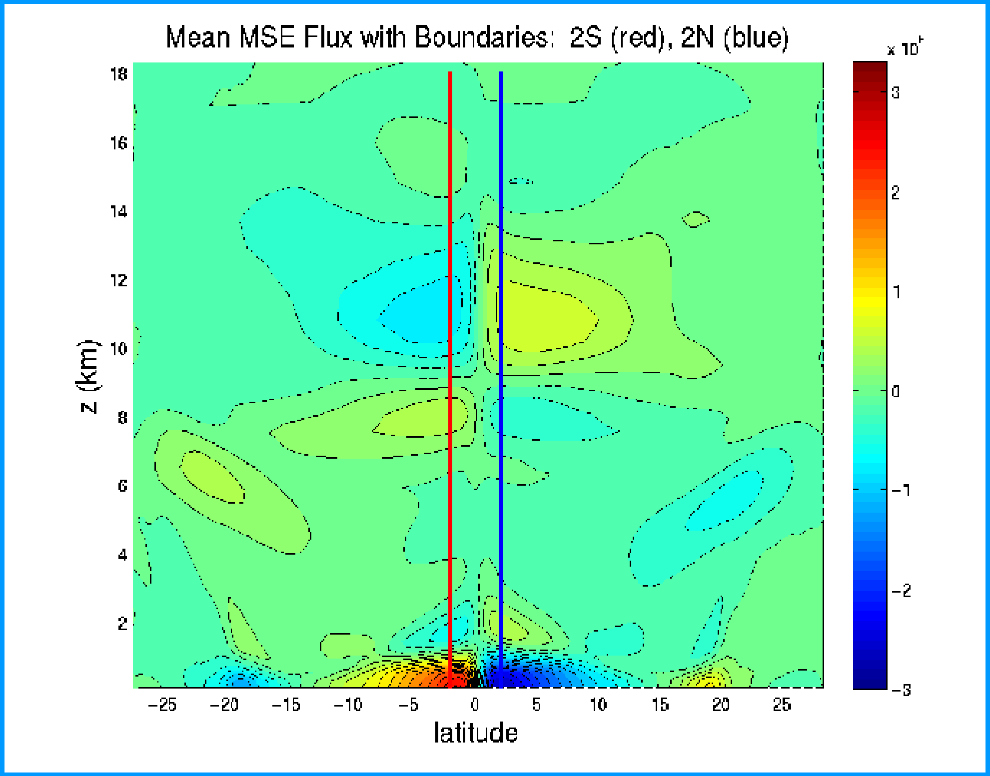
v = meridional wind velocity





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 J*m^{-1}*s^{-1}.

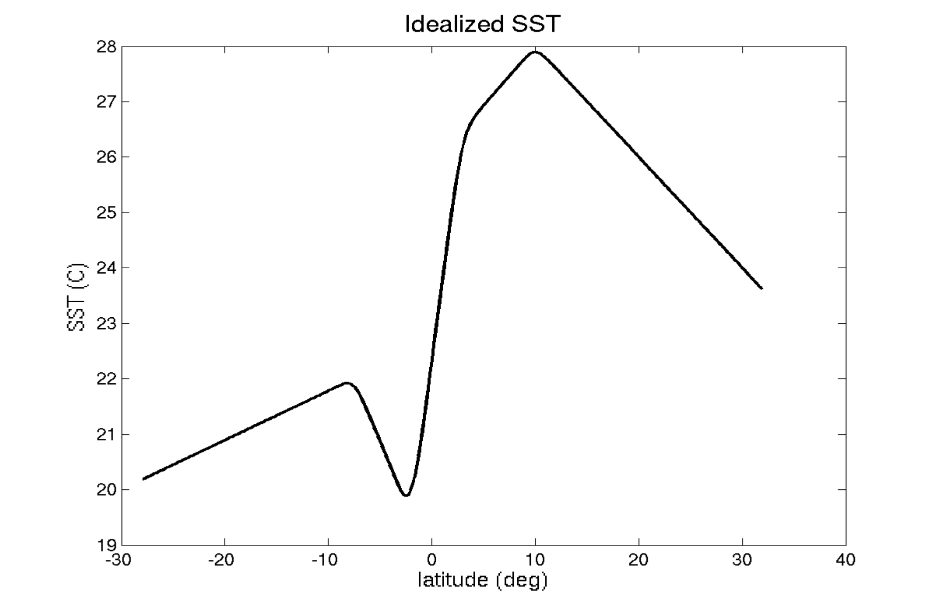
Complete Calculation of MSE Budget

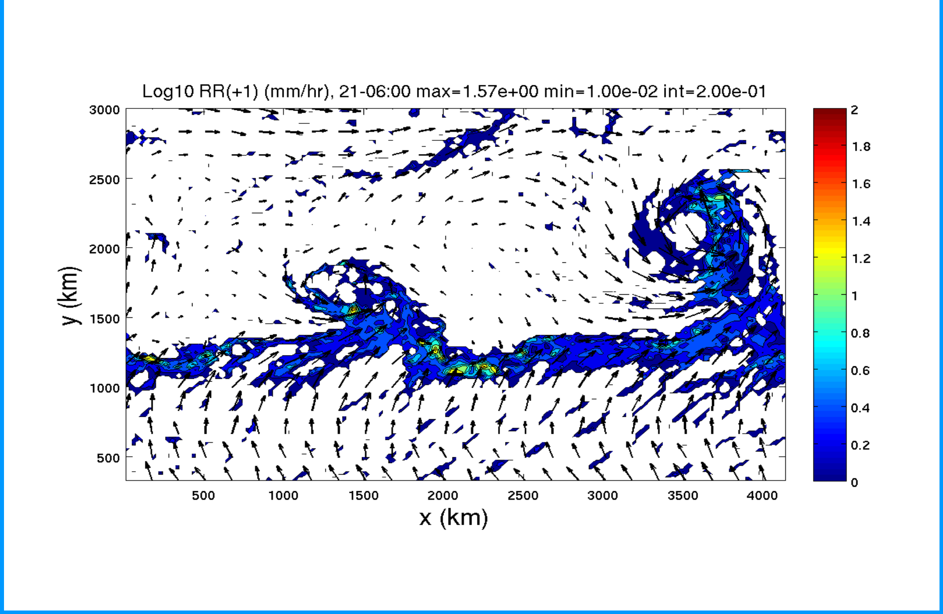
- Shortwave and longwave radiation
- Latent and sensible surface heat fluxes

- Advective terms dominate MSE budget.

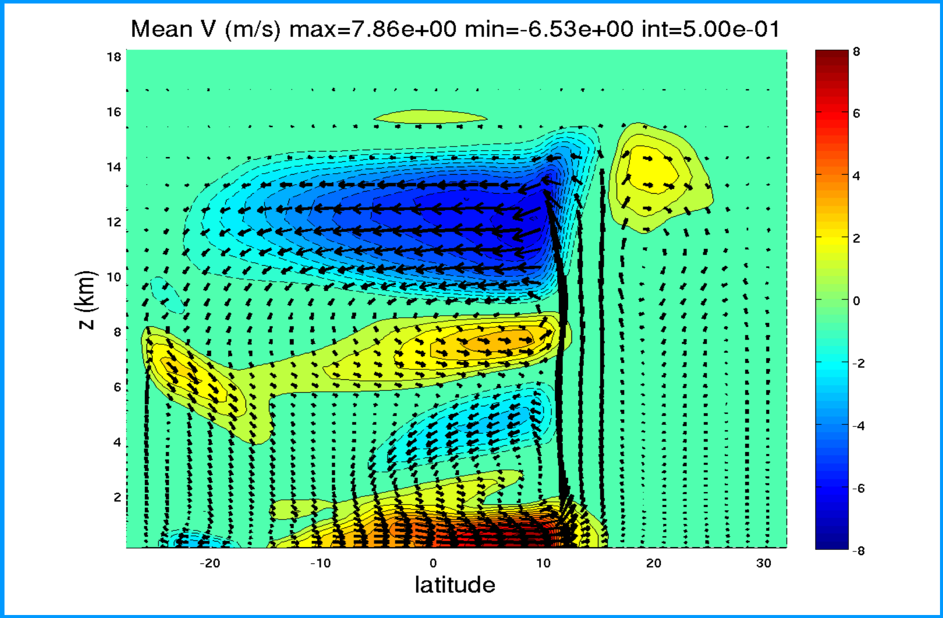
Component	Advection: 2S	Advection: 2N	Outgoing Longwave Radiation	Incoming Shortwave Radiation	Latent Heat Flux	Sensible Heat Flux	Total
MSE Flux ($J*m^{-1}*s^{-1}$)	-3.10E+7	-1.67E+7	-7.26E+7	3.90E+7	7.21E+7	9.88E+6	7.66E+5

Idealized temperature profile

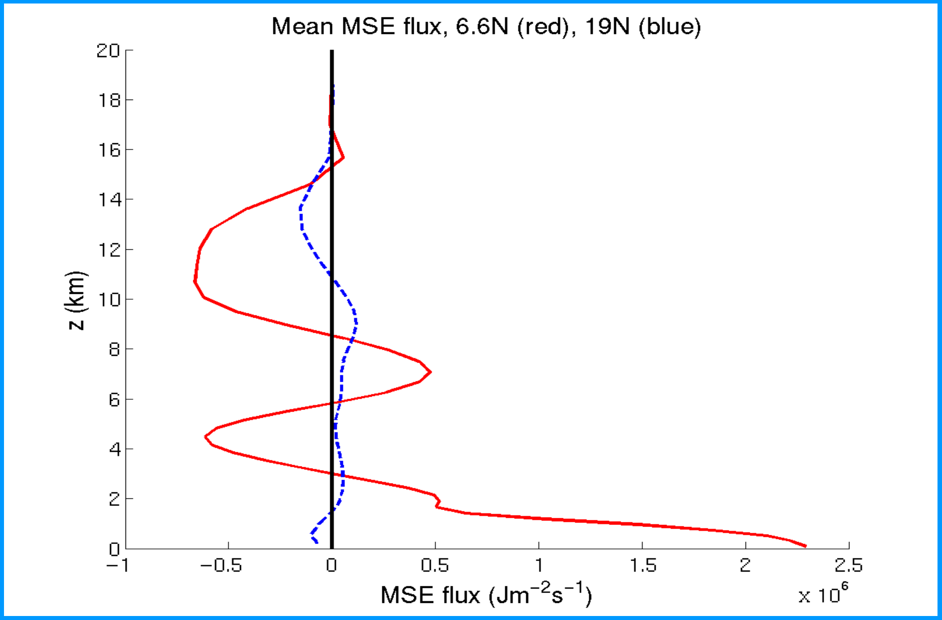


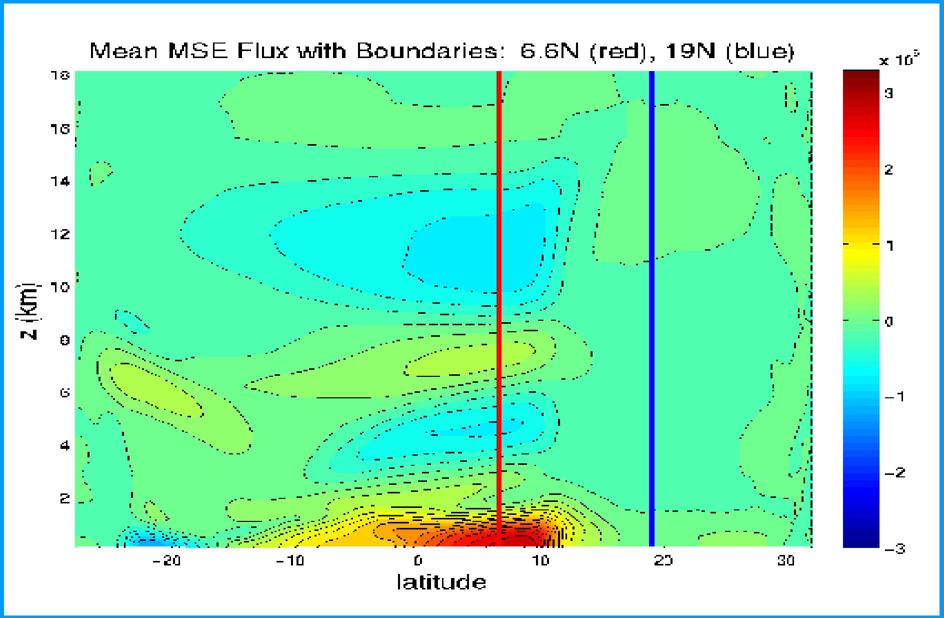


- Cold tongue region of EPAC.
- Tropical cyclones develop with ITCZ now off equator.
- More robust circulation and mid-level inflow at slightly lower level.



Advected MSE



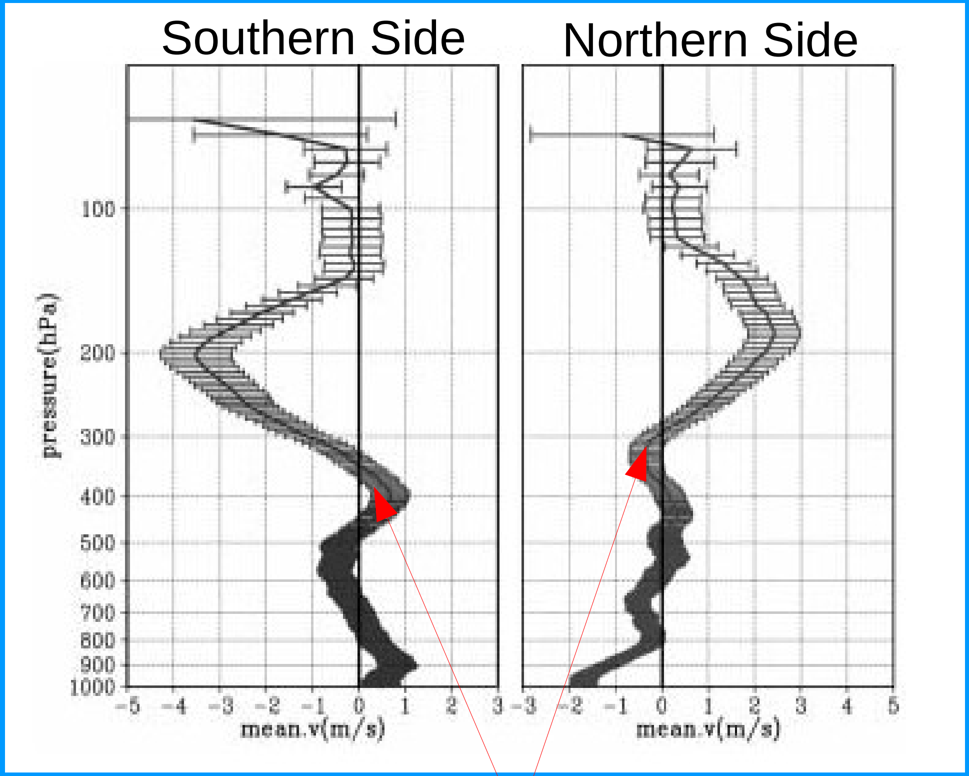


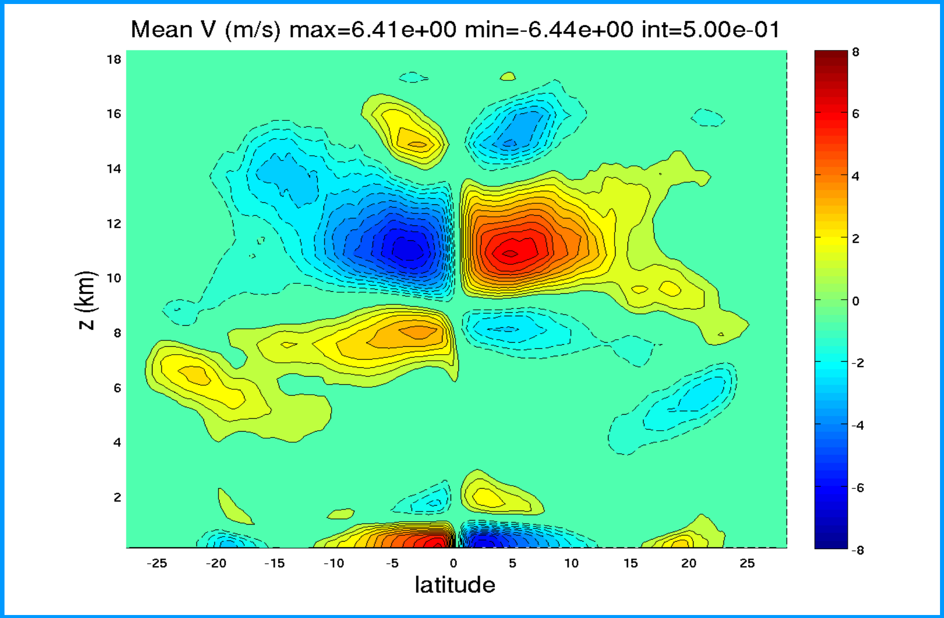
SMC Level	MSE Flux: 6.6N
Upper level return flow	-3.26E+9
Mid-level inflow	7.76E+8
Shallow return flow	-1.17E+9
Boundary Layer inflow	3.57E+9
Total	-8.40E+7

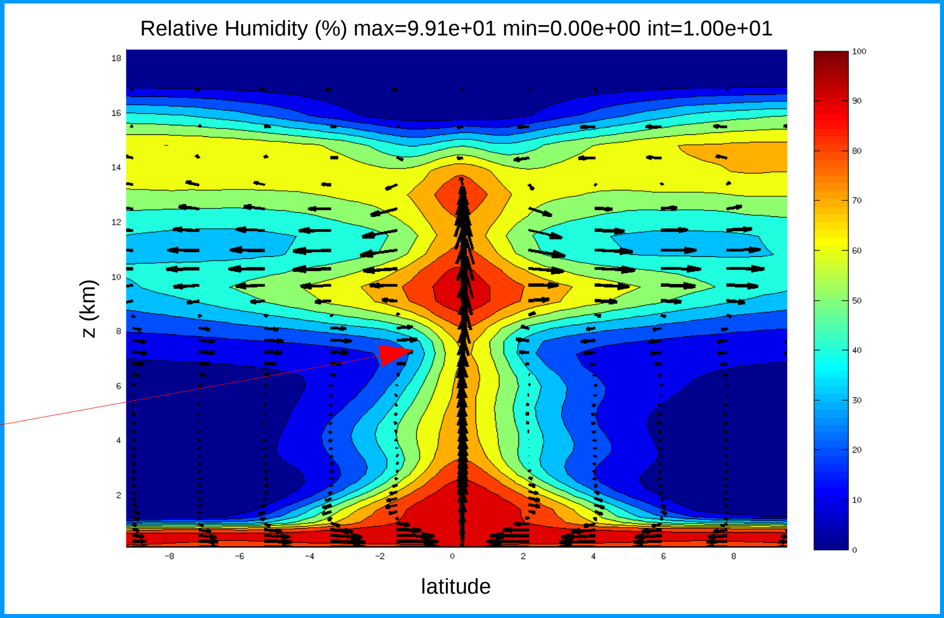
- MSE flux in the SRF comparable to the upper level and boundary layer flows.
- Nolan, et al (2007), indicates that SRF in particular is vital to budgeting water vapor transport in and out of the ITCZ.

A mid-level inflow

Takayabu, et al. (2006)







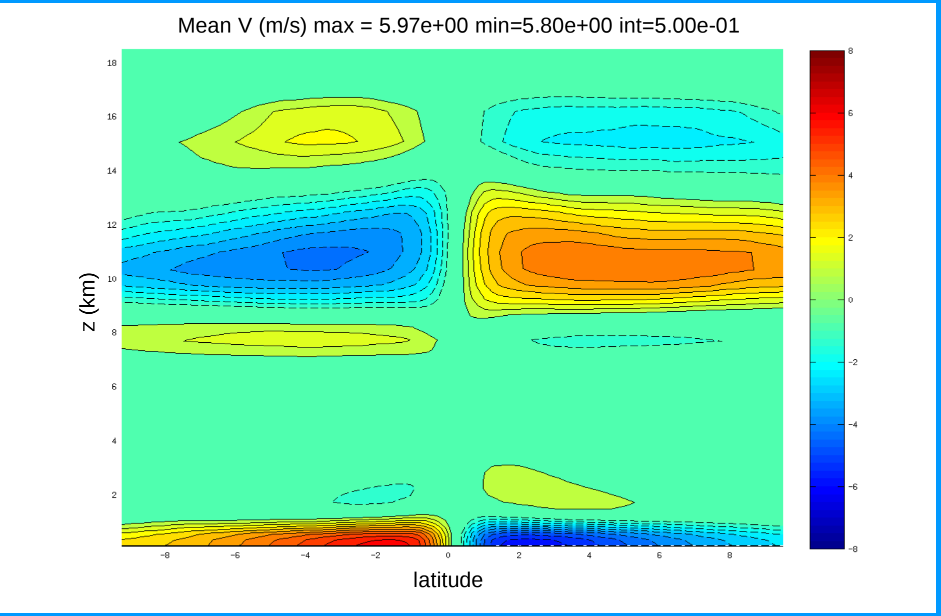
MLI

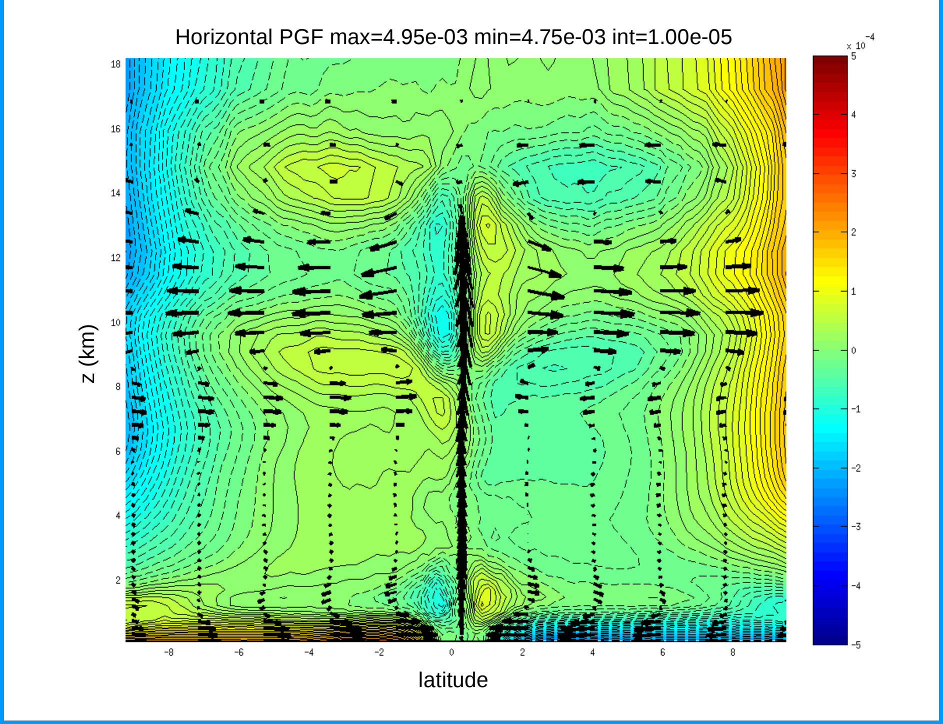
Dry mid-level inflow

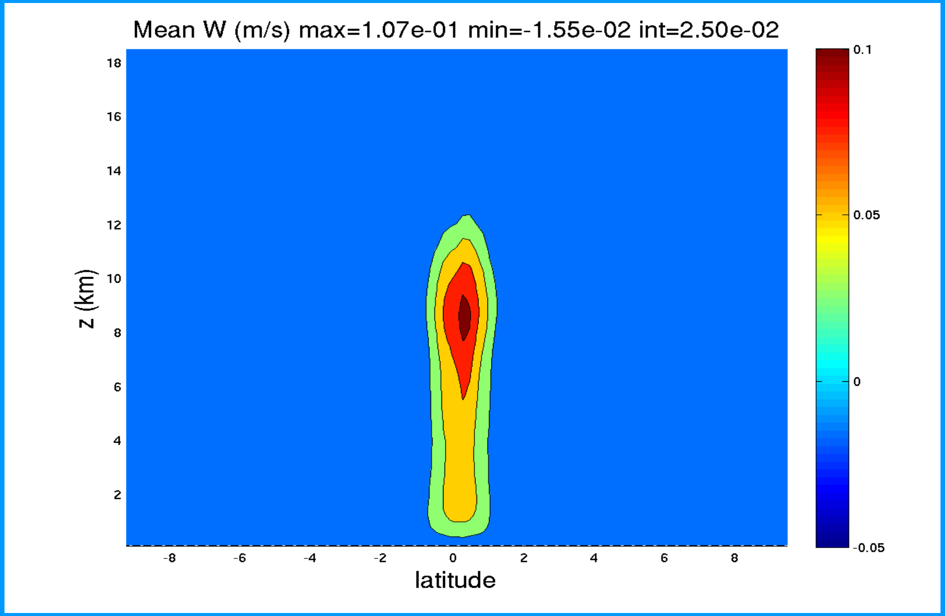
What drives a mid-level inflow?

- Forcing near ITCZ drives mid-level inflow near 8km.
- Boost of convection above melting layer due to latent heat of freezing (Zipser, 2003)
- Evaporative cooling
- MLI not completely eliminated; large scale forcing also driving inflow?

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



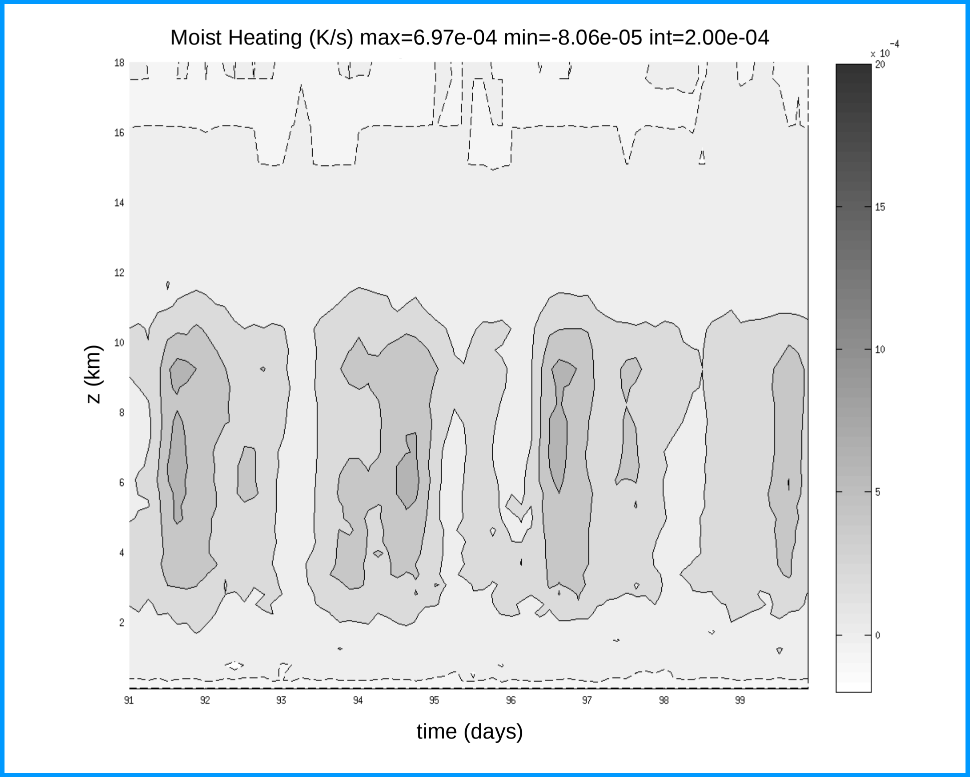


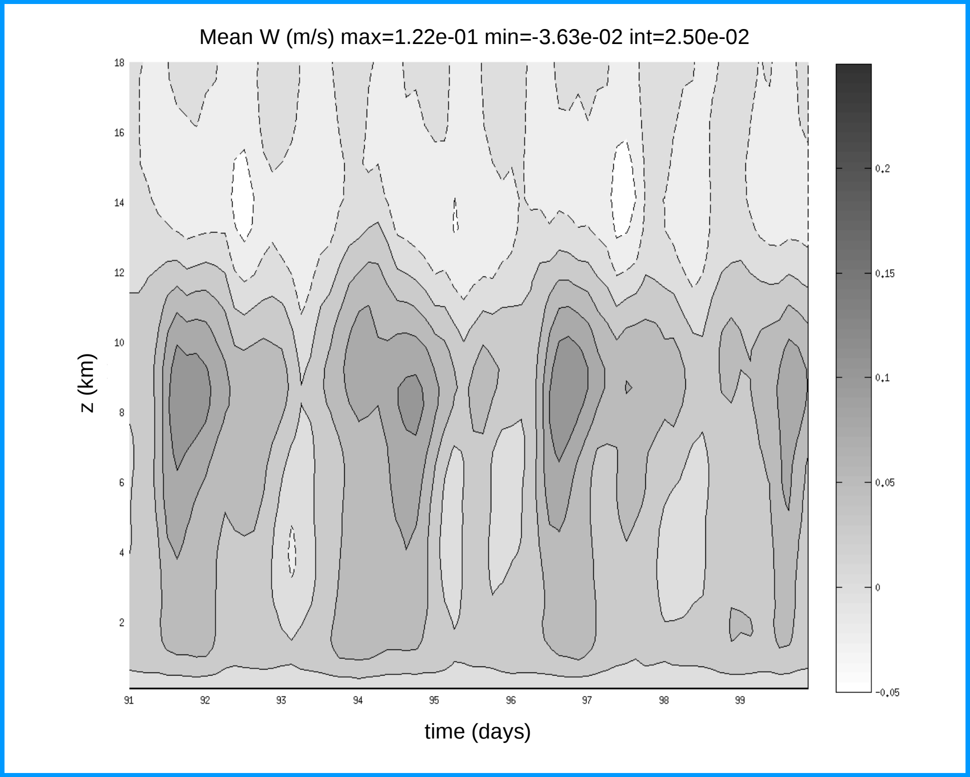


Periodic convection

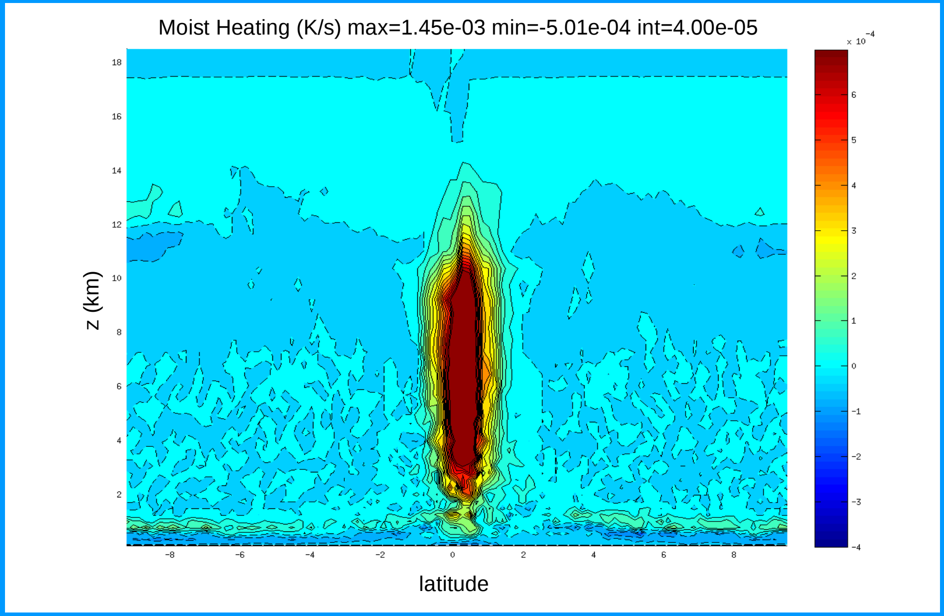
- Period of about 2.5 days

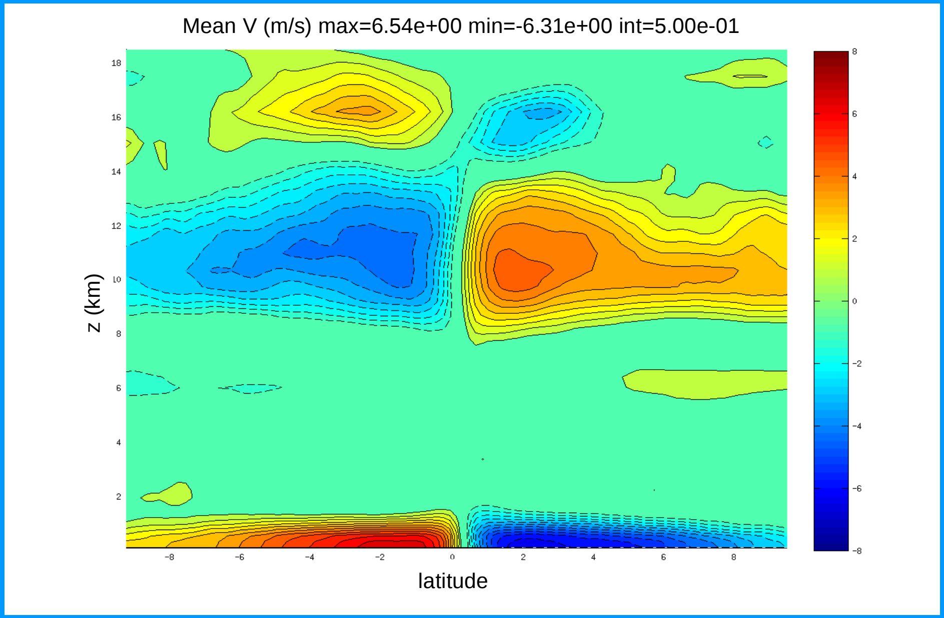
Nolan, et al. (2007) found eastward propagating equatorial Kelvin wave with period of about 2.25 days causing fluctuations in moist heating and convection.

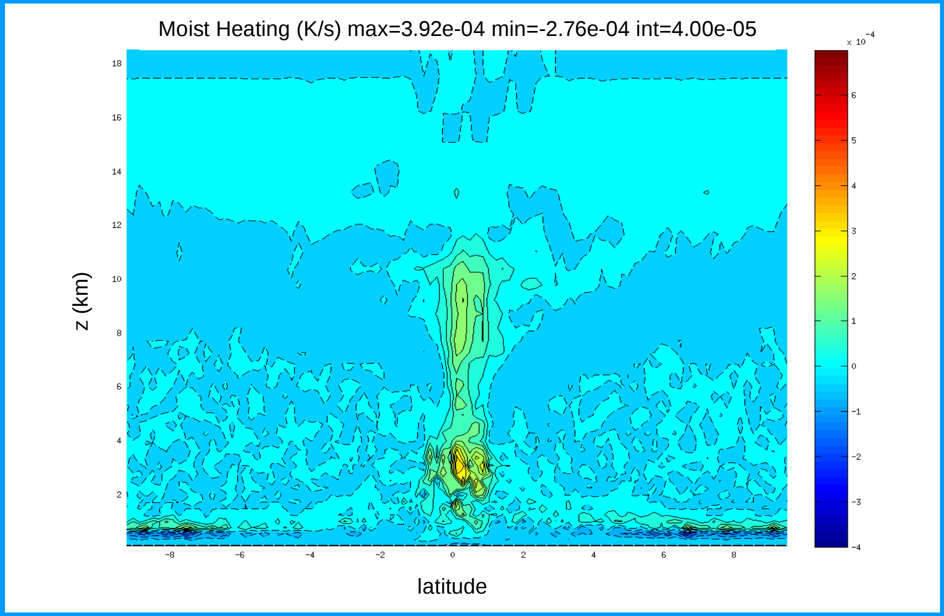


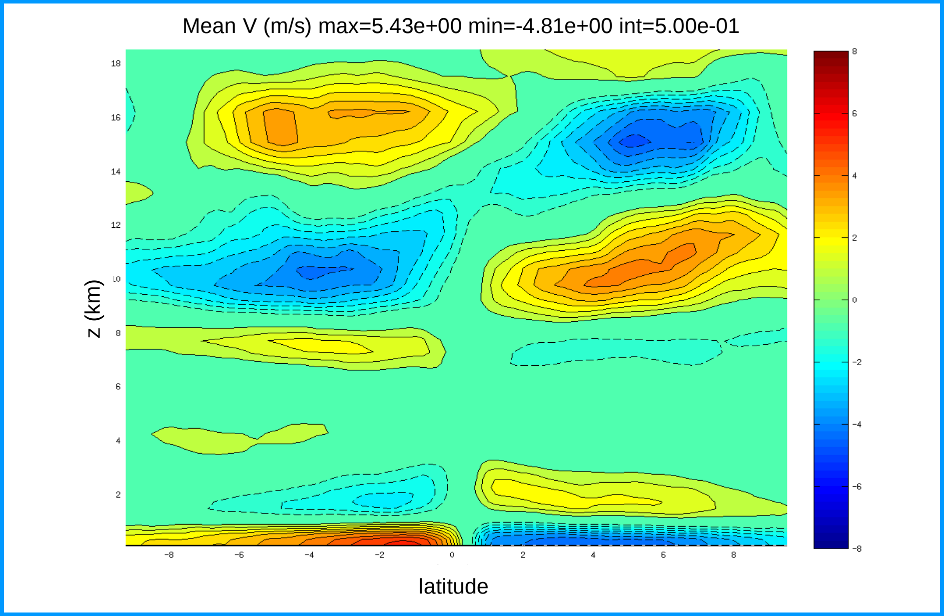


Convection negatively correlated with SRF









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.

- 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.

- SRF and mid-level inflow only present in the absence of convection; in these simulations; strength of convection at least partially modulated by equatorial wave.