

La contribución del Pacífico Suroriental a la desaceleración del Calentamiento Global



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Porque no te
calientas como
antes?

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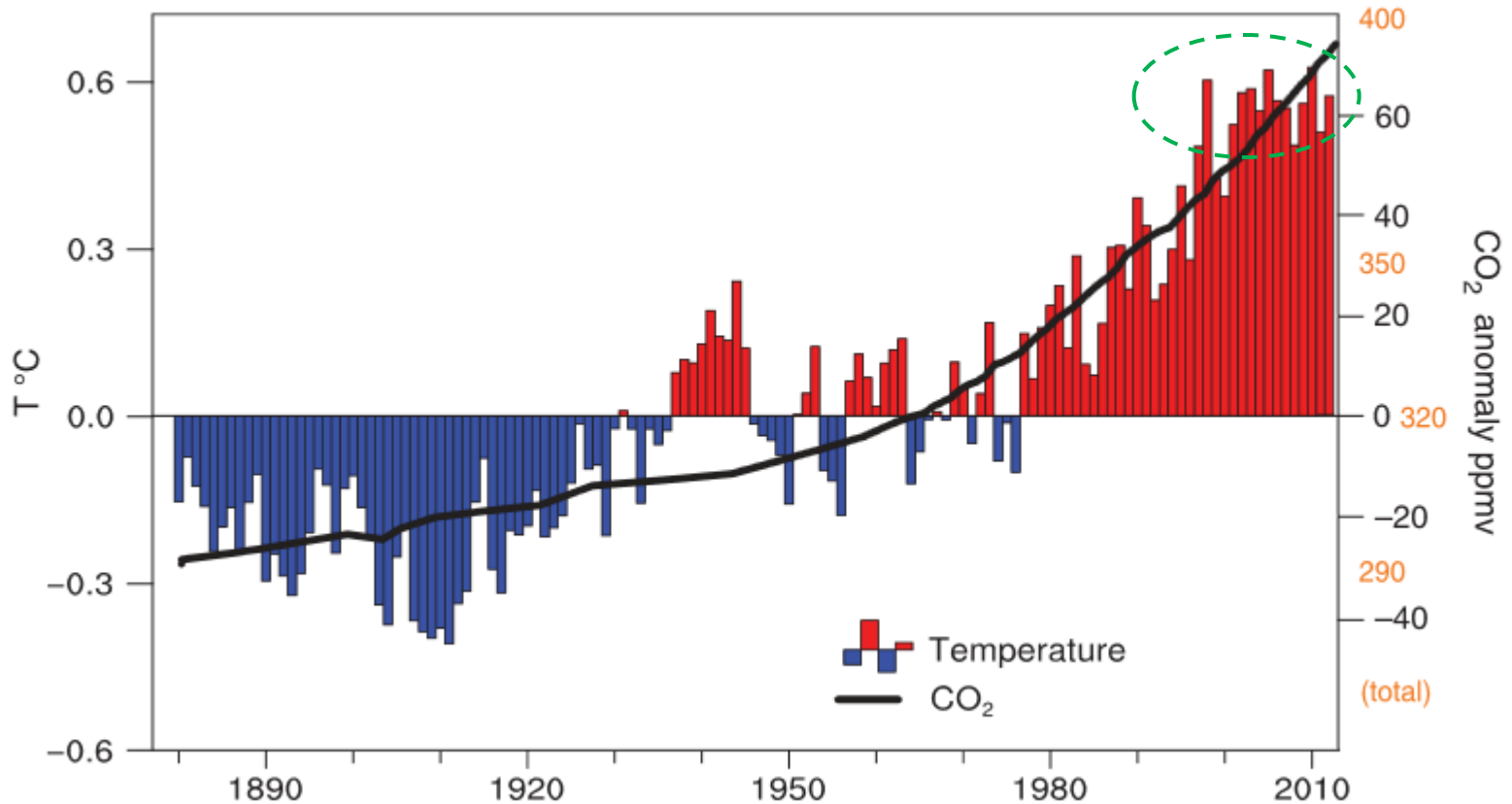
- El “Hiato” del calentamiento global
- Expansión de la Celda de Hadley
- Enfriamiento del Pacífico suroriental
- Conclusiones

Aquí esta el problema...

Concentraciones GEI continúan subiendo

→ Desbalance radiativo en TOA $\sim 0.5-1 \text{ W/m}^2$

Década más cálida del registro pero la temperatura no aumenta!



Continúan los problemas...

GCM Hist (IPCC-AR5) no ven la des aceleración del CG

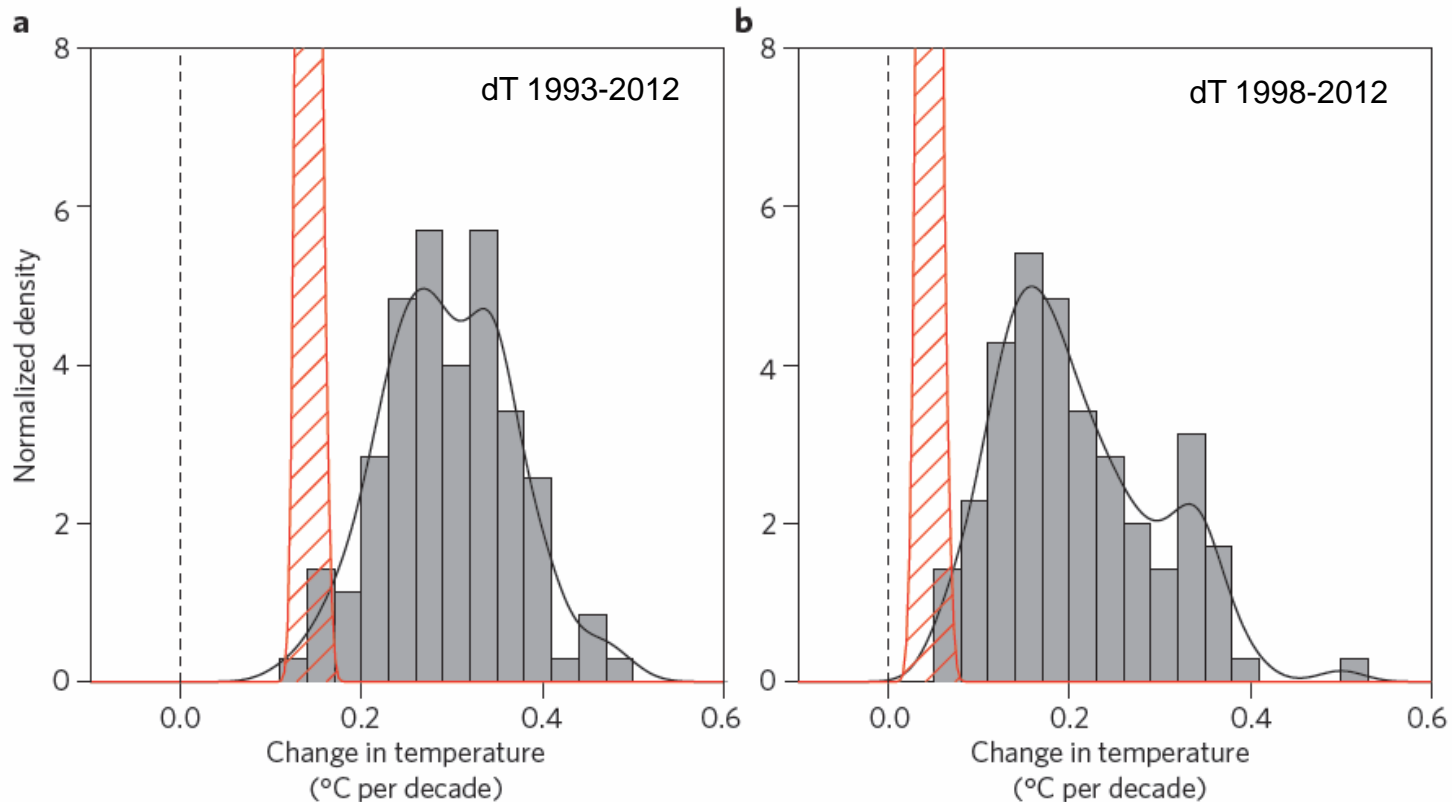


Figure 1 | Trends in global mean surface temperature. **a**, 1993–2012. **b**, 1998–2012. Histograms of observed trends (red hatching) are from 100 reconstructions of the HadCRUT4 dataset¹. Histograms of model trends (grey bars) are based on 117 simulations of the models, and black curves are smoothed versions of the model trends. The ranges of observed trends reflect observational uncertainty, whereas the ranges of model trends reflect forcing uncertainty, as well as differences in individual model responses to external forcings and uncertainty arising from internal climate variability.

Que pasa en el vecindario?

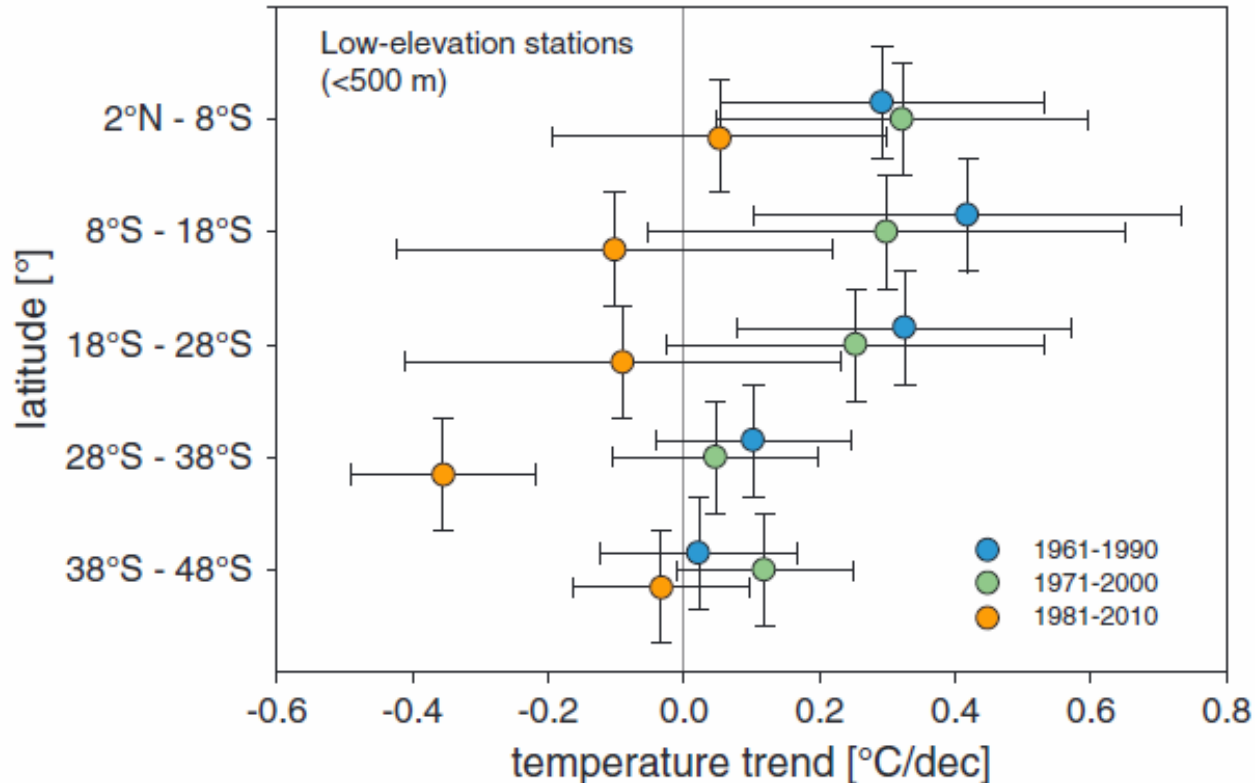


Figure 4. Temperature trends (in °C/decade) in coastal areas below 500 m (lower western slopes) as a function of time period and latitude. Trends for 1961–1990 and 1981–2010 are plotted with a slight latitudinal offset to increase clarity.

Que pasa en el vecindario?

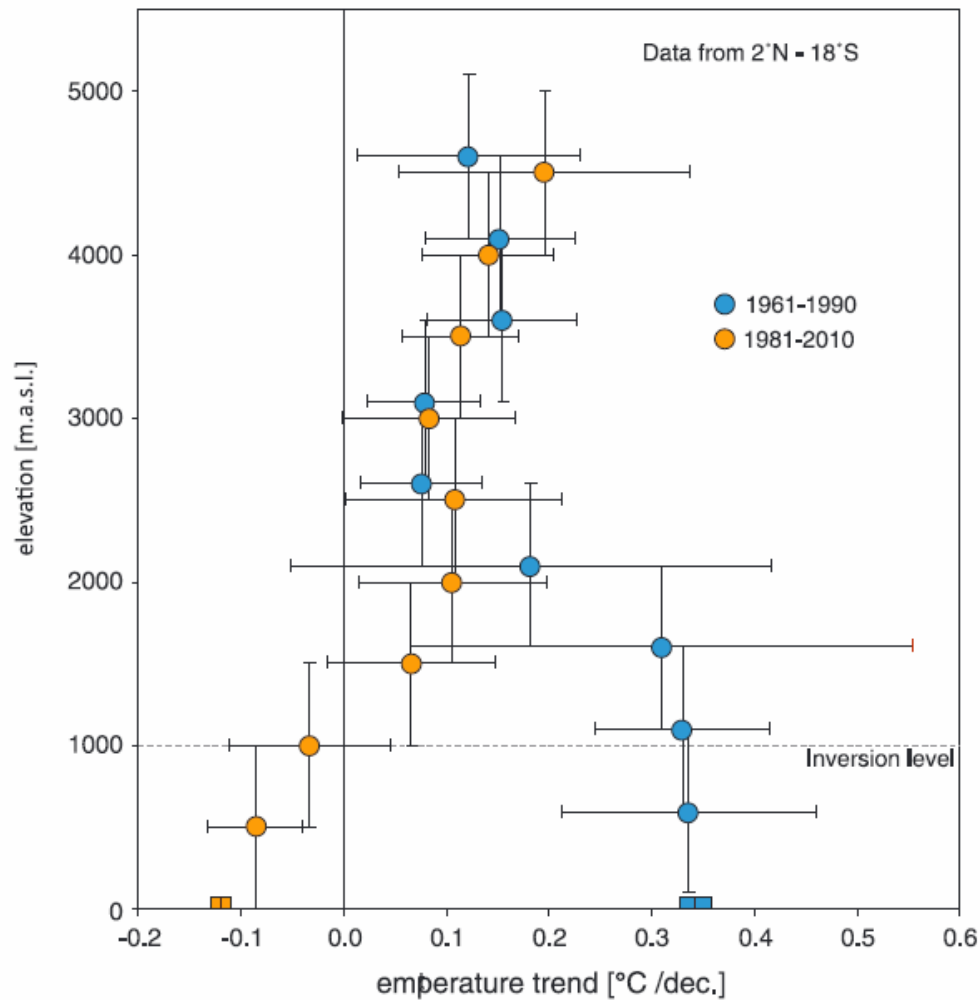
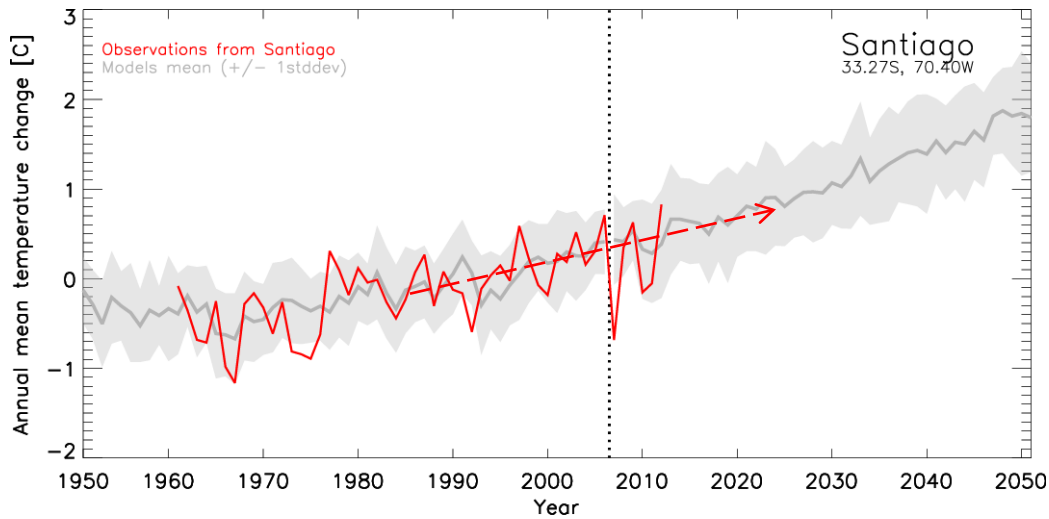
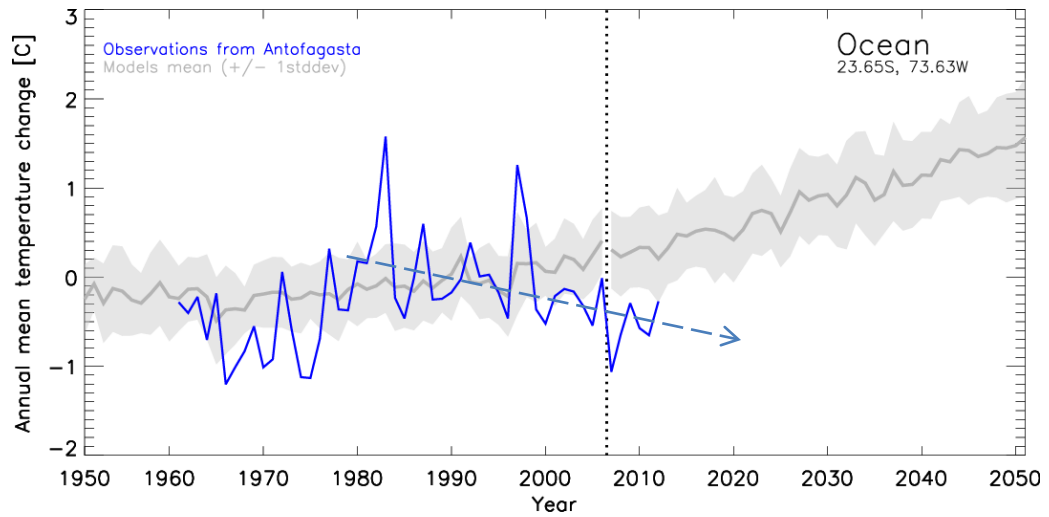


Figure 5. Temperature trends versus altitude along western tropical Andean slopes (2°N–18°S) for 1961–1990 (blue circle) and 1981–2010 (orange circle). The horizontal bars represent 95% confidence limits

Que pasa en el vecindario?



En resumen (hasta ahora):

- Concentraciones de CO₂ y otros GEI han aumentado en forma monotónica y sustancial en las últimas décadas produciendo un desbalance radiativo en TOA $\sim 0.5-1 \text{ W/m}^2$ (y que crece a 0.3 W/m^2 por década)
- Promedio global de temperatura del aire se ha estabilizado (en la parte más alta del registro) durante los últimos 15 años: **Global Warming Hiatus**
- Entonces, donde está el exceso de energía que entra al sistema climático?

Incremento en aerosoles (✘)

Incremento en humedad estratosférica (✘)

Mínimo solar (?)

Problemas en red de observación (?)

Variabilidad natural/interna (veamos....)

Primera pista: no todo se enfría....

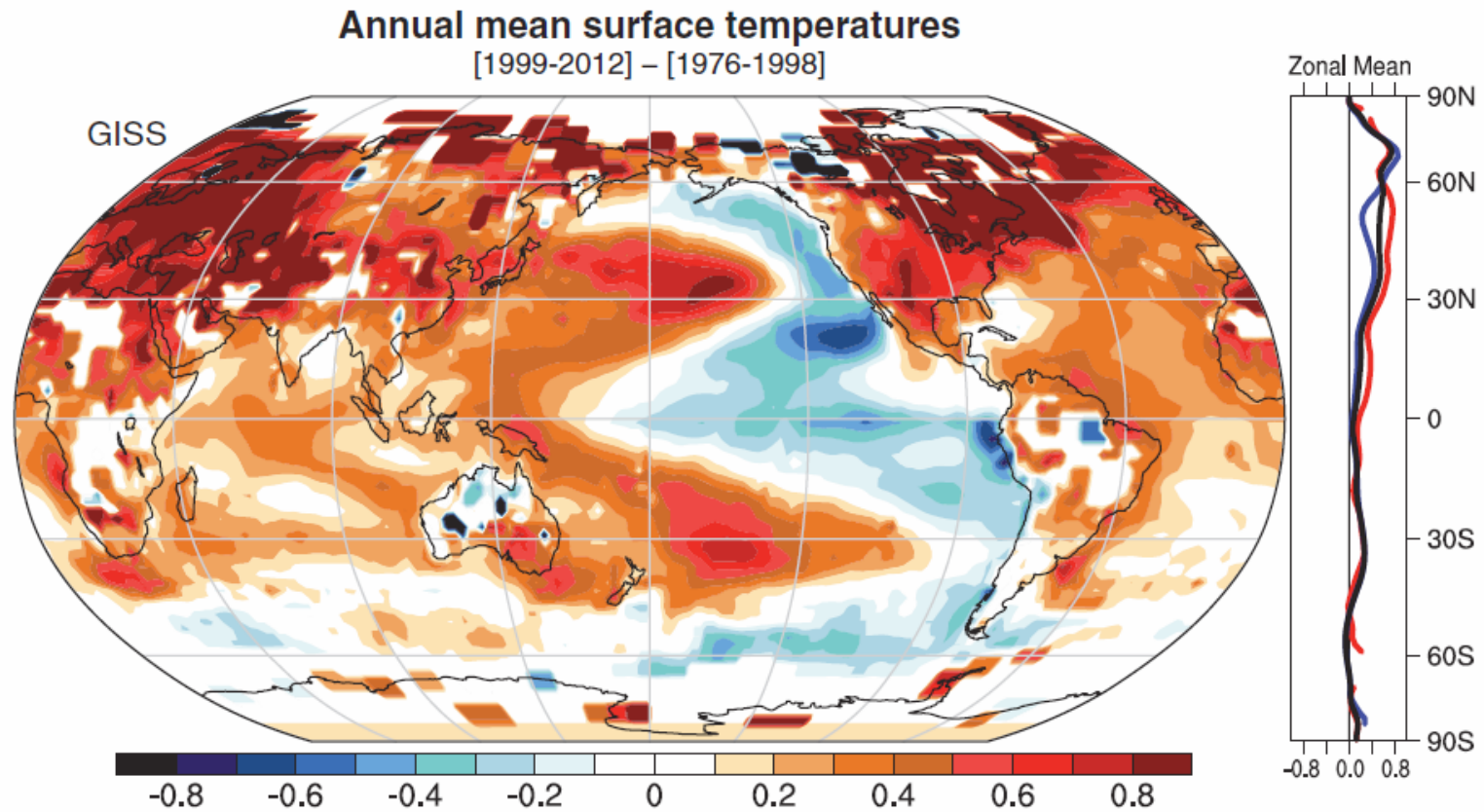
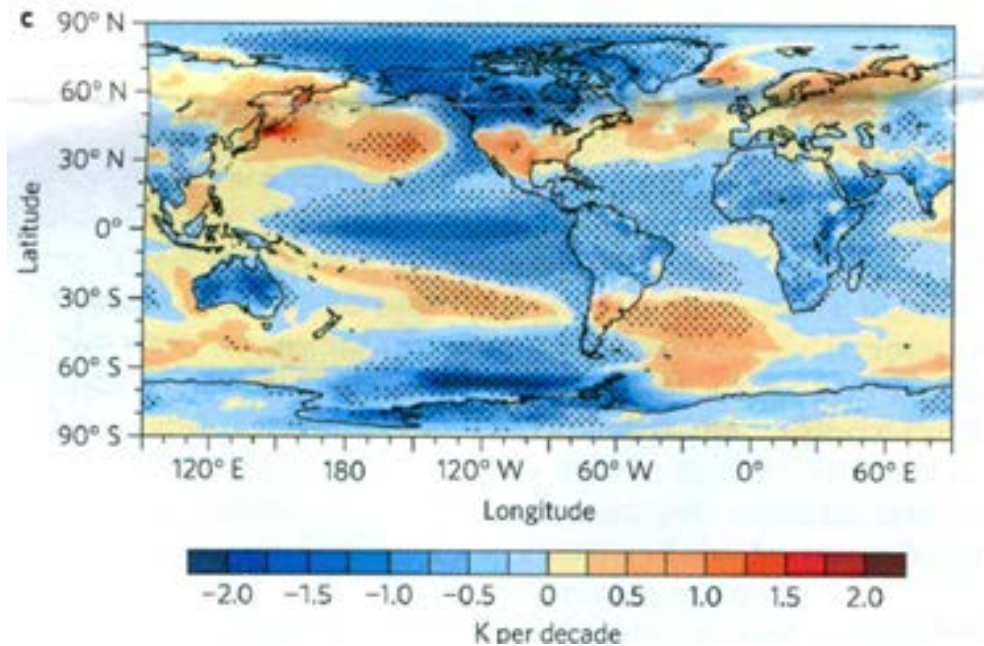
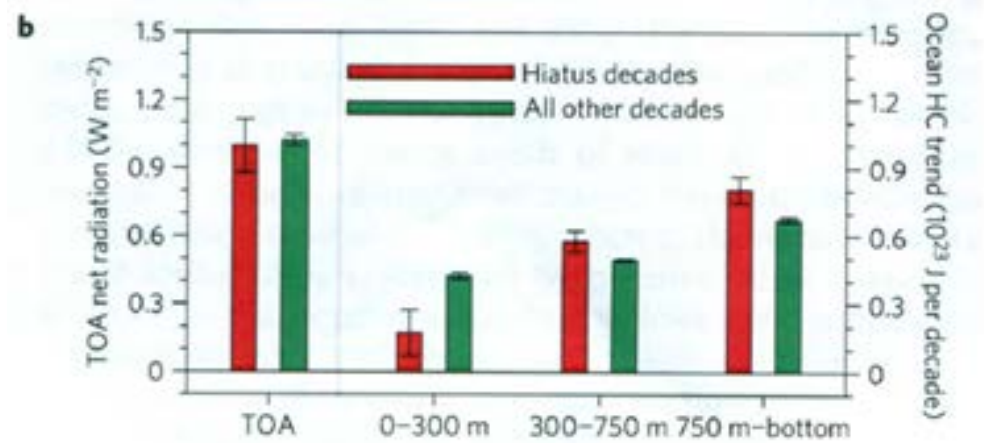
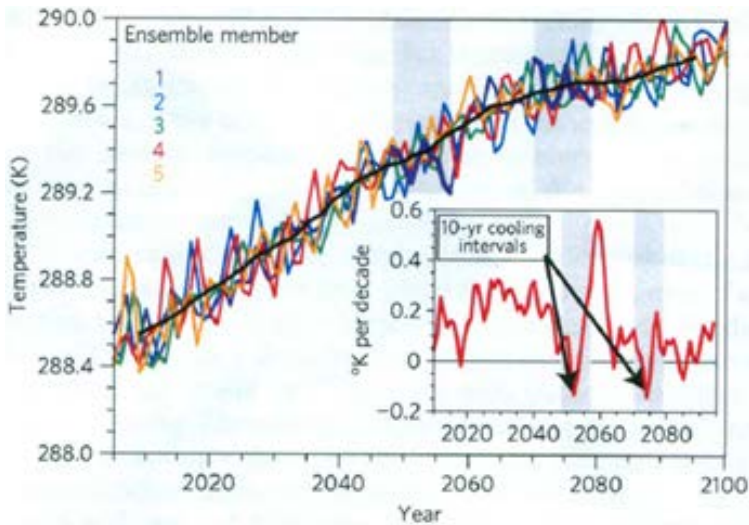


Figure 9. Mean annual surface temperature differences from GISS for 1999–2012 and 1976–1998 in °C, with zonal means at right for ocean (blue), land (red), and zonal mean (black).

Hiatos en los modelos de clima futuro

Future climate model simulation:
Look for Hiatus decade...



La energía se esta acumulando en el océano

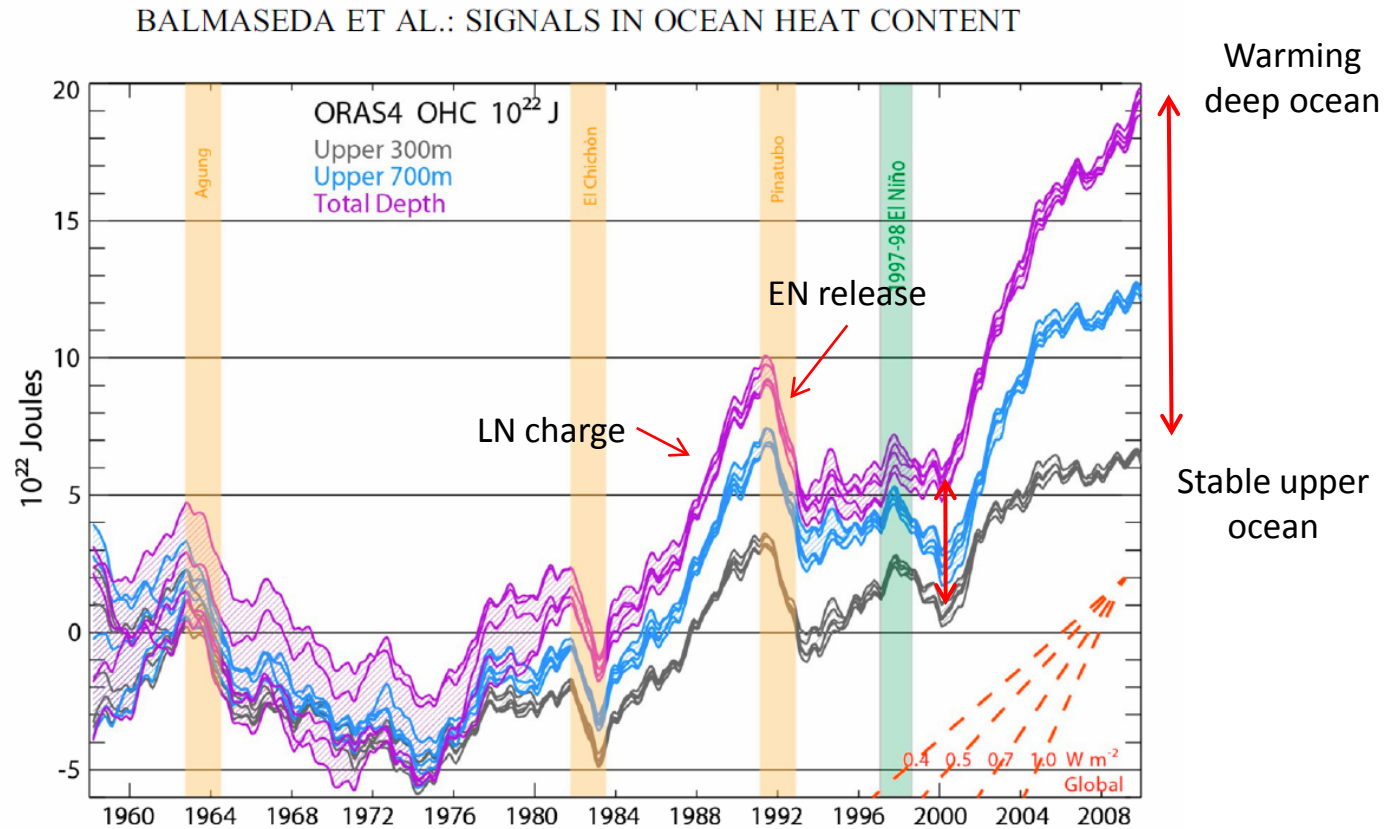
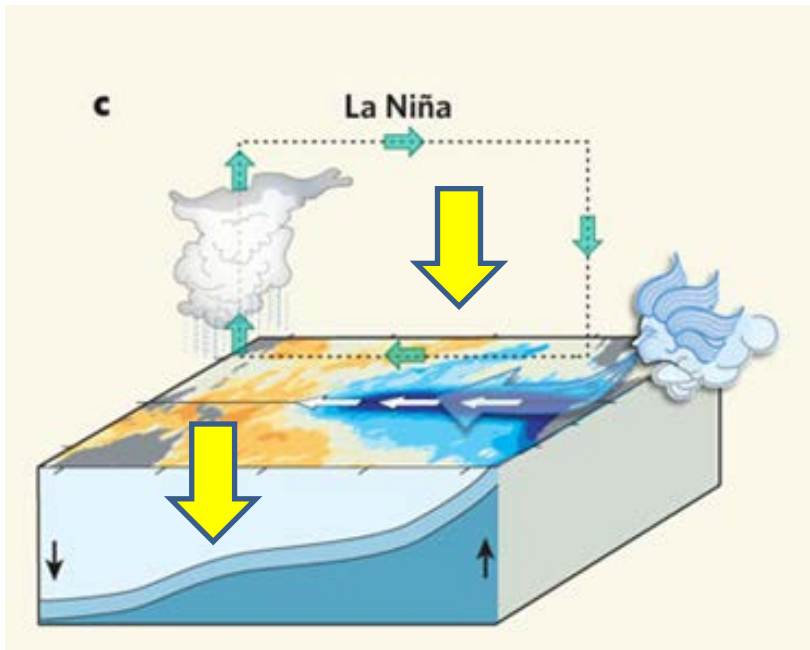
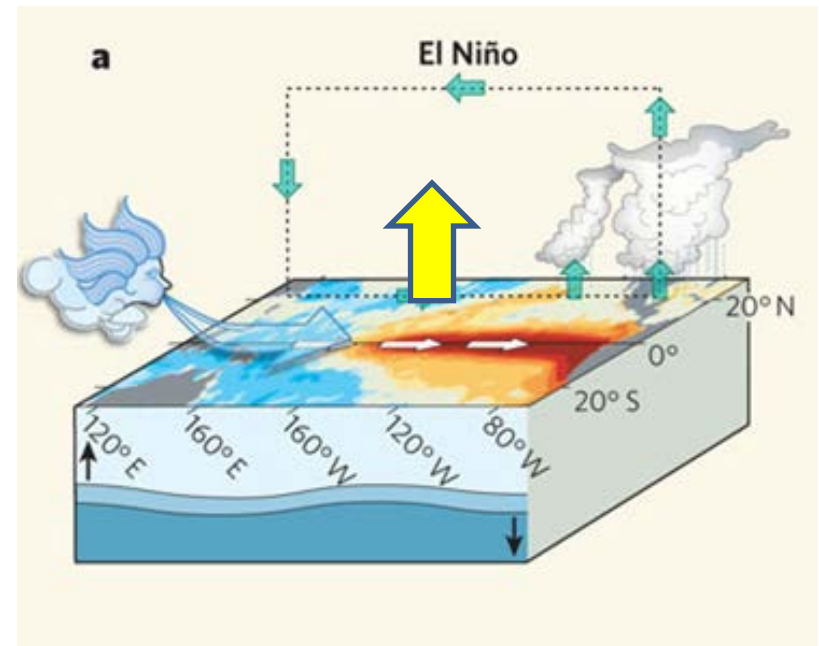


Figure 1. OHC integrated from 0 to 300 m (grey), 700 m (blue), and total depth (violet) from ORAS4, as represented by its 5 ensemble members. The time series show monthly anomalies smoothed with a 12 month running mean, with respect to the 1958–1965 base period. Hatching extends over the range of the ensemble members and hence the spread gives a measure of the uncertainty as represented by ORAS4 (which does not cover all sources of uncertainty). The vertical colored bars indicate a 2 year interval following the volcanic eruptions with a 6 month lead (owing to the 12 month running mean), and the 1997–1998 El Niño event again with 6 months on either side. On lower right, the linear slope for a set of global heating rates ($W m^{-2}$) is given.

Fases ENSO como un sistema de carga/descarga de Energía



Alisios más intensos / Mayor Insolación
Mayor surgencia en Pac. Oriental
Mayor hundimiento en Pac. Occidental
Energía ingresa al océano
Corrientes distribuyen el calor lateralmente



Alisios más débiles
Menor surgencia en Pac. Oriental
Aumento de evaporación (LE)
Energía sale del océano
Atmosfera distribuye la energía globalmente

Analogía con ENSO...

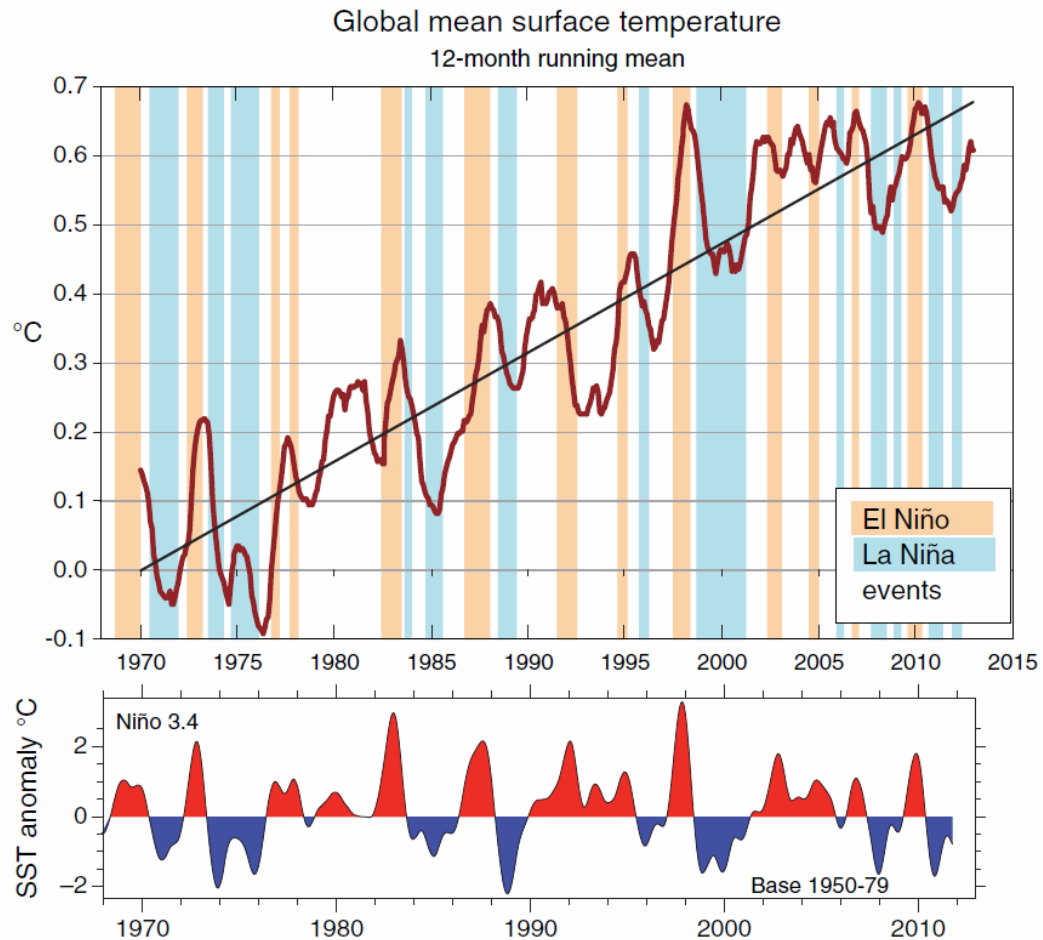


Figure 6. The NOAA global mean 12 month running mean surface temperatures are given relative to 1901–2000 along with a linear trend fit. Marked on the graph are the El Niño (buff) and La Niña (sky blue) periods as defined by NOAA's ONI, based on the Niño 3.4 SST anomalies, as given in the lower panel relative to a base period of 1950–1979.

Sospechoso #1: Fase fría de la PDO

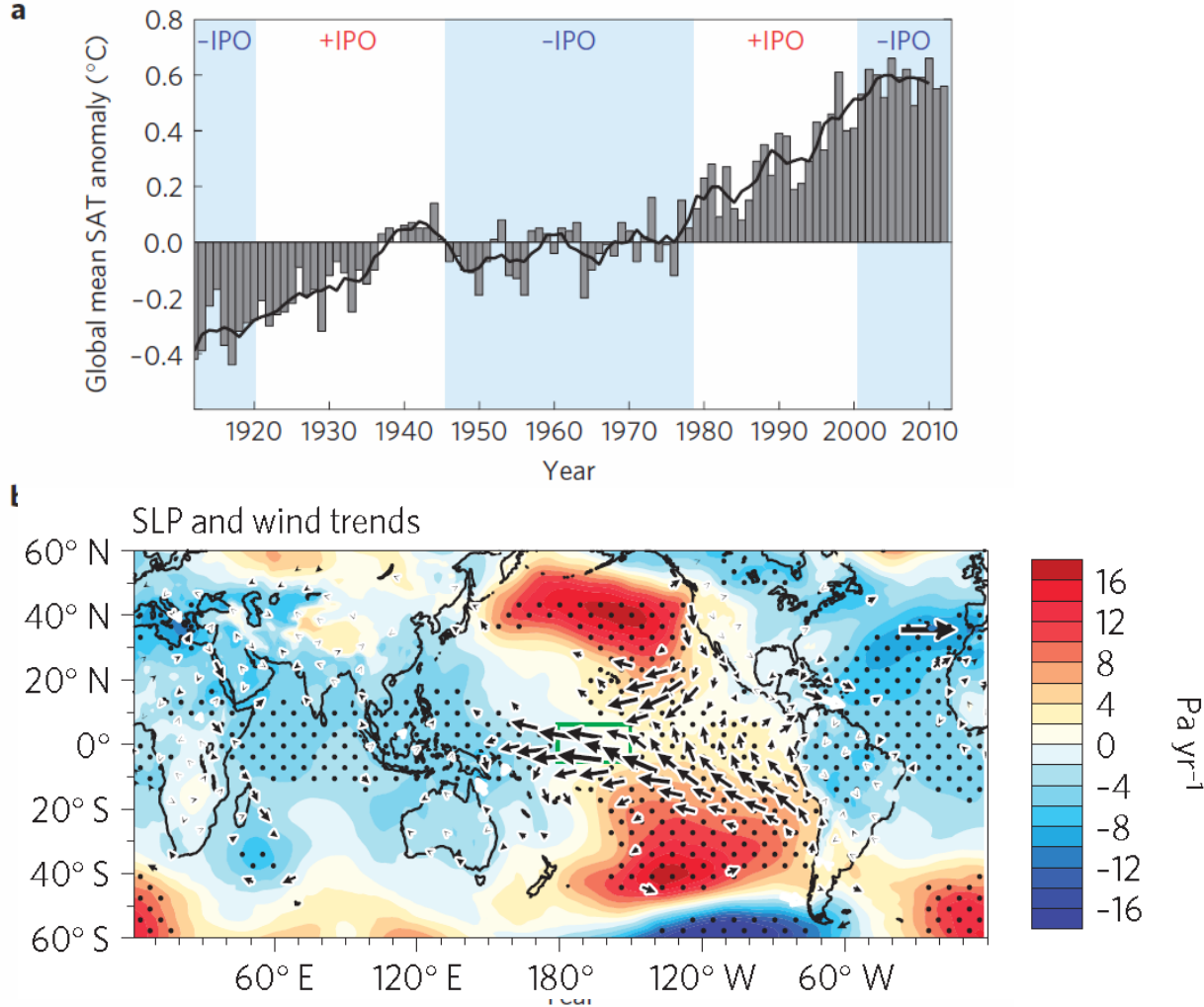


Figure 1 | Global average SAT and Pacific trade wind anomalies over the past century. a, Temperature anomalies are shown as the annual mean

Sospechoso #1: Fase fría de la PDO

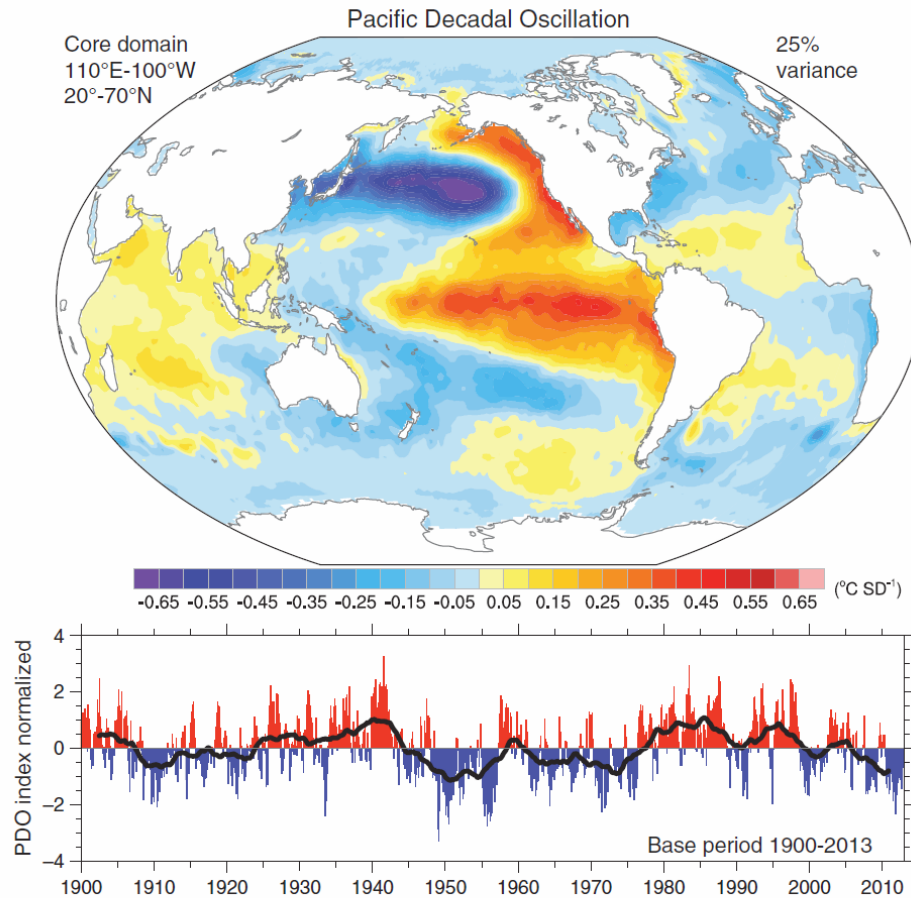


Figure 8. The Pacific Decadal Oscillation based on an EOF analysis of SST anomalies with the global mean removed from 1900 to May 2013 in the 20°N–70°N and 110°E–100°W region of the North Pacific, which explains 25% of the variance. The principal component time series, given below in normalized units, is regressed on global SSTs to give the map above. The black curve is a 61 month running average.

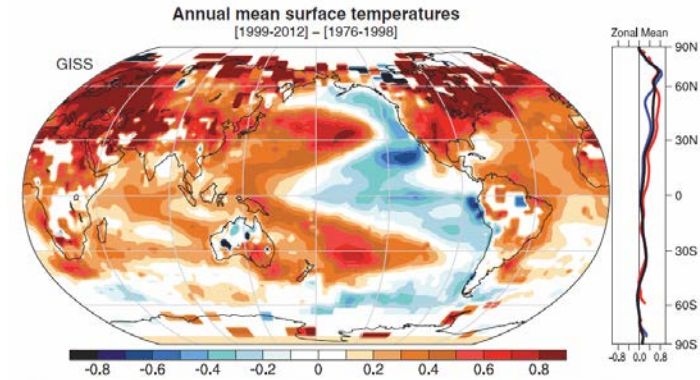


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Sospechoso #1: Fase fría de la PDO

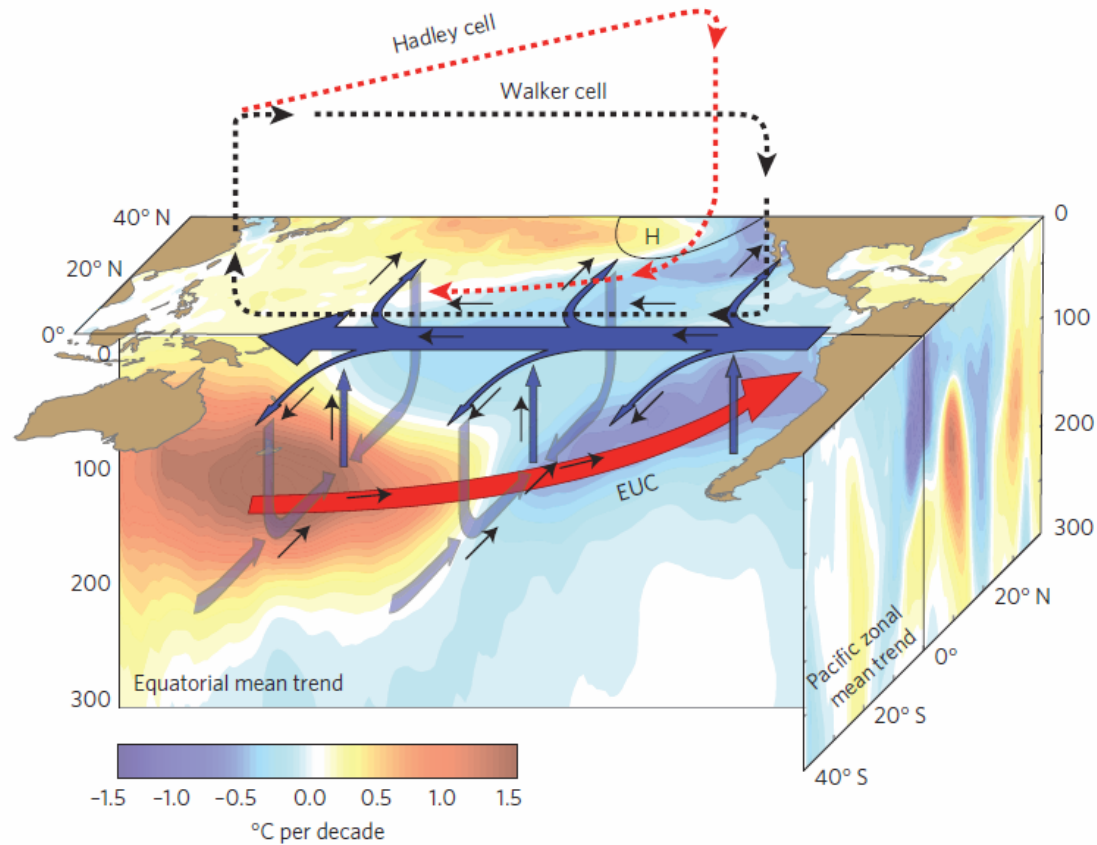
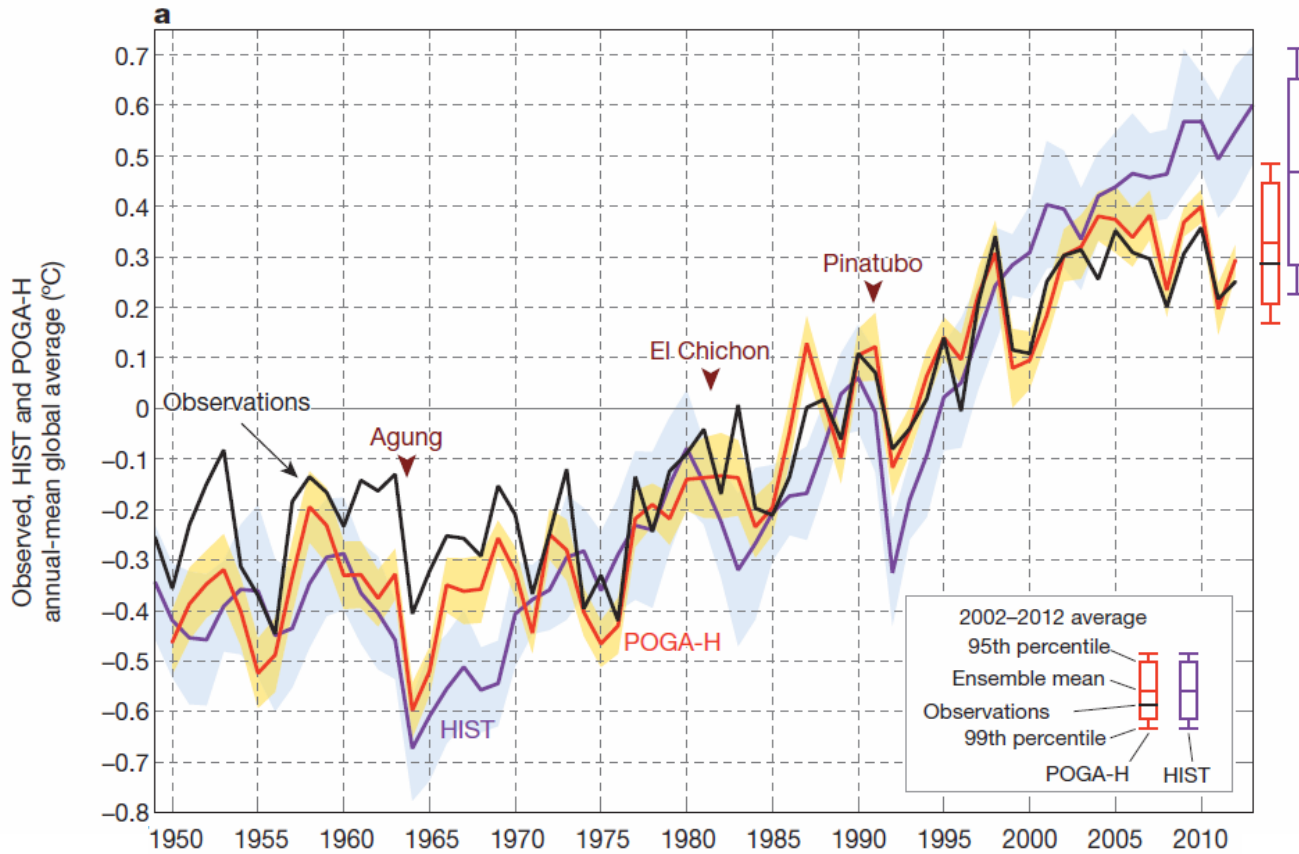


Figure 3 | Schematic of the trends in temperature and ocean-atmosphere circulation in the Pacific over the past two decades. Colour shading shows

El golpe final...

En simulación POGA-H se prescribe SST en Pac. Central ecuatorial (8% del planeta) + forzamiento radiativo (GEI)



El golpe final...

En simulación POGA-H se prescribe SST en Pac. Central ecuatorial (8% del planeta) + forzamiento radiativo (GEI)

Obs

POGA-H

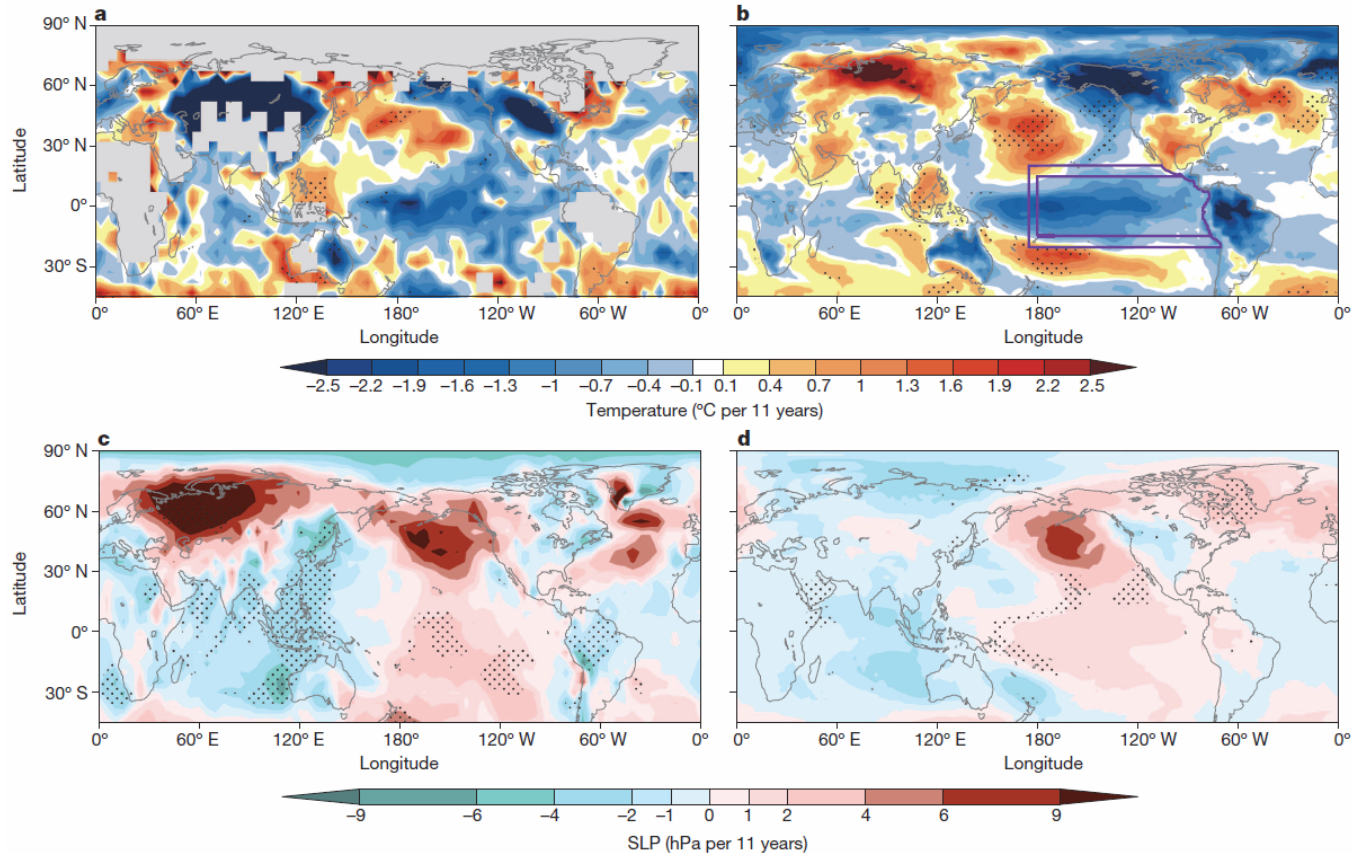
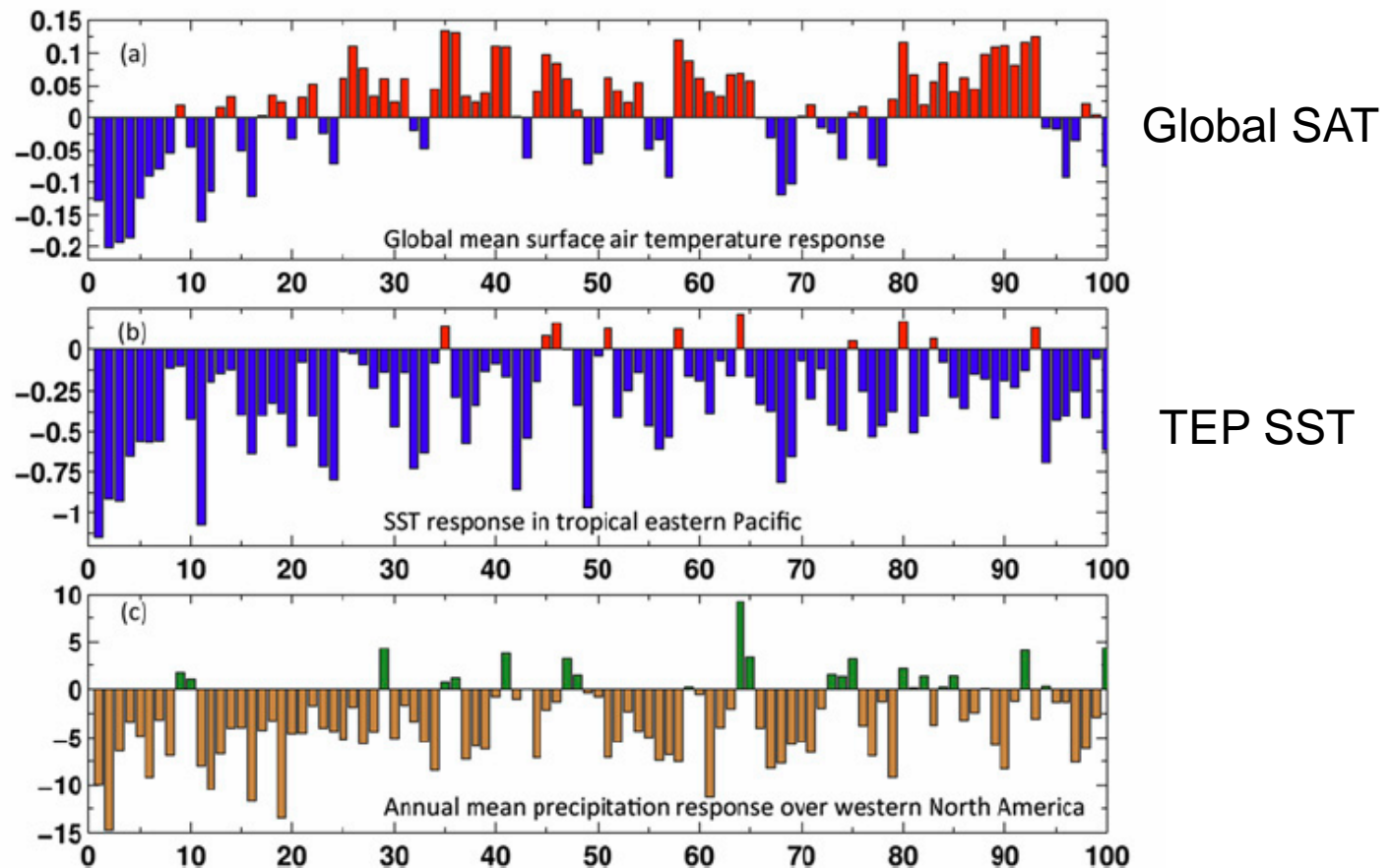


Figure 2 | Observed and simulated trend patterns in boreal winter for 2002–2012. a and b show near-surface temperature and c and d show SLP from observations (a and c) and POGA-H (b and d) in DJF. Grey shading represents

missing values. Stippling indicates regions exceeding 95% statistical confidence. Purple boxes in b show the restoring region of POGA experiments.

Y como viene la mano?

Respuesta de TSM a un incremento sostenido de alisios sobre el Pac. Tropical versus simulacion control (solo forzamiento GEI)



Mientras tanto otras cosas han pasado...

Desde (al menos) comienzos de los 80's se constata:

- Expansión de la **Celda de Hadley** en ambos hemisferios entre 1-2° de latitud / 30 años (OLR, Precipitación, Función de corriente, PNM, Tropopausa tropical...).
- Desplazamiento hacia el sur de la **corriente en chorro subtropical** en el HS
- Tendencia hacia la **polaridad positiva de SAM/AAO** con una caída de presiones sobre Antártica y un aumento de presiones en torno a los 40°S

Cual es el origen de estos cambios?

Tropical/extratropical?

Natural/Forzado?

Expansión de la Celda de Hadley

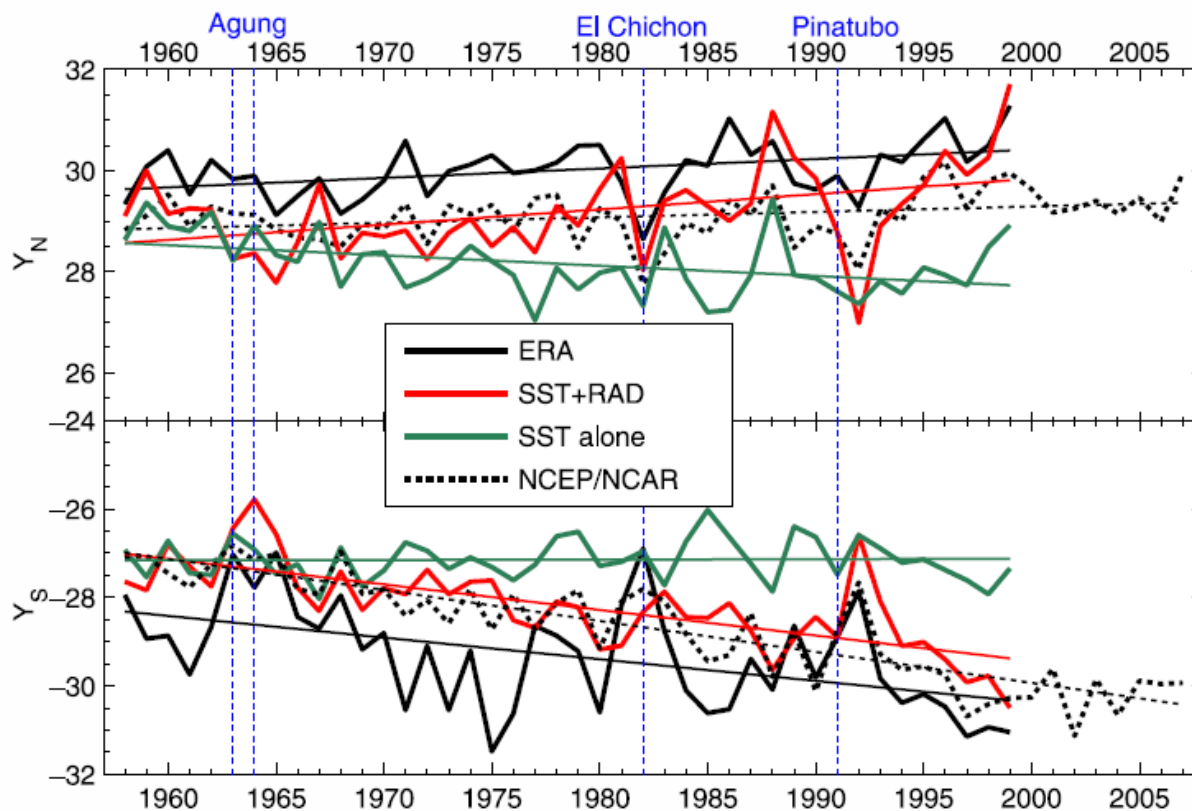


Figure 2. Annual time series of the location of the tropical edges, defined as the latitudes where days with tropopause pressures <120 hPa (heights >15 km) exceed 200 days per year. Estimates are from ERA40 (black) and NCEP/NCAR (dashed black) reanalysis data, and from the *SST* (green) and *SST+RAD* (red) simulations. The years of major volcanic eruptions are also indicated.

Expansión de la Celda de Hadley

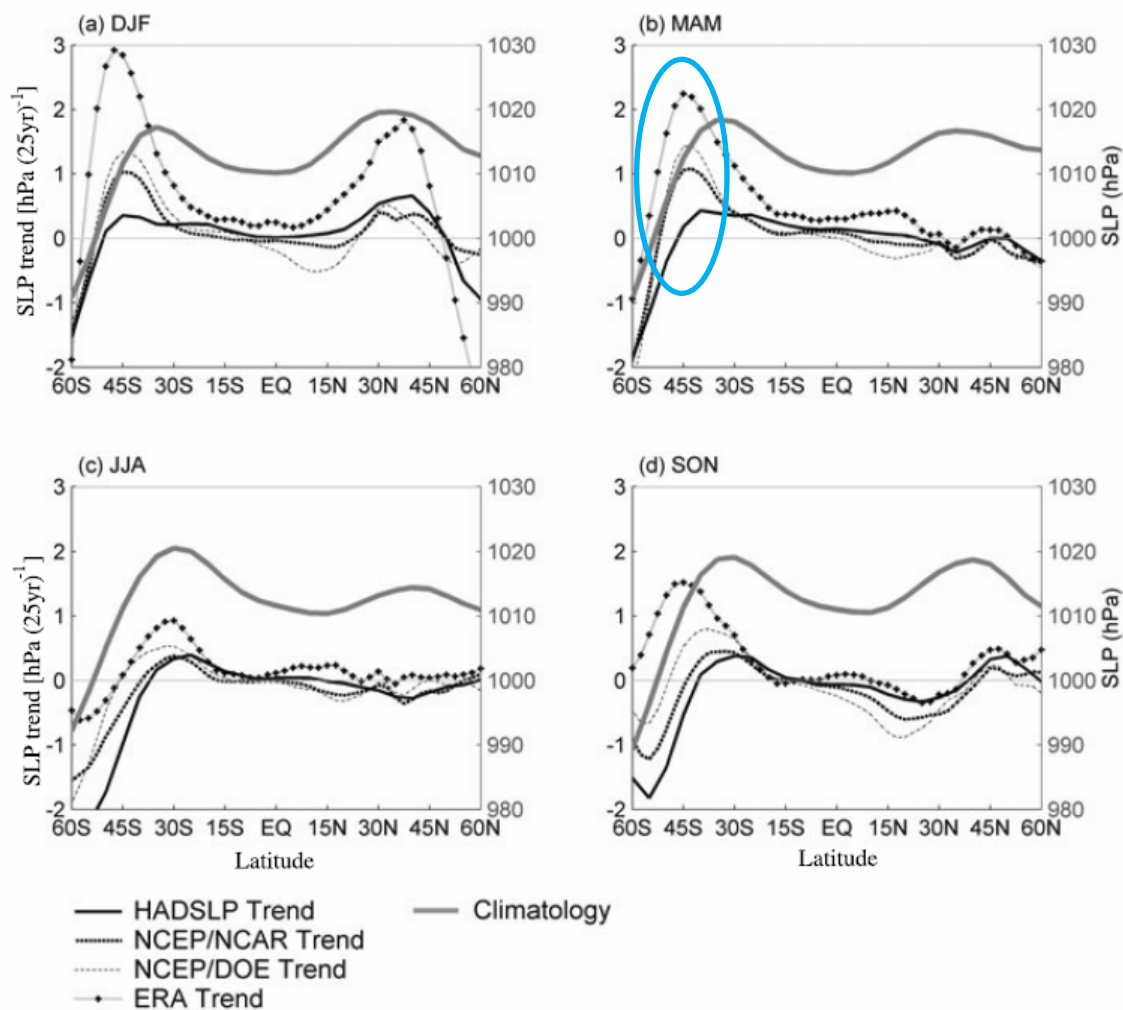


Fig. 7. Trends in annual and zonal mean SLP over the period 1980–2007. SLP trends from different datasets are marked with different styles of lines, as shown in the plots. Climatological zonal-mean precipitation is also plotted (thick gray line). The left y -axis is for trends, and the right y -axis for climatology.

Expansión de la Celda de Hadley

Modelos sugieren un forzamiento radiativo y escasa contribución de la TSM tropical (natural)

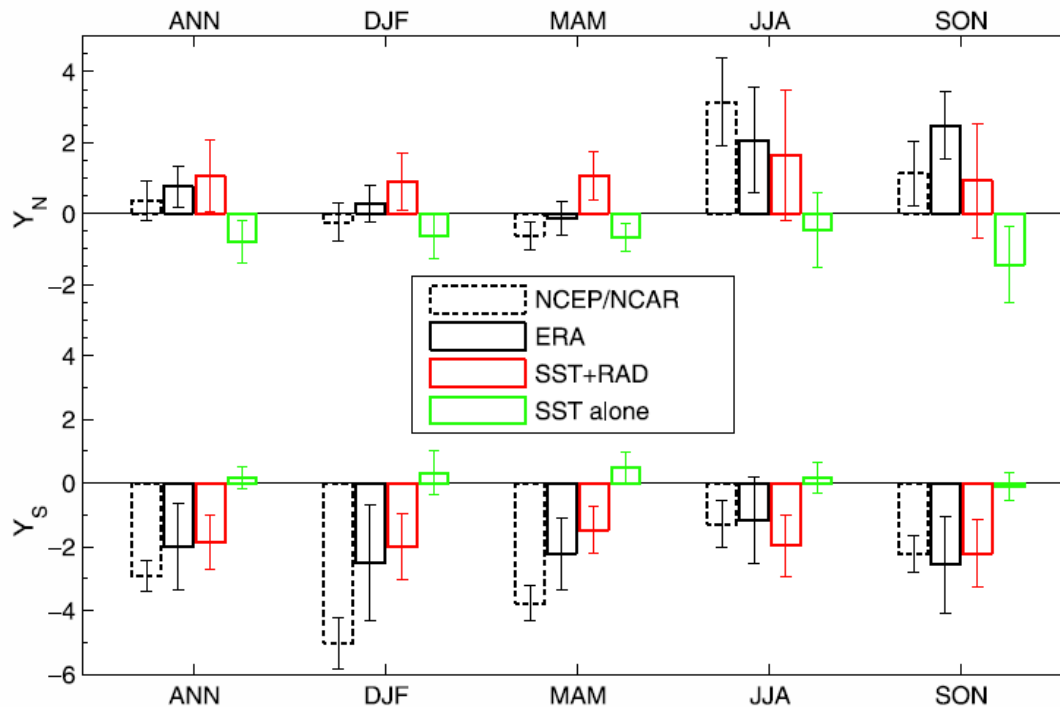


Figure 3. Linear trend (1958–1999) in the latitude of the tropical edge for the (top) northern and (bottom) southern hemisphere and their corresponding 95% confidence intervals (error bars). Results are based on ERA40 (solid black) and NCEP/NCAR (dashed black) reanalysis data, and on the *SST* (green) and *SST+RAD* (red) simulations.

Tendencia hacia polaridad positiva de SAM/AAO

Modelos sugieren un forzamiento radiativo
y escasa contribución de forzantes naturales

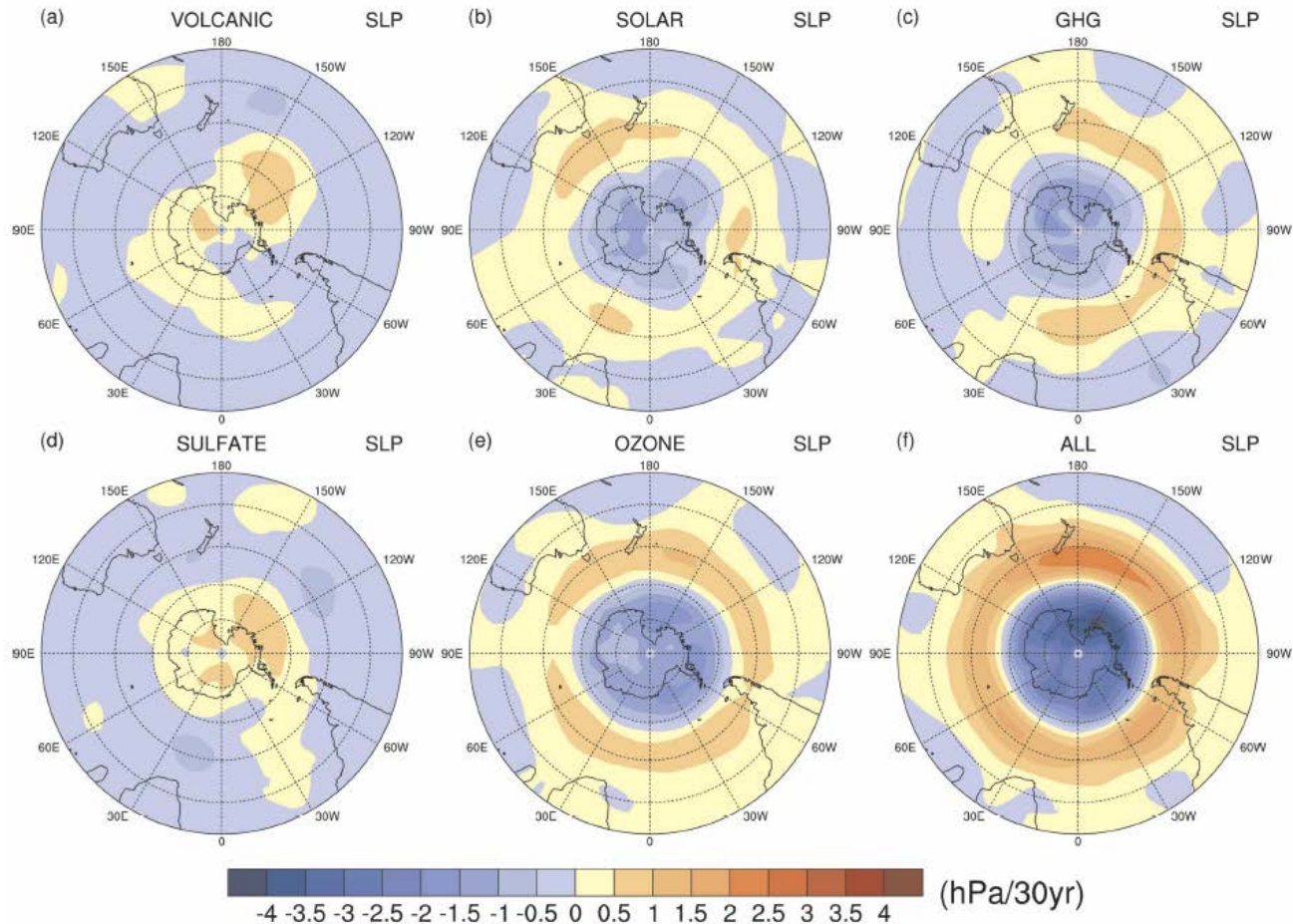
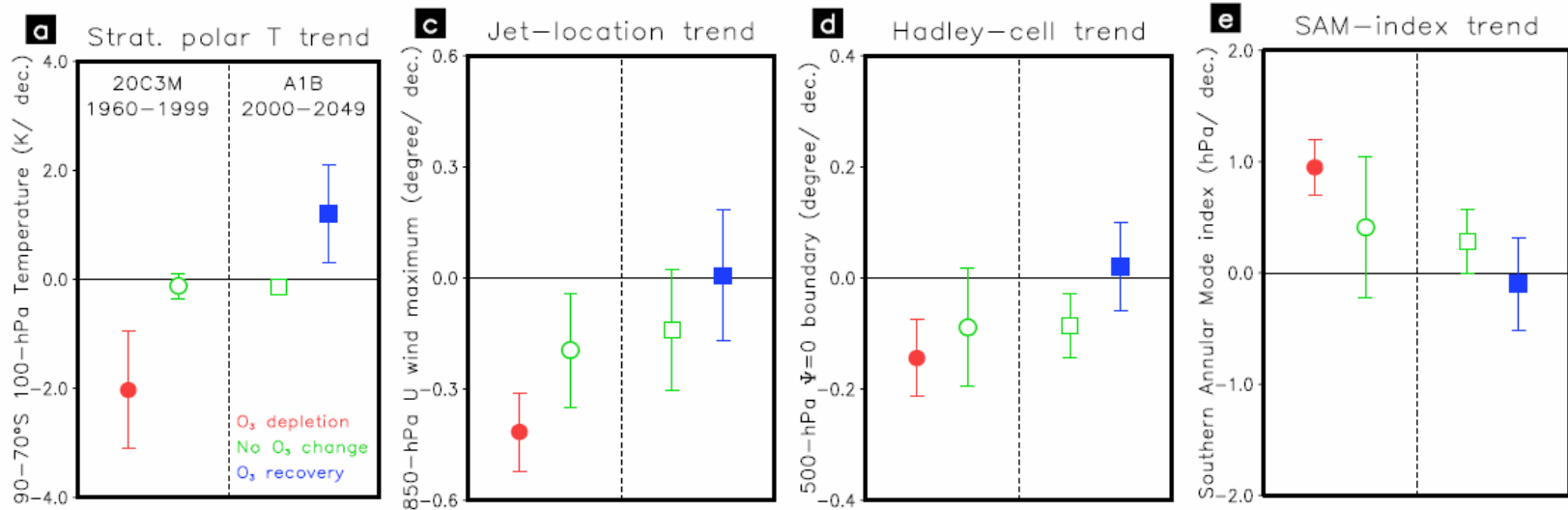


FIG. 1. Ensemble mean DJFAM sea level pressure trends ($\text{hPa } 30 \text{ yr}^{-1}$) for the period of 1958–99 of the (a) volcanic, (b) solar, (c) GHGs, (d) sulfate aerosols, (e) ozone, and (f) all-forcings simulations from the PCM.

Expansión de la Celda de Hadley / Tendencia SAM

Forzado por aumento de GEI y disminución de Ozono debido a cambios de estabilidad atmosférica y comportamiento de ondas baroclinicas

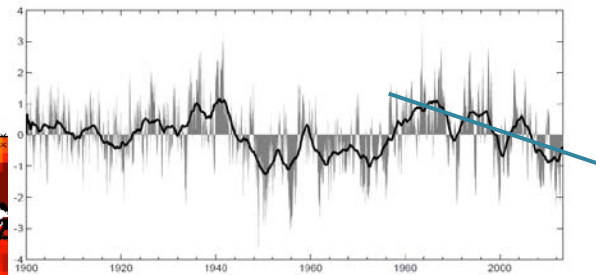
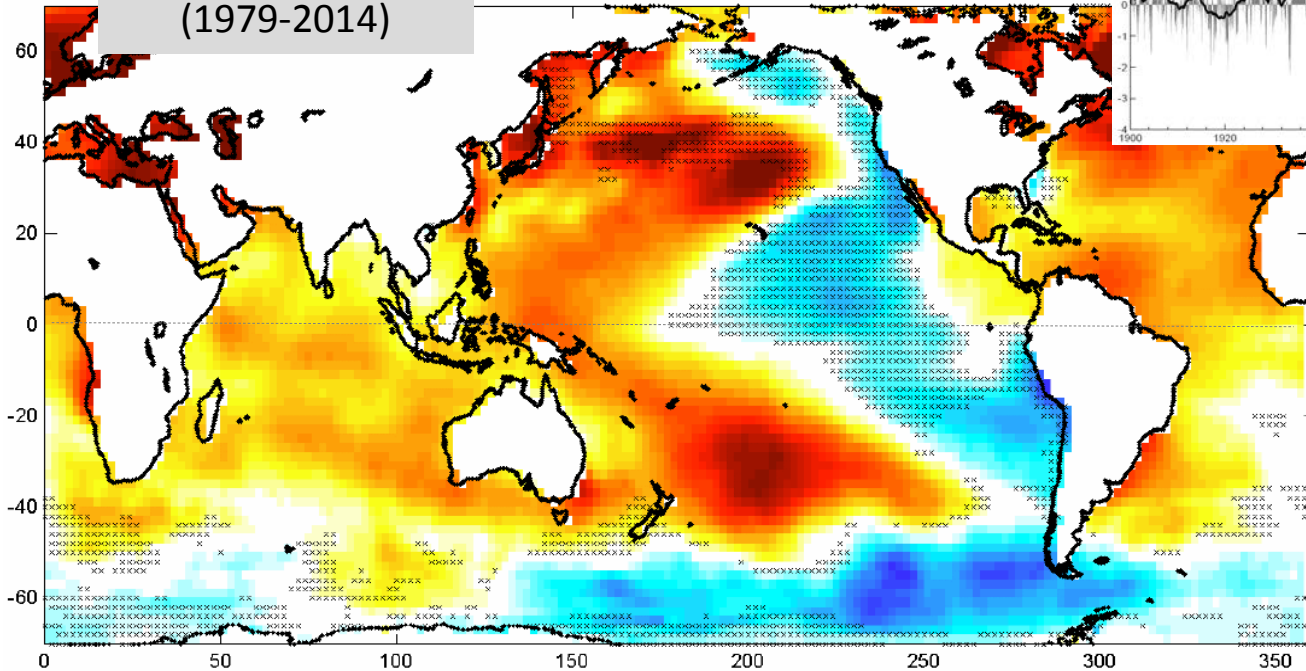


denote poleward shift in westerly jet and poleward expansion of the Hadley cell. The linear trends are computed for the time period of 1960–1999 in the 20C3M integrations (circles) and for the time period of 2000–2049 in the A1B scenario integrations (squares), and separately shown for models with (red, blue) and without time-varying stratospheric ozone (green).

Regresemos al enfriamiento del Pacifico Suroriental

Al sur de los 20°S, la tendencia congruente con la PDO explica menos del 50% de la tendencia observada...algo mas esta pasando...respuesta forzada (antropogénica)?

OI-SST linear trend
(1979-2014)

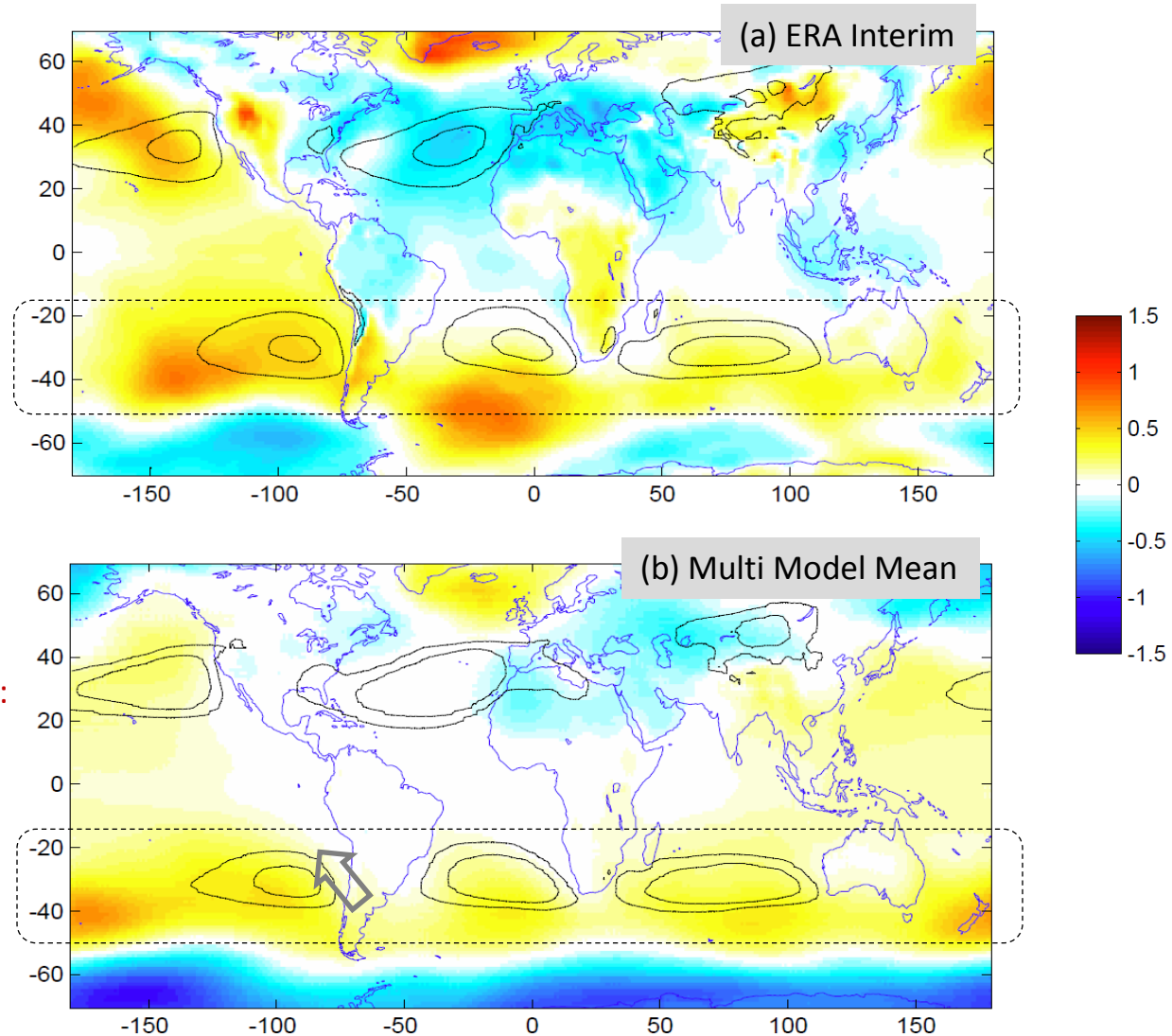


PDO time series

x: $[\delta\text{SST congruent with PDO}] / [\delta\text{SST observed}] \geq 0.5$

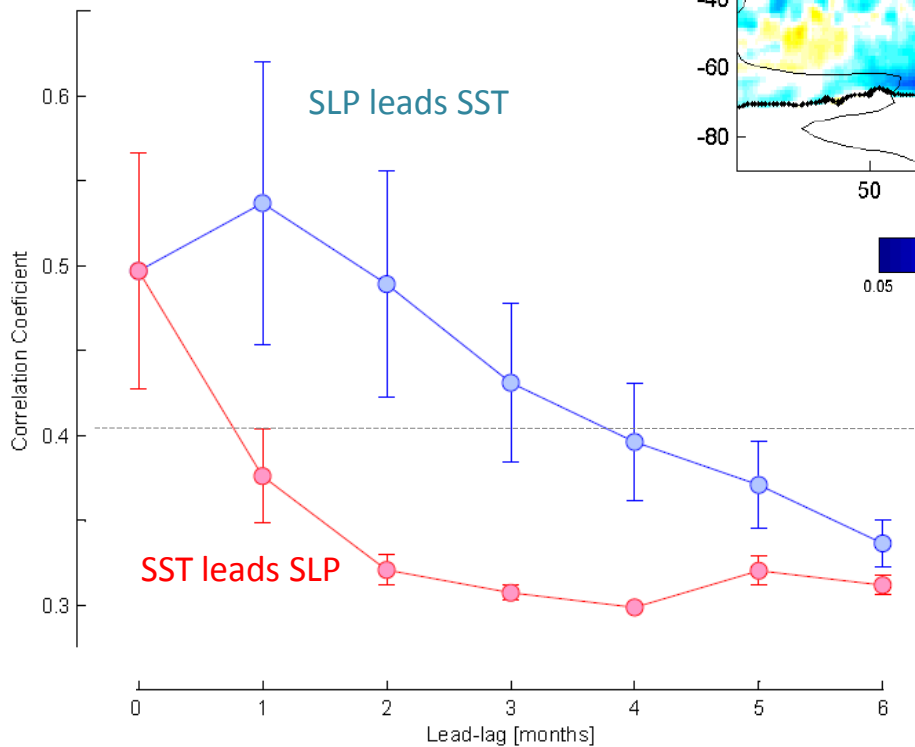
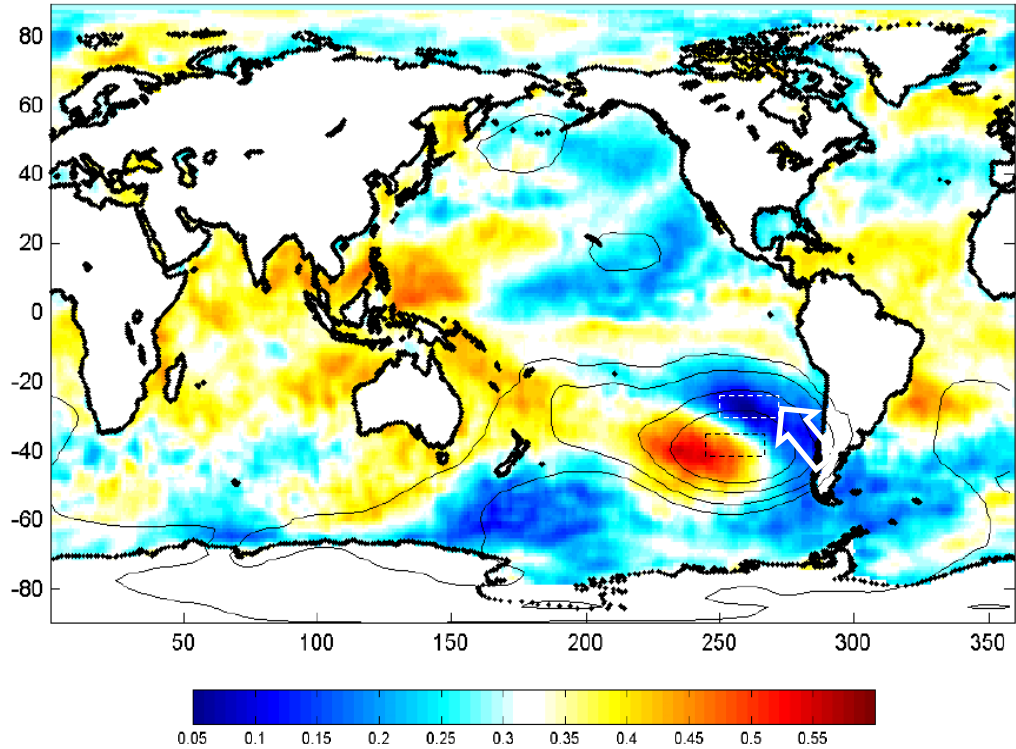
Tendencia observadas/simuladas PNM 1979-2005

Tendencia tipo-SAM/Exp. Hadley de los modelos (respuesta forzada) se proyecta razonablemente en tendencias observadas (magnitud: 0.5)



Correlation coefficients AI-OISST (colors) and AI-SLP (contours) . Seasonal cycle and ENSO removed, 0-lag

δ SLP en el Pac. Sur (40°S) puede forzar enfriamiento subtropical? Observaciones

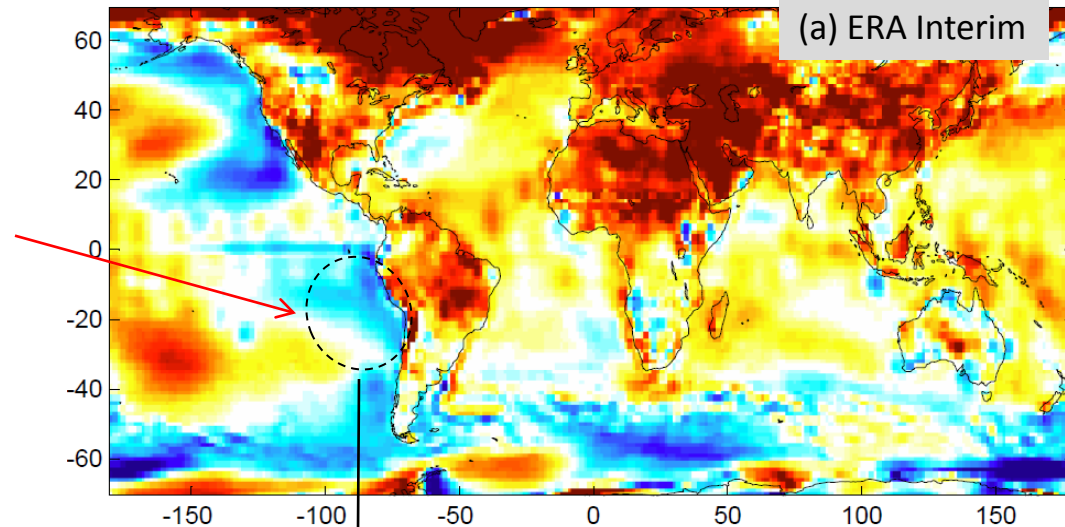


Incremento del PNM
 Aumento de los vientos SE
 Aumento de surgencia
 Aumento de calor latente
 Enfriamiento de la sfc. del mar

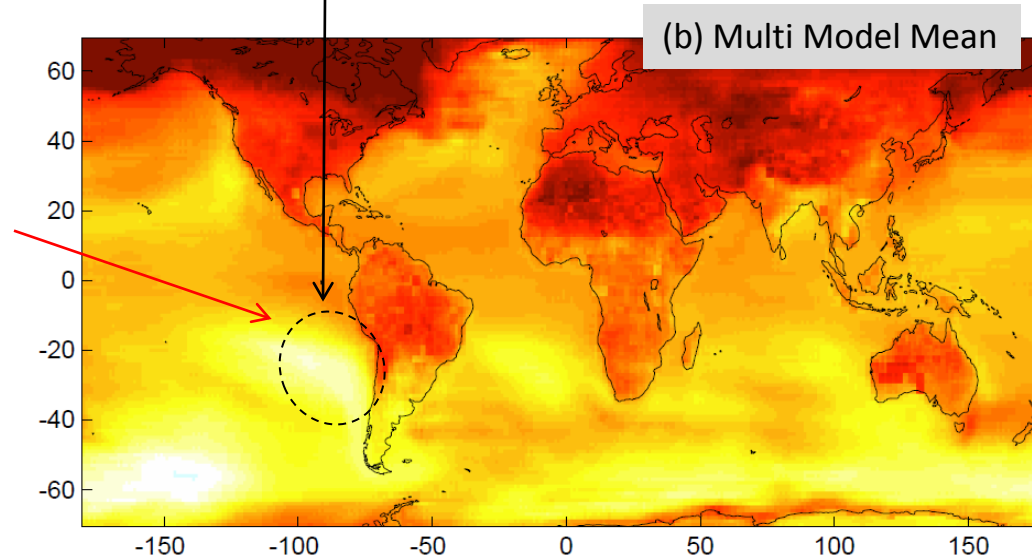
Tendencia observadas/simuladas SST/SAT 1979-2005

Ok...modelos CMIP5 (22) no reproducen enfriamiento en PSO pero si indican un mínimo de calentamiento...

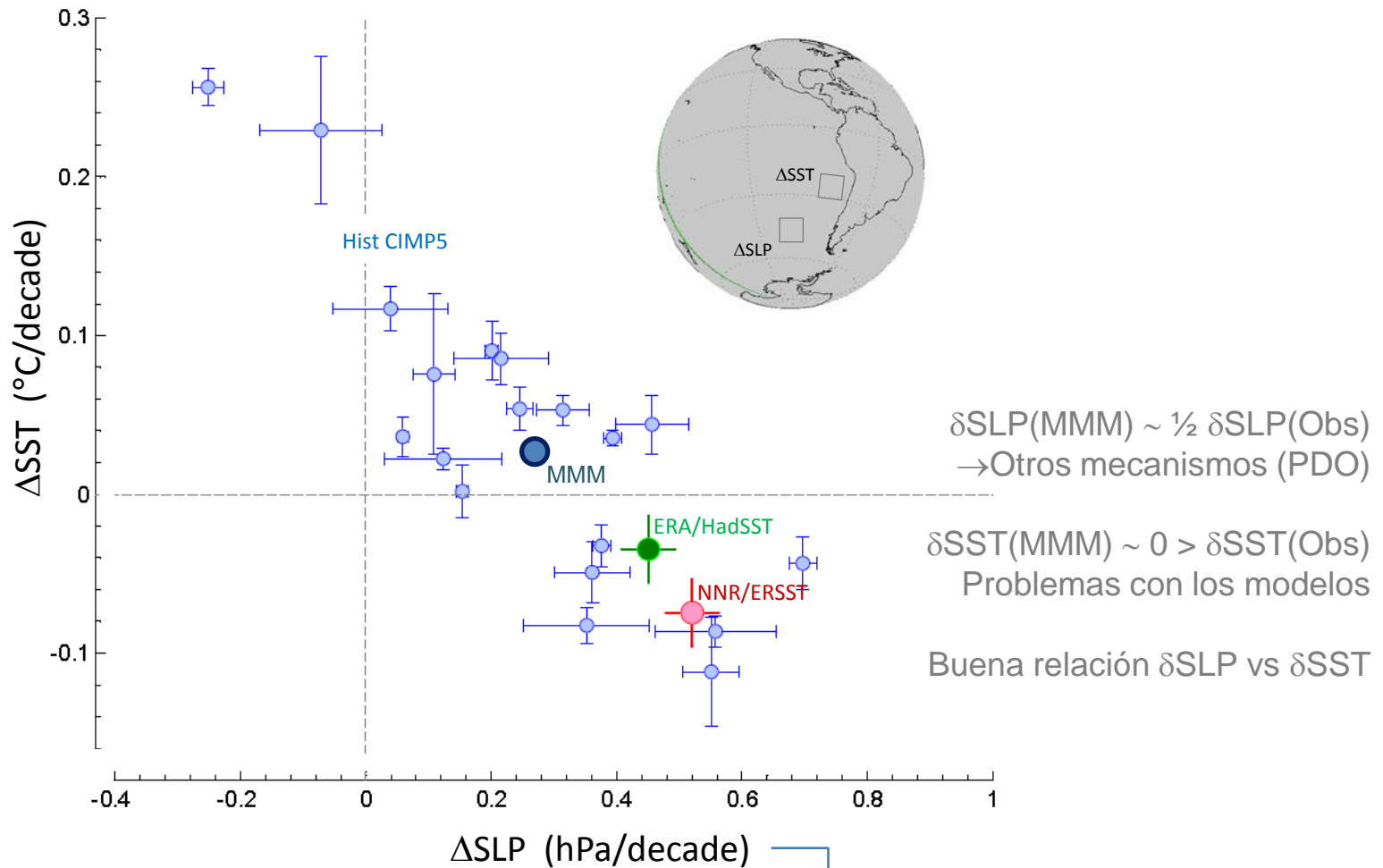
Obs.: Var. Natural +
Forzamiento Radiativo



Promedio Multi modelo
(22): Respuesta forzada



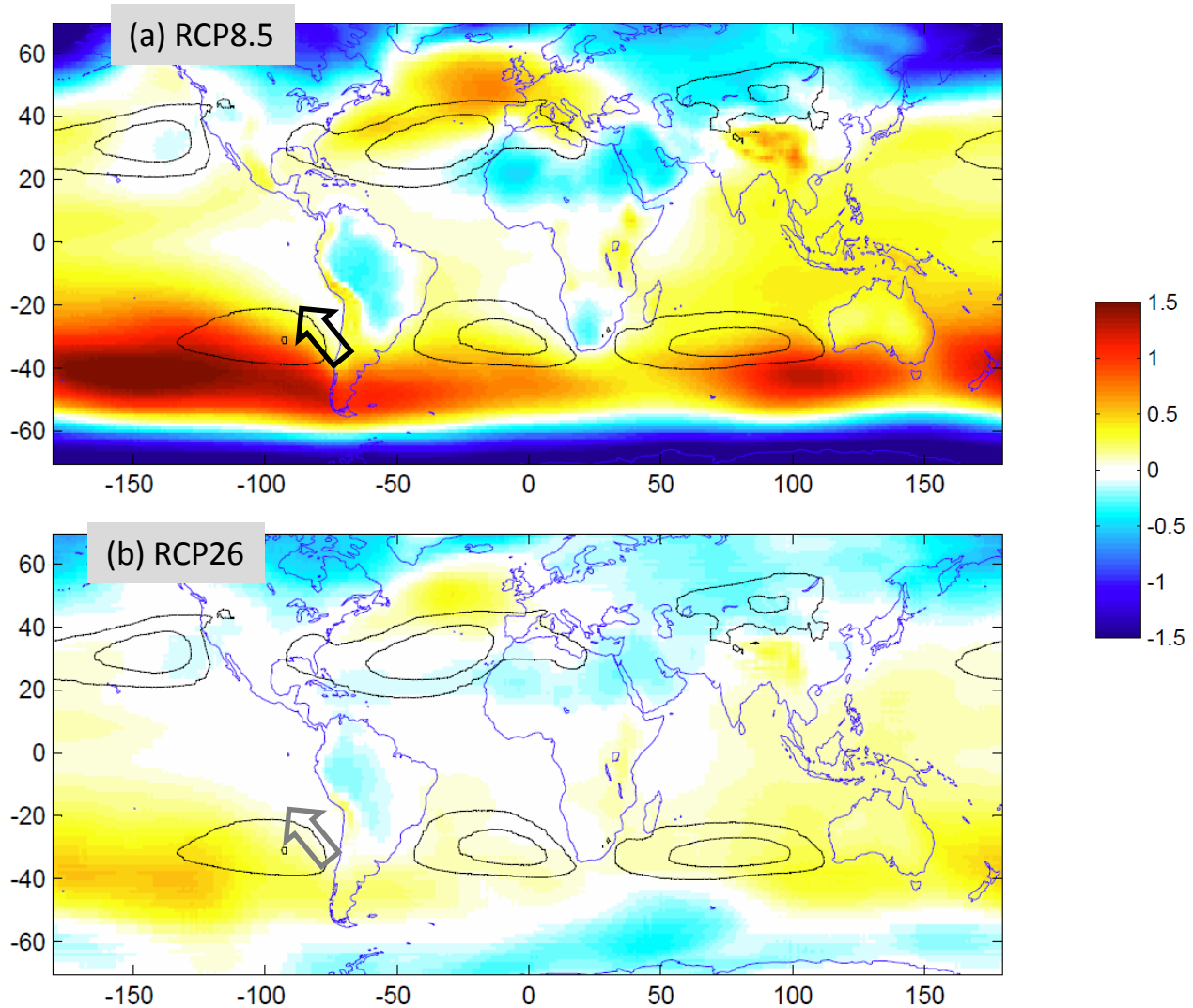
Desplazamiento del Anticiclón y enfriamiento oceánico: Tendencias observadas y simuladas 1979-2005



De que depende $dSLP$?

Desplazamiento del Anticiclón en el futuro

Promedio multi-modelo del cambio de PNM futuro (2080-2100) menos presente (1980-2000): Mayor en escenario con mas GEI

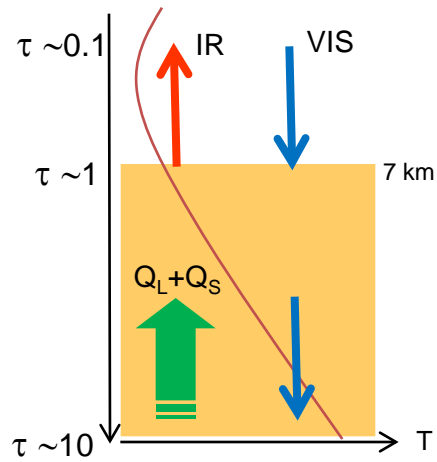


Conclusiones I

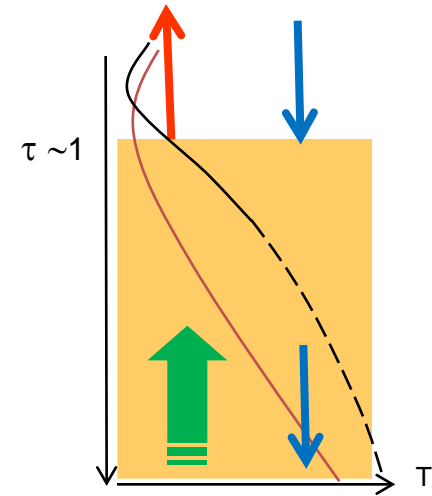
Cambio Climático →

→ *Calentamiento Global*

CO₂: 280 ppm
Equil. actual



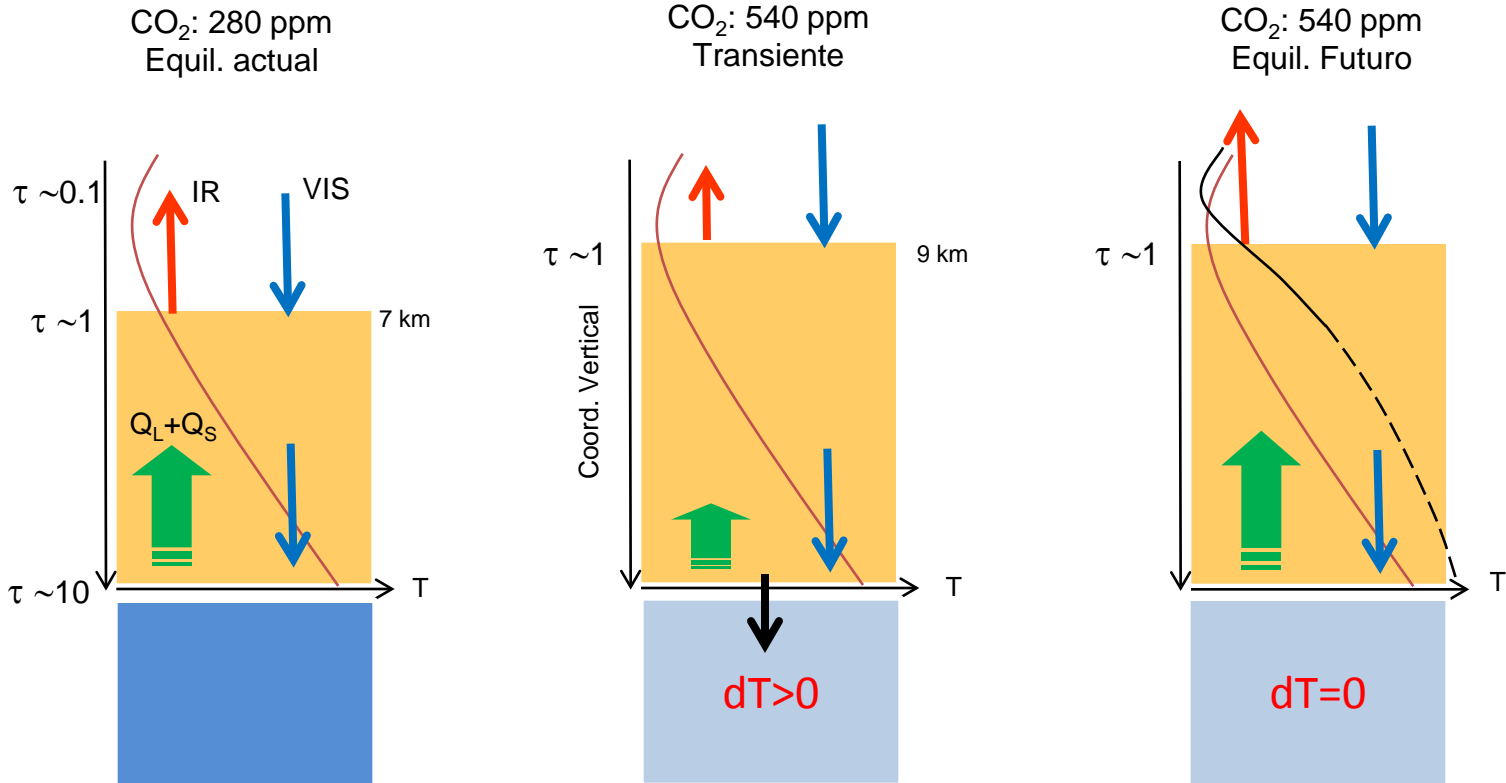
CO₂: 540 ppm
Equil. Futuro



$$\tau_\lambda = \int_z^\infty k_\lambda \rho \cdot dz$$

Conclusiones I

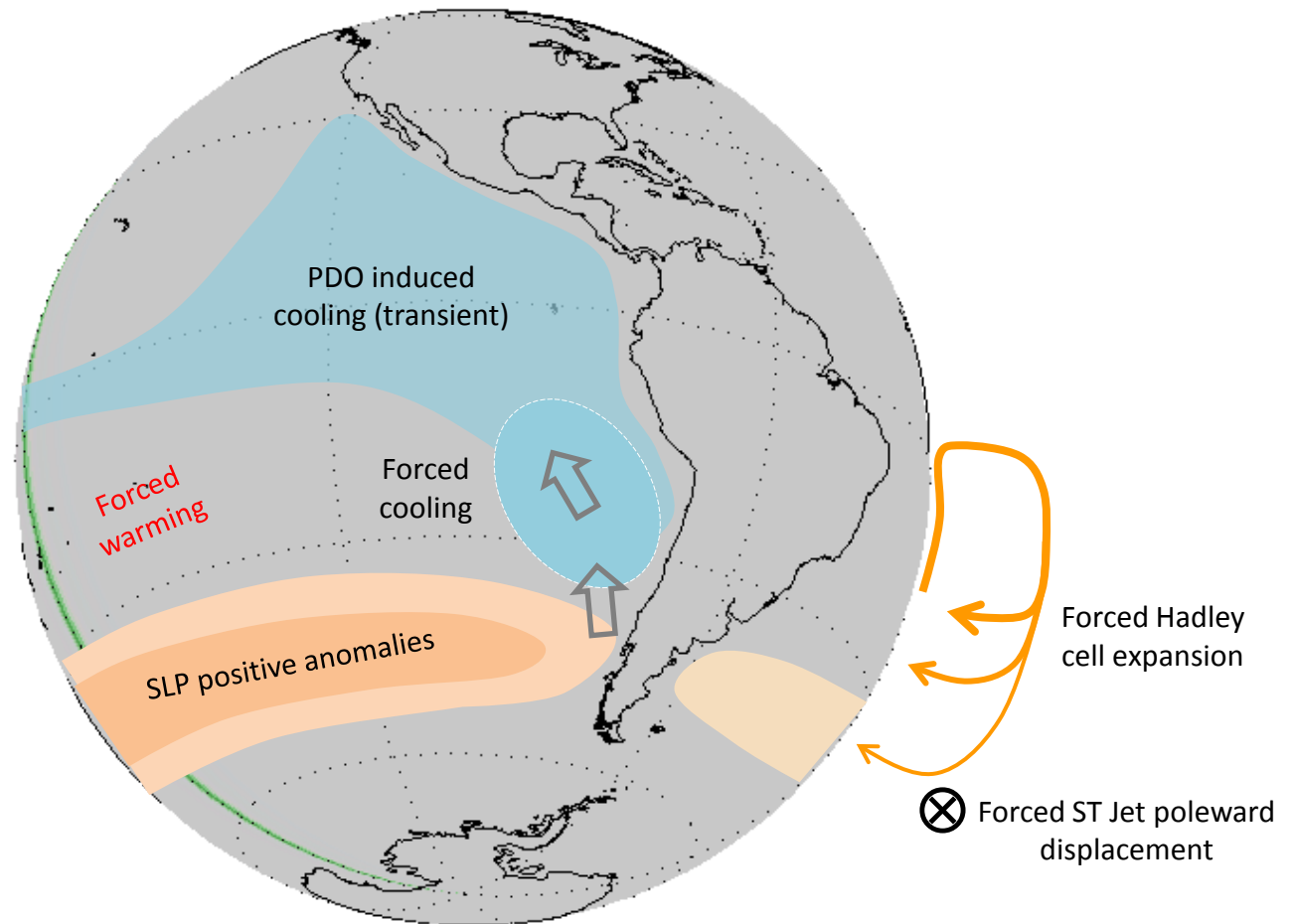
Cambio Climático → Energización Global → *Calentamiento Global*



$$\tau_{\lambda} = \int_z^{\infty} k_{\lambda} \rho \cdot dz$$

Conclusiones II

Actual tendencia al enfriamiento en Pacífico suroriental producto del incremento de los vientos del SE (surgencia y evaporación), el cual resulta de superposición de fase fría de la PDO y forzamiento radiativo.



Conclusiones III

Si quiere publicar en Nature Climate Change,
consiga un GCM y haga sus propios experimentos...

Y respecto a la pregunta del perro,
no olvide responder: “No eres tu, soy yo...”

V1: XII CONGREGMET, Mar del Plata, Argentina
27-31 Mayo 2015