The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

1968-15

Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

Response of zonal mean atmosphere circulation: global warming vs. El Nino

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Response of the zonal mean atmospheric circulation

El Niño vs. global warming

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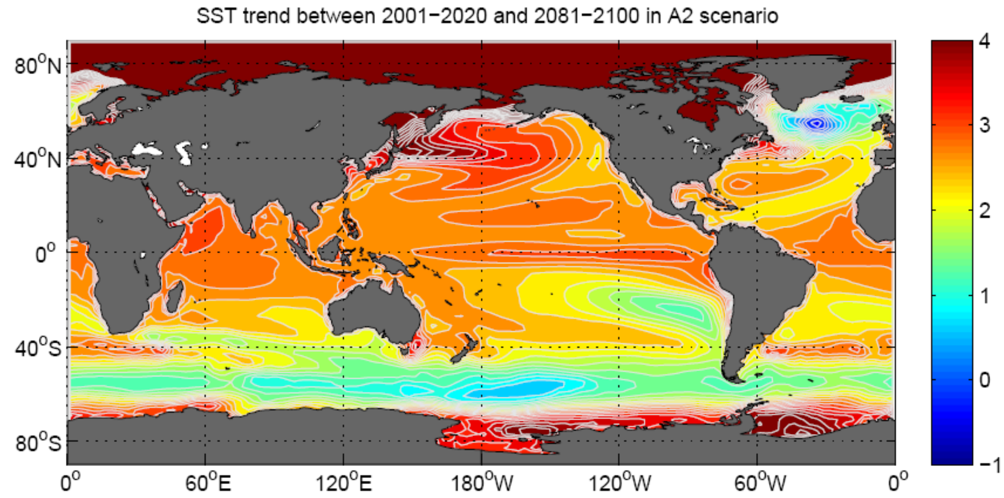
Conference on Teleconnection in the Atmosphere and Ocean
Trieste, Italy, 17-20 November, 2008

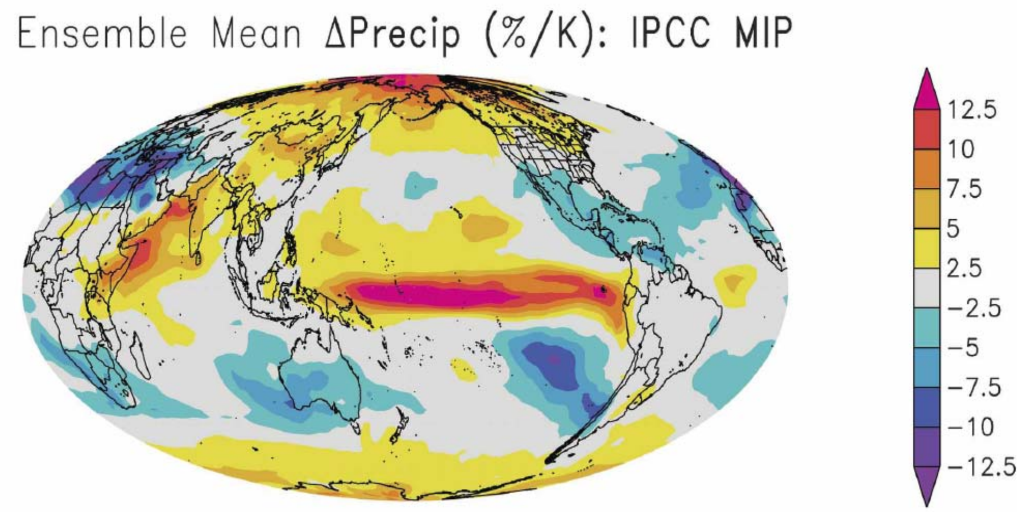
"El Nino-like" global warming

- Equatorial Pacific warming
- Enhanced tropical convective precip
- Walker cell slowdown
- Shoaling of thermocline
- *"trop forcing dominates atmospheric response"*

(a)



(b)



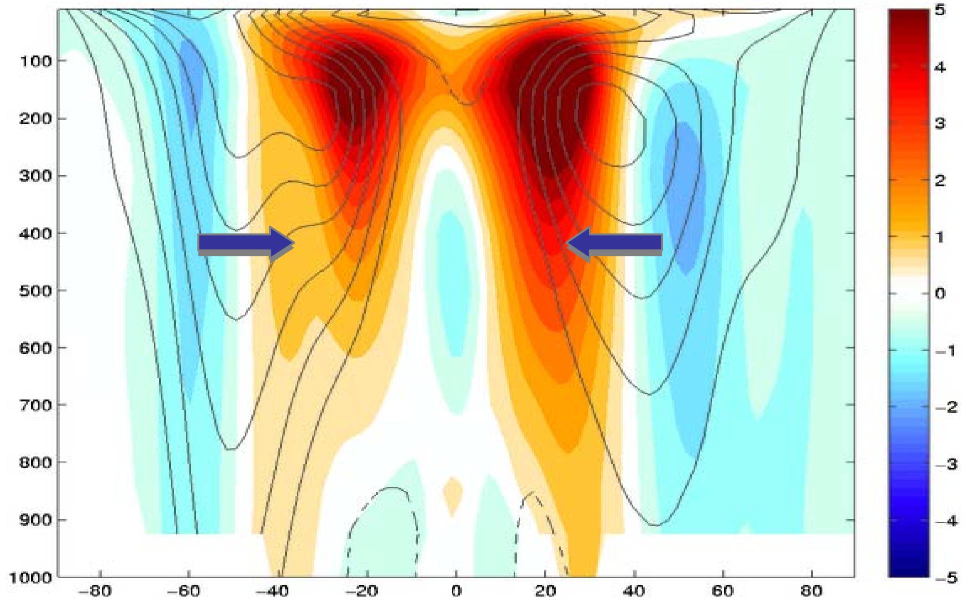
Oldenborgh et al. 2005
Yamaguchi and Noda, 2006

Vecchi and Soden, 2007

$\overline{\mathbf{U}}$

interannual composite

El Nino - La Nina

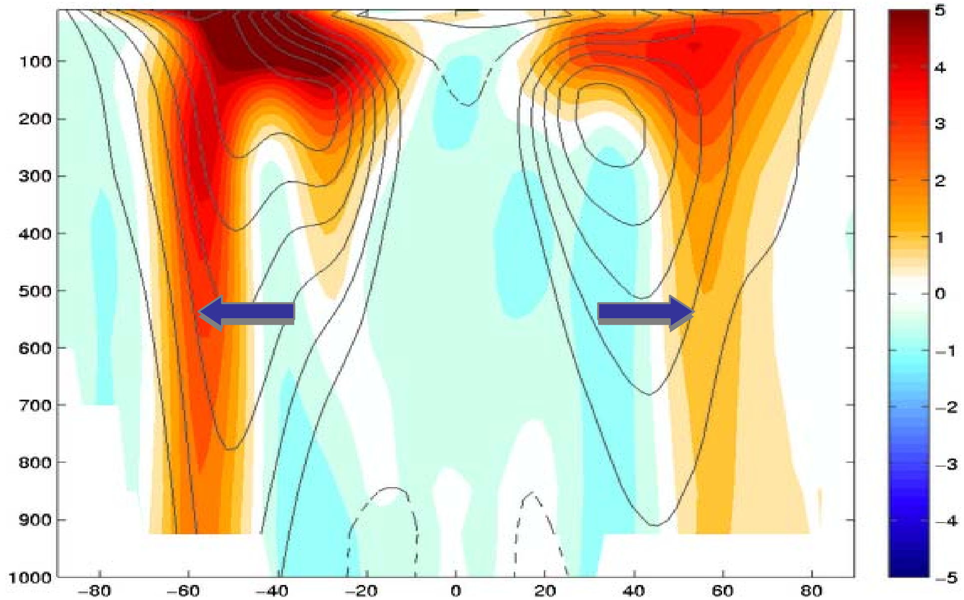


contours: background

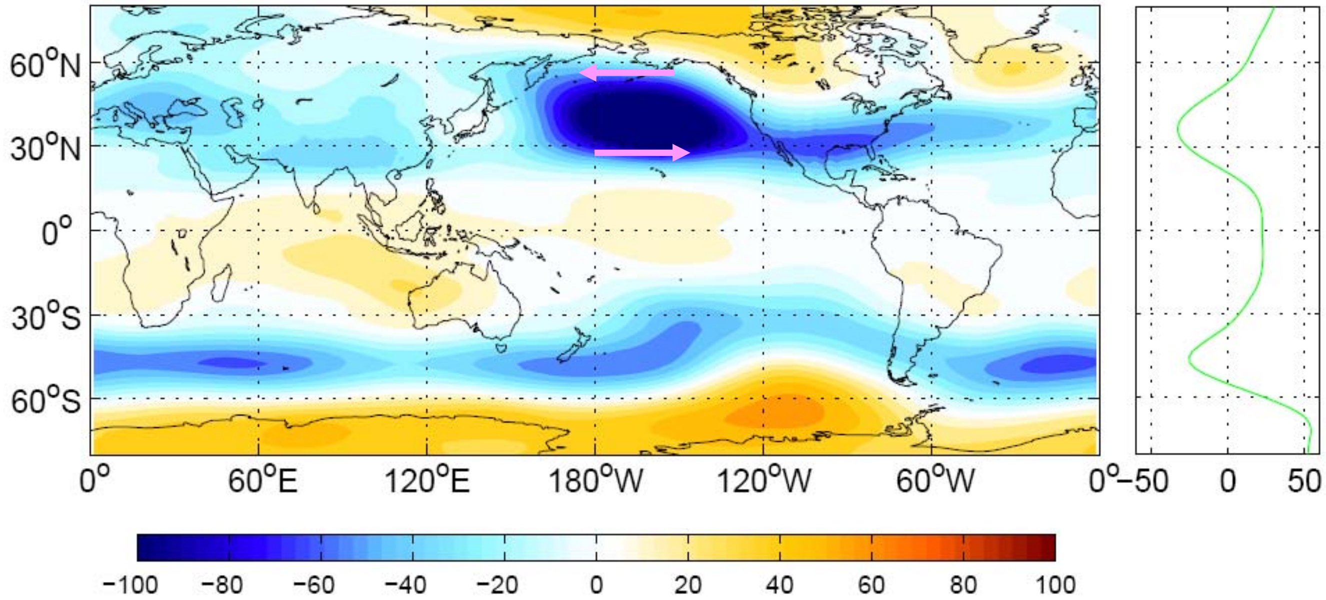
colors: anomalies

2081-2100 minus 2001-2020 in A2

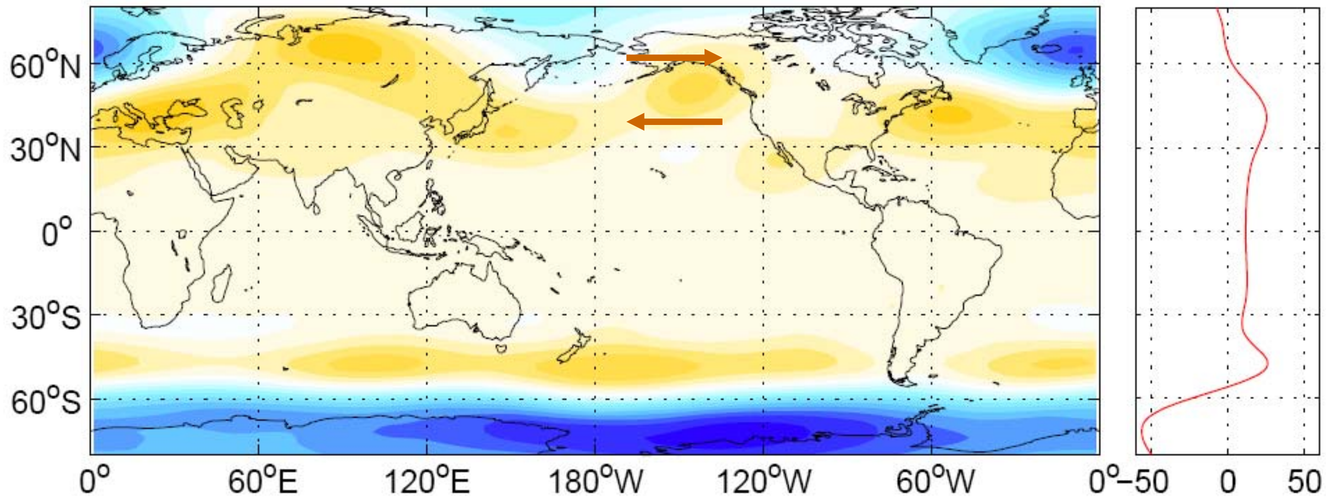
trend



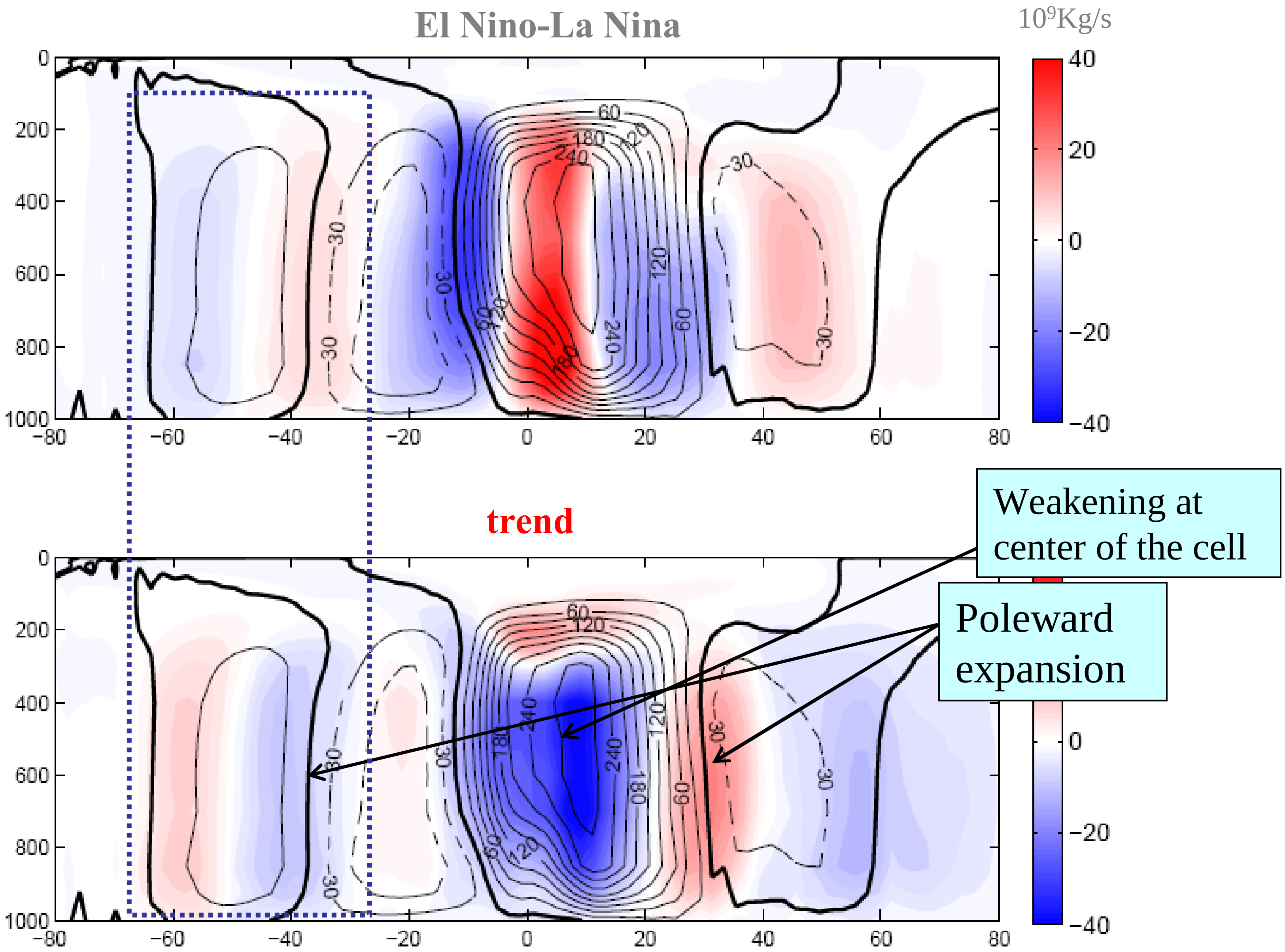
Z500
interannual composite



trend



Multi-model Mean Changes in streamfunction



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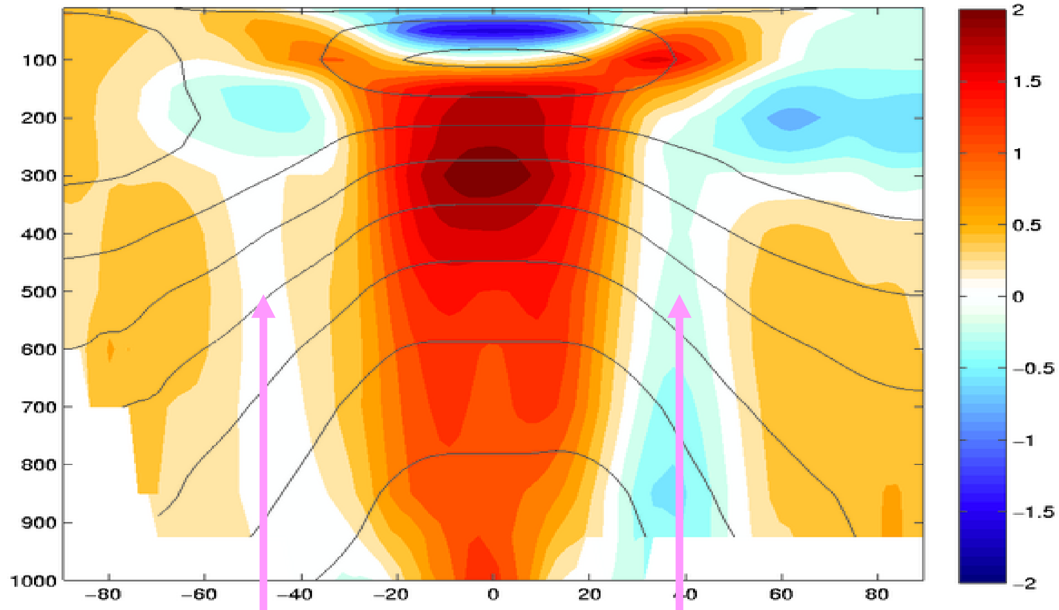
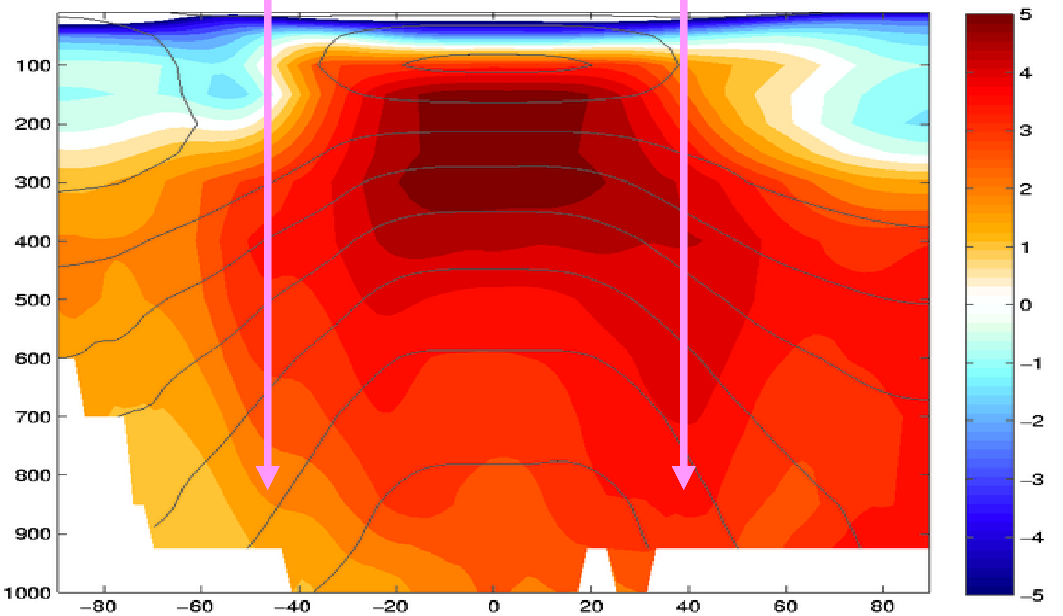
interannual composite

El Nino-La Nina



trend

trend



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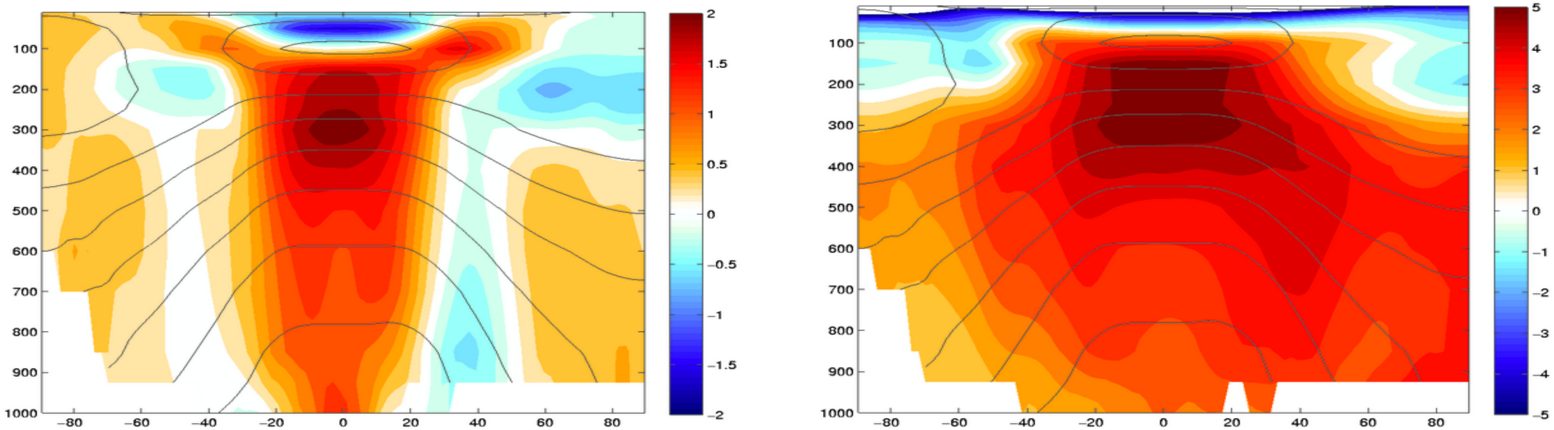
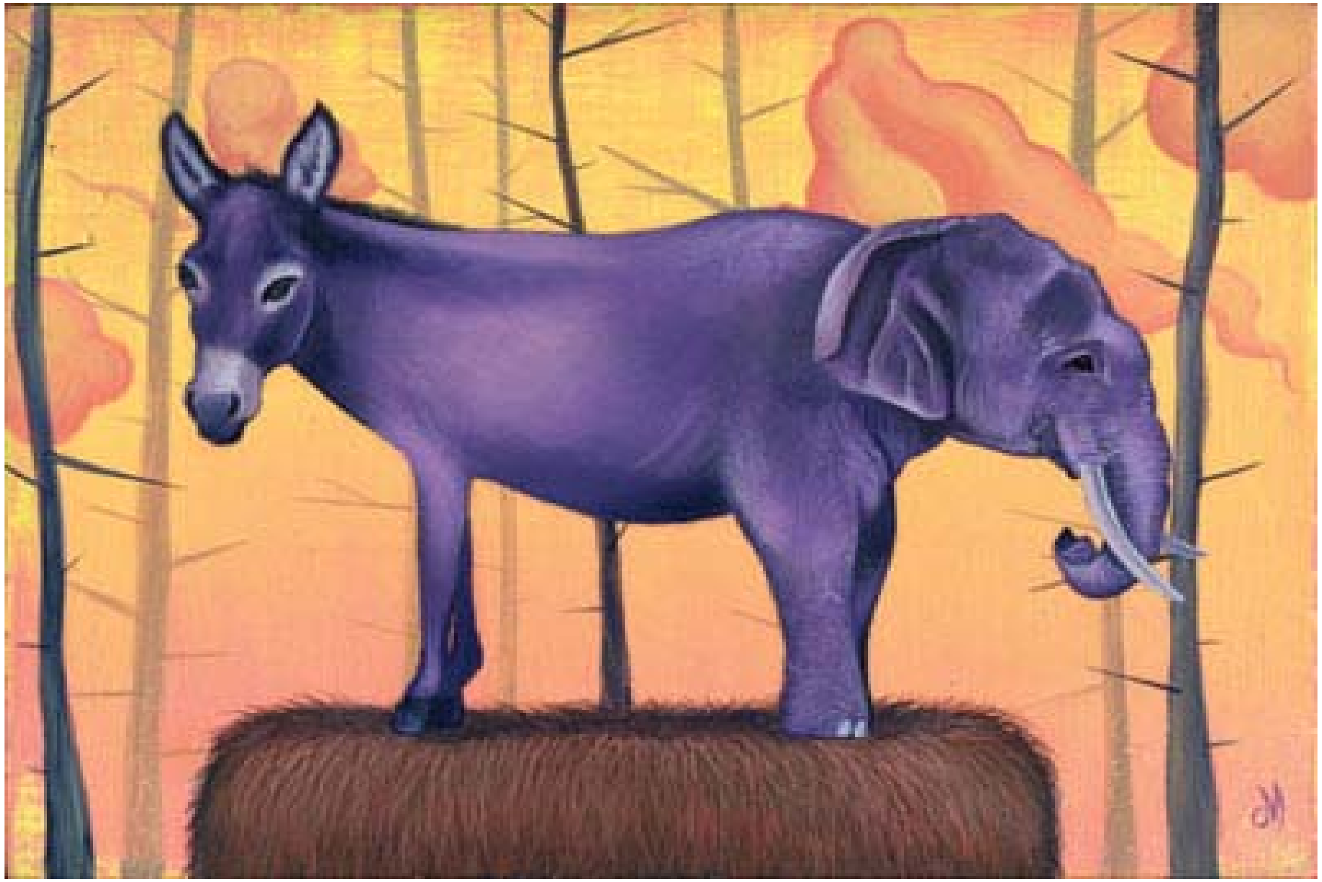
El Nino-La Nina

trend



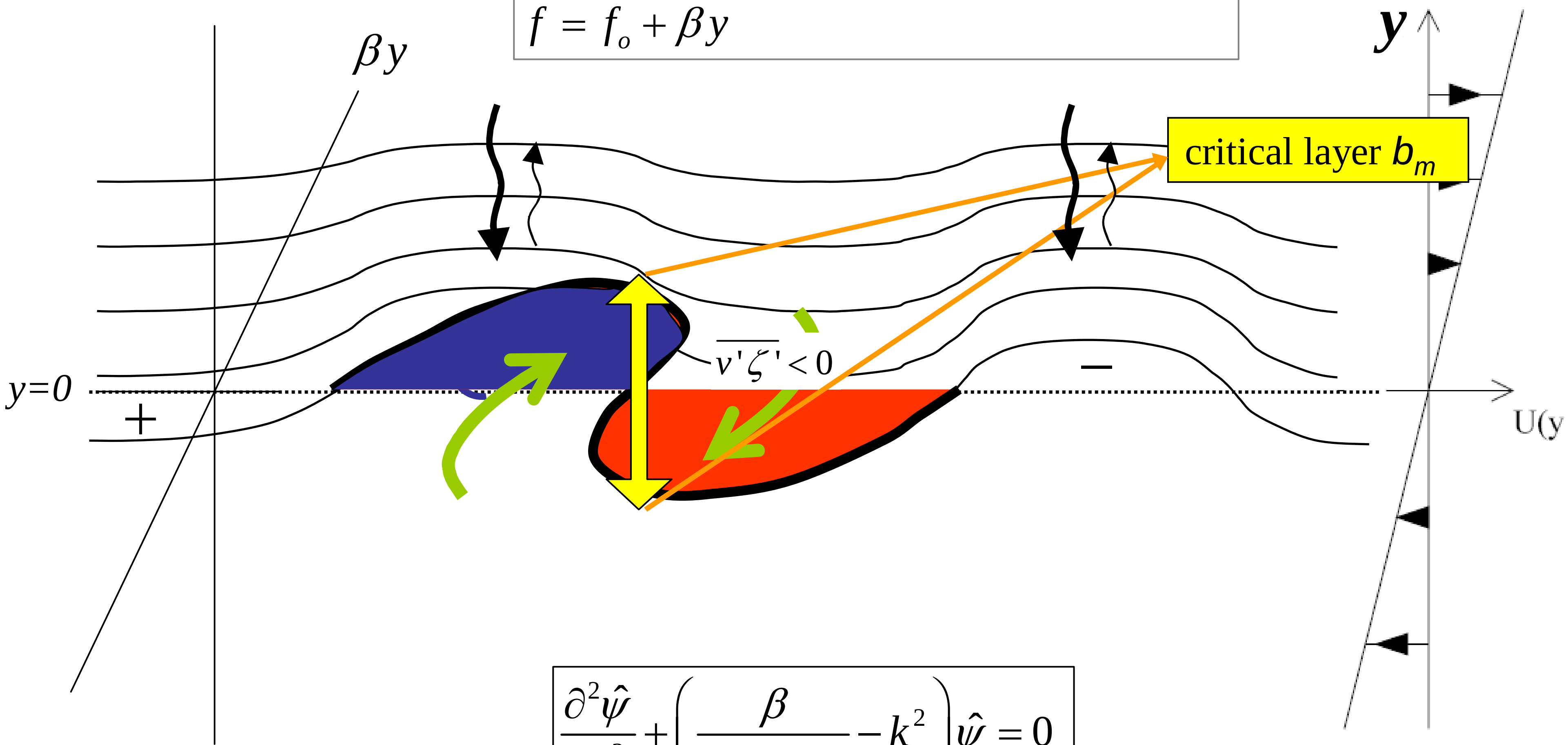


Critical latitude

$$dQ / dt = 0$$

$$\left(\frac{\partial}{\partial t} + (U(y) + u_g)\frac{\partial}{\partial x} + v_g \frac{\partial}{\partial y}\right)(\zeta + f) = 0$$

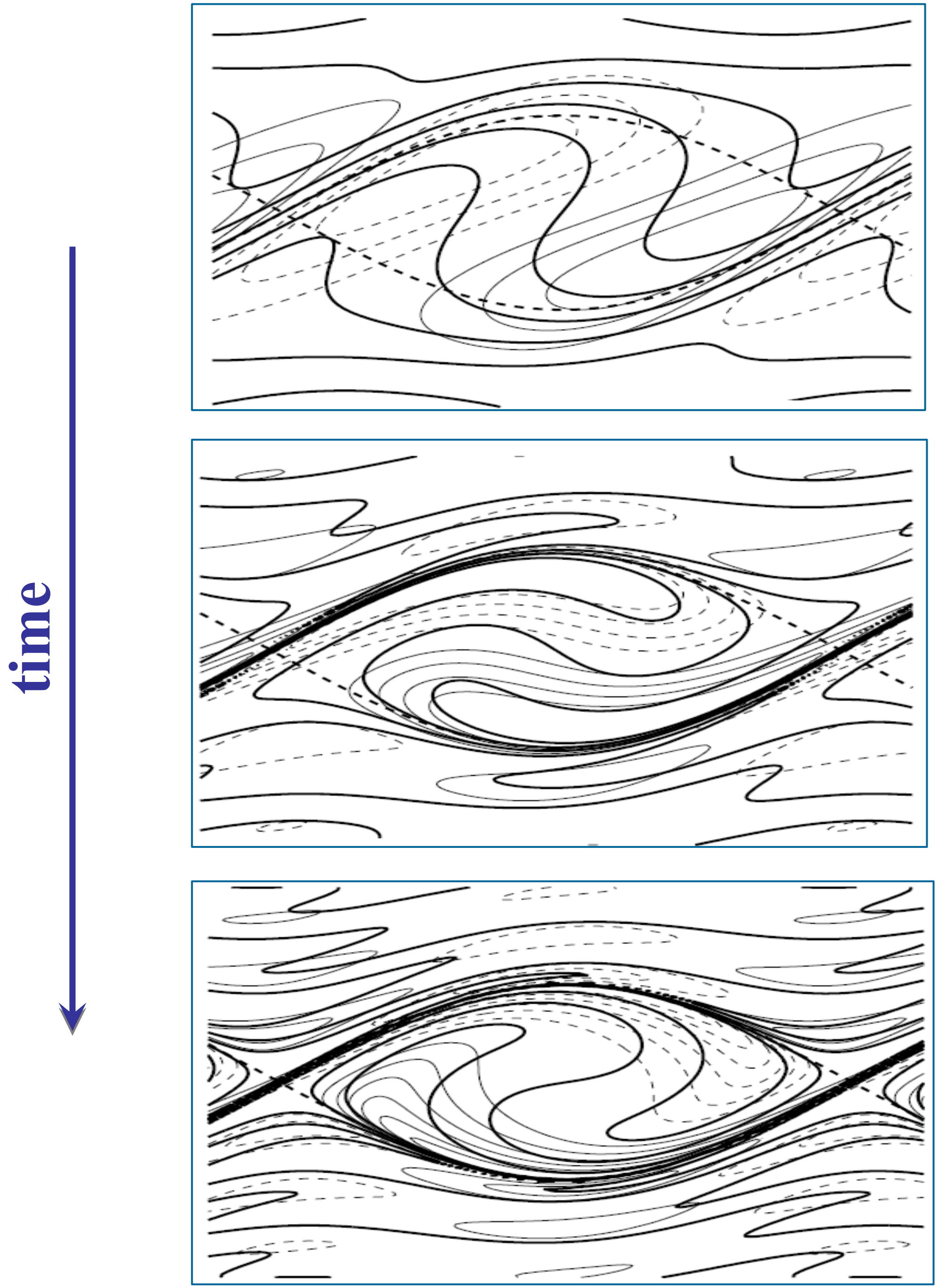
$$f = f_o + \beta y$$



Linearized:

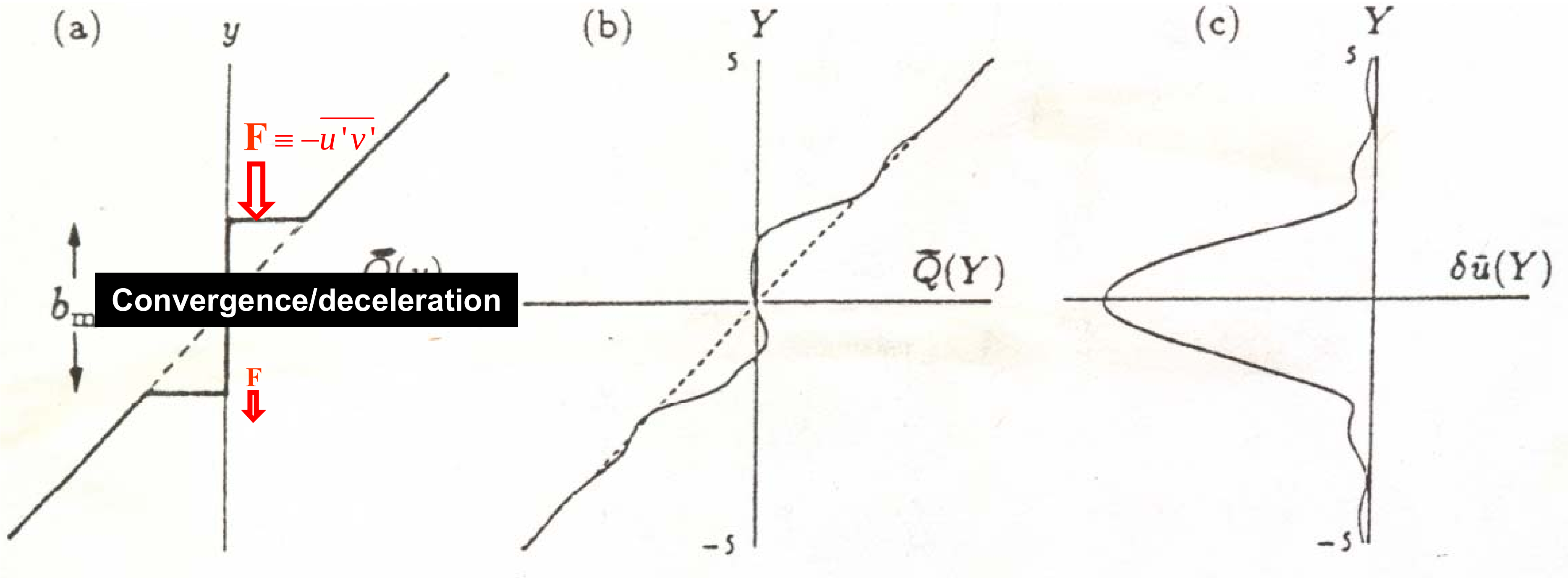
$$\frac{\partial^2 \hat{\psi}}{\partial y^2} + \left(\frac{\beta}{U(y) - c} - k^2\right)\hat{\psi} = 0$$

$$\psi'(x, y, t) = \mathrm{Re}\left[\hat{\psi}(y) e^{ik(x-ct)}\right]$$


time

Critical latitude

Impact on mean flow due to PV homogenization during wave breaking



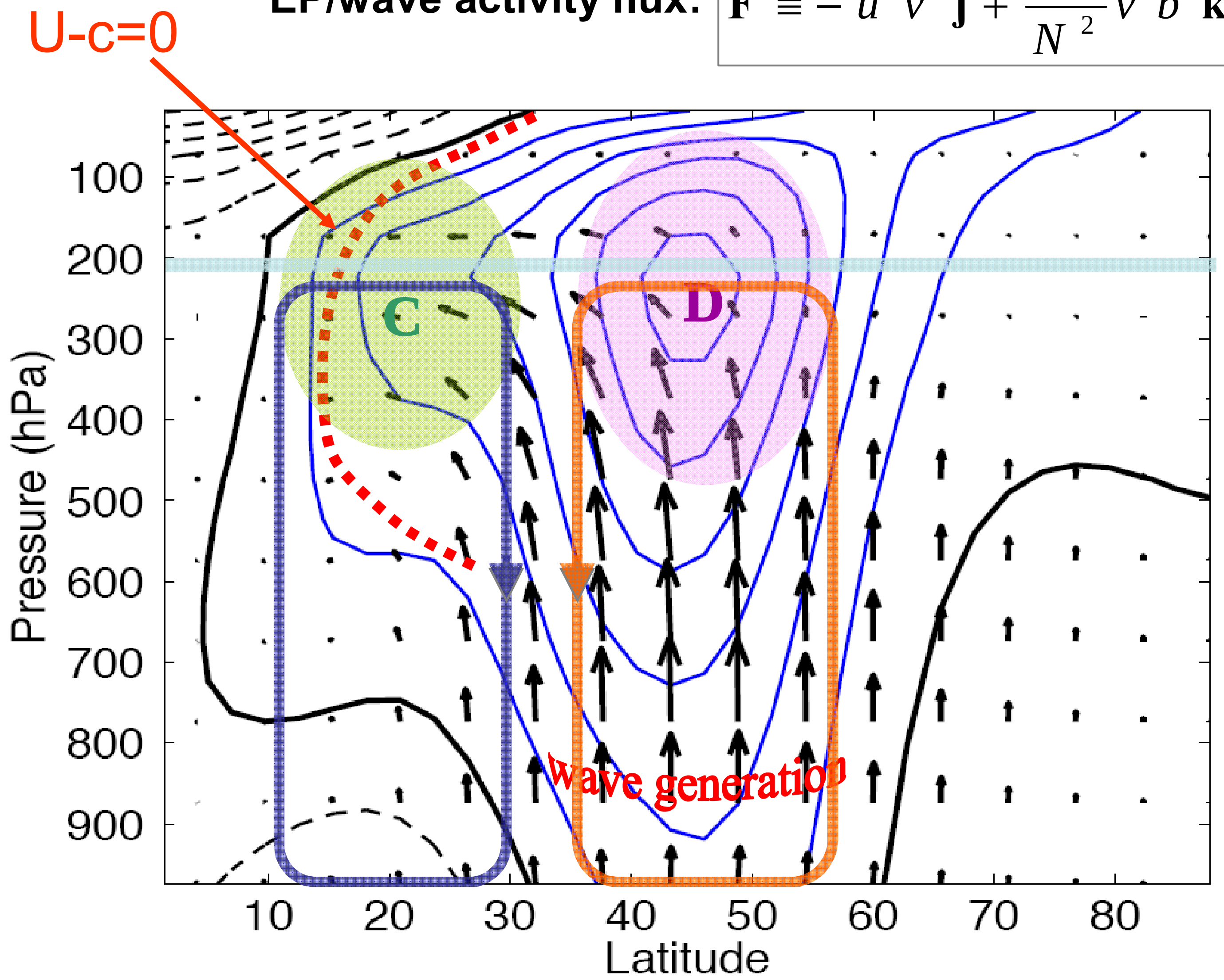
$$\delta\overline{u}(y) = -\int_{-\infty}^{y} \delta\overline{Q}dy = \begin{cases} \frac{1}{2}\beta(y^2 - \frac{1}{4}b_m{}^2) & (-\frac{1}{2}b_m < y < \frac{1}{2}b_m) \\ 0 & (y < -\frac{1}{2}b_m, y > \frac{1}{2}b_m) \end{cases}$$

Haynes, 2002; Haynes, 1989;
Stewartson, 1978; Warn & Warn, 1977;
Killworth and McIntyre, 1985

$$\frac{\partial \bar{u}}{\partial t} - f\bar{v}^* = \overline{v'q'} = \nabla_\chi \cdot \mathbf{F}$$

$$\frac{\partial A}{\partial t} + \nabla_\chi \cdot \mathbf{F} = D$$

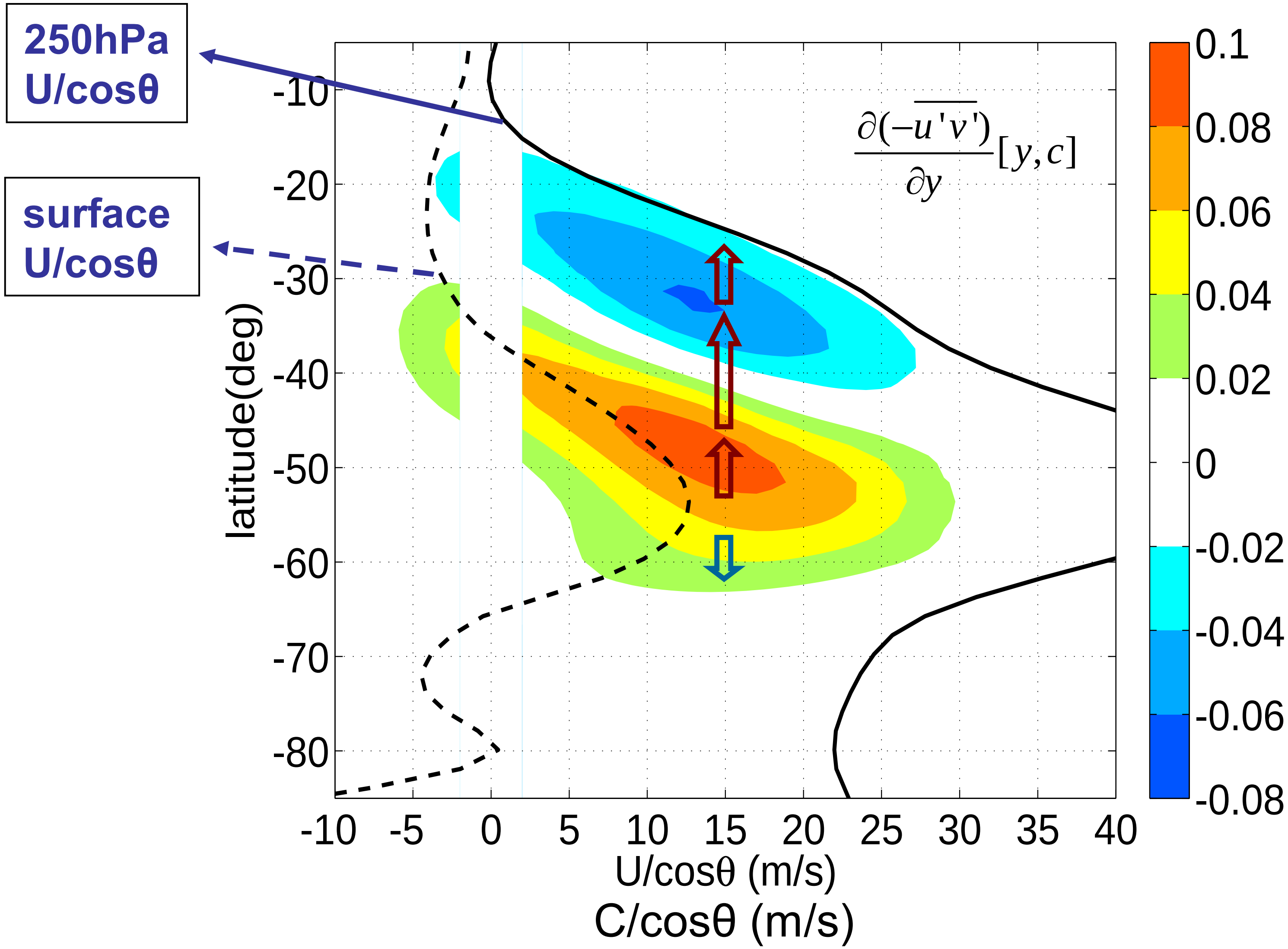
EP/wave activity flux: $\mathbf{F} \equiv -\overline{u'v'}\,\vec{\mathbf{j}} + \frac{f}{N^2}\overline{v'b'}\,\vec{\mathbf{k}}$



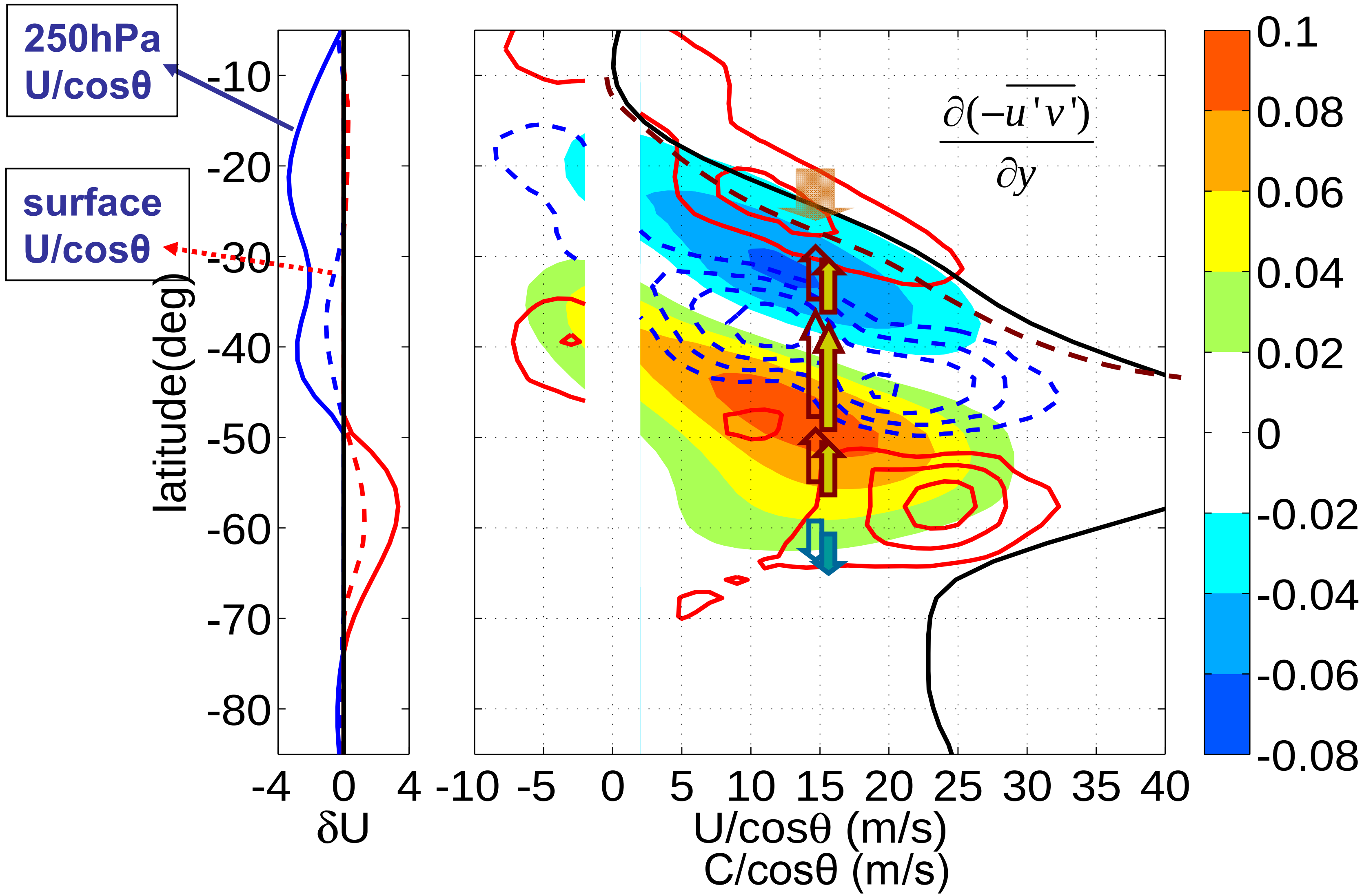
$$\int_{p_s}^{0} dp$$

$$\kappa \bar{u}_s \approx \int_{p_s}^{0} -\frac{\partial \overline{u'v'}}{\partial y}$$

Climatological mean spetra of eddy activity flux



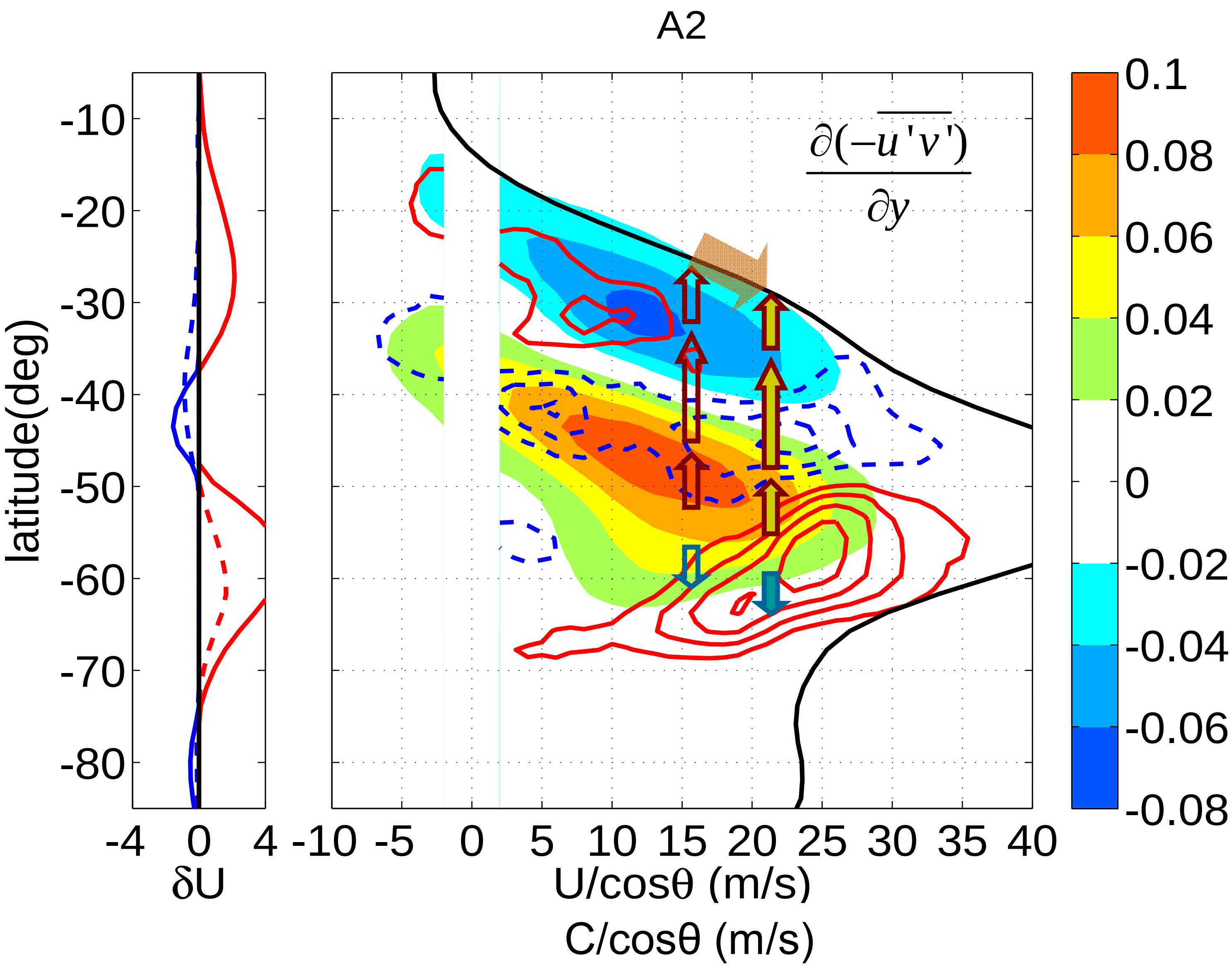
Mechanism of tropical forcing (DJFM, La Nina−El Nino)



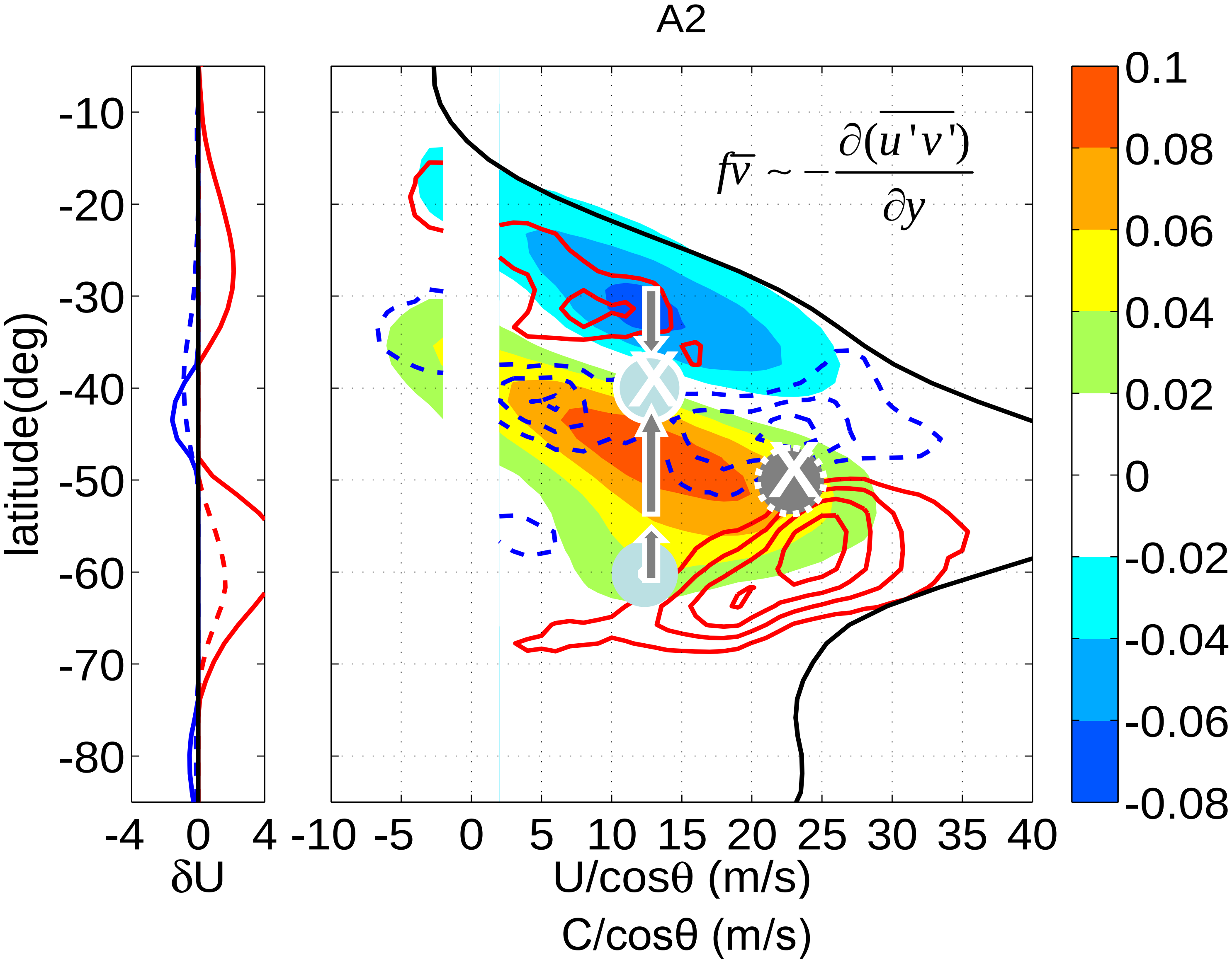
Contours: -∂(vu)/∂y trend; red: divergence; blue:convergence

Solid black lines: U(250hPa) climatology (black)

Response to GHG warming (DJFM)



Response to GHG warming (DJFM)



Summary

- The response of the zonal mean atmospheric circulation to global warming differs dramatically from that forced by El Nino.

- Comparing the eddy-mean flow interaction near the subtropical ciritical latitudes between El Nino and global warming implies that the jet shift and expansion of the Hadley Cell in the latter case may have an extratropical origin;

- The same eddy activity flux forcing, owing to the phase speed change, is accountable for both the shift of the jet and the expansion of the Hadley cell under global warming (at least for DJF).

- Why waves speed increases?
  - Doppler-effect
  - Elasticity