

Cambio climático en Nor-Patagonia



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Mar Interior de Chiloé

Desafíos ante el cambio global

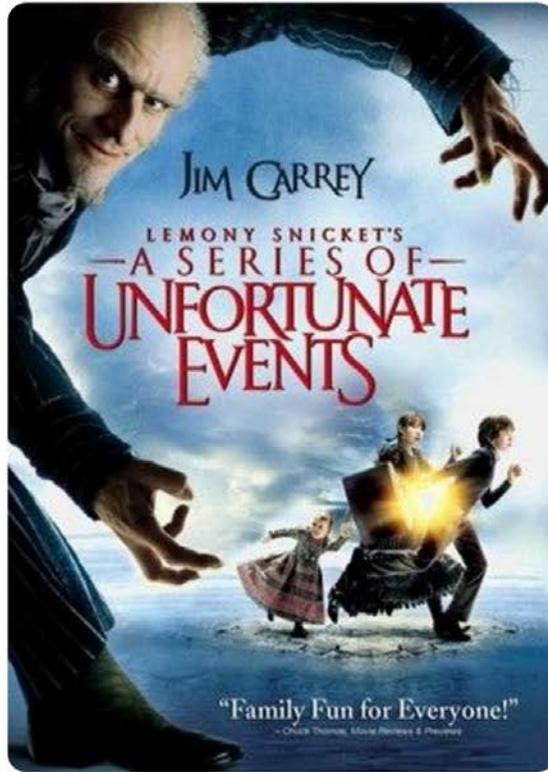
Julio 2017

Estructura

- Como llegamos a esto? (personal)
- Clima, variabilidad y cambio
- El terrible 2016
- El pasado reciente
- El futuro cercano
- La letra chica y comentarios finales

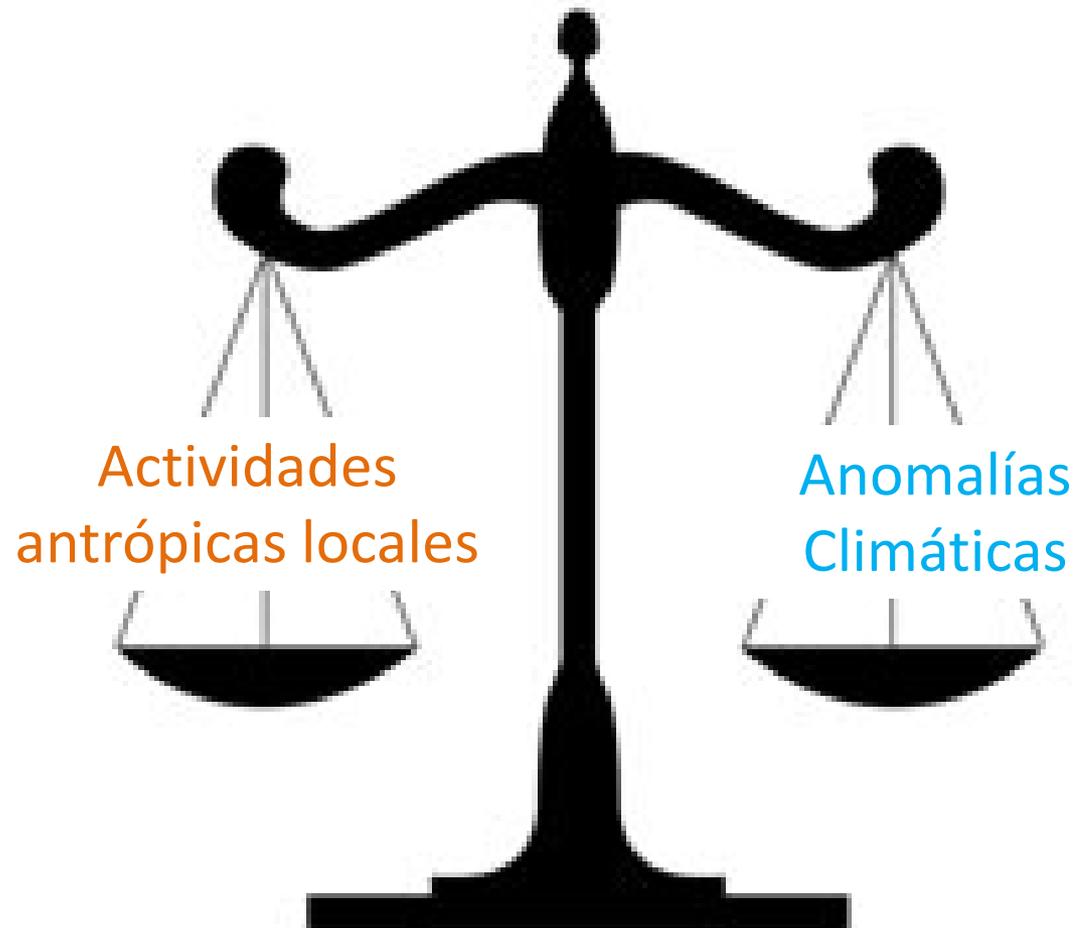
Para mi todo comenzó con un llamado telefónico en Abril del 2016



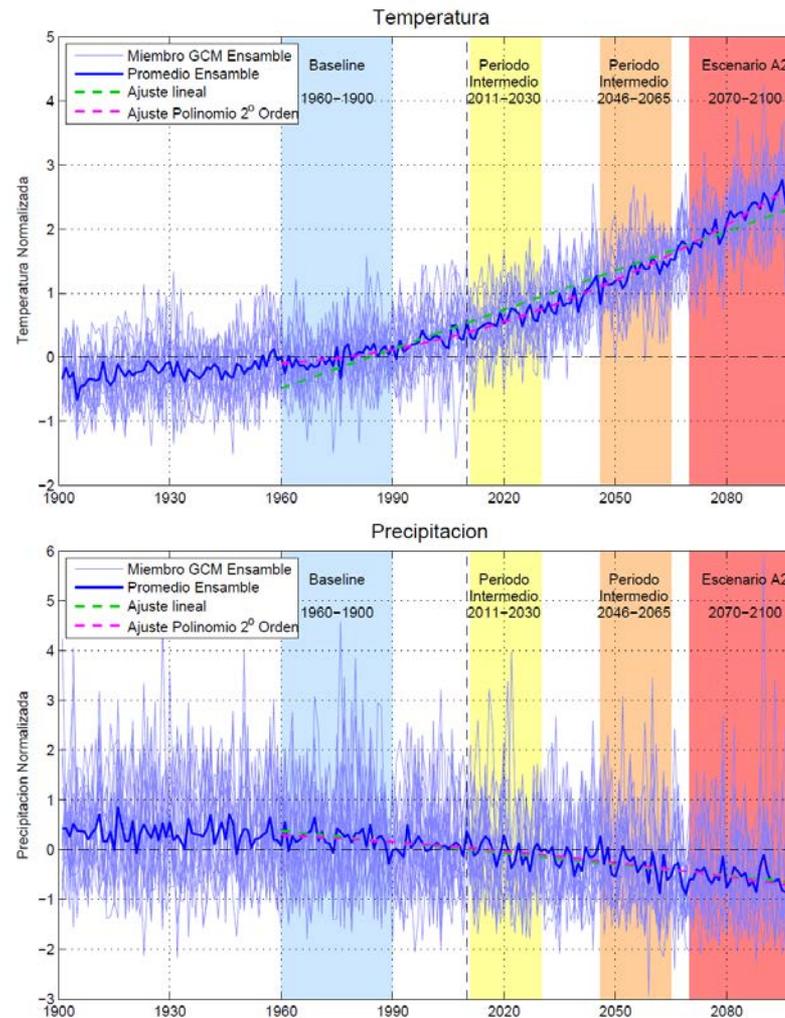


Cambios y extremos ambientales

→ Tensiones sociales

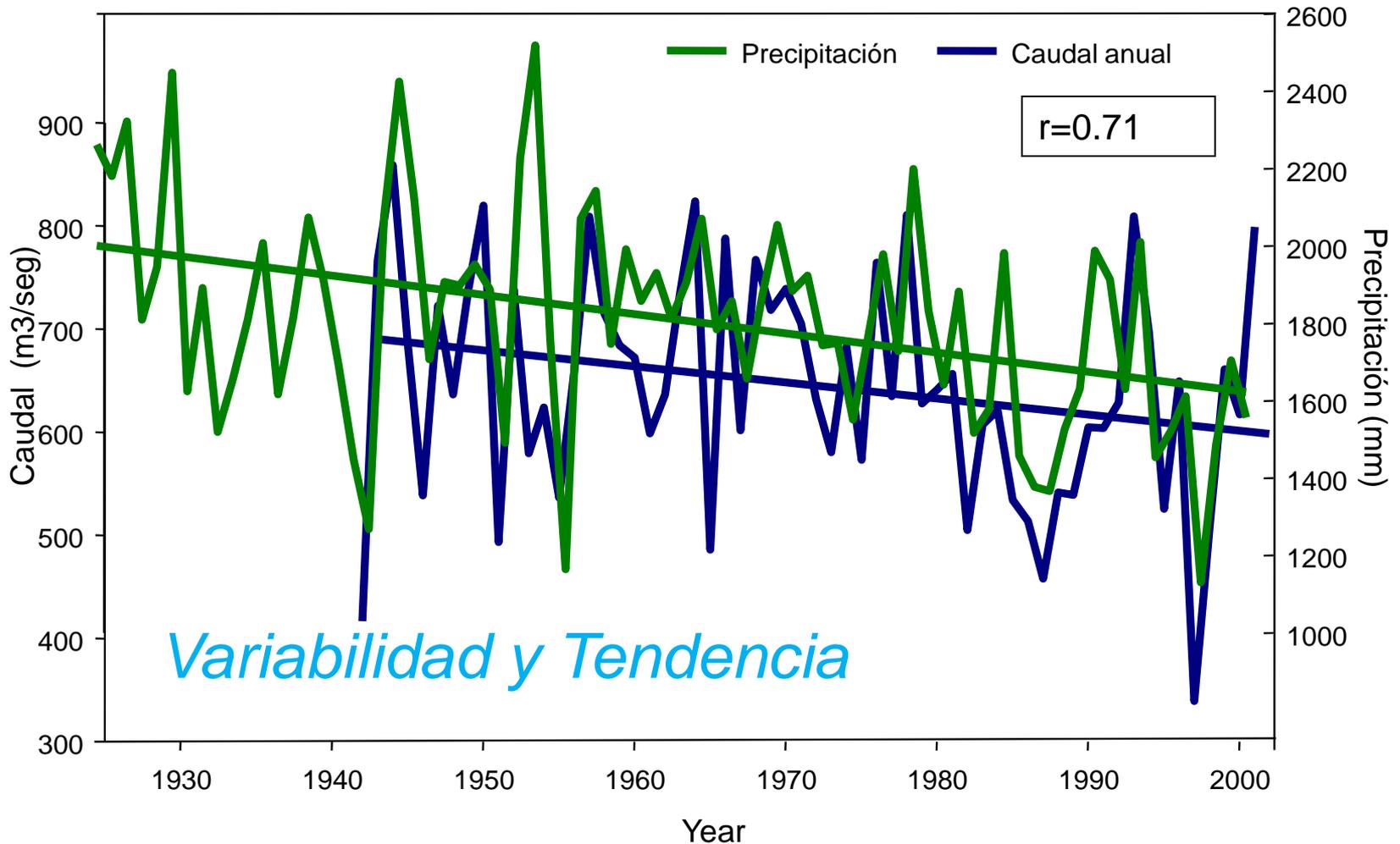


Proyecciones de Temperatura y precipitación para Chile centro-sur en base a ensemble multi-modelo CMIP3



Podemos terminar esta clase?

Comparación entre la precipitación de Puerto Montt y el caudal del Río Puelo (Fuente: Antonio Lara, UACH)

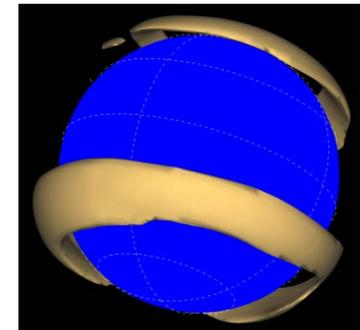
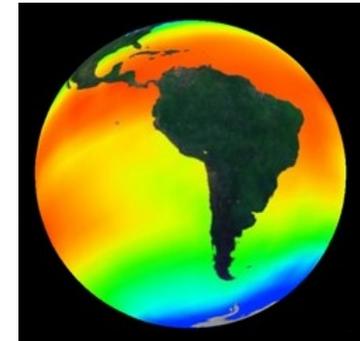


Cambios ambientales en Patagonia

→ Tensiones sociales

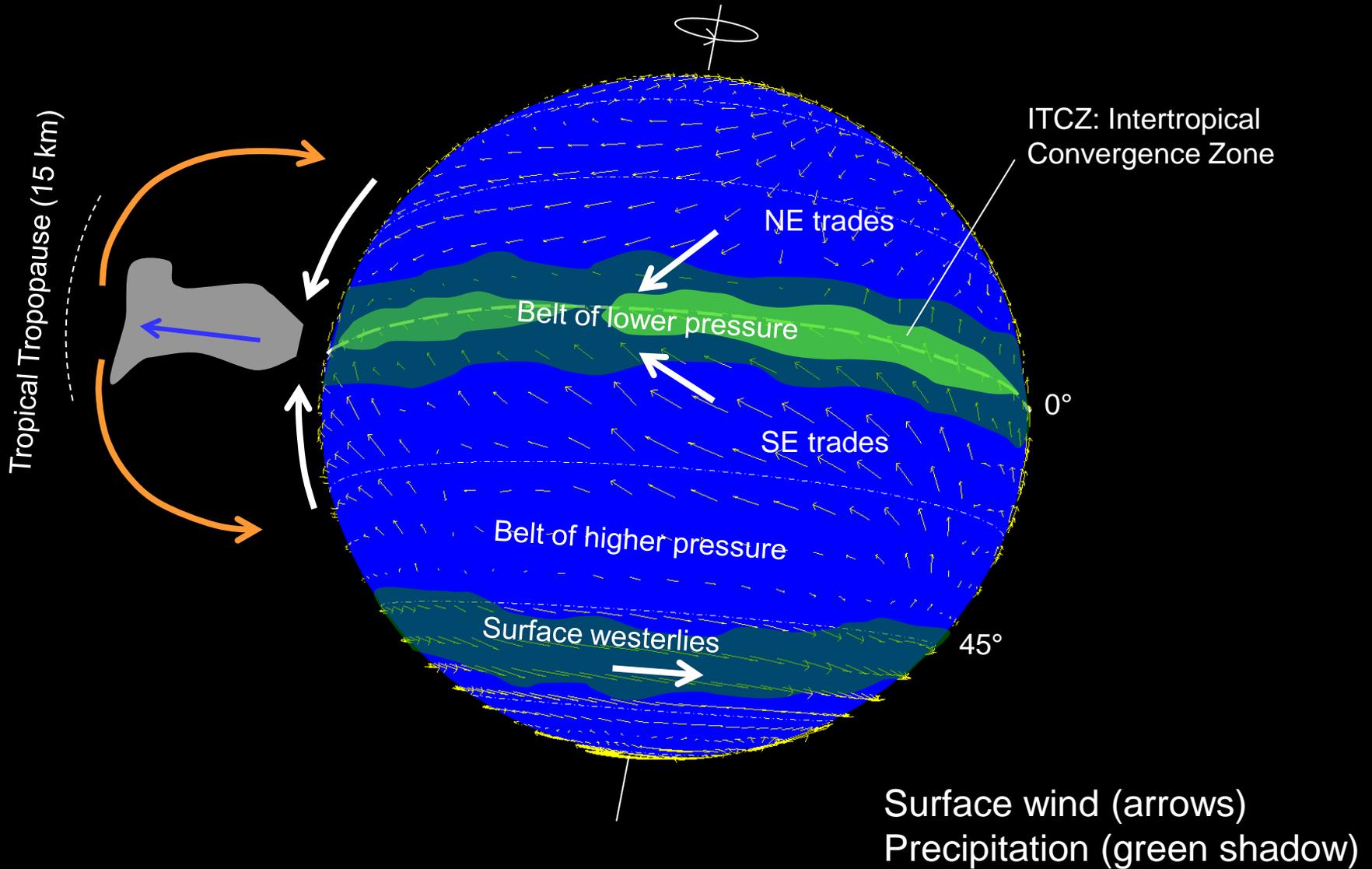


Actividades
antrópicas locales

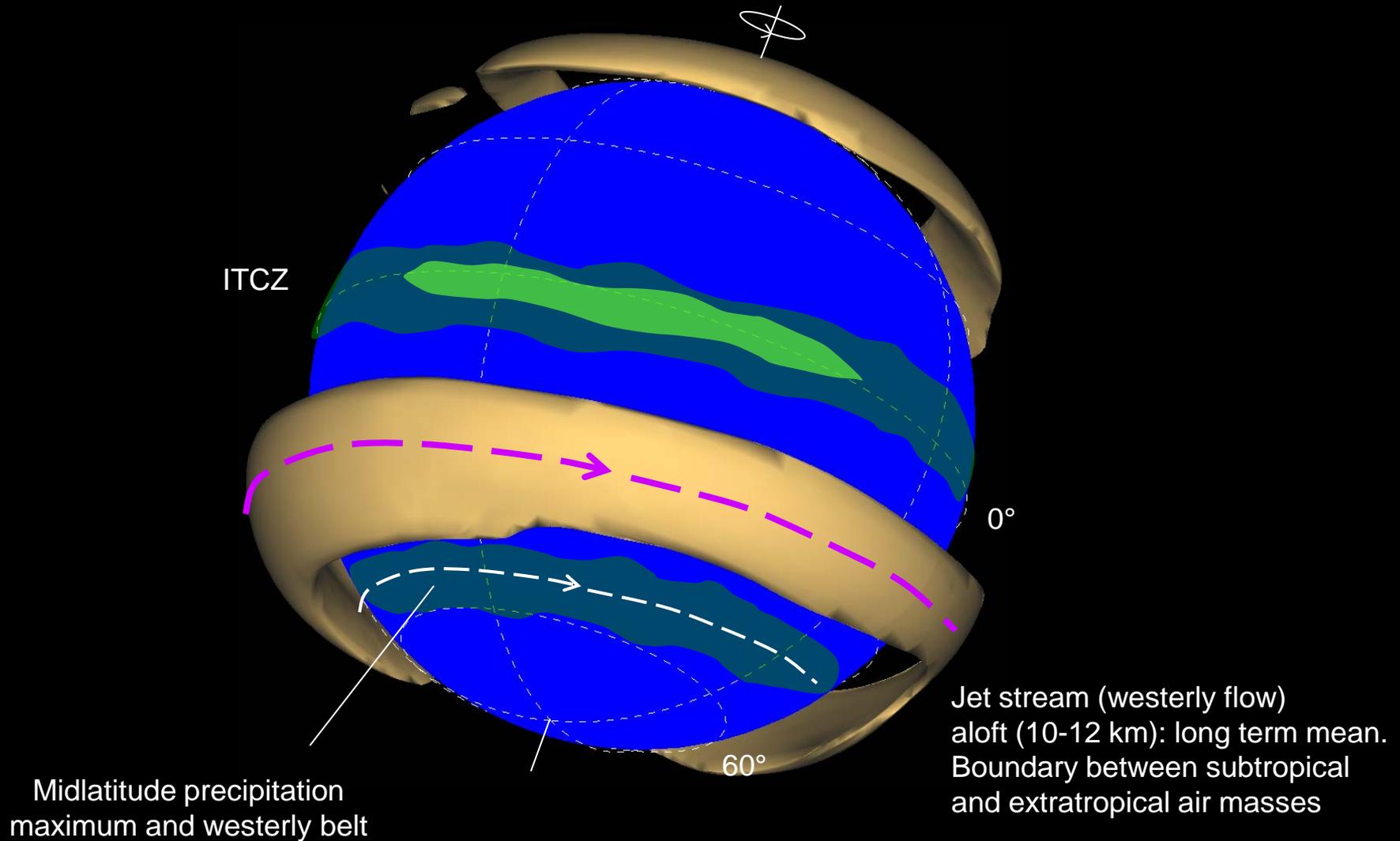


Variabilidad natural
Cambio climático

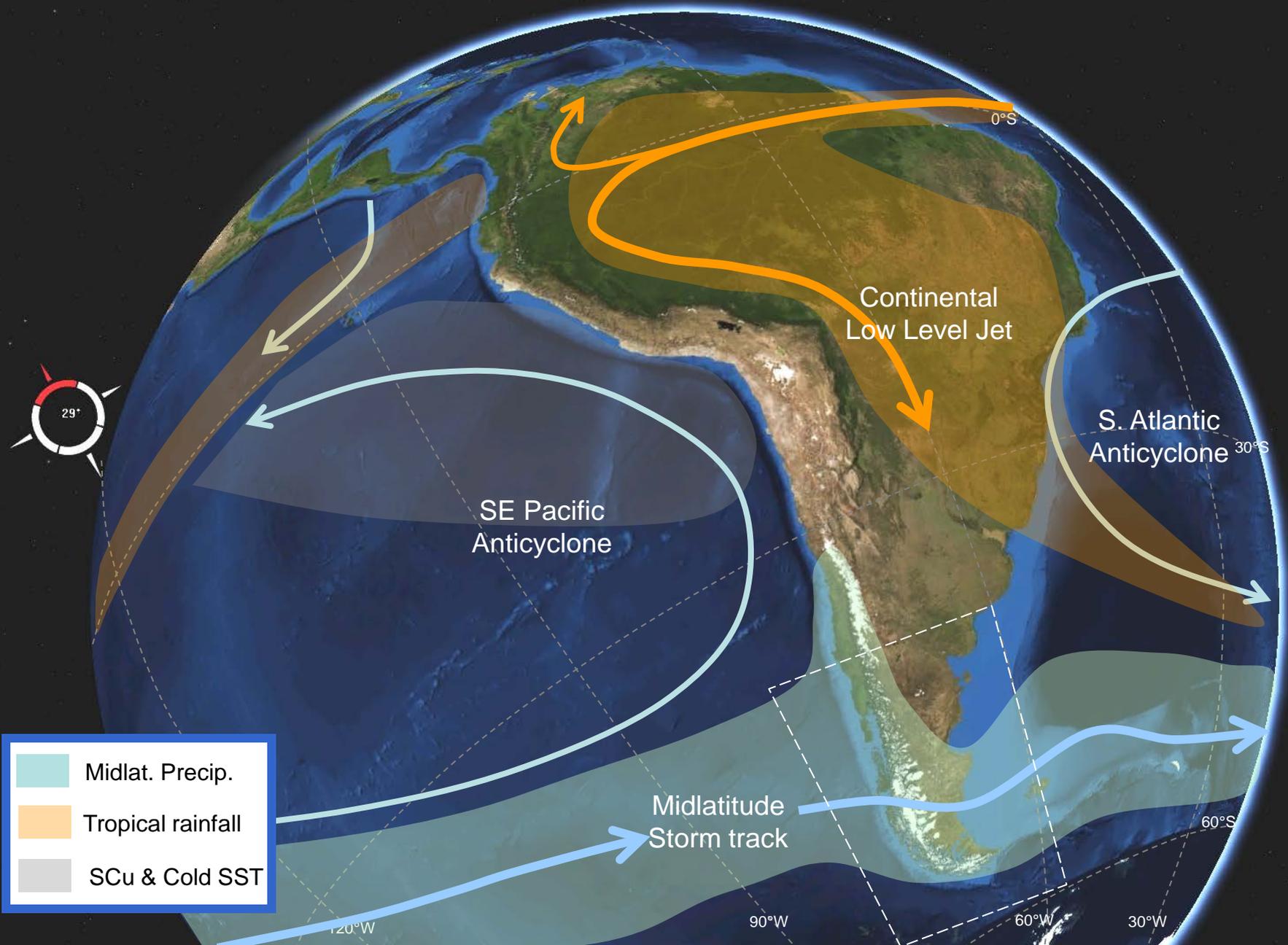
General circulation in an aqua-planet Perpetual Equinox



General circulation in an aqua-planet Perpetual Equinox

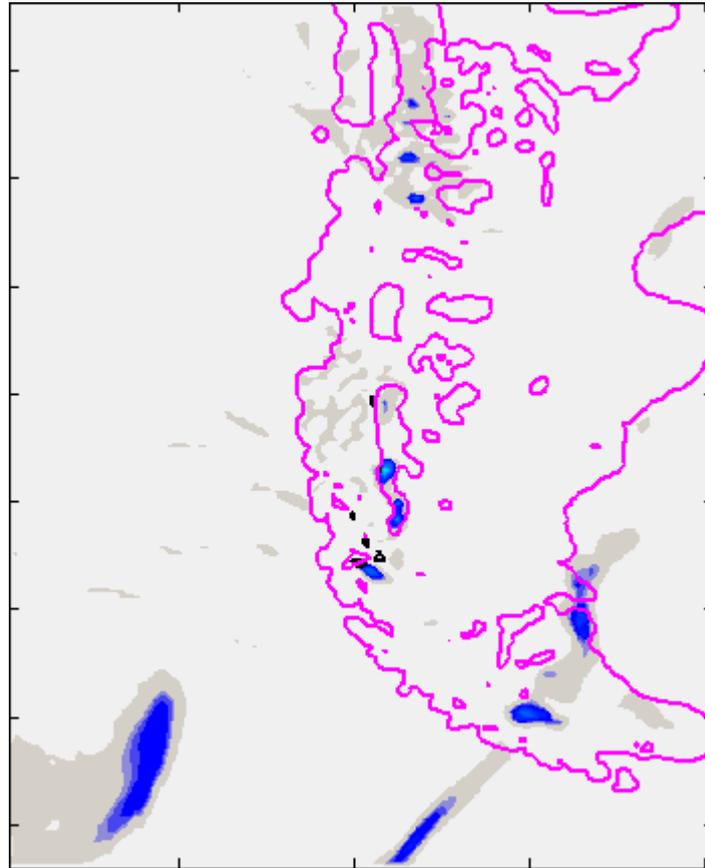


El Panorama Continental



One (typical) storm simulation (WRF)

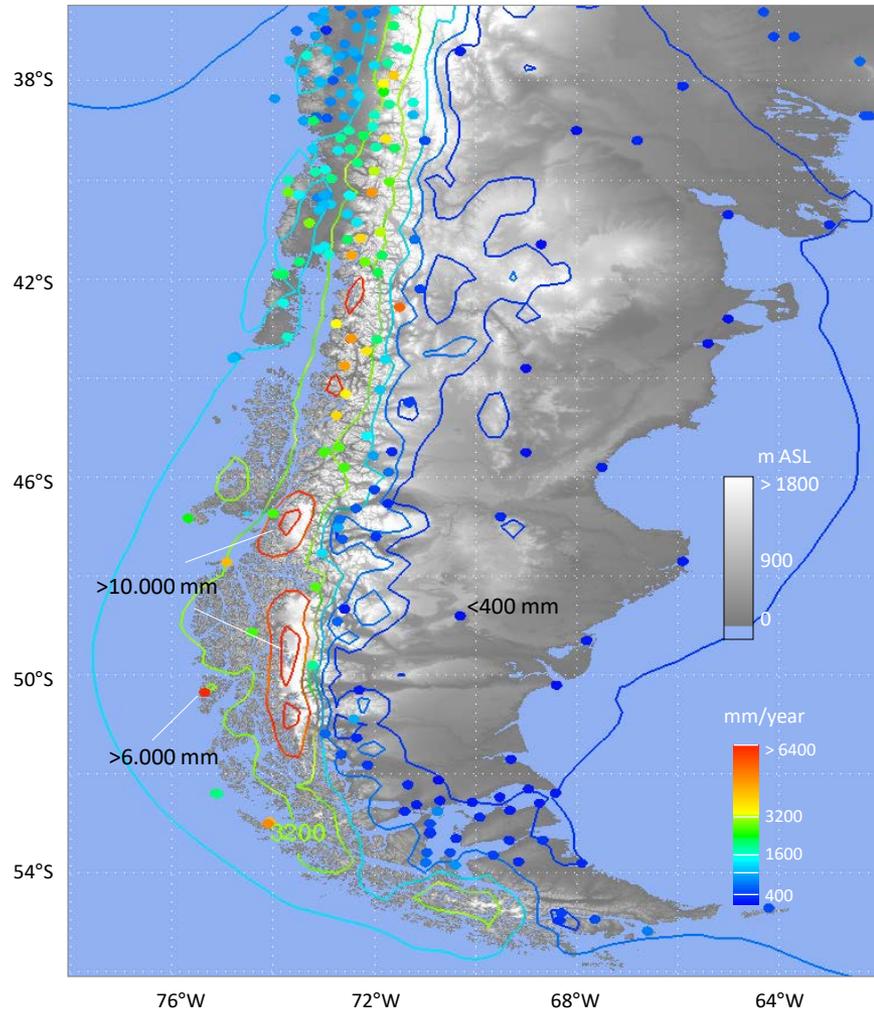
Hourly results during a 3 day period. Resolved precipitation (colors),
Convective rainfall (contours) and topography



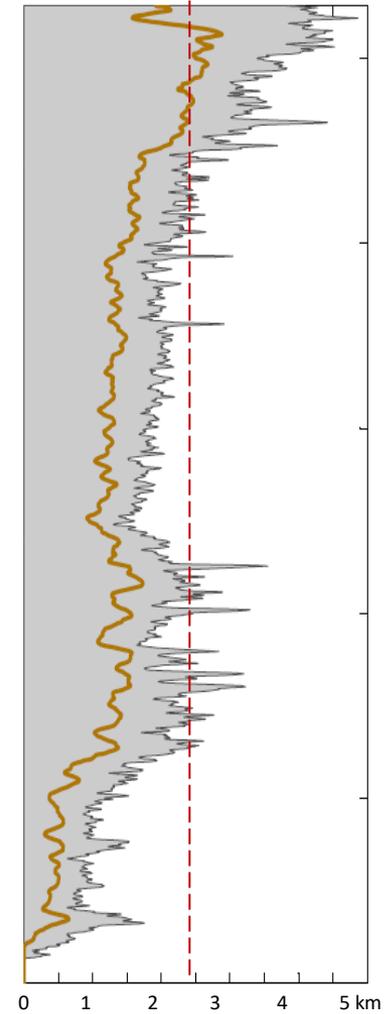
Salient features: Rainfall enhancement over the Andes windward slope,
Rain shadow, Convective rainfall along the coast

Patagonia 101: Precipitation

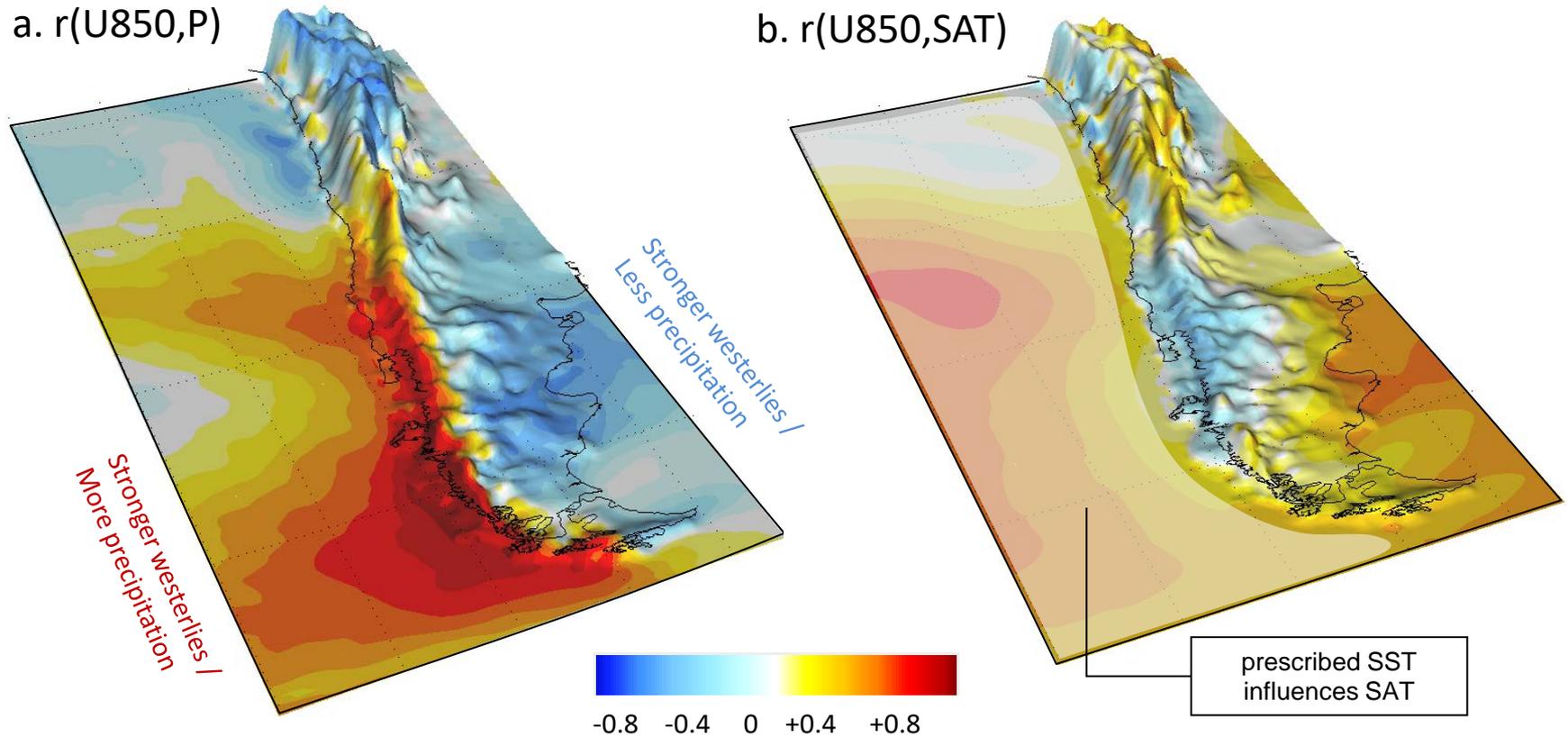
Mean Annual Rainfall (everybody guess)



Height (max, 90%)



Correlación entre viento zonal (oeste) y precipitación en escala interanual...



Entre más intenso los Oestes, mayor la precipitación
Entre más débiles los Oestes, menor la precipitación

Impactos de ENOS, PDO and SAM (AAO)

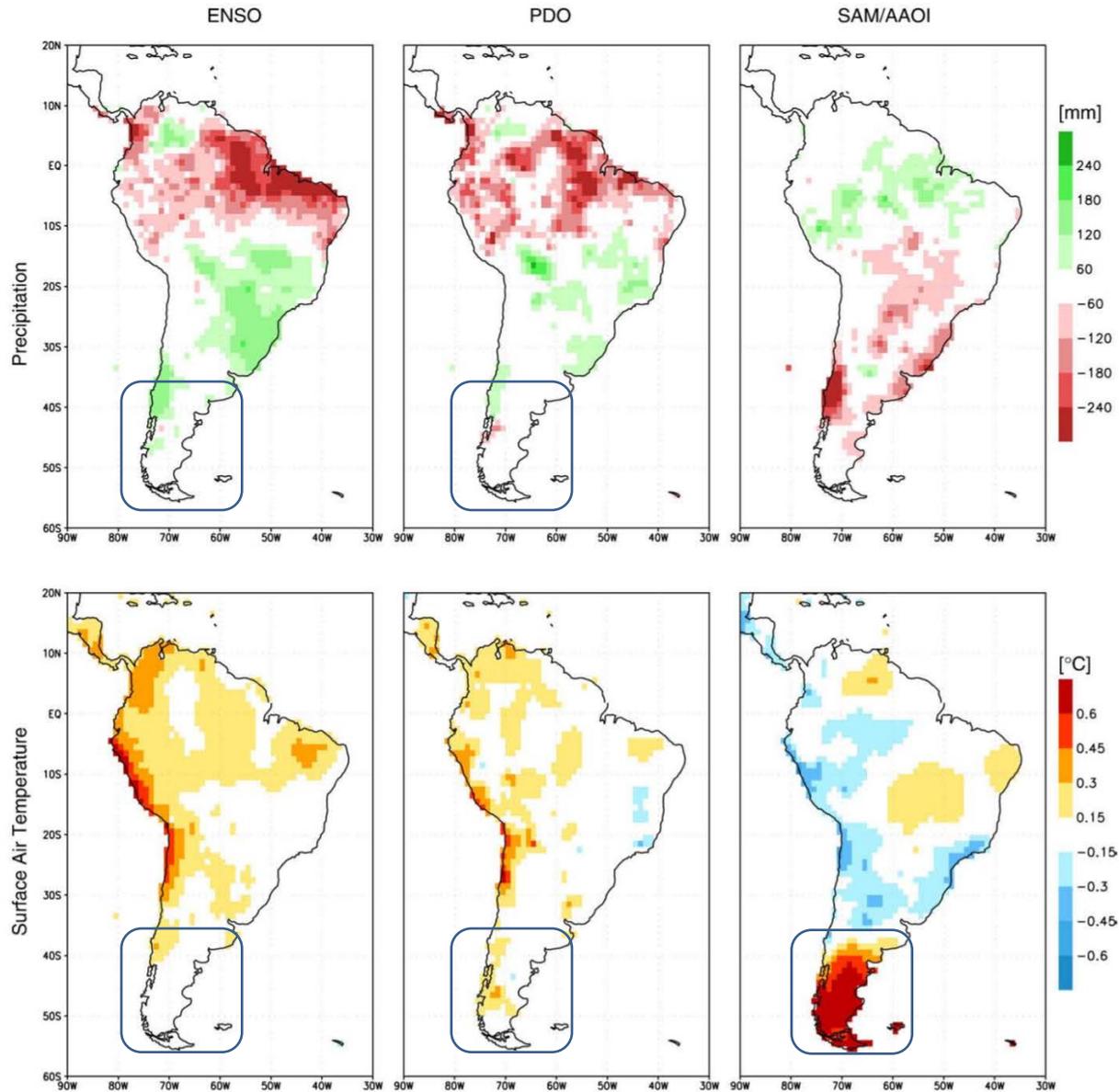
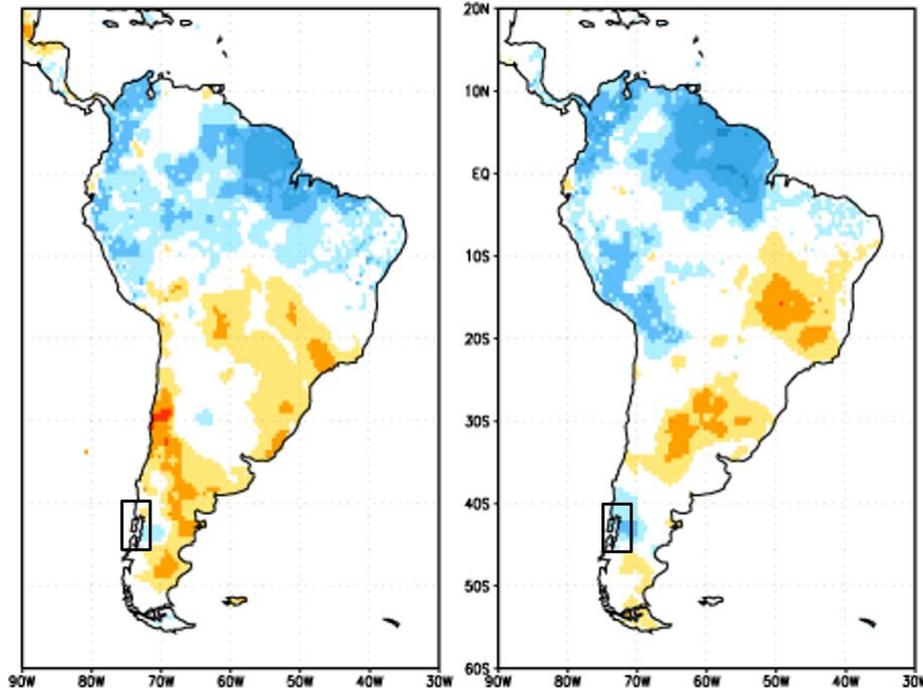
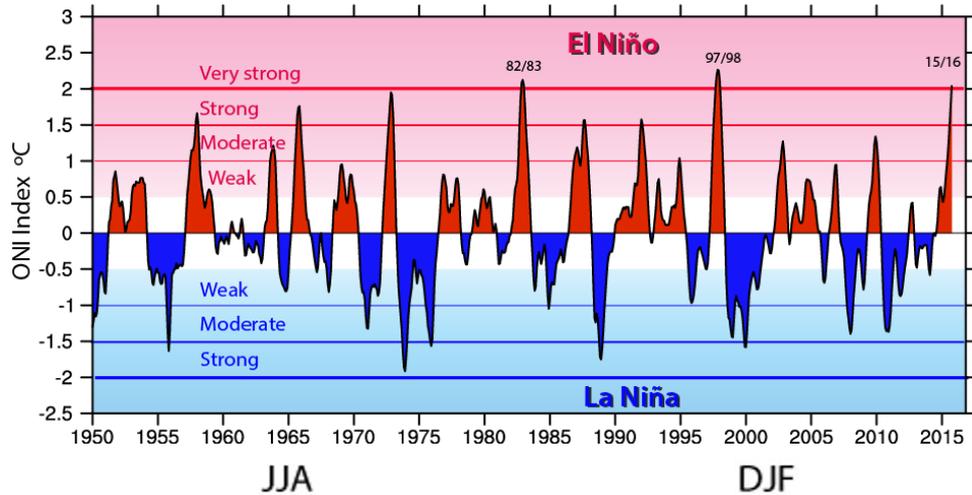
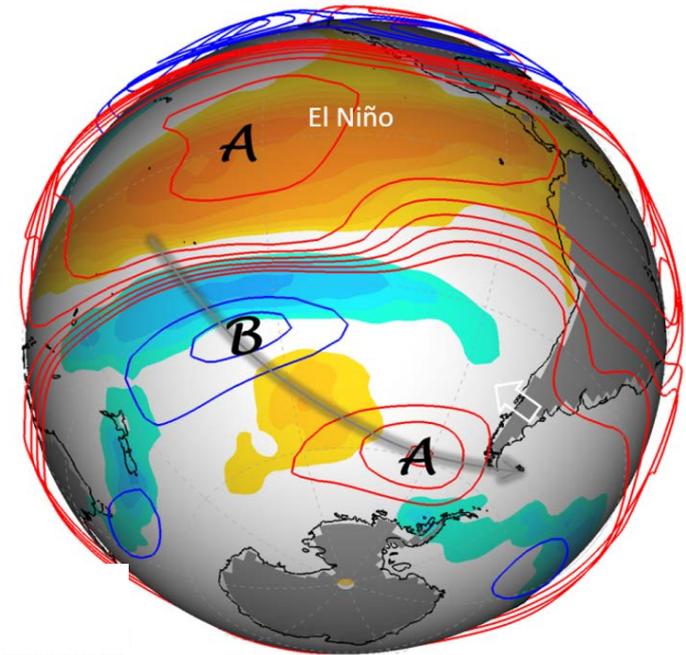


Fig. 10. Annual mean precipitation (upper row) and surface air temperature (lower row) regressed upon MEI (left column), PDO index (center column) and AAOI (right column). Precipitation and surface air temperature from University of Delaware gridded dataset.

Impactos de ENSO en Patagonia



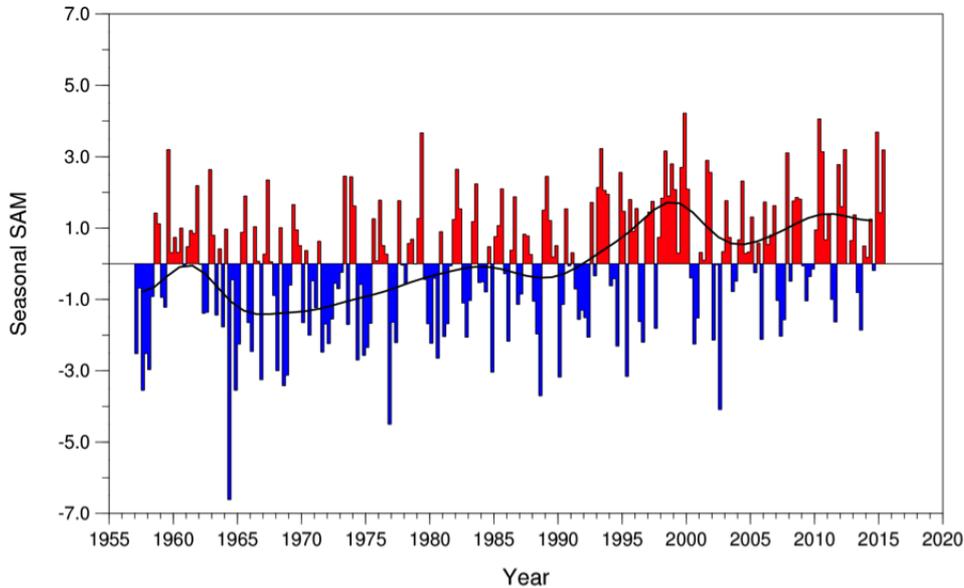
Compuesto El Niño EFM



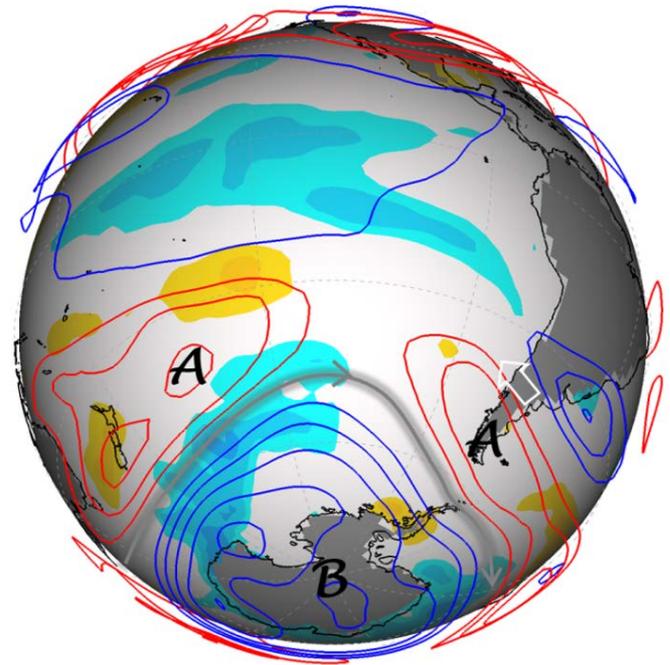
Colors: SST anomalies
Contours: Z300 anomalies

← Correlación estacional
ONI-PP

Impactos de SAM en Patagonia

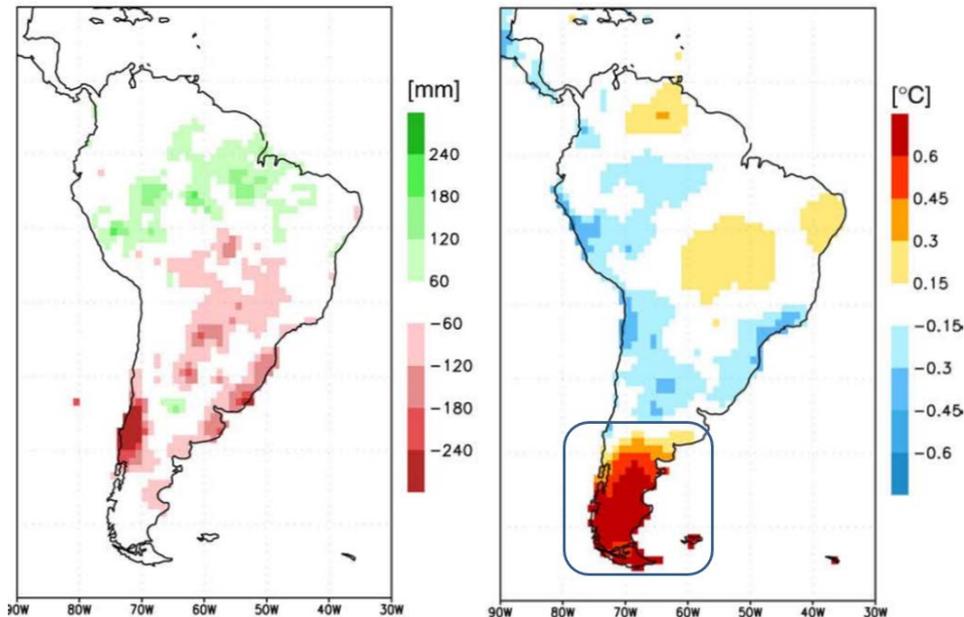


Compuesto SAM+

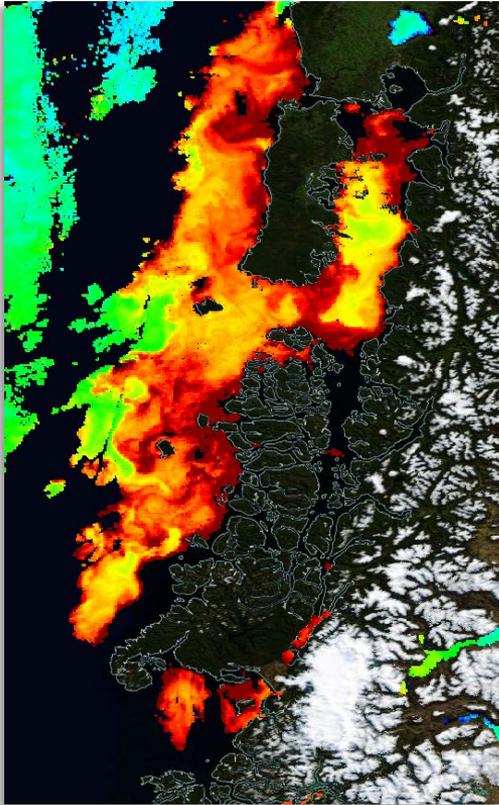


Colors: SST anomalies
Contours: Z300 anomalies

← Regresión anual
SAMI-PP,T



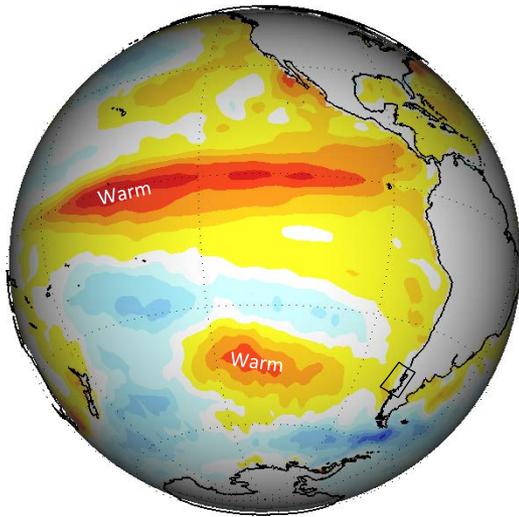
El terrible 2016 (JFM)



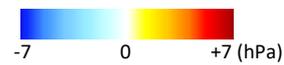
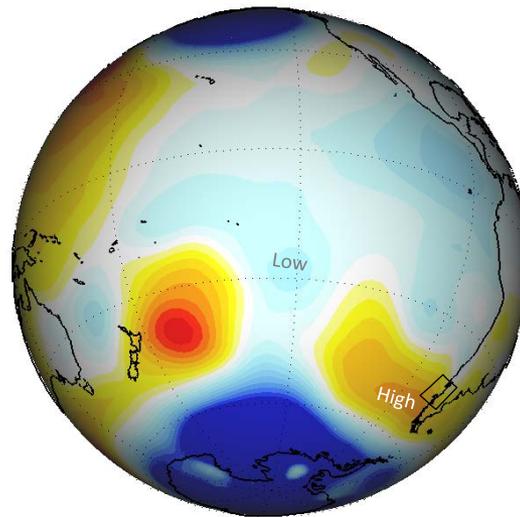
Clorofila, 03 Marzo 2016. MODIS

Condiciones de gran escala – EFM 2016

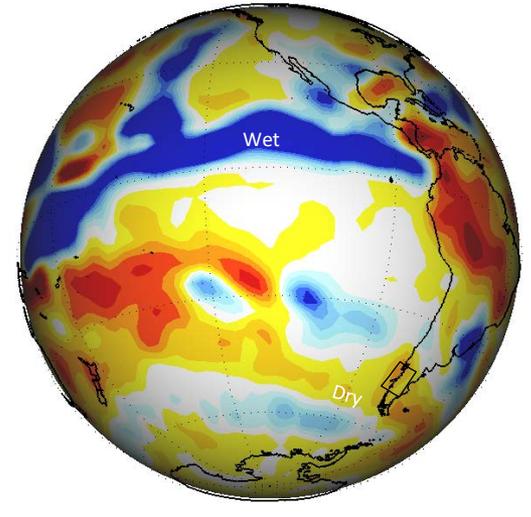
(a) SST (NOAA OI)



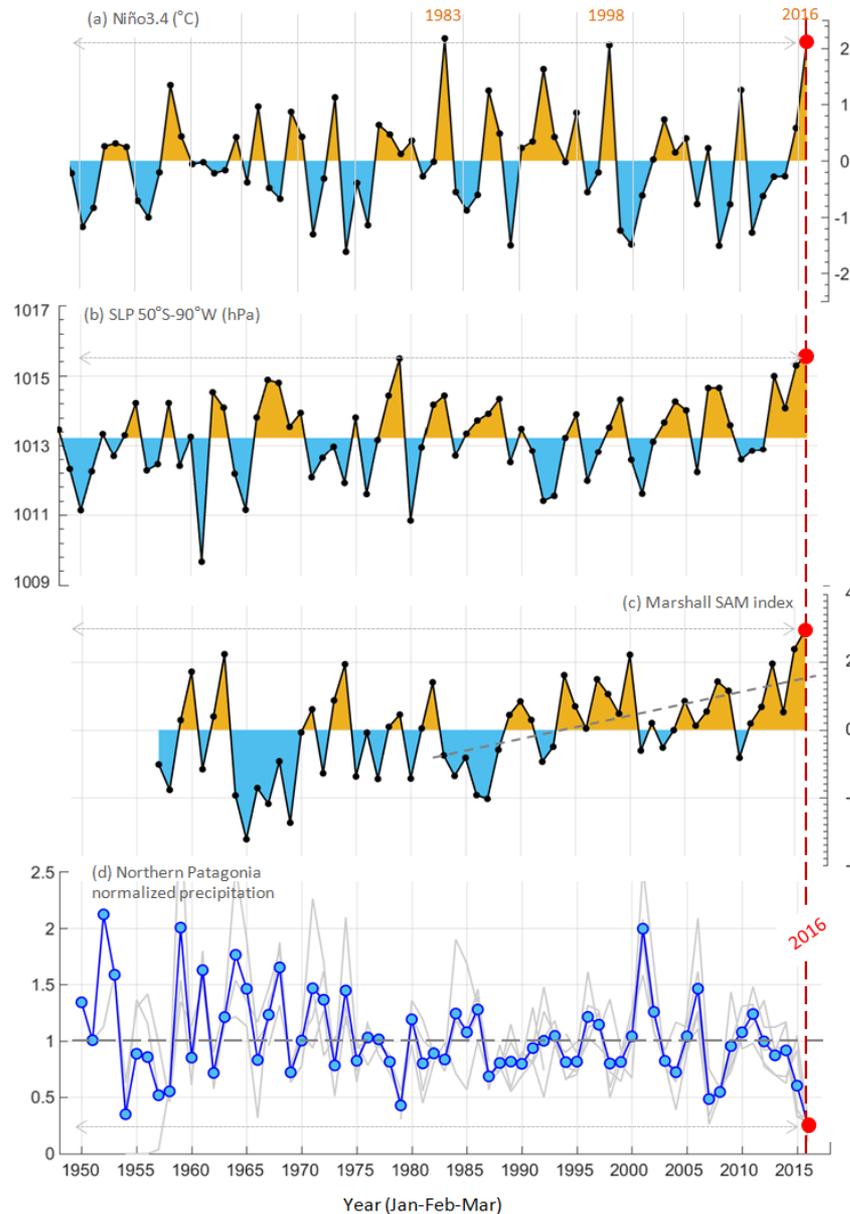
(c) SLP (NNR)



(b) Precipitation (CMAP)



Condiciones de gran escala – EFM 2016



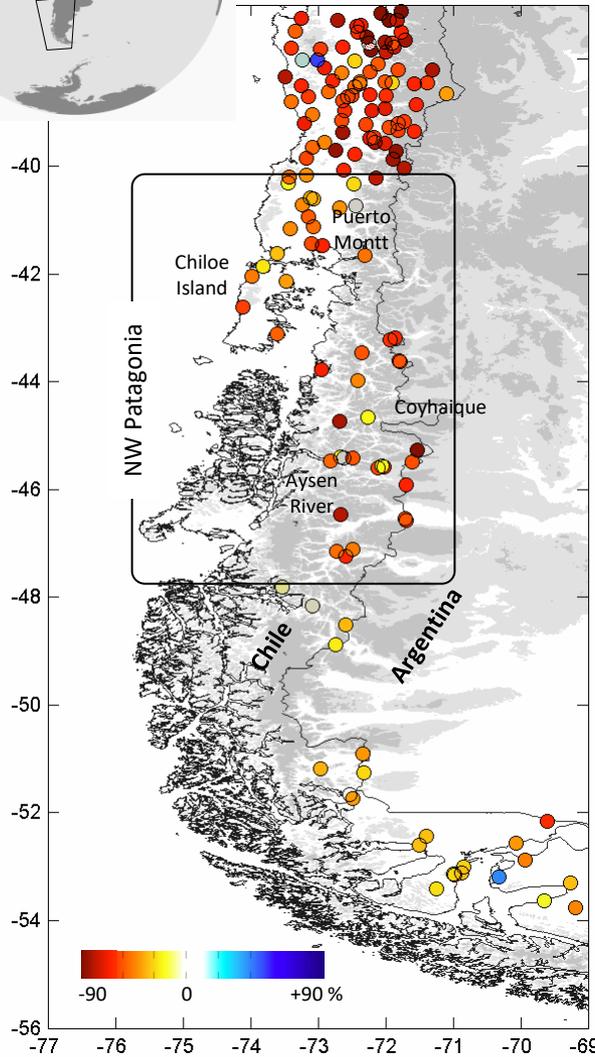
El Niño!
Natural....

SAM!
Antropogénico

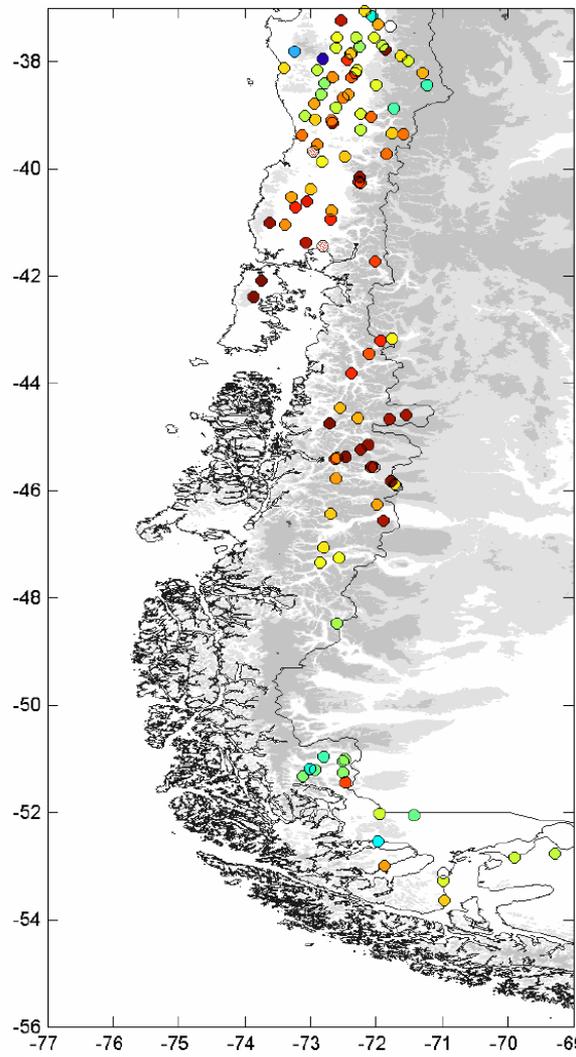
El terrible 2016 (JFM)



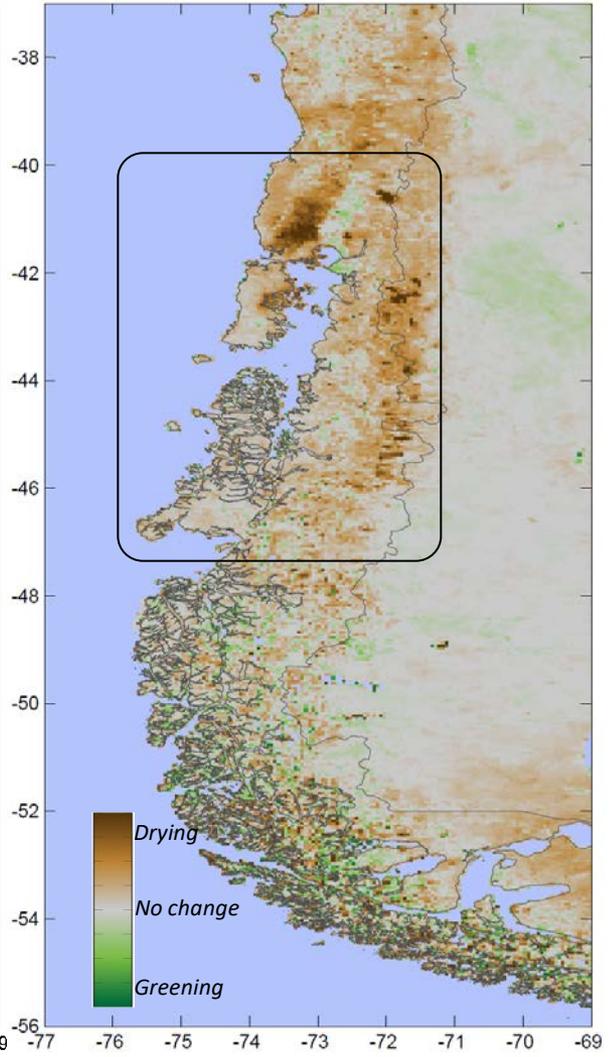
(a) Precipitation anomalies



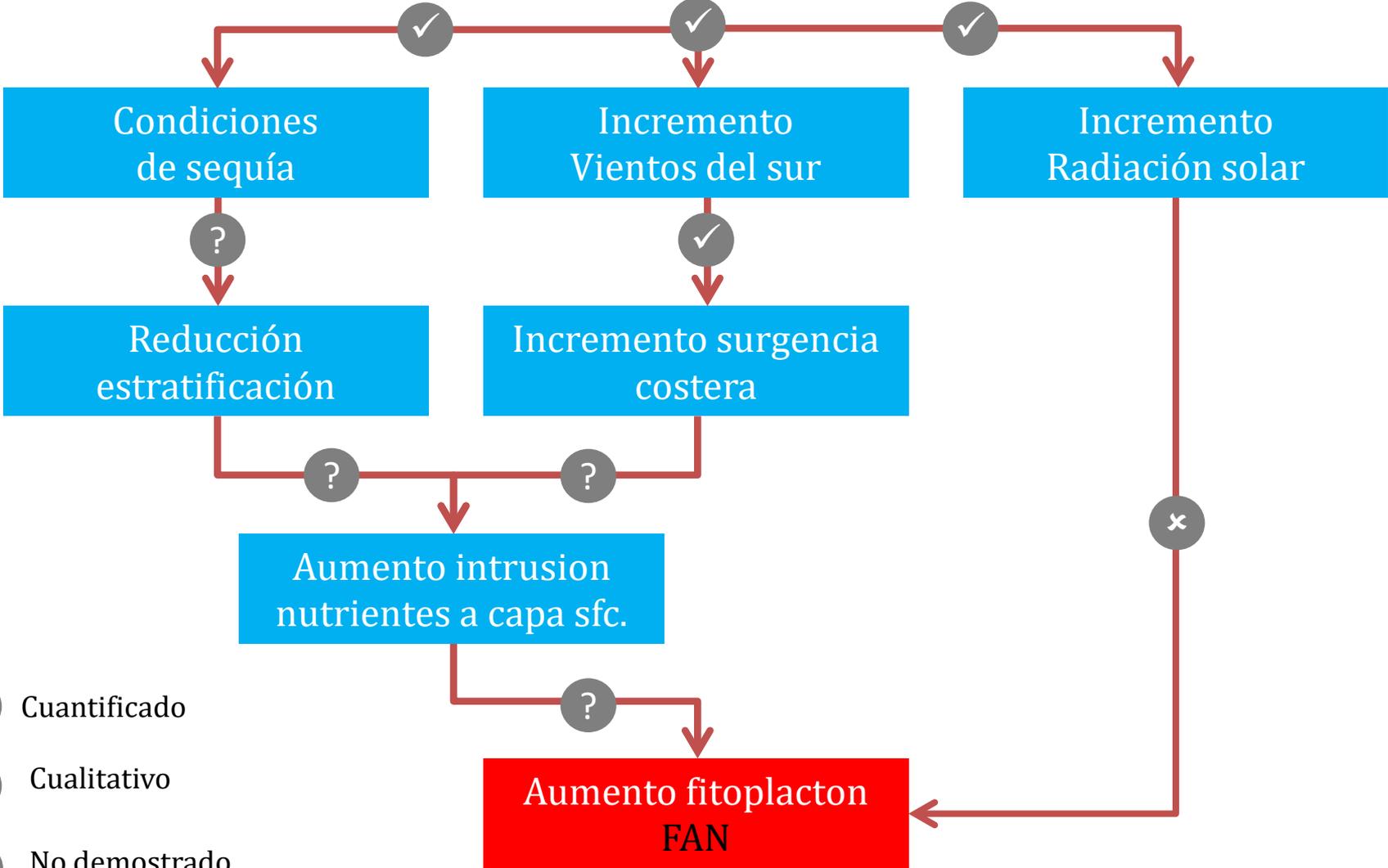
(a) Streamflow anomalies



(b) Enhanced Vegetation Index anomalies



Alteraciones climáticas globales (EN, SAM+)



- ✓ Cuantificado
- ? Cualitativo
- x No demostrado

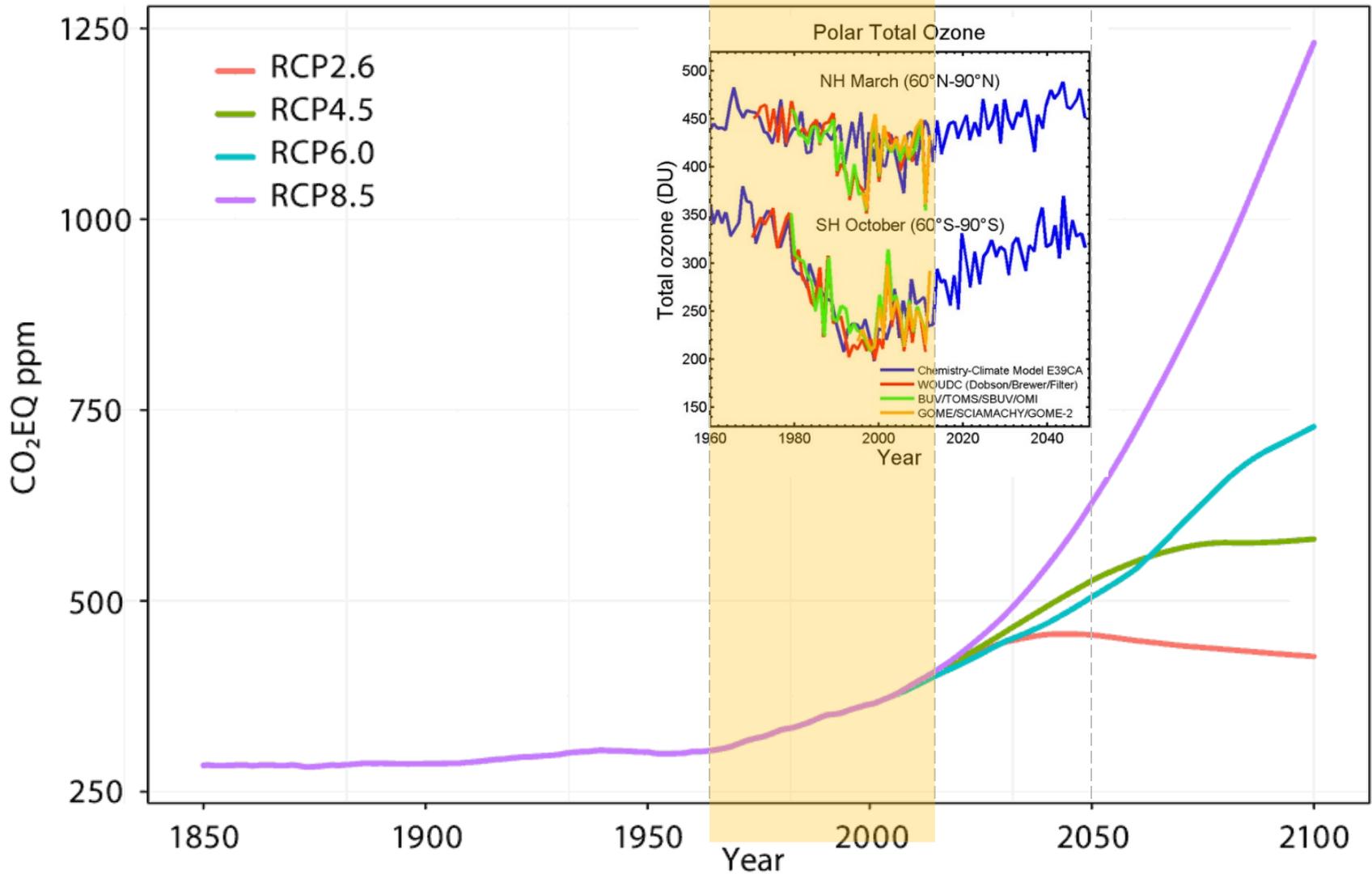
El pasado reciente (5 décadas)



what happened yesterday?

Greenhouse Gases and Ozone, the main drivers of climate change

CO₂ Equivalent Concentrations in RCPs



Tendencia hacia polaridad positiva de SAM/AAO

Modelos sugieren un forzamiento radiativo
y escasa contribución de forzantes naturales

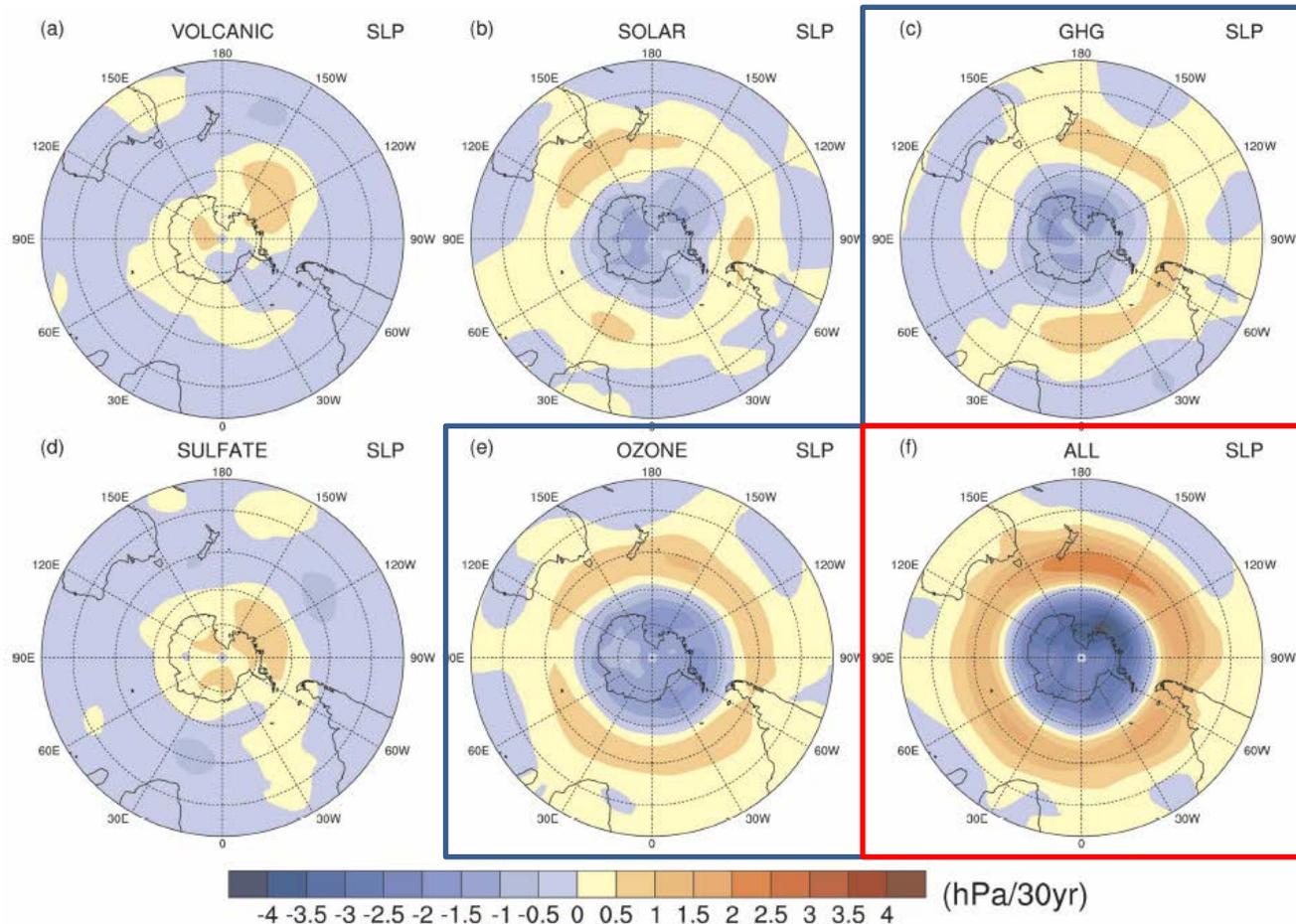
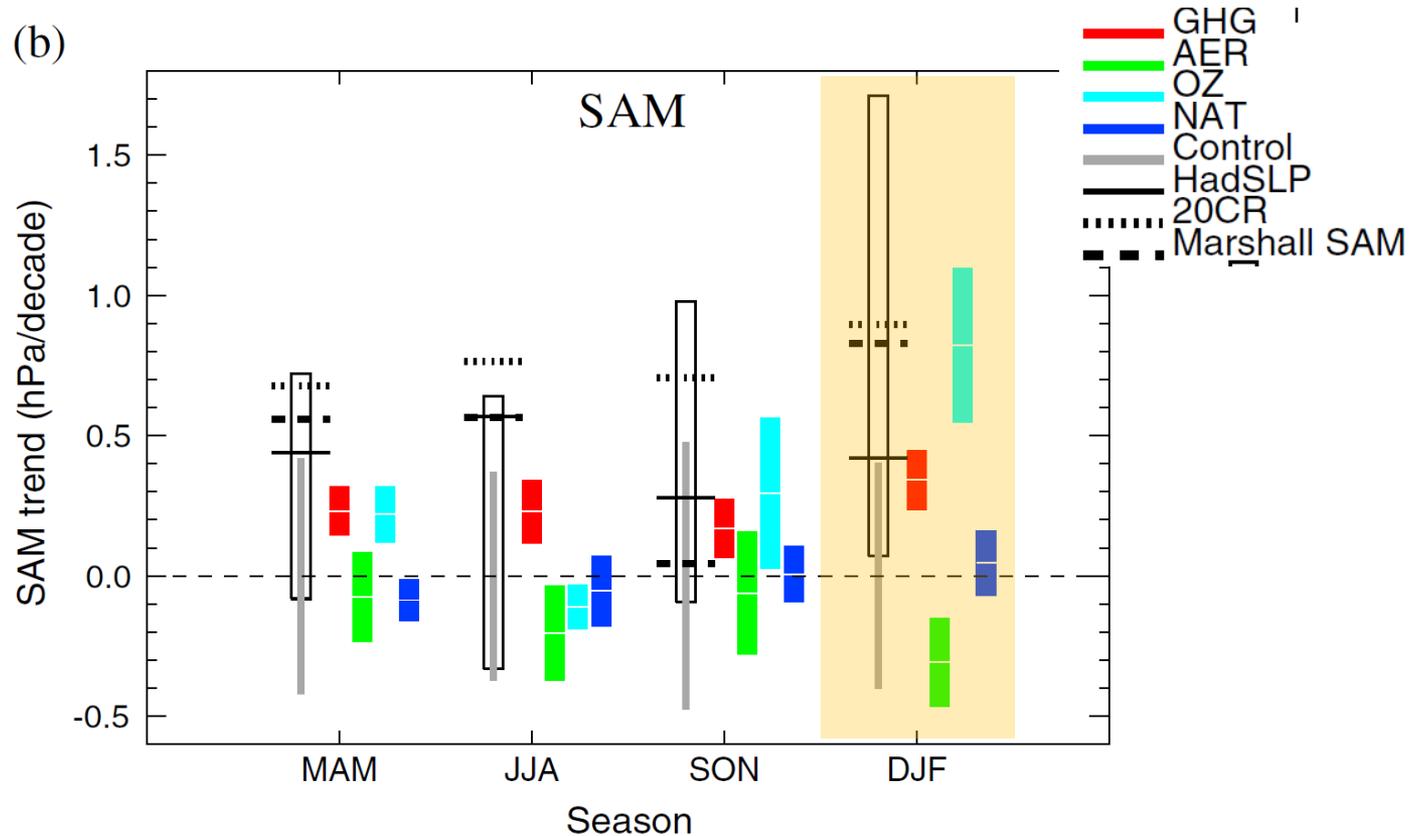


FIG. 1. Ensemble mean DJF/MAM sea level pressure trends ($\text{hPa } 30 \text{ yr}^{-1}$) for the period of 1958-99 of the (a) volcanic, (b) solar, (c) GHGs, (d) sulfate aerosols, (e) ozone, and (f) all-forcings simulations from the PCM.

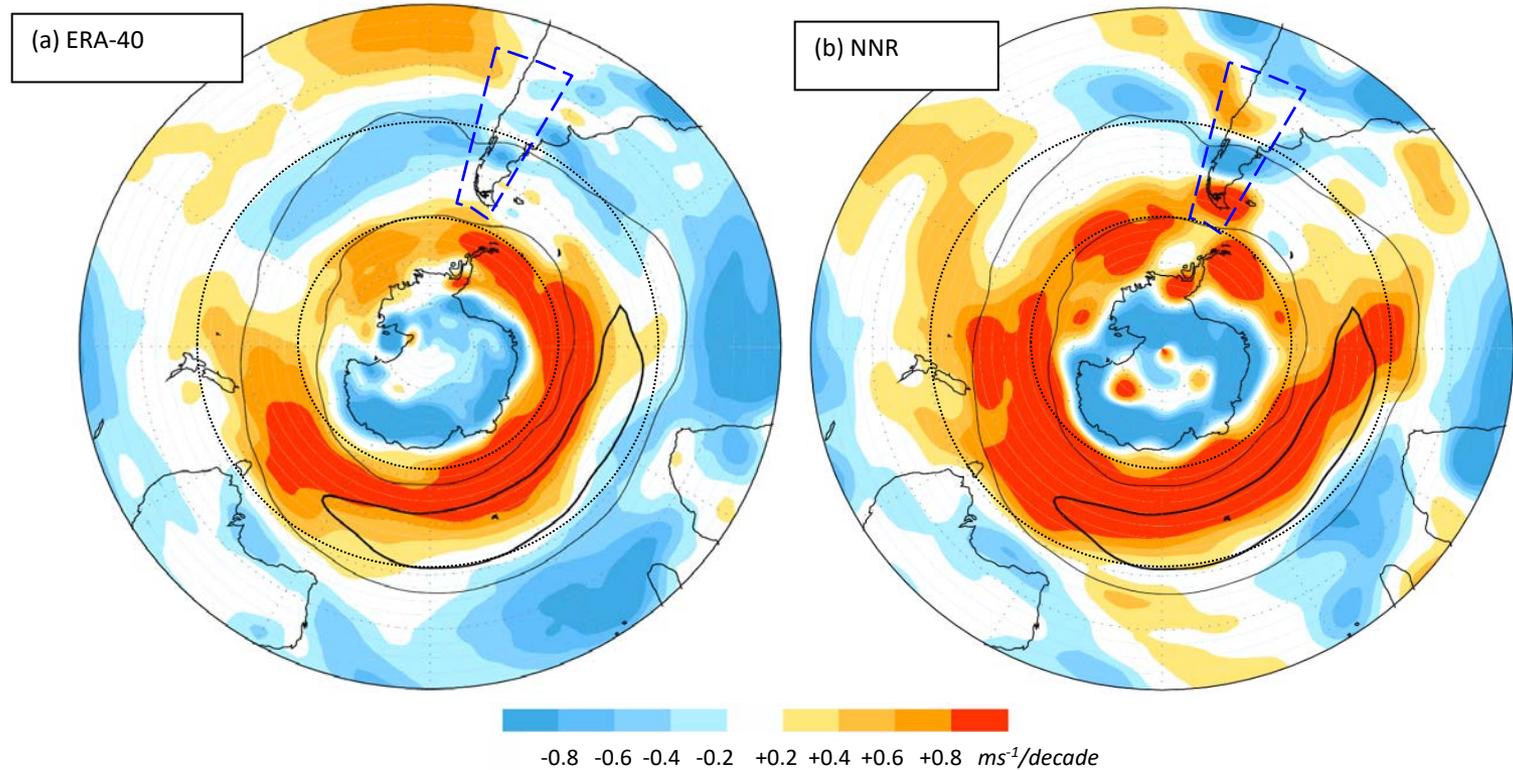
SAM trends 1950-2011: Observations and attribution



Attribution of observed sea level pressure trends to greenhouse gas, aerosol, and ozone changes

Nathan P. Gillett,¹ John C. Fyfe,¹ and David E. Parker²

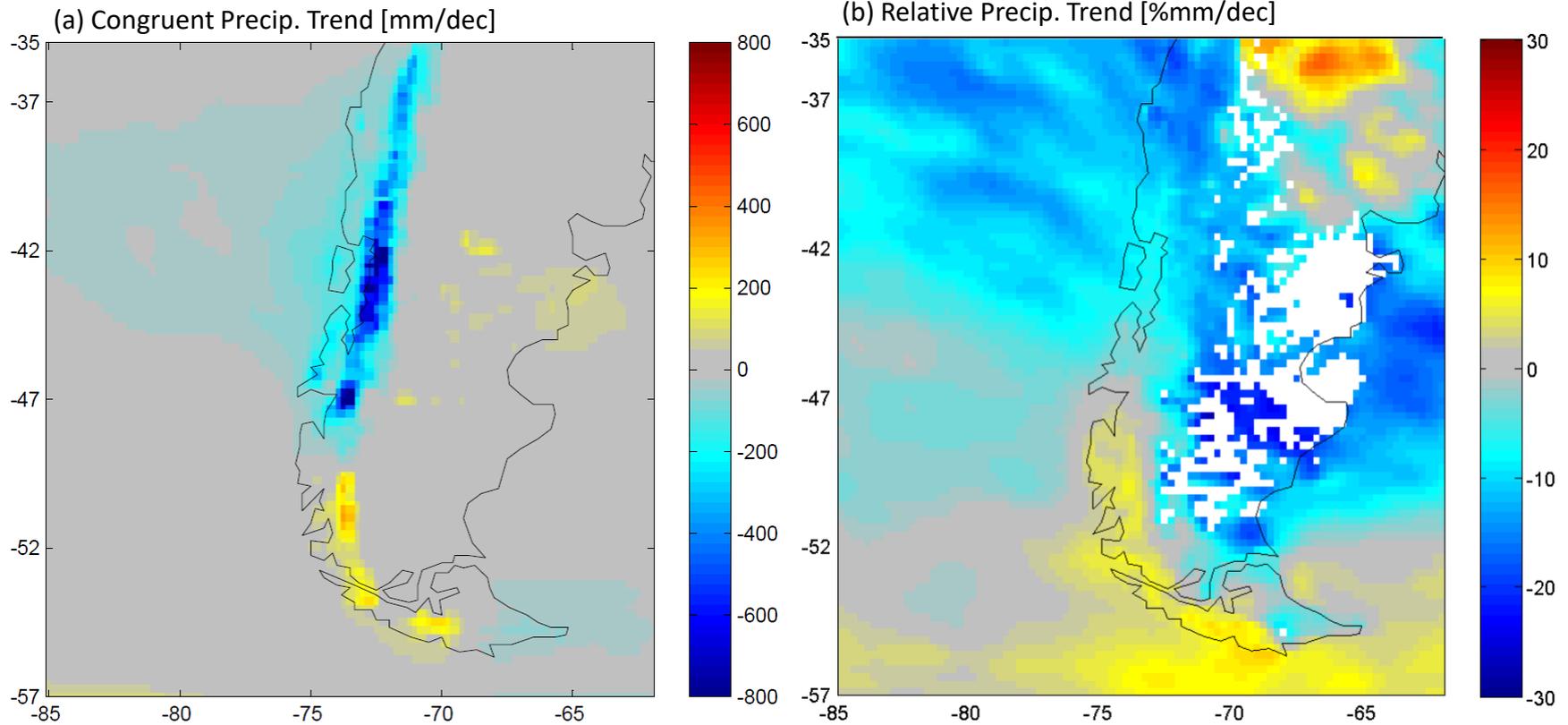
Tendencias (1968-2001) de Viento Zonal asociadas a SAM



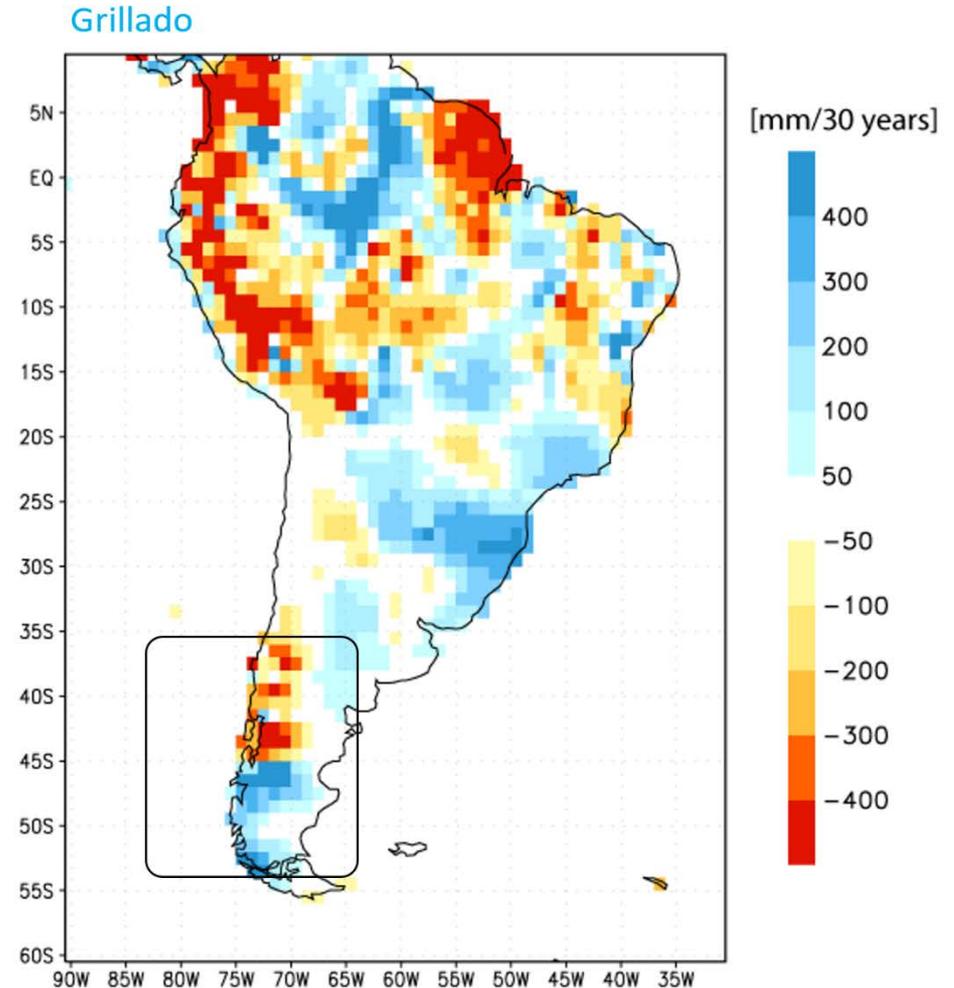
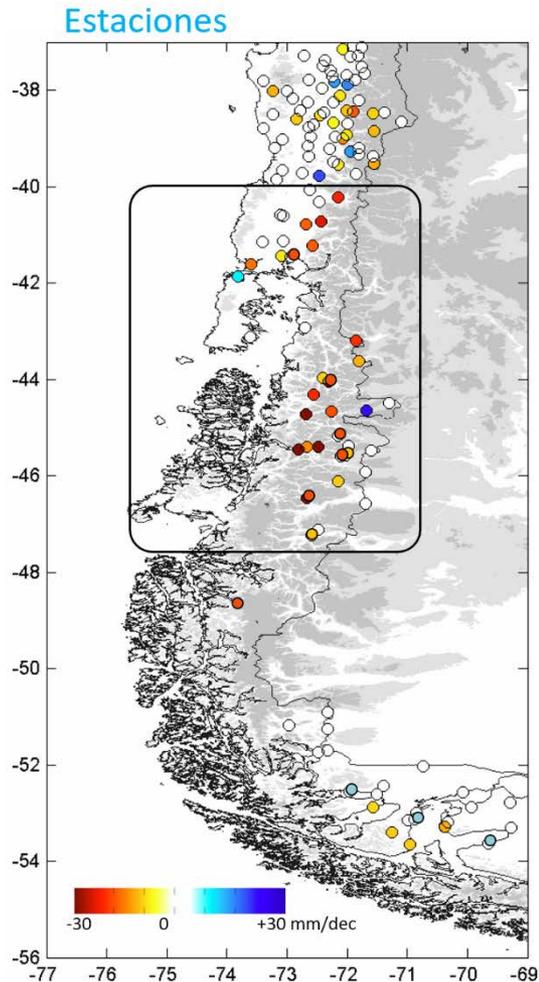
Linear trends in the annual mean zonal wind at the 850 hPa level using the (a) ERA-40 and (b) NCEP-NCAR reanalysis. **Shading indicates the change between 1968 and 2001 of a linear least squares trend fit calculated at each grid-box**

Wind-congruent precipitation trends(1968-2001)

$$\Delta P^* = \beta \cdot \Delta U_{850}$$

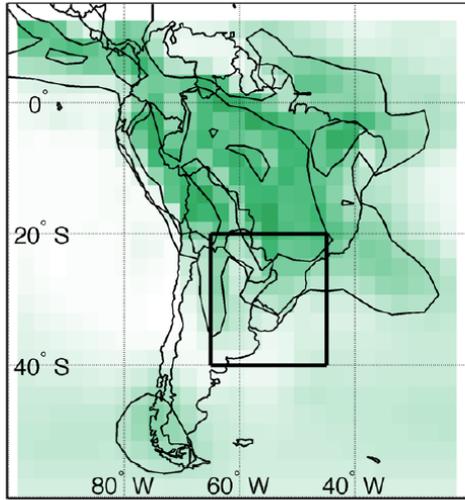


Tendencias observadas de precipitación (ONDEFM; 1970-2016)

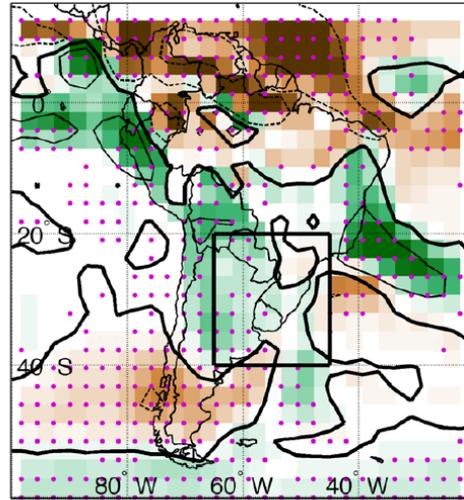


CAM3 transient runs - DJF 1960-1999

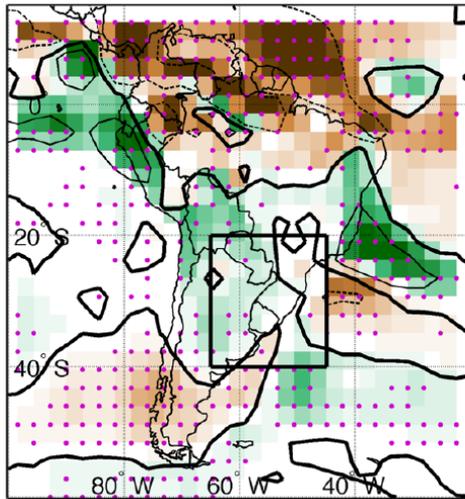
(a) all-forcings (40) - Mean



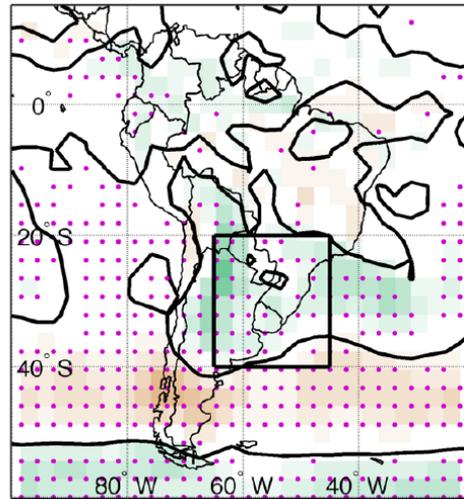
(b) all-forcings (40) - Change



(c) GHG-only (40) - Change



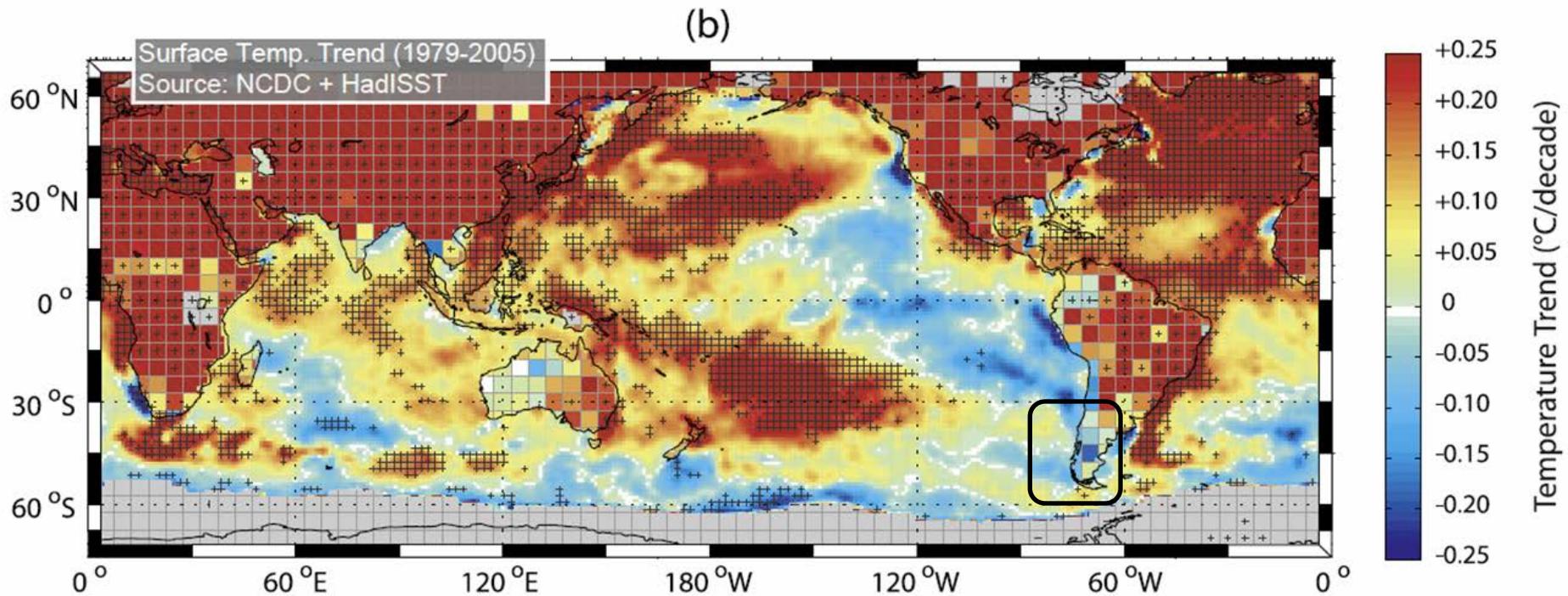
(d) ozone-only (40) - Change



Precipitation change
Drying
Increasing Pr.

Stratospheric ozone depletion: a key driver of recent precipitation trends in South Eastern South America

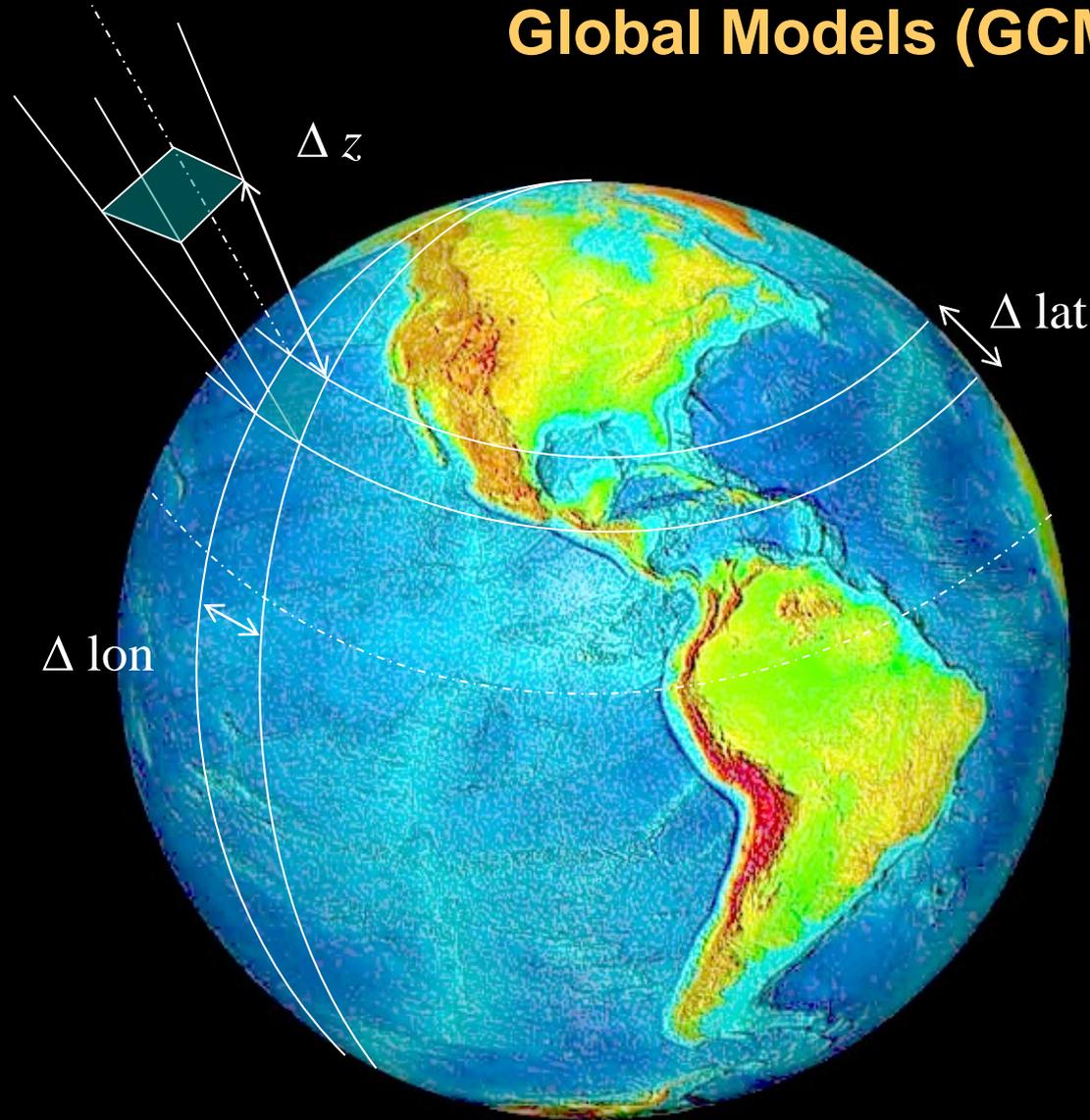
Cambios Observados de Temperatura 1979-2005





And
What
Next...

Global Models (GCM)



$$\frac{d\vec{V}}{dt} + f\hat{k} \times \vec{V} = -\frac{1}{\rho} \nabla p - F_R + g$$

$$\left(\frac{\partial}{\partial t} + \vec{V} \cdot \nabla\right)T - S_p \omega = \underbrace{Q_{RAD} + Q_{Conv} + Q_{Sfc}}_{\text{radiative, convective, and surface fluxes}}$$

$$\nabla \cdot \vec{V} + \frac{\partial \omega}{\partial p} = 0$$

$$\frac{\partial(gz)}{\partial p} = -\frac{RT}{p}$$

$\Delta lat \sim \Delta lon \sim 1^\circ - 3^\circ$

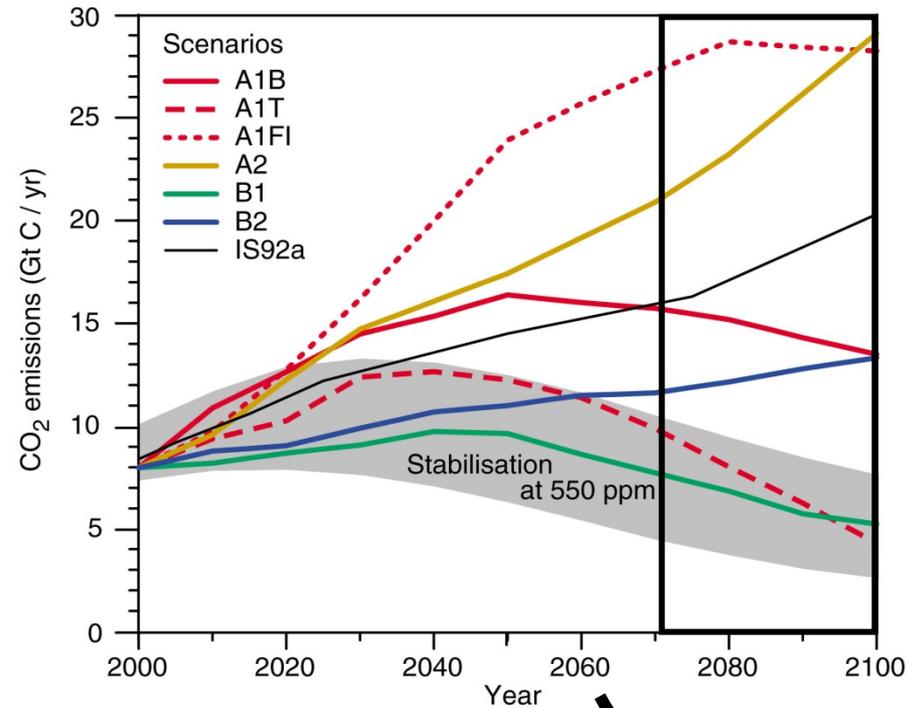
$\Delta z \sim 1 \text{ km}$

$\Delta t \sim \text{minutes-hours}$

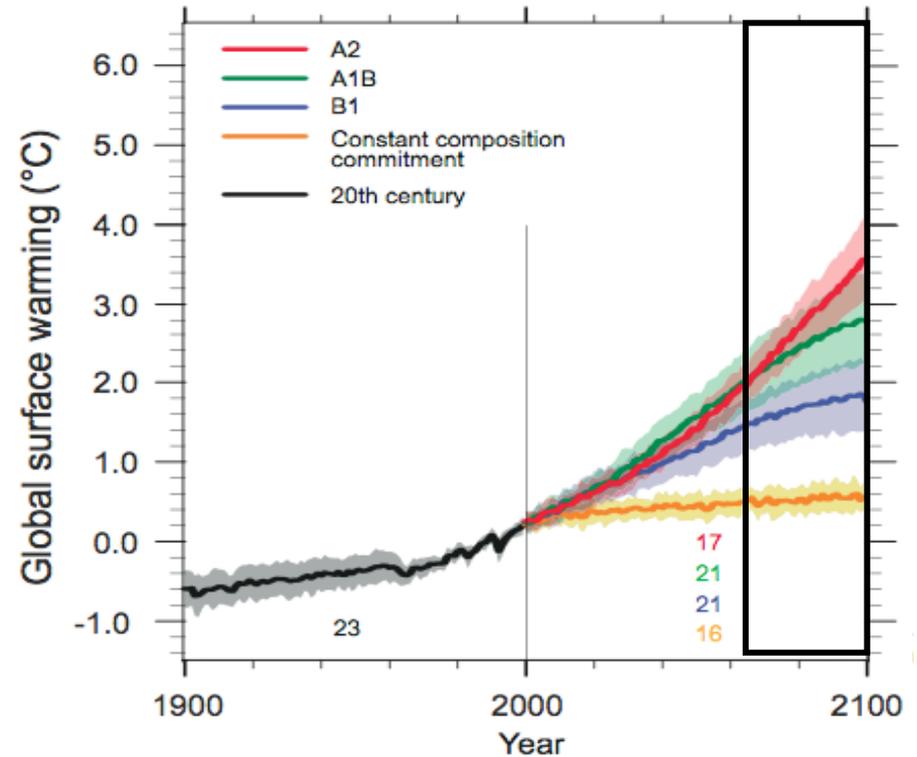
Top of atmosphere: 15-50 km

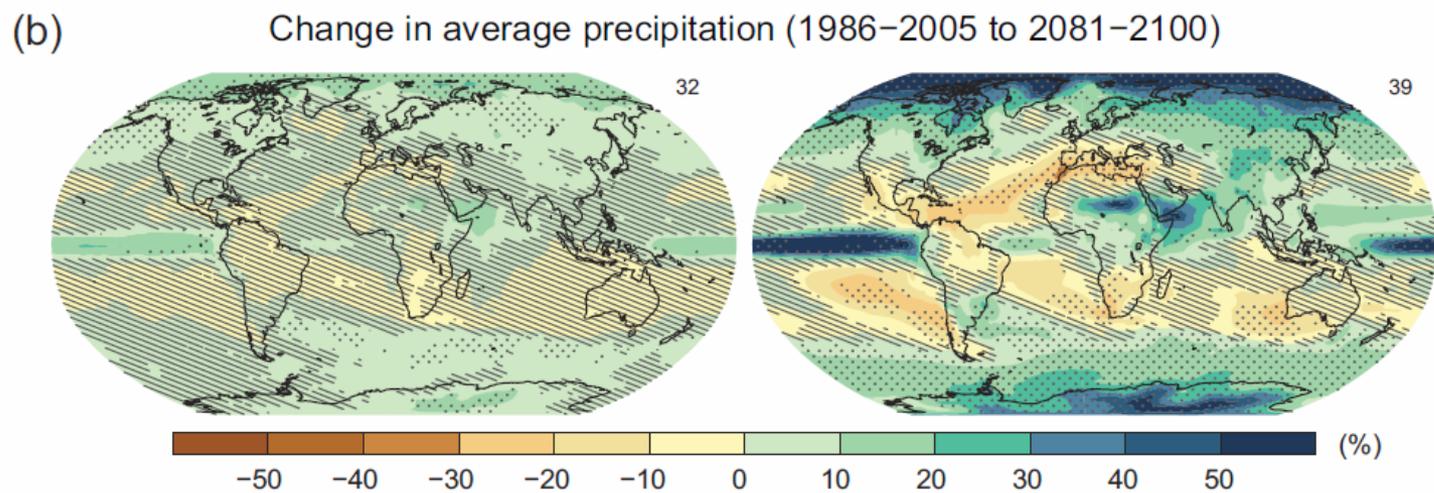
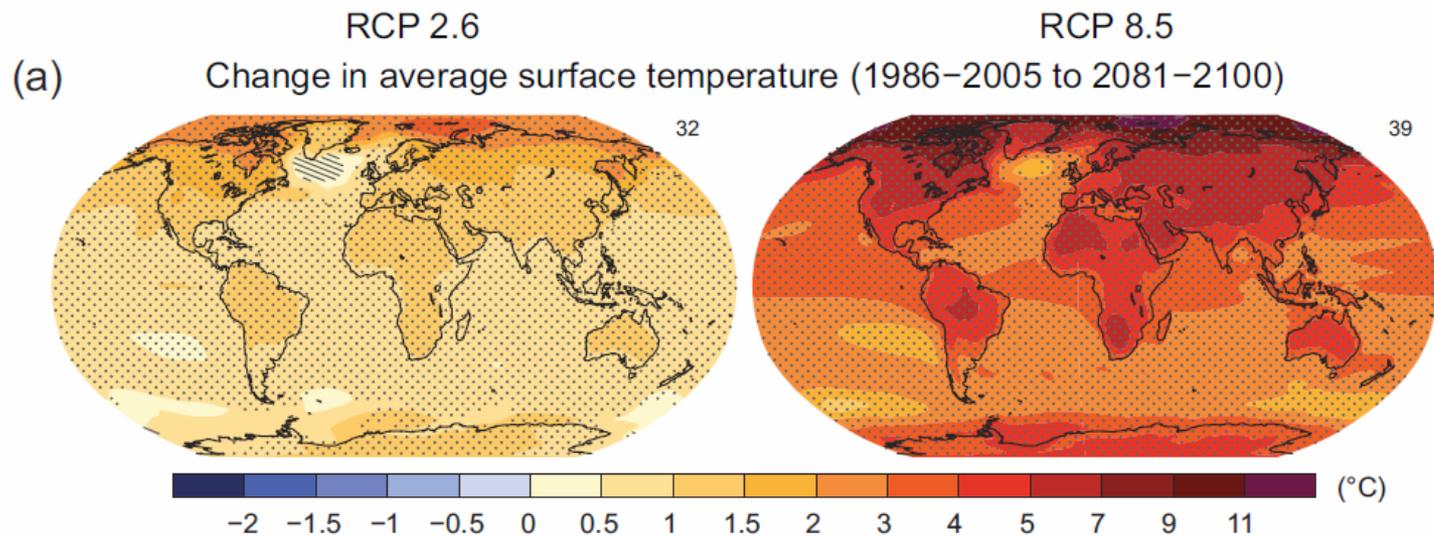
Future Climate Scenarios

GHG (CO₂,...) emissions projections + GCMs



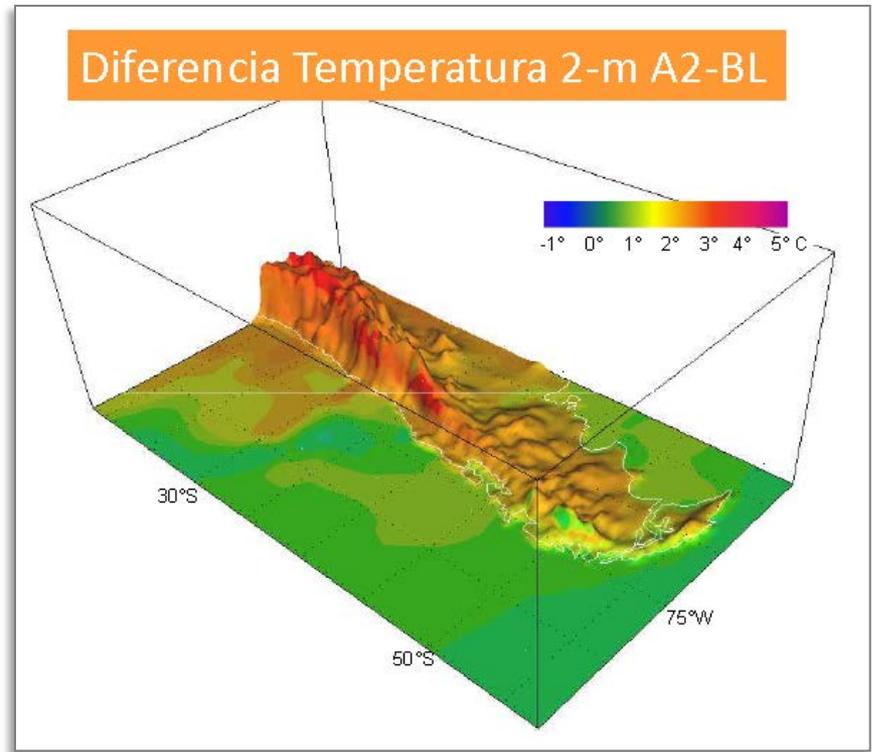
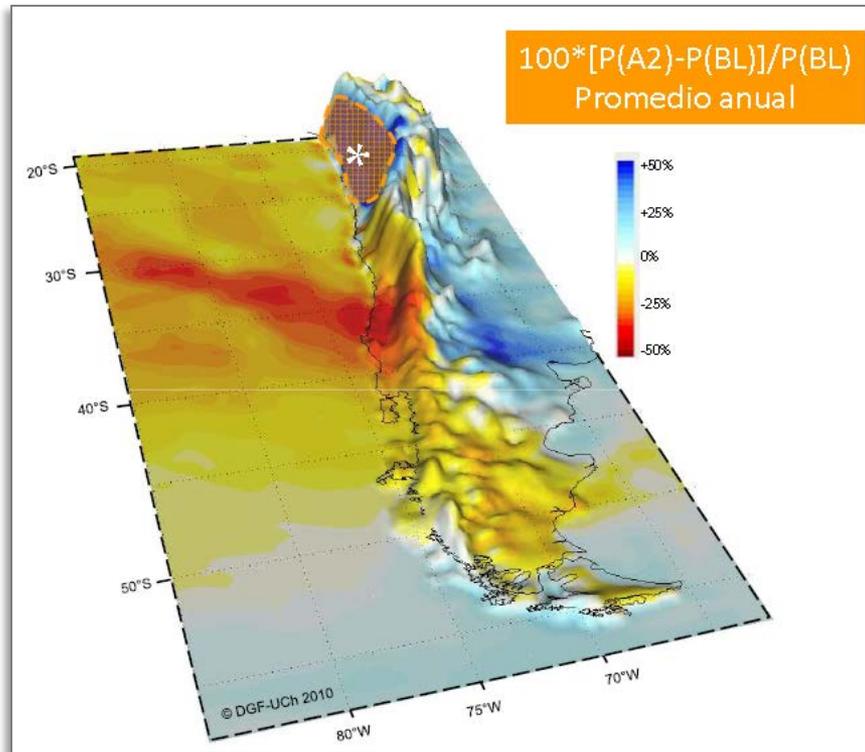
20+ GCMs
CMIP3/IPCC AR4





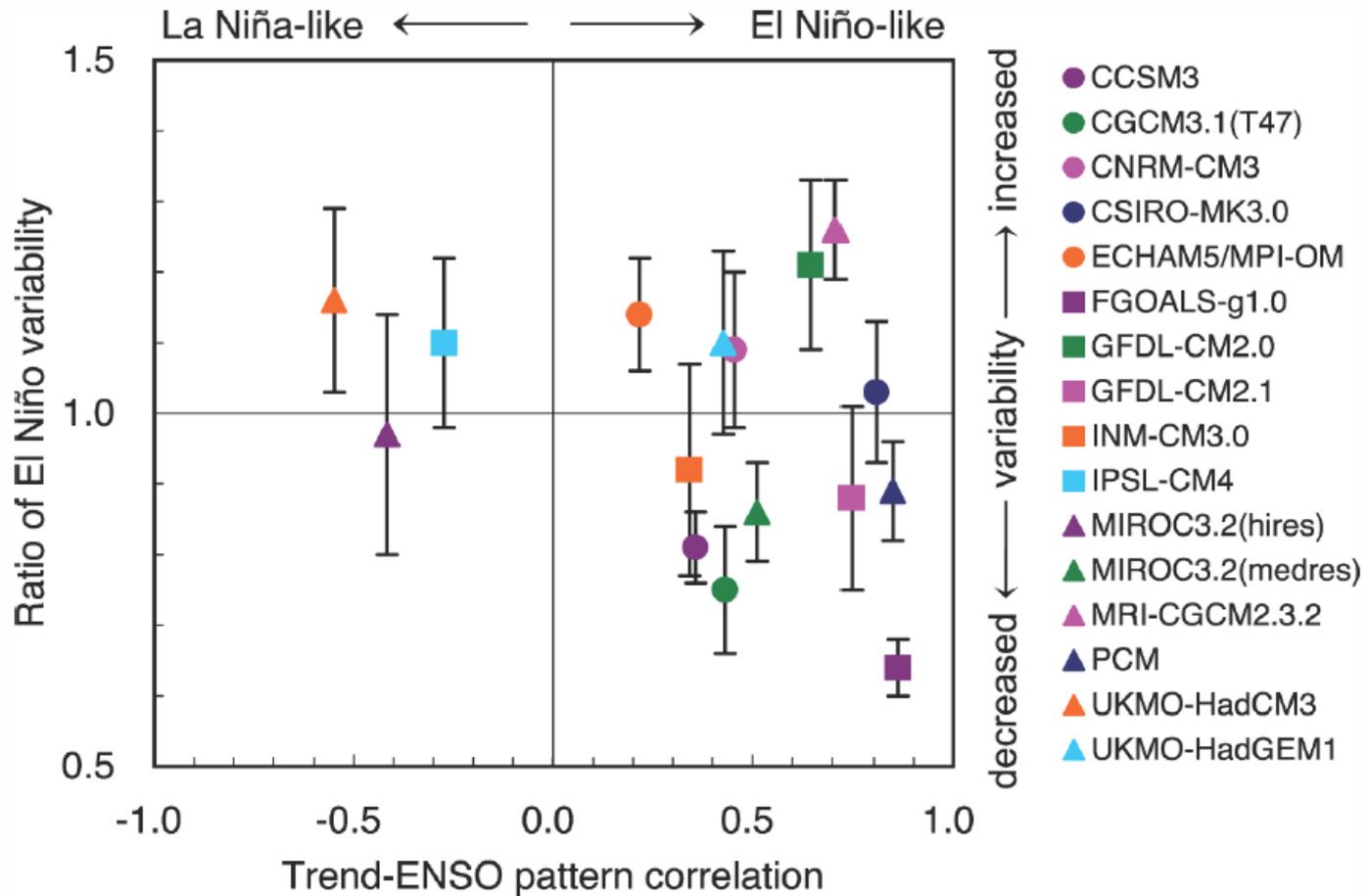
Impactos Regionales del Cambio Climático

- Aumento de temperatura 1-2°C (*)
 - Disminución de precipitación 15-25% (*)
- (*) Proyección a fin de siglo bajo escenario A2



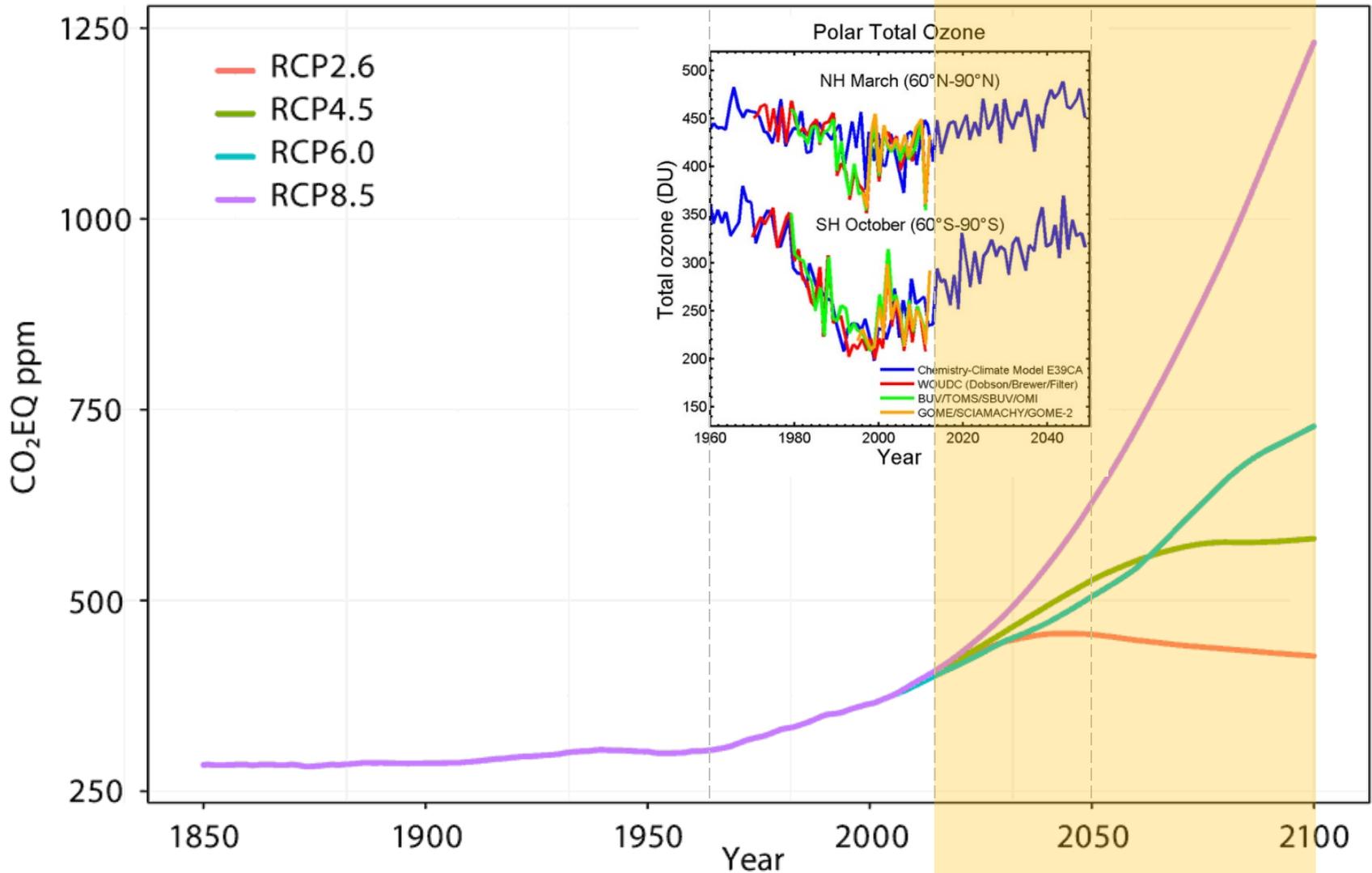
Una pregunta sin respuesta: ENSO en el futuro?

Digamos que sigue igual...



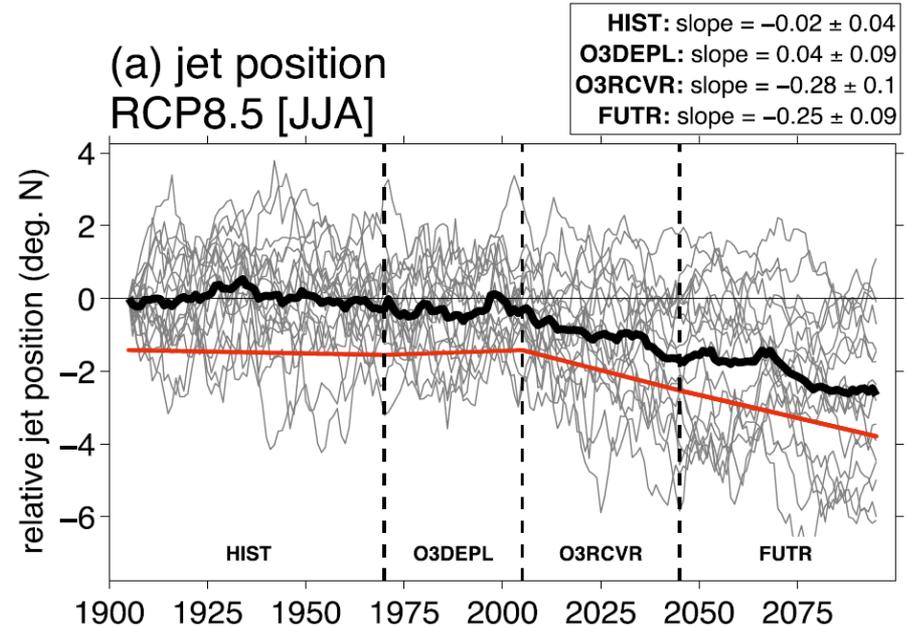
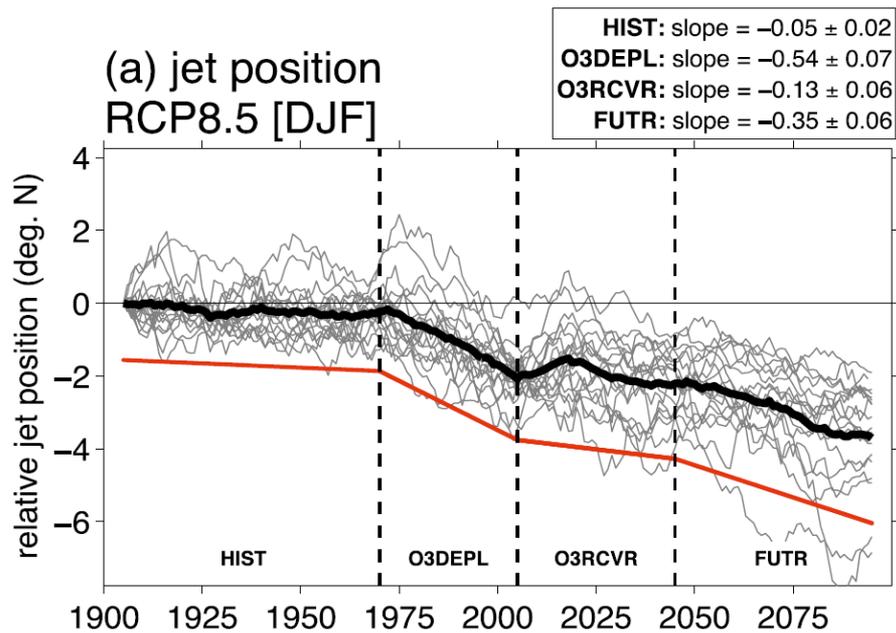
Greenhouse gases and Ozone: the main drivers of climate change

CO₂ Equivalent Concentrations in RCPs

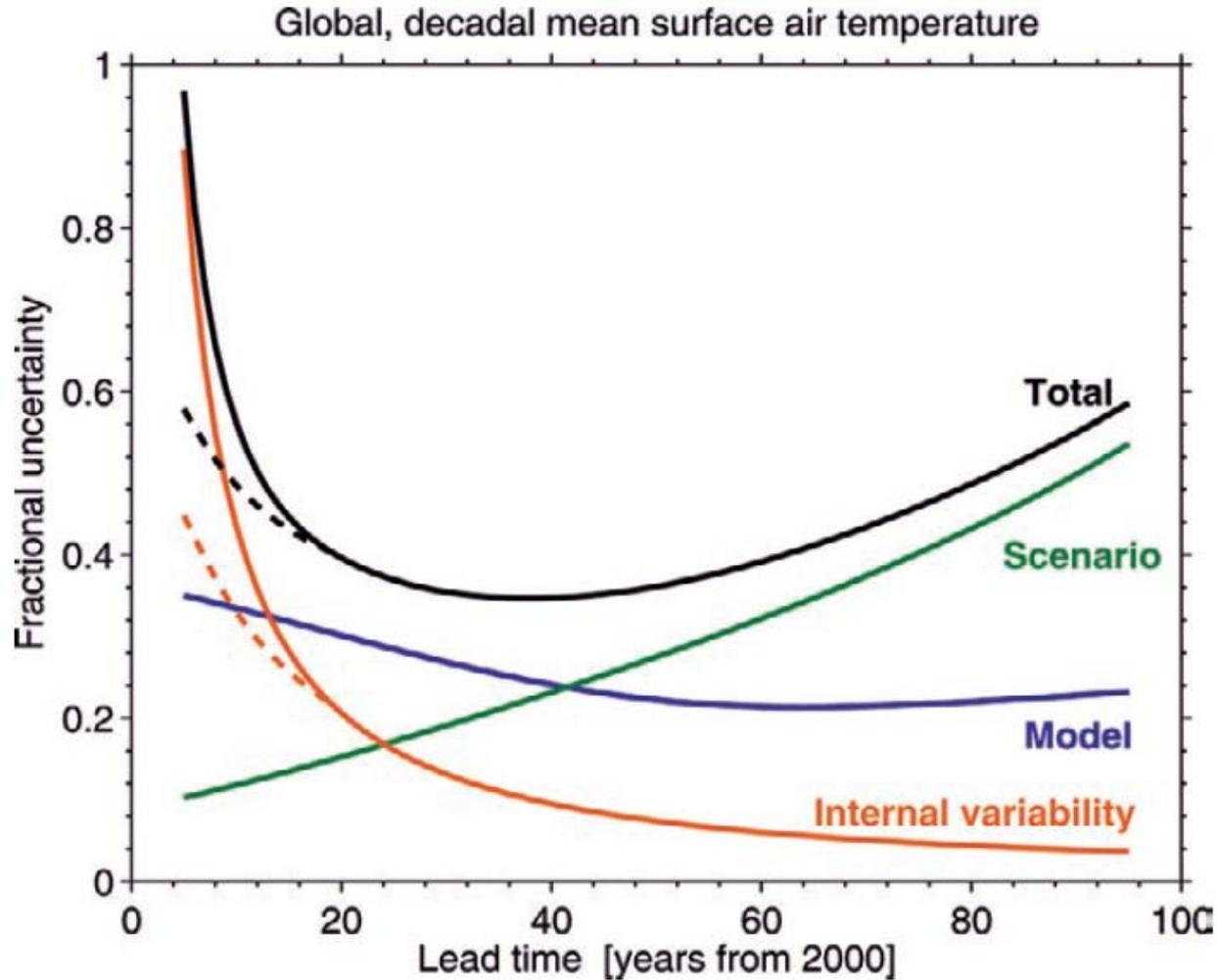


Projections of Jet Position

Implications for Patagonia hydro climate



Delayed Southern Hemisphere Climate Change Induced by Stratospheric Ozone Recovery, as Projected by the CMIP5 Models



Fractional uncertainty = signal/noise = ensemble mean / ensemble spread

Warning: uncertainty is not obviously related to accuracy.

Conclusiones

* Anomalías climáticas locales de alto impacto (sequia, alta radiación solar, vientos del sur) se explican por el debilitamiento de los Oestes y altas presiones al sur del continente.

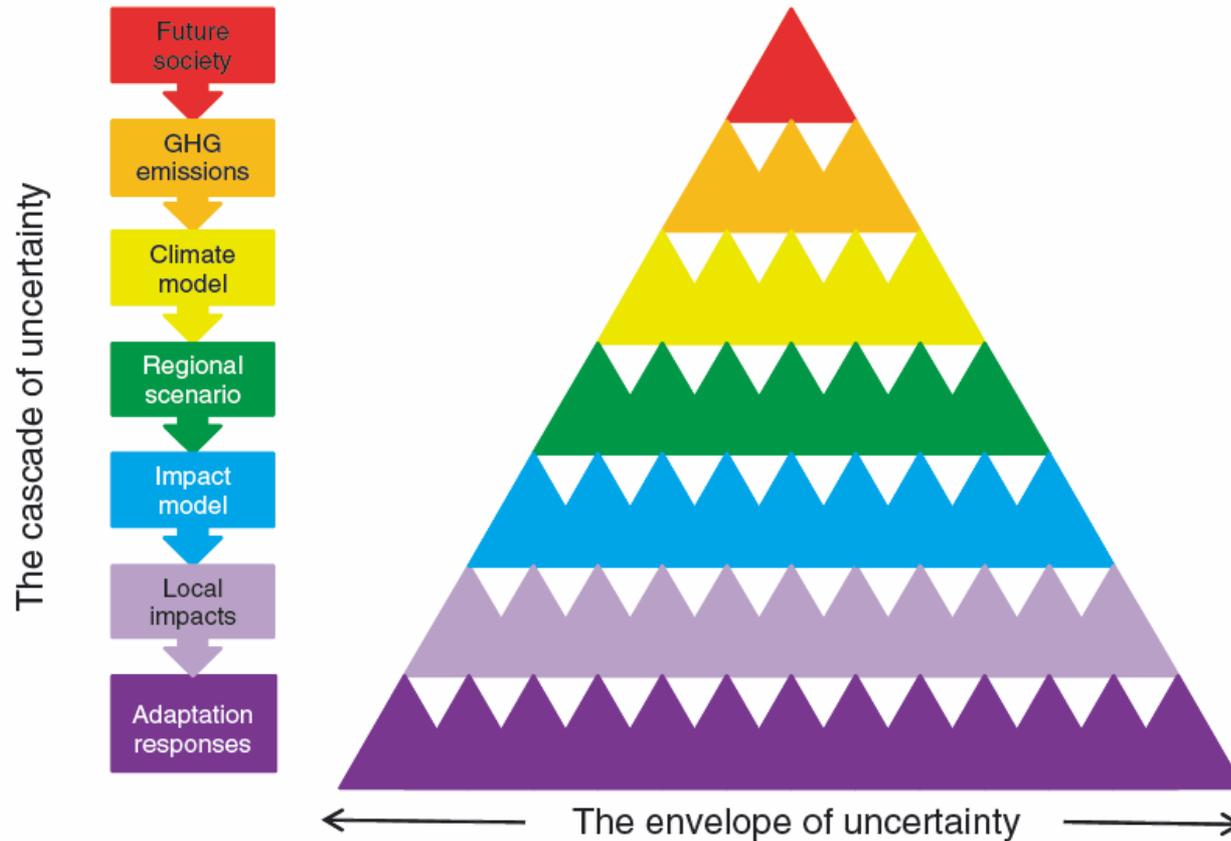
* Estas anomalías climáticas forzadas por El Niño (natural) y el cambio climático antropogénico

* El futuro climático de la Patagonia: Disminución de precipitación y leve aumento de temperatura, superpuesta en variabilidad natural.

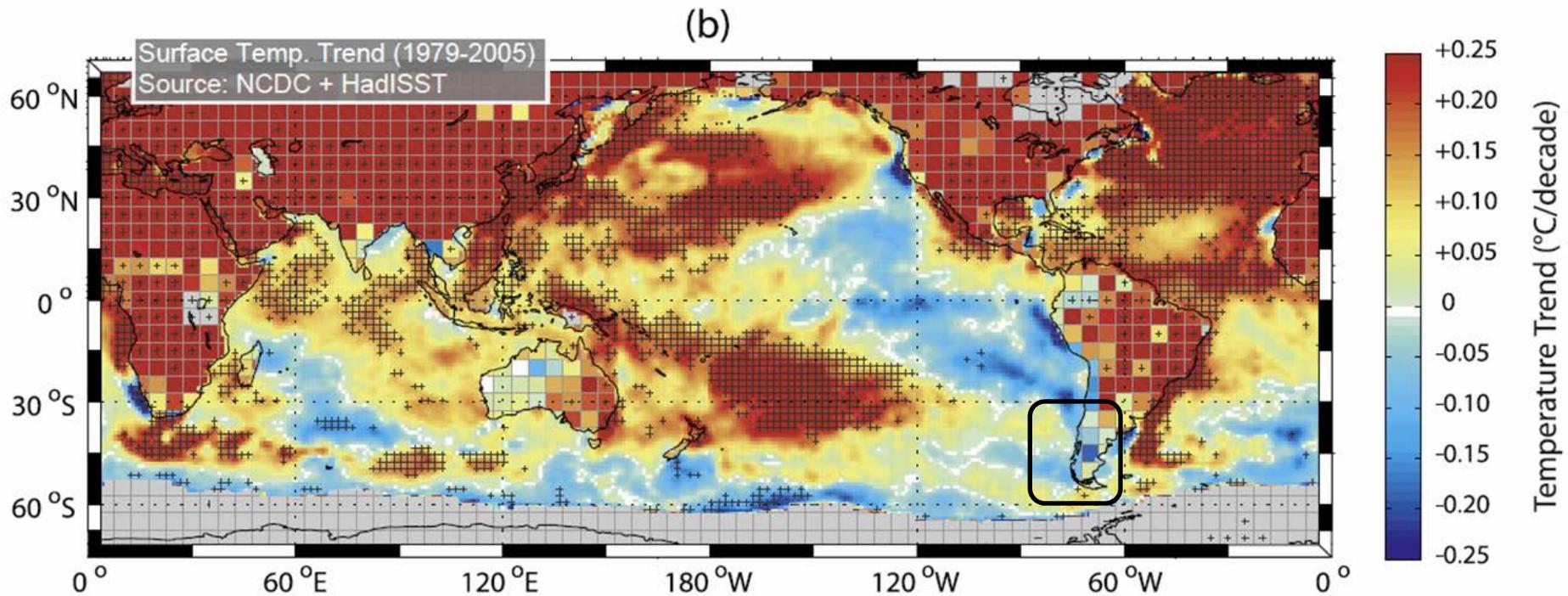
ENSO continua como siempre. Incertidumbre en próximas décadas. No se aceptan devoluciones....

Material de apoyo

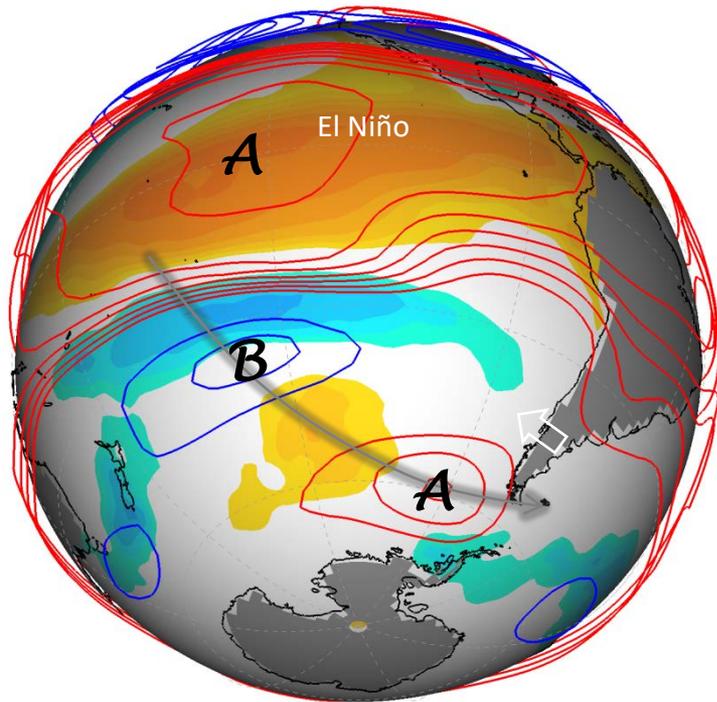
La pirámide de incertidumbre



Cambios Observados de Temperatura 1979-2005

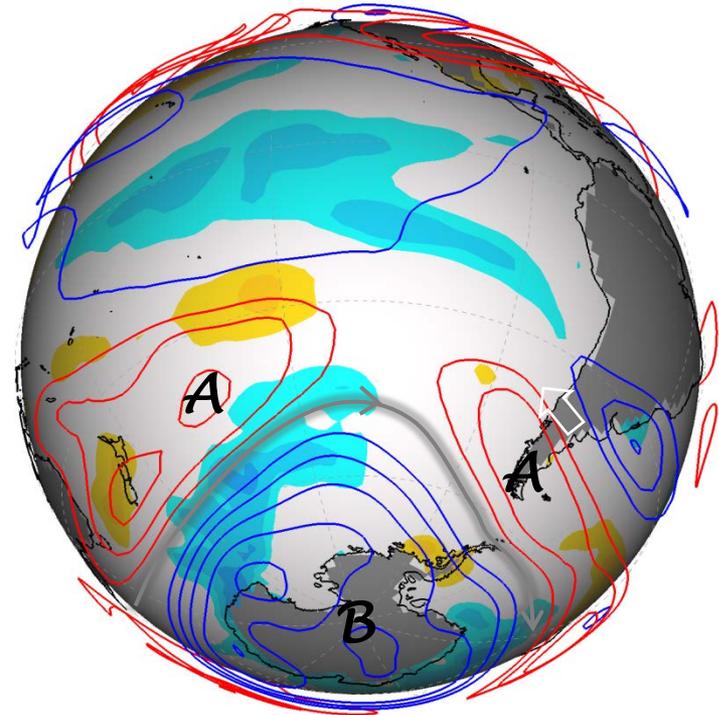


Impacto de El Niño (ENOS) y el Modo Anular del Sur (SAM+) en Patagonia durante primavera-verano



El Niño

(Variabilidad Natural)

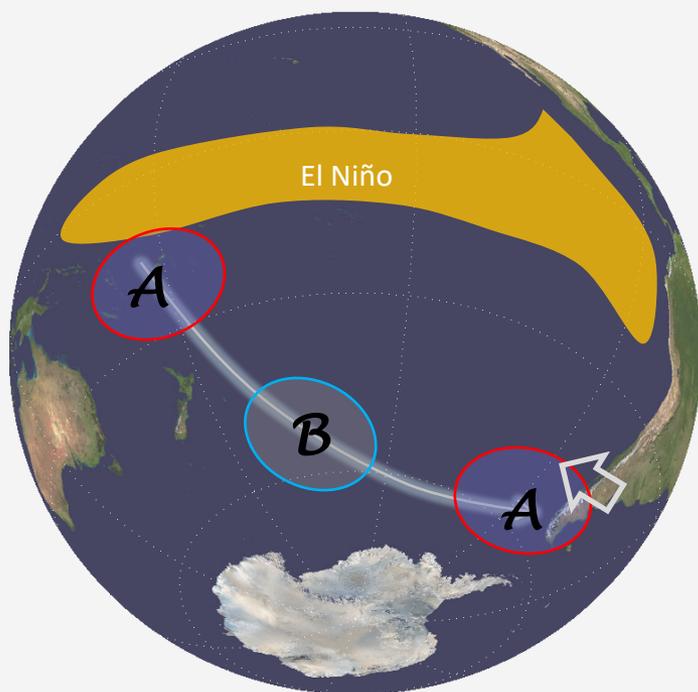


Fase SAM+

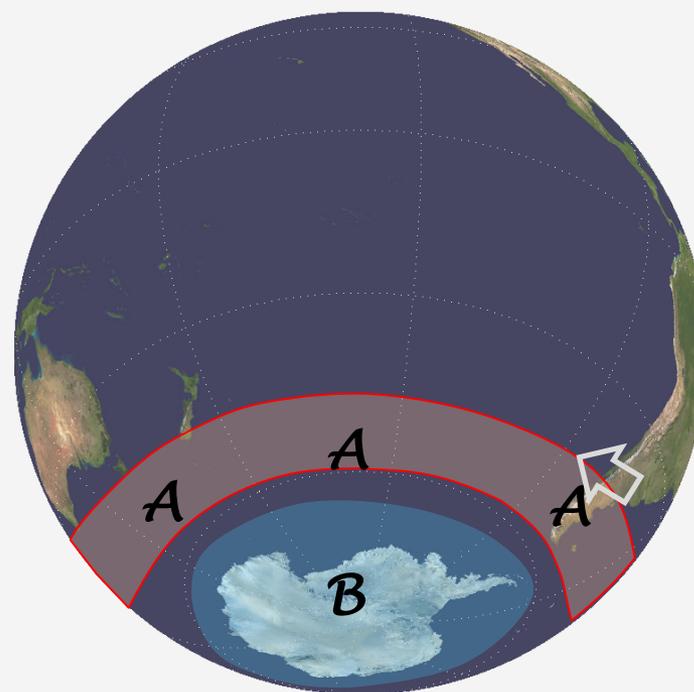
(Antrópico: GEI y O3)

Diferentes forzamiento, respuesta similar:
Condiciones anticiclónicas y sequía en Patagonia

Impacto de El Niño (ENOS) y el Modo Anular del Sur (SAM+) en Patagonia durante primavera-verano



Fase ENOS+
(Variabilidad Natural)



Fase SAM+
(Antrópico: GEI y O3)

Diferentes forzamiento, respuesta similar:
Condiciones anticiclónicas y sequía en Patagonia