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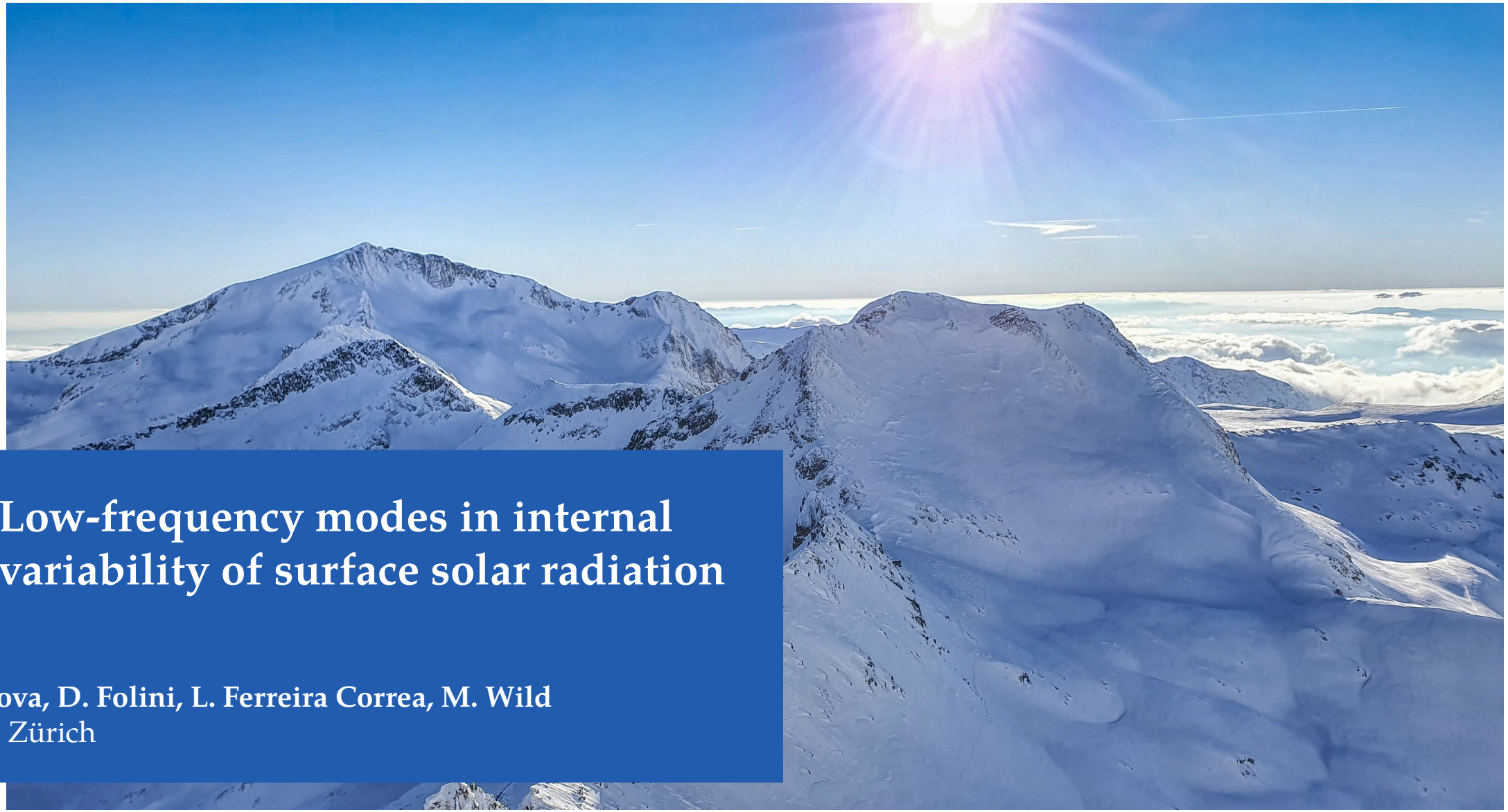

Low-frequency modes in internal variability of surface solar radiation

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Internal variability (IV) and surface solar radiation (SSR)

IV comprises all processes that occur within the climate system **without** any **natural** or **anthropogenic** forcing; usually stochastic in nature.

IV leads to uncertainties when detecting the forced signal (trend) in both **climate models** and **observations**.

Analysis of CMIP5+6 unforced control runs (piControl) shows that the **magnitudes of unforced SSR trends** may be similar to those of the **forced signal**. The magnitudes of SSR trends of arbitrary lengths and percentiles can be **linked** analytically.

Important for 2 reasons:
1) causes unforced trends;
2) interferes with the forced signal and might entirely mask a forced trend.

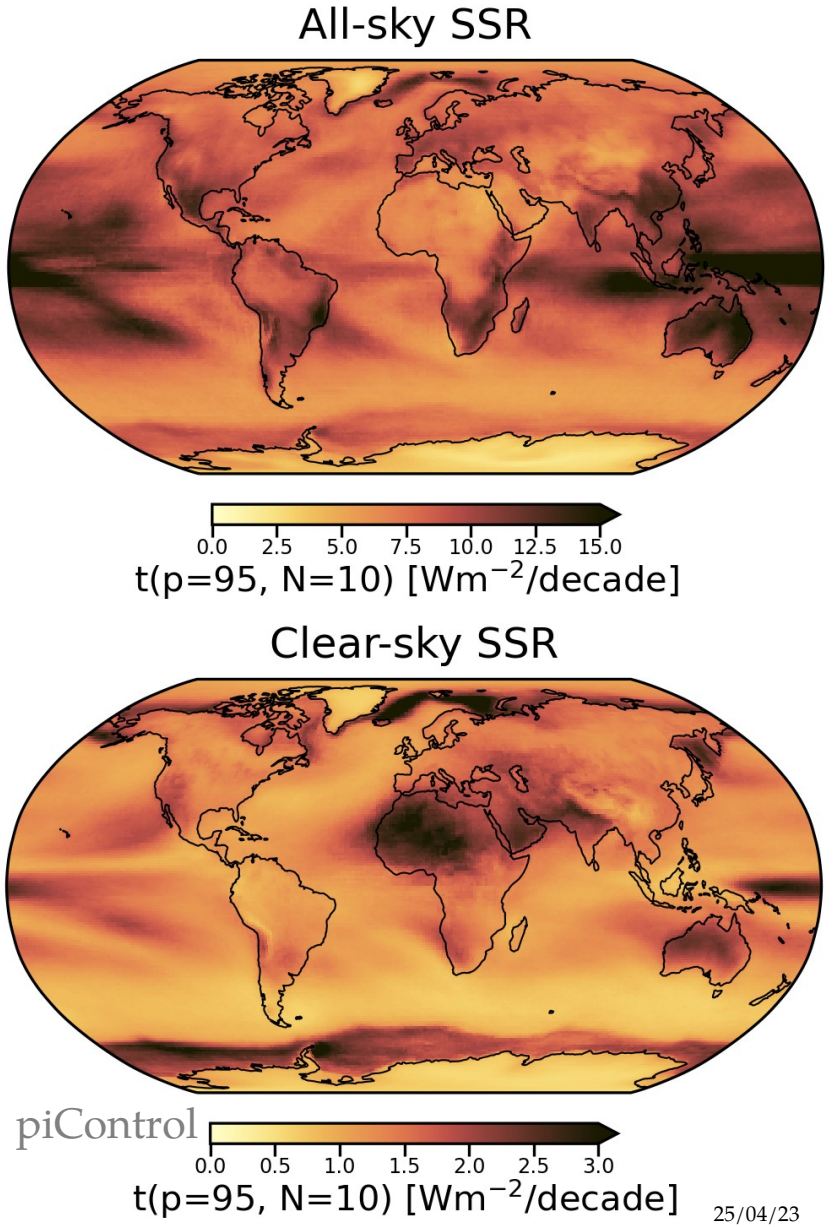


Figure: 95th percentile of all possible 10-year trends based on CMIP6 piControl
Folini et al. (2017) JGR: Atm., Chtirkova et al. (2021) JGR: Atm.

From long unforced simulations, we have sufficient statistics to generalise the relationship between the climate modes of variability (SST) and SSR.

What is the mean response of the planet to a PDO, etc.?

Seek periods of strong transitioning in SST

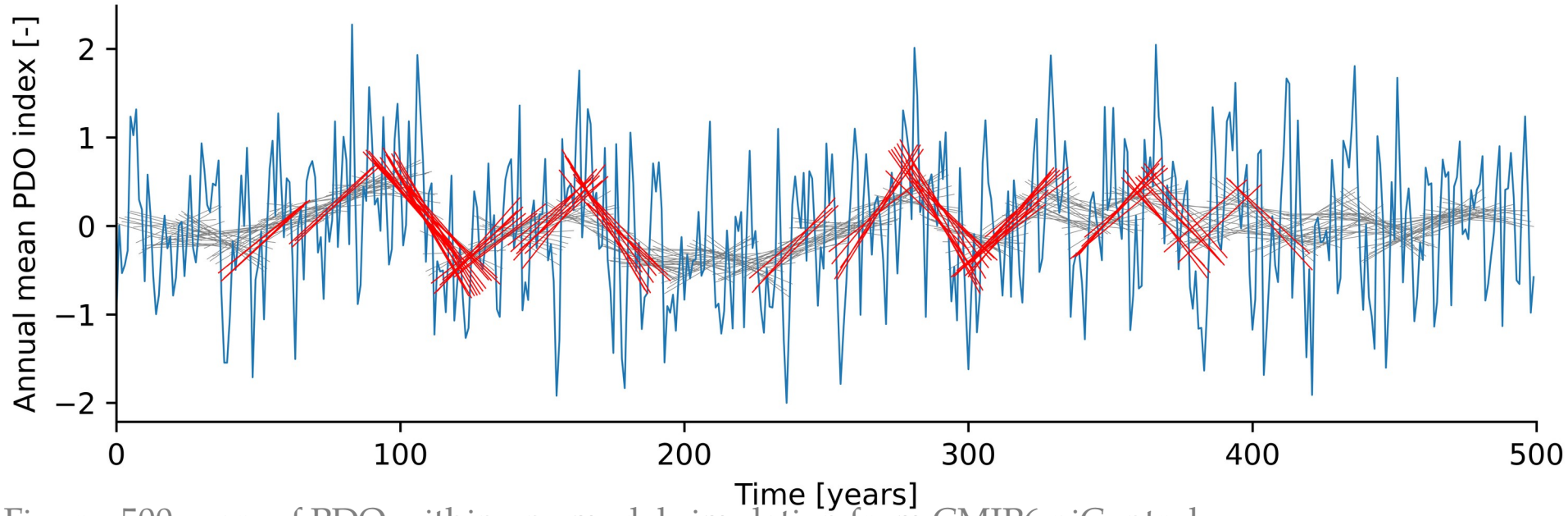
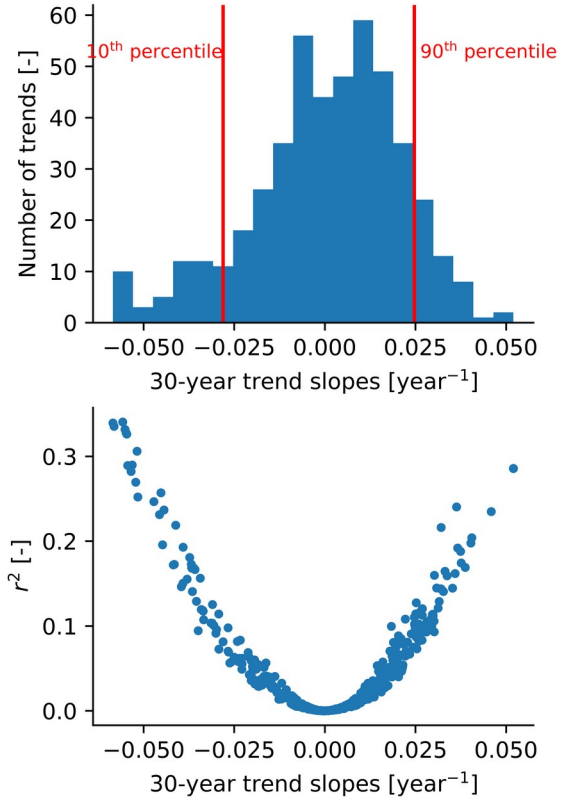


Figure: 500 years of PDO within one model simulation from CMIP6 piControl

Distribution of all 30-year trends



Data from 57 models with piControl simulations of length 500-2000 years

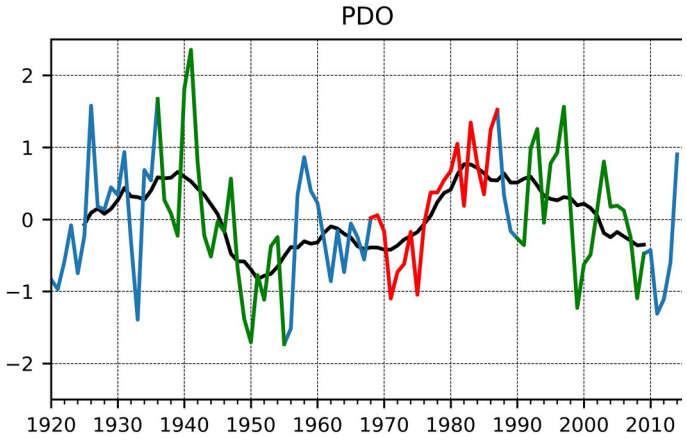
PDO mirrored in SSR trends

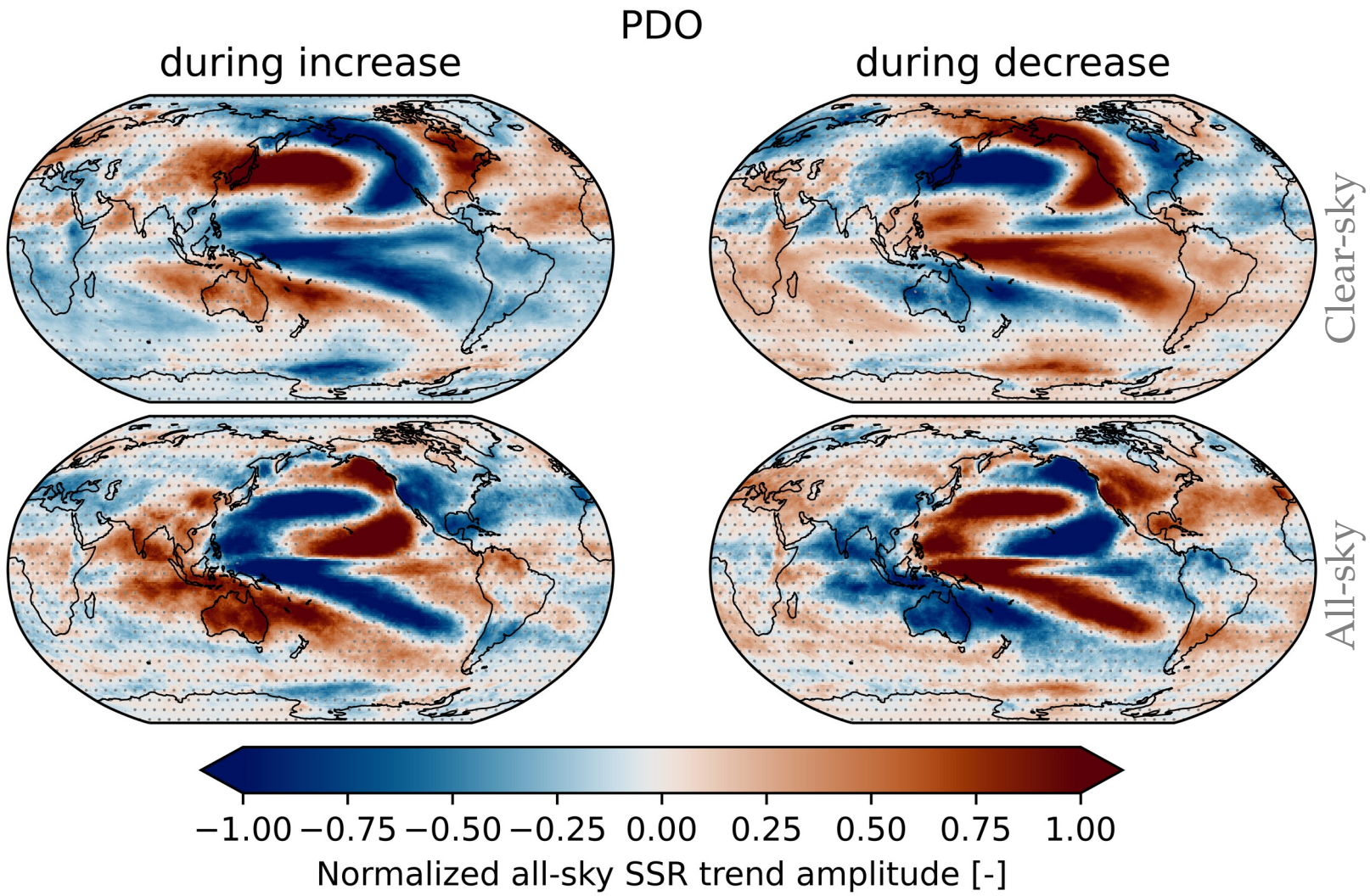
Pacific Decadal Oscillation:
- $\Delta T \sim \pm 2K$
- Zonal, couples to Walker cell
- Related to ENSO and IPO

- clear-sky changes mirrors SST changes through water vapour

- opposite trends in clear-sky and all-sky in NH

- impact on Europe and the SH





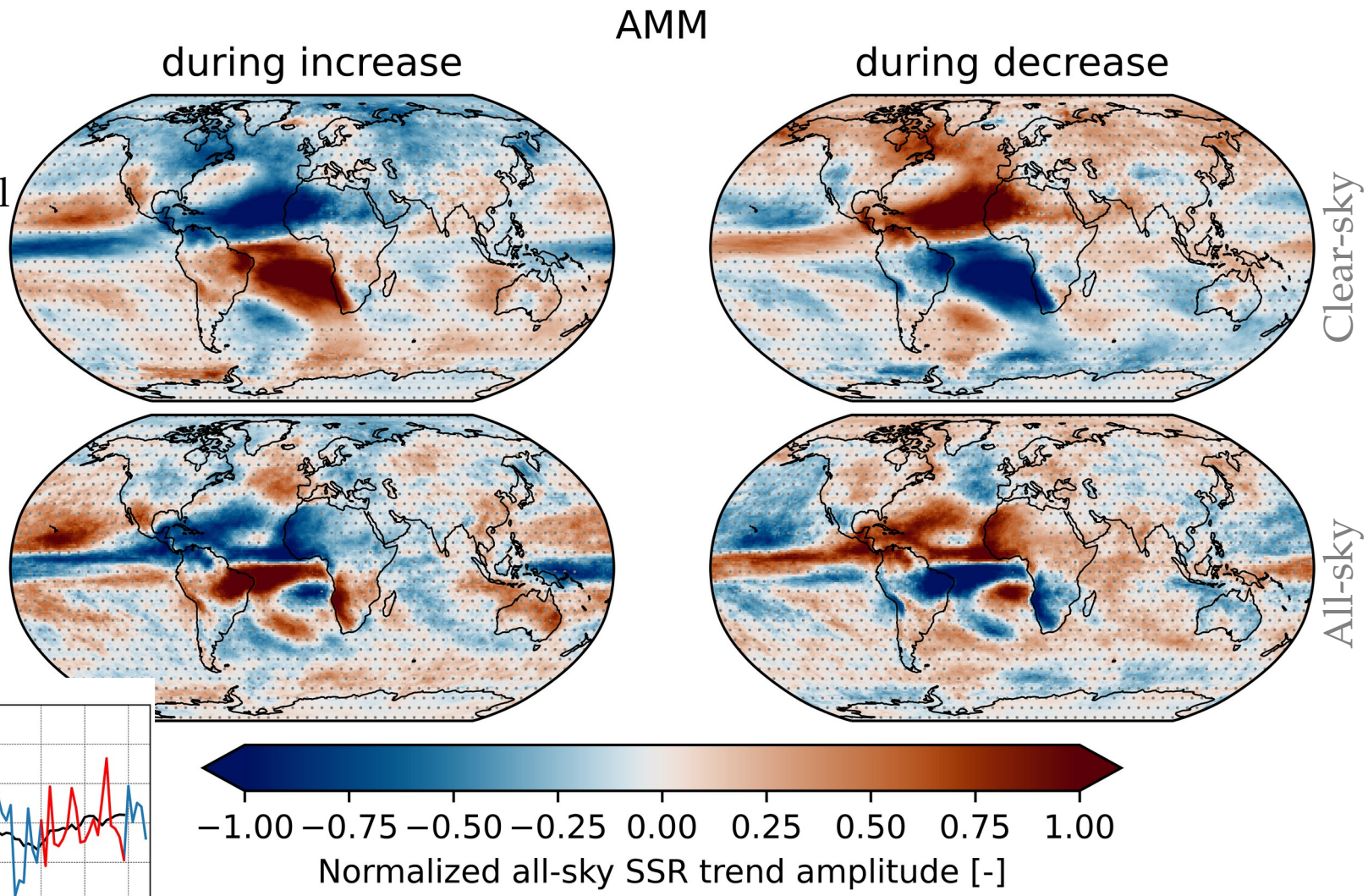
AMM mirrored in SSR trends

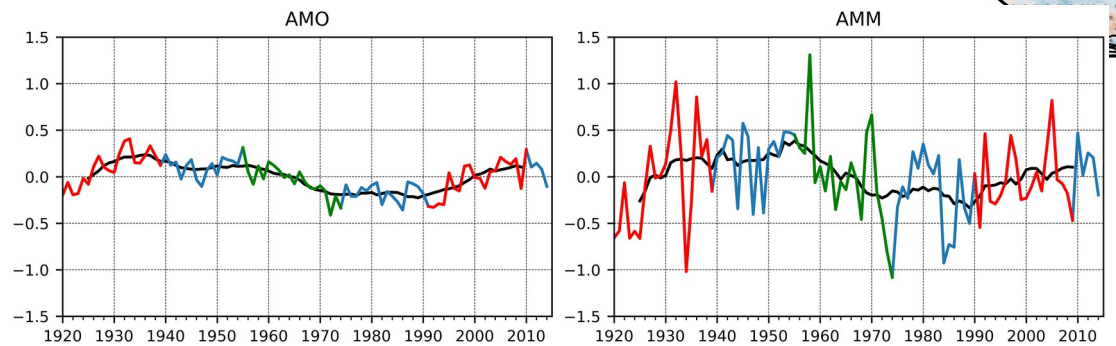
Atlantic Meridional Mode
- AMO: $\Delta T \sim \pm 0.5$ K
- AMM: $\Delta T \sim \pm 1.0$ K
- Excited by AMO
- Meridional, couples to Hadley cell

- associated with Atlantic cyclone activity (increased number and duration)

- a link between tropical and extratropical activity

- important for Africa, Central and South America





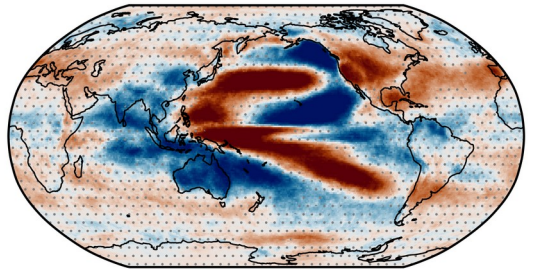
Conclusions: IV mirrored in decadal SSR trends

Knowing the state of the modes during the historical period, we can infer whether IV contributed to positive or negative SSR trends in the different periods.

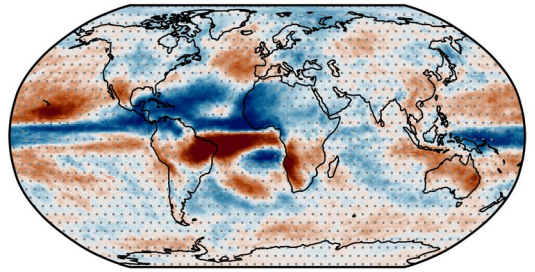
We would expect **PDO↓ (1990-2010)** to induce:
brightening in U.S., Europe, Middle East, S. South America, North West Pacific Ocean;
and **dimming** in India, China, Australia, North S. America, East Pacific Ocean.

AMM↑ (1990-2010) – important for Eastern Brazil and South Africa (**brightening**);
Mexico, the Caribbean, West Africa (**dimming**);

PDO ↓



AMM ↑



Comparing the **historical PDO** time series with **observed dimming and brightening**, we suspect that IV interacted with the aerosol signal in the following way:

- **U. S. dimming** and **brightening** were enhanced by PDO.

- The second half of **Chinese** and **Indian dimming** was probably counteracted by PDO↑ (1970-1985). Similarly, PDO↓ (1990-2010) may have counteracted the consecutive **brightening**.

- Central and Southern **European early brightening, dimming** and **brightening** might have been enhanced by the corresponding transitions in PDO.

Popular climate modes

- Atlantic Multidecadal Oscillation (AMO)
- Atlantic Meridional Mode (AMM)
- Atlantic Nino (ATL3),
  also known as Atlantic Zonal Mode (AZM)
- North Tropical Atlantic (NTA)
- South Tropical Atlantic (STA)

- Indian Ocean Dipole (IOD)
- Tropical Indian Ocean (TIO),
  also known as Indian Ocean Basin (IOB)

- El Nino and Southern Oscillation (ENSO)
- Pacific Decadal Oscillation (PDO)
- Interdecadal Pacific Oscillation (IPO)

- Southern Ocean (SO)

- Global SST (global SST)

Chtirkova, B., Folini, D., Correa, L. F., & Wild, M.
Internal variability of the climate system mirrored in decadal-scale trends of surface solar radiation.
Under revision, JGR: Atm. Preprint available at ESSOAR.

Link to preprint

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