



Arctic land surface hydrology influences on regional and hemispheric temperature and circulation responses

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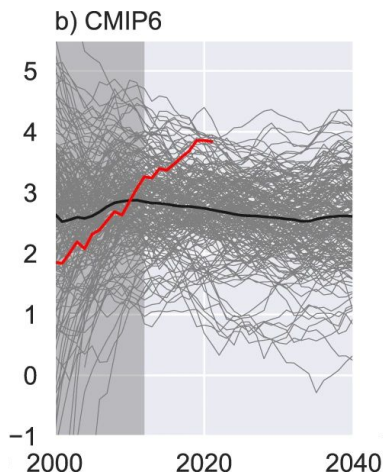
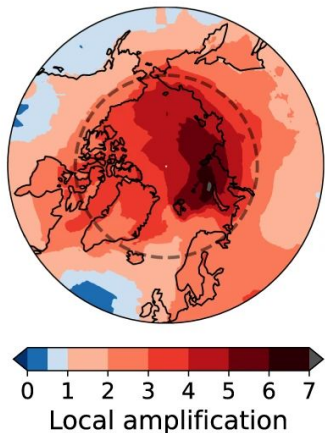
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Arctic Amplification (AA)

Rantanen et al., (2022)



The Arctic warms 4 times faster models underestimate its magnitude

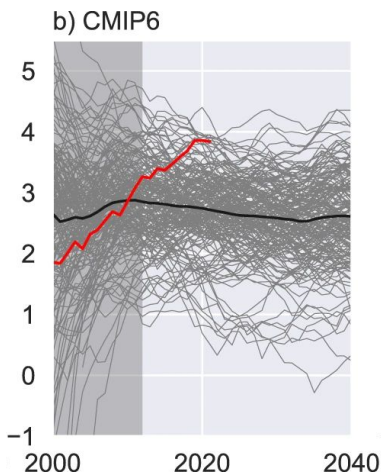
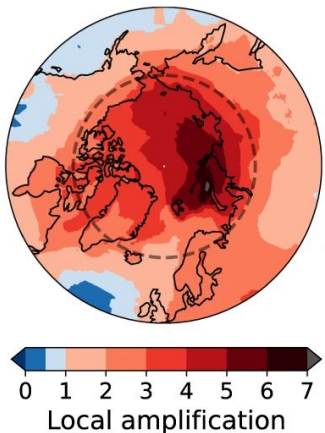
Natural variability is boosting the AA in observations

Rantanen et al., (2024)
Zhou et al., (2024)

Why are changes in the Arctic so important?

Arctic Amplification (AA)

Rantanen et al., (2022)

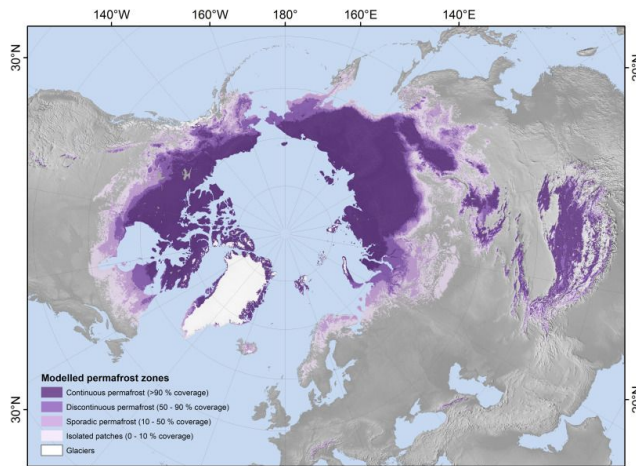


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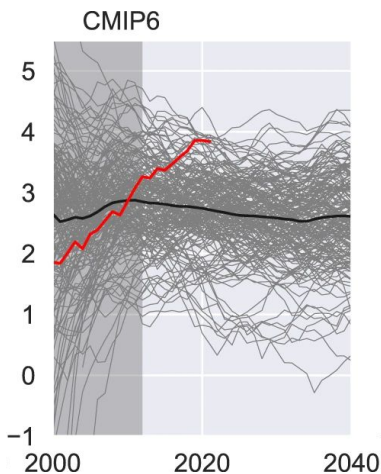
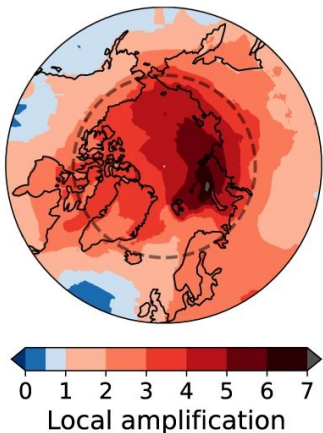
Why are changes in the Arctic so important? Permafrost, large amounts of carbon inside



Obu et al., (2019)

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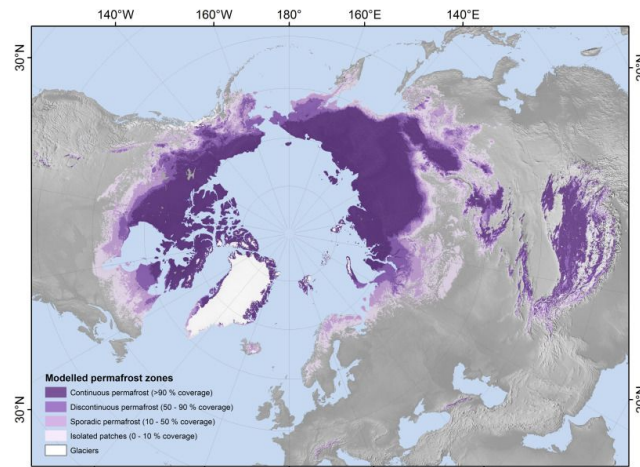


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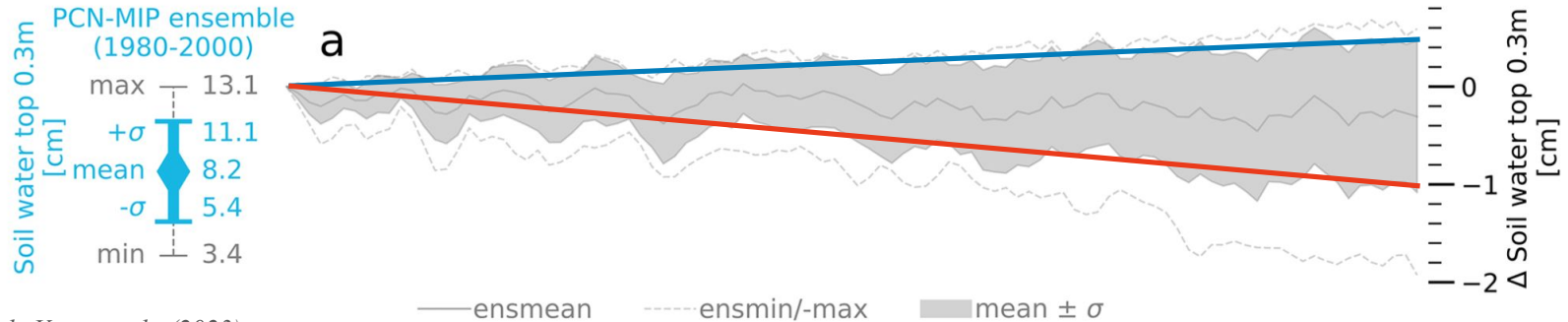


Obu et al., (2019)

Improving Arctic climate realism is essential

Would the Arctic become wetter (**WET**) or drier (**DRY**)?

PCM-MIP ensemble reproduces high uncertainties in soil moisture.
We don't know if the Arctic will become wetter or drier in the future

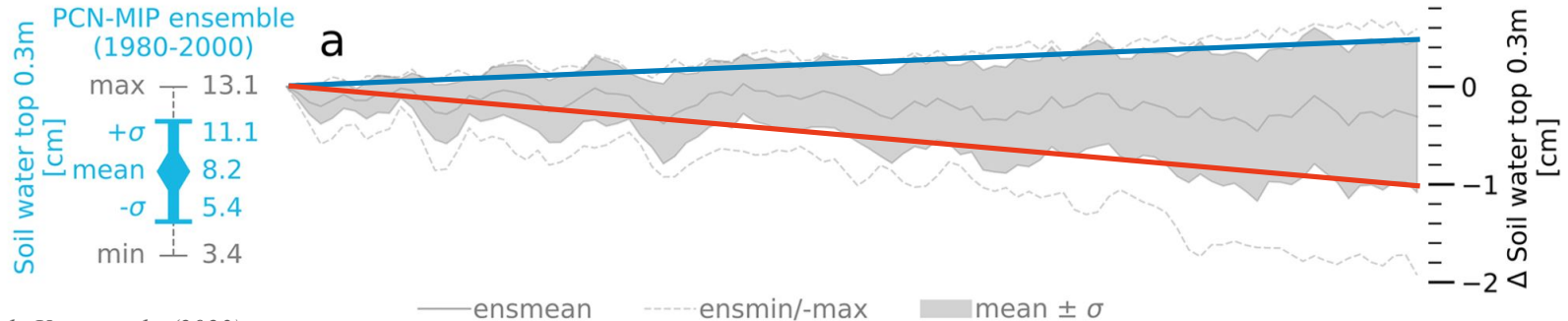


de Vrese et al., (2023)

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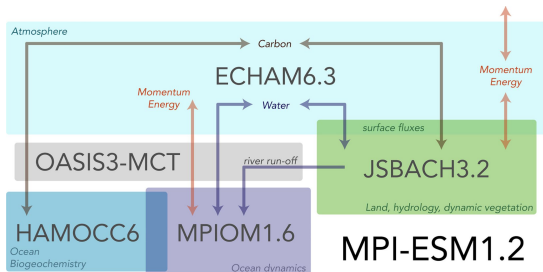
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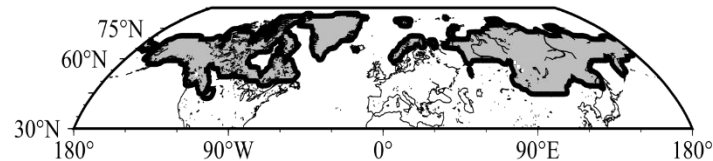
de Vrese et al., (2023)

Some current LSMs can't accurately represent what is happening in Arctic soils

The Permafrost Physics Ensemble (PePE): MPI-ESM JSBACH

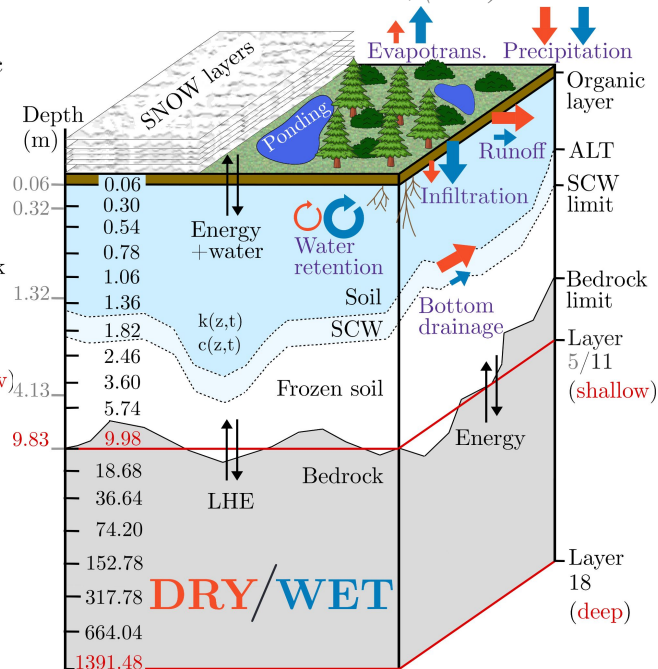
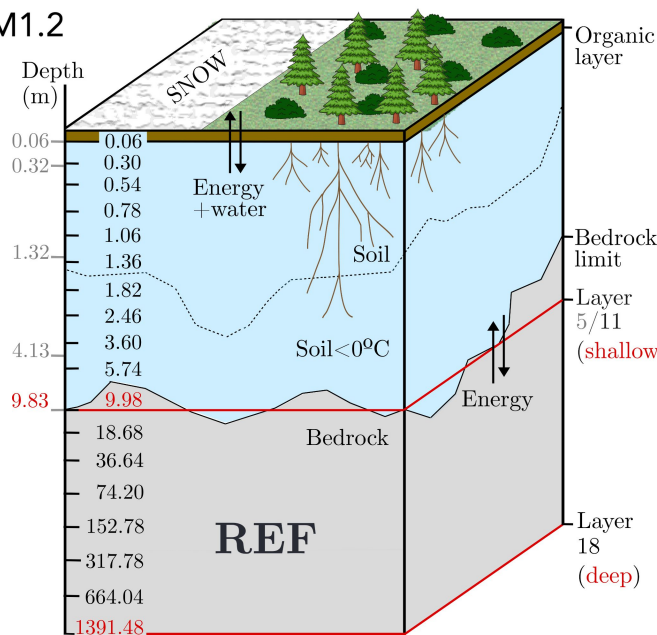


González-Rouco et al., (2021)
Steinert et al., (2021)

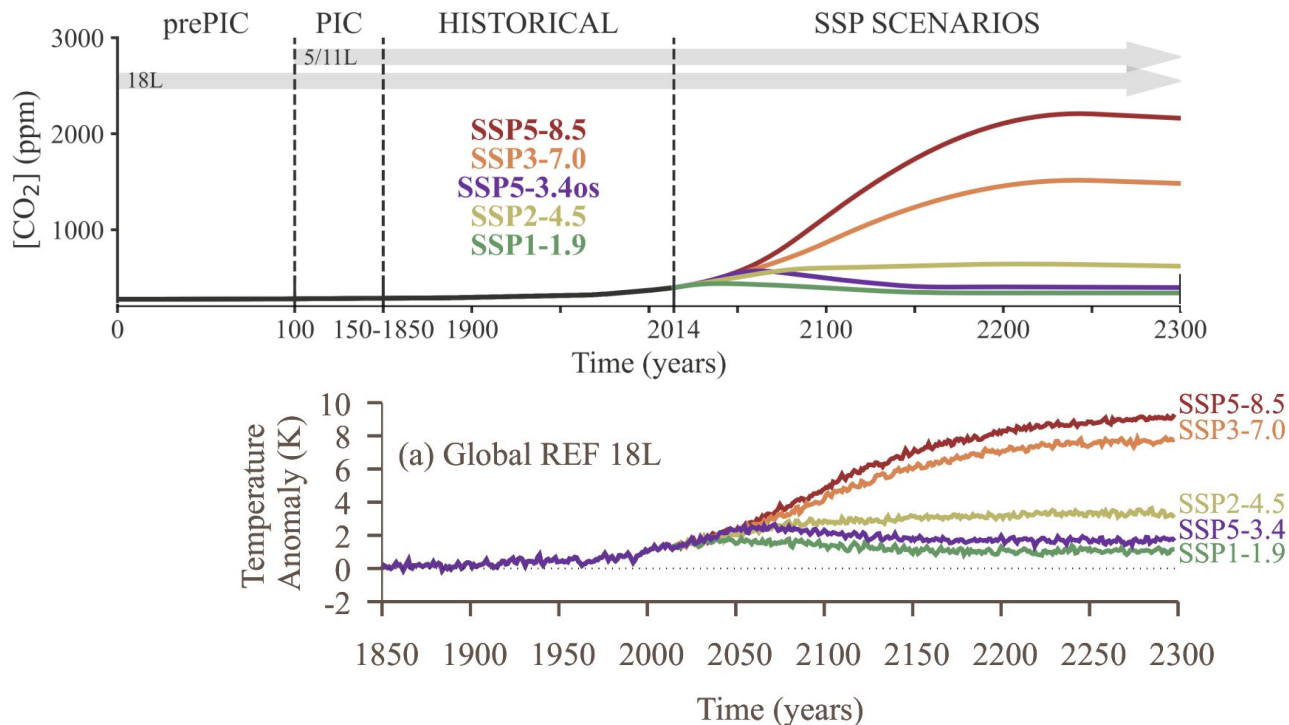


García-Pereira et al., (2025)

- **Hydrology:** **WET**, **DRY**, REF (over the permafrost mask)
- **Thermodynamics:** 5, 11 and 18 layers (included globally) and phase changes (over the permafrost mask)

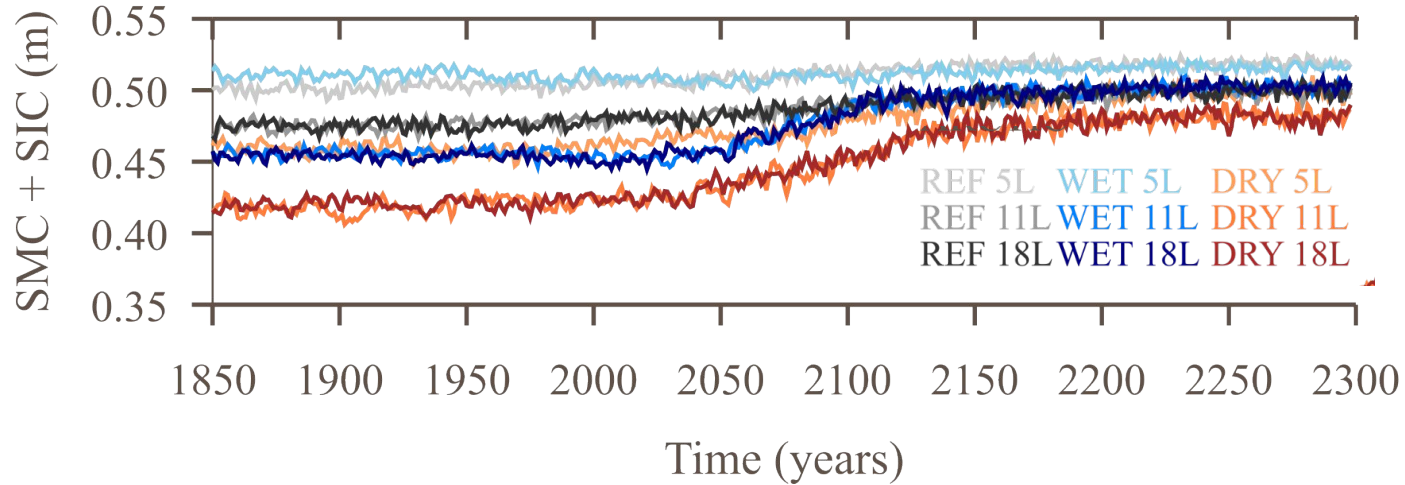


The Permafrost Physics Ensemble (PePE): MPI-ESM JSBACH



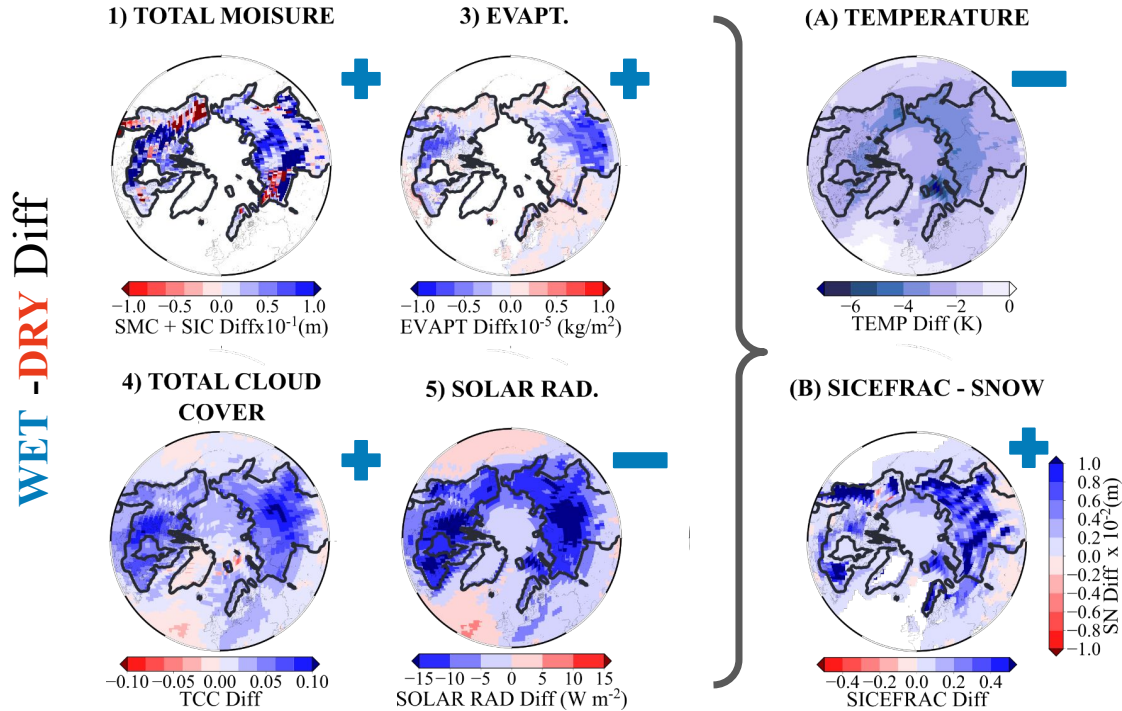
Ensemble of 9 configurations in 5 different SSP scenarios until **2300**.

Soil moisture response



Total moisture is higher in **WET** than in **DRY** as expected

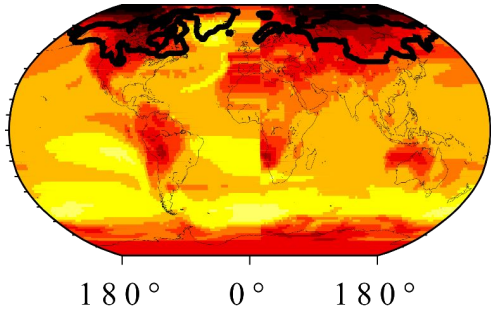
How does soil moisture affect other variables?



WET: higher total moisture → more evapotranspiration → more total cloud cover → less solar radiation → less temperature
DRY: less total moisture → less evapotranspiration → less total cloud cover → more solar radiation → more temperature

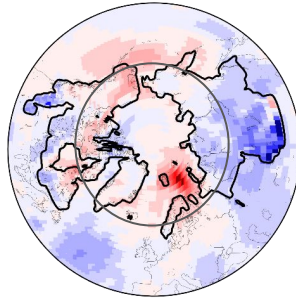
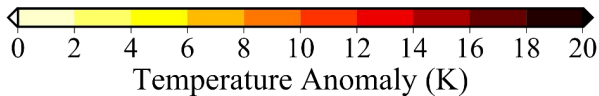
... and what about temperatures?

Anomaly with respect to 1850-1900

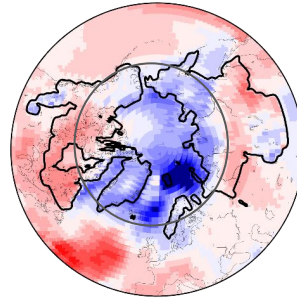


180° 0° 180°

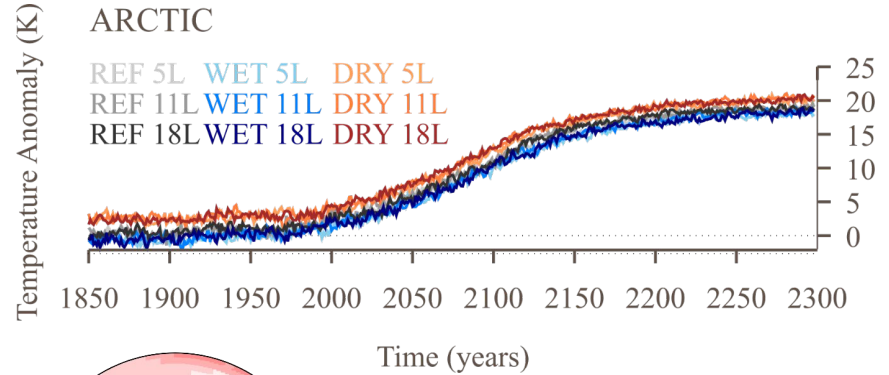
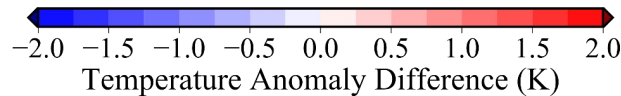
REF ANOM



WET ANOM - REF ANOM



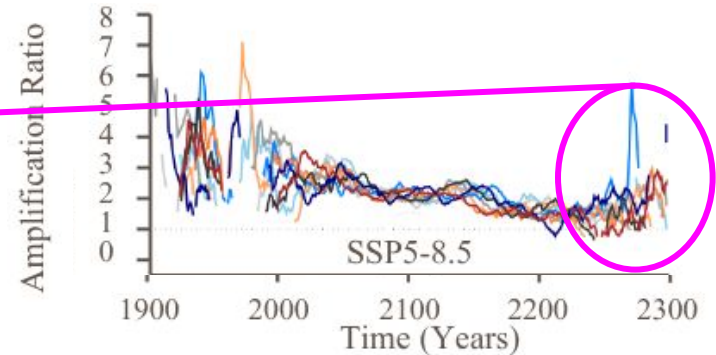
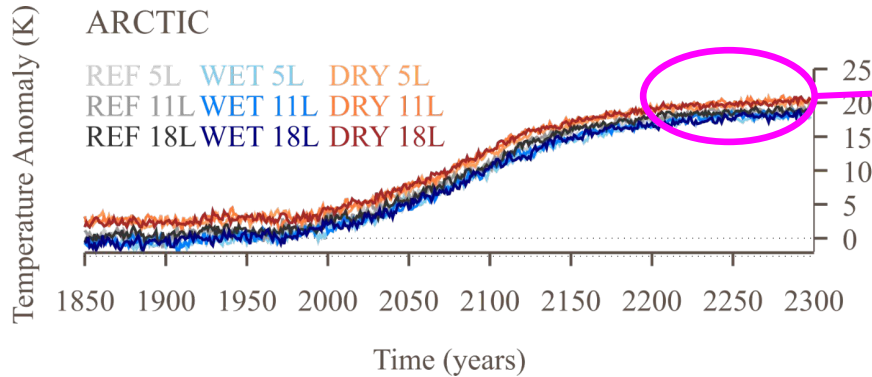
DRY ANOM - REF ANOM



DRY: warmer and warms less
WET: colder and warms more
(ice-albedo feedback)

Does the AA ratio reflect those temperature differences?

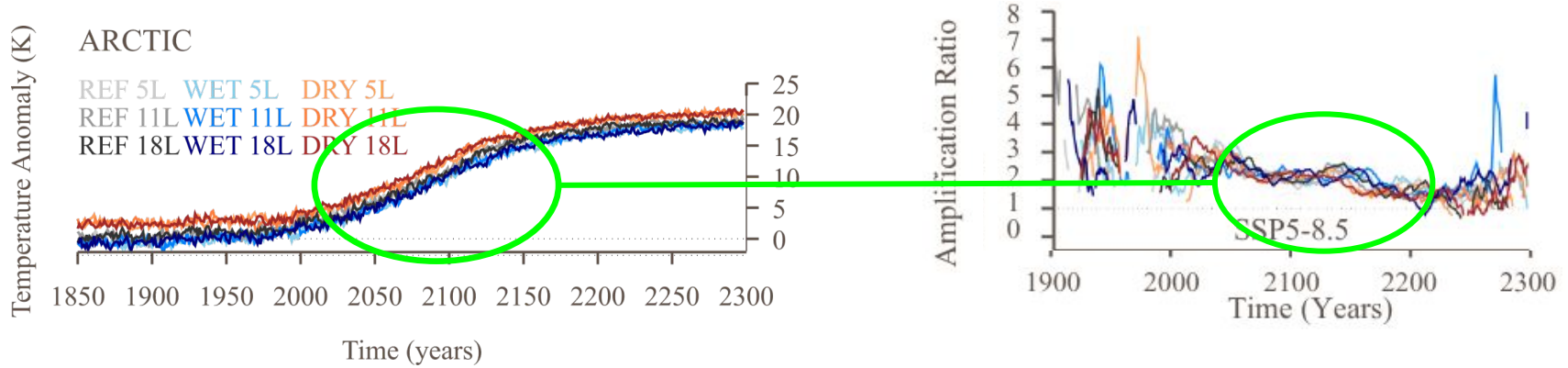
$$AAR = \frac{dT_A/dt}{dT_G/dt} \quad \longleftarrow \quad \text{Amplification ratio}$$



If internal variability dominates then simulations diverge to values higher than 4

Does the AA ratio reflect those temperature differences?

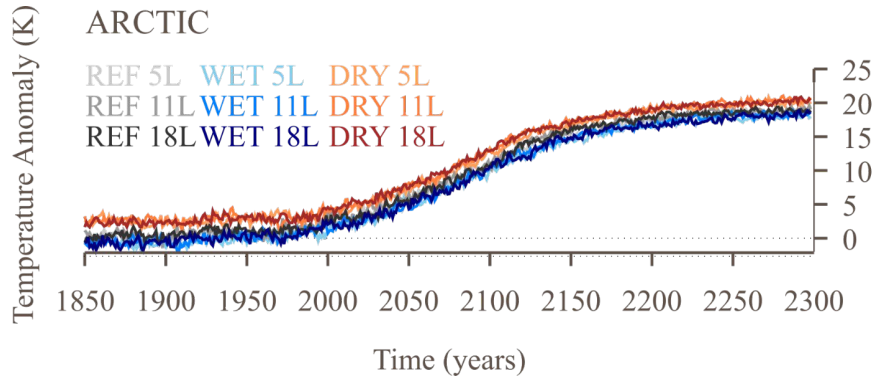
$$AAR = \frac{dT_A/dt}{dT_G/dt} \quad \longleftarrow \quad \text{Amplification ratio}$$



If external forcing is dominant (temperature trends are high), simulations converge to a factor of 2-3

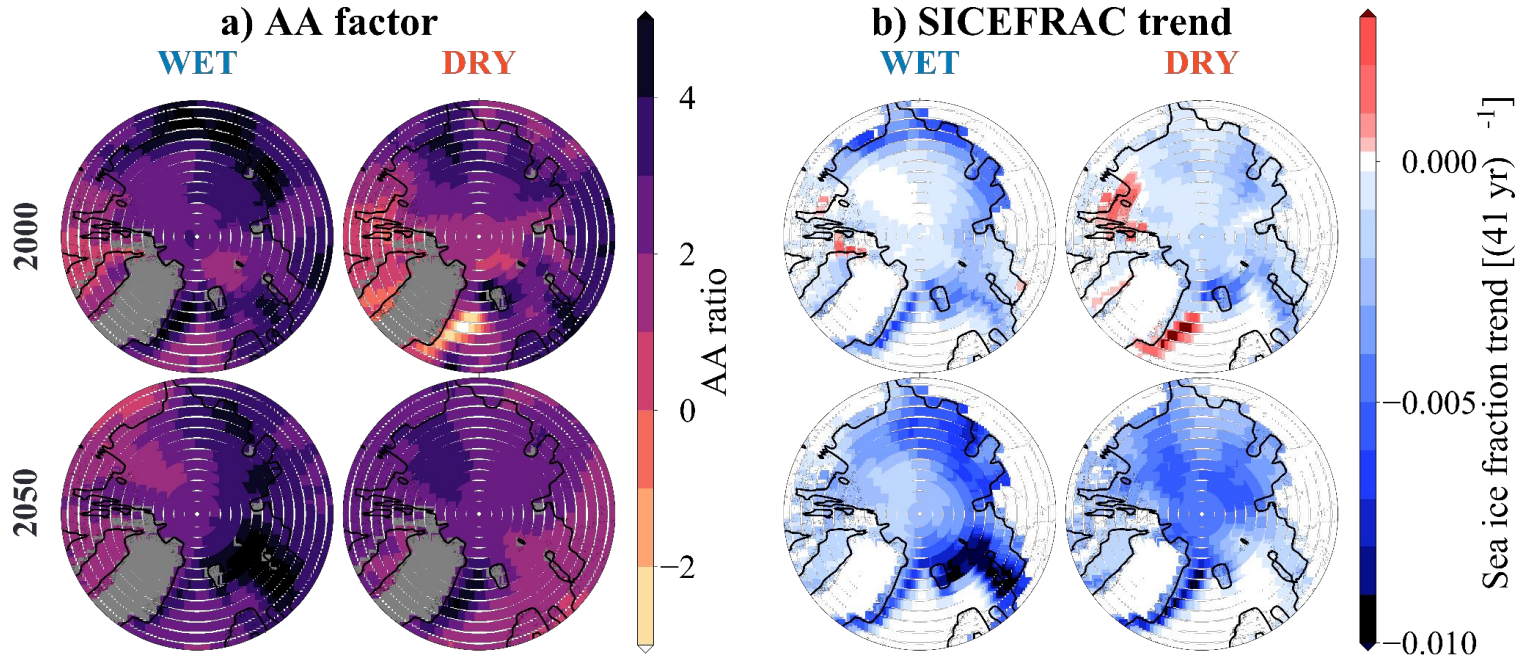
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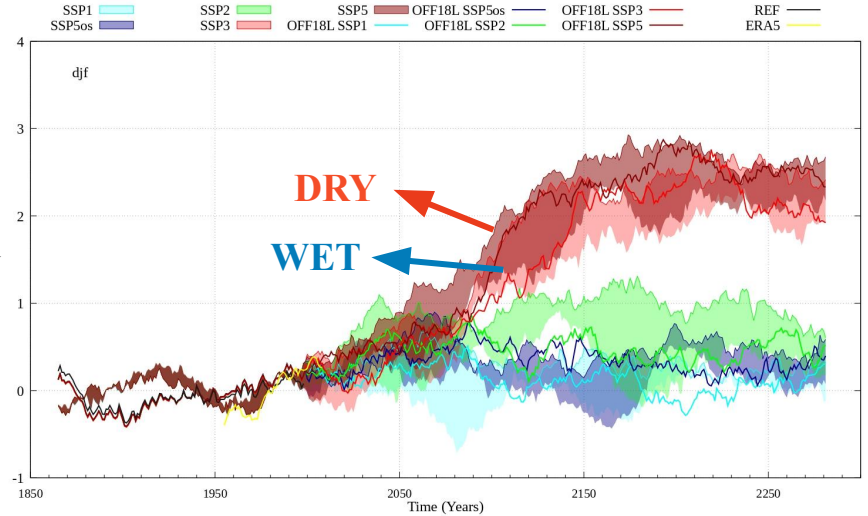
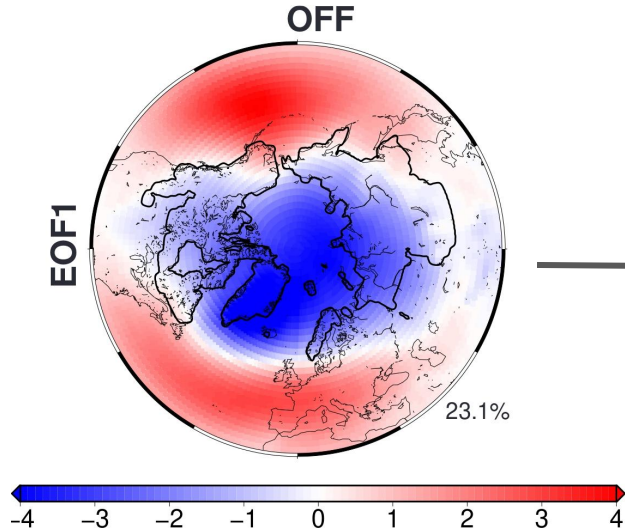
Internal variability could be responsible for such high AA values in observational studies

What about local effects?



Important differences linked to hydrology changes in spatial patterns. Sea ice trends correlate perfectly with AA factor

Arctic oscillation (AO)



Top (bottom) edges of shaded areas represent
DRY (WET) configurations

DRY has to a more positive winter AO

Changes in soil hydrology affect atmospheric circulation. More (less) positive winter AO in **DRY (WET)**

What did we learn?

Soil hydrology
shapes Arctic
climate
background

Observed AA is
driven by internal
variability. AA
converges to a
factor of 2-3 is there
is external forcing

Changes in soil
hydrology affect
atmospheric
dynamics by
producing a more
positive winter AO
in DRY

Work in progress

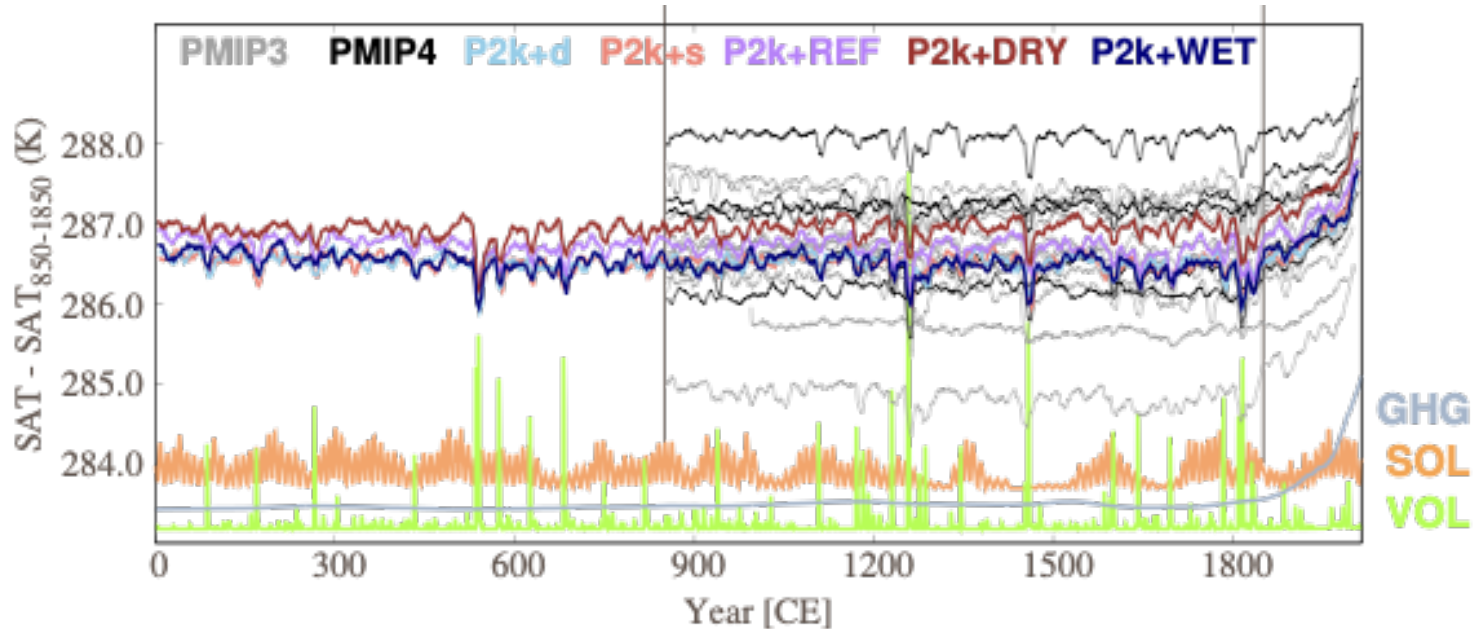
There is an ensemble of simulations with the WET and DRY configurations from 0 to 2100.

Thank you for your attention

Eskerrik asko

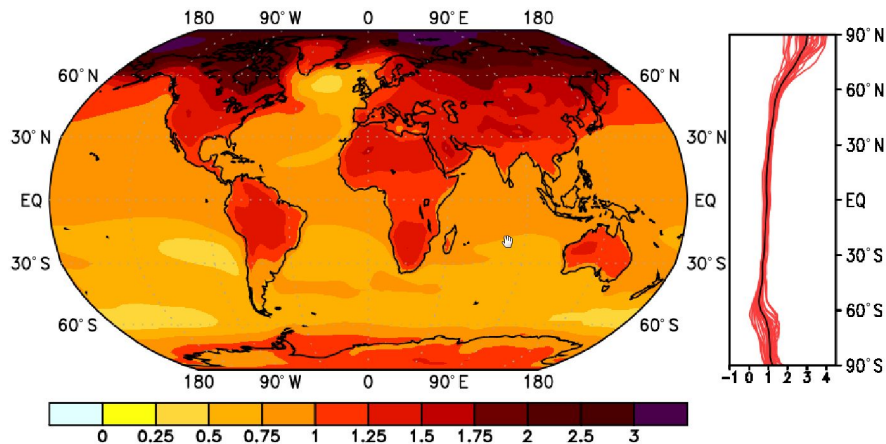
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<https://mad.csic.es/>



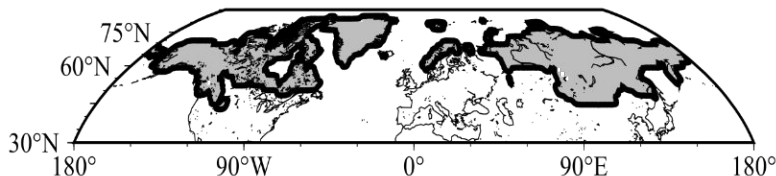
The Arctic warms faster than the rest of the world: Arctic Amplification (AA)

Smith et al., GMD, 2019

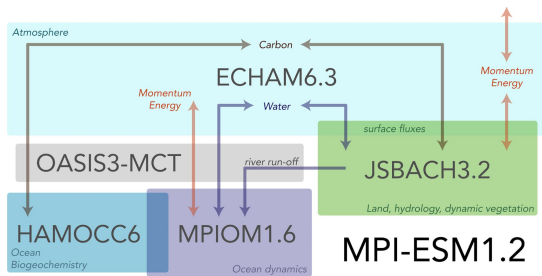


The Arctic is in particular sensitive to the global warming because of feedback processes among many other things.

Mask from data in Hugelius et al., ESSD, 2013/2014



The only way of knowing what would happen is using Earth System Models (ESMs)

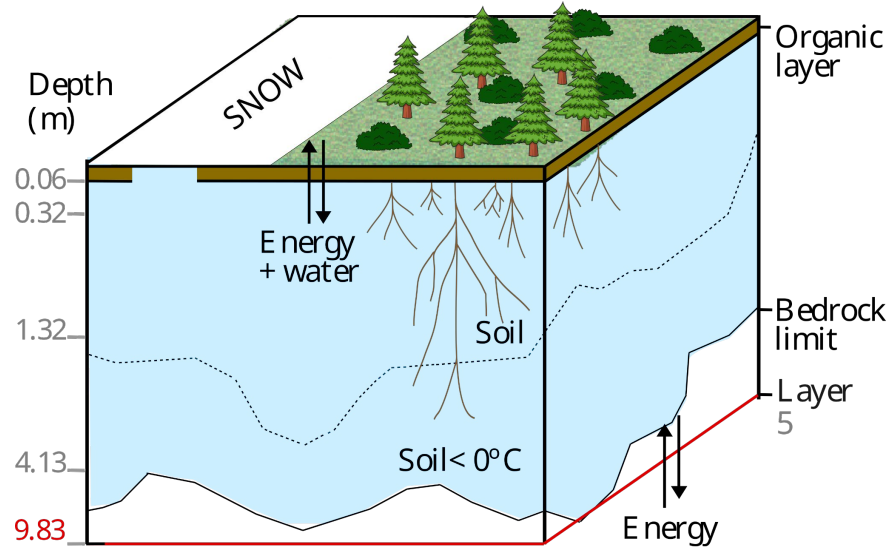


MPI-ESM1.2

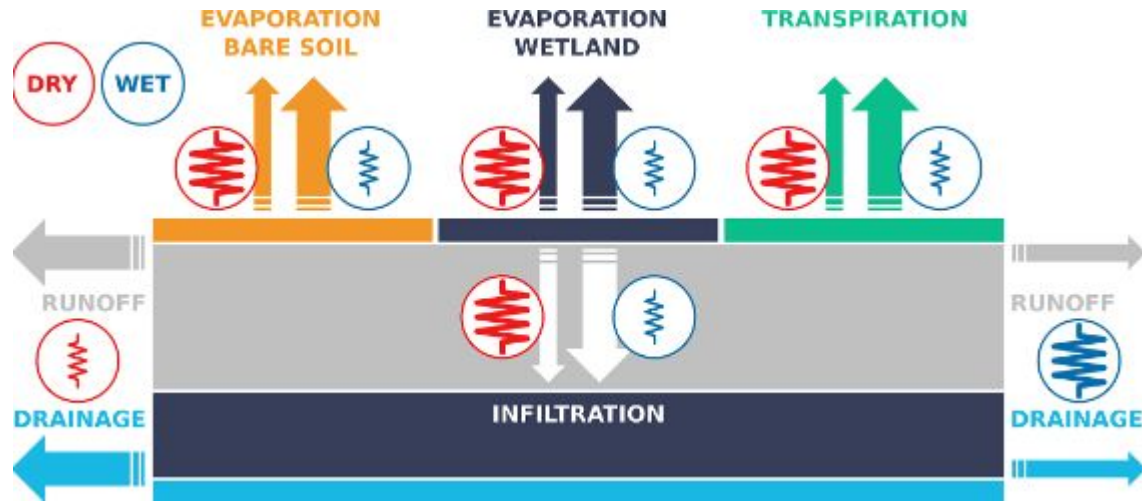
Mauritsen et al., JAMES, 2019

Soils in this region store large amounts of carbon that, under global warming, could be released into the atmosphere and amplify the warming

REFERENCE 5L MPI-ESM



Idealized **WET** vs. **DRY** set-ups to capture hydrological uncertainties



Idealized **WET** vs. **DRY** set-ups to capture hydrological uncertainties

WET		DRY
Low resistance (ignores organic porosity)	Infiltration resistance	High resistance (includes organic matter porosity constraints)
High retention capacity	Water retention	Low retention capacity
Stationary/Immobilized	Supercooled Water (SCW)	Mobile
Restricted lateral drainage (by sub)	Drainage and runoff	High bottom drainage and surface runoff
High	Evapotranspiration rate	Low

WHY 5L HAS MORE HUMIDITY THAN 11L

