Tropical precipitation regimes: contrasting two aquaplanet general circulation models

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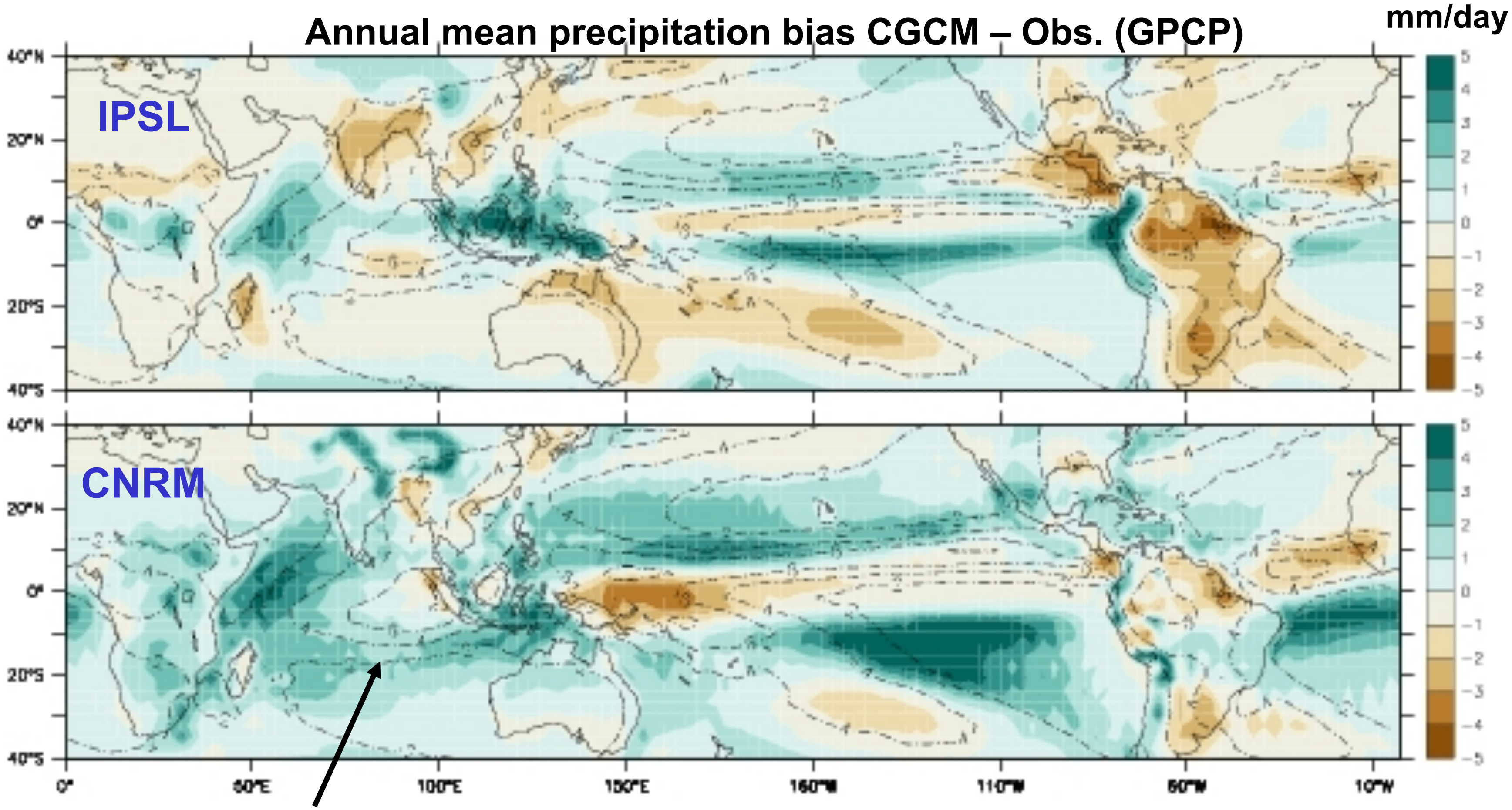
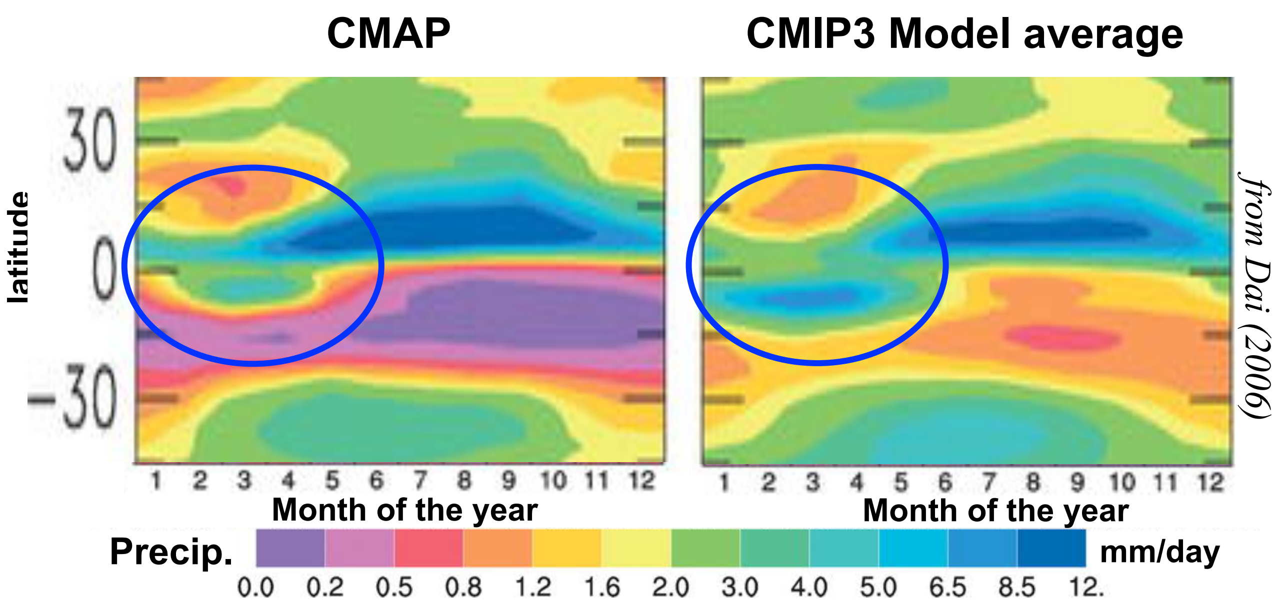
CMIP3 showed some systematic biases in the tropical precipitation simulated by CGCMs

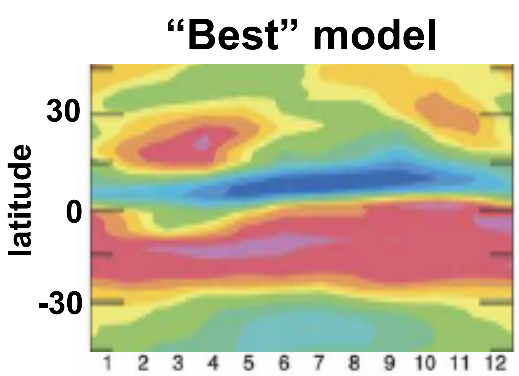


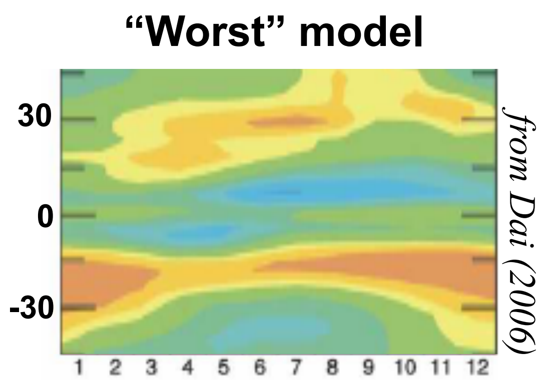
Contours: observed precipitation (GPCP)

CMIP3 GCMs simulated poorly the precipitation in the East Pacific

Average seasonal cycle of precipitation in the East Pacific (80W-120W)





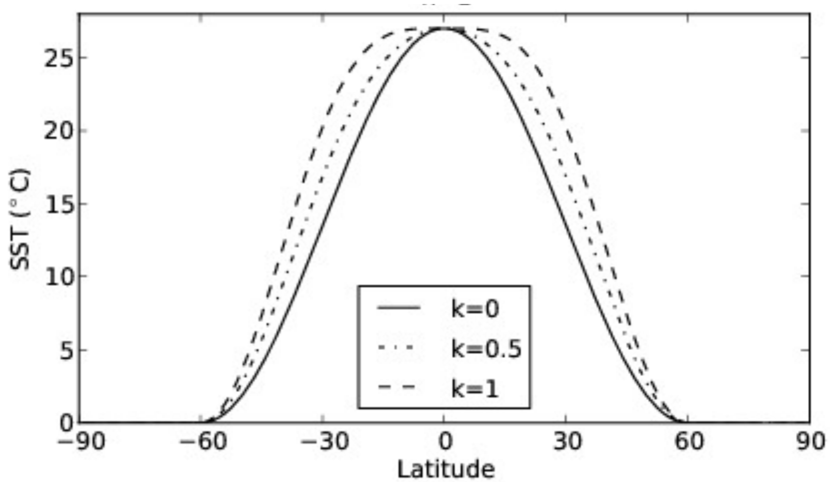


We need a better understanding of the mechanisms that control the ITCZ location in these models
→ Aquaplanet?

Single - double transition

• **All GCMs exhibit this transition when the meridional gradients of SST in the tropics are weakened**

APE - type SST:



• **Sensitivity experiments show that this transition can occur when parameters of the models are changed (mostly convection, but also diffusion and resolution)**

Hayashi and Sumi (1986); Lau et al. (1988); Sumi (1992); Numaguti (1993); Hess et al. (1993); Frierson (2007)

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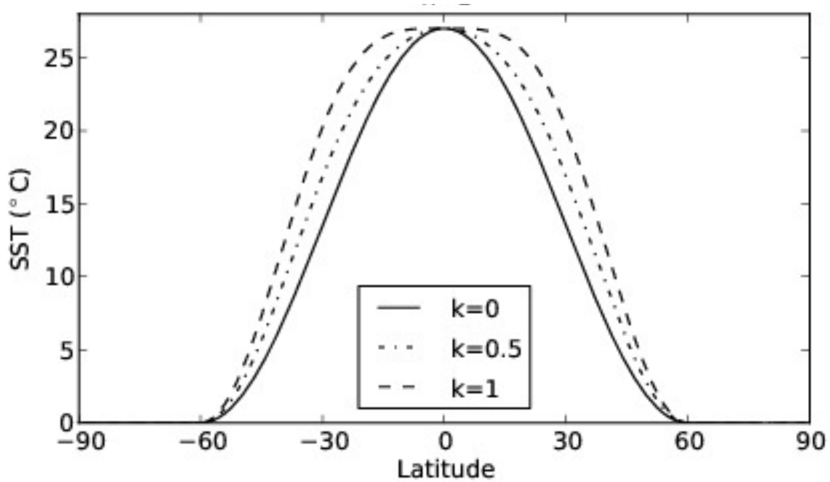

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References

Two AGCMs

ARPEGE

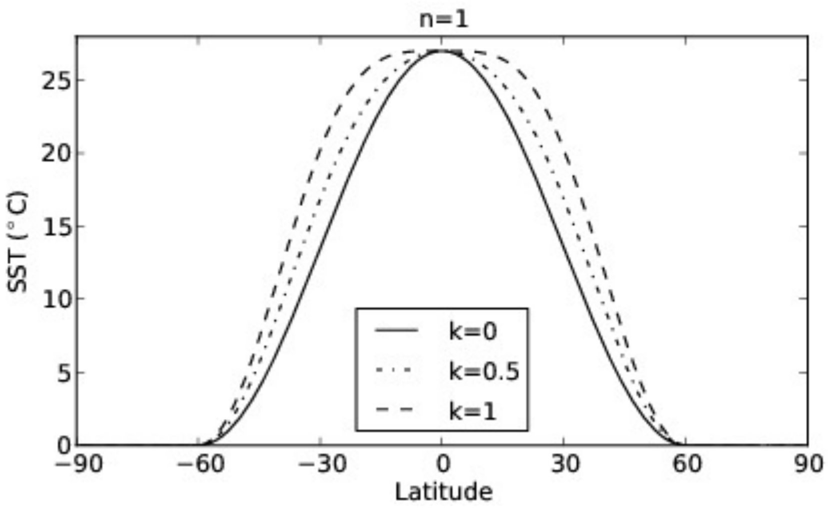
- Version 5.2
- Atmospheric component of CNRM-CM5
- Spectral model
- Bougeaud (1985)'s parameterization of convection: closure on convergence

LMDz

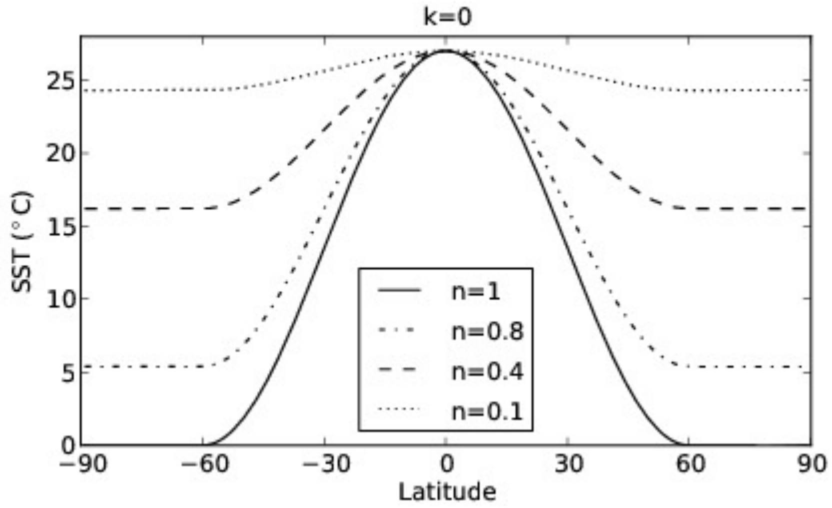
- Version 5
- Atmospheric component of IPSL-CM5A
- Gridpoint model
- Emanuel (1994)'s parameterization of convection: closure on CAPE

APE – type SST forcing:

Varying location of SST gradients

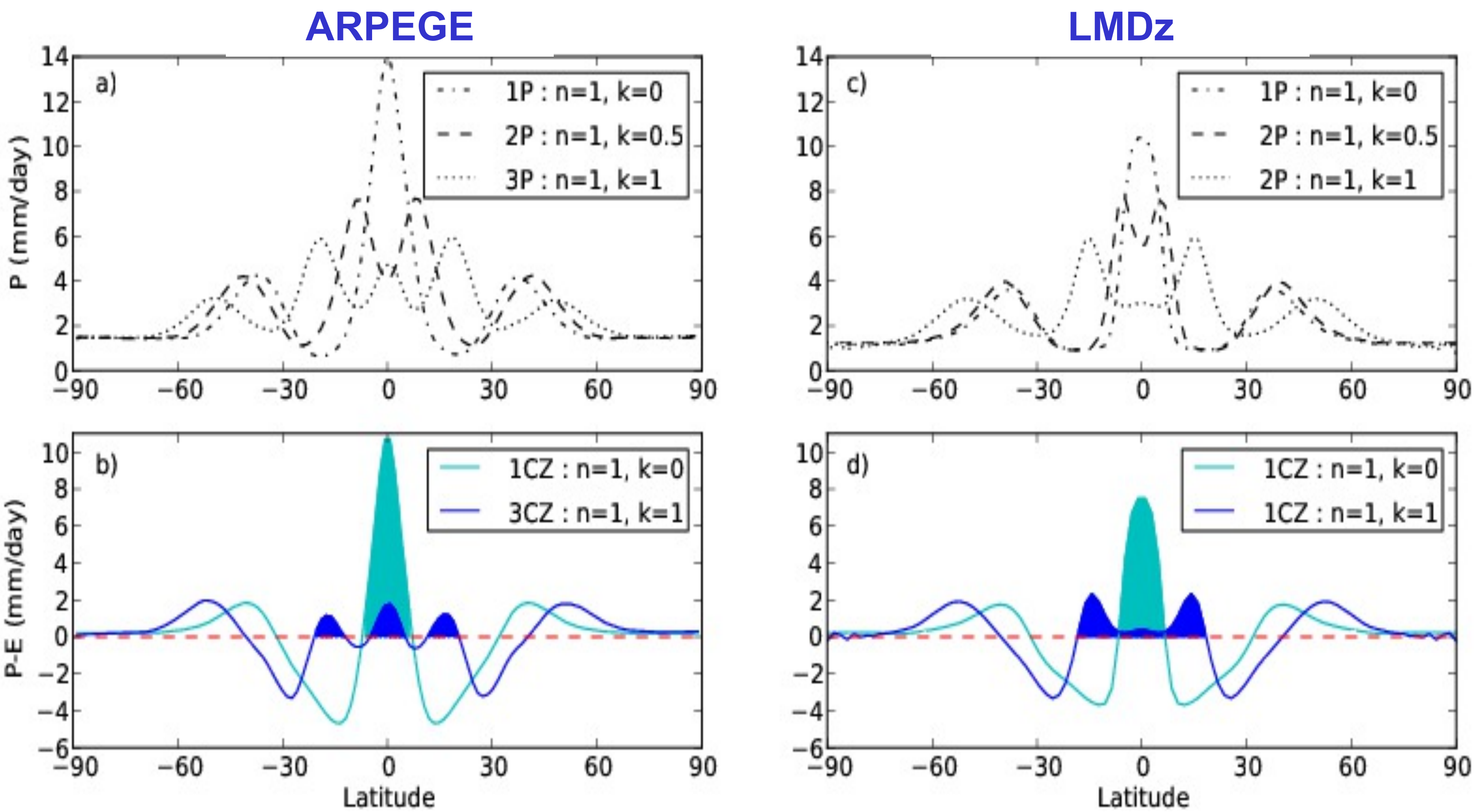


Varying equator-pole SST difference

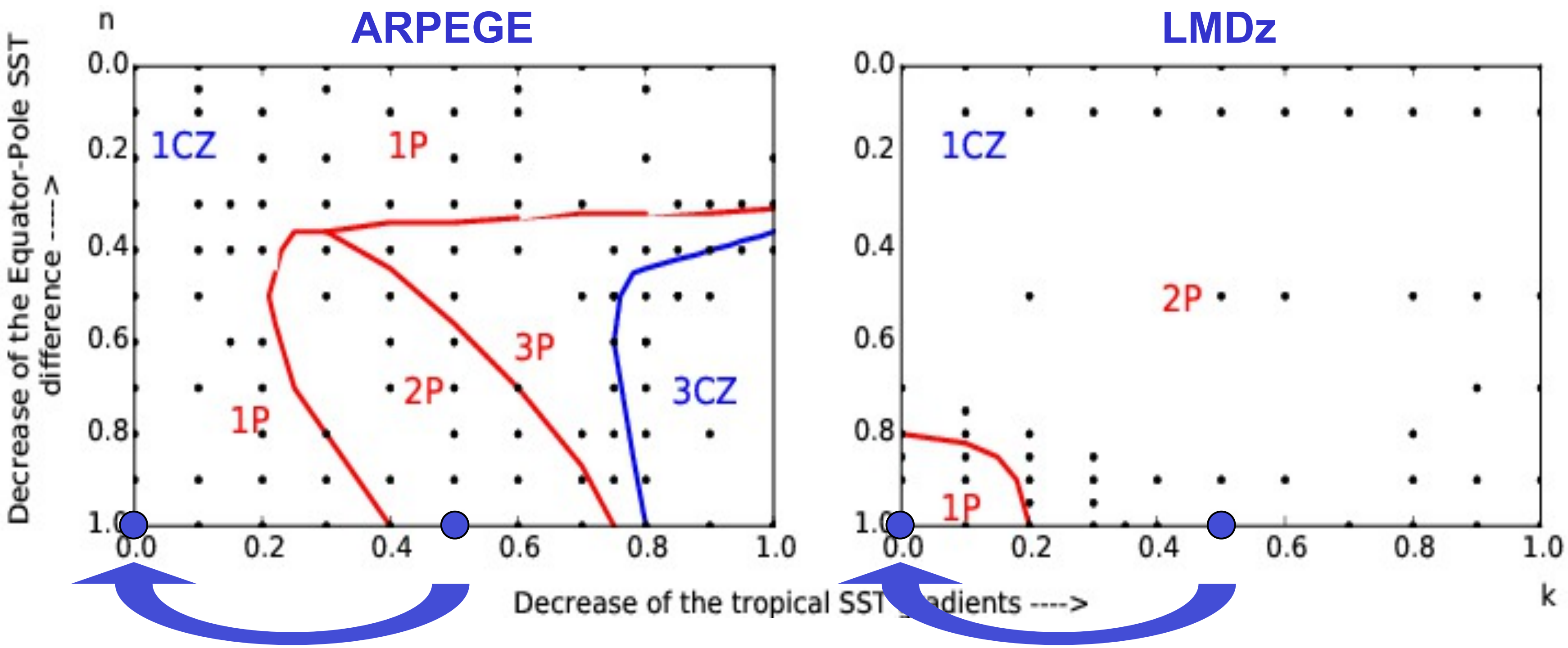


5-year simulations (2-yr spin up; analysis of the 3-yr, zonal average)

Regimes of precipitation and humidity convergence



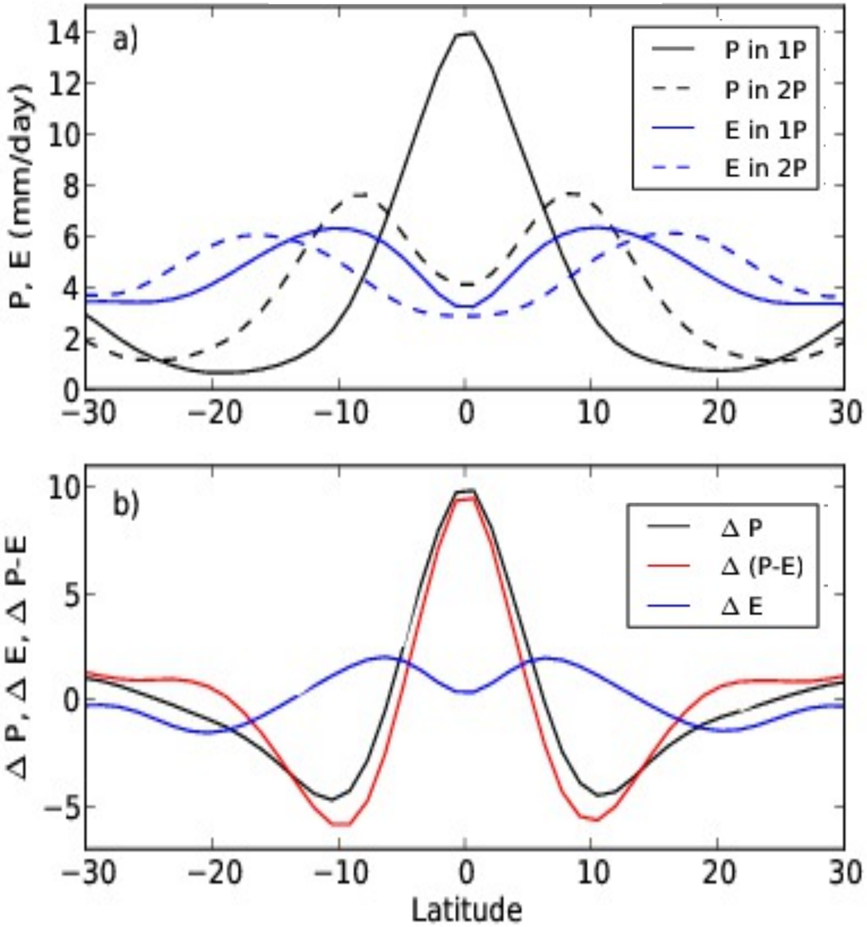
Regimes of precipitation and humidity convergence



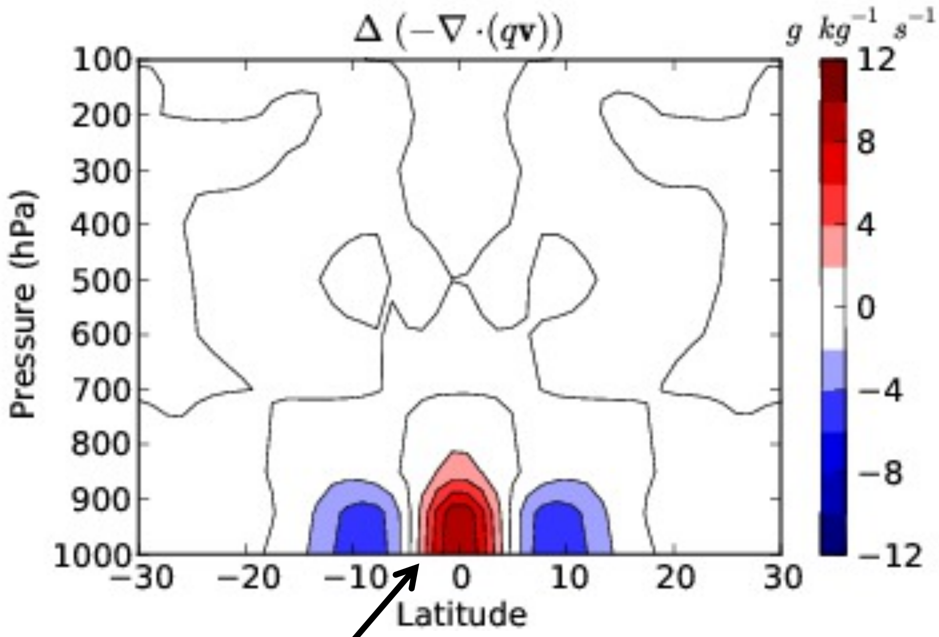
nP = n maxima of precipitation
nCZ = n convergence zones

Low-level humidity convergence drives the transition

ARPEGE



Δ = difference between the simulations 1P (k=0, n=1) and 2P (k=0.5, n=1)



driven by convergence

What drives the low-level convergence?

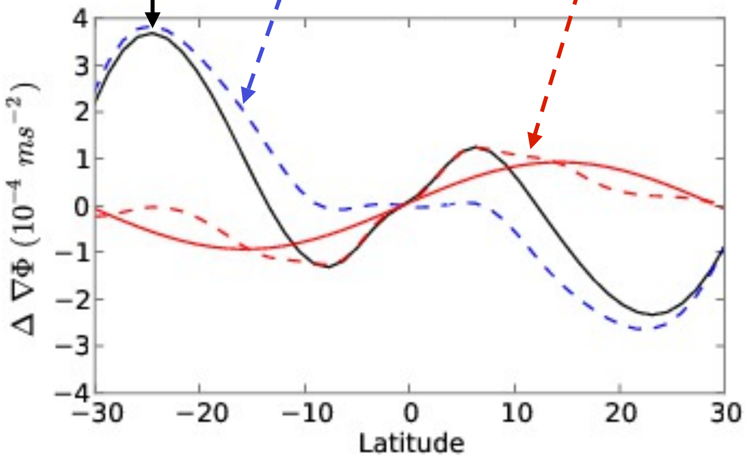
$$\Phi\,(1000\text{hPa}) = \Phi\,(800\text{hPa}) + \int_{800}^{1000} R\,T\,\frac{dp}{p}$$

"Gill" "Lindzen-Nigam"

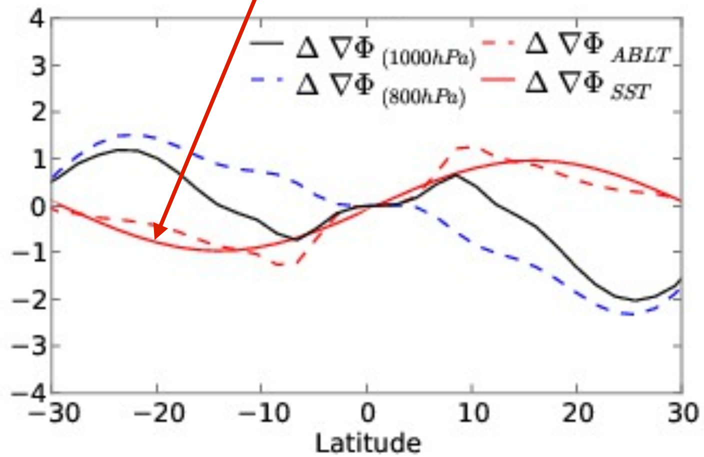
$$\int_{800}^{1000} R\,SST\,\frac{dp}{p}$$

$\Delta\nabla\Phi$

ARPEGE



LMDz



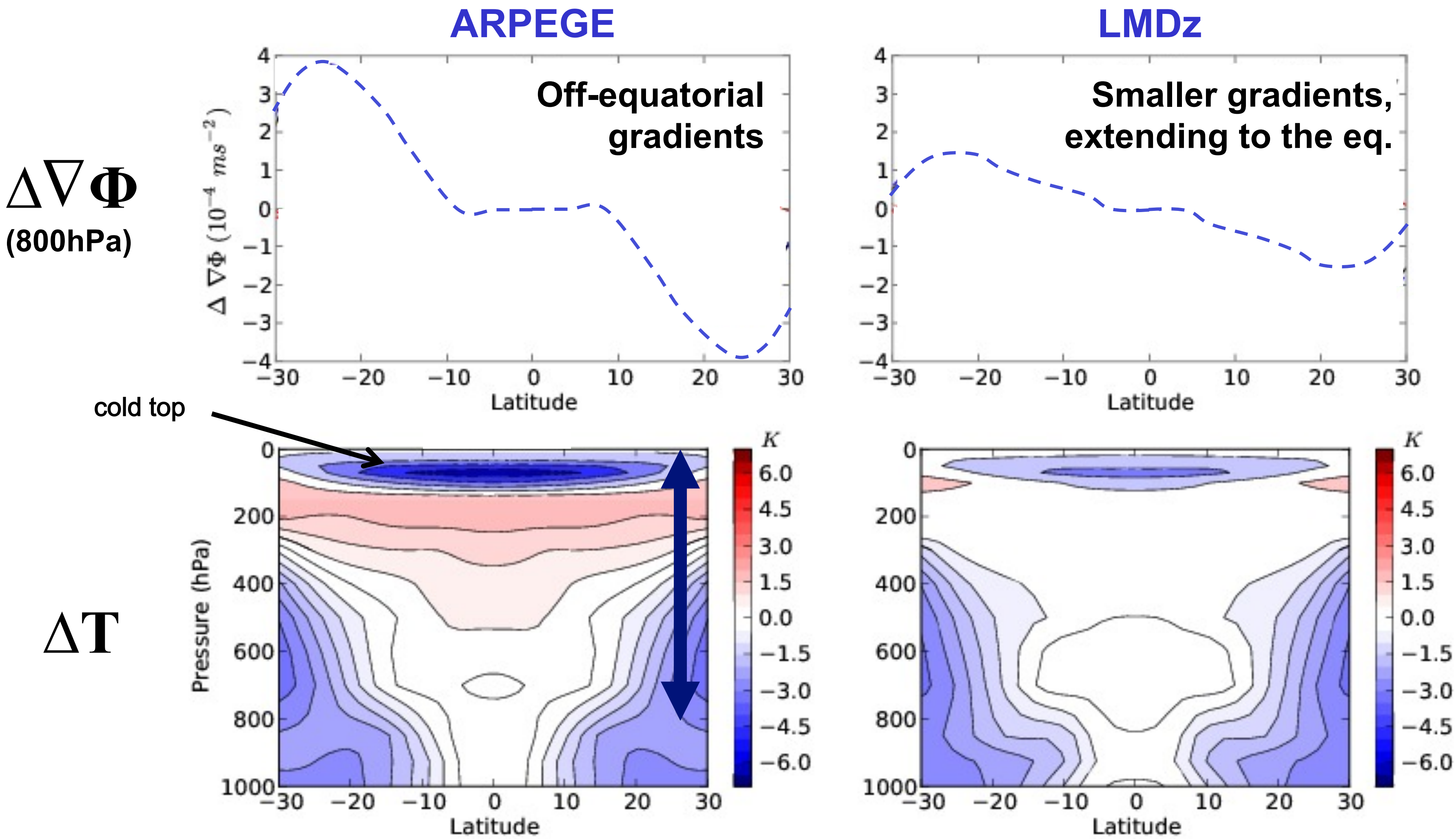
The contribution of ABL temperature dominates in the equatorial band

Smaller contribution of ABL temperature, larger compensation from above.

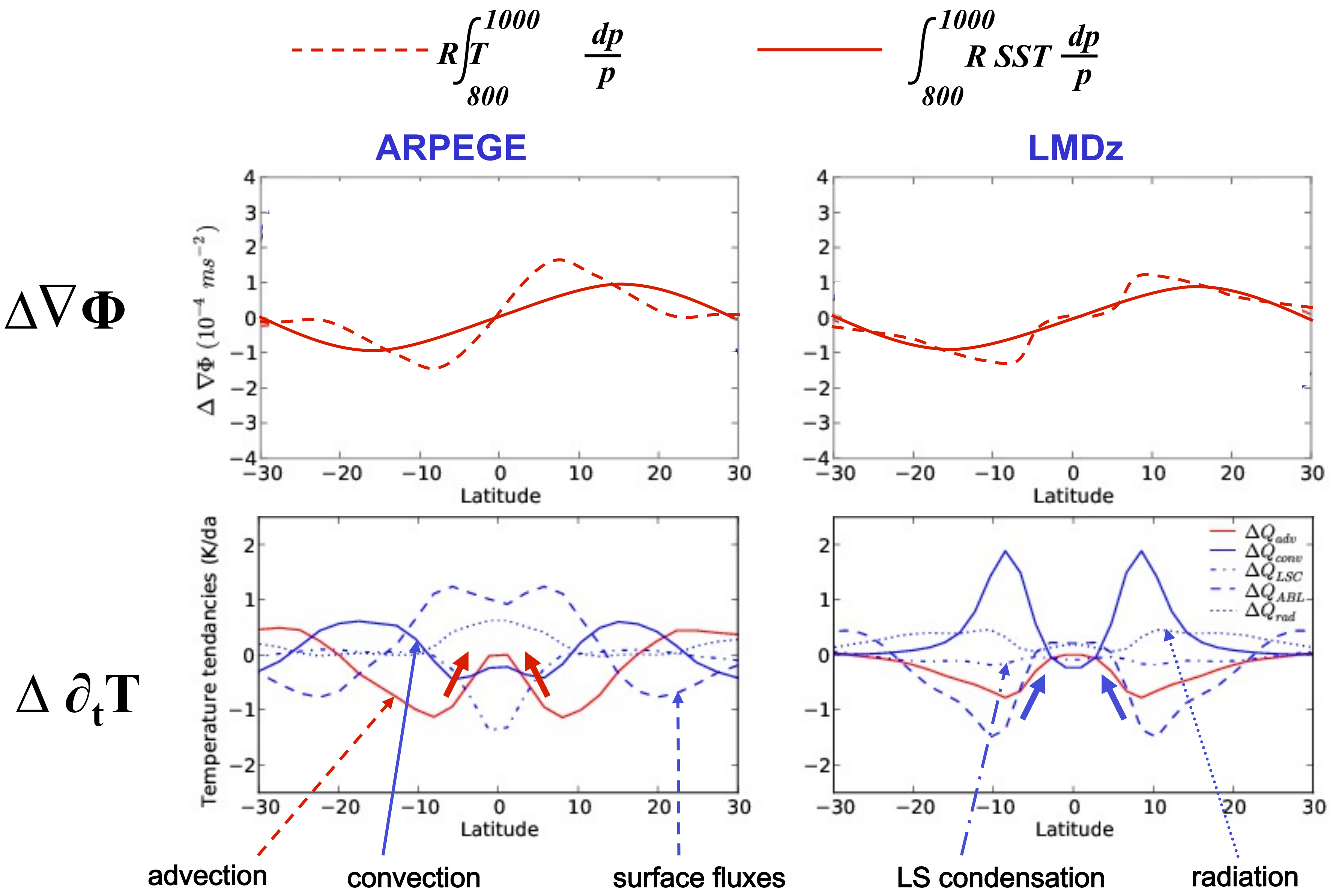
Results: mechanisms of the double-single transition

$$\Phi\ (800\text{hPa}) = \int_0^{800} R\,T\,\frac{dp}{p}$$

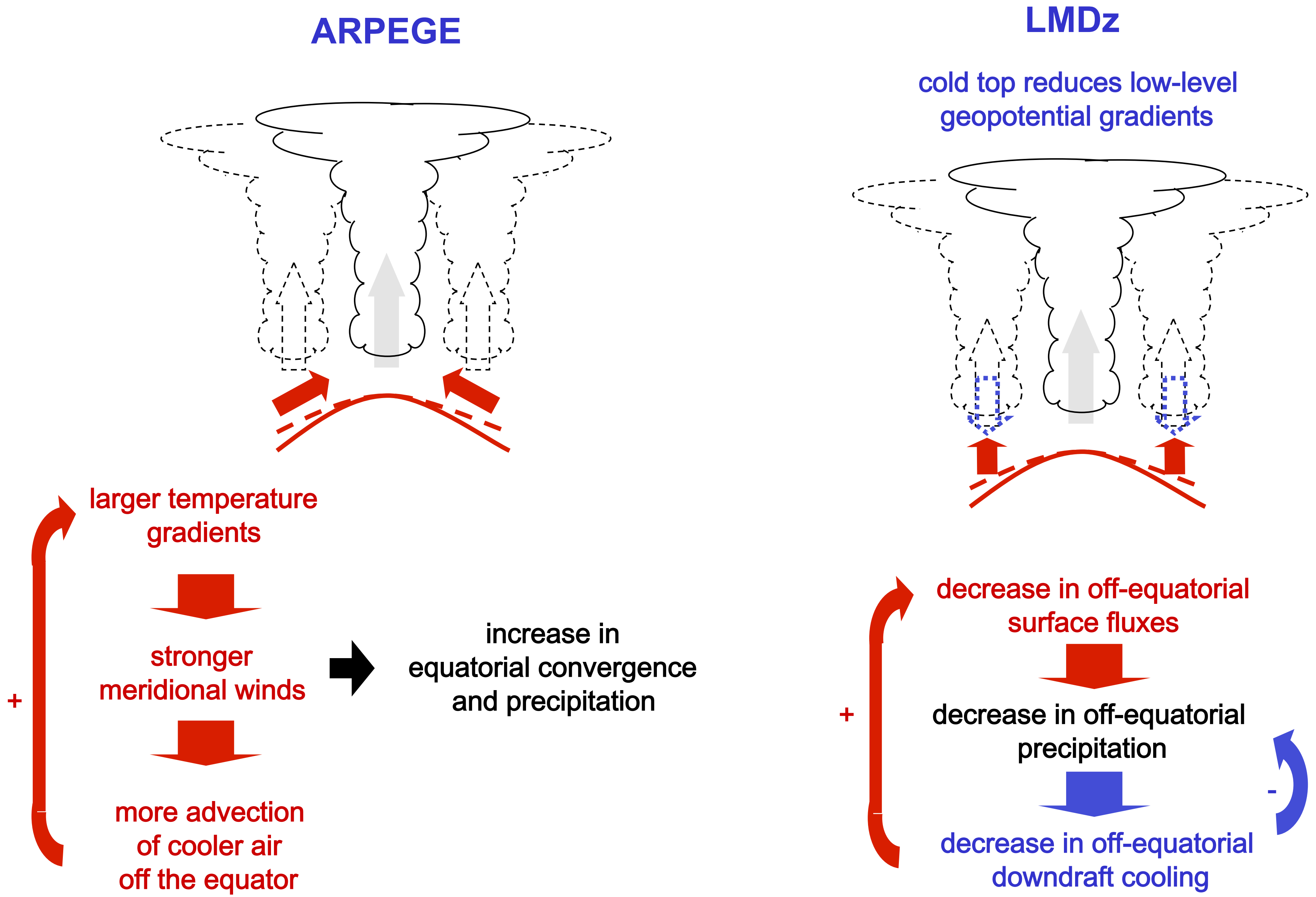
The cold-top signal dominates the free-tropospheric geopotential gradients



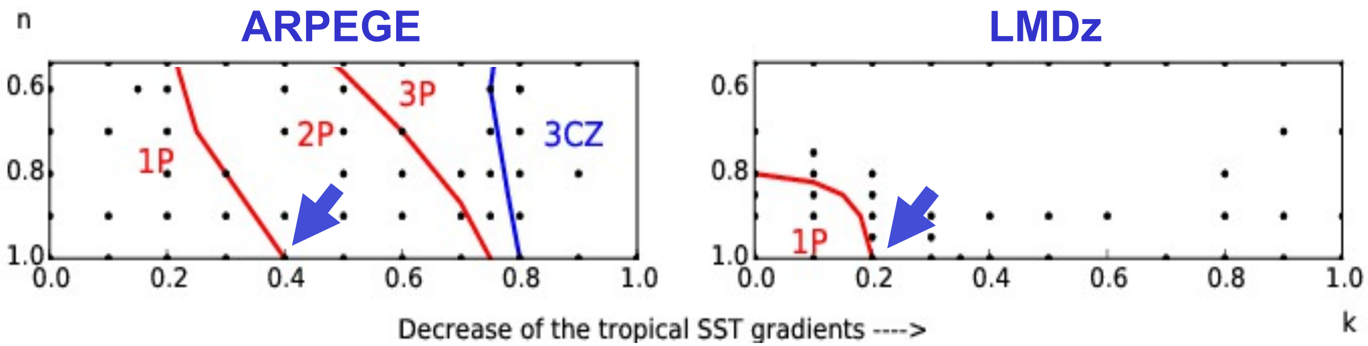
Results: mechanisms of the double-single transition



Summary


ARPEGE
LMDz
cold top reduces low-level geopotential gradients
larger temperature gradients
stronger meridional winds
more advection of cooler air off the equator
+
increase in equatorial convergence and precipitation
decrease in off-equatorial surface fluxes
decrease in off-equatorial precipitation
decrease in off-equatorial downdraft cooling
+
-

• The mechanisms that control the SST-forced transition are extremely model-dependent. They might explain the difference in threshold between the two models.



• In the LMDz, the heating profile associated with convection is crucial, both in the lower levels (downdrafts) and above, including in the upper-atmosphere (cold top). Negative feedbacks on the transition result from it.

• In ARPEGE, the mechanisms are essentially dry: horizontal advection of temperature is a strong positive feedback on the double-single transition.

• It confirms that there will not be a unique solution to the double ITCZ syndrom. (they still might be a finite number of solutions).