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Assessing the vulnerability of the Antarctic Peninsula to climate change using high-resolution regional climate projections

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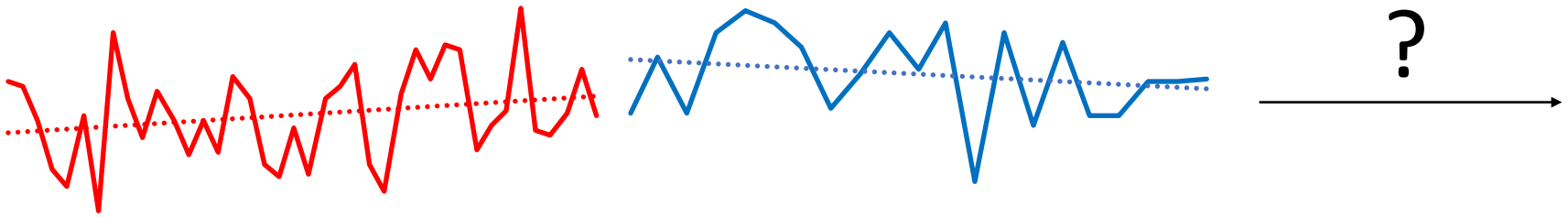
Ministerio del Medio Ambiente, Gobierno de Chile
fcfm Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile
GAIA Antártica, Universidad de Magallanes
CMM Center for Mathematical Modeling
Byrd Polar & Climate Research Center, Polar Meteorology Group, The Ohio State University



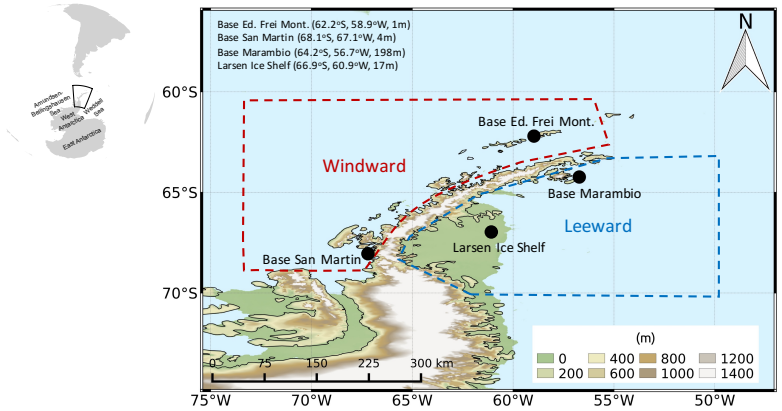
1955-1990s **1990s-2015** **2020-2050**

Motivation:

Recent climate change in the Antarctic Peninsula

Near future climate change in the Antarctic Peninsula

Data and methodology: Recent climate change in the Antarctic Peninsula



- An analysis of the recent climate variability of the Antarctic Peninsula using meteorological stations, reanalyses and satellite products (1990-2015).
- A relatively mild and humid marine climate on the western coast of the peninsula (windward) and a colder continental climate on the eastern coast (leeward)

Data	Source	Variable	Temporal resolution	Spatial resolution
Stations	Chilean Meteorological Service, British Antarctic Survey and Global Historical Climate Network Daily	Precipitation, Temperature	Monthly	
ERA5	The European Centre for Medium-Range Weather Forecasts (ECMWF)	Precipitation, Temperature Sea level pressure, Zonal wind, specific humidity	Daily, Monthly	0.28x0.28 (~30 km)
ERA-Interim	The European Centre for Medium-Range Weather Forecasts (ECMWF)	Precipitation, Temperature	Daily, Monthly	0.75x0.75 (~80 km)
NOAA/NSIDC	NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3	Sea ice concentration	Monthly	0.25x0.25 (~27 km)

Data and methodology: Near future climate change in the Antarctic Peninsula

Regional climate model simulations

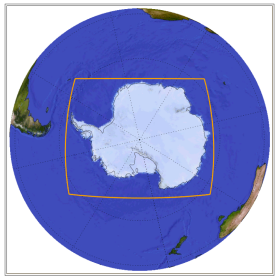
Polar Weather Research and Forecasting Model (Polar-WRF version 3.9.1)

Simulation	Lateral Boundary Conditions	Spatial Resolution	Simulation Period
PWRF-ERA	ERA-Interim	45 km y 15 km	1990-2015
PWRF-HIST	NCAR-CESM1 (r6i1p1)	45 km y 15 km	1975-2005
PWRF-RCP85	NCAR-CESM1 (r6i1p1)	45 km y 15 km	2006-2045

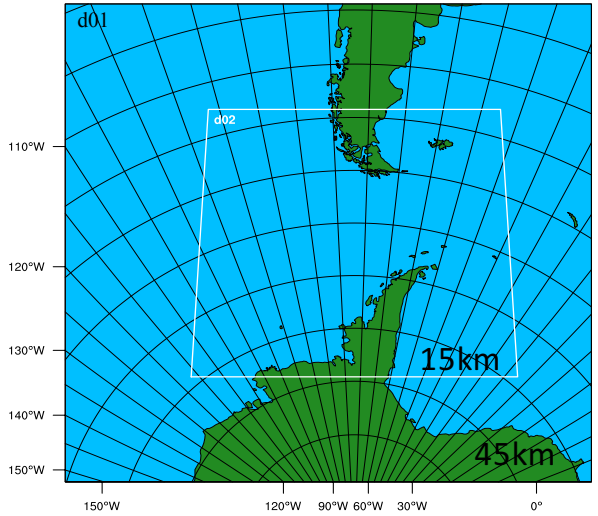
Microphysics	Morrison
Radiation	RRTMG
Land Surface	Noah-MP
Planetary Boundary Layer	MYJ
Cumulus	Grell-Freitas

- One-way nesting
- 45 km: 118 x 114 grid cells
- 15 km: 208 x 190 grid cells
- 61 vertical levels (model top at 10 hPa)
- Spectral nudging

+



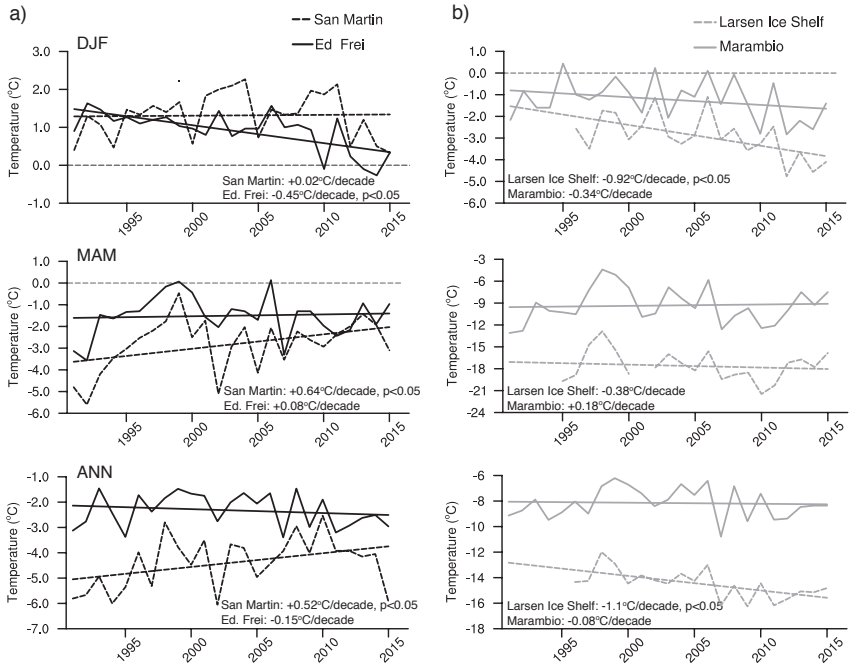
CORDEX-ANTARCTICA
KNMI-RACMO21P
(50 km)



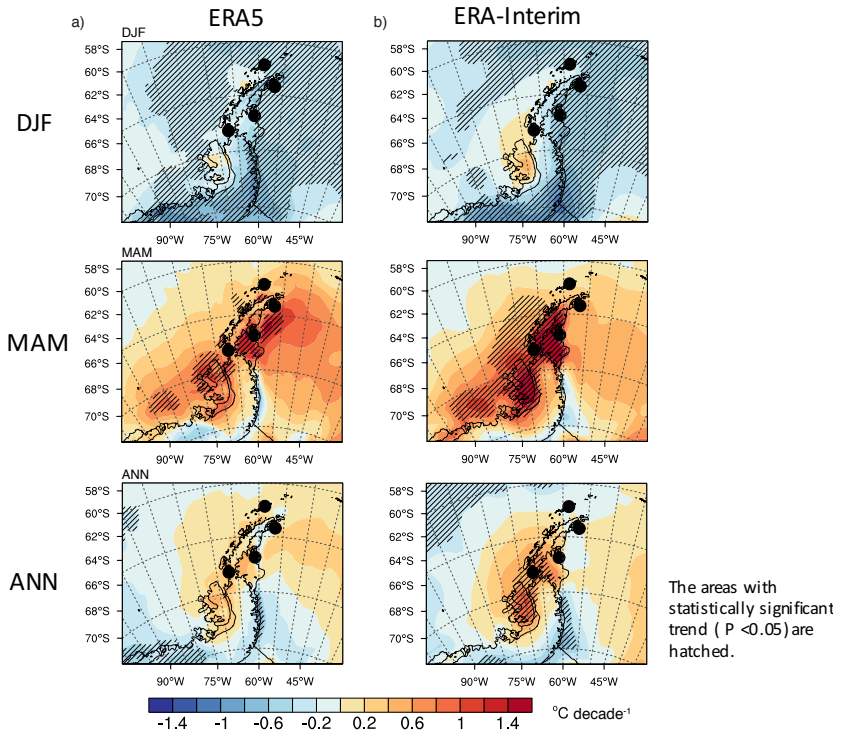
Results: Recent period climate change

Temperature

1991-2015



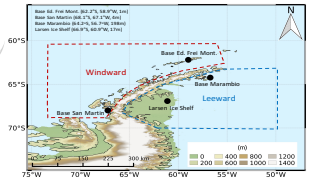
- Observed trends show contrasts between summer and autumn.
- Annual warming (cooling) trend is notable at San Martin (Larsen Ice Shelf) station.



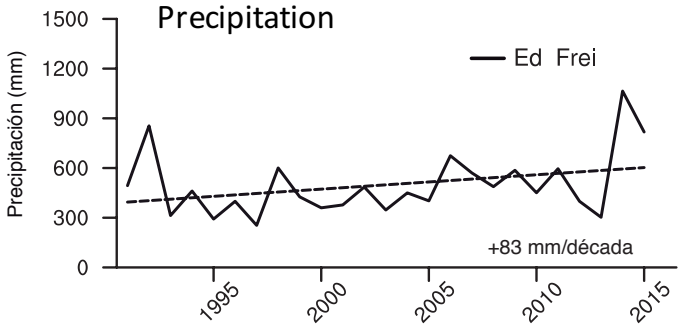
The areas with statistically significant trend (P <0.05) are hatched.

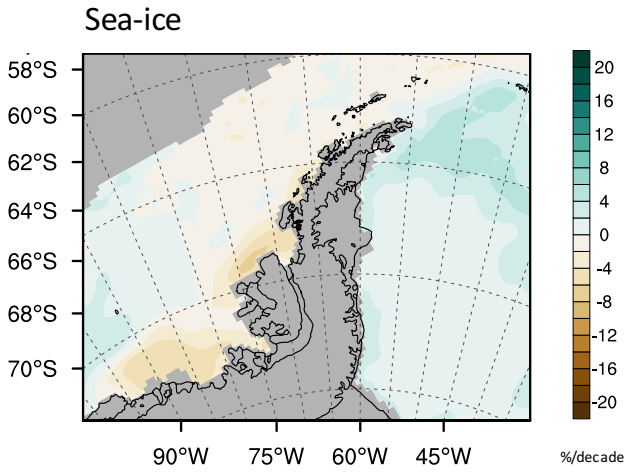
- A robust summer cooling and autumn warming
- Amplified autumn leeward warming detected in ERA-Interim
- Warming in Larsen Ice Shelf (MAM and at annual scale)

Results: Recent period climate change



1991-2015

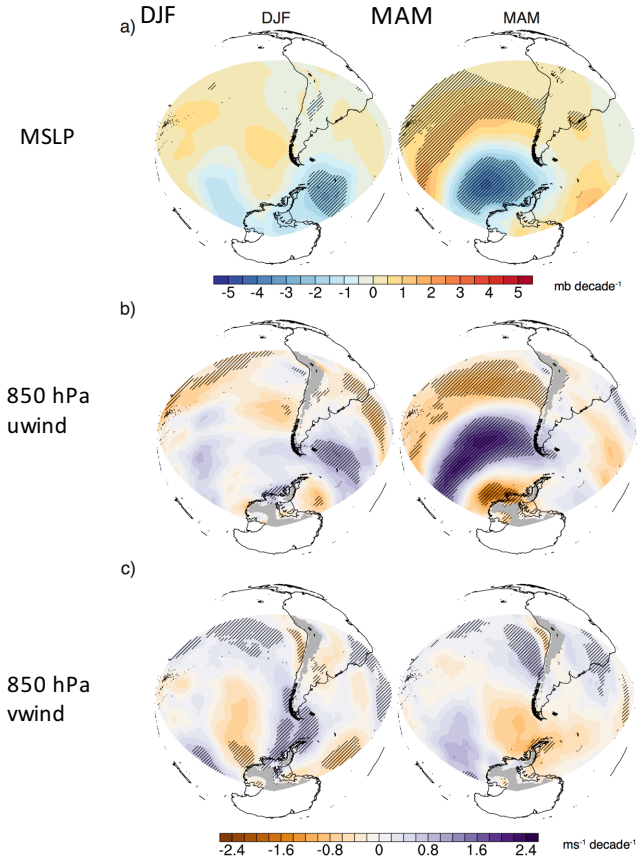




Source: NOAA/NSIDC

- An increase trend in precipitation (83 mm/decade).
- Following the general trend pattern of the temperature on the Antarctic Peninsula (i.e., windward warming and leeward cooling), satellite products indicate a decreasing trend in sea ice on the windward coasts and an increase trend on the leeward side.

Results: Recent period climate change (Circulation patterns)



The areas with statistically significant trend (P <0.05) are hatched.

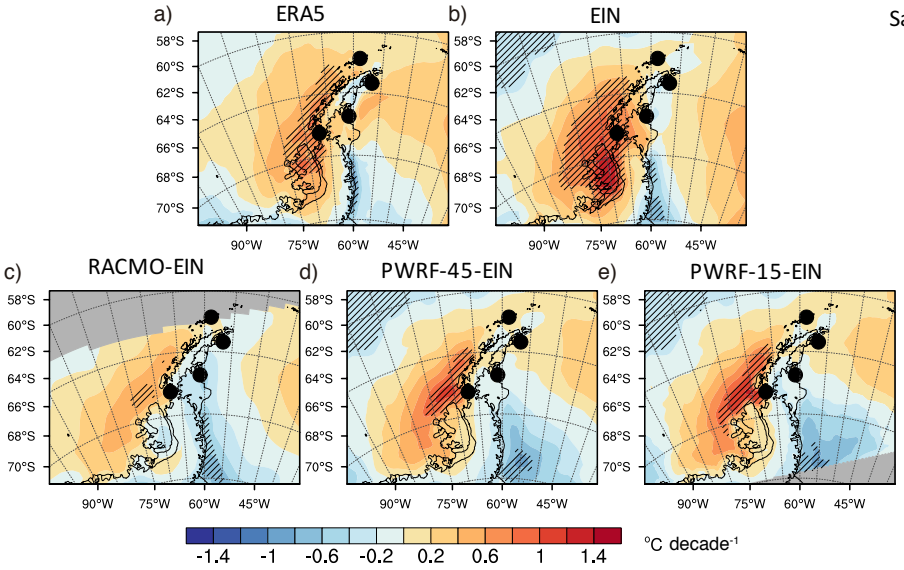
1991-2015

- **Summer (DJF)** is characterized by the strengthening of the Weddell Sea low as well as an anticyclonic trend over the Amundsen/Bellingshausen Sea. This synoptic variability is accompanied with northward (positive) meridional winds, which results in increased transport of cold continental air over the Antarctic Peninsula.

- **Autumn (MAM)** warming is likely to be associated with the recent deepening of the Amundsen/Bellingshausen Sea low and anomalous northerly warm advection towards the West Antarctic sector and Antarctic Peninsula.

Results: Recent period climate change (hindcast simulations)

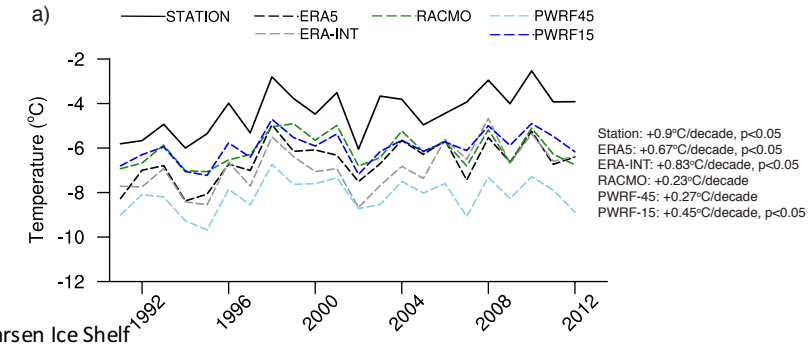
1991-2012



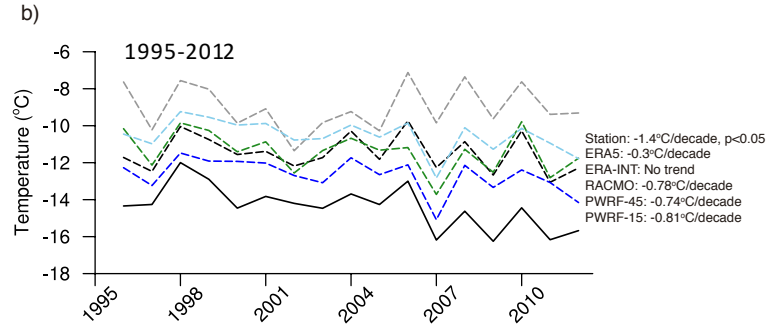
- Regional climate model simulations, in general, reproduce a close trend map to each other.
- Unlike the reanalysis, numerical simulations indicate a clear pattern of windward warming and leeward cooling at annual time-scale.

Bozkurt, D., D. H. Bromwich, J. Carrasco, K. M. Hines, J. C. Maureira, and R. Rondanelli, 2020: Recent near-surface temperature trends in the Antarctic Peninsula from observed, reanalysis and regional climate model data. *Adv. Atmos. Sci.*, **37**(5), https://doi.org/10.1007/s00376-020-9183-x. (in press)

San Martin



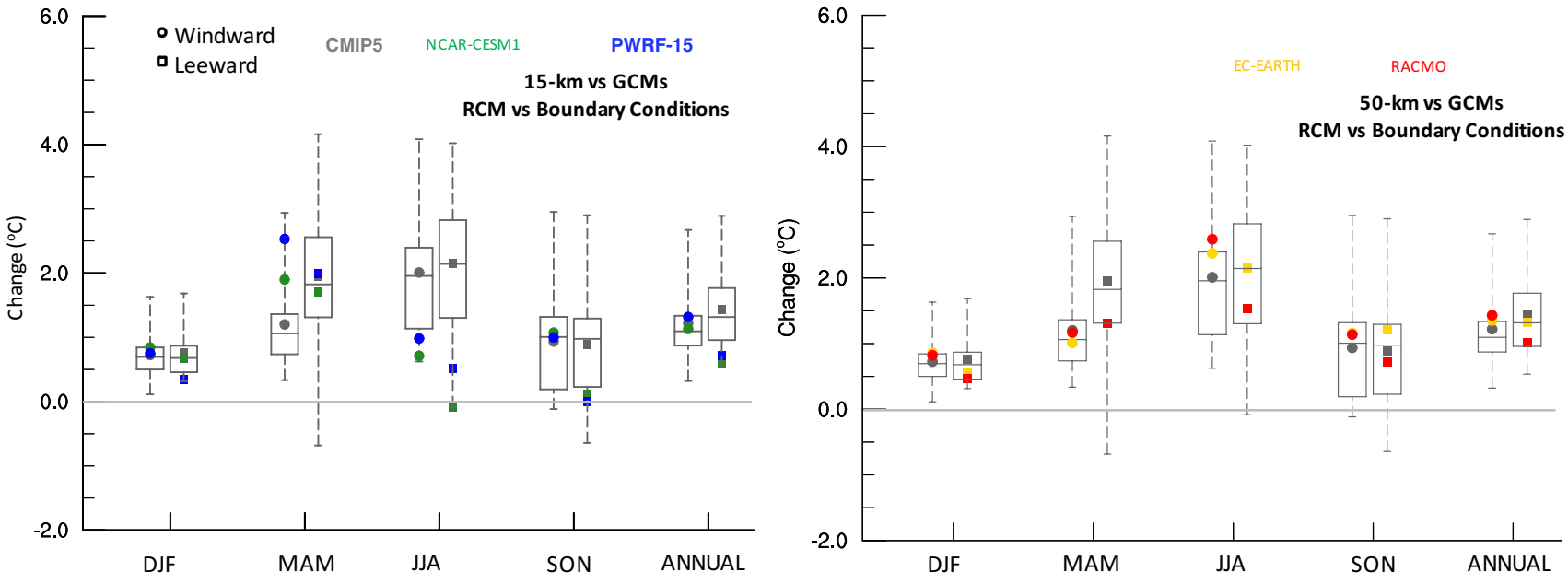
Larsen Ice Shelf



- Better skill is obtained using regional climate model simulations, demonstrating the existence of added value of these simulations and the importance of the spatial resolution in the Antarctic Peninsula

Results: Near future climate change

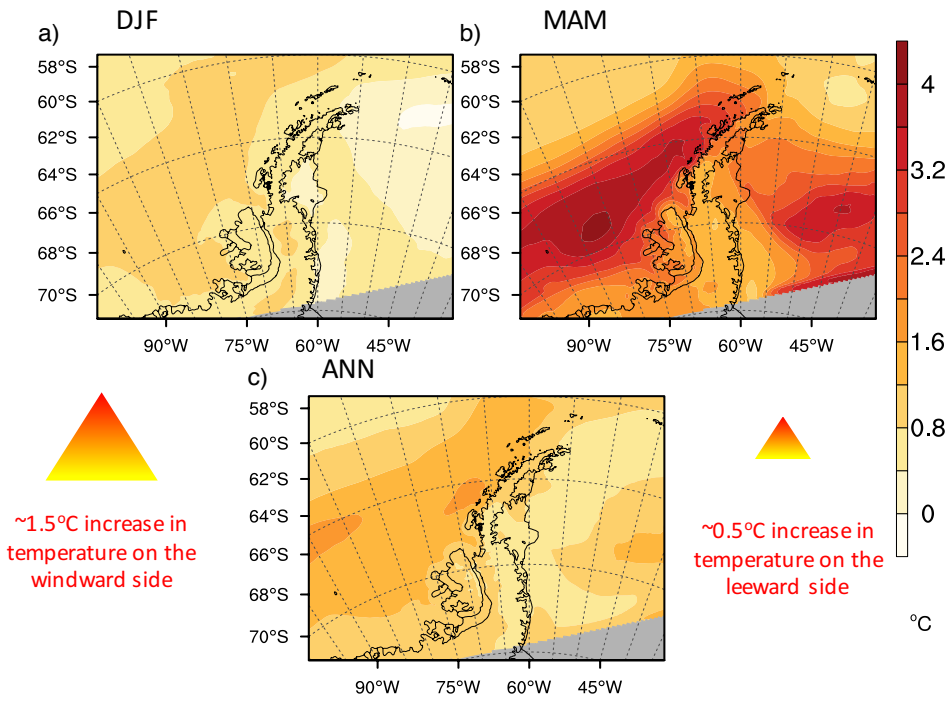
Temperature (mean changes in 2025-2044 wrt 1986-2005, RCP8.5)



- High variability among global models on the leeward side in MAM and JJA
- Generally, PWRF-15 and boundary conditions tends to project weaker warming over the leeward side compared to the global models.

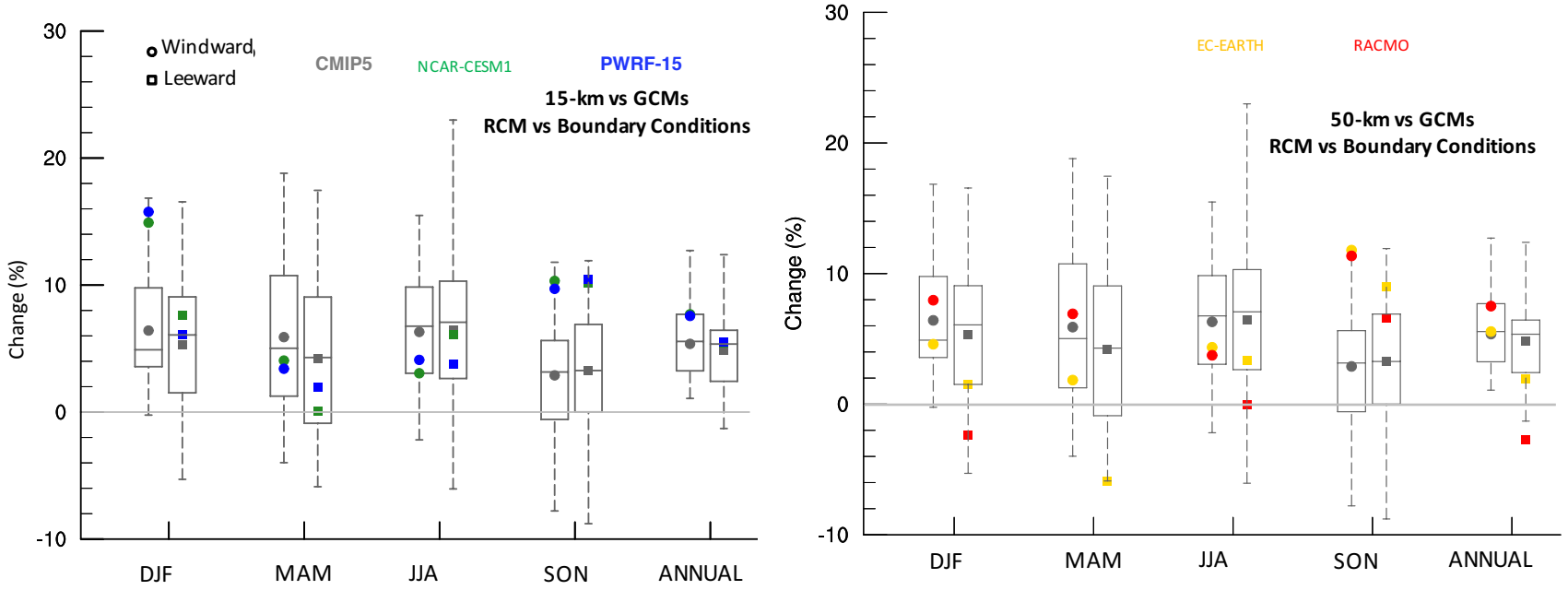
Results: Near future climate change

15-km (PWRF) temperature projections (mean changes in 2025-2044 wrt 1986-2005, RCP8.5)



Results: Near future climate change

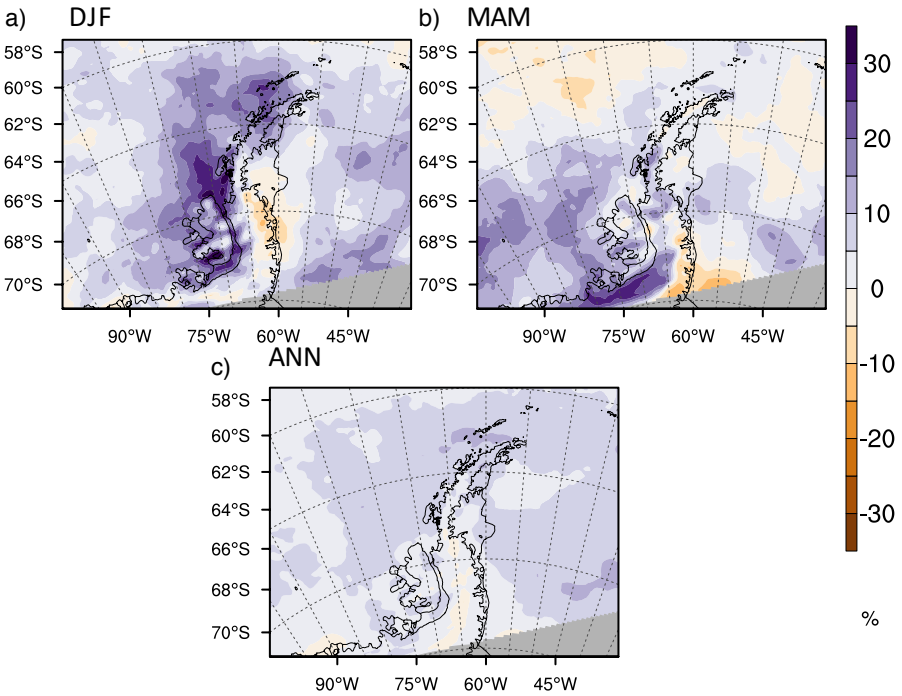
Precipitation (mean changes in 2025-2044 wrt 1986-2005, RCP8.5)



- In general, the mean CMIP5 projects an increase in rainfall in the Antarctic Peninsula on the both sides (from 2% to 8%)
- The windward side generally has slightly larger rainfall increases (DJF and MAM) compared to the leeward side
- PWRF-15 shows large increase in precipitation in DJF (~ 15% in) similar to the boundary conditions

Results: Near future climate change

15-km (PWRF) precipitation projections (mean changes in 2025-2044 wrt 1986-2005, RCP8.5)

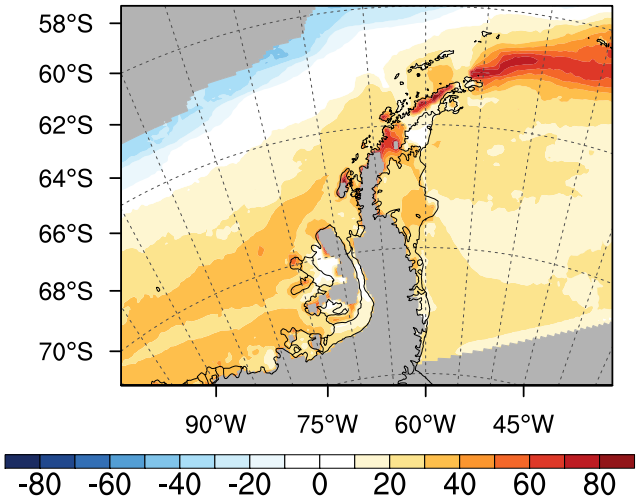


5% a 10% increase in precipitation. Summer shows the largest increases in precipitation (~15% to 30%) on the windward slope

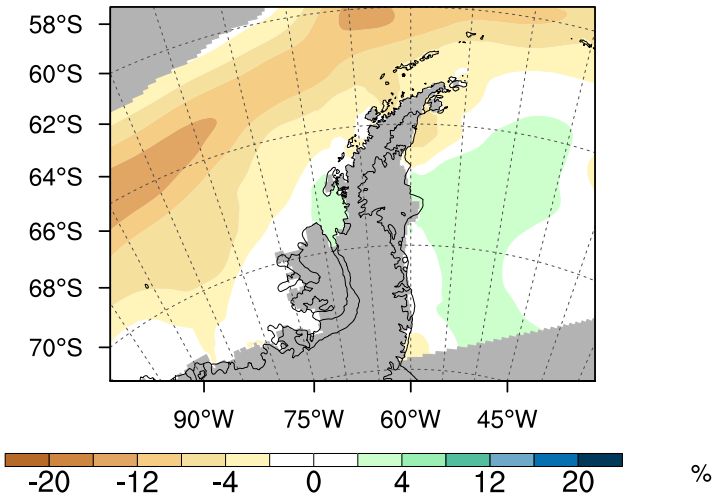
Results: Near future climate change

Projections for mean annual **surface melting (a)** and **sea ice (b)** for 2025-2044 period, with respect to 1986-2005 period (RCP8.5, PWRF-15)

a)



b)



more surface melting and loss of sea ice on the windward side!

Conclusions (Recent climate change)

- Observed trends show contrasts between summer and autumn. Annual warming (cooling) trend is notable at San Martin (Larsen Ice Shelf) station.
- Unlike the reanalysis, numerical simulations indicate a clear pattern of **windward warming** and **leeward cooling** at annual time-scale.
- These temperature changes are accompanied by a decreasing and increasing trend in sea ice on the windward and leeward coasts, respectively.
- The precipitation record over the northern Peninsula indicates an **increase in precipitation** during the 1991-2015 period.
- It is likely that these observed changes are associated with changes in large-scale circulation patterns. In particular, low-pressure centers at sea level in the Amundsen / Ross Sea sector and in the Weddell Sea sector play an important role in the trends observed in the peninsula.

Conclusions (Near future climate change)

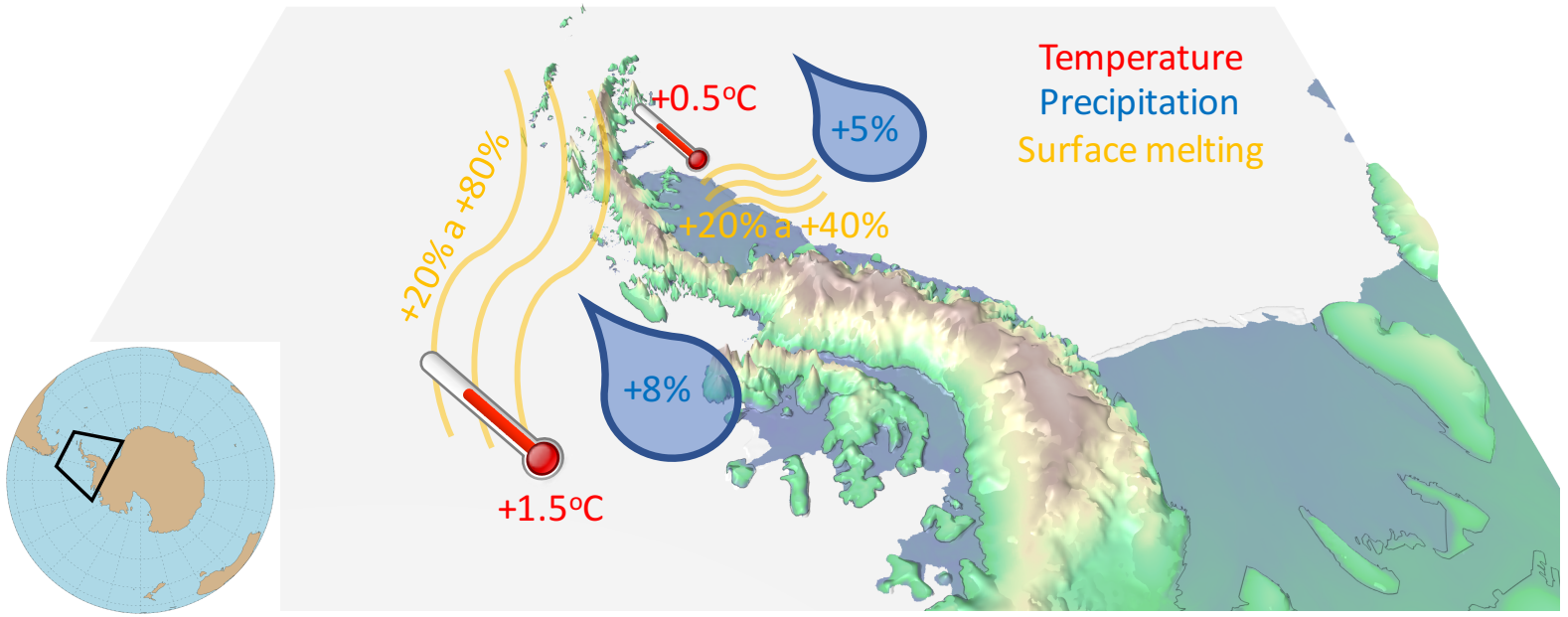
- Climate change projections (RCP8.5) indicate that observed windward warming will continue in the near future.

- High resolution projections indicate an annual average temperature increase of ~ 1.5°C on the windward side and 0.5°C on the leeward side in the 2025-2044 period (wrt 1986-2005 period). Particularly, the windward side shows notable increases in temperature (~ 3.5°C) in autumn.

- In general, the projections show an increase in precipitation on both sides of the peninsula (5% to 10%, over the period considered). The windward zone generally shows slightly larger precipitation increases compared to the leeward. This increase is more pronounced in summer (15%) on the windward side.

- A more notable warming projected on the windward side results in a marked increase in surface melting (~ + 20% to + 80%, over the period considered) and a decrease in sea ice (-4% to - 20%) on that side.

Conclusions (Near future climate change)



Regional climate projections for the near future (2025-2044, mean annual) according to the PWRF-15 simulations under RCP8.5 scenario with respect to the reference period 1986–2005