

Long-term variability of central Andes precipitation in the IPSL-CM6A-LR model: origin and causes.

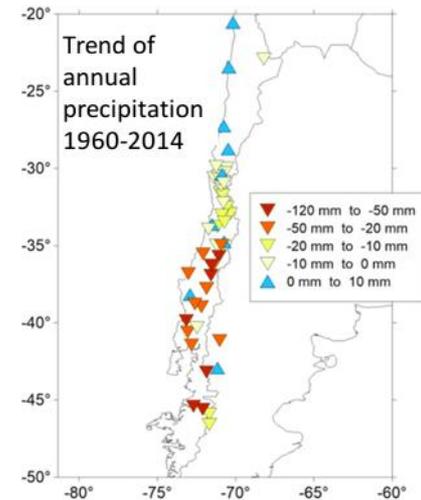
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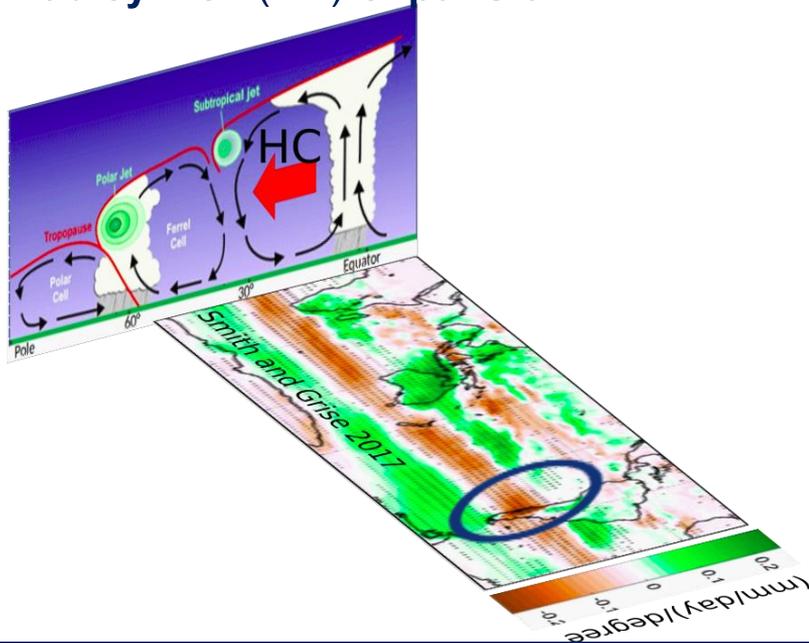
Background

➤ **Drying trend in Southwestern South America (SWSA) linked to:**

- Interdecadal Pacific Oscillation (IPO) (Boisier 2016)
- Southern Annular Mode (SAM) (Boisier 2018)



➤ Emerging **Hadley Cell (HC) expansion** associated with subtropical drying (Smith and Grise 2017)



Motivation:
**Any link between SWSA
drying and HC
expansion?**

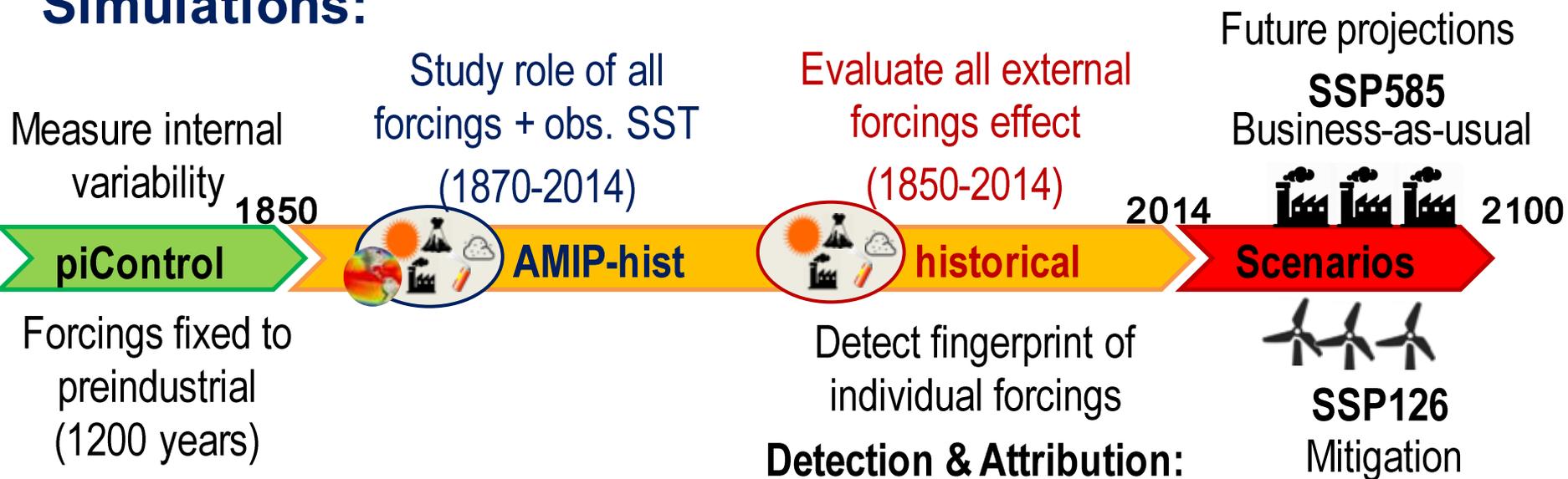
IPSL-CM6A-LR simulations

Model: IPSL-CM6A-LR new version (Boucher et al. 2020) for CMIP6



Atm. resolution: 2.5° lon x 1.5° lat x 79 levs

Simulations:



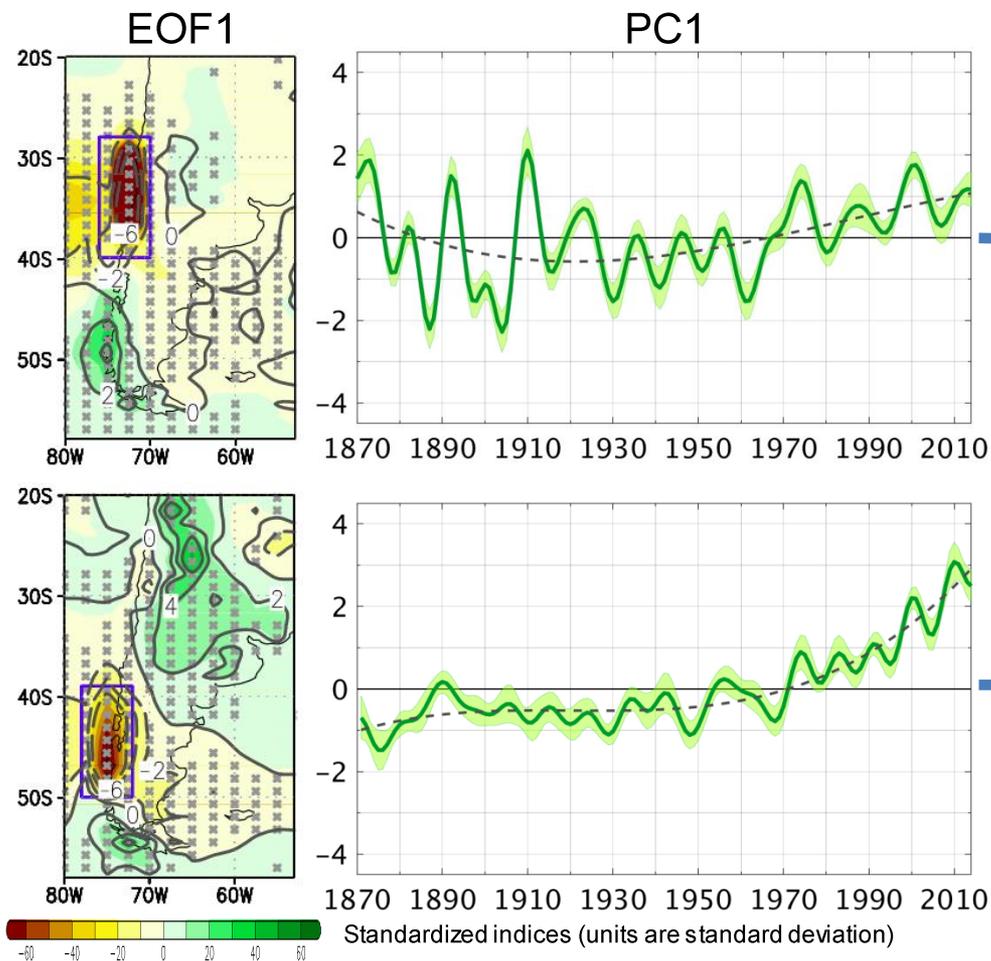
Detection & Attribution:

- natural
- ozone depletion
- GHG
- aerosols



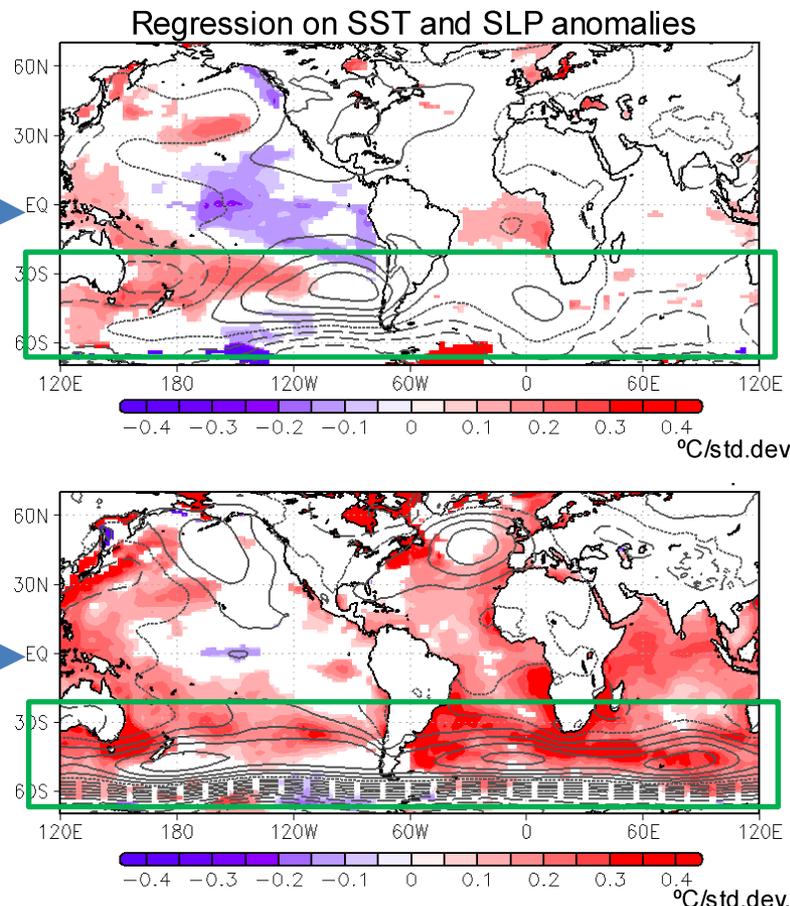
AMIP-hist

SWSA drying since ~1970s



mm/std.dev.
Contours: precip. linear trend

SST internal and forced variability: IPO + Global Warming



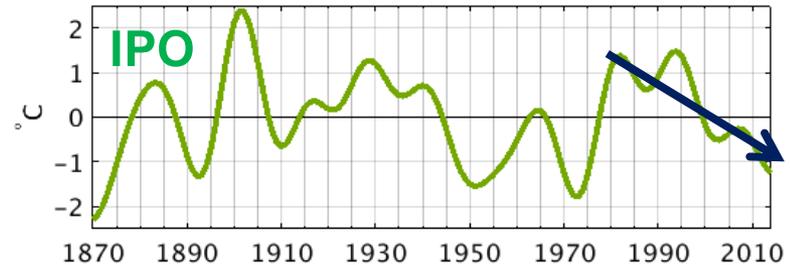
Contours: SLP anomalies in intervals of 0.2 hPa/std.dev.

Linked to IPO phase shifts?

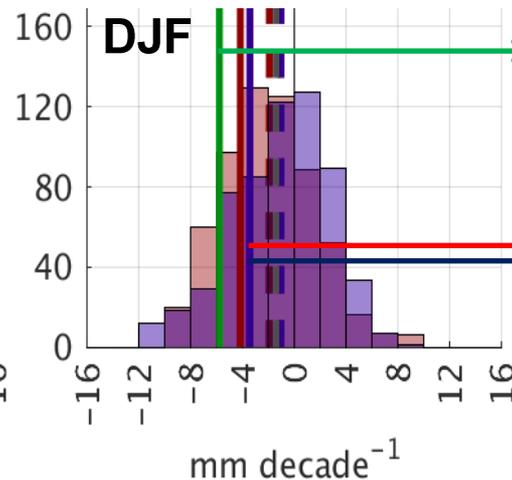
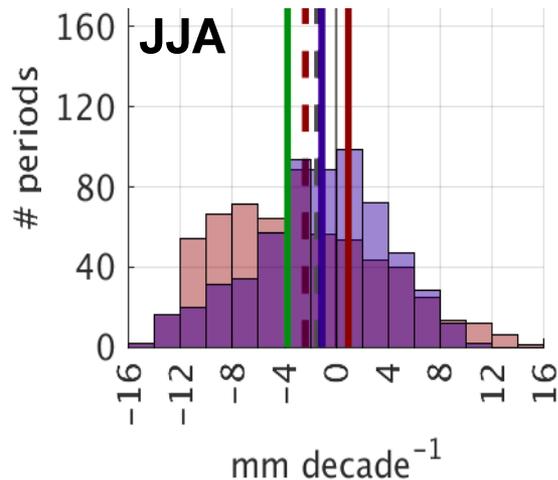


AMIP-hist

Wide IPO negative phase shift in **1979-2014**
(Boisier et al. 2016; Jebri et al. 2020)



PDFs of precipitation trend over 36-year periods with IPO positive (**redish bars**) and negative (**blue bars**) phase shifts in amip-hist individual members



Green line: amip-hist ensemble-mean trend in 1979-2014

Red and blue lines: mean trend in 1979-2014 when the IPO presents **positive** and **negative** phase shift in **historical simulations**

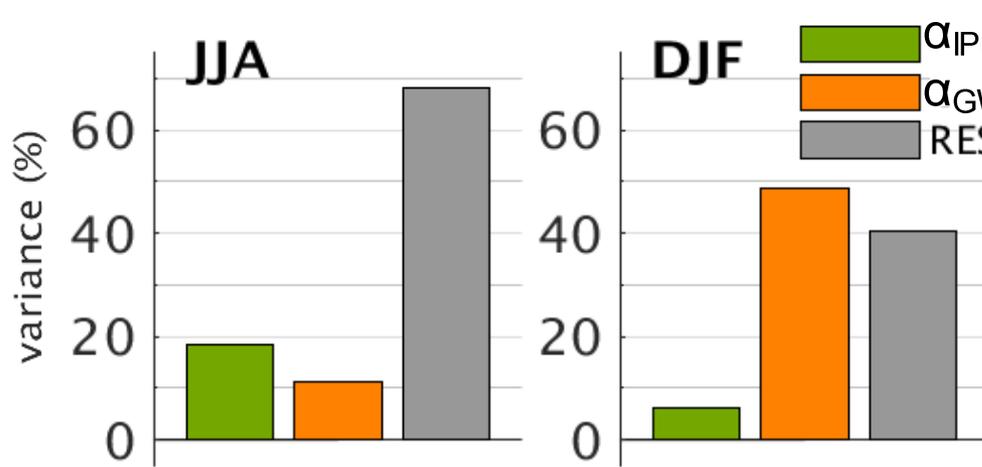
➤ **Simulated precipitation trends independent of IPO phase whifts.**

SST influence: Internal vs forced variability



AMIP-hist

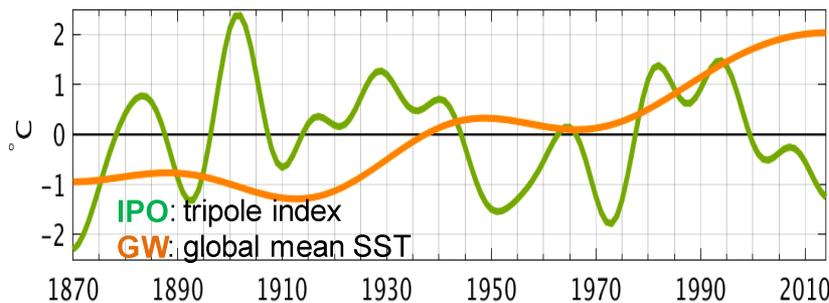
Decomposition of precipitation variance: $\text{var}[\text{PR}] = \alpha_{\text{IPO}}^2 + \alpha_{\text{GW}}^2 + \text{RES}$



α_{IPO} and α_{GW} multilinear regression coefficients

Residual induced by other drivers:

Forced dynamical or thermodynamical processes?



➤ **External forcing plays a major role**

External forcing: dynamics vs thermodynamics



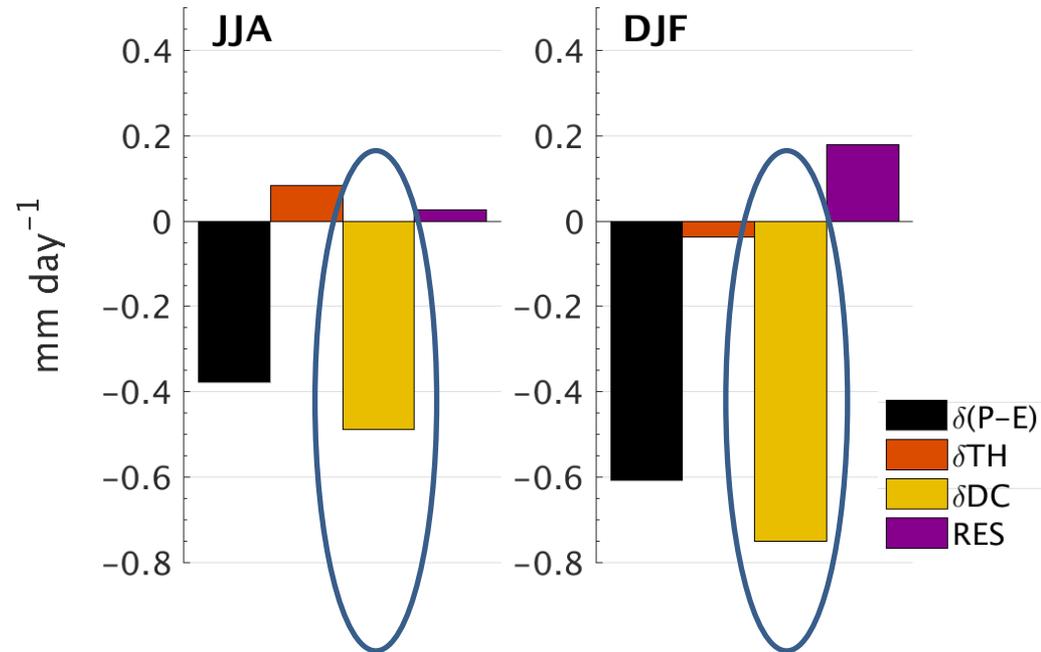
historical

Decomposition of net moisture budget change ($\delta(P-E)$) in SW SA from 1851-1910 to 2005-2014:

$$\delta(P-E) = \delta TH + \delta DC + RES$$

Thermodynamic: $\delta TH \approx -\frac{1}{gp_w} \cdot \nabla \int_0^{P_s} u_r \cdot \delta q \, dp$

Dynamic: $\delta DC \approx -\frac{1}{gp_w} \cdot \nabla \int_0^{P_s} \delta u \cdot q_r \, dp$
(Ting et al. 2018)



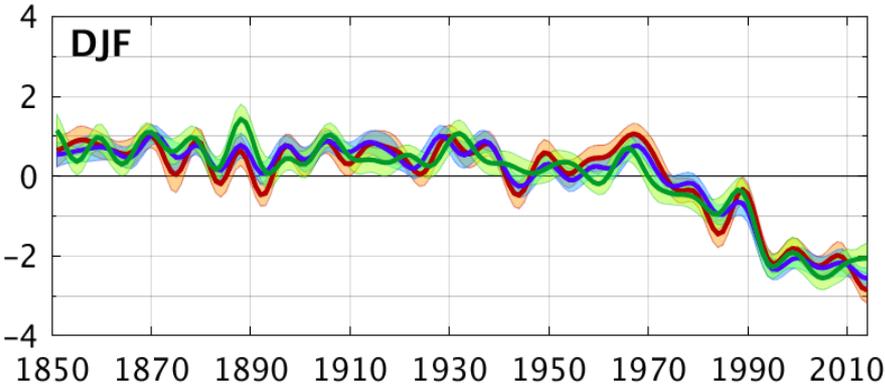
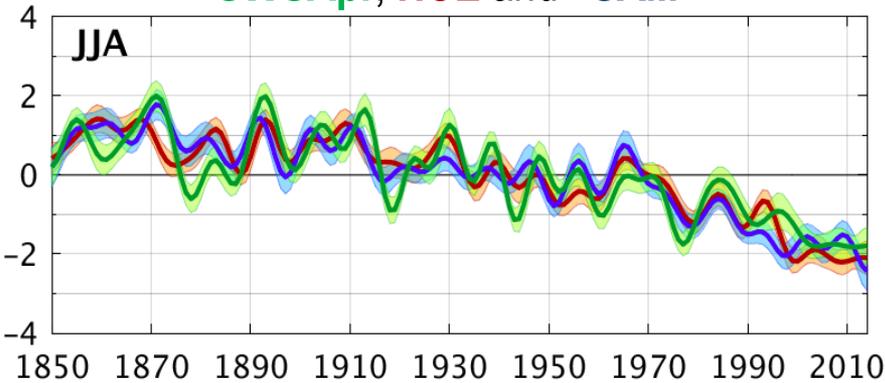
- **Dynamical processes dominate forced changes in SW SA**
Is it the HC expansion?

Dynamical modes: SAM and HCE

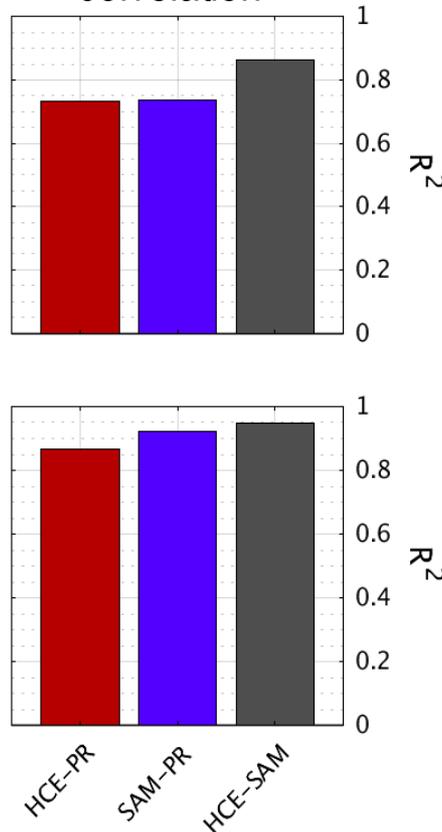


historical

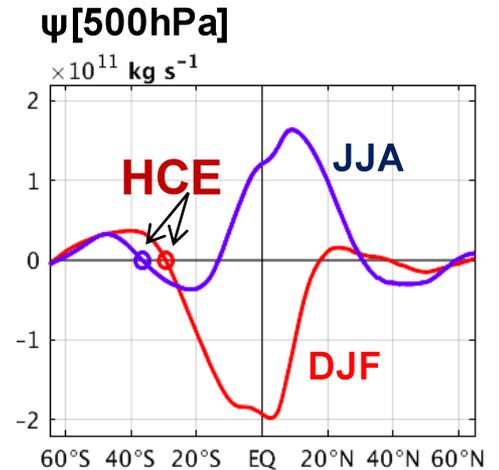
Standardized indices:
SWSApr; **HCE** and **-SAM**



Square of correlation



Index of HC extent (**HCE**):
 low-pass-filt. zero-crossing of
 500-hPa meridional
 streamfunction (ψ).

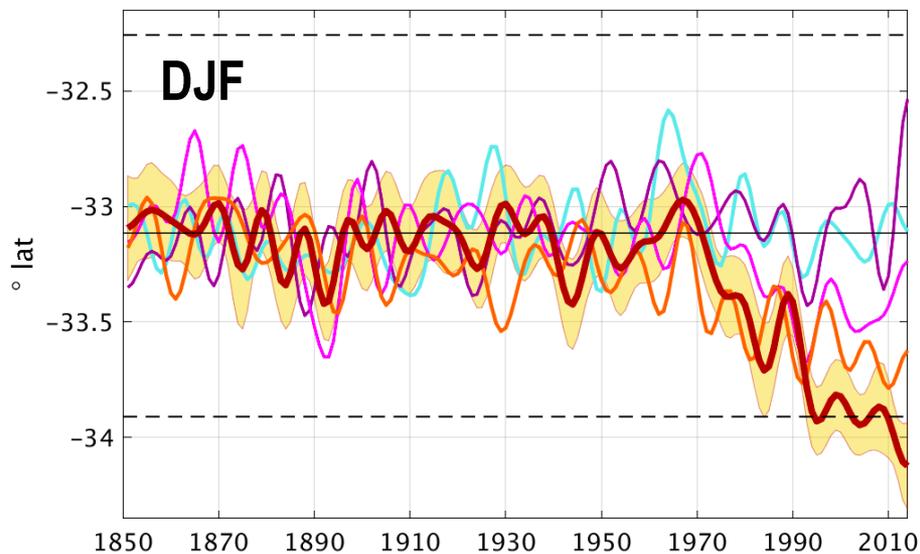
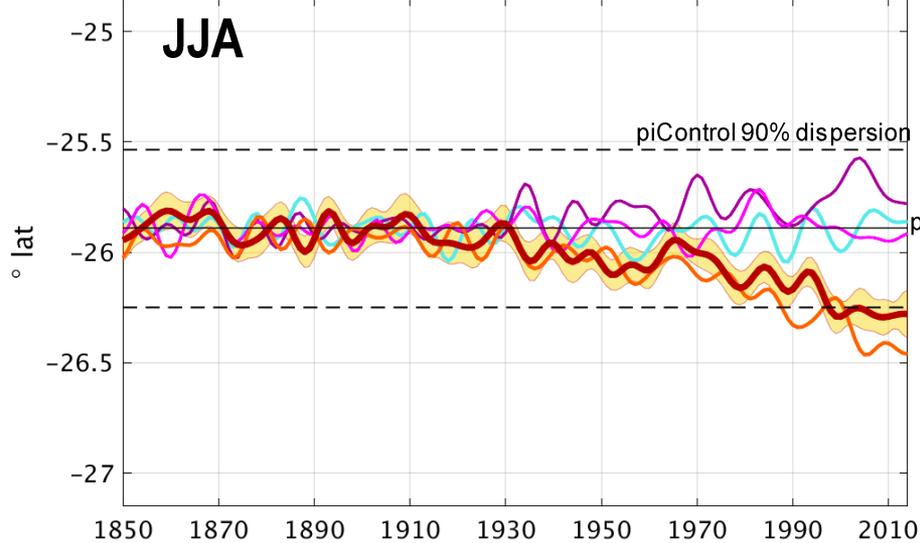


Southern Annular Mode (**SAM**):
 PC1 of low-pass-filt. SLP
 anomalies south of 20° S.

➤ High colinearity with HC expansion and the SAM strengthening

HC expansion: attribution

Ensemble-mean HCE indices



➤ Extreme HC expansion in response to antropogenic forcings:

- **GHG** in all seasons

- Plus **ozone depletion** in DJF

aerosols 

natural 

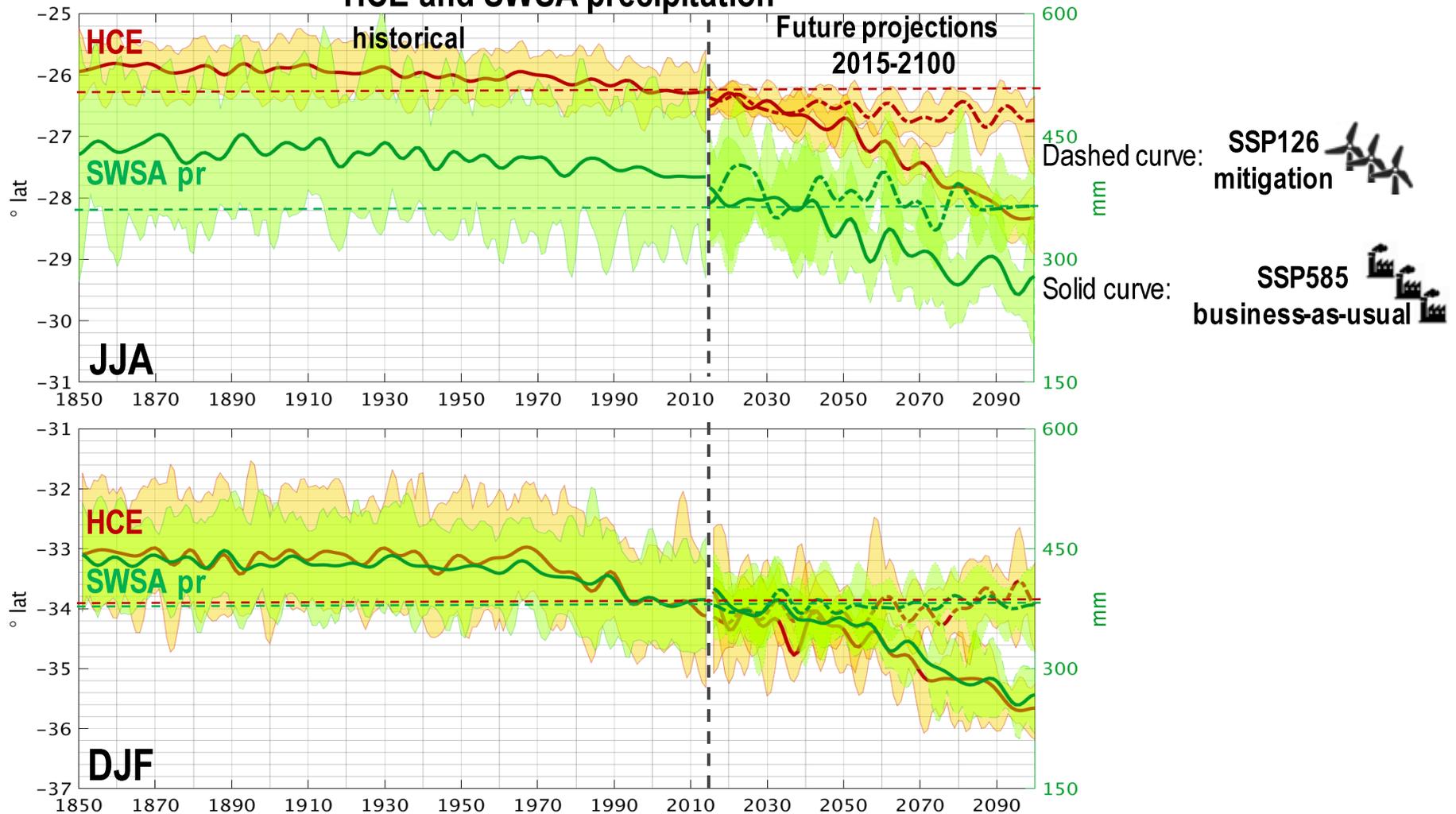
ozone depletion 

GHG 

all forcings 

Future HC expansion and SWSA drying

HCE and SWSA precipitation



➤ Future scenarios project persistent HC expansion and SWSA drying due to anthropogenic forcing

Main findings

- The emerging **SWSA drying** trend since the ~1970s is **captured by the IPSL-CM6A-LR**.
- **External forcing has the leading role** compared to decadal internal variability of SST (i.e., IPO):
 - Origin : forced **dynamical changes** such as HC expansion and SAM strengthening.
 - Causes : anthropogenic forcings of **GHG** and **ozone depletion**.
- The HCE and SWSA precipitation values emerge from the threshold of internal variability by the mid-1990s in DJF
- The HC expansion and SWSA are projected to persist until 2100 under business-as-usual conditions and to stabilize under mitigation scenario.