Single to Double-ITCZ transitions

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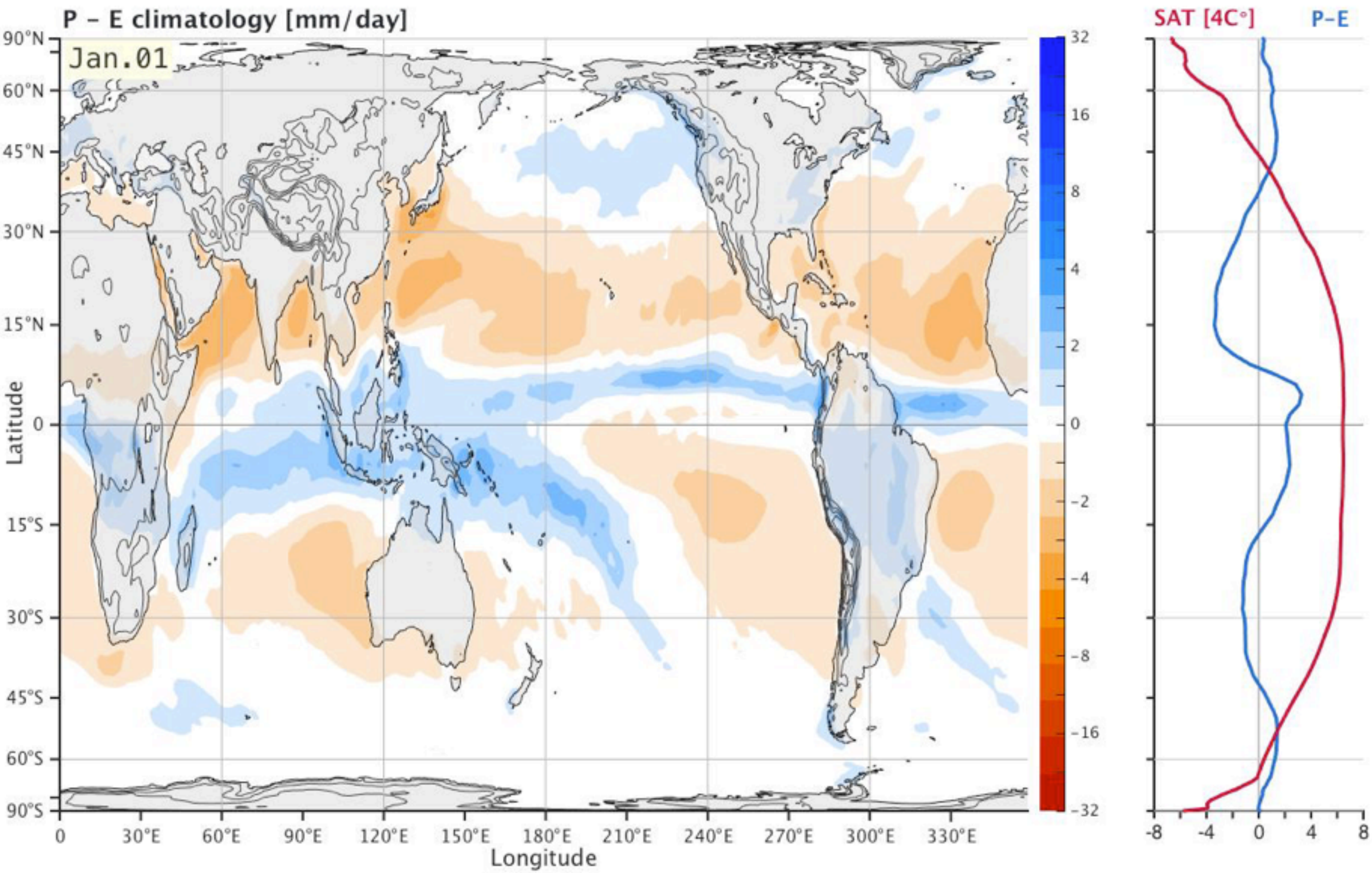
Simona Bordoni (Caltech), Ori Adam (ETH)

Les Houches, 2015

Motivation - Reanalysis Data



Video by Ori Adam

Motivation - Reanalysis Data

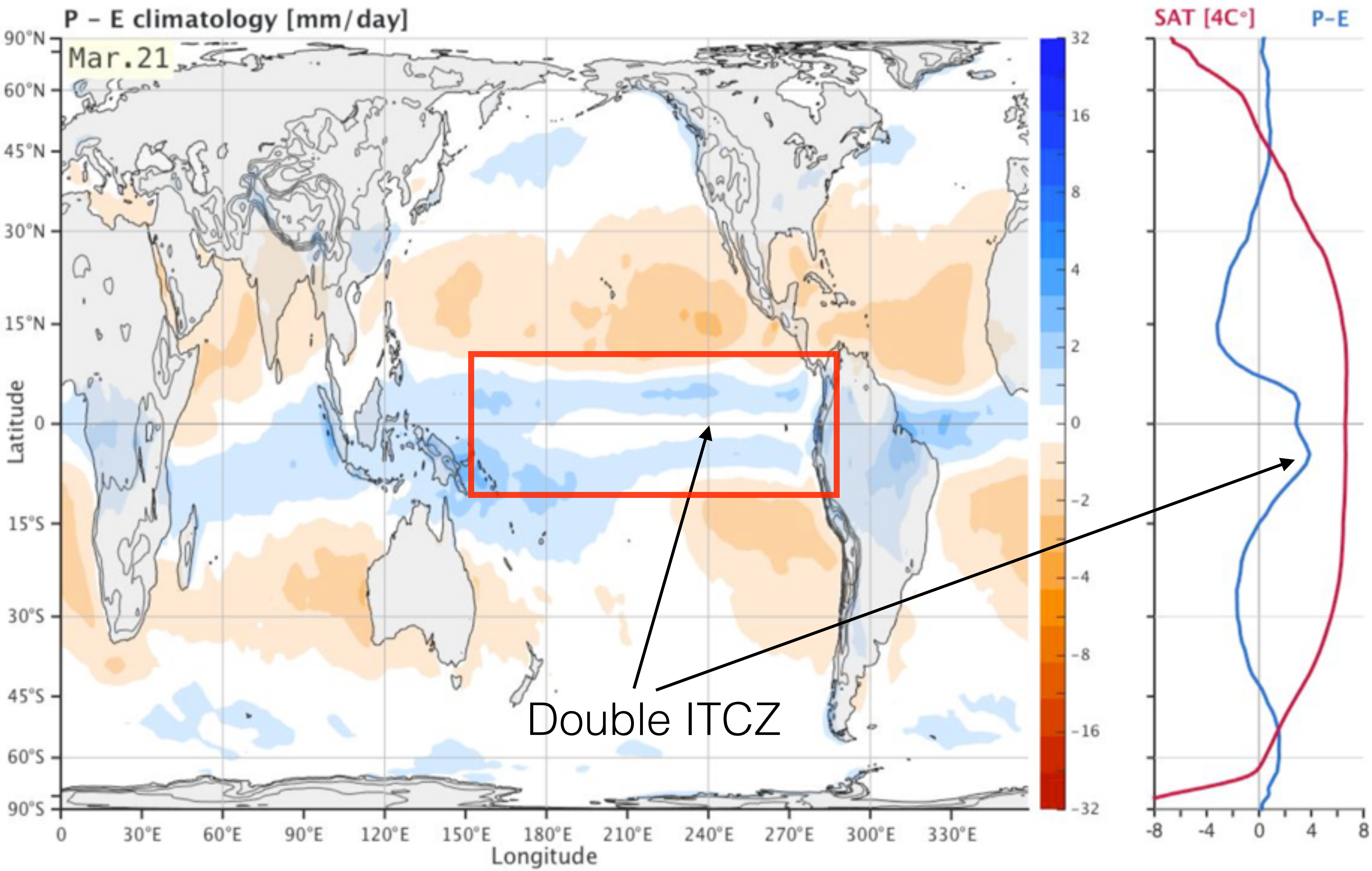


Figure by Ori Adam

Motivation - Reanalysis Data

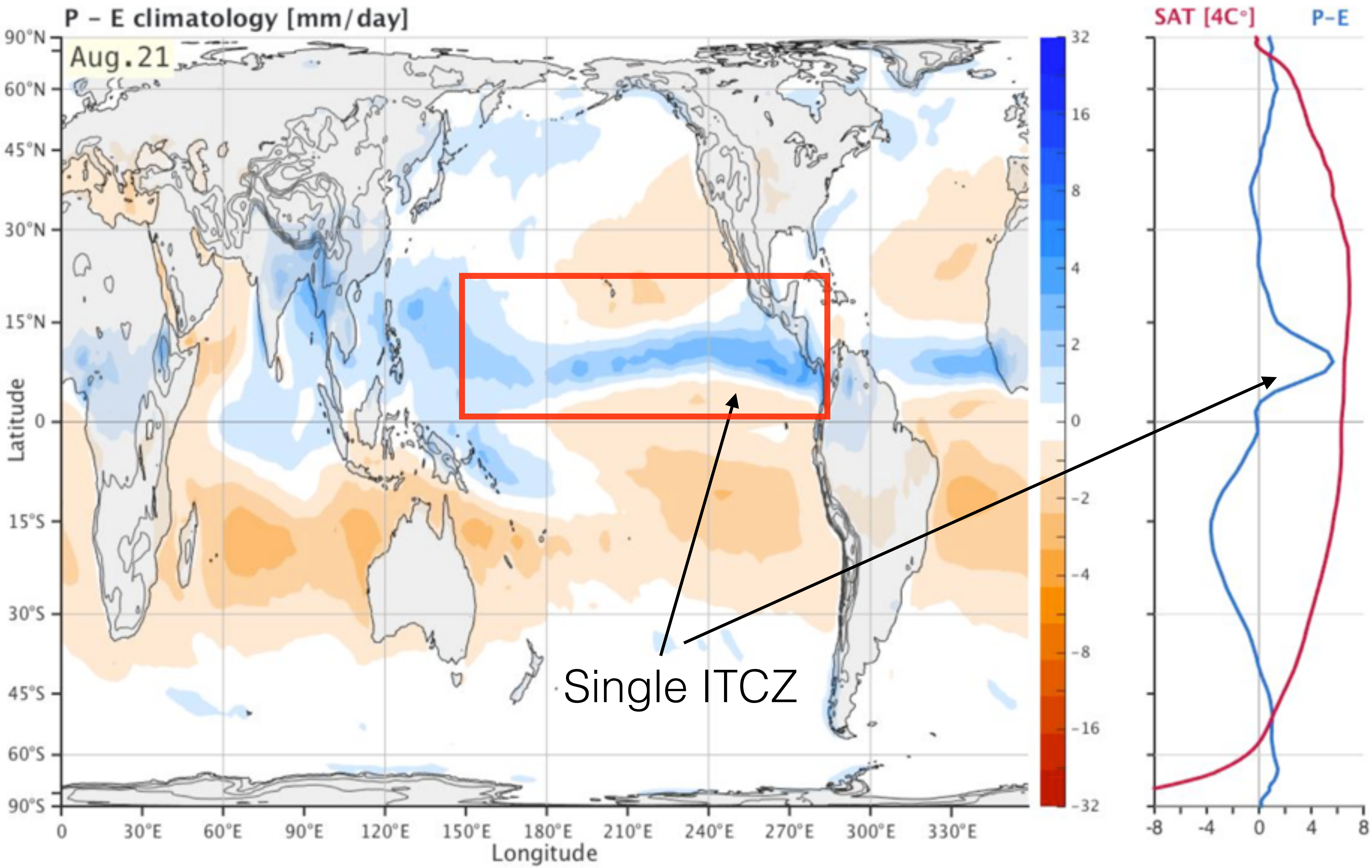
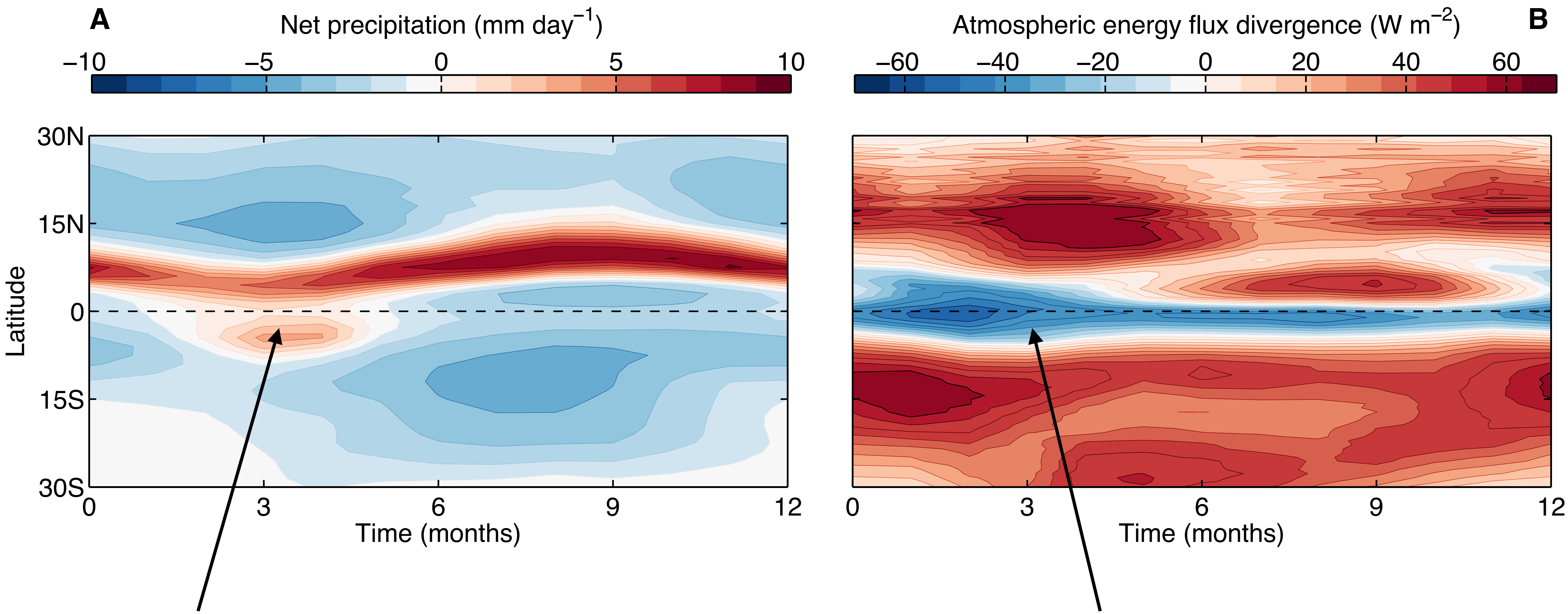


Figure by Ori Adam

Motivation - Reanalysis Data, 200-260E

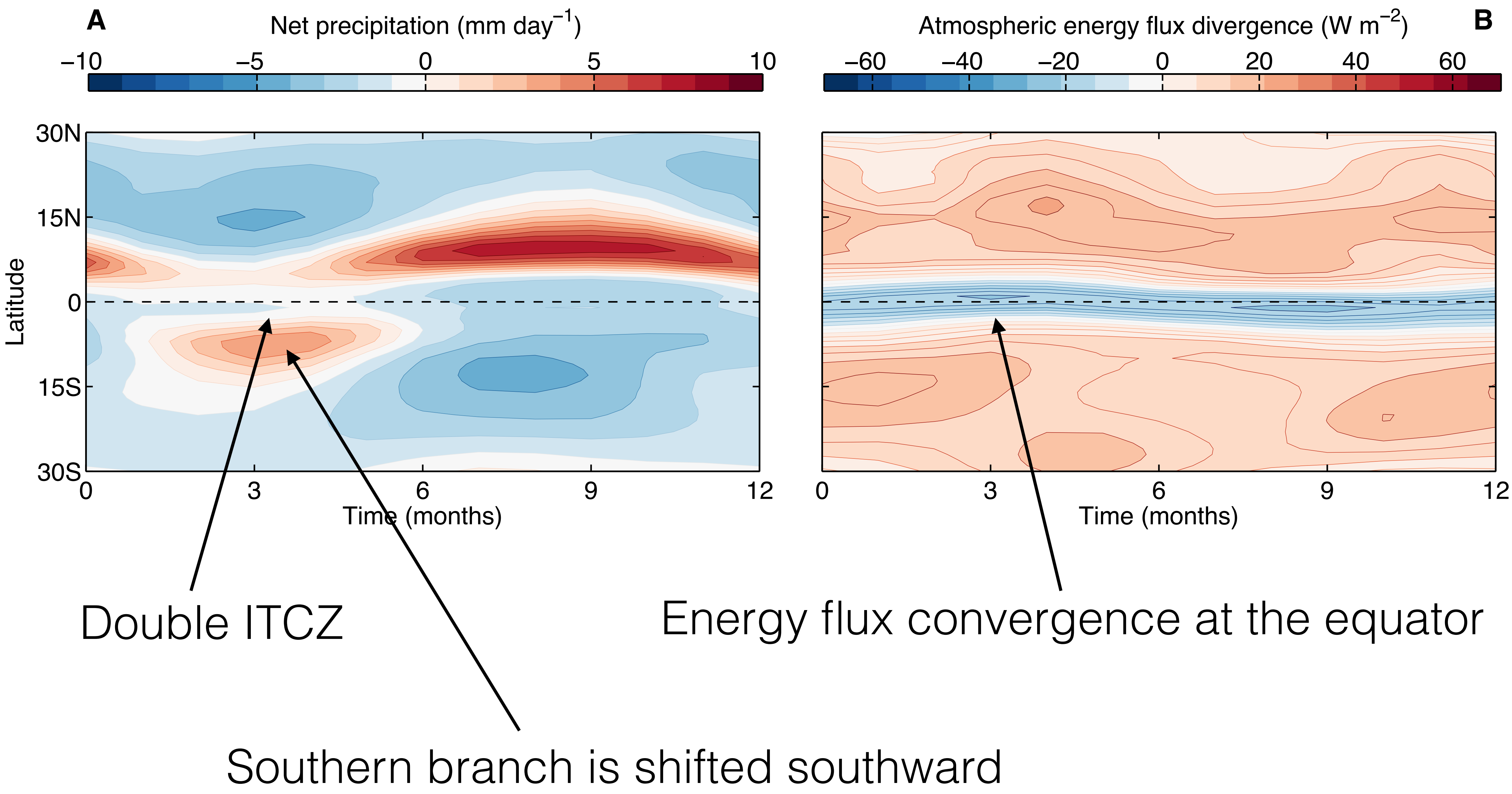


Double ITCZ

Energy flux convergence at the equator!

Source: NCAR ERA-I

Motivation - CMIP5, 200-260E



Motivation - What do we know?

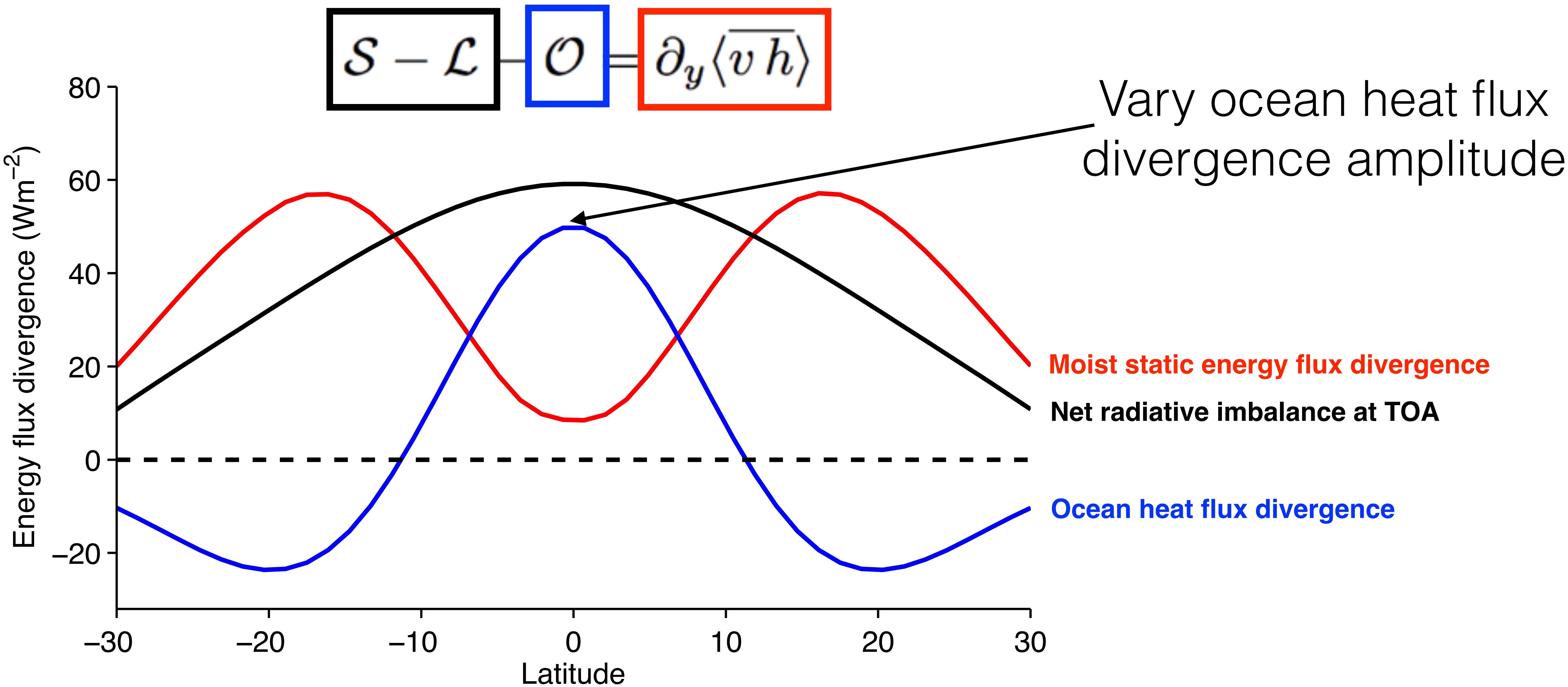
- ITCZ tends to shift to hemisphere with more heating, causing asymmetries in precipitation (e.g., Chiang & Bitz '05, Kang '08/'09)
- Double-ITCZ bias related to Southern Ocean cloud biases, tropical SST biases, etc. (e.g., Lin' 07, Hwang and Frierson '13)
- Net precipitation follows moist static energy flux divergence (Neelin and Held '87)

Motivation - What we want to understand

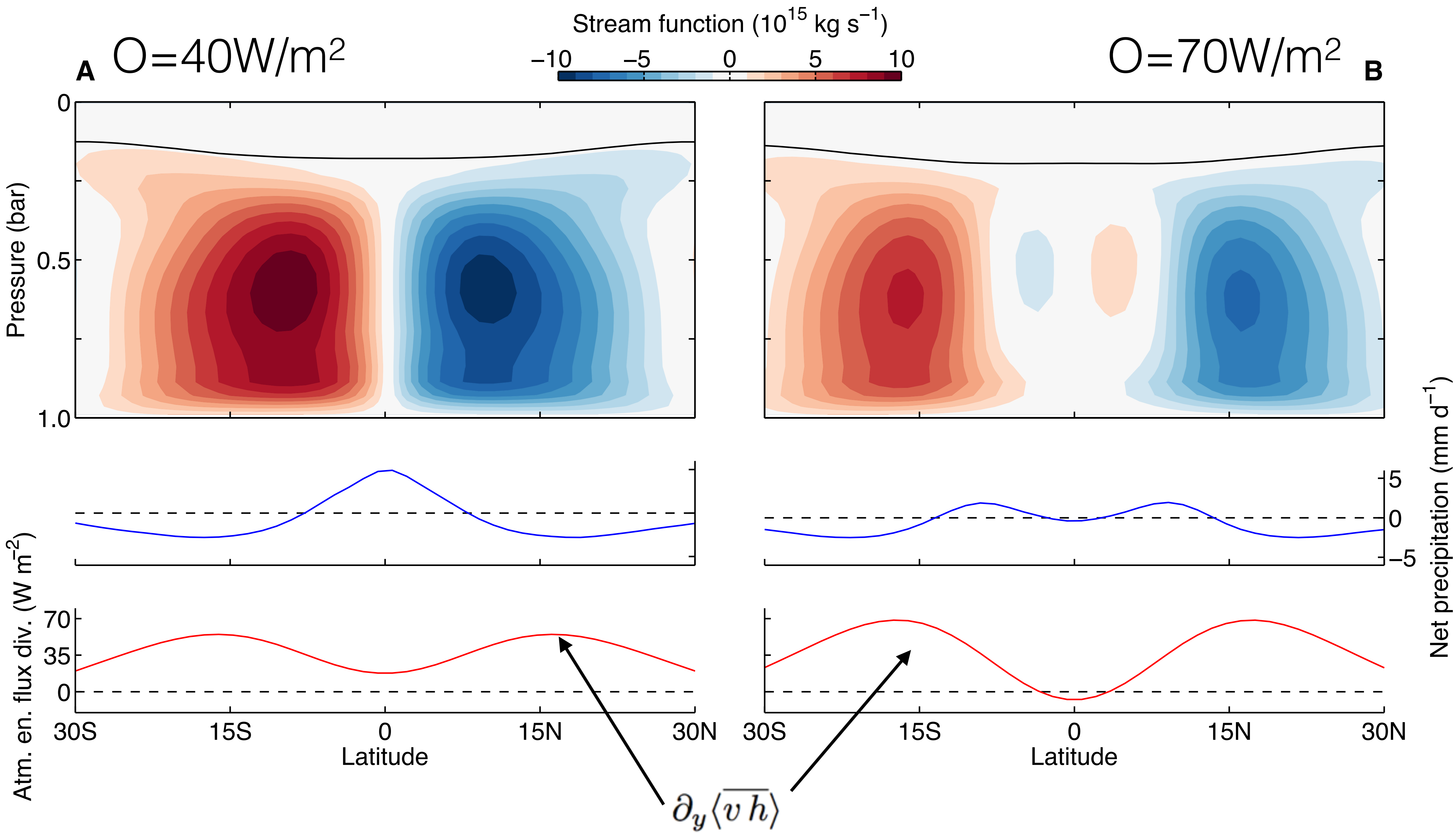
- Under what circumstances do double-ITCZs form?
- Where are the double-ITCZ branches located?
- (What are the implications for climate models?)

Simulations

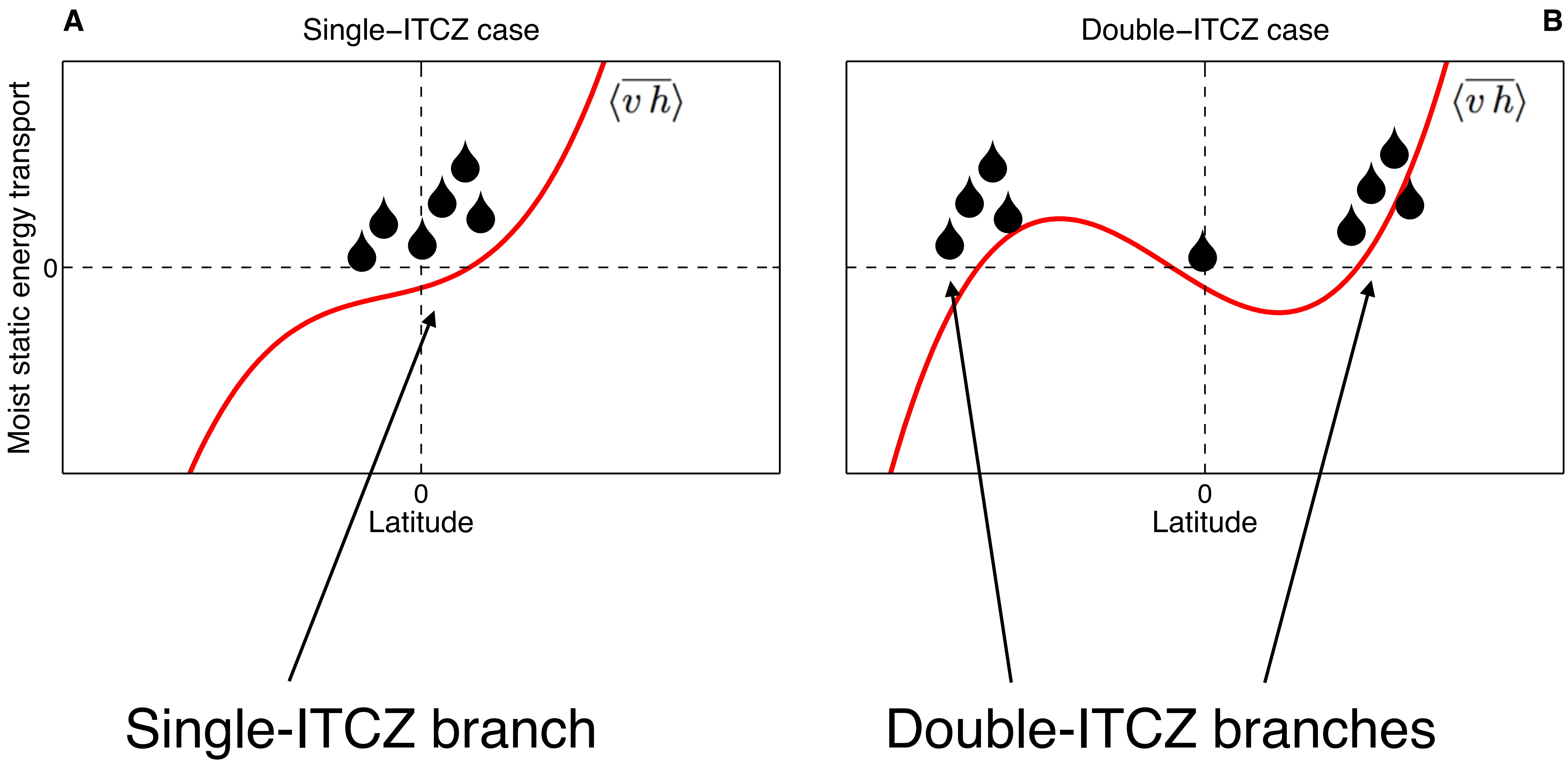
- Aqua-planet with **fixed prescribed ocean heat flux divergence**
- Earth-like configuration, no seasonal cycle (later)
- No clouds, aerosols, etc.



Simulations - Two Examples



ITCZ Location



—> Energy Flux Equator

ITCZ Location

$$\partial_y \langle \overline{v\,h} \rangle = \mathcal{S} - \mathcal{L} - \mathcal{O}$$

Energy Budget

$$\langle \overline{v\,h} \rangle_\delta \approx \langle \overline{v\,h} \rangle_0 + a\partial_y \langle \overline{v\,h} \rangle_0 \, \delta + \frac{1}{2} a^2 \partial_{yy} \langle \overline{v\,h} \rangle_0 \, \delta^2 + \frac{1}{6} a^3 \partial_{yyy} \langle \overline{v\,h} \rangle_0 \, \delta^3,$$

Taylor Expansion

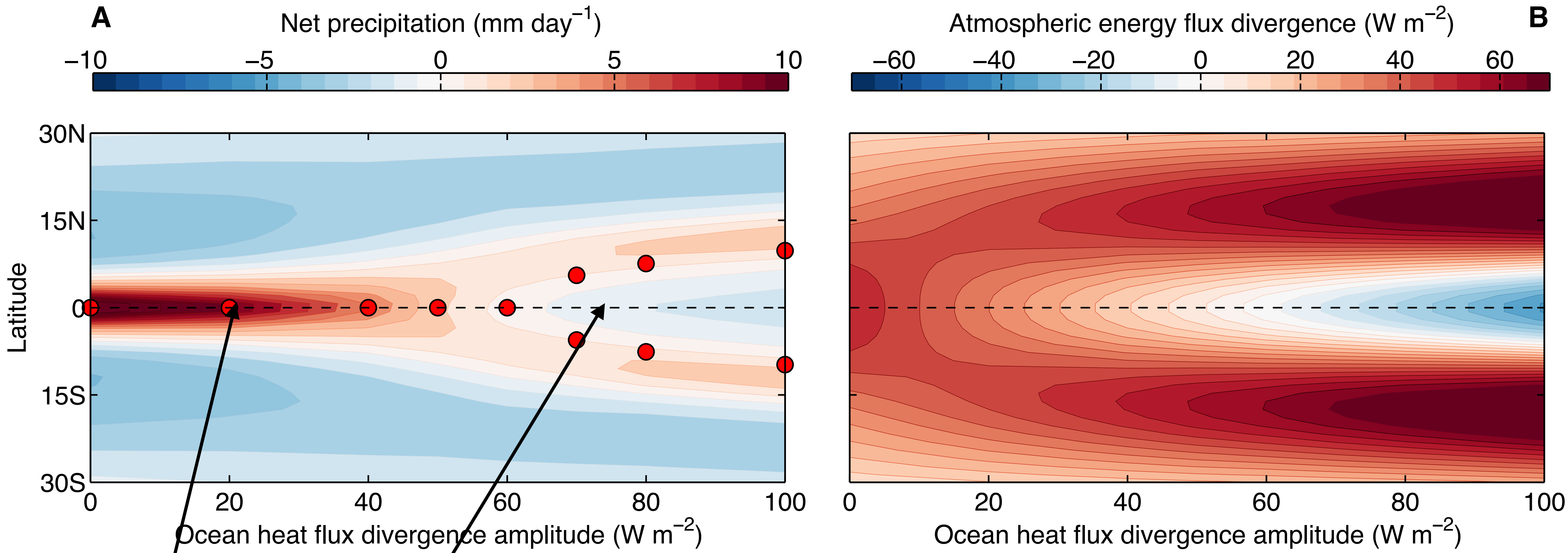
$$0 \approx a\partial_y \langle \overline{v\,h} \rangle_0 \, \delta + \frac{1}{6} a^3 \partial_{yyy} \langle \overline{v\,h} \rangle_0 \, \delta^3 = \left(a\partial_y \langle \overline{v\,h} \rangle_0 + \frac{1}{6} a^3 \partial_{yyy} \langle \overline{v\,h} \rangle_0 \, \delta^2 \right) \delta.$$

$$\delta_{1,2} \approx \pm \frac{\sqrt{6}}{a} \sqrt{- \frac{[\mathcal{S} - \mathcal{L} - \mathcal{O}]_0}{\partial_{yy} [\mathcal{S} - \mathcal{L} - \mathcal{O}]_0}}$$

$$\delta_3 = 0.$$

v: mrdnl velocity, h: MSE, a: radius

Simulations - Wide Range of Climates

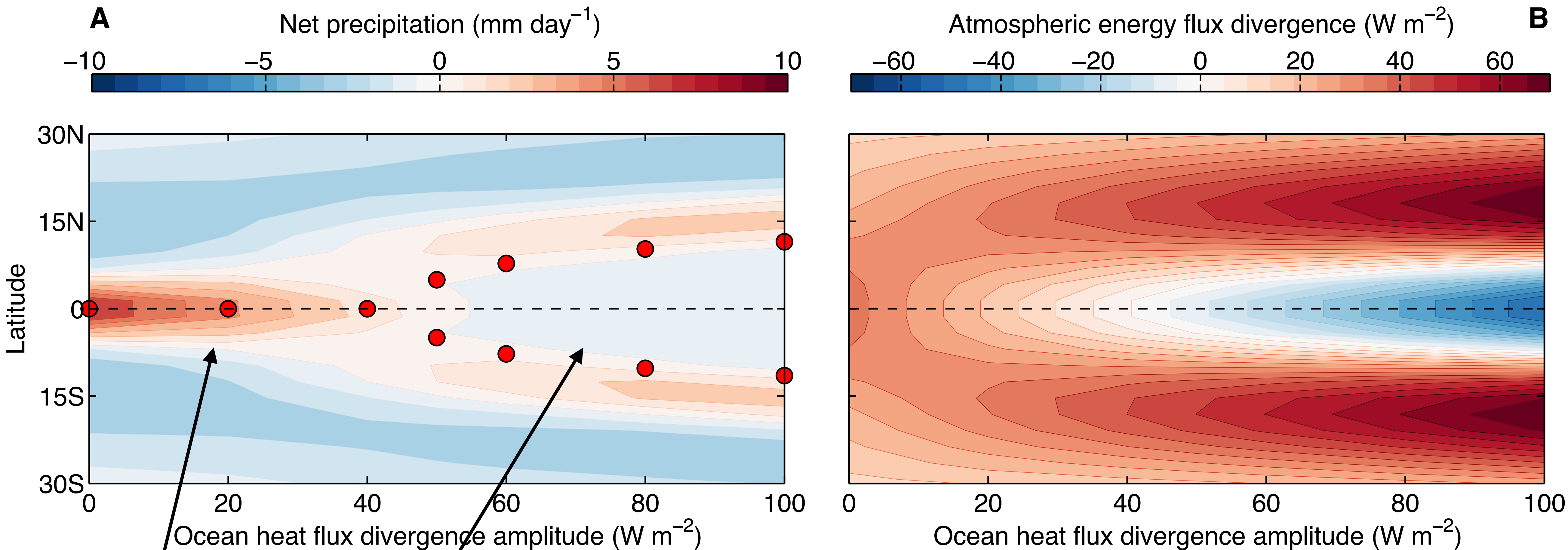


$$\delta = 0$$

$$\delta = \pm\sqrt{-6\frac{\mathcal{S}_0 - \mathcal{L}_0 - \mathcal{O}_0}{\partial_{yy}\left(\mathcal{S} - \mathcal{L} - \mathcal{O}\right)_0}}$$

Single-to double-ITCZ transition at O=50–60 W/m

Simulations - Seasonal Cycle



$$\delta = 0$$

$$\delta = \pm\sqrt{-6\frac{\mathcal{S}_0 - \mathcal{L}_0 - \mathcal{O}_0}{\partial_{yy}\left(\mathcal{S} - \mathcal{L} - \mathcal{O}\right)_0}}$$

Single-to double-ITCZ
transition at O=50–60 W/m

Summary & Conclusions

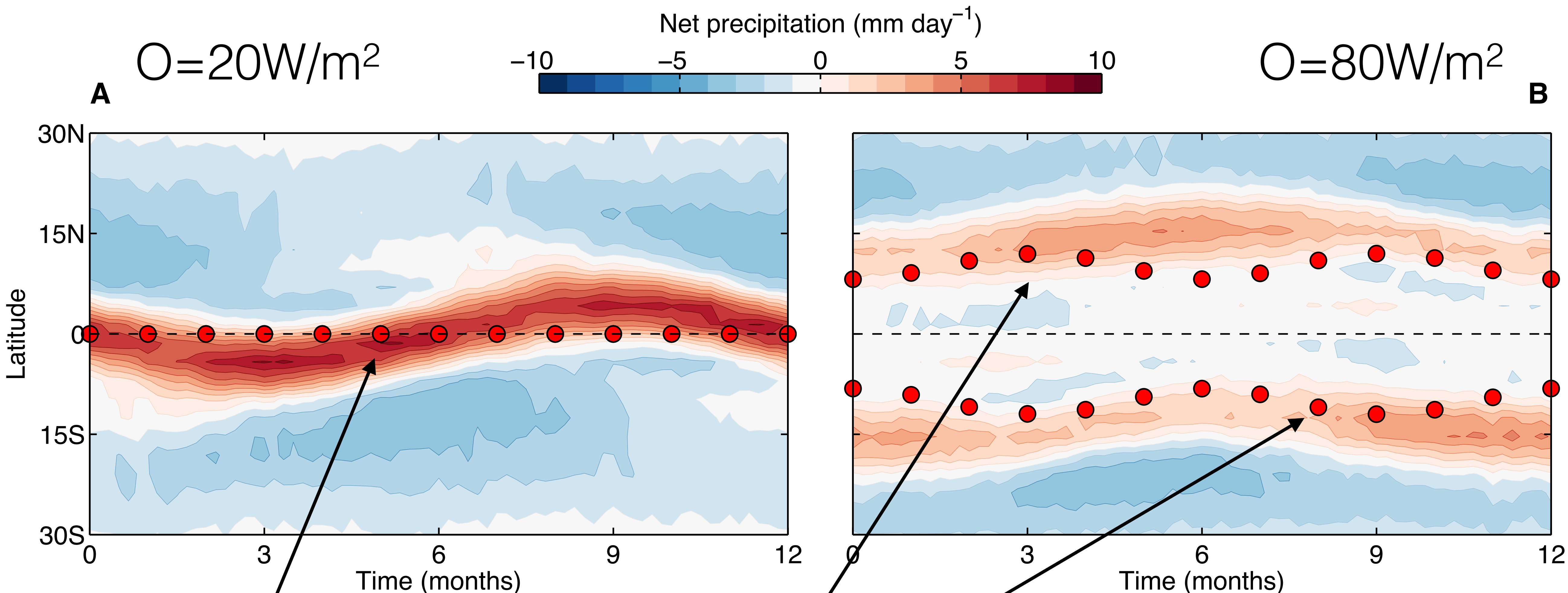
- Double-ITCZs form when the top-of-atmosphere energy budget becomes small at the equator

- The location of the double-ITCZ branches is determined by the top-of-atmosphere energy budget and its curvature at the equator

- Biases in the tropical energy budget (clouds, SSTs) can impact the location of double-ITCZ branches

Thanks for your attention.
Questions?

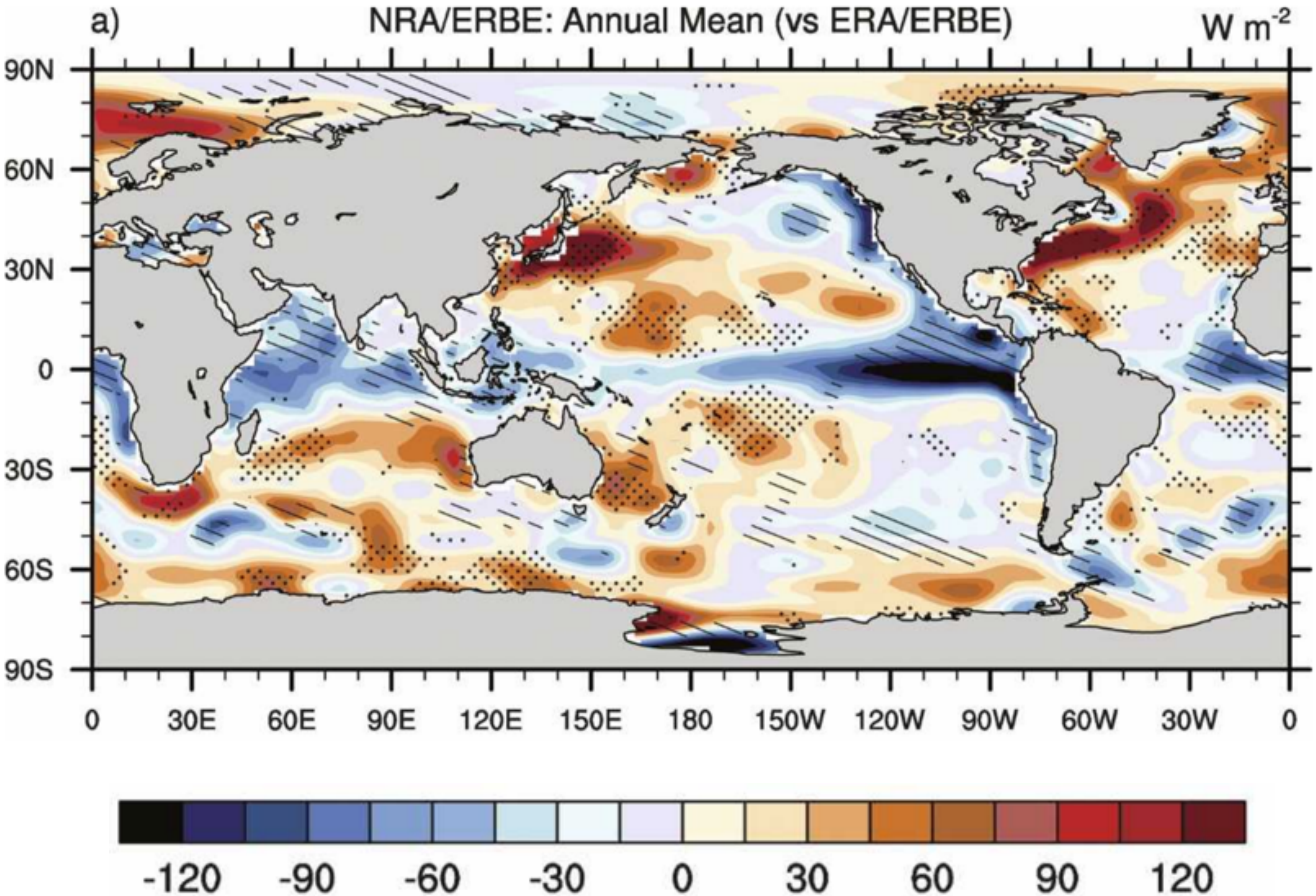
Simulations - Seasonal Cycle



$$\delta = 0$$

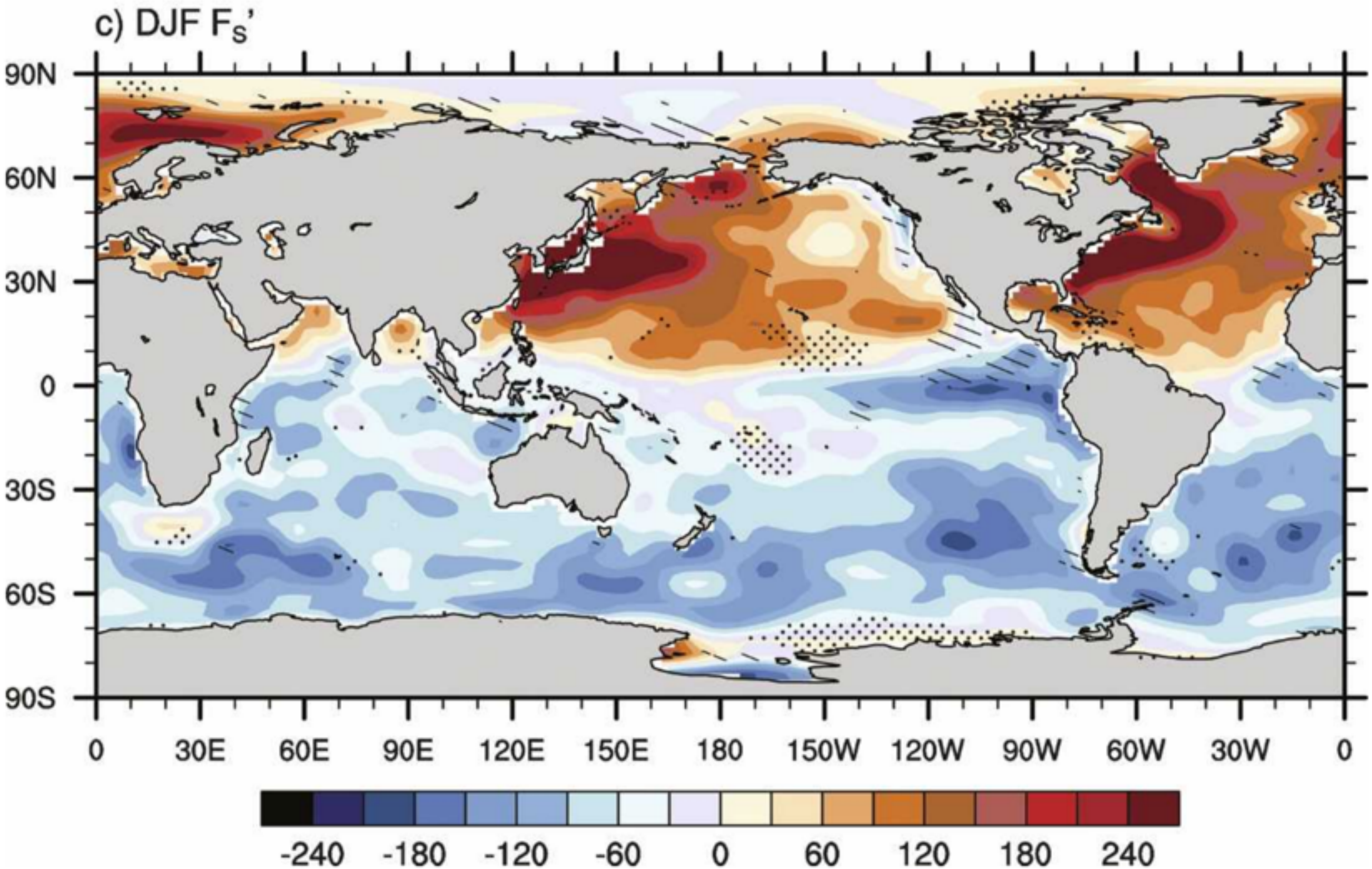
$$\delta = \pm\sqrt{-6\frac{\mathcal{S}_0 - \mathcal{L}_0 - \mathcal{O}_0}{\partial_{yy}\left(\mathcal{S} - \mathcal{L} - \mathcal{O}\right)_0}}$$

Motivation - Reanalysis Data



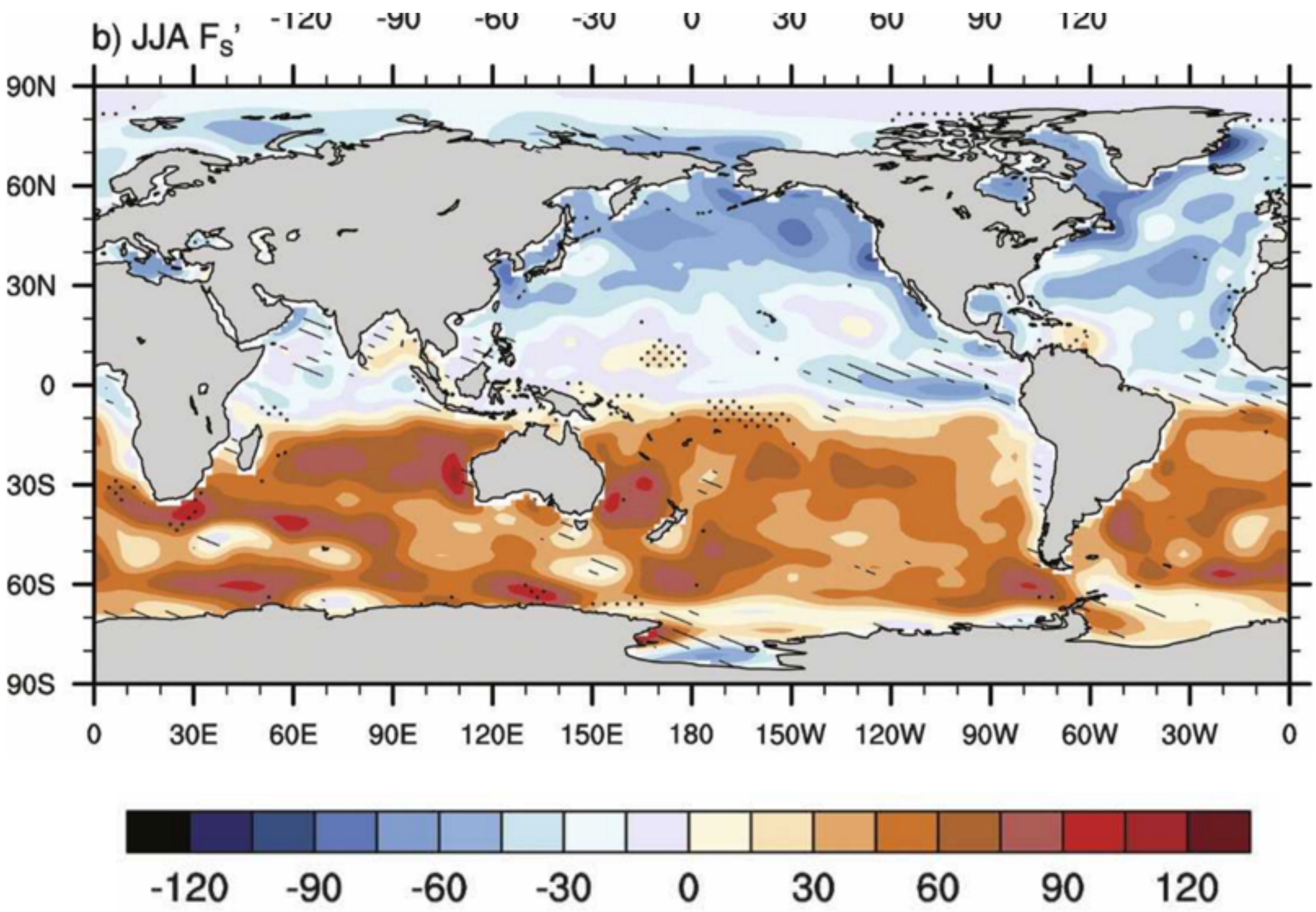
Trenberth & Fasullo '07

Reanalysis Data



Trenberth & Fasullo '07

Reanalysis Data



Trenberth & Fasullo '07