Model selection for RCM downscaling in ISMIP6

Evaluation of CMIP5-6 global climate models in the Arctic and Antarctic regions

Cécile Agosta, Alice Barthel et al.

ISMIP6 Ice Sheet Model Intercomparison Project for CMIP6

ISMIP7 Ice Sheet Model Intercomparison Project

LSCE

IGE

KING'S College LONDON

AWACA Atmospheric WAter Cycle over Antarctica past, present & future

European Research Council Established by the European Commission

This presentation is part of the AWACA project that has received funding from the European Research Council (ERC Synergy) under the European Union's Horizon 2020 Research and Innovation Programme (Grant agreement No 951596)

Protect CRYOSPHERE & SEA LEVEL

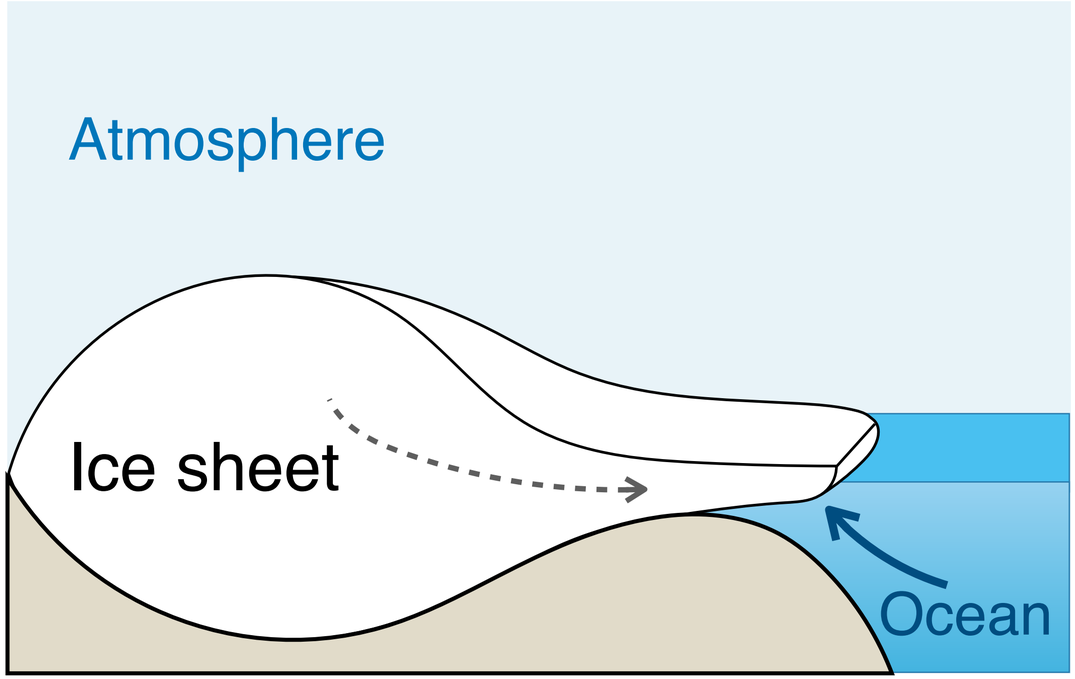
This presentation is part of the PROTECT project that has received funding from the European Union's Horizon 2020 Research and Innovation Programme (Grant agreement No 869304).

Objective: **Assessment ('Sanity check') of CMIP models large scale fields over polar regions**

ISMIP7
Ice Sheet Model Intercomparison Project

Ice Sheet models

+ Atmosphere & Ocean forcing (from CMIP)



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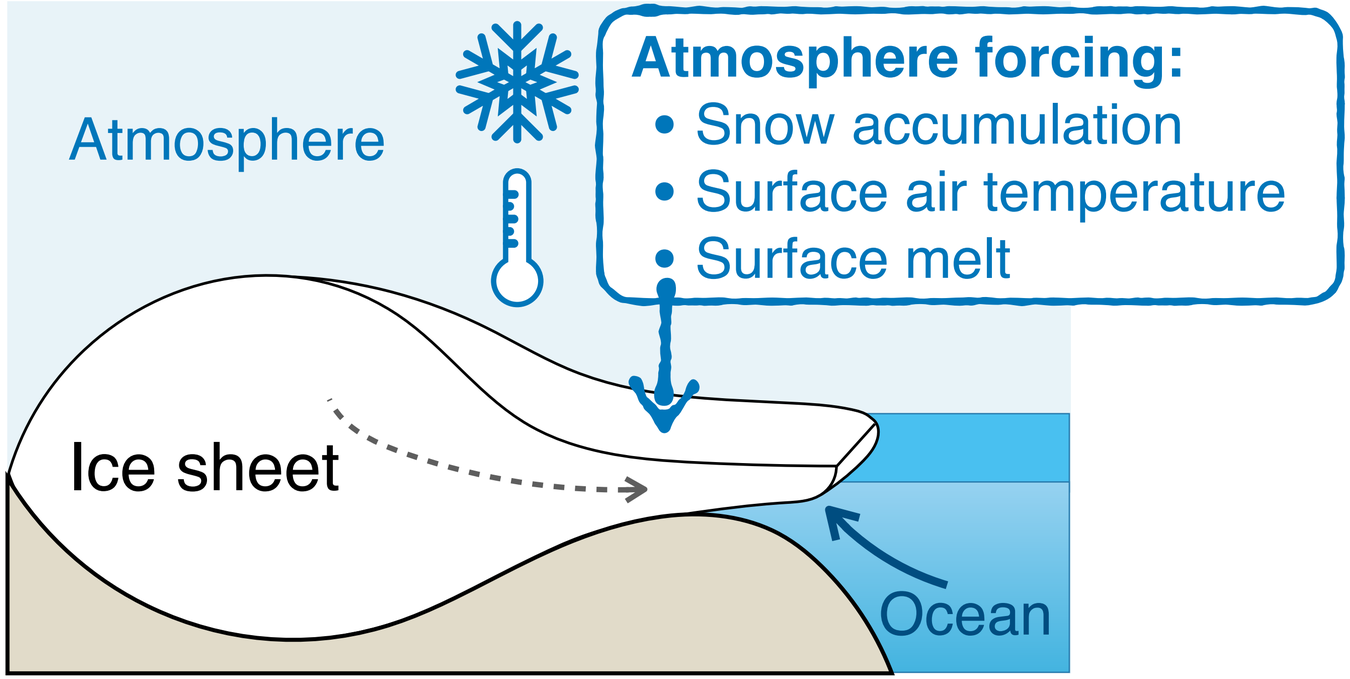

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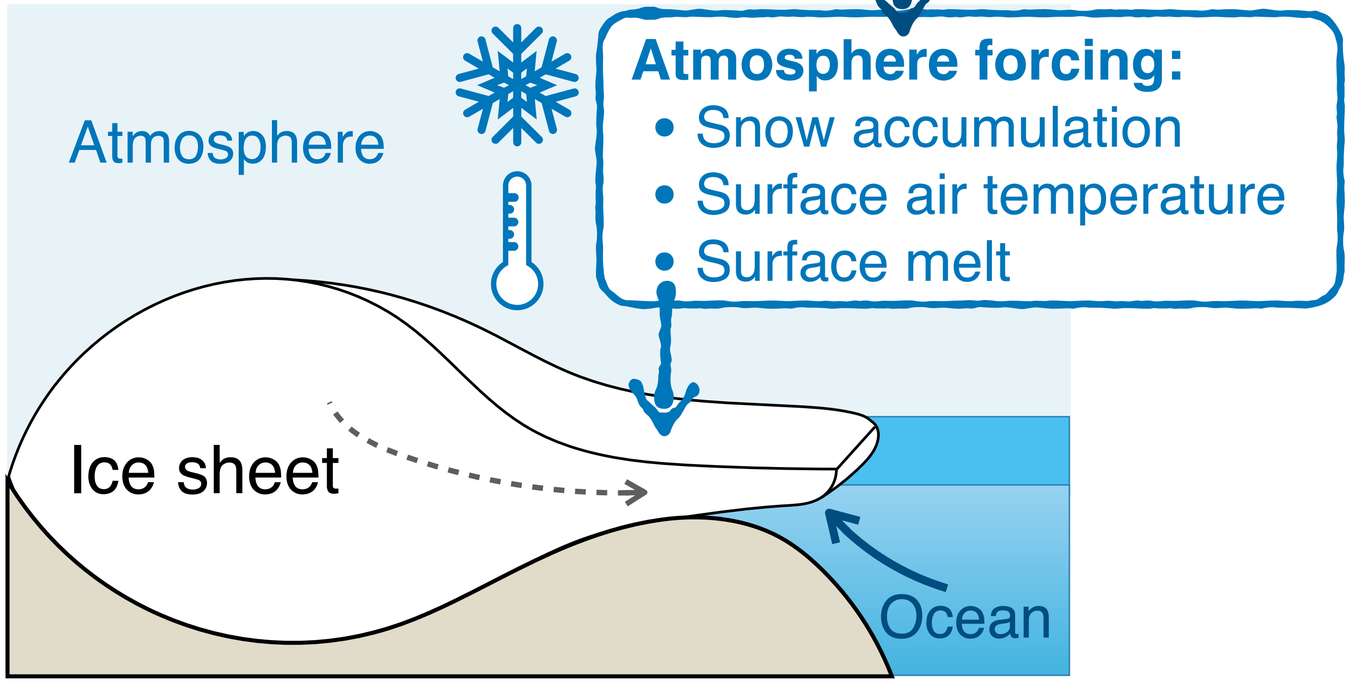
CMIP model

Large scale circulation
(i.e. above boundary layer)
Sea surface conditions

+ Polar physics:
- *Clouds*
- *Snow*
- *Boundary layer*



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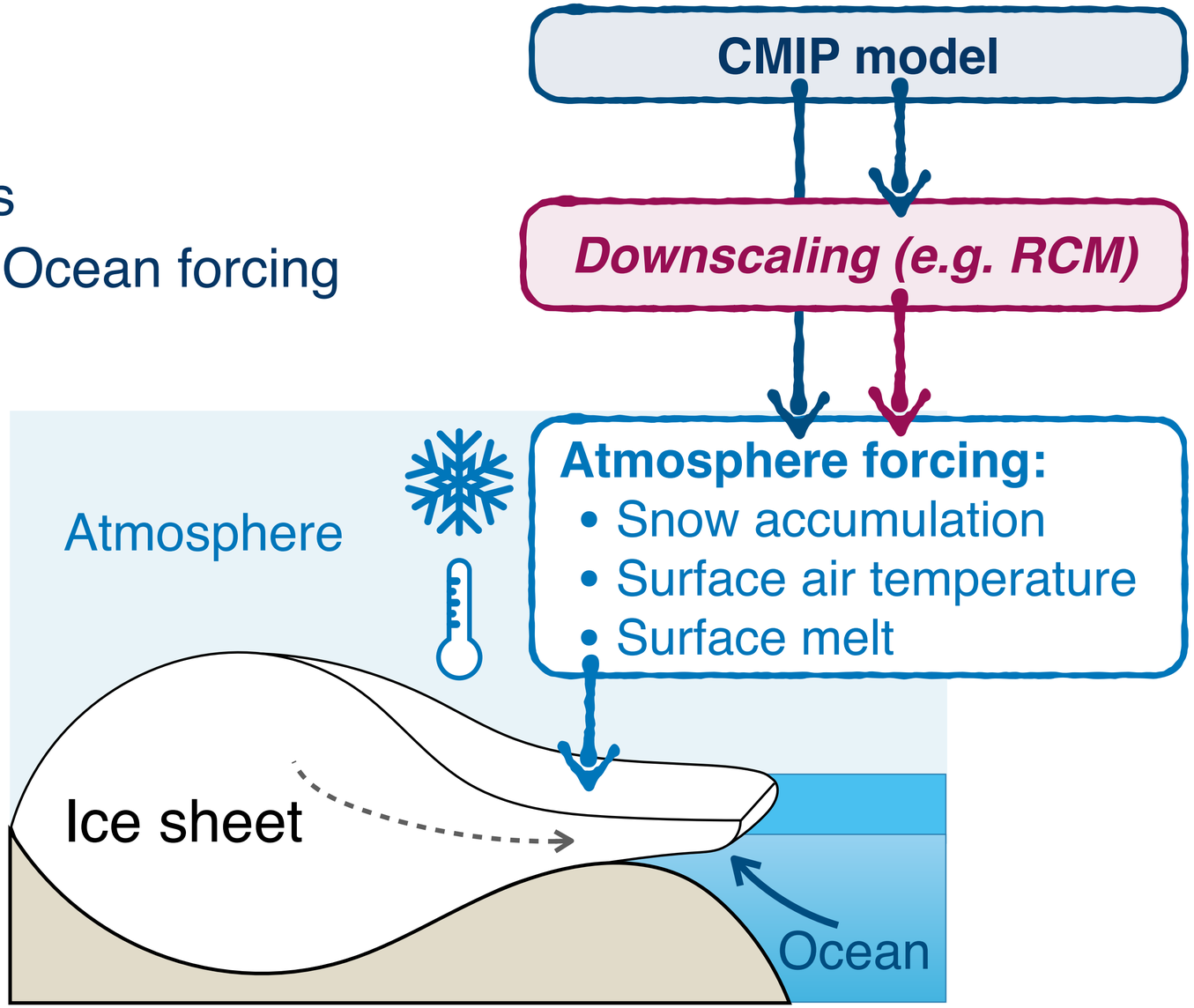


Large scale circulation
(i.e. above boundary layer)
Sea surface conditions

+ Polar physics:
- *Clouds*
- *Snow*
- *Boundary layer*

+ Resolution

Objective: **Assessment ('Sanity check') of CMIP models large scale fields over polar regions**

Biases at present impact projections
(e.g. sea ice, Bracegirdle et al. 2015)

Spatial bias patterns are stationary
Krinner & Flanner 2018

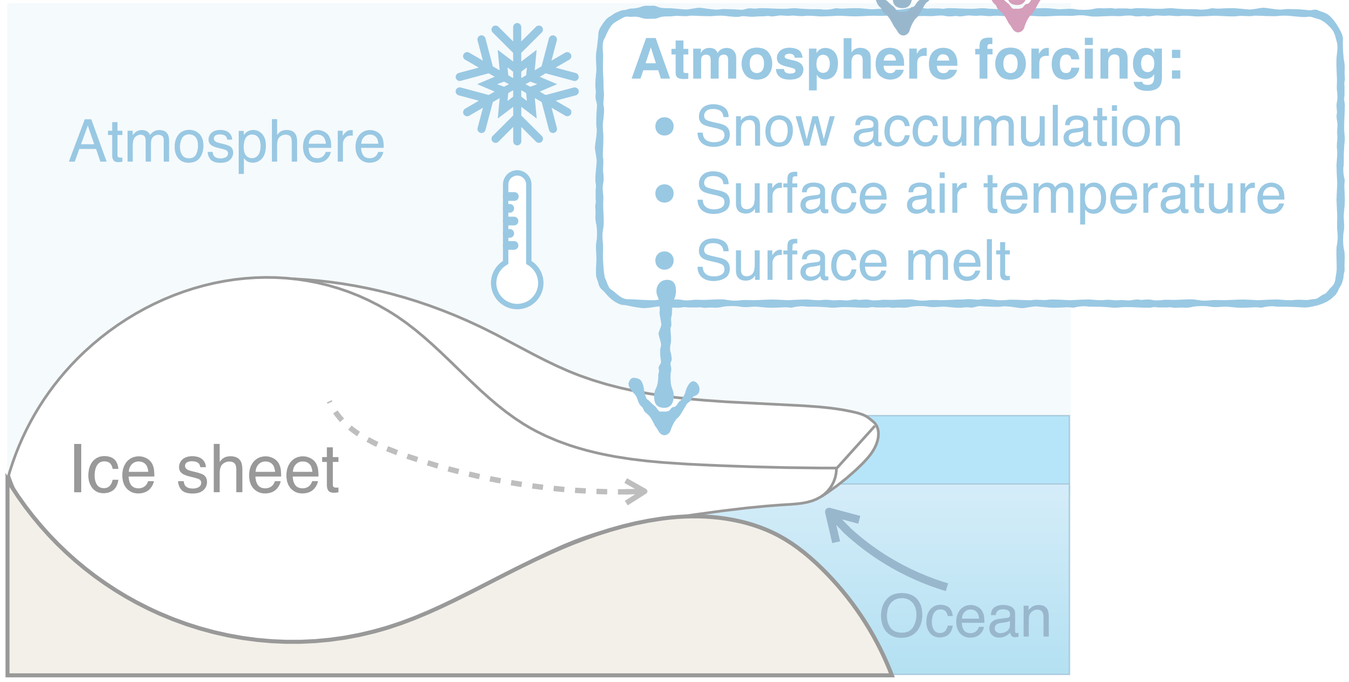
CMIP model

Large scale circulation
(i.e. above boundary layer)
Sea surface conditions

Downscaling (e.g. RCM)

+ Polar physics:
- *Clouds*
- *Snow*
- *Boundary layer*

+ Resolution



Atmosphere forcing:
- Snow accumulation
- Surface air temperature
- Surface melt

Objective: **Assessment ('Sanity check') of CMIP models large scale fields over polar regions**

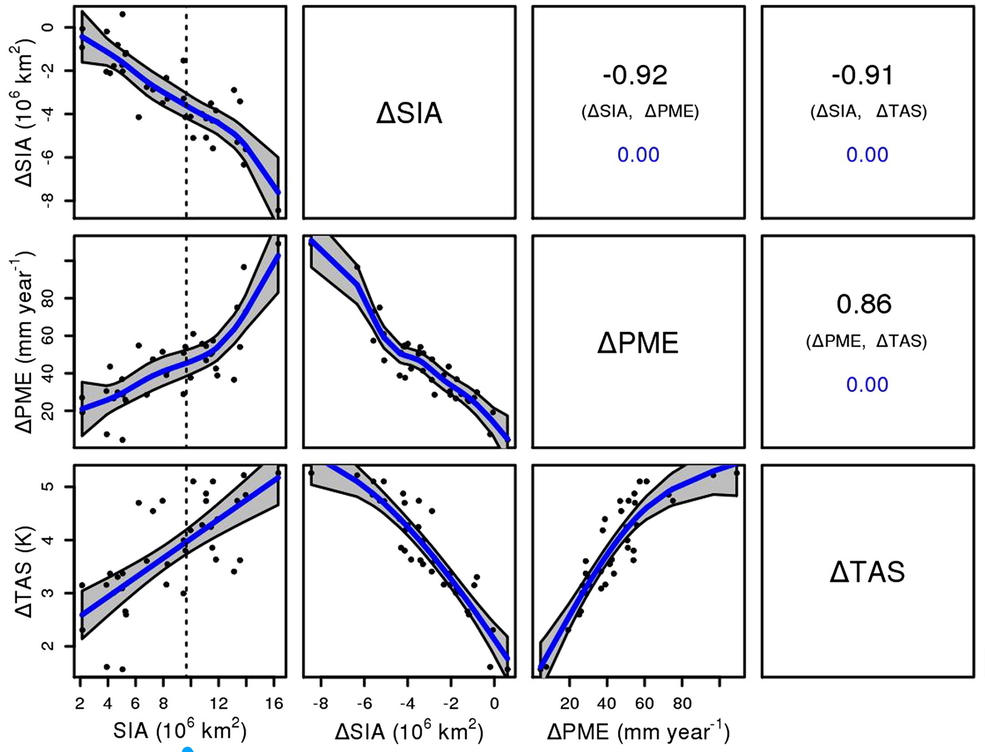
Biases at present impact projections
(e.g. sea ice, Bracegirdle et al. 2015)

CMIP model

Large scale circulation
(i.e. above boundary layer)
Sea surface conditions

ΔAccumulation Antarctica
Change during the 21st c.

ΔTAS Antarctica
Change during the 21st c.



Bracegirdle et al. 2015

Present day Antarctic Sea Ice Area

Objective: **Assessment ('Sanity check') of CMIP models large scale fields over polar regions**

⟹ Evaluation of **CMIP large-scale fields**
i.e. inputs of regional atmospheric models

Large scale circulation
(i.e. above boundary layer)
Sea surface conditions

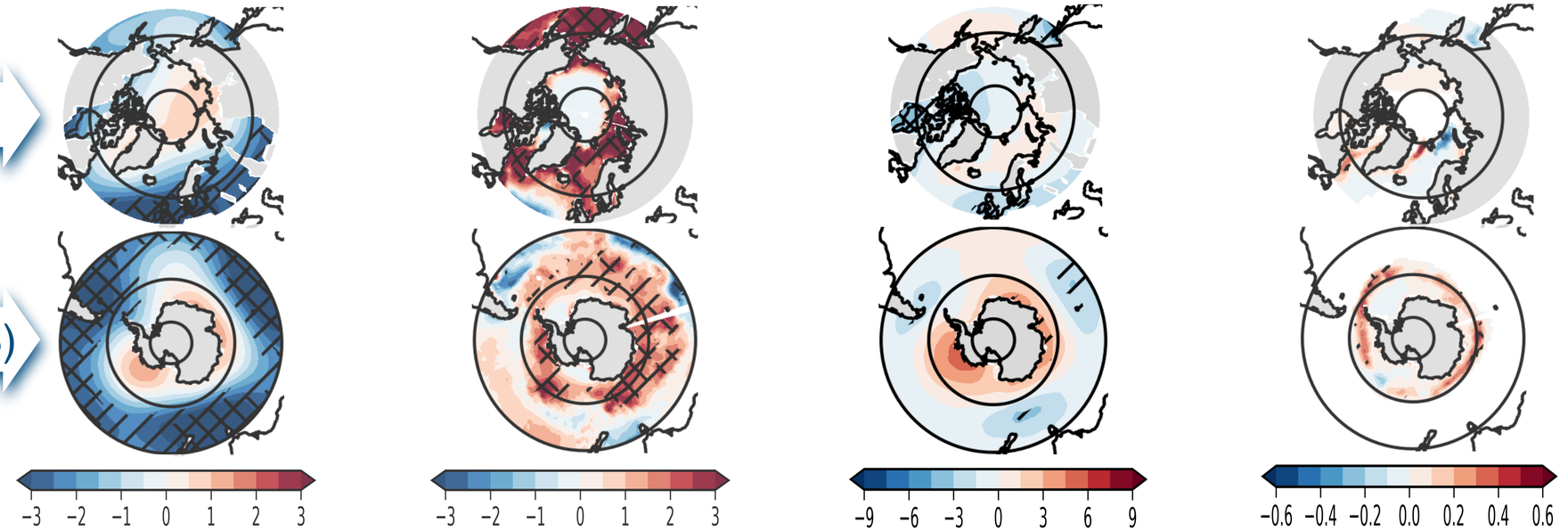
Method :
- 1979-2005 time-mean
- Annual or Seasonal
- Difference with ERA5
- 2 regions

Arctic (> 50°N)

Antarctic (< 40°S)

Exemple for one CMIP model : IPSL-CM6A-LR

Temperature | **Humidity** | **Circulation** | **Surface ocean**



9 variables
83 CMIP models
2 regions

Reference: ERA5, 1979-2005

Objective: **Assessment ('Sanity check') of CMIP models large scale fields over polar regions**

⟹ Evaluation of **CMIP large-scale fields**
i.e. inputs of regional atmospheric models

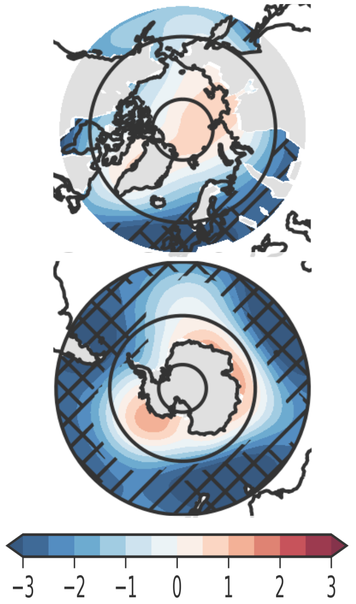
Large scale circulation
(i.e. above boundary layer)
Sea surface conditions

Defining metrics and scores

For ISMIP6 : **RMSE** for each variable + **Scaling** by median RMSE
i.e. ***Relative metrics*** *for each variable*

Agosta et al. 2015; Barthel et al. 2020 (ISMIP6), ESMValTool (e.g. Eyring et al. 2020)

IPSL-CM6A-LR
ΔT850[ann]



RMSE (°C) = √spatial mean(**Δ²**)

→ **Scaled-RMSE** = RMSE **/ Median RMSE among all CMIP models**

9 variables
83 CMIP models
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Score: mean Scaled-RMSE among variables
for each CMIP model and each region

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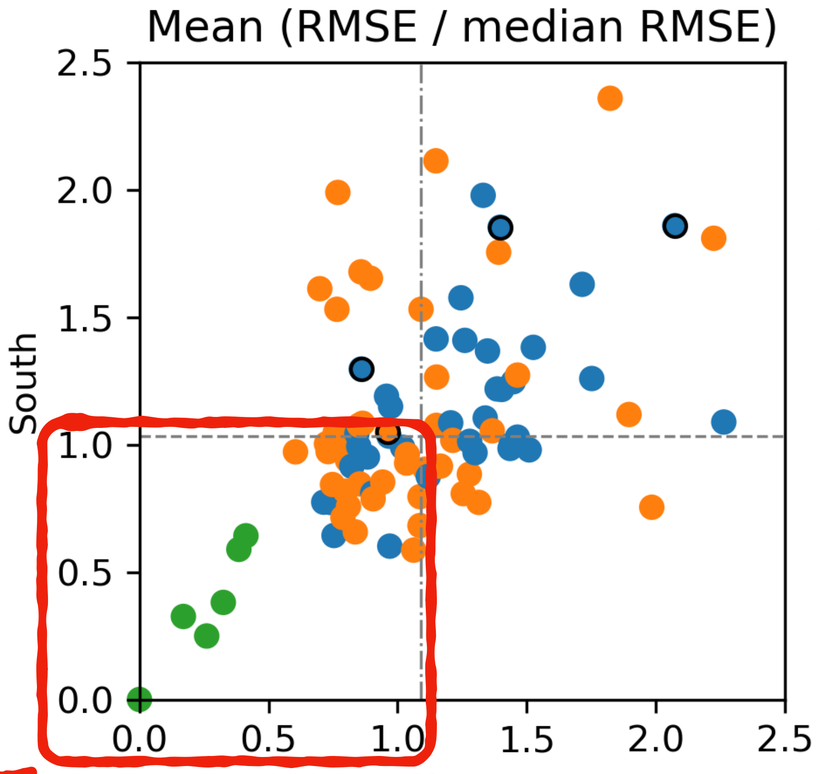
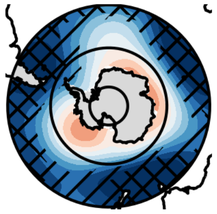


Antarctic
(< 40°S)



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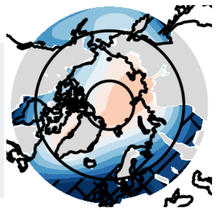

Best half

38 CMIP5
45 CMIP6
6 reanalyses

28 (34 %) CMIP models in the
« **best half** » for **both** regions
9 CMIP5, **19** CMIP6
(25% of CMIP5 vs. 40% of CMIP6)

Objective: **Assessment ('Sanity check') of CMIP models large scale fields over polar regions**

Score: mean Scaled-RMSE among variables
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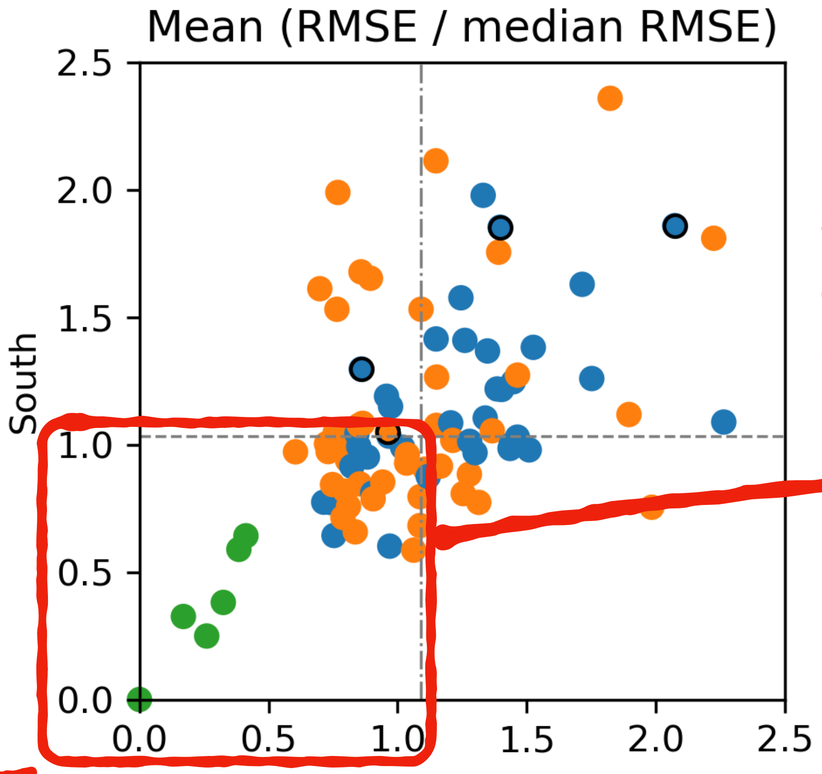

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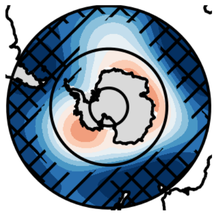

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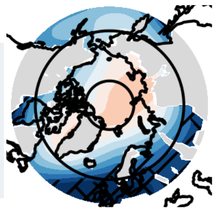


38 CMIP5
45 CMIP6
6 reanalyses

+ Sample a diversity of climate sensitivity (local ECS)

Best half

28 (34 %) CMIP models in the « **best half** » for **both** regions
9 CMIP5, **19** CMIP6
(25% of CMIP5 vs. 40% of CMIP6)

What can we do better? (among other things…)

Replace relative metrics by absolute metrics

« **Implausibility** », absolute metric used in history matching

- ✓ discard only implausible models
- ? **require uncertainty quantification on model and observations**

Design CMIP sampling in view of emulation of the CMIP ensemble

From **selected CMIP** forcing to **all CMIP** : **need to extrapolate**

e.g. use statistical emulator (Edwards et al. 2021)

The selected CMIP models need to **sample a parameter space** impacting **ice sheet response**

⟹ **design the parameter space before selection process**

Supplement

CMIP evaluation: **Relative metrics**

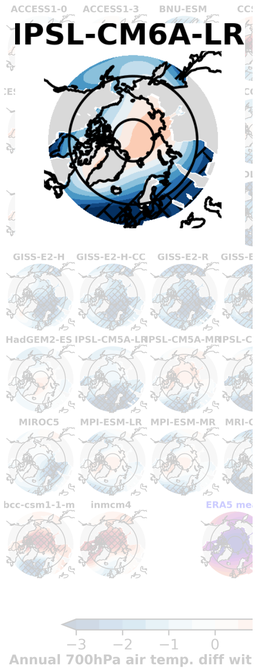
9 variables
83 CMIP models
2 regions

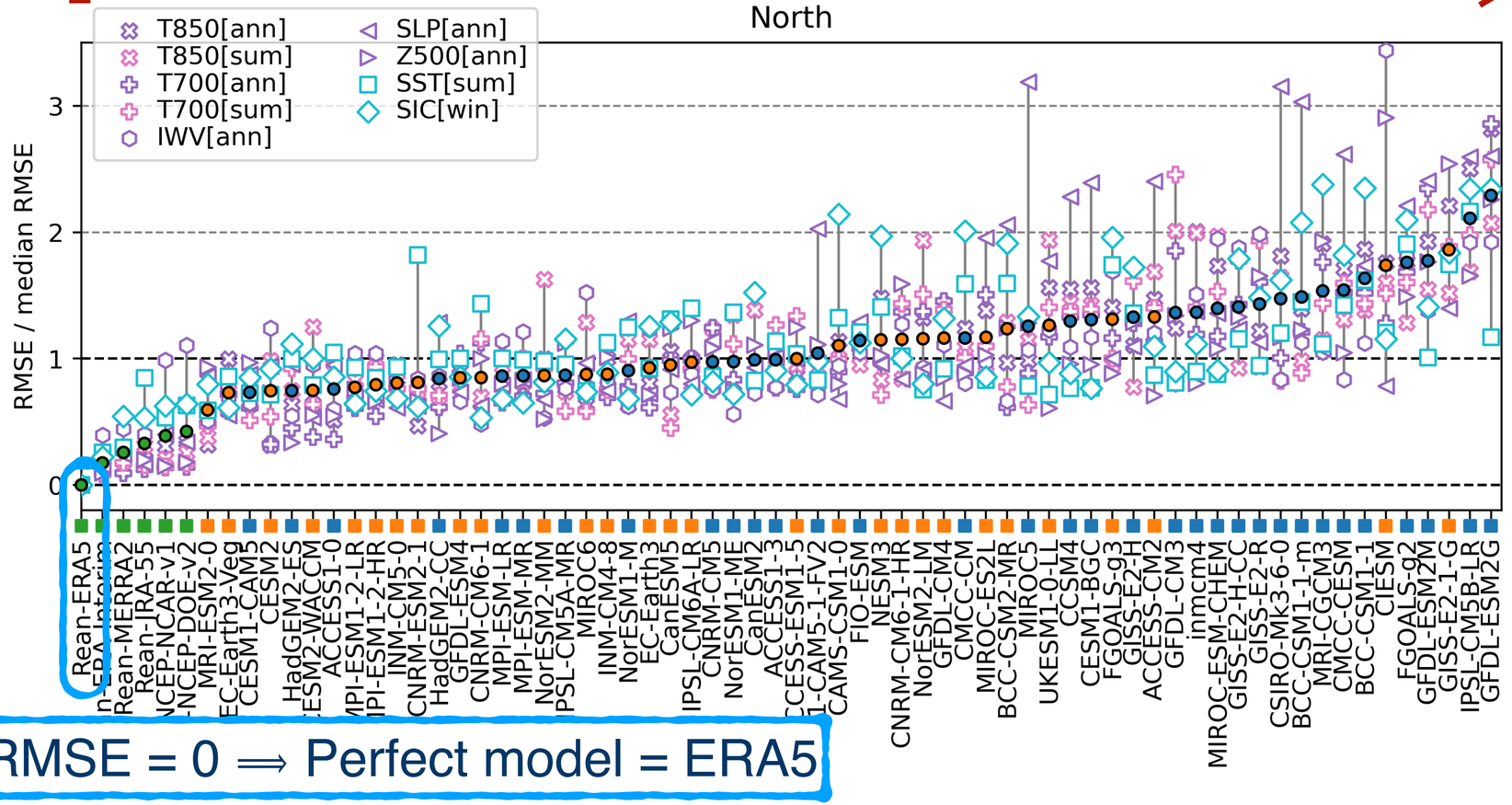
First method : **Relative metrics**

Scaling of metrics to combine them among variables

Agosta et al. 2015; Barthel et al. 2020 (ISMIP6), ESMValTool (REF)

Rank: mean Scaled-RMSE among variables





Scaled RMSE = 0 ⟹ Perfect model = ERA5

CMIP evaluation: **Relative metrics**

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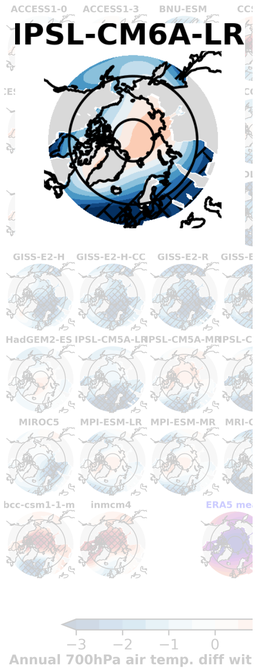

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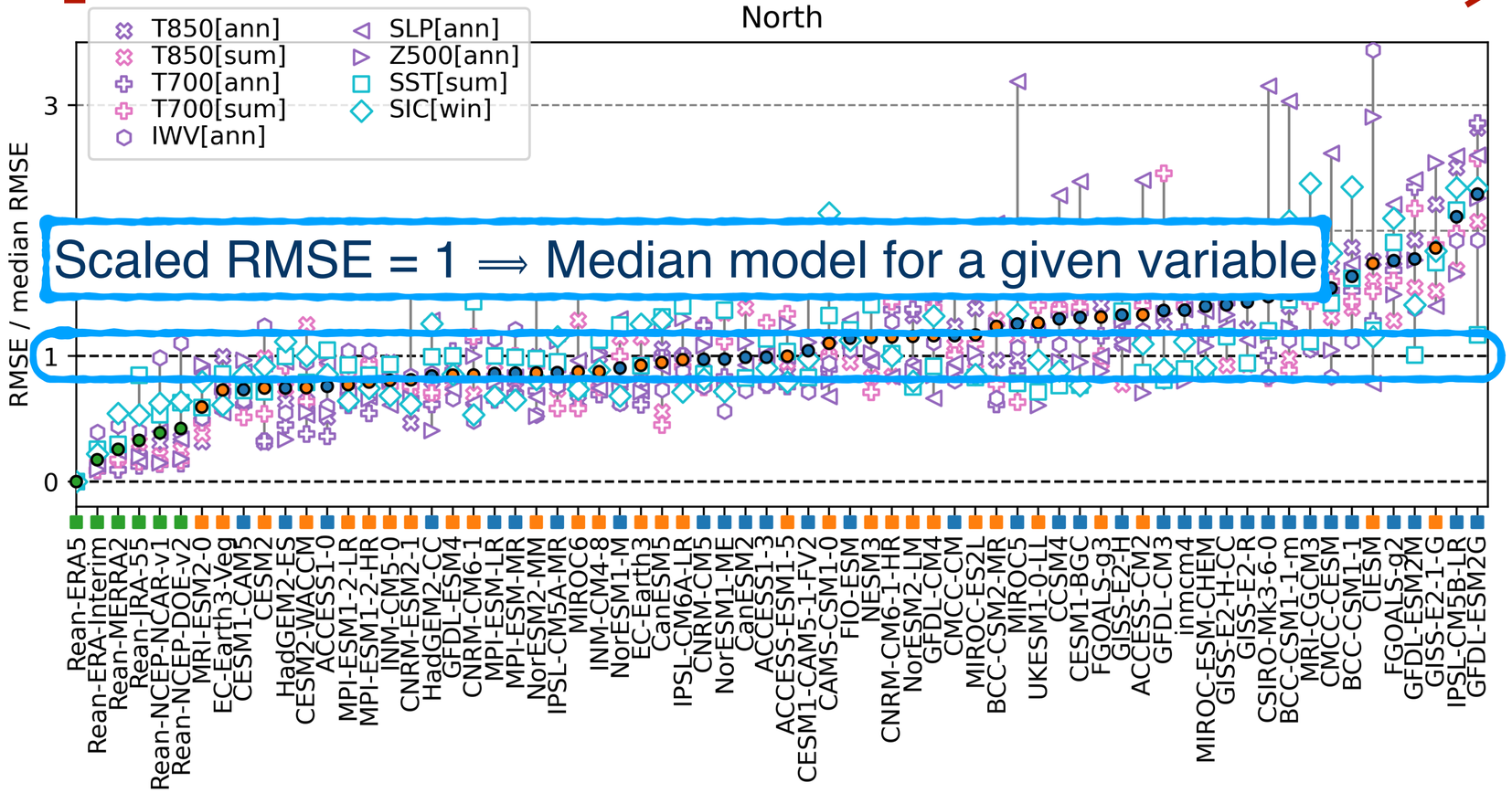

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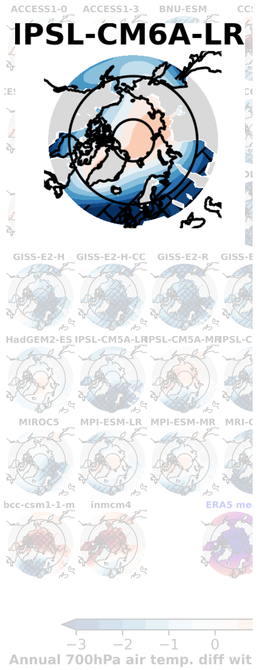

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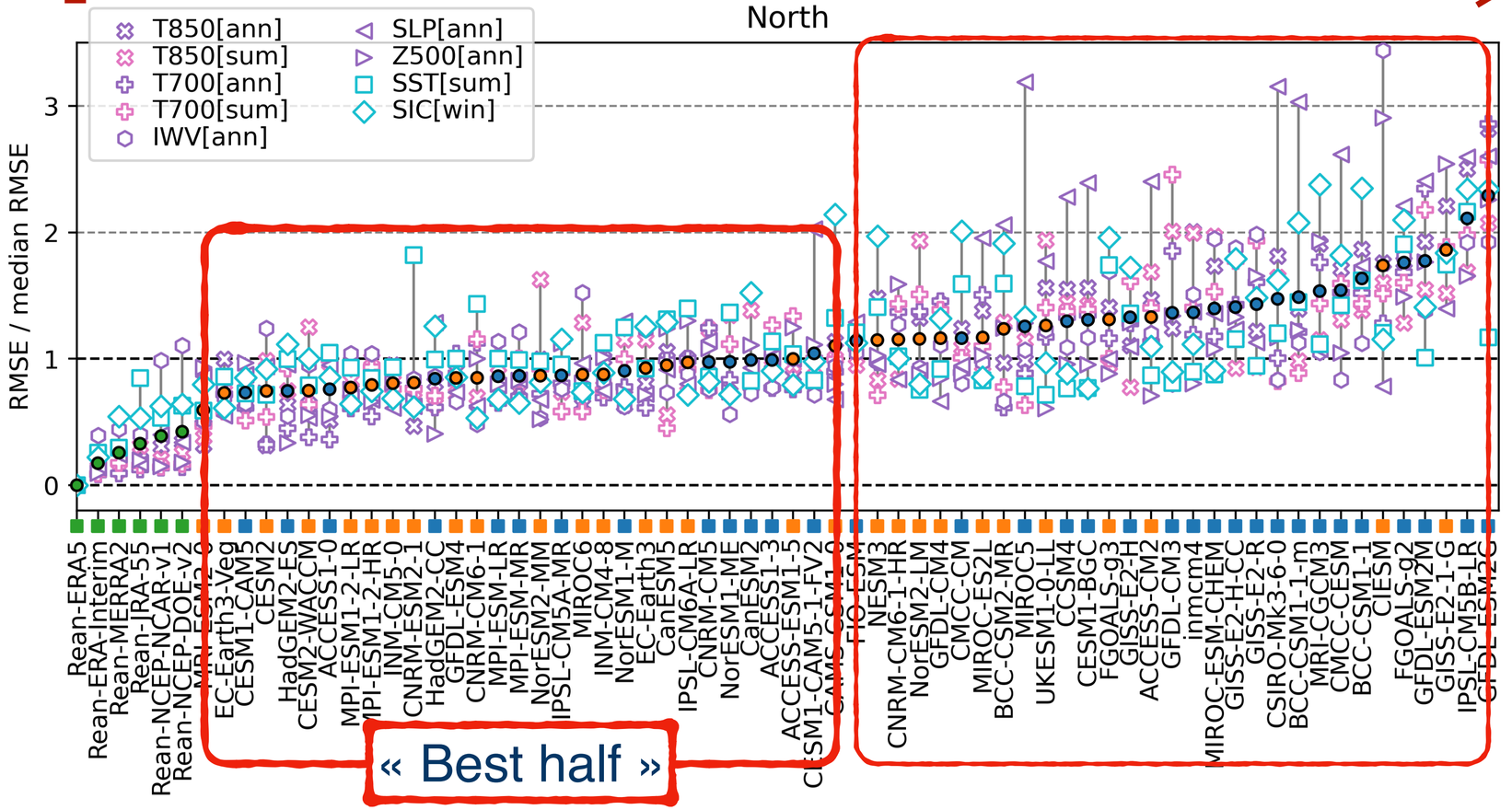


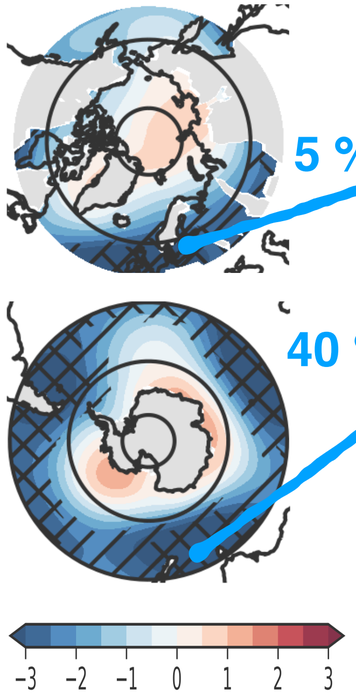
CMIP evaluation: **Relative metrics**

9 variables
83 CMIP models
2 regions

Second method : **Implausible fraction**
Absolute metric, **No scaling**

History matching, « Not Ruled Out Yet » method (Pukelsheim, 1994, Rougier, 2015), applied e.g. in Gladstone et al. 2012; Edwards et al., 2019

IPSL-CM6A-LR
ΔT850[ann]



Hashes: **Δ > 3 std$_{1yr}$(reference)**

Portion of the surface where **Δ** with ERA5
is **greater that 3 x ERA5 interannual variability**
= « **Implausible fraction** » of the surface

Score: *2nd* **max implausible fraction**
(We let 1 variable / 9 be more implausible)

CMIP evaluation: **Absolute metrics**

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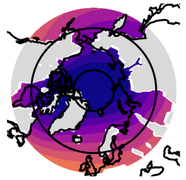
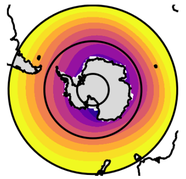
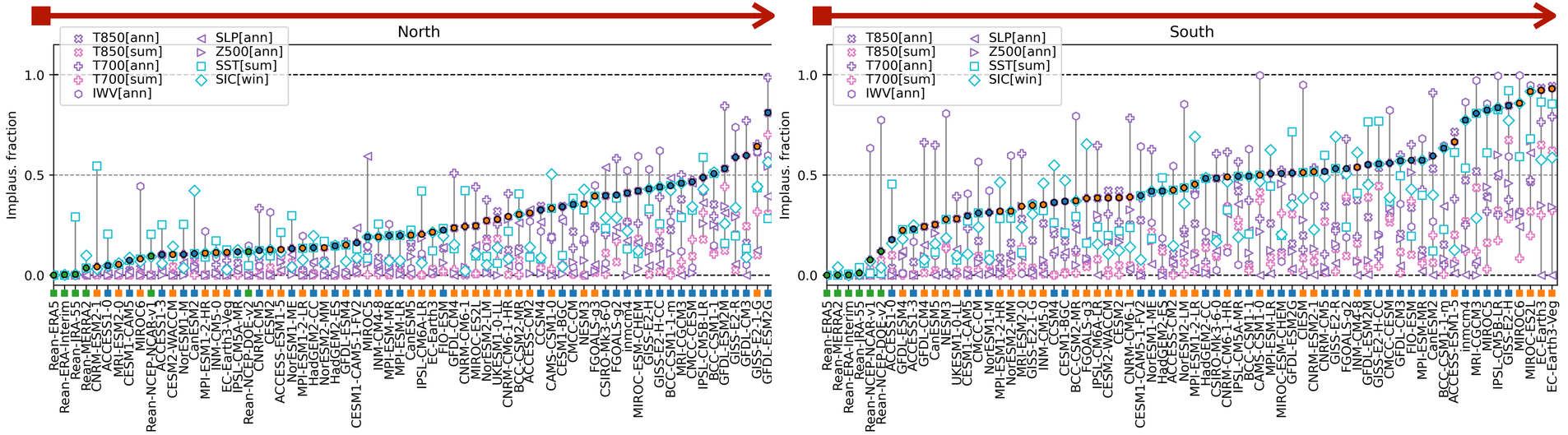
Second method : **Absolute metric**
Implausible fraction, **No scaling**

Arctic (> 50°N) 

Antarctic (< 40°S) 

Rank: 2nd max implausible fraction

(We let one variable be very implausible)



CMIP evaluation: **Absolute metrics**

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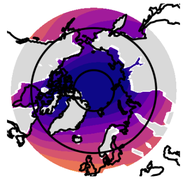
83 CMIP models
2 regions

Second method : **Absolute metric**
Implausible fraction, **No scaling**

CMIP models are **more implausible in the Antarctic than in the Arctic**

Arctic (> 50°N)



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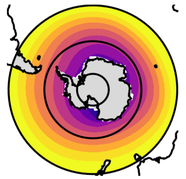

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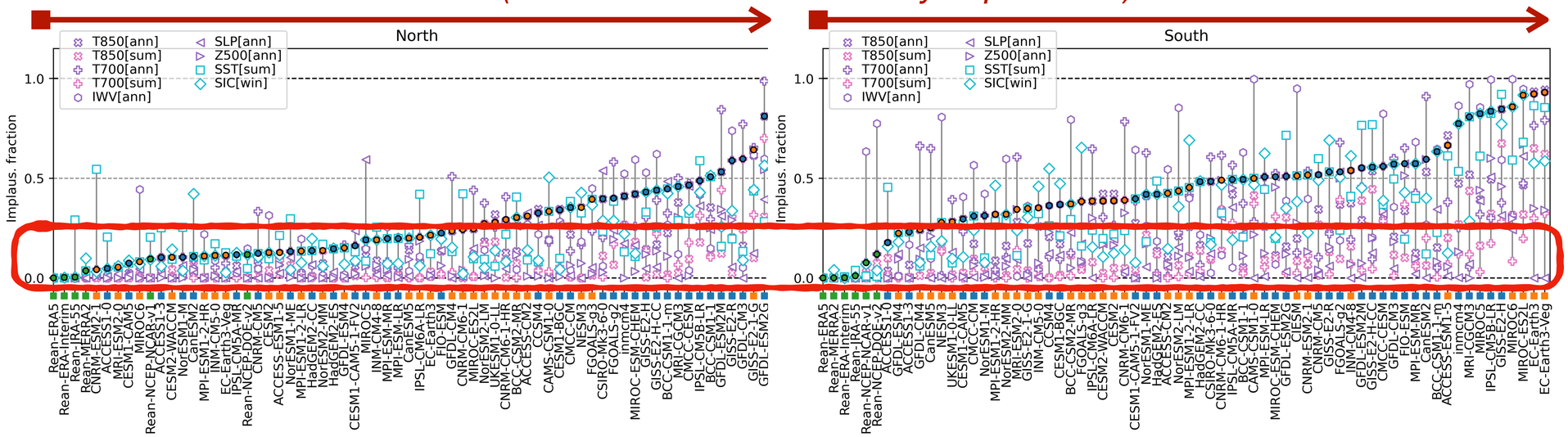

Conclusions: CMIP models over polar regions

Contact: cecile.agosta@lsce.ipsl.fr

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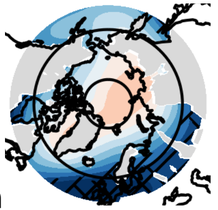
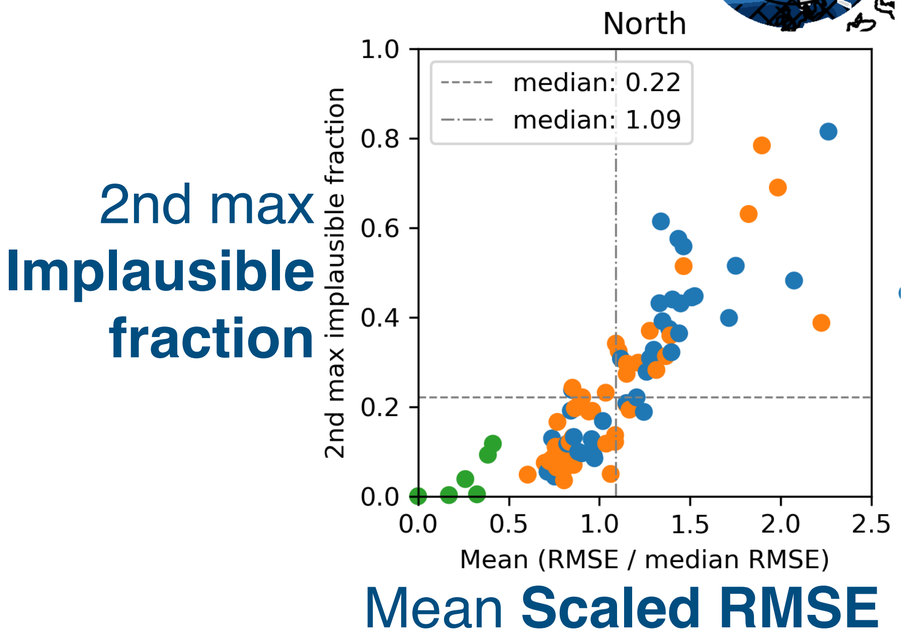
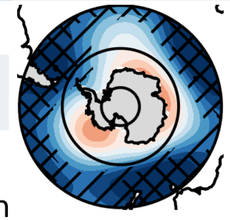


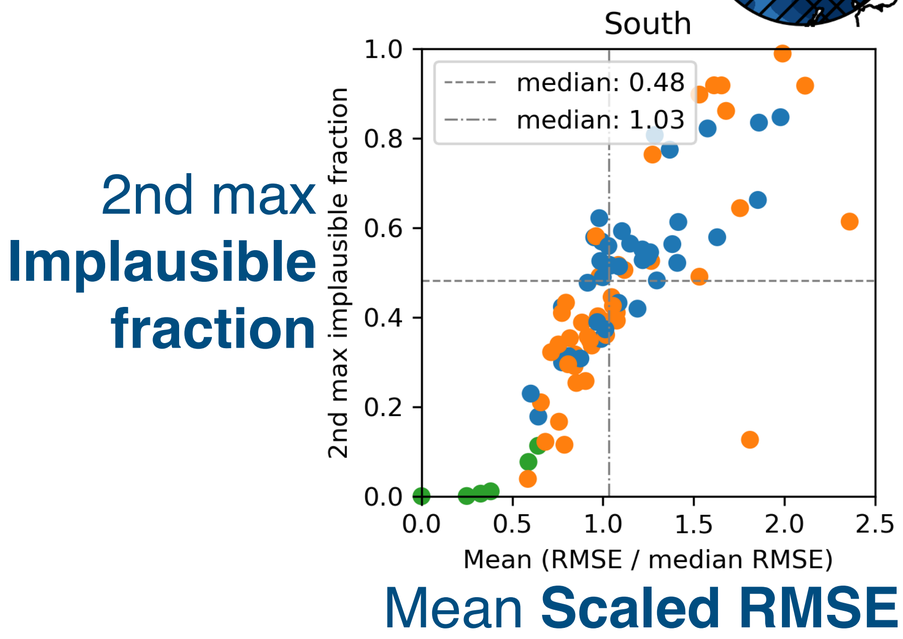


2nd max **Implausible fraction**

Mean **Scaled RMSE**

Antarctic (< 40°S)





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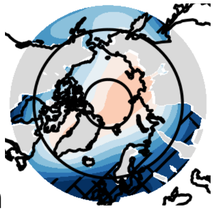

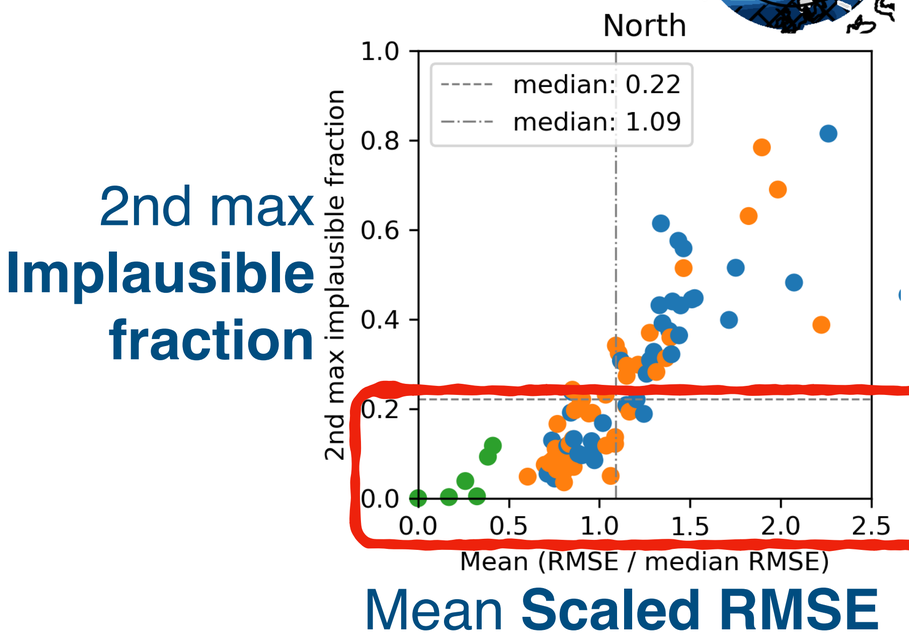

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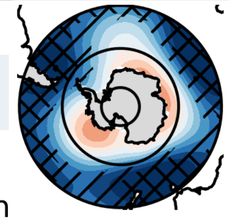

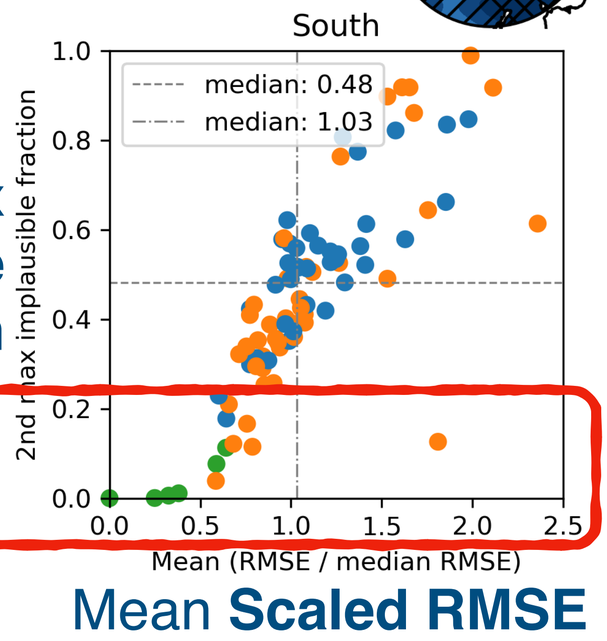

2nd max **Implausible fraction**

Mean **Scaled RMSE**

- CMIP models are **more implausible in the Antarctic** than in the Arctic

Conclusions: CMIP models over polar regions

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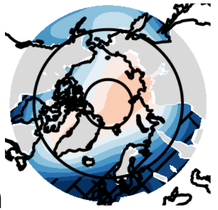
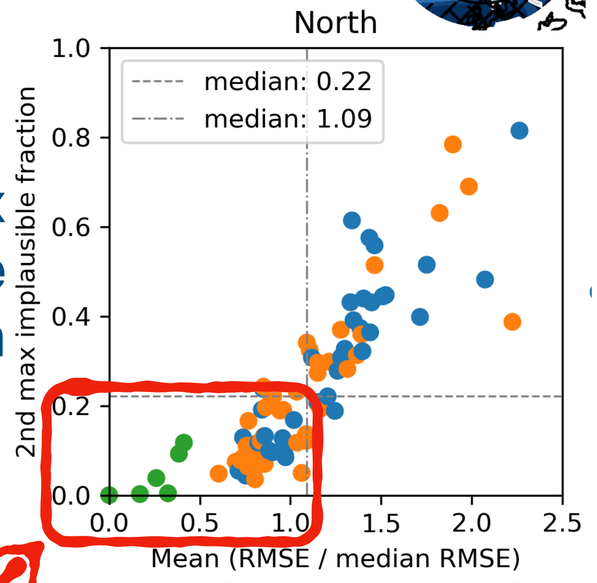


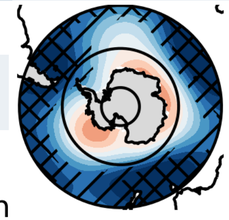


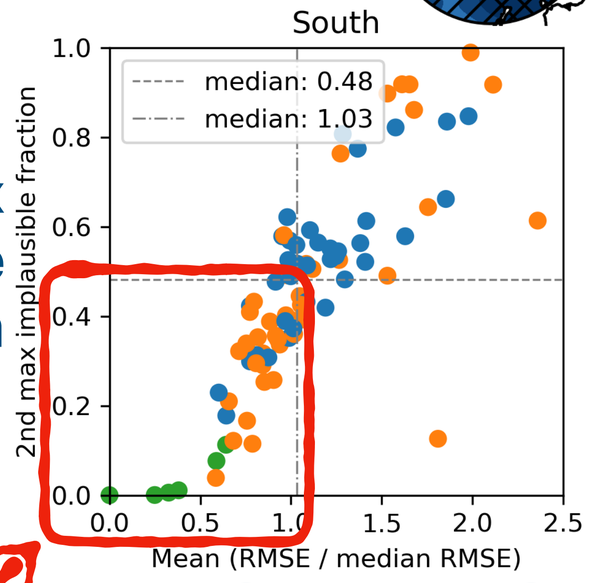
2nd max **Implausible fraction**

Mean **Scaled RMSE**

Best half

Antarctic (< 40°S)





2nd max **Implausible fraction**

Mean **Scaled RMSE**

Best half

- CMIP models are **more implausible in the Antarctic** than in the Arctic
- **Same « Best half »** for Scaled RMSE and Implausibility

Conclusions: CMIP models over polar regions

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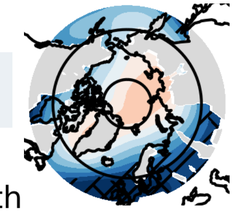

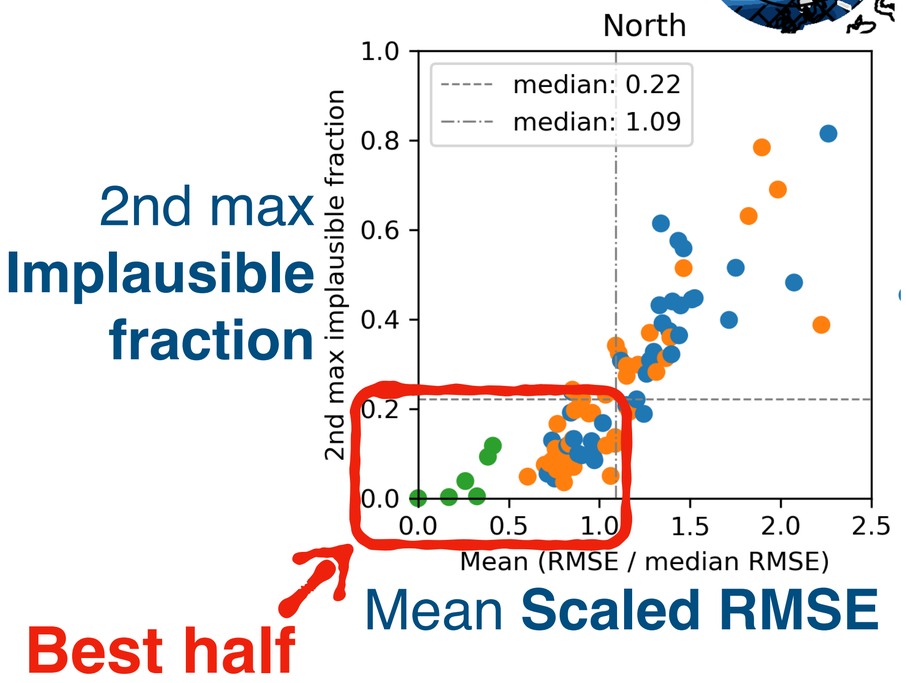

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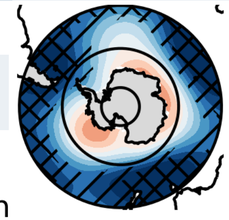

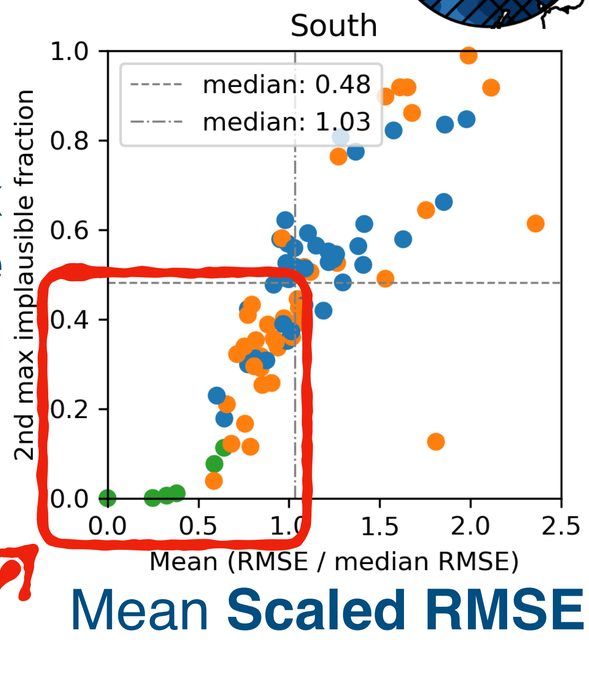

2nd max **Implausible fraction**

Mean **Scaled RMSE**

Best half

- CMIP models are **more implausible in the Antarctic** than in the Arctic
- **Same « Best half »** for Scaled RMSE and Implausibility
- « Best half » contains **both CMIP5 and CMIP6 models**