Southern Hemisphere surface climate response to human activities analyzed using LESFMIP simulations

Leandro B. Díaz, Marisol Osman
Centro de Investigaciones del Mar y la Atmósfera
(University of Buenos Aires - CONICET, Argentina)
ldiaz@cima.fcen.uba.ar

Motivation

Trends in Southern Hemisphere (SH) atmospheric circulation over recent decades have been shaped by a combination of factors, including the rise in greenhouse gas (GHG) concentrations, the depletion of stratospheric ozone due to ozone-depleting substances (ODS), and anthropogenic emissions of aerosols.

The extent to which each of these drivers influences surface climate at regional levels remains an open question.

Objective

Attribute SH temperature and precipitation trends during the historical period (1850–2014) using simulations from the Large Ensemble Single Forcing Model Intercomparison Project (LESFMIP, Smith et al. 2022).

Data & Methodology

LESFMIP simulations

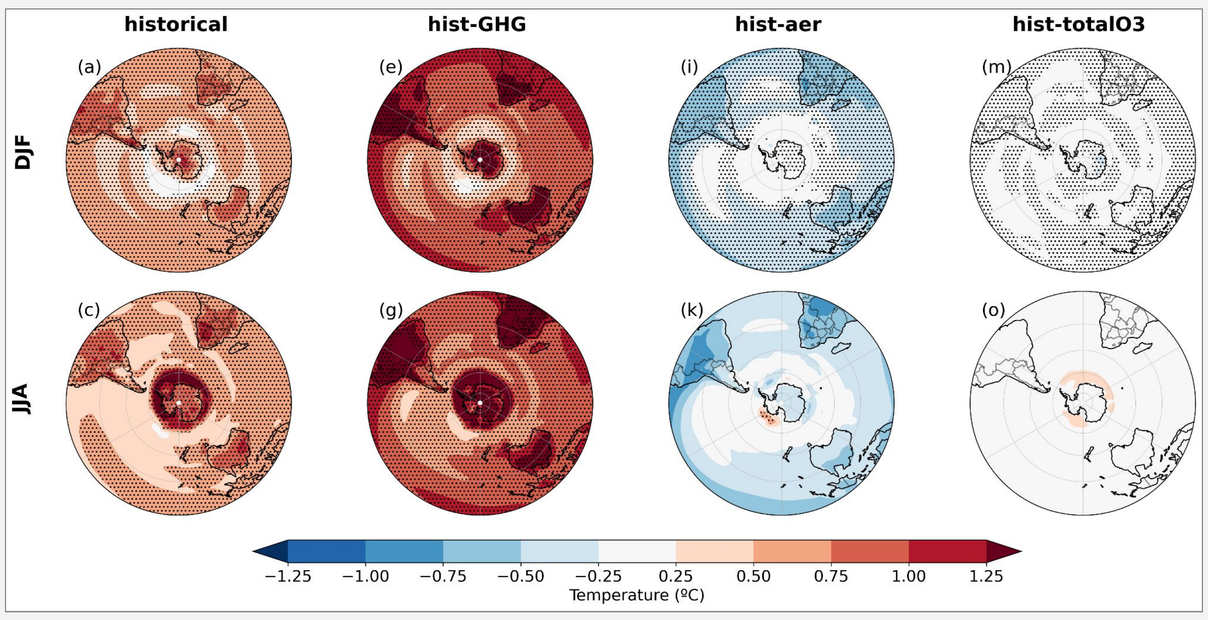
Model	Experiments			
	Historical	hist-GHG	hist-aer	hist-totalO3
ACCESS-ESM1-5	40	10	10	
CanESM5	65	50	30	10
CMCC-CM2-SR5	10	10	10	
CNRM-CM6-1	30	10	10	
GISS-E2-1-G	40	40	40	40
HadGEM3GC31-LL	55	55	55	50
IPSL-CM6A-LR	33	10	10	
MIROC6	50	50	10	10
MPI-ESM1-2-LR	50	30	30	30
NorESM2-LM	43	23	23	20

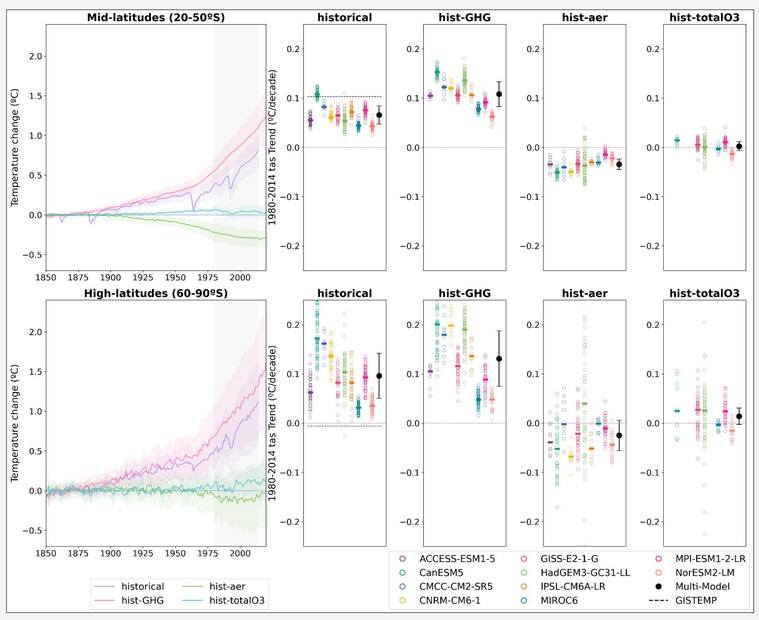
- Large ensemble size allows for better quantification of internal variability.
- Availability of multiple models, which allows for quantification of model uncertainty.
- Ability to isolate the role of different forcings.

Multi-model mean: equal weight for each model.

Model Agreement: stippling when >80% models match.

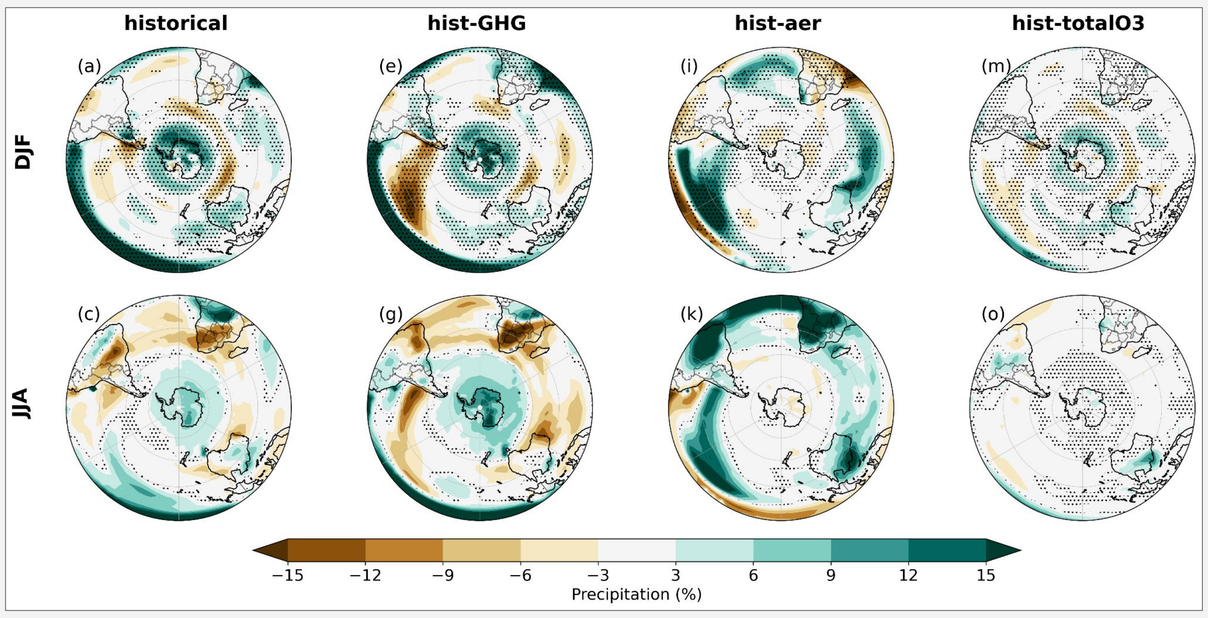
LESFMIP Multi-Model mean change 1980-2014 - 1850-1884
Near-Surface Air Temperature (°C)

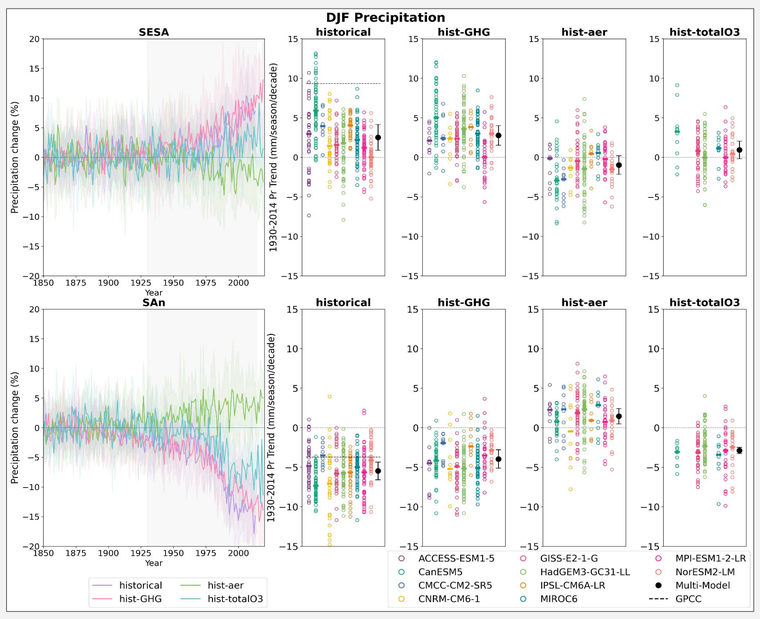


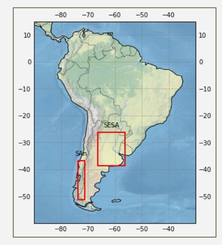


- General temperature increase over the Southern Hemisphere, with higher magnitude in continental areas. Lower model agreement in winter.
- Temperature changes mainly driven by greenhouse gas increases, but partly counteracted by aerosol forcing. Negligible role for ozone forcing.
- The average response in the historical simulations is smaller than the sum of the responses to individual forcings.

LESFMIP Multi-Model mean change 1980-2014 - 1850-1884
Precipitation (%)

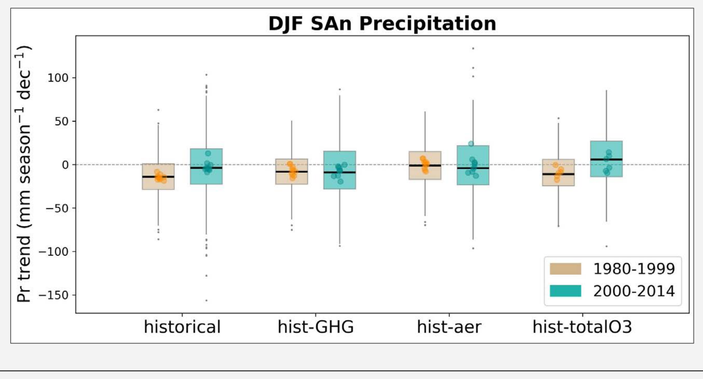




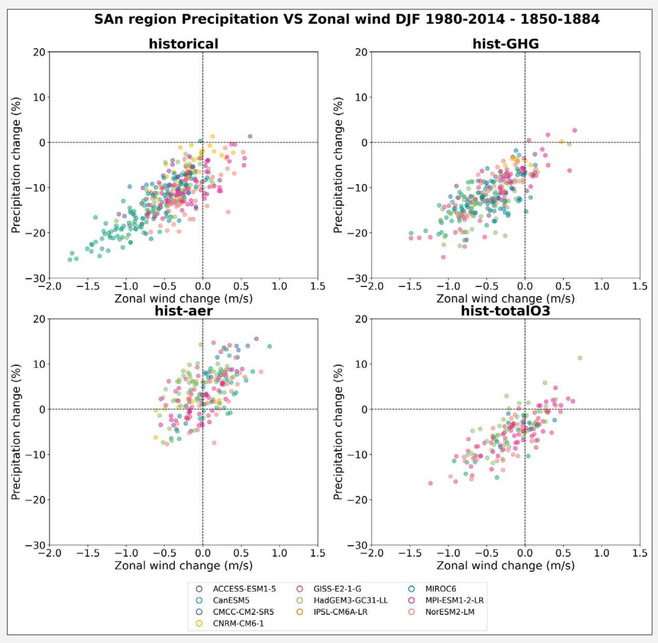


- Most simulations underestimate the trends observed in SESA.
- Despite uncertainties from models and internal variability, the signals remain consistent across models.
- Trends in SESA are primarily driven by increased GHG emissions, while unclear influence of ozone forcing.
- Trends in SAn are influenced by both GHG emissions and ozone changes.

- High (Low) agreement in austral summer (winter) between models.
- SH historical rainfall changes are mostly explained by GHG forcing.
- Aerosol forcing mitigates or cancels GHG forcing in tropical/subtropical regions.
- In mid/high latitudes, ozone forcing may play a slight role.



- Simulations suggest that ozone recovery could be counteracting GHG increasing trends in precipitation in SAn.



- Decreases in SAn precipitation could be explained by a negative trend in zonal wind intensity (r=0.78) that is also related to SAM positive trend), primarily due to greenhouse gas (GHG) and ozone forcing, although the latter has a smaller impact.

Conclusions

- There are significant anthropogenic influences (especially from greenhouse gas forcing) on temperature and precipitation patterns in the Southern Hemisphere (SH).
- Changes in precipitation and surface temperature may partly be driven by large-scale shifts in atmospheric circulation.
- Further research is needed to better understand how changes in large-scale variability could explain regional temperature and precipitation changes.

Acknowledgments

The research was supported by UBACyT20020170100428BA, CONICET-PIP 11220200102038CO, CONICET-PIBAA 2428720210100758CO, PICT-2021-GRF-TI-00498.
The lead author wants to thank the World Climate Research Programme (WCRP) and Atmospheric Processes And their Role in Climate (APARC) for the financial support to attend the Joint EPESC-LEADER Science Meeting.