Influence of the Atlantic Warm Pool on the Southeast Pacific

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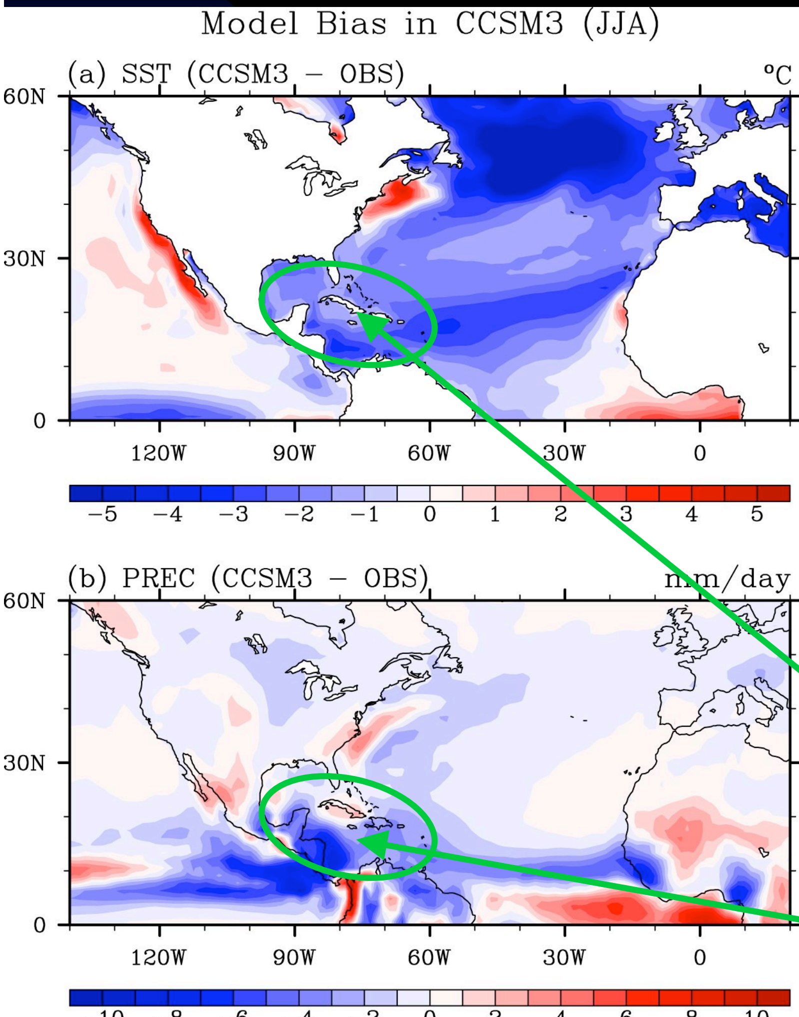
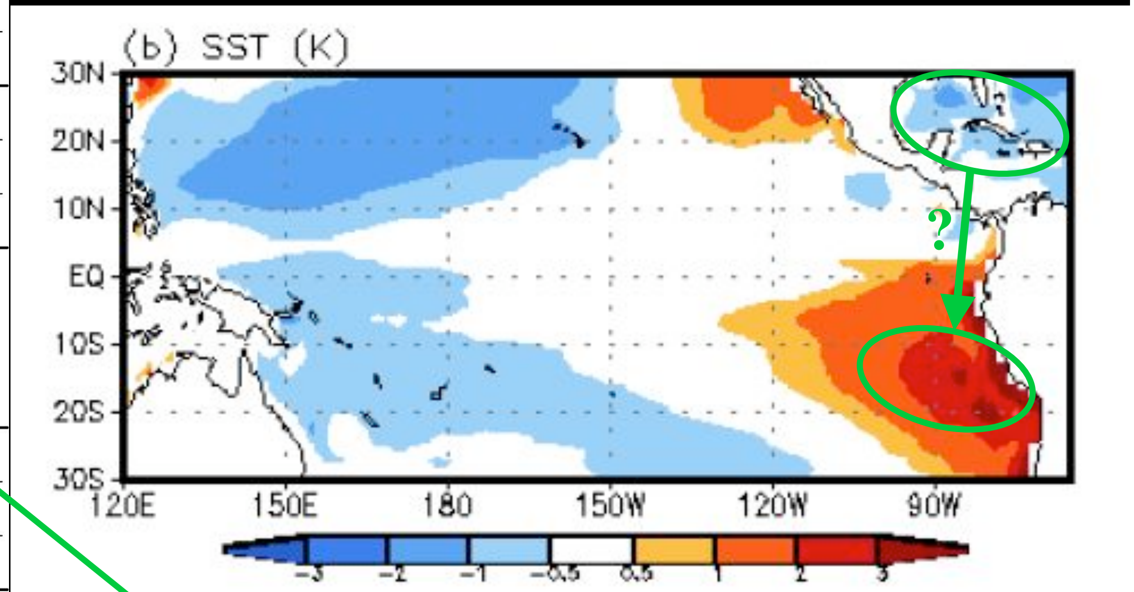
Motivation: Is it possible for model bias in the AWP to affect model error over the S. E. Pacific?



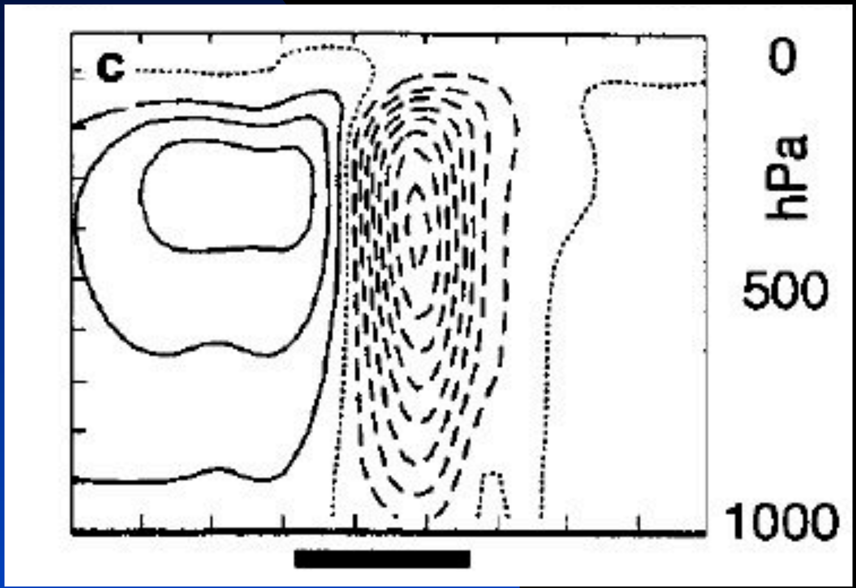
CFS Model Bias



Atlantic warm pool (AWP)

Motivation: What Maintains the Subsidence over SE Pacific?

Vertical Pressure Velocity



S. E. Pacific S. A. Heating S. Atlantic

From Rodwell and Hoskins (2001, *JC*)

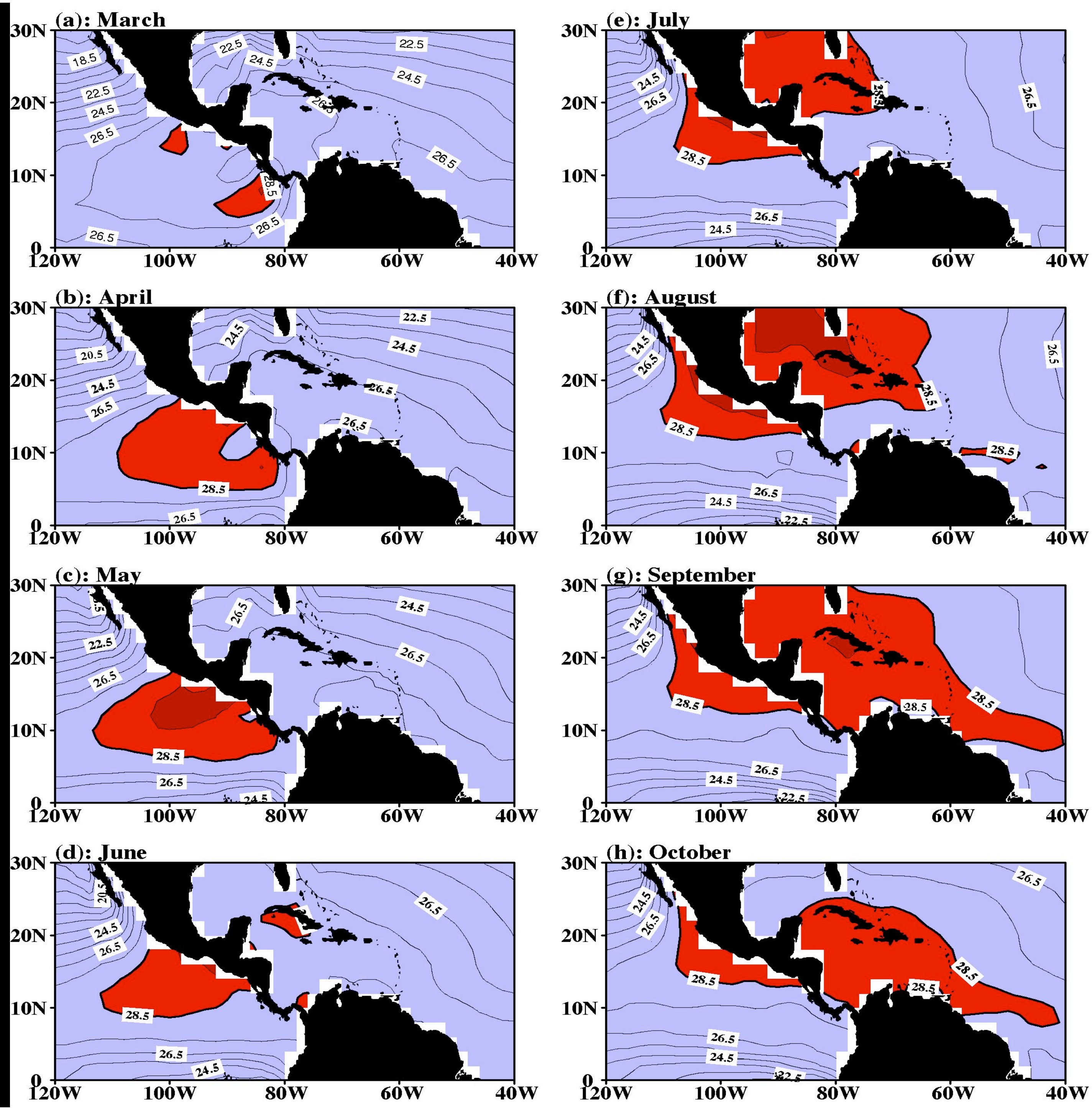
- Rodwell & Hoskins (2001) show that the subsidence over SE Pacific is maintained by continental heating over South America in austral summer.
- During austral winter (boreal summer), when convective activity over South America is weaker, what sustains the subsidence over SE Pacific?

Outline

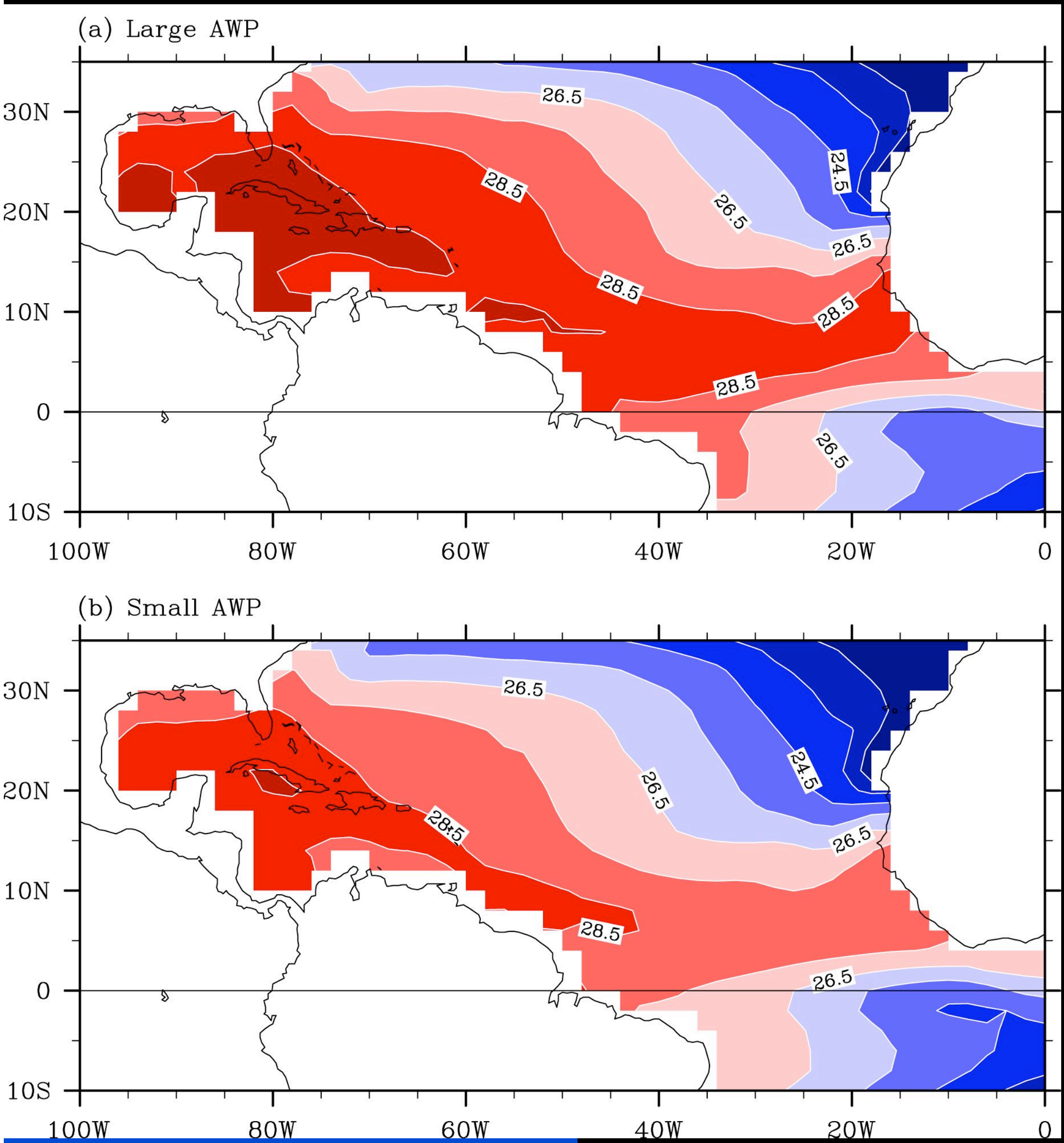
- Observations of the Atlantic warm pool (AWP) and its influence on the SE Pacific.
- Results from an atmospheric general circulation model (CAM3).
- Results from a simple linearized atmospheric model.
- Summary.

Wang & Enfield (2001, GRL) named the Western Hemisphere warm pool (WHWP)

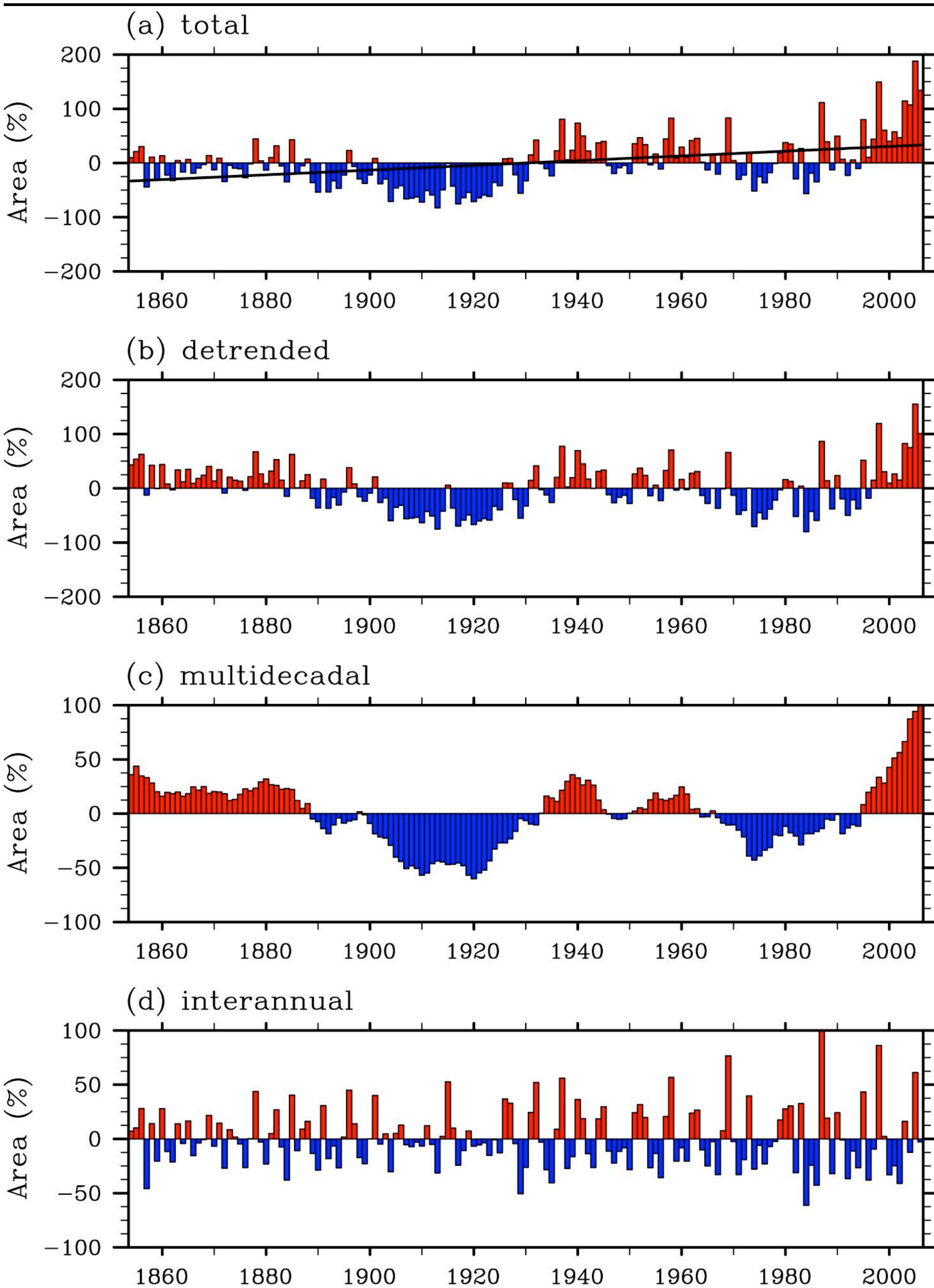
SST ≥ 28.5°C



Composite of the Atlantic Warm Pool (AWP)



- ERSST from 1854-2006.
- AWP variability is large.
- Large AWPs are almost three times larger than the small ones.

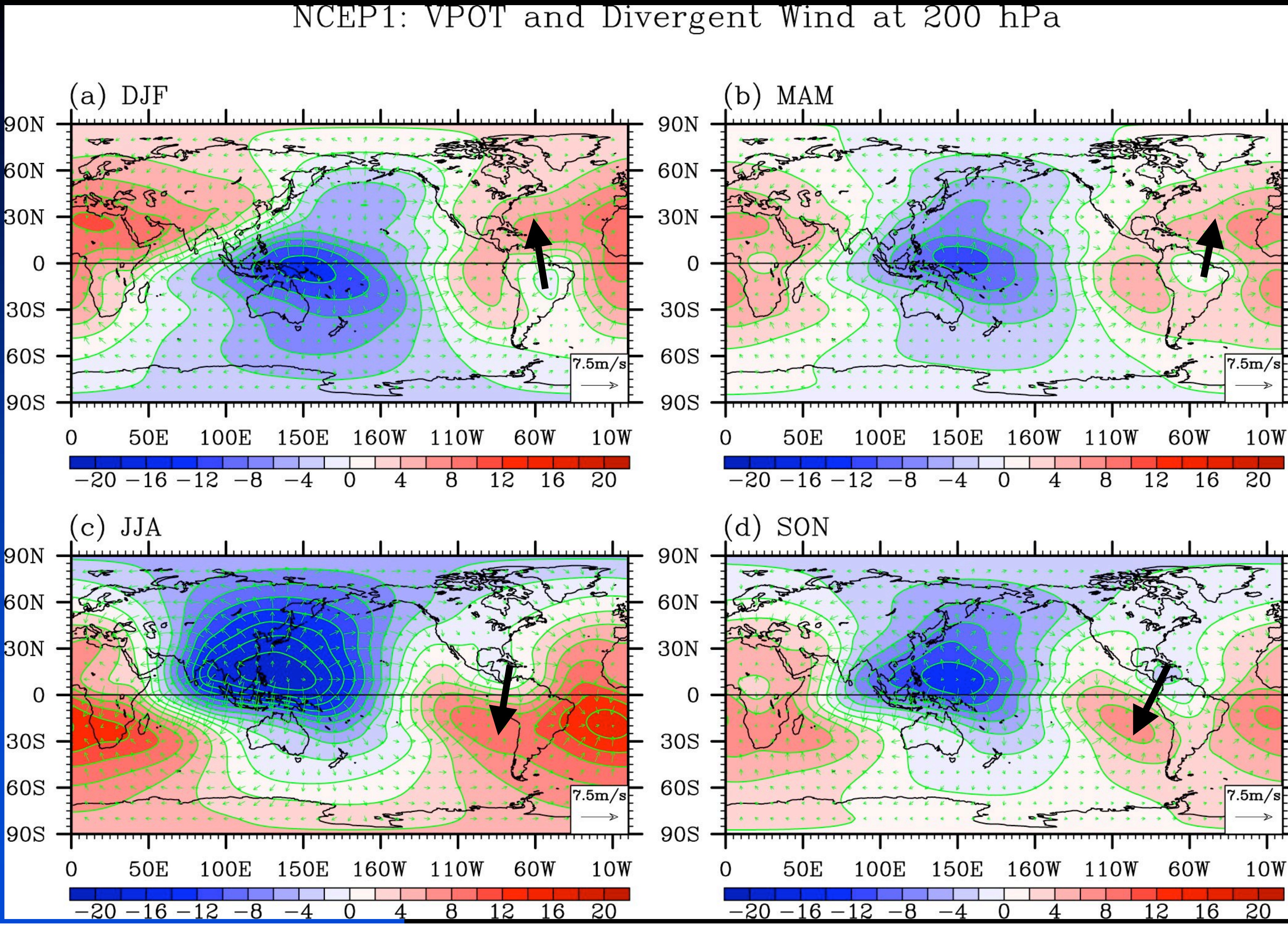


AWP (SST ≥ 28.5°C) area anomaly indices during the Atlantic hurricane season of June-November

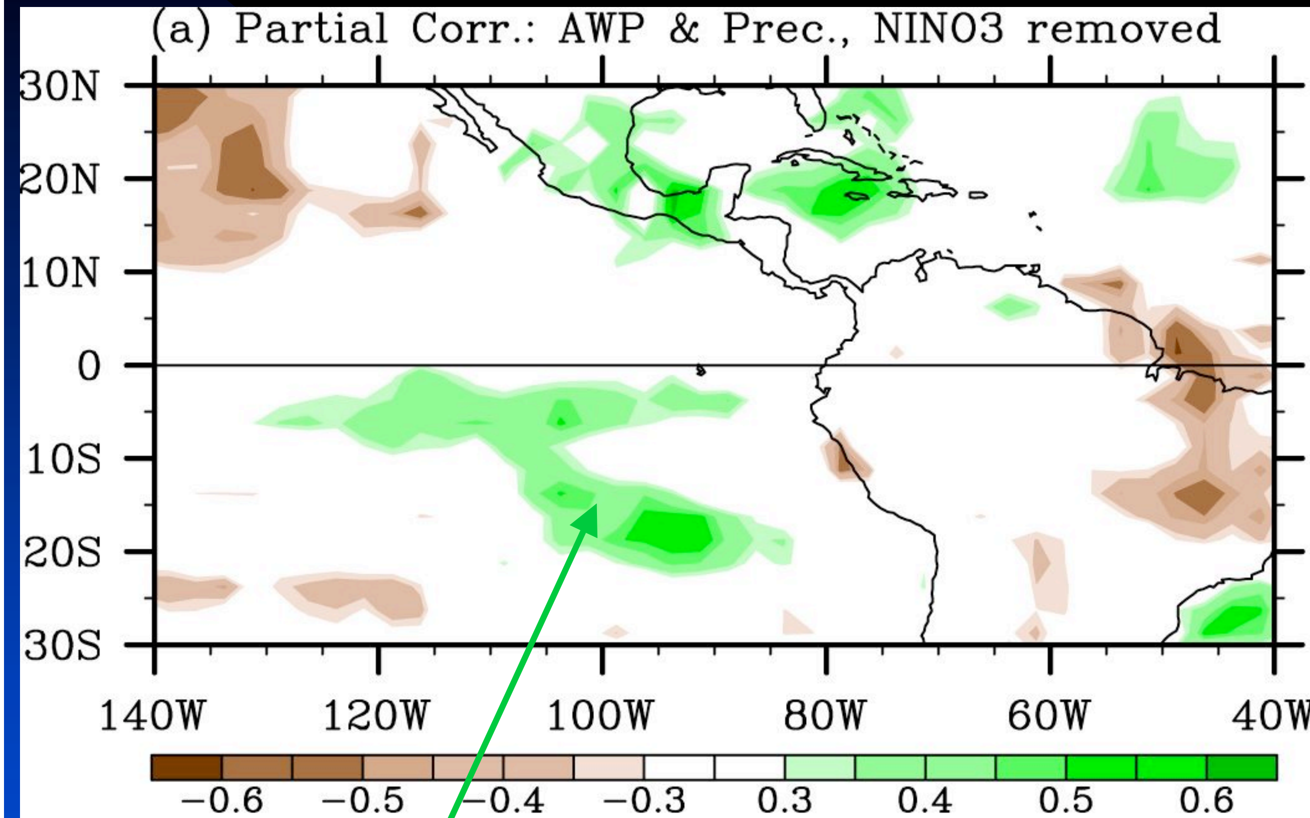
The AWP shows multiscale variability: Interannual, multidecadal, and linear warming trend variations.

Wang et al. (2008, *G*[3])

WHWP (Amazonia) is summer (winter) heat source of divergent circulation in the Western Hemisphere



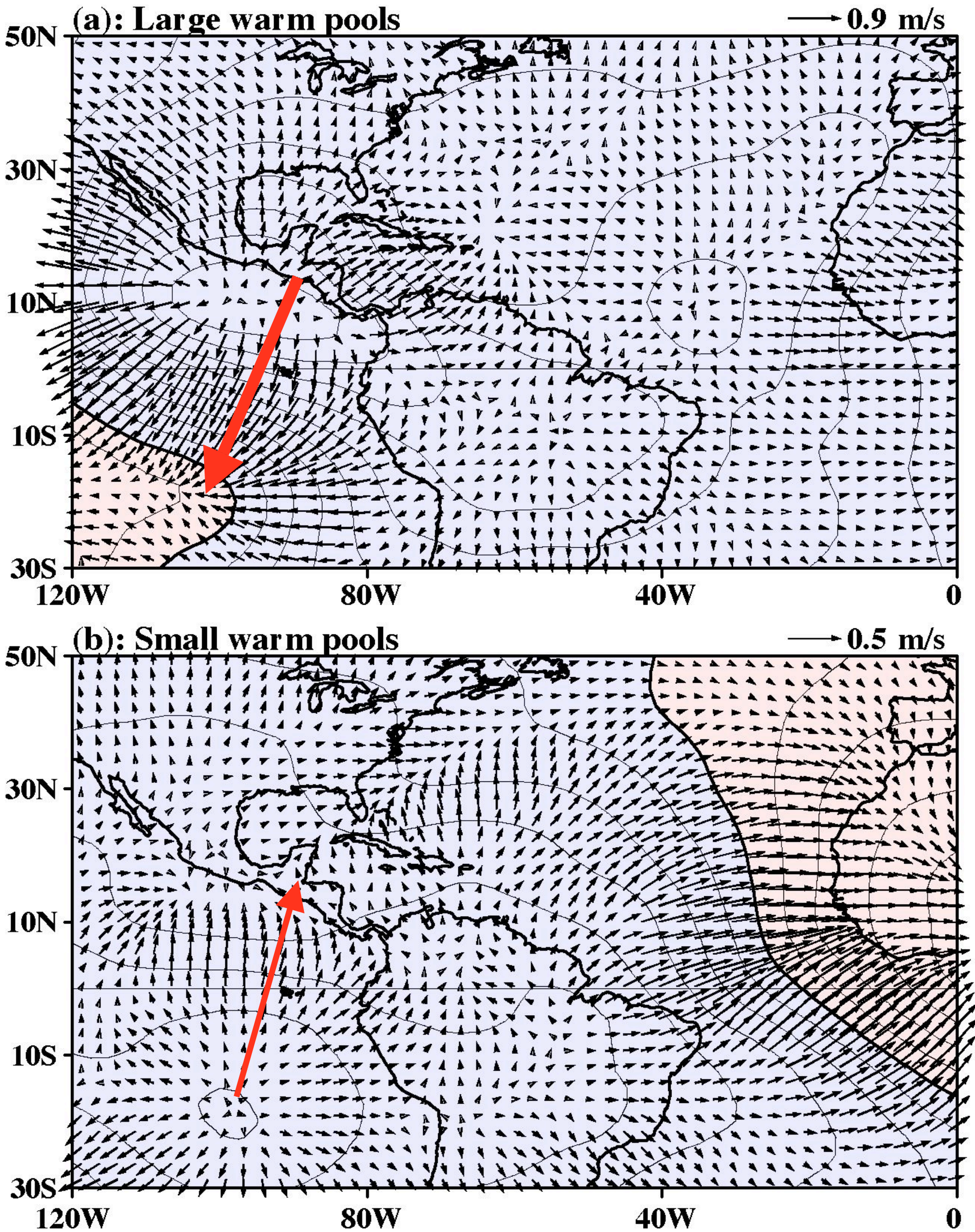
Impact of the AWP on rainfall anomalies during boreal summer



Positive rainfall correlation

- ENSO has little to do with the positive AWP-rainfall correlation over SE Pacific.
- Local SST anomalies can not explain the positive rainfall correlation either.
- What is the mechanism for the positive rainfall correlation?

Regional Hadley circulation links the AWP with SE Pacific



Anomaly composites (V. Potential & Div. Wind) at 200-mb

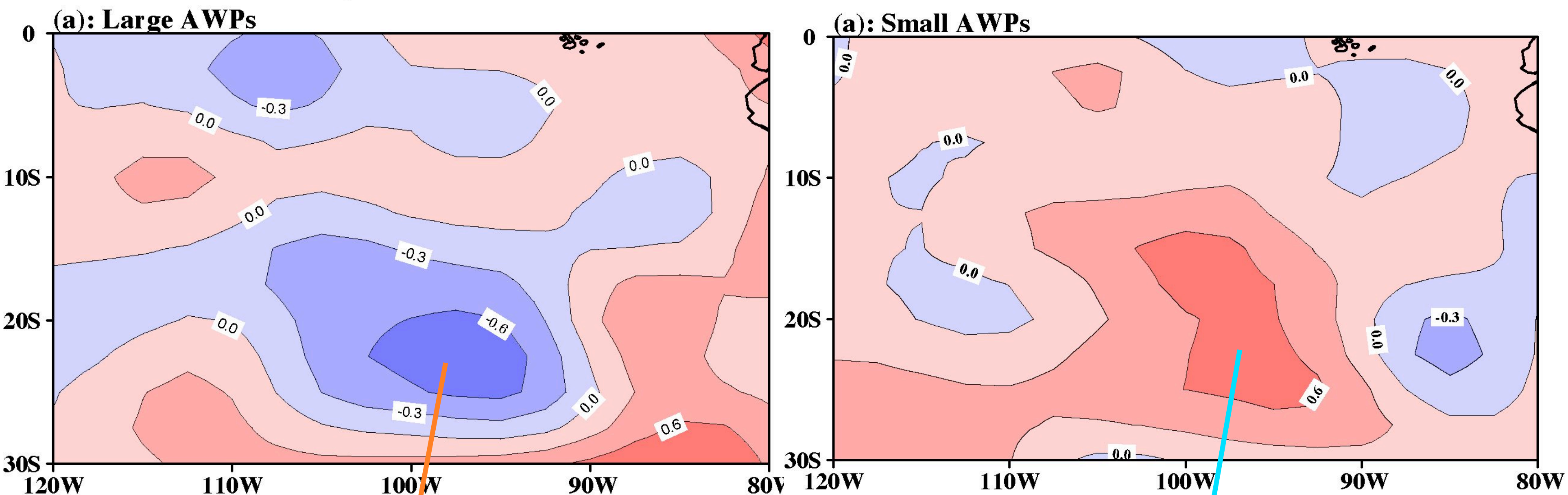
Large (small) AWPs are associated with a strong (weak) regional Hadley cell emanating from the warm pool into the SE Pacific which strengthens (weakens) subsidence over the SE Pacific. This will change the stratus cloud and rainfall (drizzle) over the SE Pacific.

Wang et al. (2006, *J. Climate*)

Regional Hadley circulation links the AWP with SE Pacific

Large warm pools

Small warm pools



Anomalous descending motion

Anomalous ascending motion

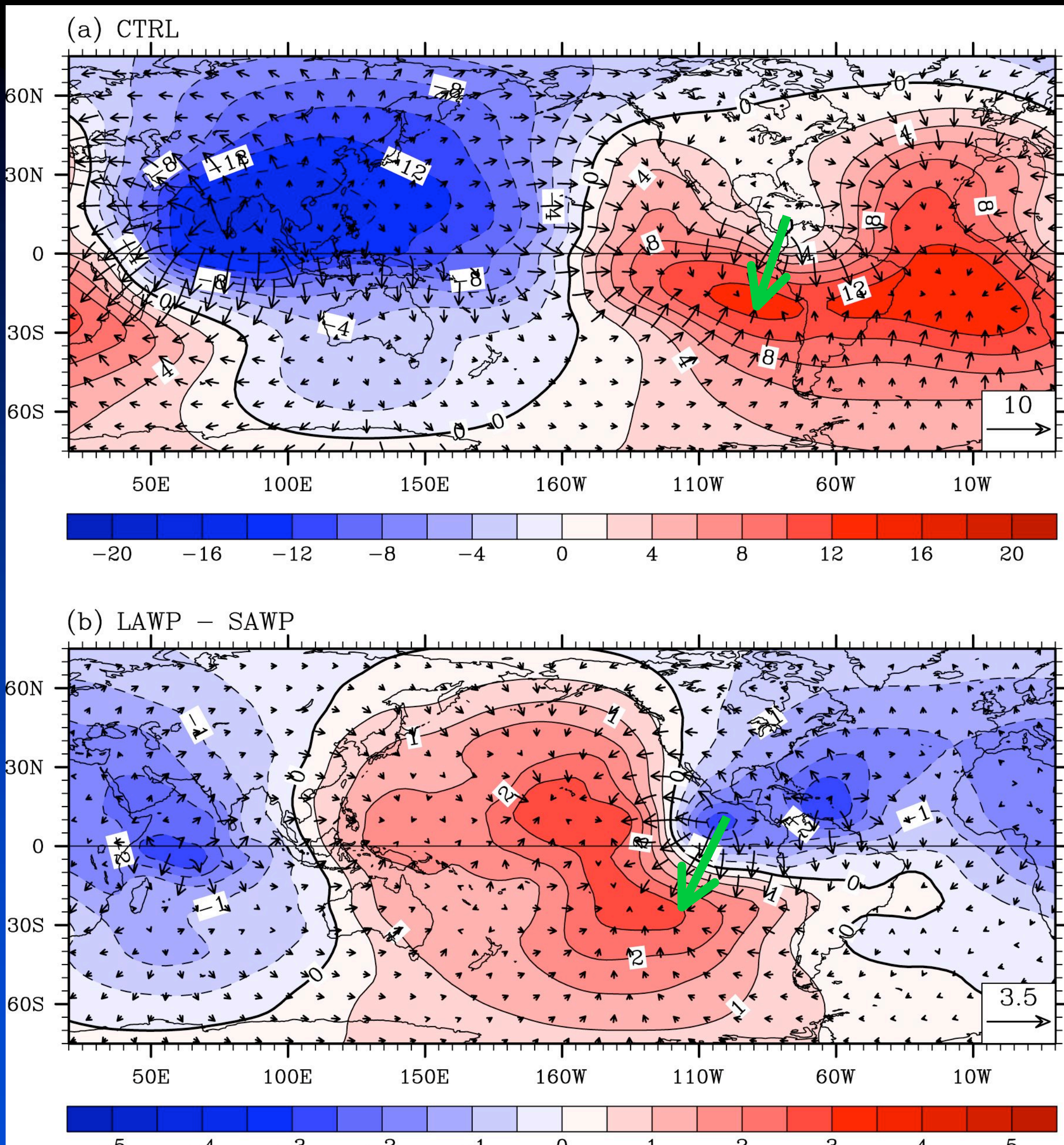
The 500-mb vertical velocity anomalies confirm and support the notion that the Hadley circulation links the AWP and southeast Pacific.

NCAR Community Atmospheric Model (Version 3.1; CAM3.1)

- A global spectral model (T42 with 26 vertical layers; equivalent to a 2.8°×2.8° horizontal resolution).
- SST from the Hadley Centre (UK) as the model-forcing.
- The control (CTRL) ensemble (with 18 members) run: Climatological SST is prescribed globally.
- The large AWP (LAWP) ensemble run: SST composite for large AWP is used in the AWP region.
- The small AWP (SAWP) ensemble run: SST composite for small AWP is used in the AWP region.
- The difference is taken between the LAWP and SAWP runs.

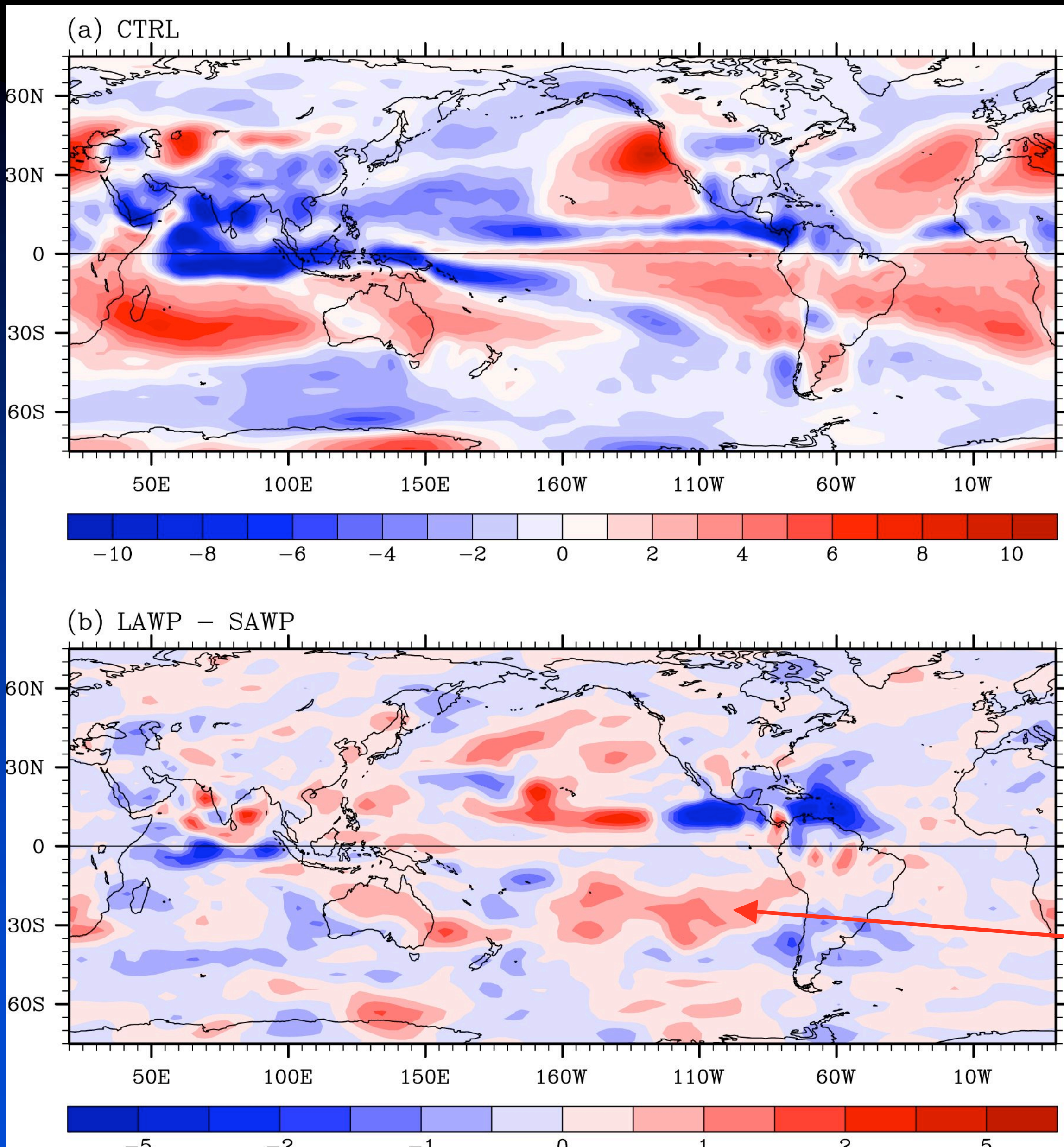
Wang et al. (2008 & 2009, *JC*)

AWP has an inter-hemispheric influence on the southeast Pacific



Velocity Potential and Divergent Wind at 200 mb during JJA

AWP has an inter-hemispheric influence on the southeast Pacific

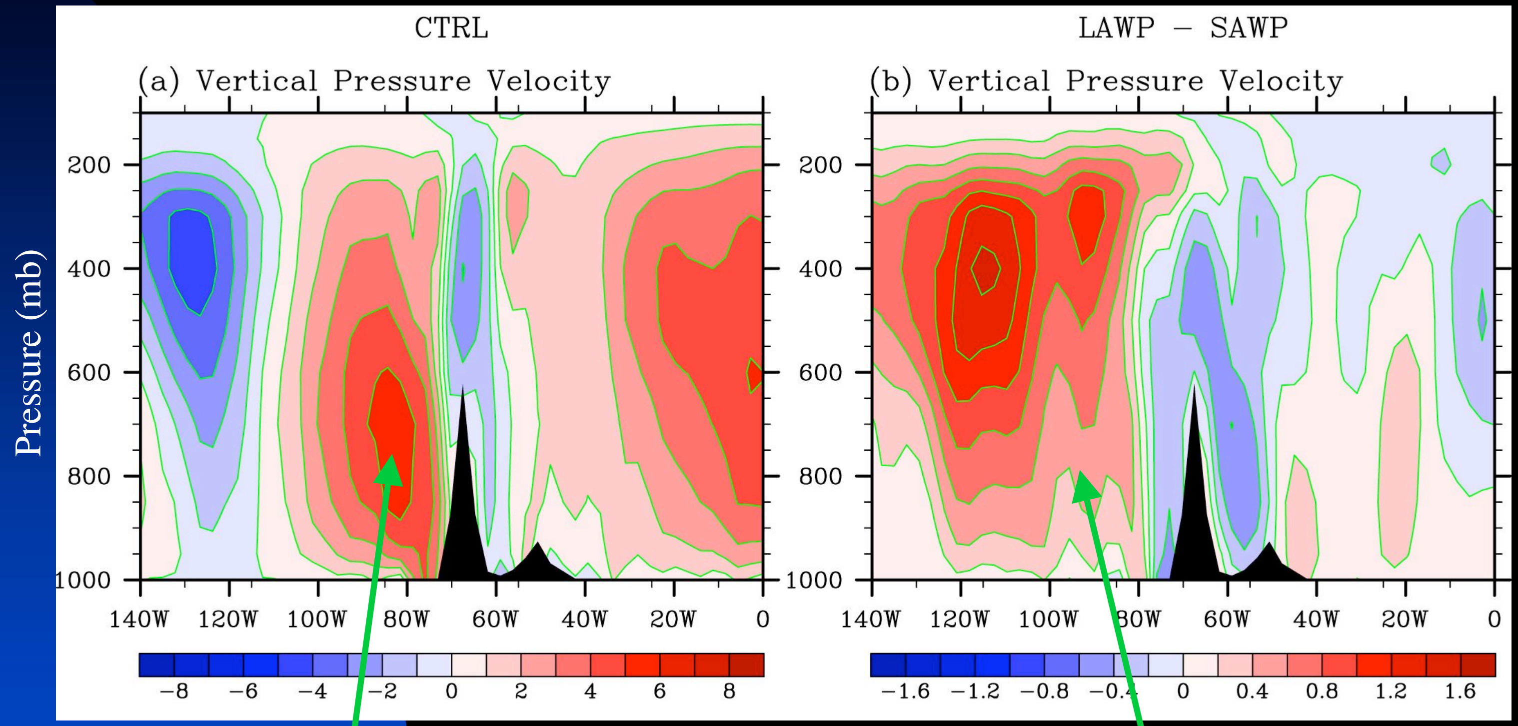


Vertical Pressure Velocity at 500 mb during JJA

Anomalous subsidence

AWP has an inter-hemispheric influence on the southeast Pacific

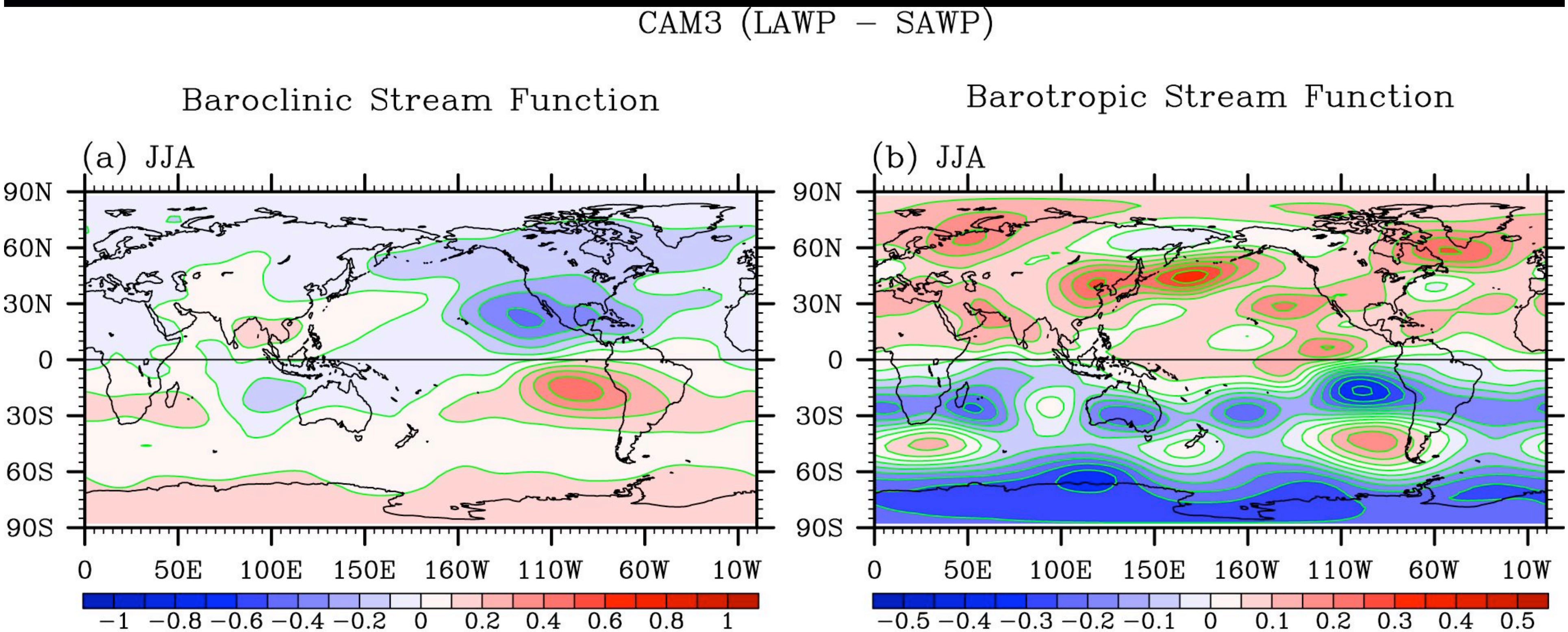
CAM3: Vertical Pressure Velocity at 25°S in JJA



Seasonal subsidence over SE Pacific

Anomalous subsidence

AWP has an inter-hemispheric influence on the southeast Pacific



- Baroclinic stream function shows a pair of cyclones straddled in NE & SE Pacific.
- Barotropic stream function shows a wave train that teleconnects into the Southern Hemisphere.

A Simple Linearized Model with Barotropic & Baroclinic Components

Lee et al. (2009, JC, Issue of Jan. 15)

$$\overline{U}\frac{\partial\overline{\zeta}}{\partial x} + \left(\beta - \frac{d^2\overline{U}}{dy^2}\right)\overline{v} = -r_0\overline{\zeta} + A_0\nabla^2\overline{\zeta} + F_{\overline{\zeta}} \tag{1}$$

$$F_{\overline{\zeta}} = \hat{v}\frac{d^2\hat{U}}{dy^2} + \frac{d\hat{U}}{dy}\left(\frac{\partial\hat{u}}{\partial x} + \frac{\partial\hat{v}}{\partial y}\right) - \hat{U}\frac{\partial\hat{\zeta}}{\partial x}$$

$$\overline{U}\frac{\partial\hat{u}}{\partial x} + \left(\frac{\partial\overline{U}}{\partial y} - f\right)\hat{v} = -\frac{\partial\hat{\phi}}{\partial x} - r_1\hat{u} + A_1\nabla^2\hat{u} + F_{\hat{u}} \tag{2}$$

$$\overline{U}\frac{\partial\hat{v}}{\partial x} + f\hat{u} = -\frac{\partial\hat{\phi}}{\partial y} - r_1\hat{v} + A_1\nabla^2\hat{v} + F_{\hat{v}} \tag{3}$$

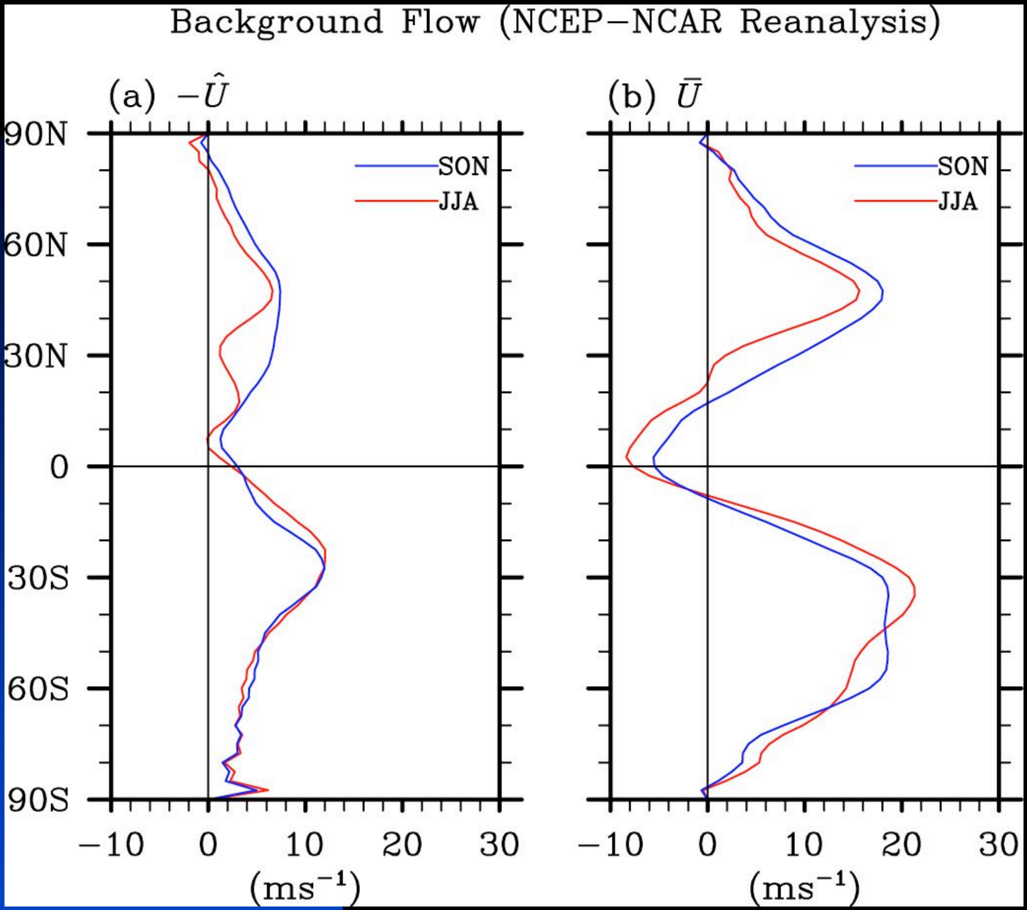
$$F_{\hat{u}} = \hat{U}\frac{\partial\overline{u}}{\partial x} + \overline{v}\frac{\partial\hat{U}}{\partial y} \qquad F_{\hat{v}} = \hat{U}\frac{\partial\overline{v}}{\partial x}$$

$$\gamma\hat{\phi} + c_g^2\nabla^2\hat{\chi} = -Q \tag{4}$$

Barotropic variable: $\overline{Y} = (Y_{750\,mb} + Y_{250\,mb})/2$

Baroclinic variable: $\hat{Y} = (Y_{750\,mb} - Y_{250\,mb})/2$

The mean background states are specified in the model

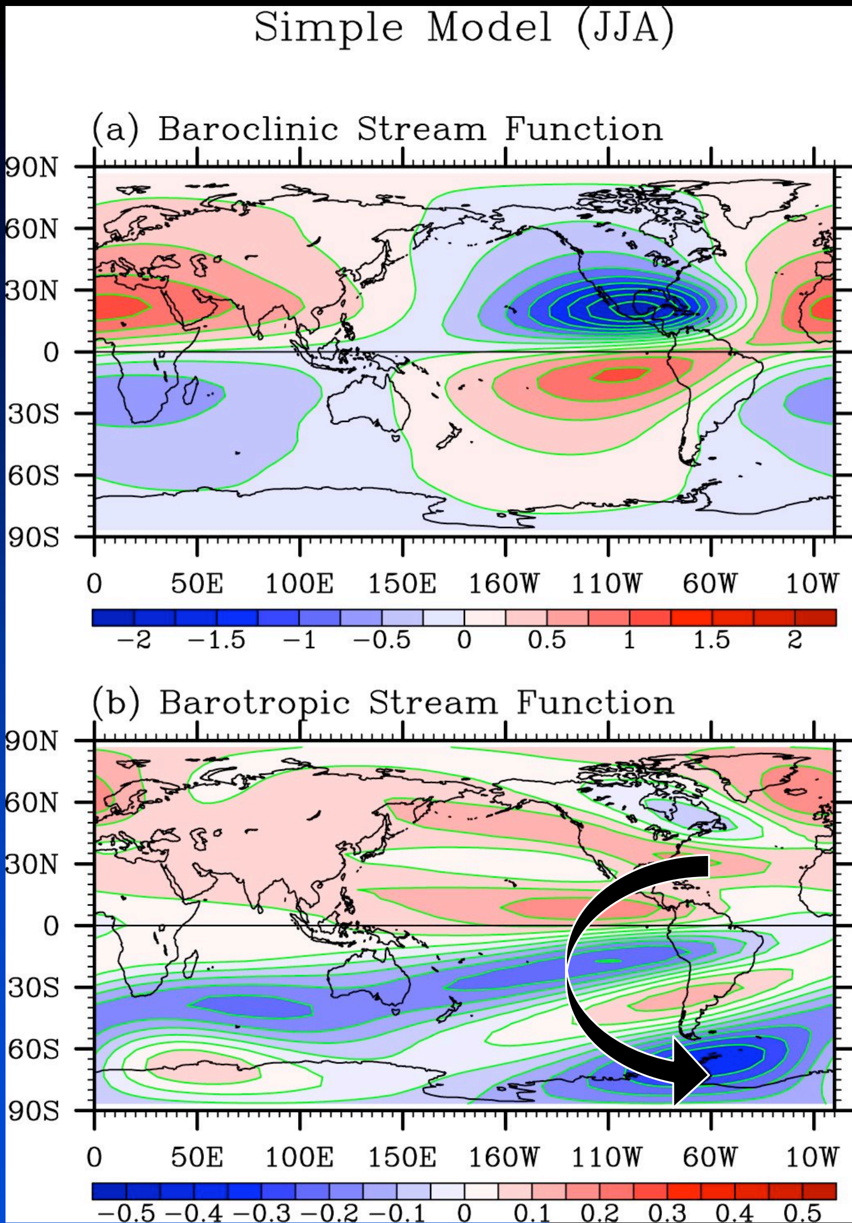


Zonally averaged between 120°W-40°W

Baroclinic background zonal wind: $\hat{U} = (U_{750mb} - U_{250mb})/2$

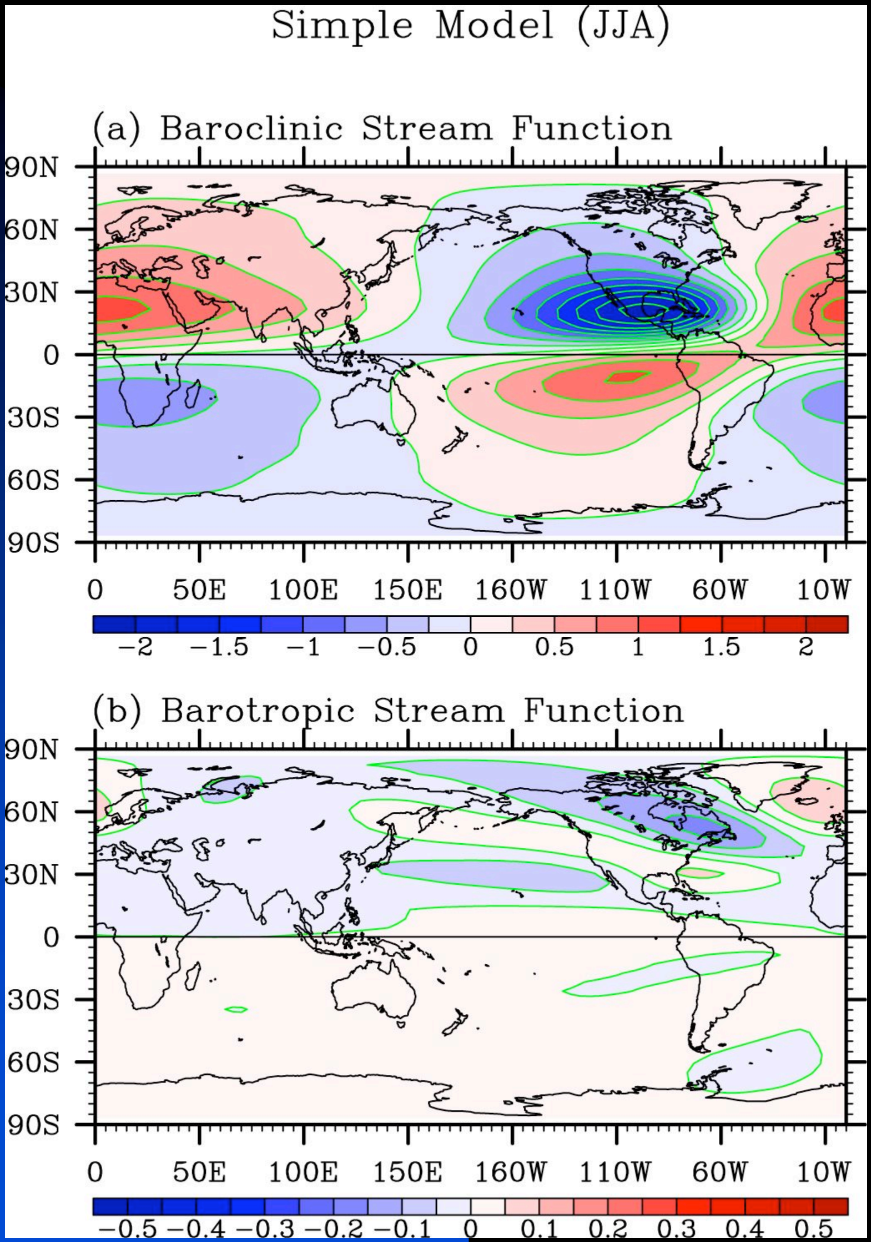
Barotropic background zonal wind: $\bar{U} = (U_{750mb} + U_{250mb})/2$

Simple model response to heating anomaly in the AWP



- Baroclinic stream function shows a pair of cyclones straddled in NE & SE Pacific, consistent with Gill's model (1980).
- Barotropic stream function shows an alternatively high and low pattern that emanates from the AWP and transmits to high latitudes.
- In particular, the AWP heat-induced stream function transmits and crosses the equator into high latitudes of the Southern Hemisphere.

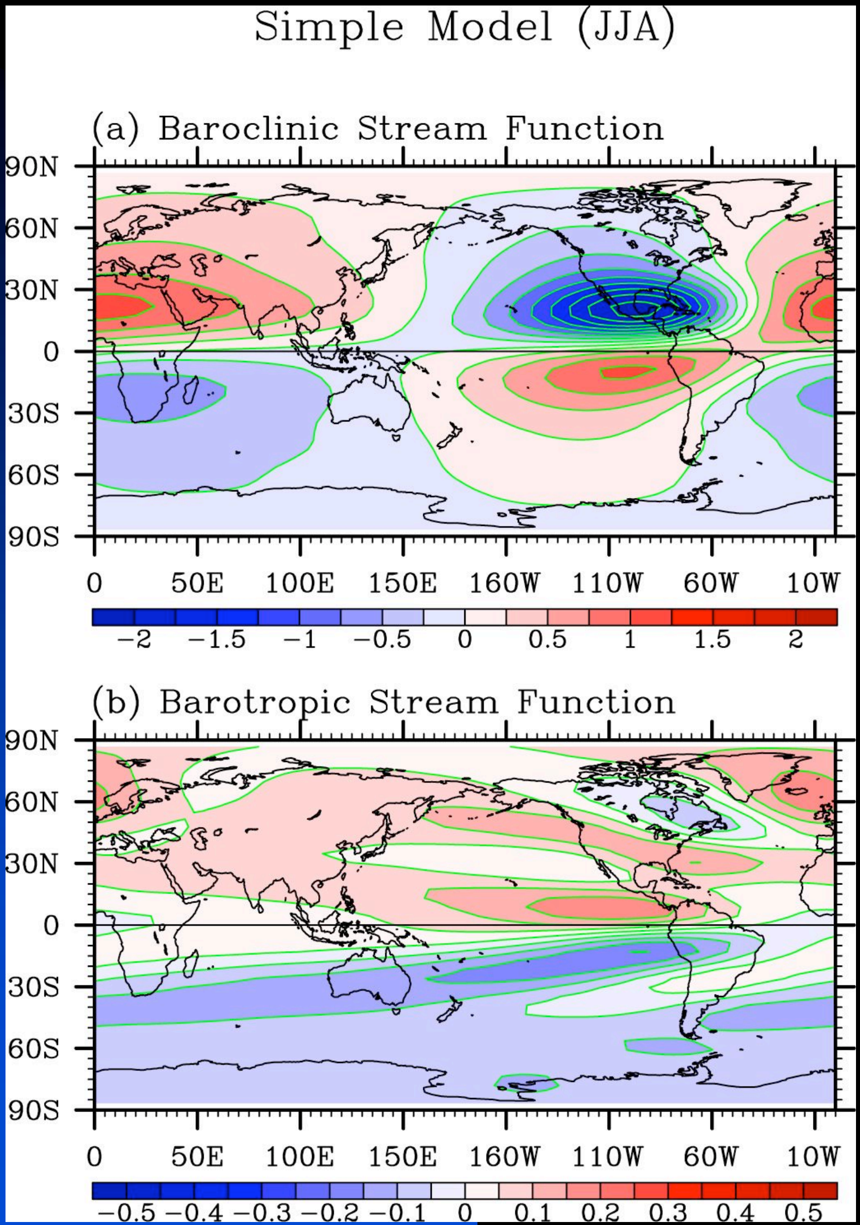
The importance of mean background zonal-wind



$\hat{U} = 0$ over the Southern Hemisphere

- Local baroclinic response to the AWP heating is largely independent of the mean background winds.
- In contrast, the mean background winds play a key role for barotropic stream function to be transmitted to the Southern Hemisphere.
- AWP-induced baroclinic anomalies cannot interact with the mean background wind (specified to be zero) to produce barotropic motion in the Southern Hemisphere.

The importance of mean background zonal-wind



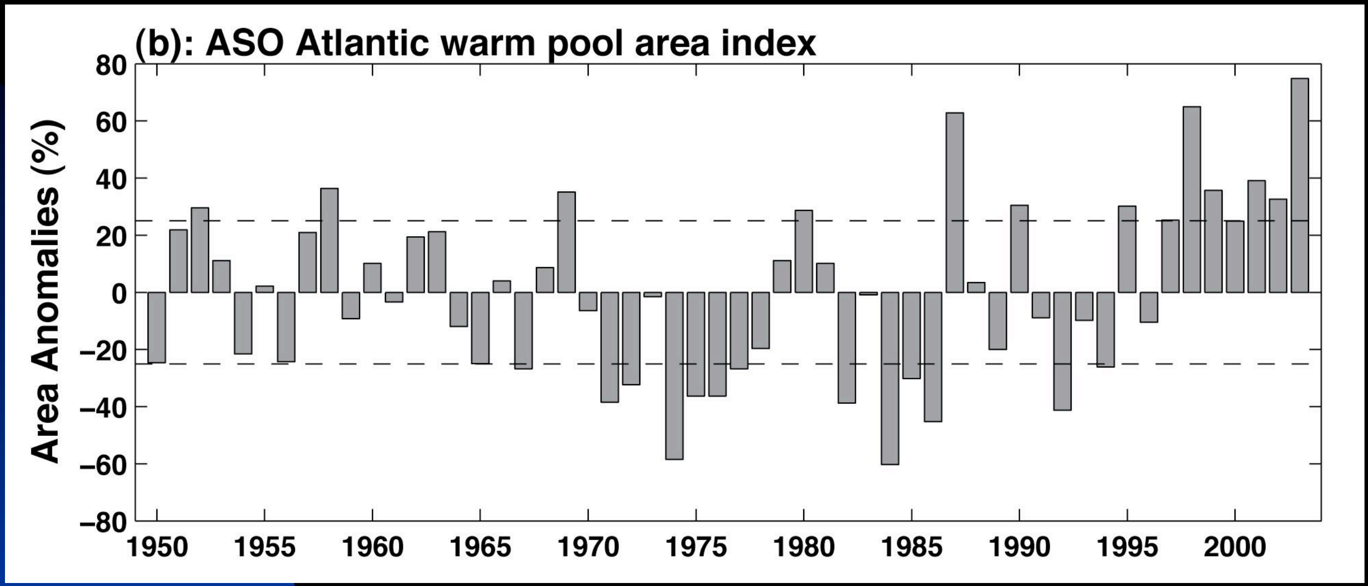
$\bar{U} = 0$ over the Southern Hemisphere

- Barotropic stream function in the Southern Hemisphere is much weaker and does not penetrate into high latitudes.
- Depth-independent background westerly wind in the Southern Hemisphere is important for the AWP heat-induced signals to transmit to high latitudes of the Southern Hemisphere .

Summary

- During the boreal summer, a strong Hadley circulation emanates from the AWP, forks into the SE Pacific region, and maintains the subsidence over the SE Pacific.
- Anomalously large (small) AWP strengthens (weakens) the summer Hadley circulation and thus enhances (suppresses) the subsidence over the SE Pacific.
- It implies that numerical models need to correctly simulate AWP variability in order to reduce model biases in the SE Pacific.

Atlantic Warm Pool (AWP): Atlantic side of the WHWP

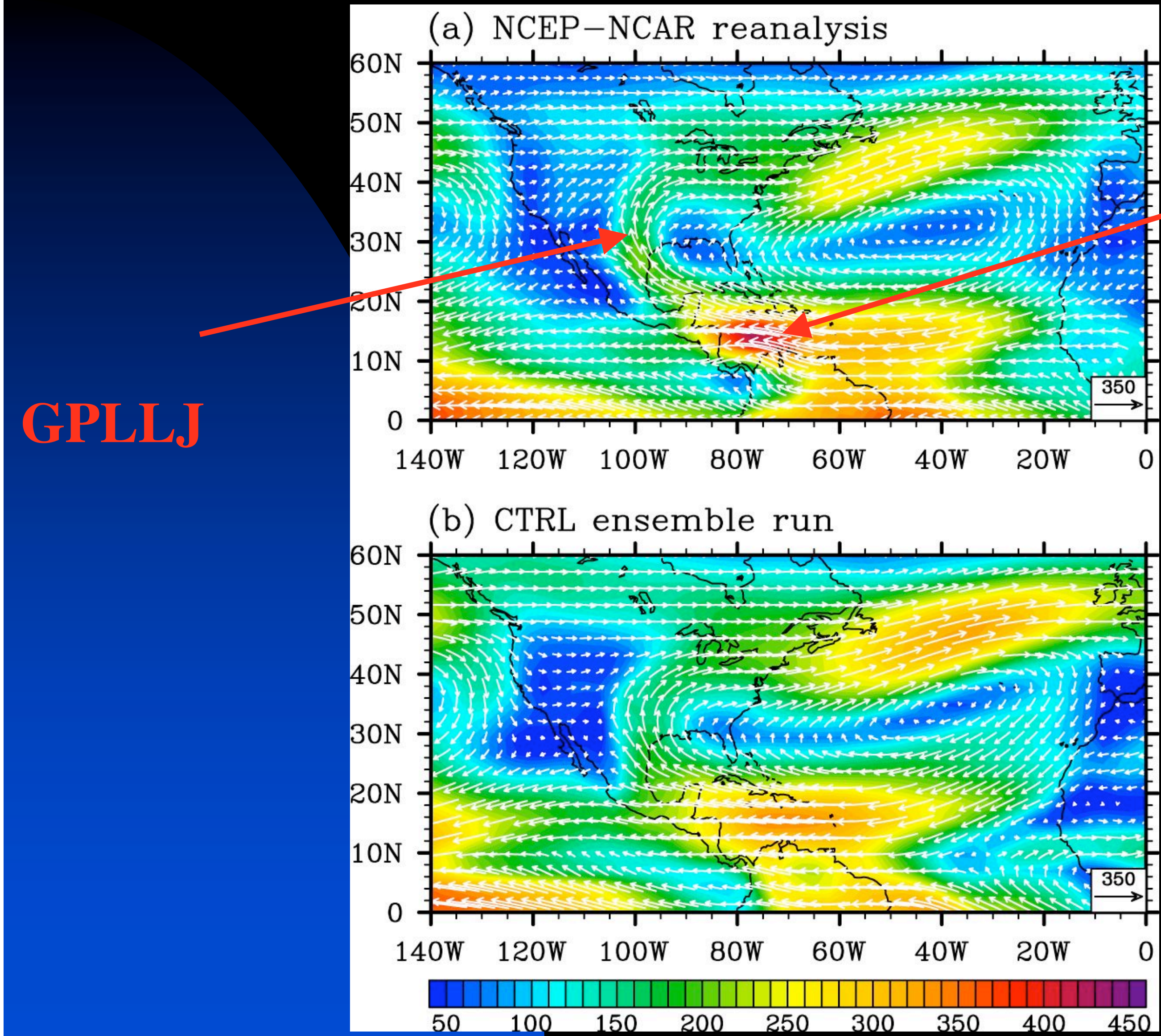


A warm pool 25% larger (smaller) than climatological warm pool area is identified as a large (small) AWP:

- 14 large AWPs: for 9 cases the Pacific does not show El Niño in preceding winter.
- 15 small AWPs: for 10 cases the Pacific does not show La Niña in preceding winter.

=> Two thirds of AWPs occur without preceding winter Pacific ENSO events. That is, the AWP is not significantly correlated with ENSO.

How does CAM3.1 perform?



Vertically integrated moisture flux in summer (JJA):

$$\vec{Q} = \int_{300mb}^{sfc} (q\vec{u} / g) dp$$

Warm pool is a heating source of summer Hadley circulation in the WH

Wang & Enfield (2003) and Wang (2005)