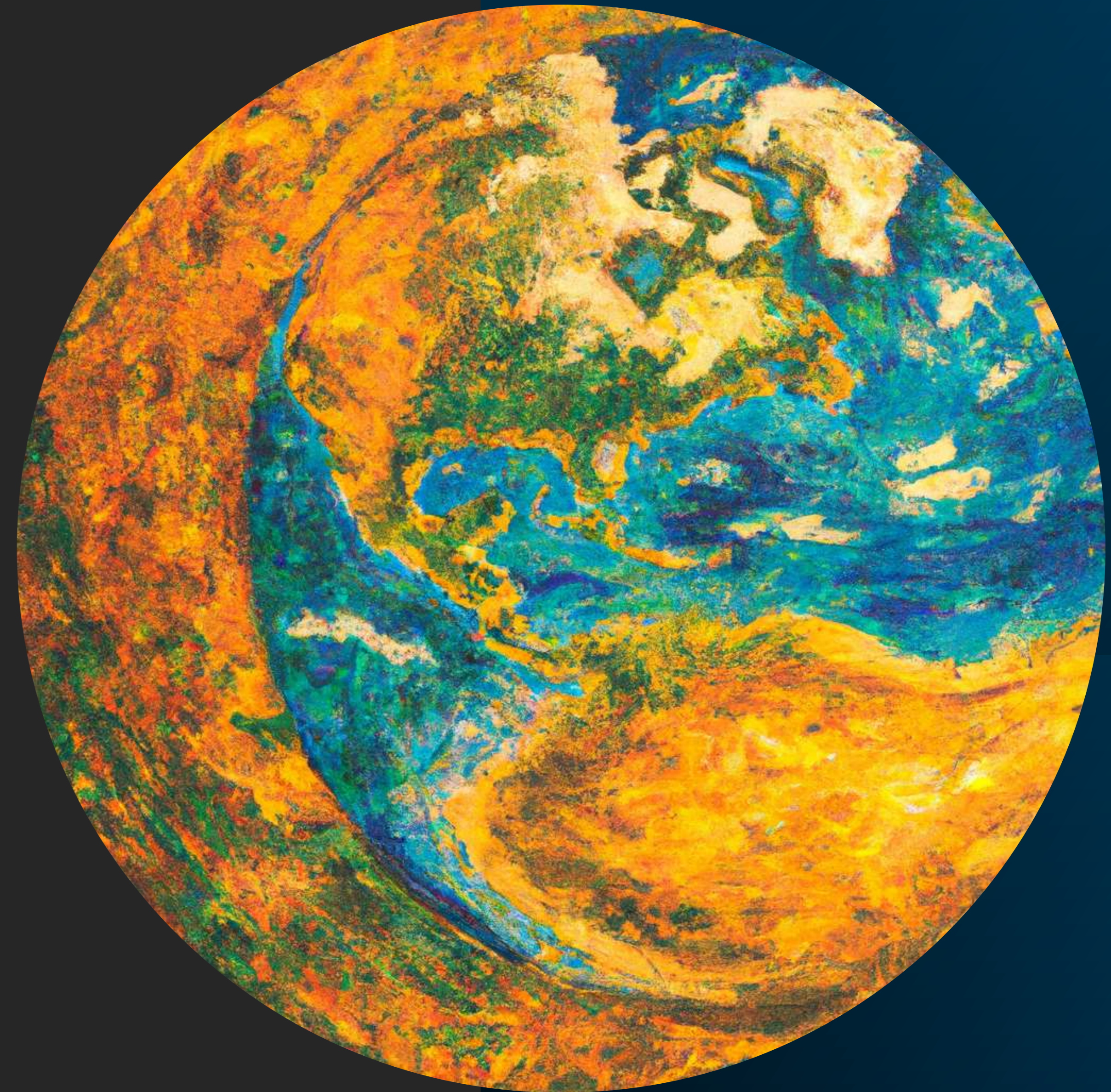


Assessing the Performance of CTSM in Simulating Arctic Permafrost Regions ~~and its Sensitivity to~~ ~~Atmospheric Forcings and~~ ~~Soil Properties~~

Adrien Damseaux
Heidrun Matthes



a Van Gogh painting of a globe over the Arctic
by Dall-E

Model setup

CTSM version 5.1.dev086	Compset 2000_DATM%GSWP3v1_CLM50% SP_SICE_SOCN_SROF_SGLC_SWAV	Grid Arctic domain above 57°N Icosahedral grid (240860 p) resolution = 12 km ²
Atmospheric forcings ERA5 from 1980-2021	Spin-up 30 years loop from 1980 to 1989	Snow parameter reset_snow = .true. h2osno_max = 800

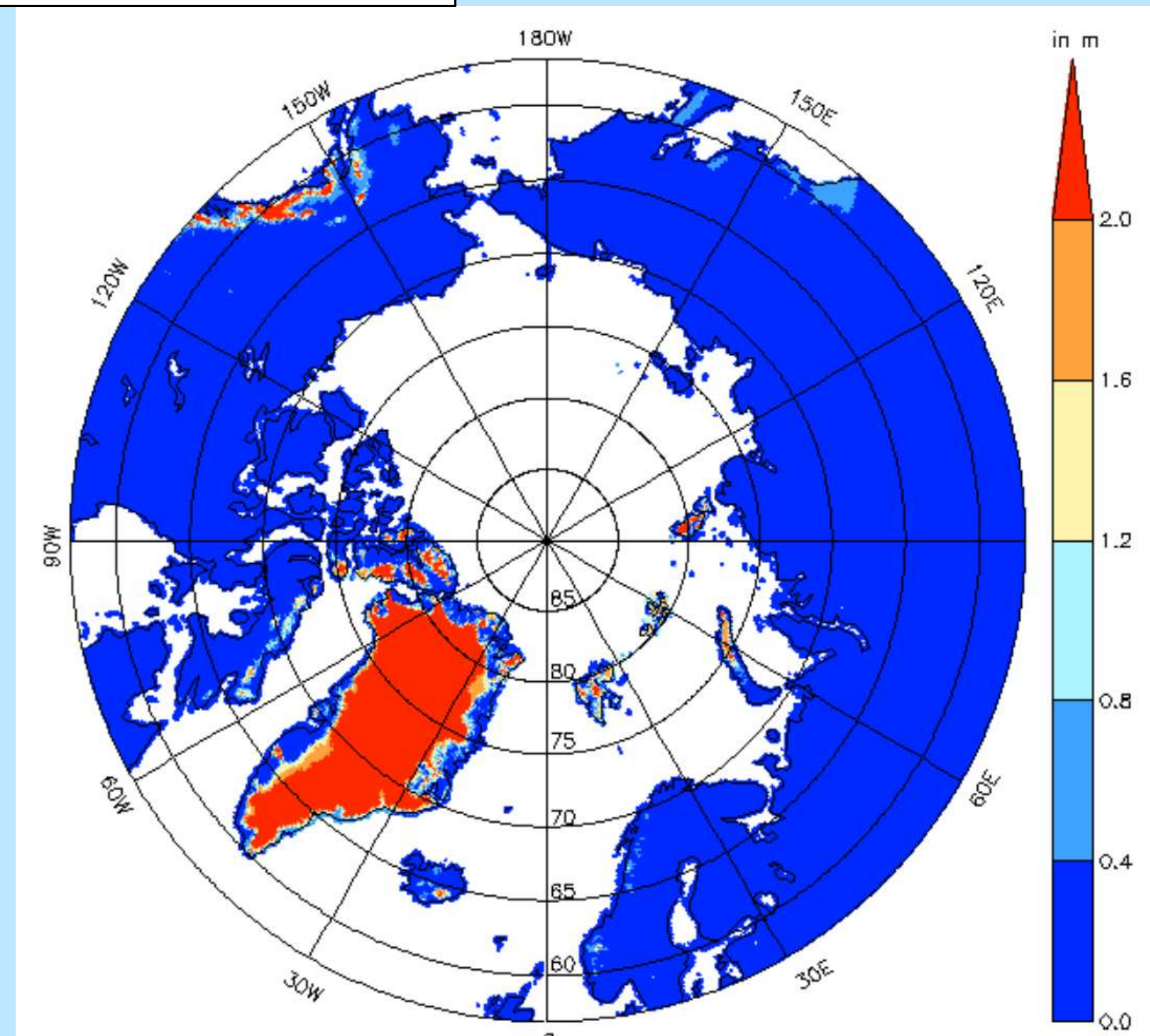
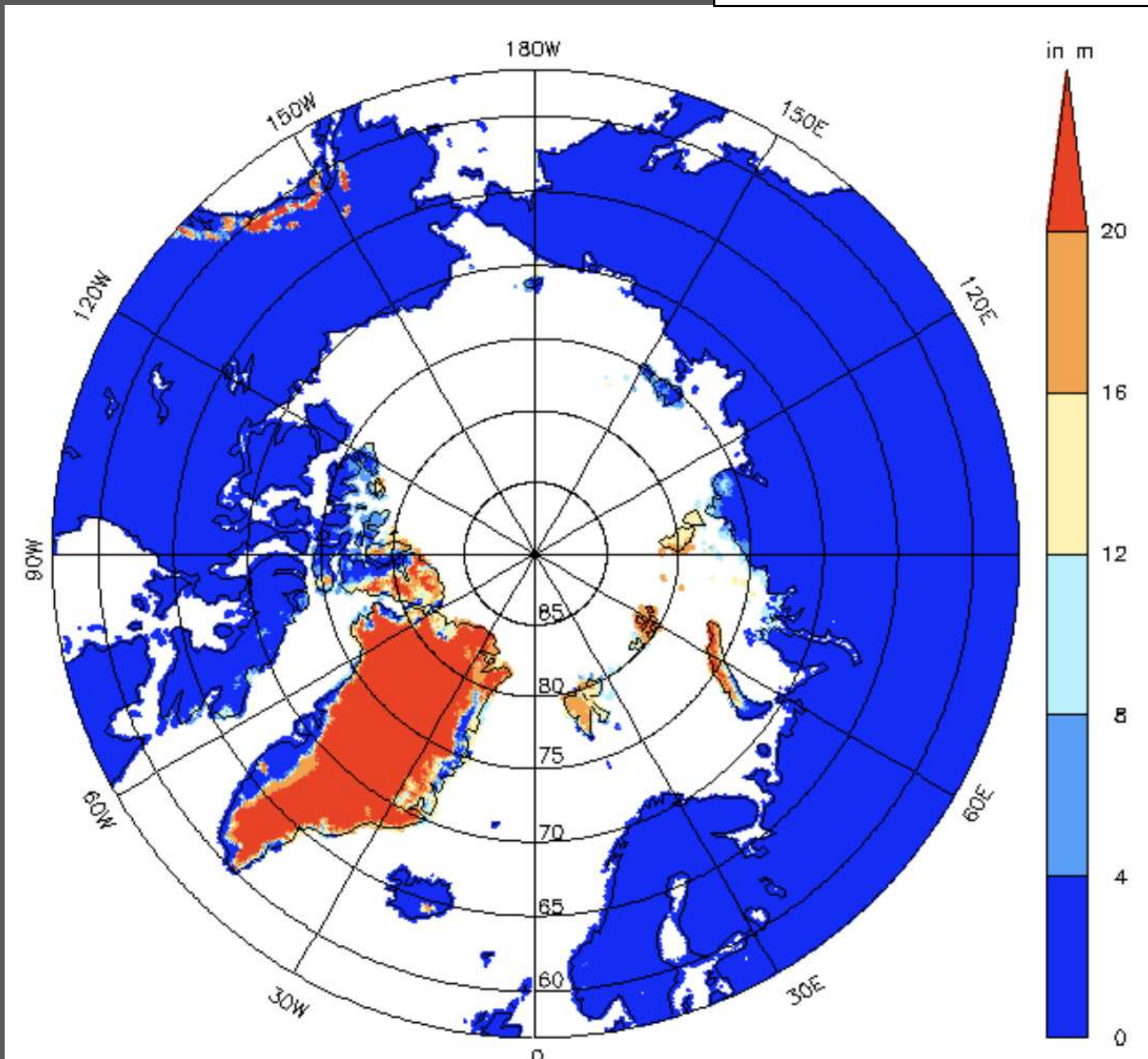
Default snow parameters

Reset_snow = false
h2osno_max = 10 m

Adjusted snow parameters

Reset_snow = true
h2osno_max = 0.8 m

Snow depth average in January 1980



Observation products

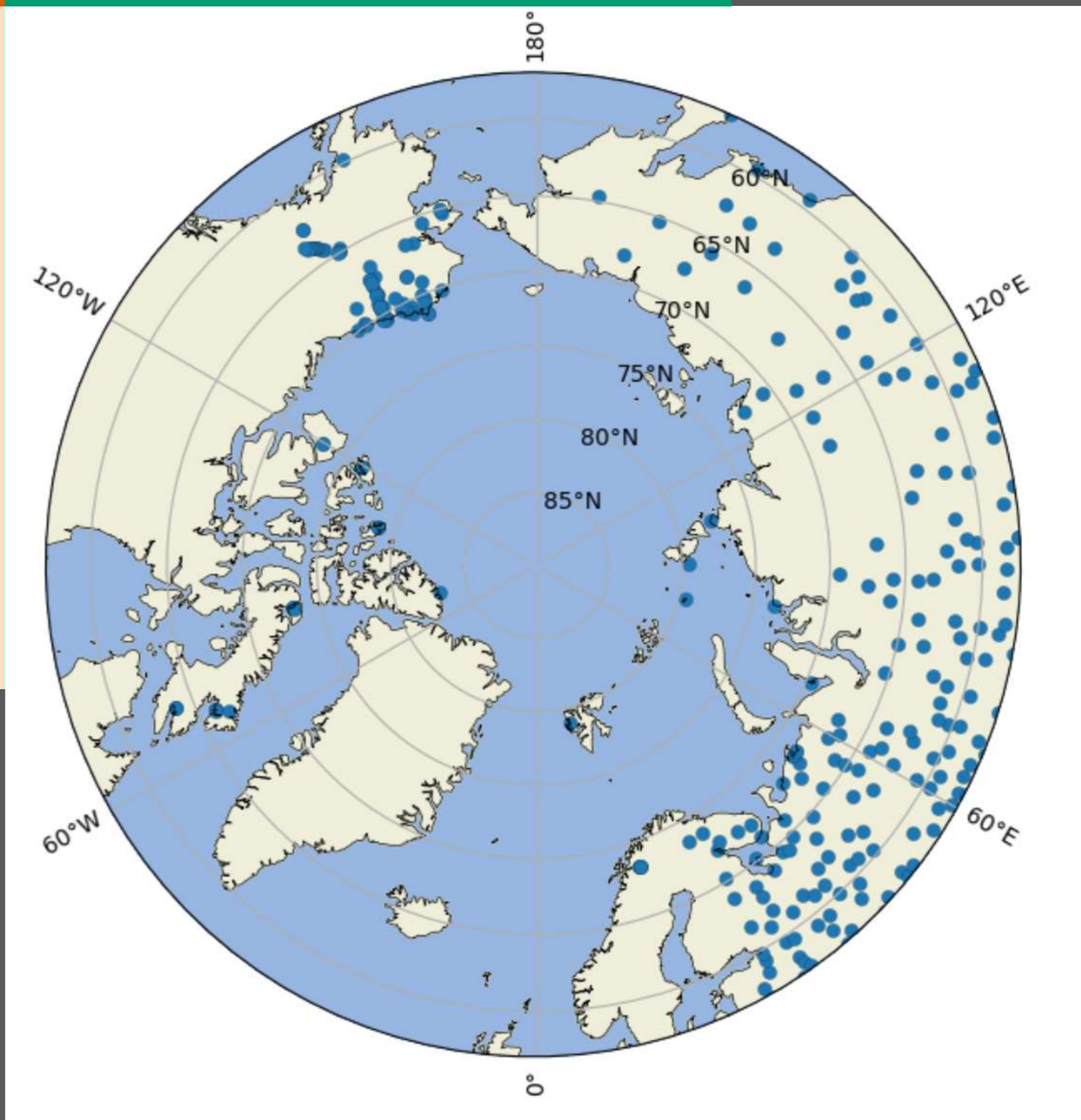
ESACCI products

- From the ESA Climate Change Initiative
- Remote sensing products
- Soil temperature (at 1, 5 and 10m), ALT and PFR extent
- Year averages (1997-2019)
- Period averaged
- Domain resolution 1 km²

CALM network

- Circumpolar Active Layer Monitoring (CALM) network
- 98 stations
- Active Layer Thickness (ALT) column
- Year averages (1991-2021)
- Period averaged

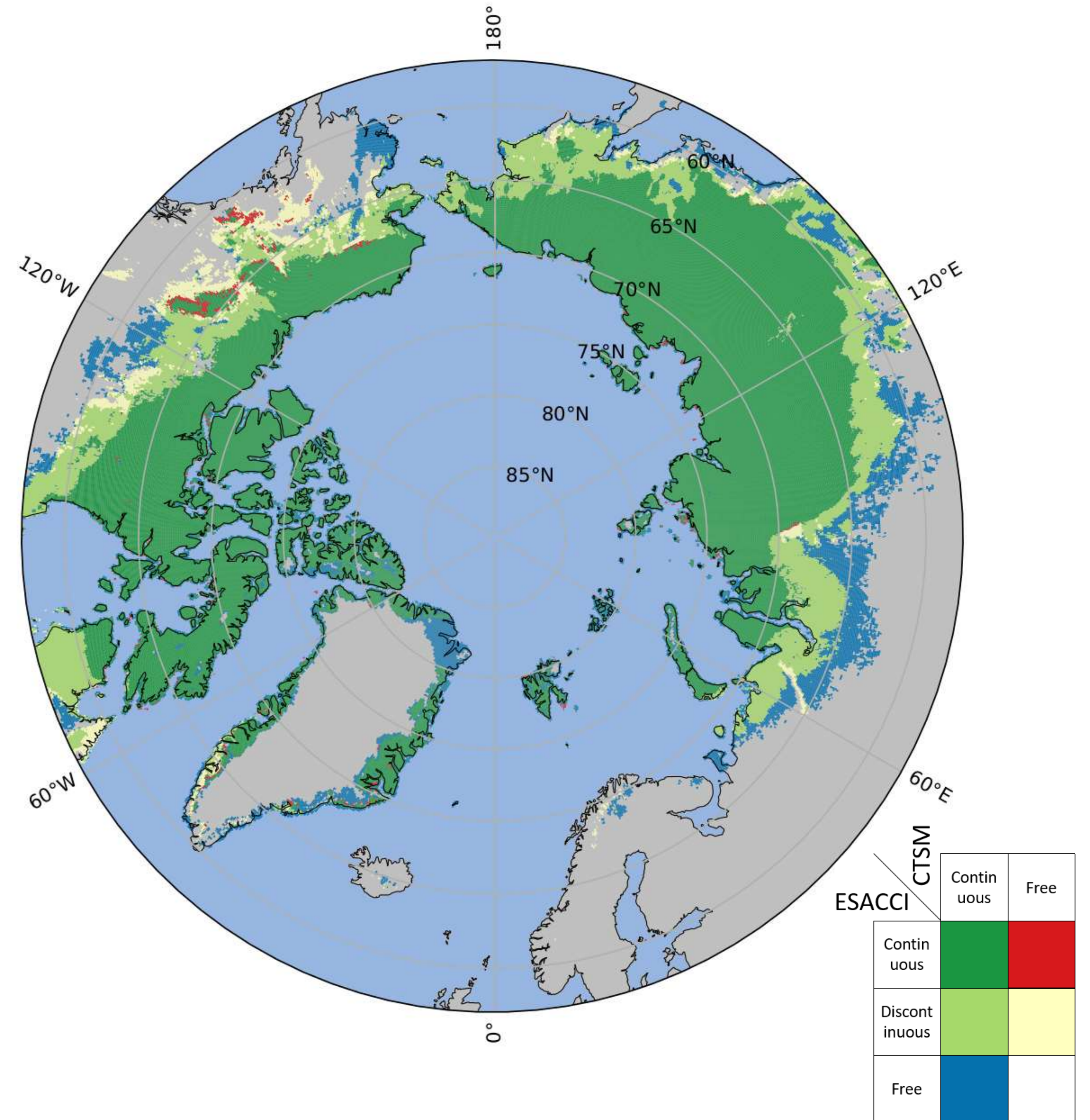
In-situ observations



Permafrost extent mask difference CTSM – ESACCI

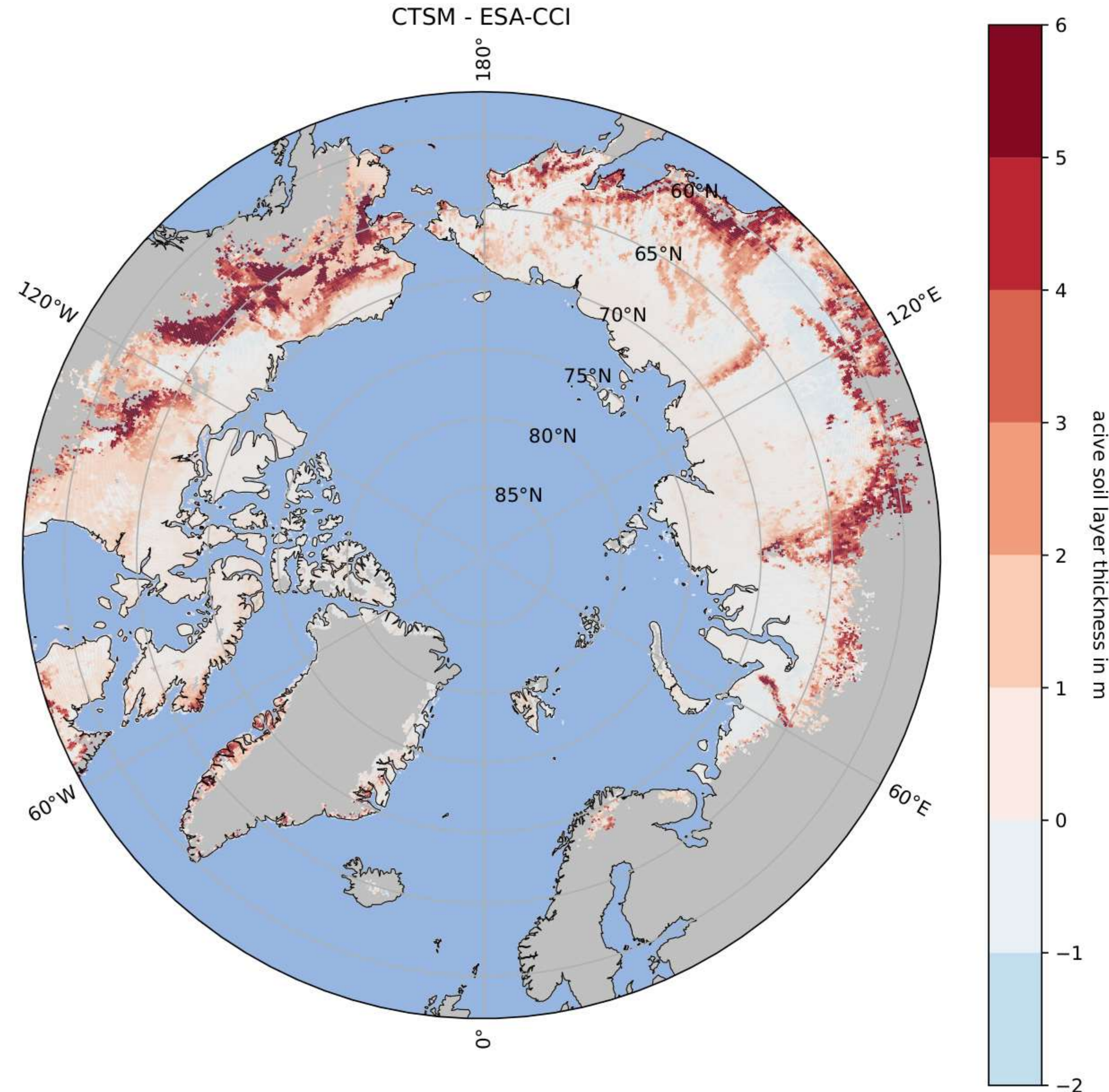
- Strong agreement with ESACCI (93%)
- Slight overestimation of the permafrost extent, mostly in Siberia

Permafrost extent area:
CTSM = 13.358 - ESACCI = 12.544 10e6km²



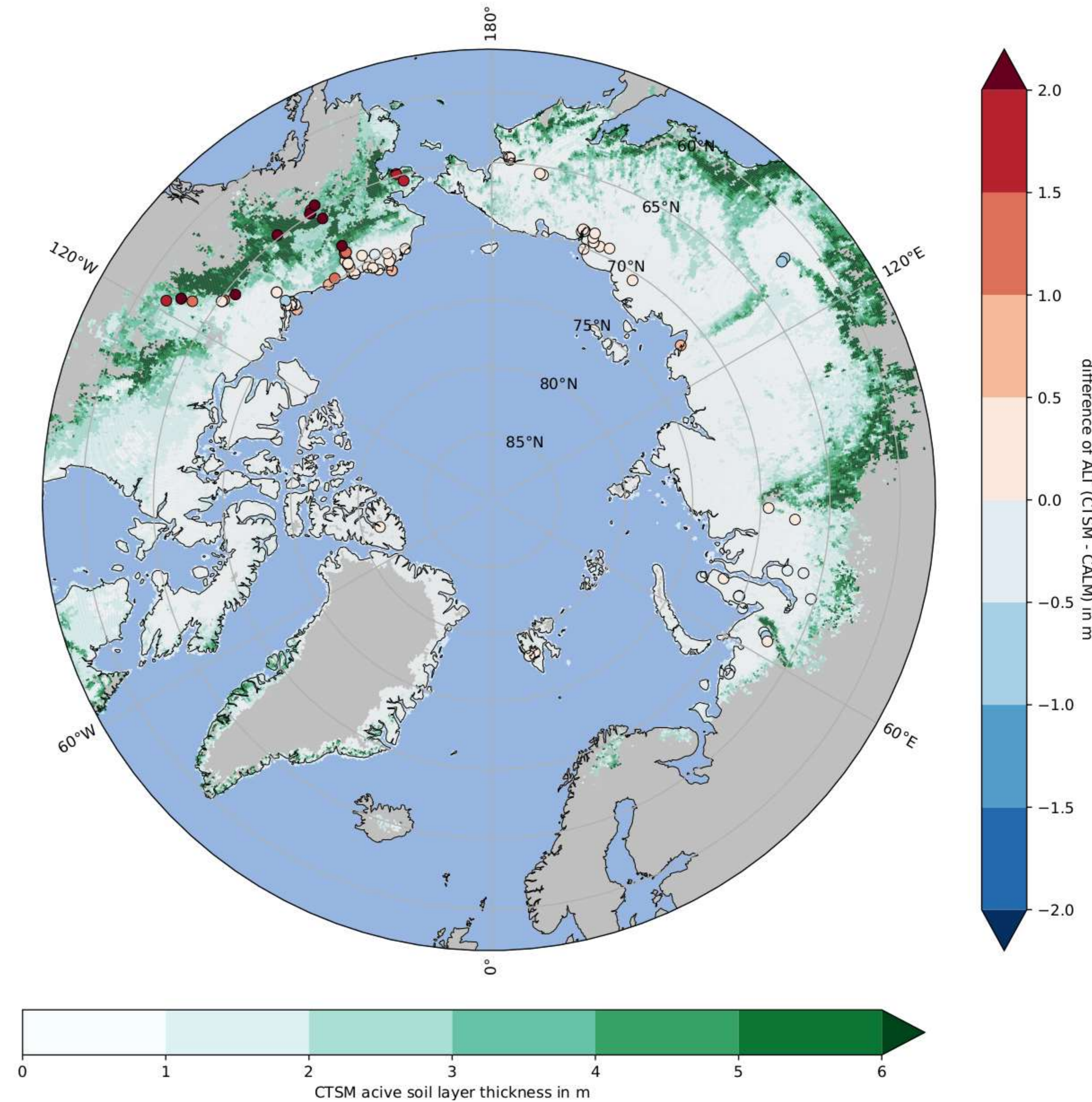
Active Layer Thickness difference CTSM - ESACCI

- Above 65°N, CTSM is within 1 m of ESACCI
- CTSM overestimates ALT in warm permafrost regions (borders)



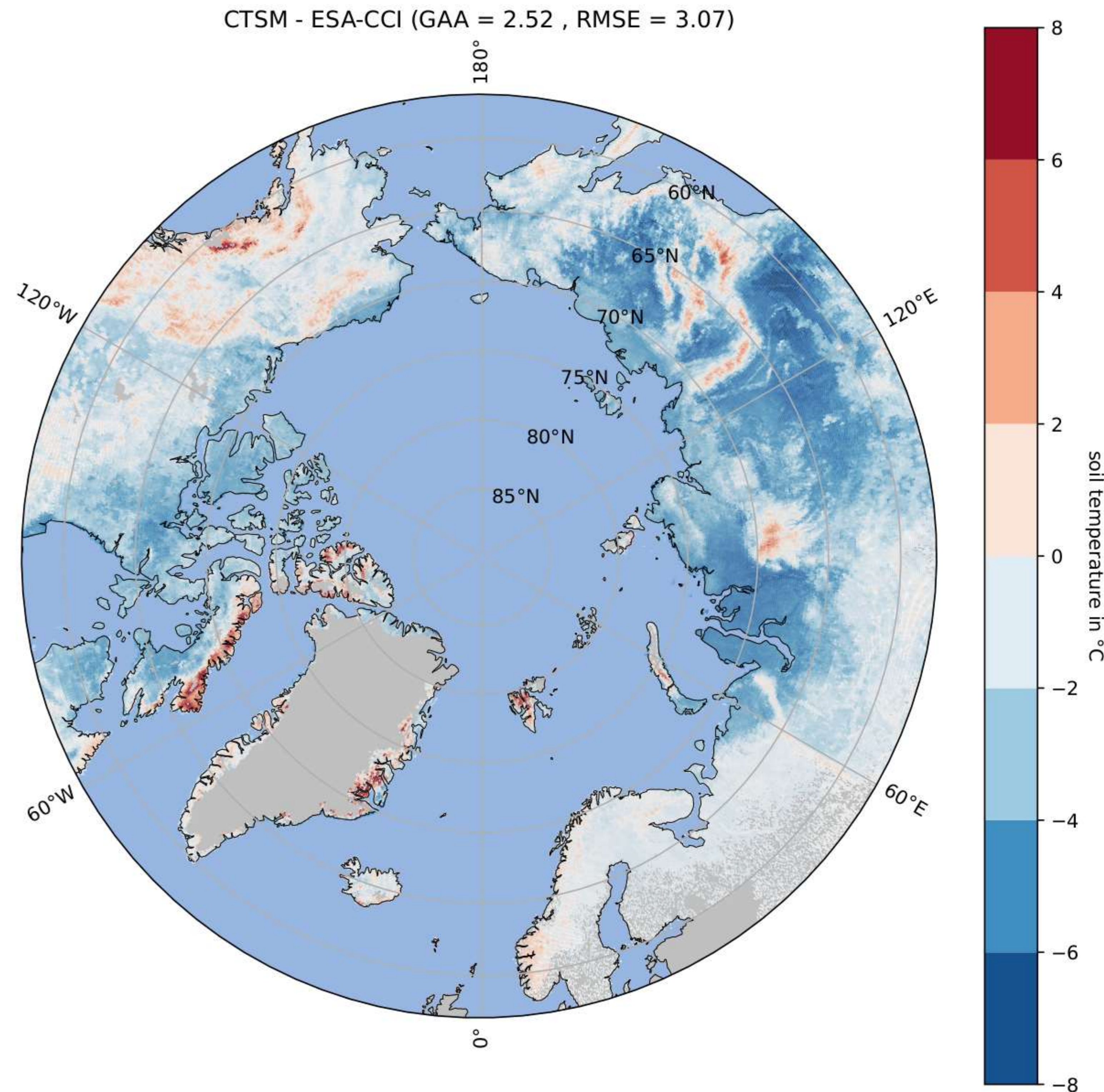
Active Layer Thickness difference CTSM - CALM

- Same conclusion as ESACCI comparison
- Unfortunately, no station in warm permafrost over Siberia



Soil temperature difference at -1 m CTSM - ESACCI

- Strong cold difference, up to -8°C in Siberia
- More significant over Siberia, less over Canada
- Same in -5 and -10 m (additional slides)



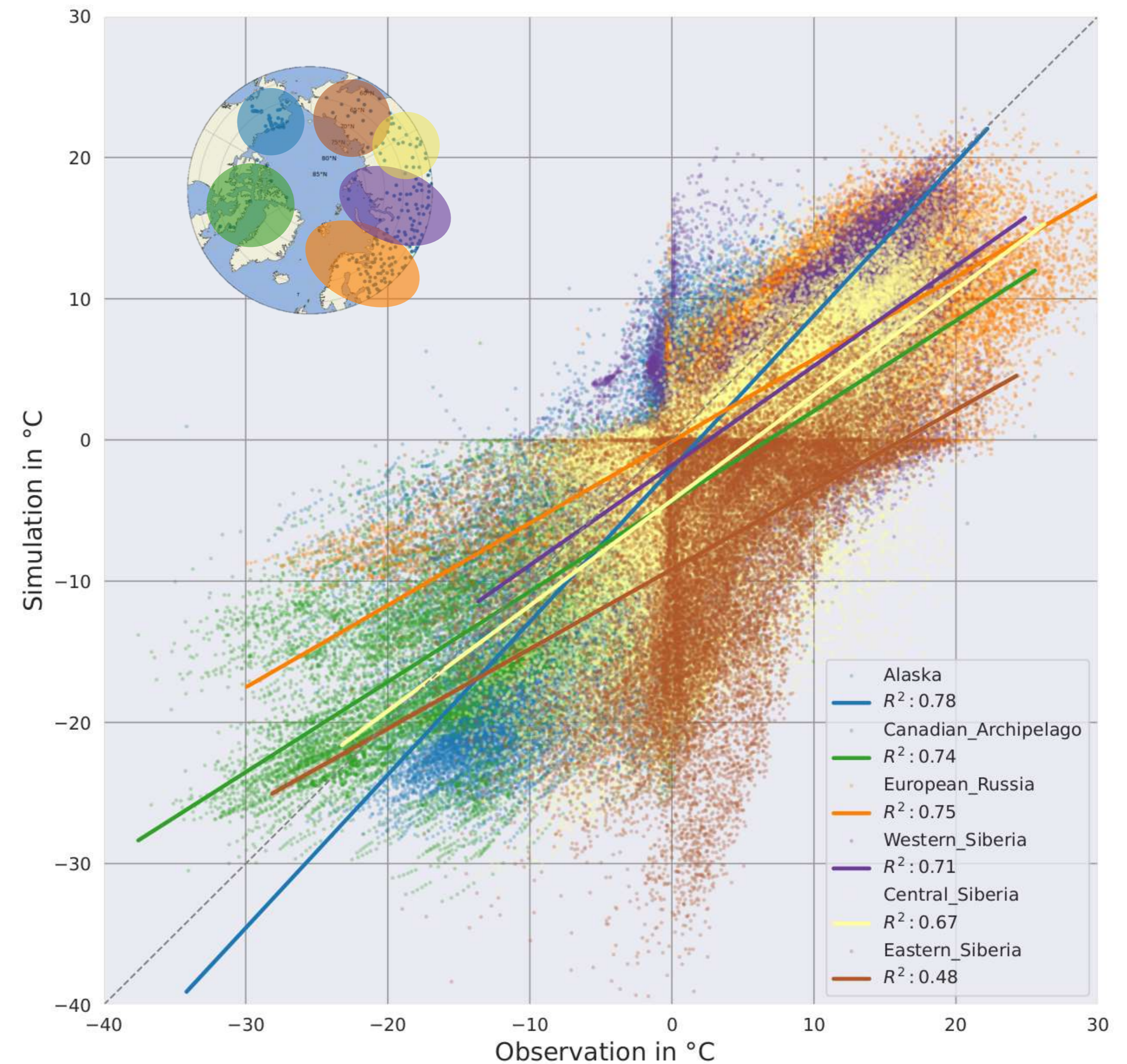


a cube consists of 1 million smaller cubes
containing observations data
by Dall-E



Soil temperature difference CTSM – In-situ Region clustering

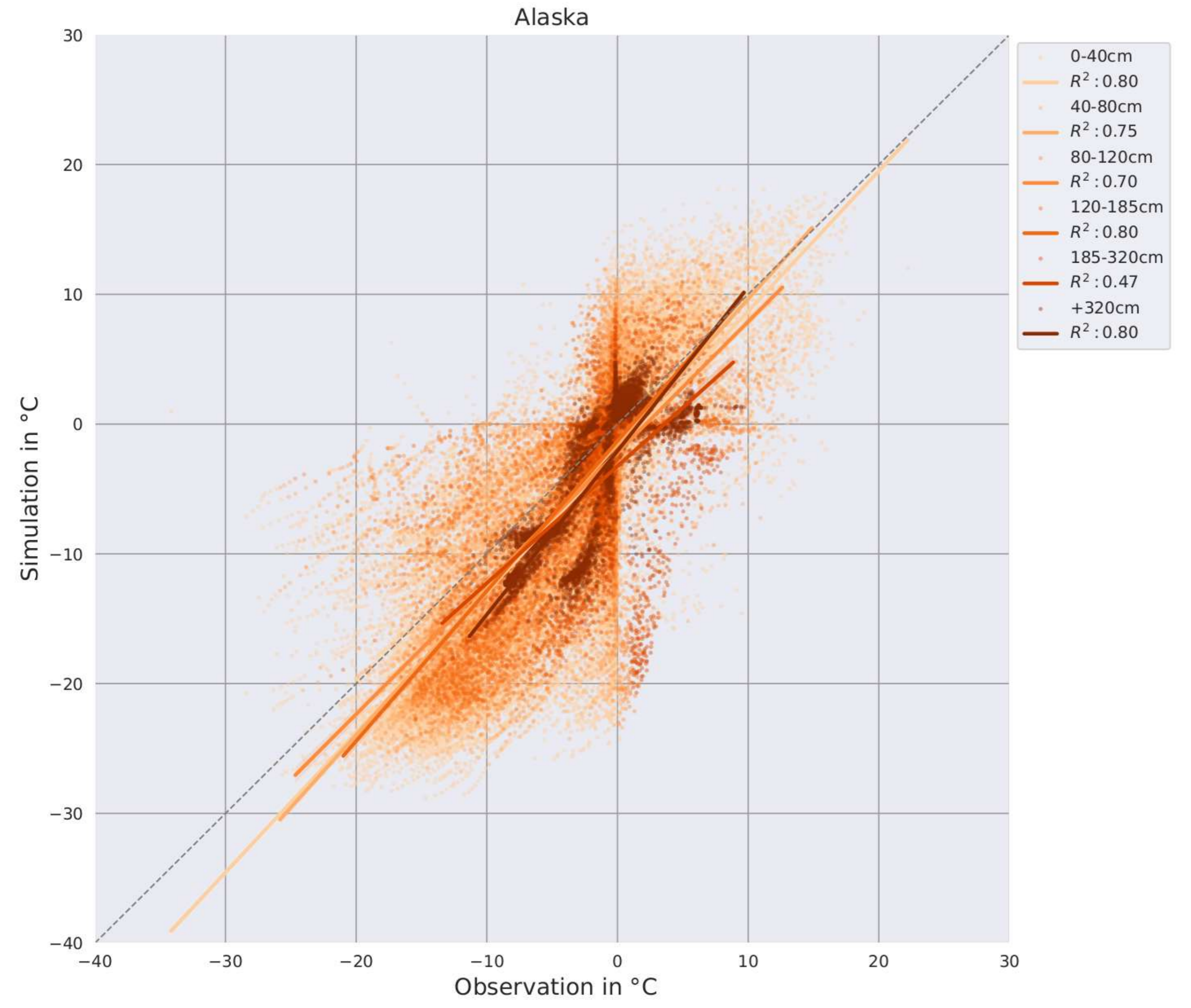
- R^2 highly dependent on regions
- Linear gradient from west with high coefficient to east with low coefficient



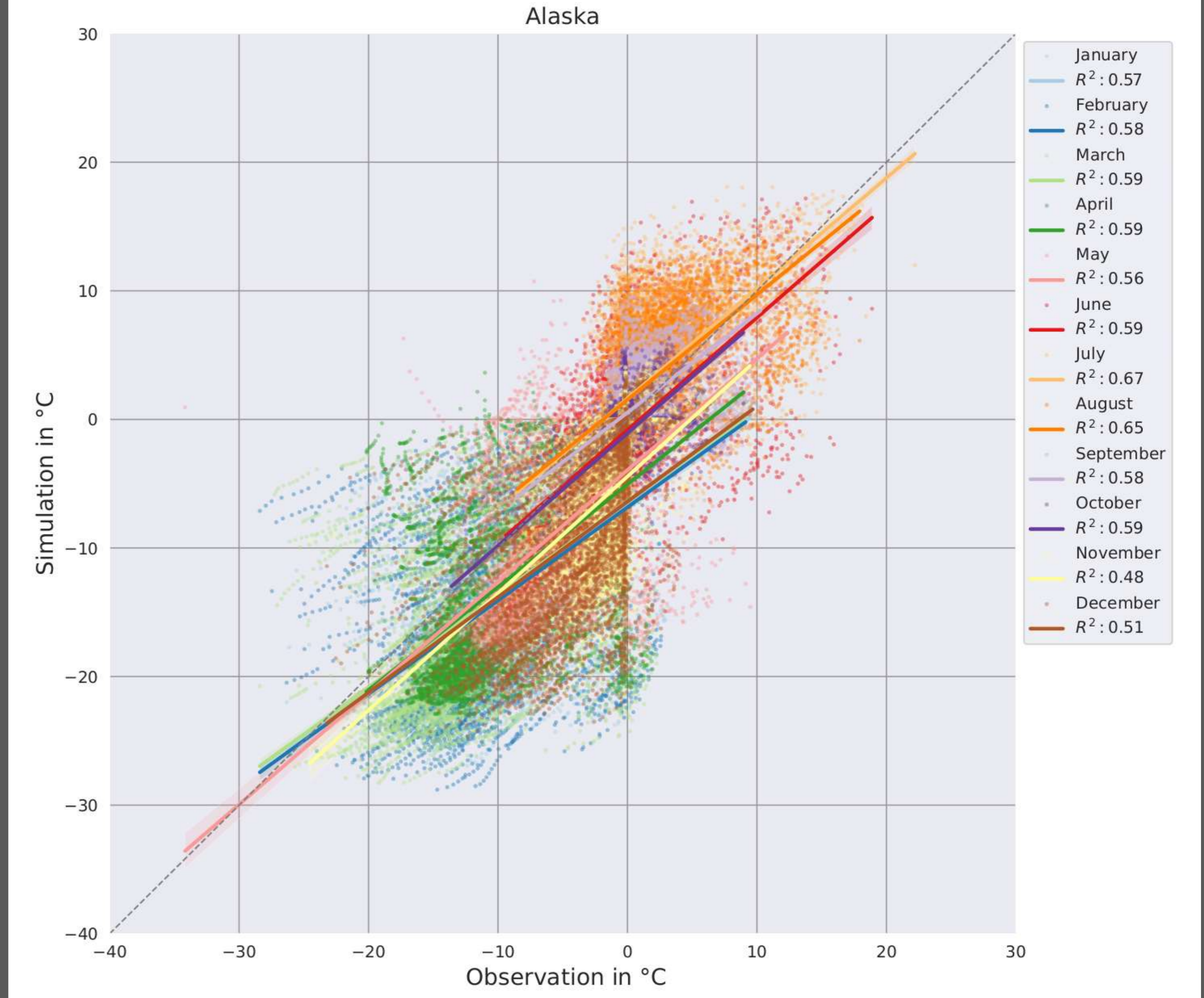
Soil temperature difference only for Alaska



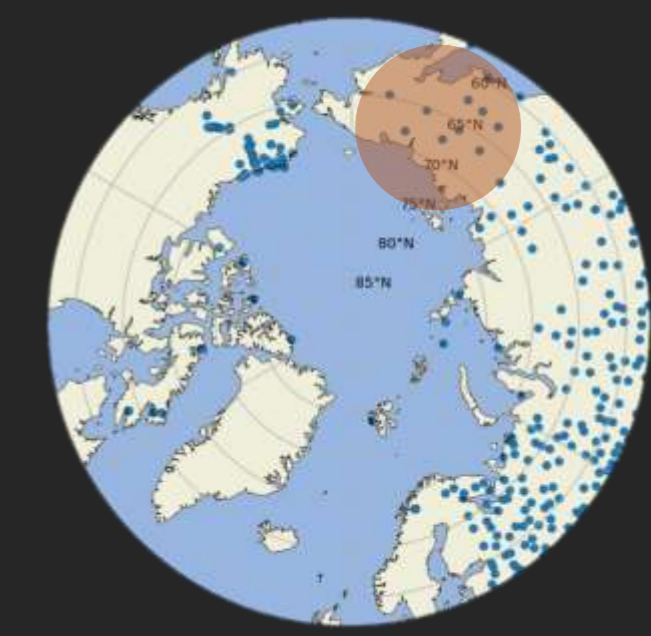
Depth clustering



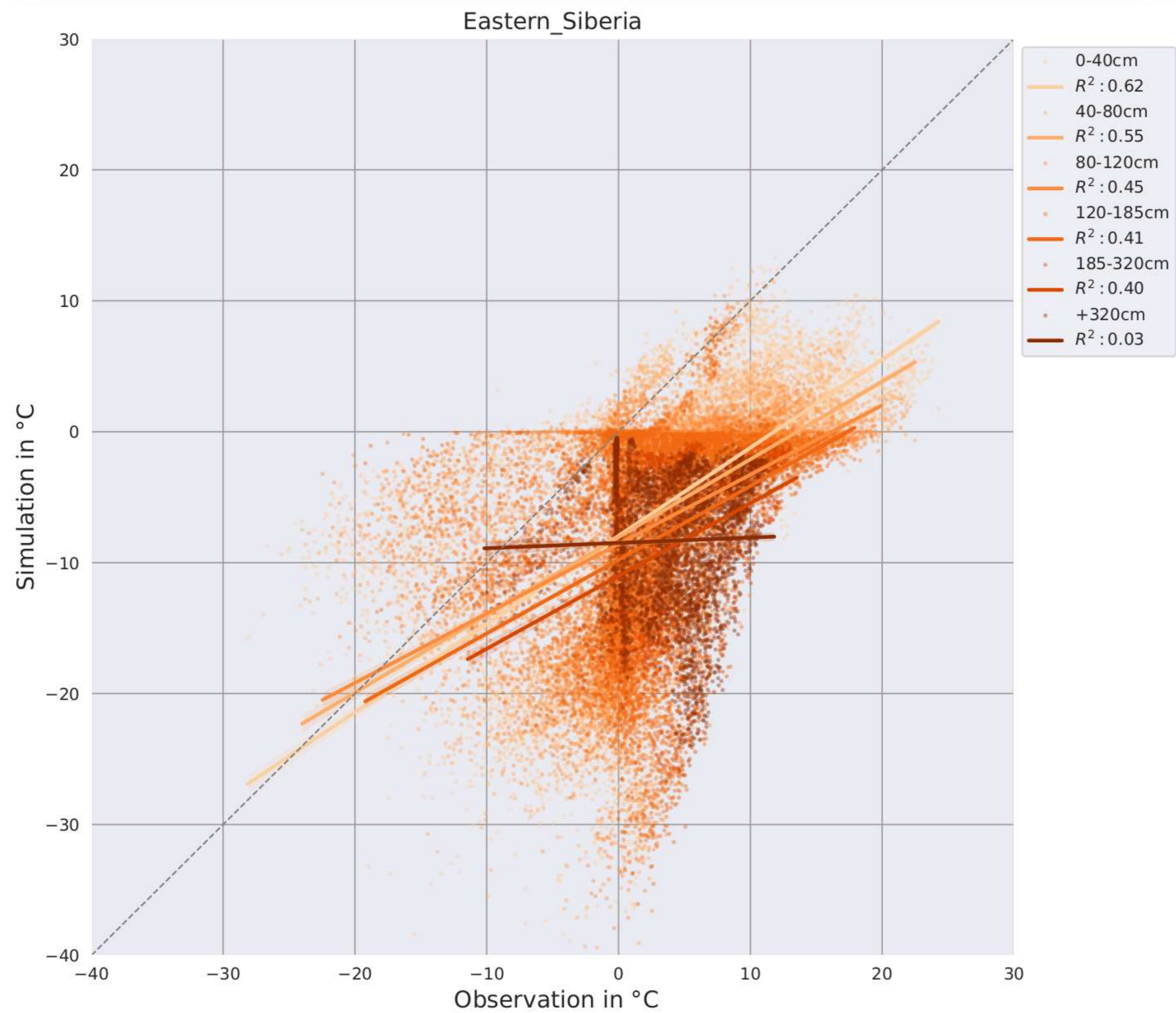
Month clustering



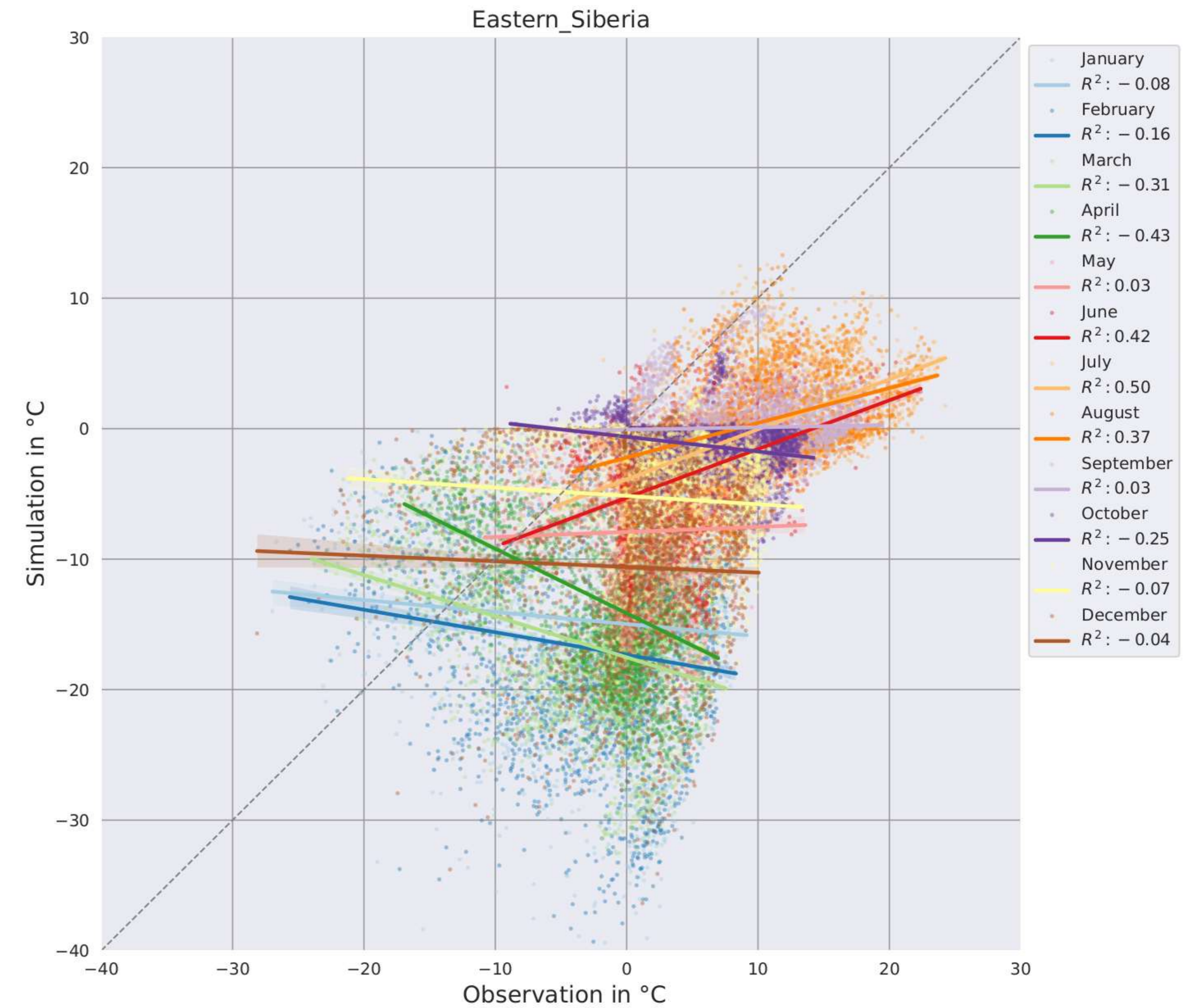
Soil temperature difference only for Eastern Siberia



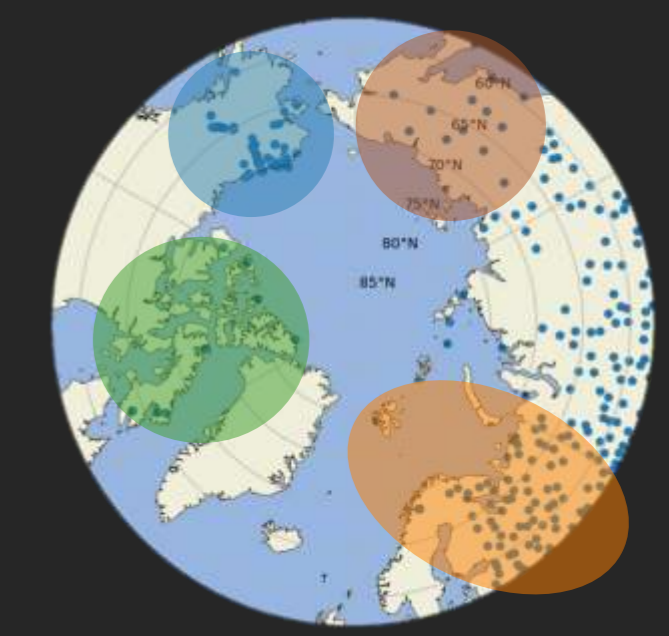
Depth clustering



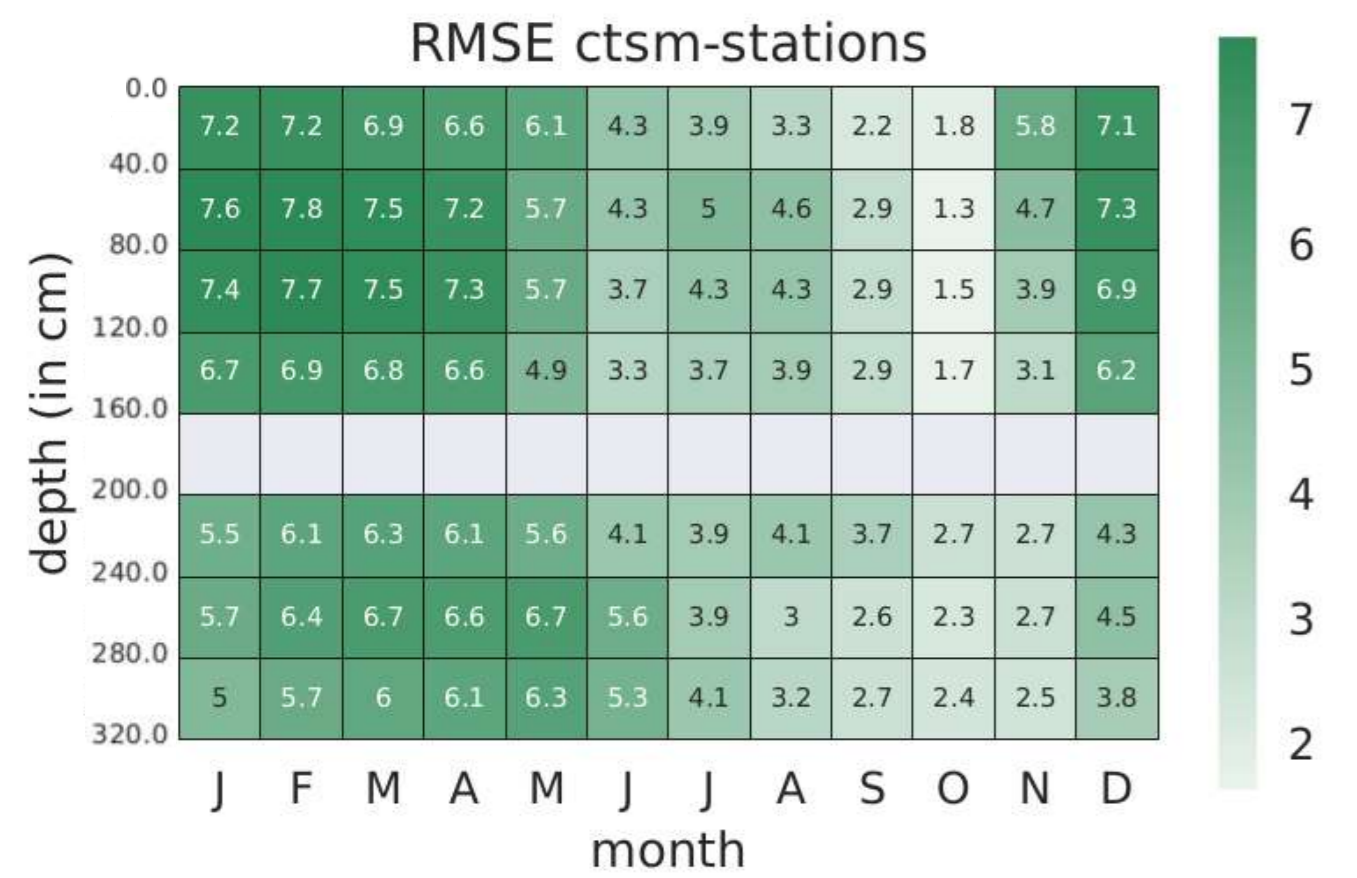
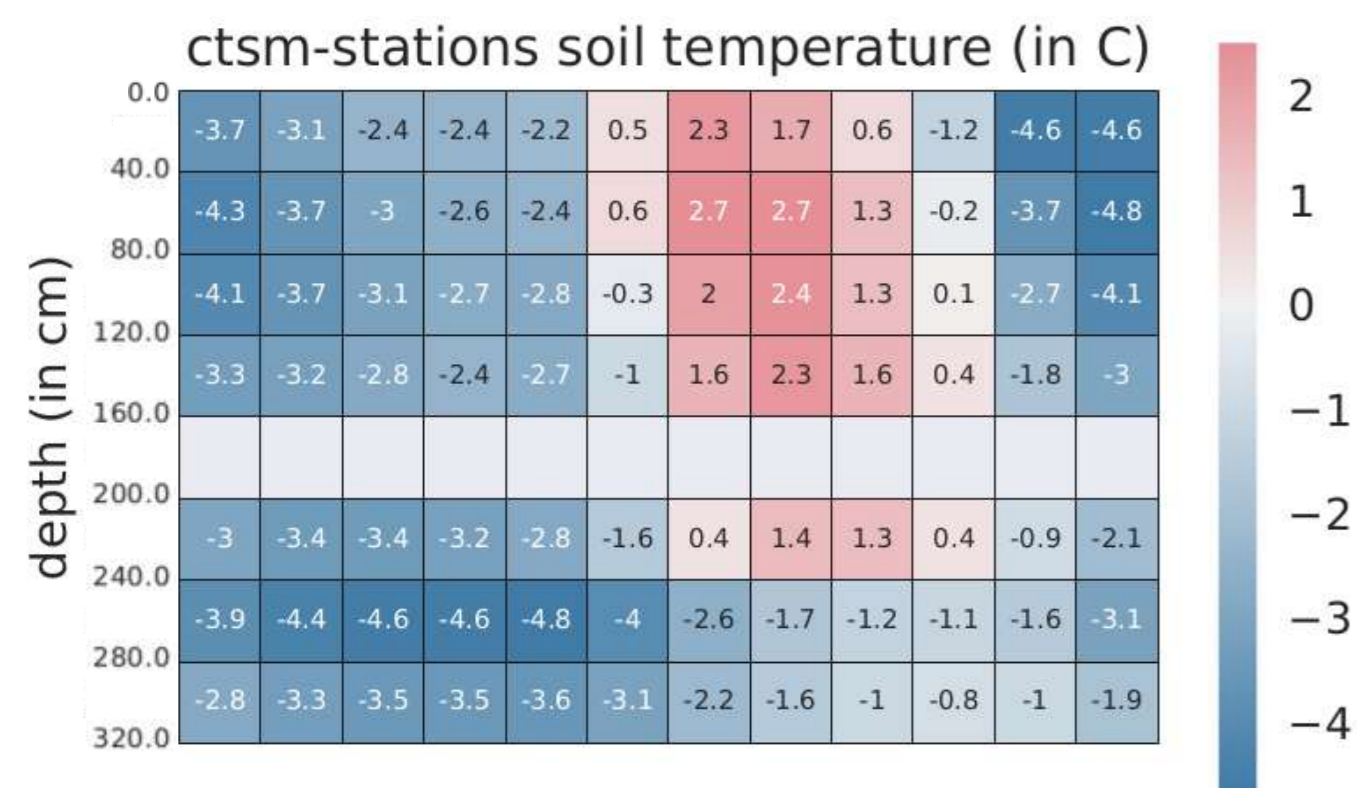
Month clustering



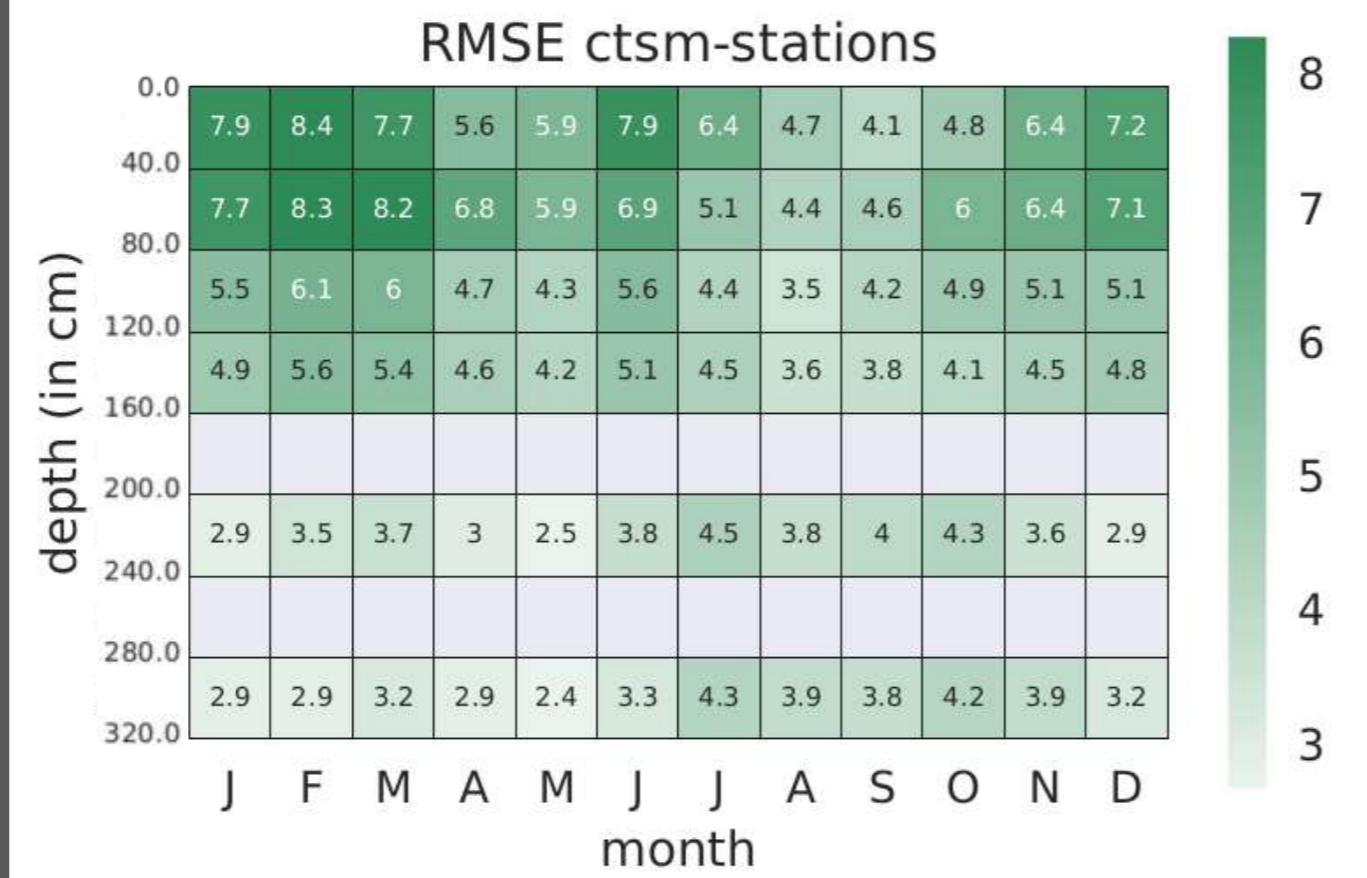
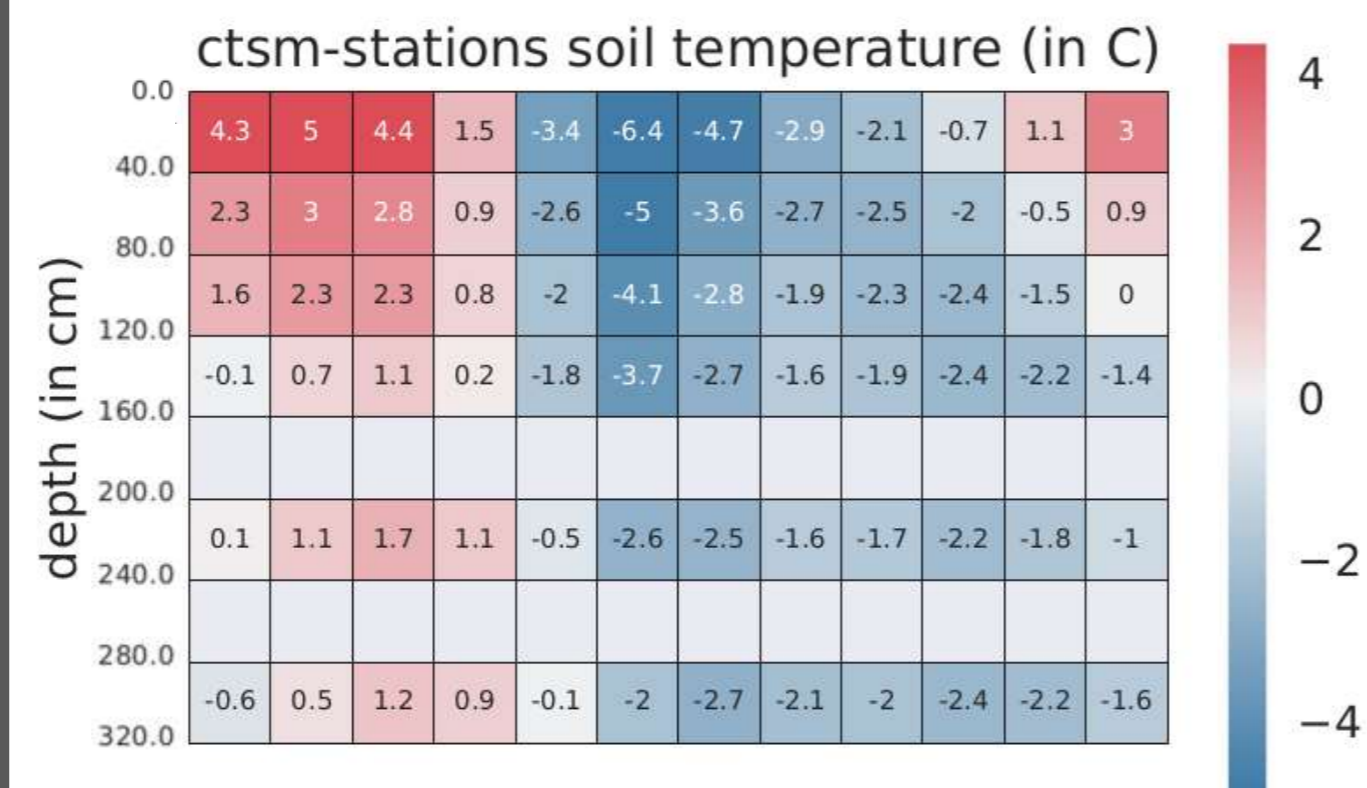
Heatmap of soil temperature difference CTSM – In-situ



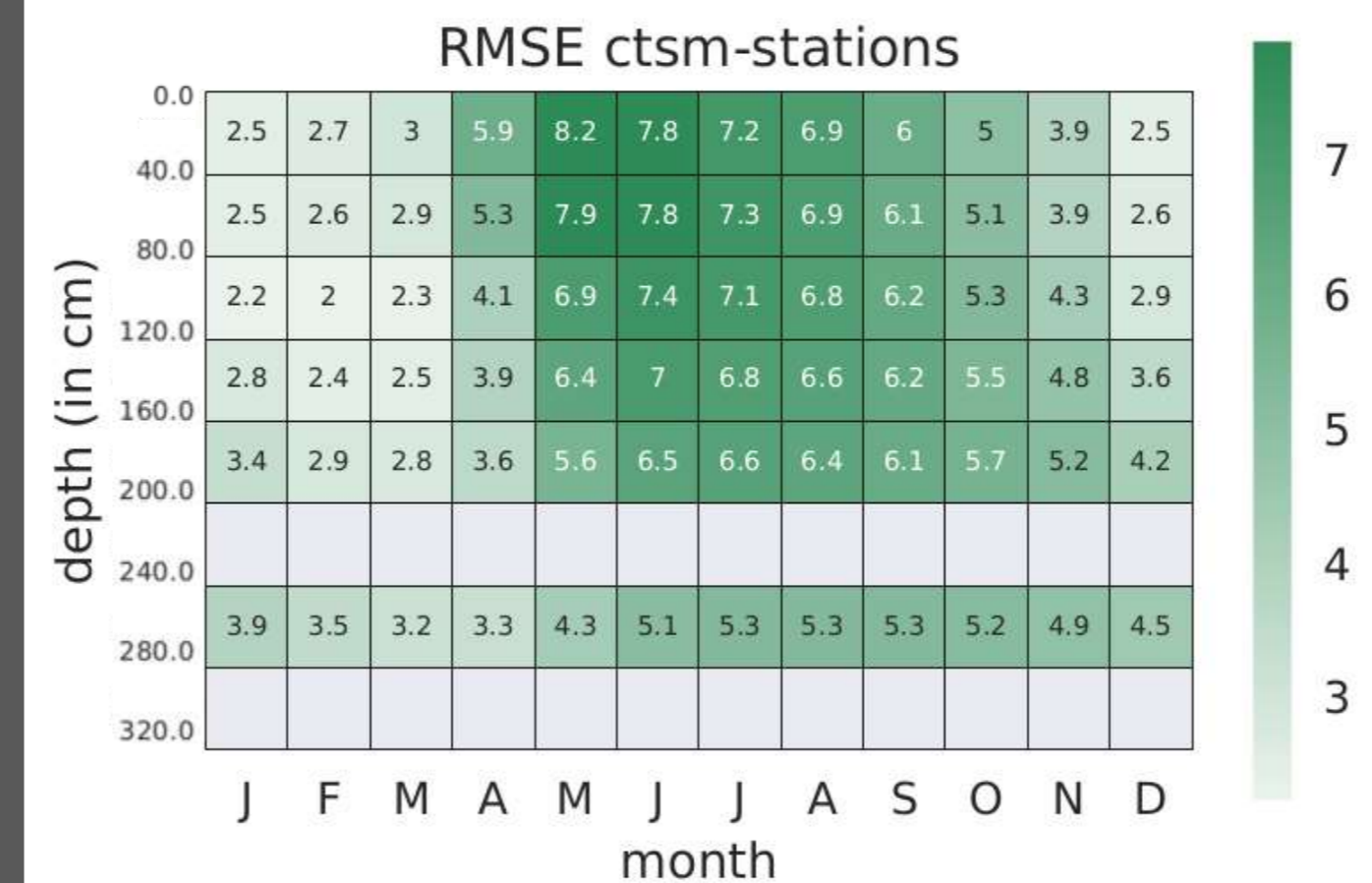
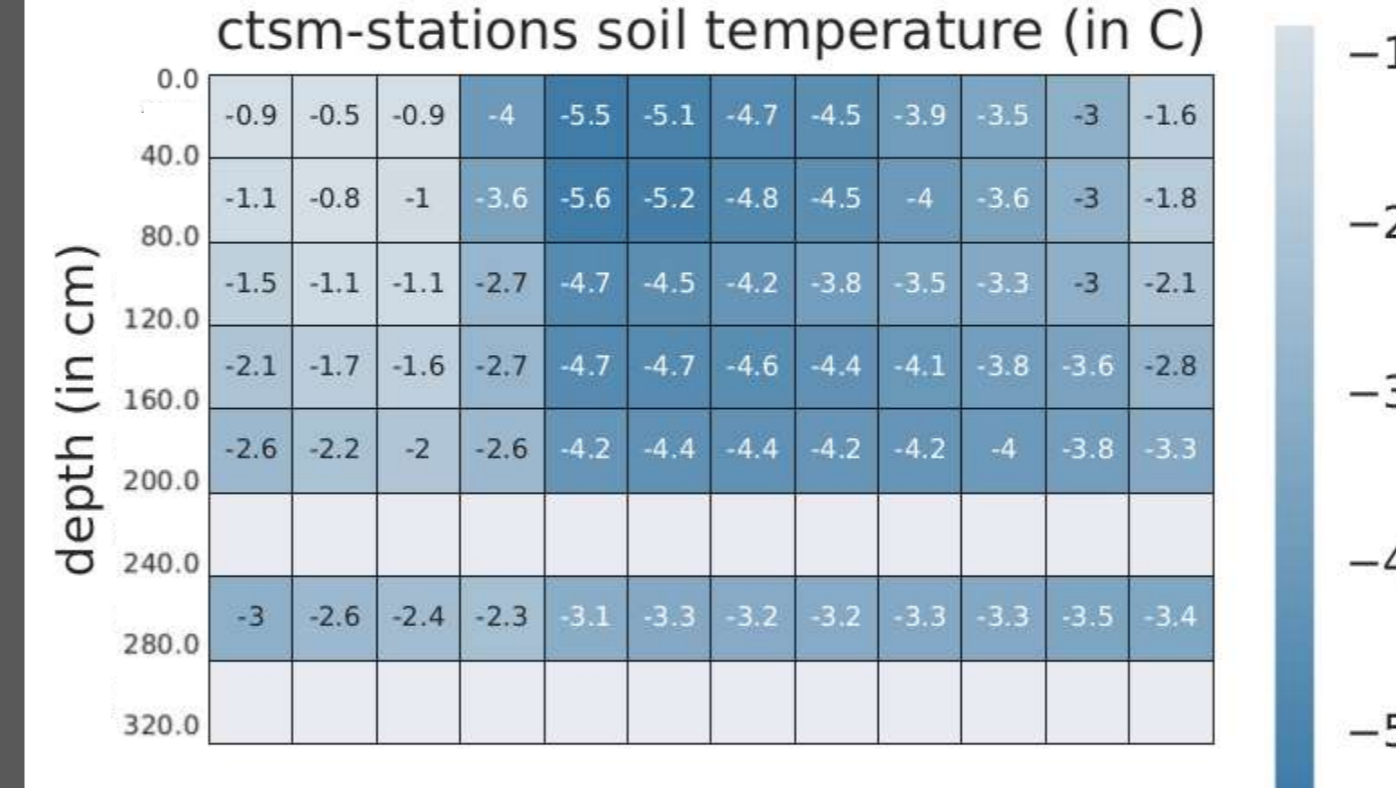
Alaska



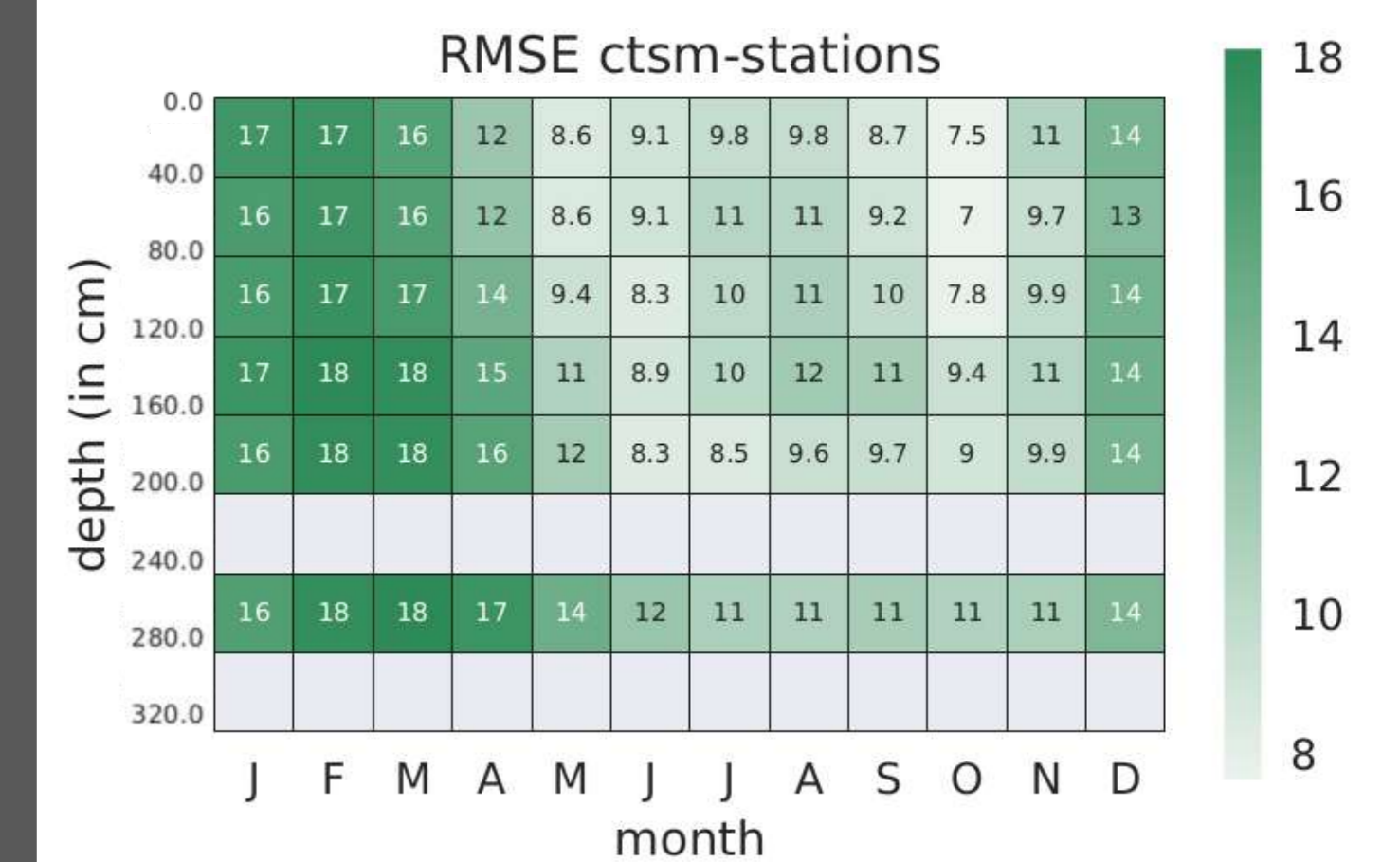
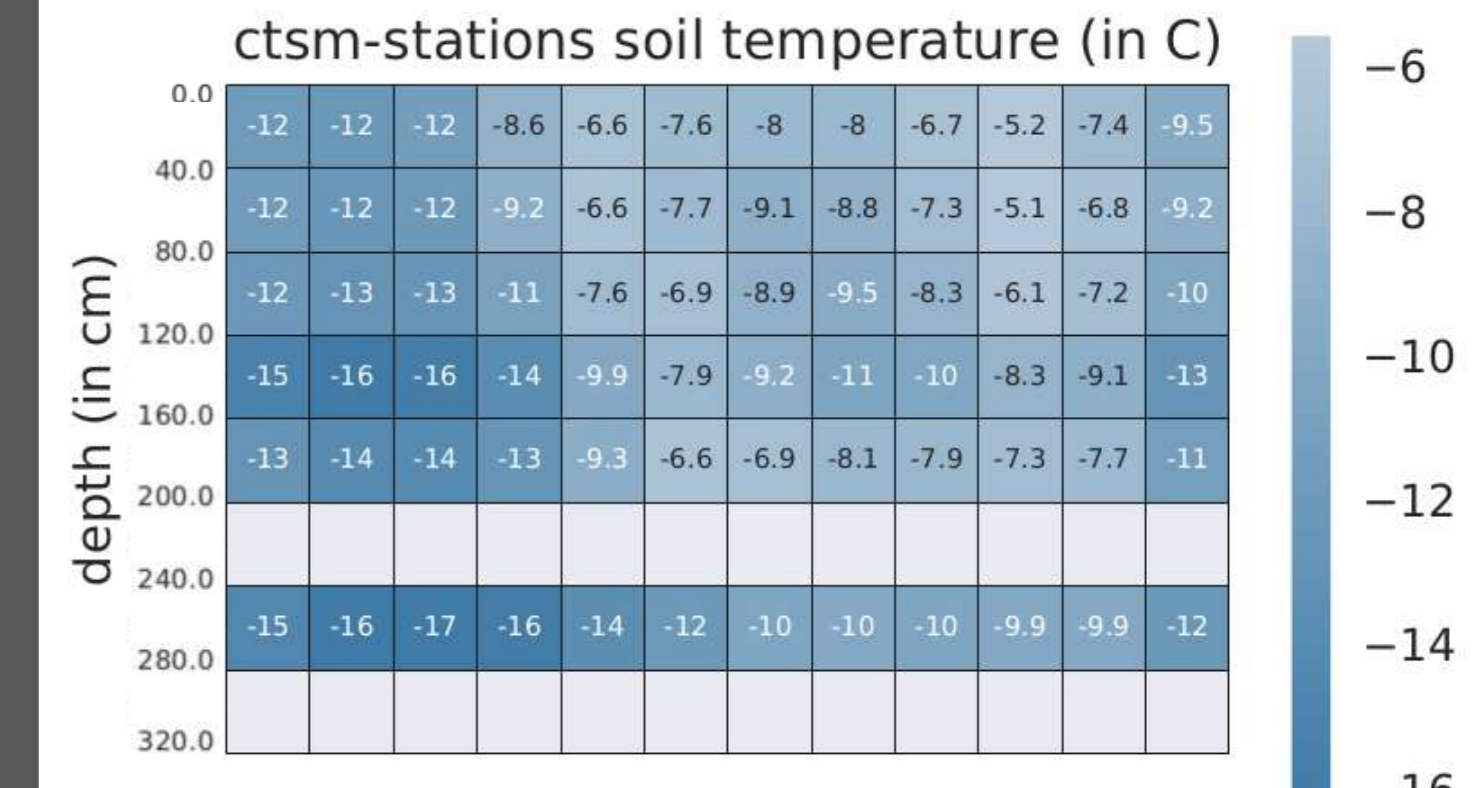
Canada



European Russia



Eastern Siberia



Main observations

Why?

ESACCI

- Permafrost extent in strong agreement with ESACCI (slight overestimation) -> **model too cold over Siberia**
- Active Layer Thickness exaggerated over warm permafrost -> **why?**
- Strong cold temperature difference globally, especially over Siberia

CALM

- Same conclusions as ESACCI

In-situ stations

- 0.80-0.40 R^2 depending on regions
- Colder in Europe, worst in the east -> **water content, snow representation, parametrization in Siberia is not adapted?**
- Winter warmer in Canada -> **observed very high snow depth values -> thermal insulation**
- Higher coefficient in top soil layers in east side -> **more dependent on atmospheric forcings?**
- CTSM lacks proper representation of seasonality, leading to a spurious high yearly correlation as months are offsetting each others

Github project:

<https://github.com/AdrienDams/cegio>

AdrienDams / cegio Public

Pin Unwatch 1 Fork 0 Starred 2

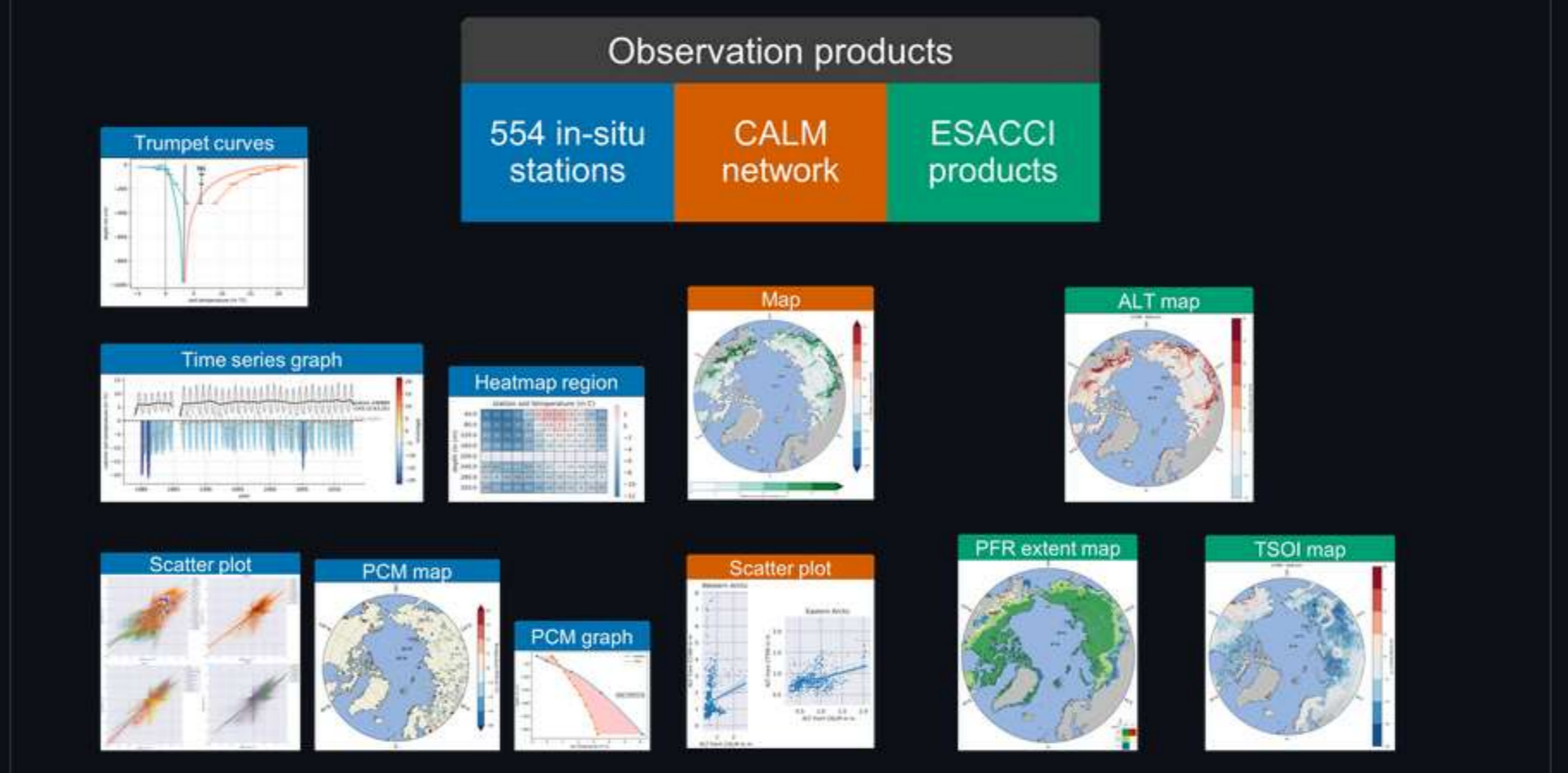
Code Issues Pull requests Actions Projects Wiki Security Insights Settings

main 1 branch 0 tags

Go to file Add file Code

AdrienDams	change grouping from sorting to masking, big clustering from months t...	fa61a83 now	144 commits
evaluation	change grouping from sorting to masking, big clustering from months t...		now
postproc	remove empty lines		2 days ago
README.md	Add diagram		7 minutes ago

README.md



Requirements

- Daily files from CTSM (minimum 3 years period)
- ESACCI and in-situ observation files (available by request at adamseau@awi.de)
- python3 (numpy, pandas, scipy, matplotlib, seaborn, netCDF4, similaritymeasures, cartopy libraries)
- cdo (minimum 2.0.3)
- nco (minimum 5.0.6)
- bash shell
- sbatch

Install

About

CTSM Evaluation with Grid based and In-situ based Observations and reanalysis products on an arctic domain

python evaluation land-surface-model

Readme 2 stars 1 watching 0 forks

Languages

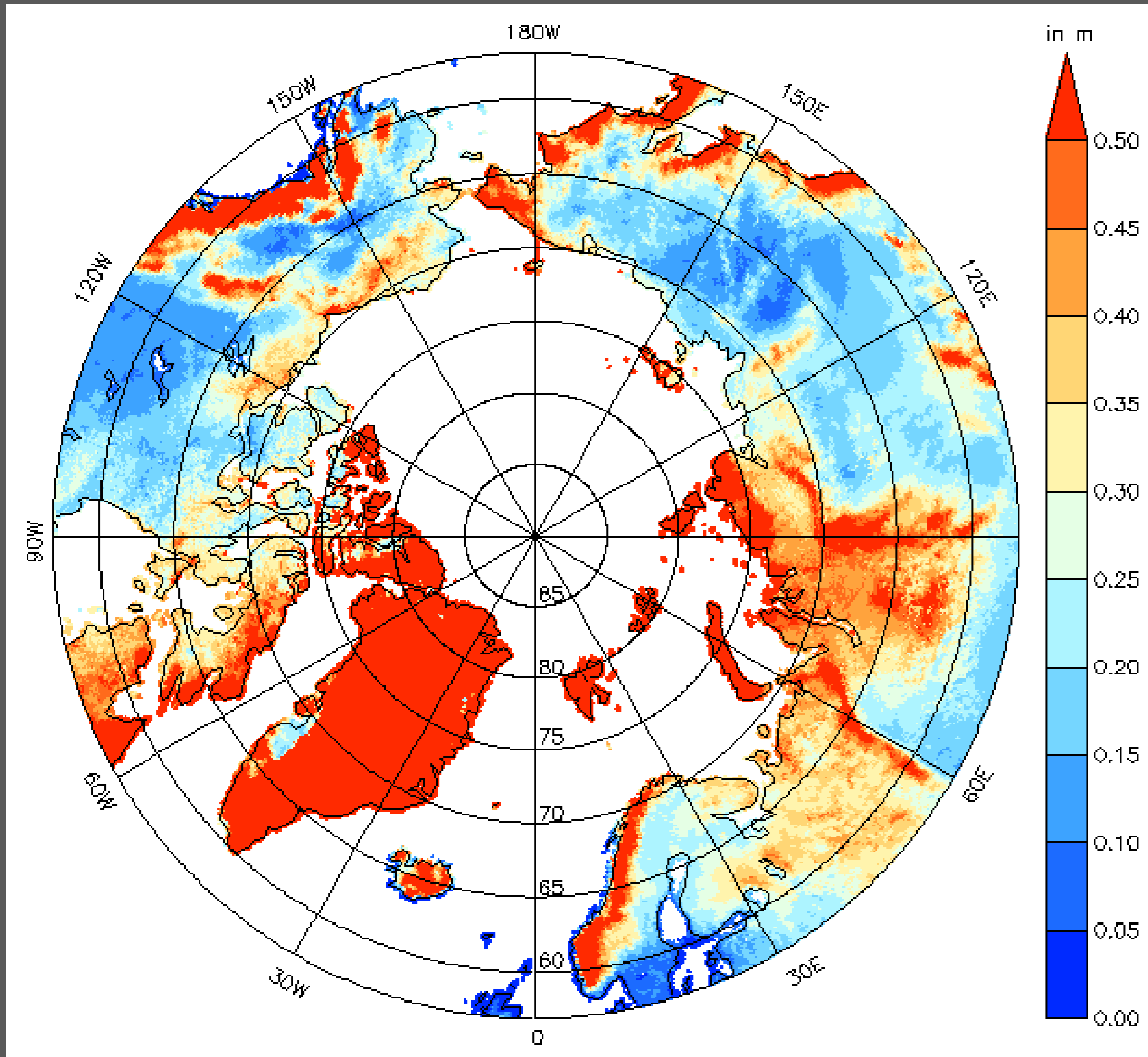


Additional slides

Default snow parameters

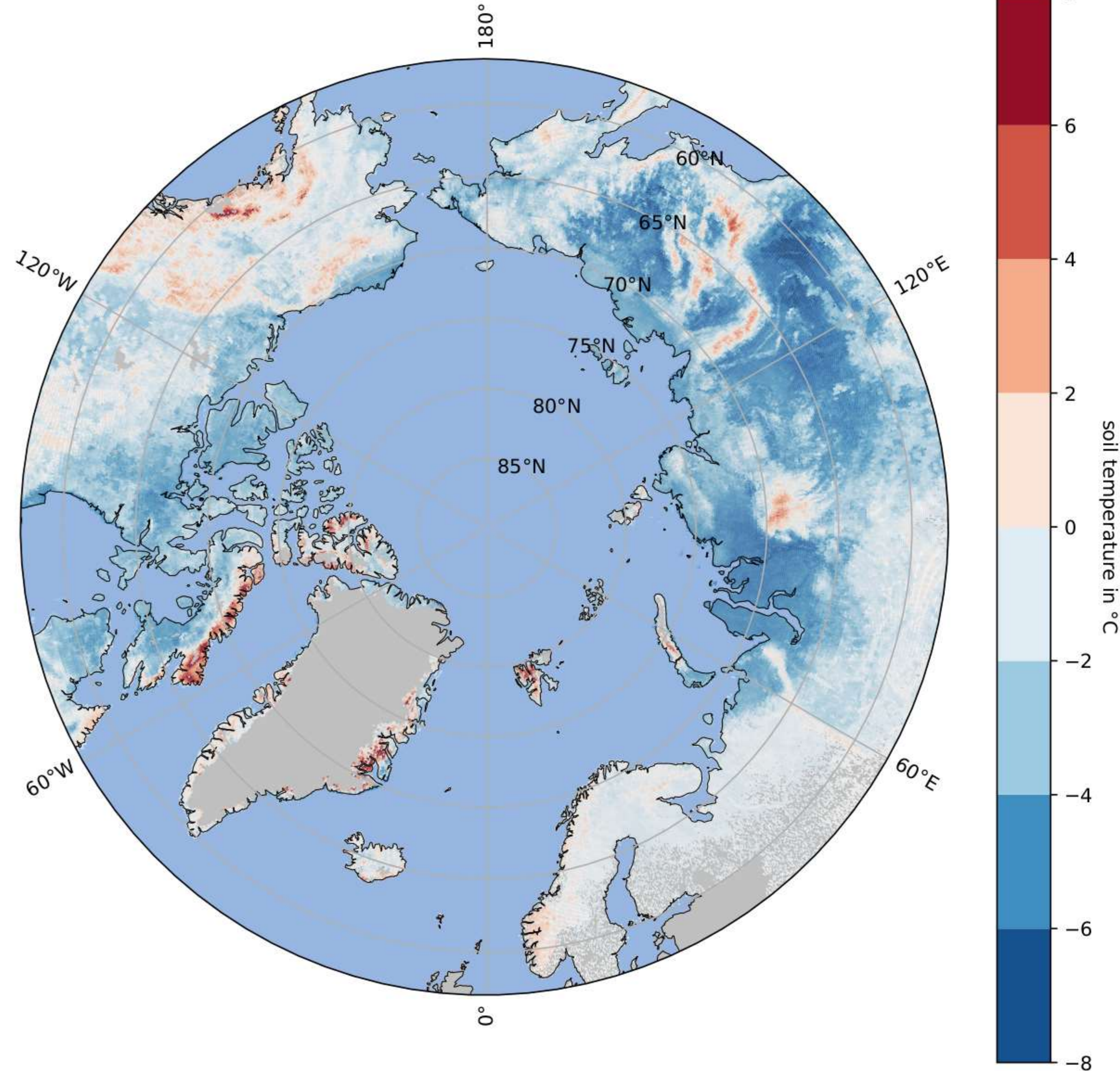
Reset_snow = false
h2osno_max = 10 m

Snow depth average



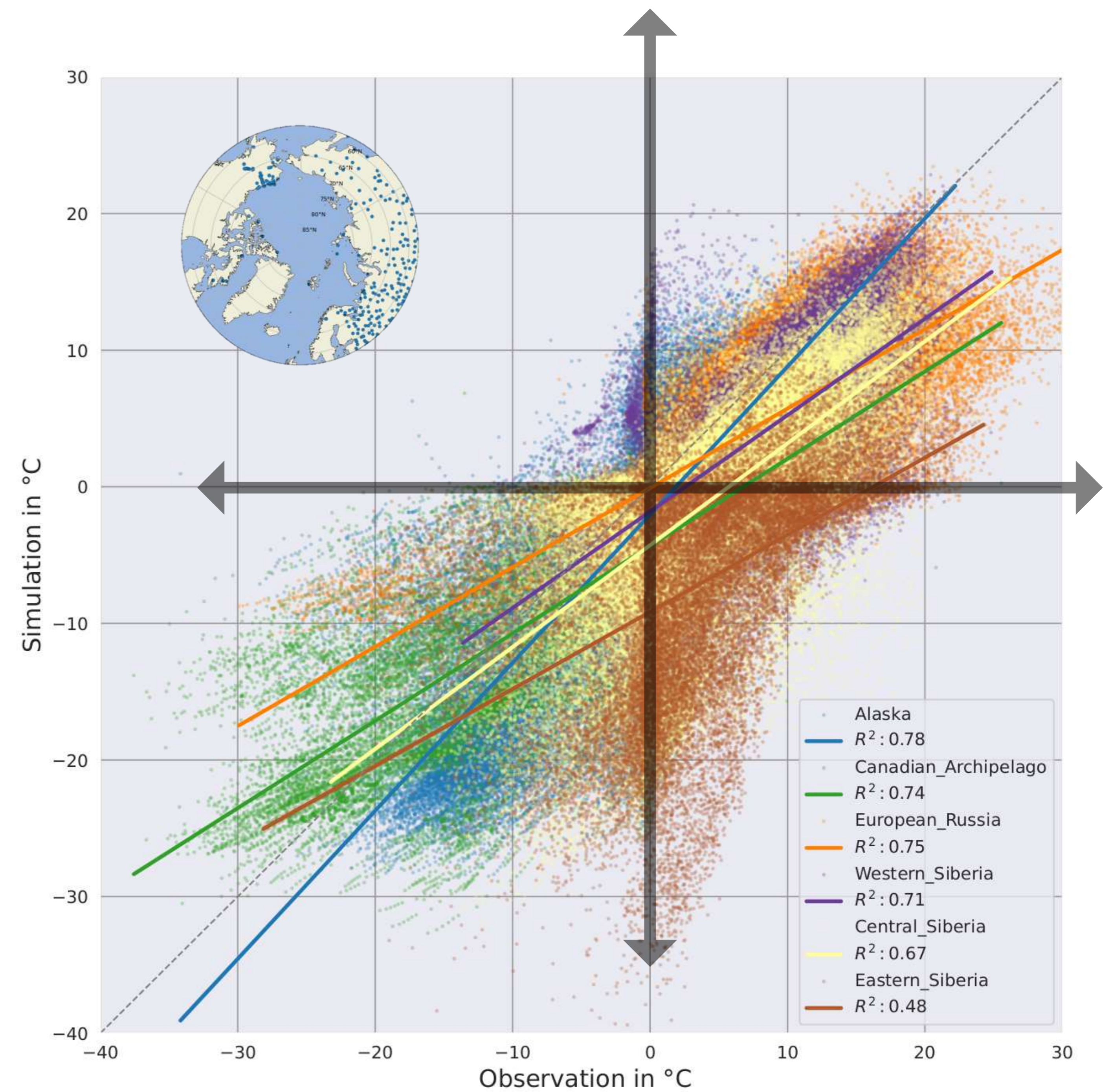
Adjusted snow parameters

CTSM - ESA-CCI (GAA = 2.52 , RMSE = 3.07)



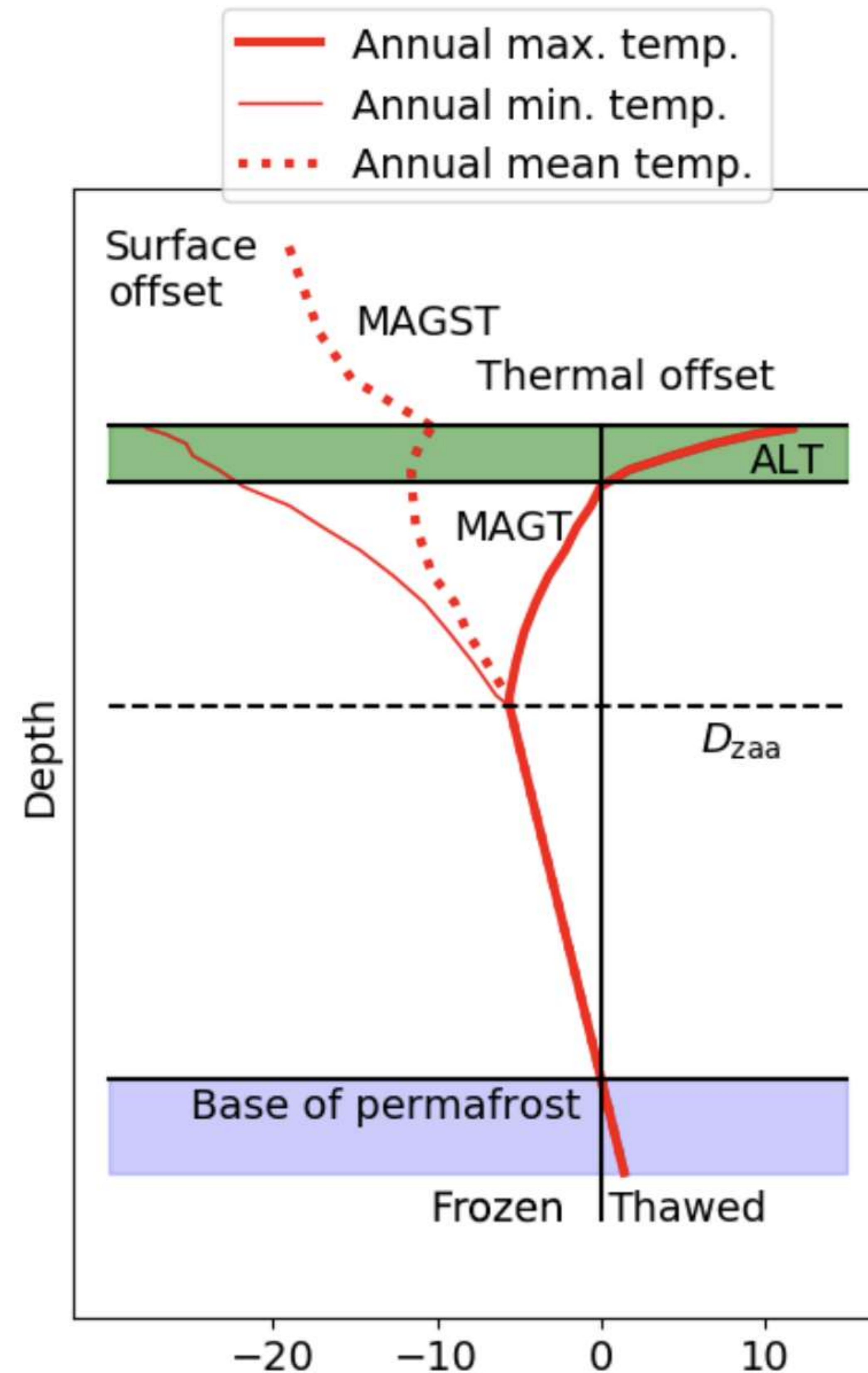
Cross anomaly?

- Explained by the thawing and freezing timing mismatch during phase transition



What's the Active Layer?

- The soil layer which thaws during the summer
- High decomposition of organic carbon
- Release of methane and other GHGs

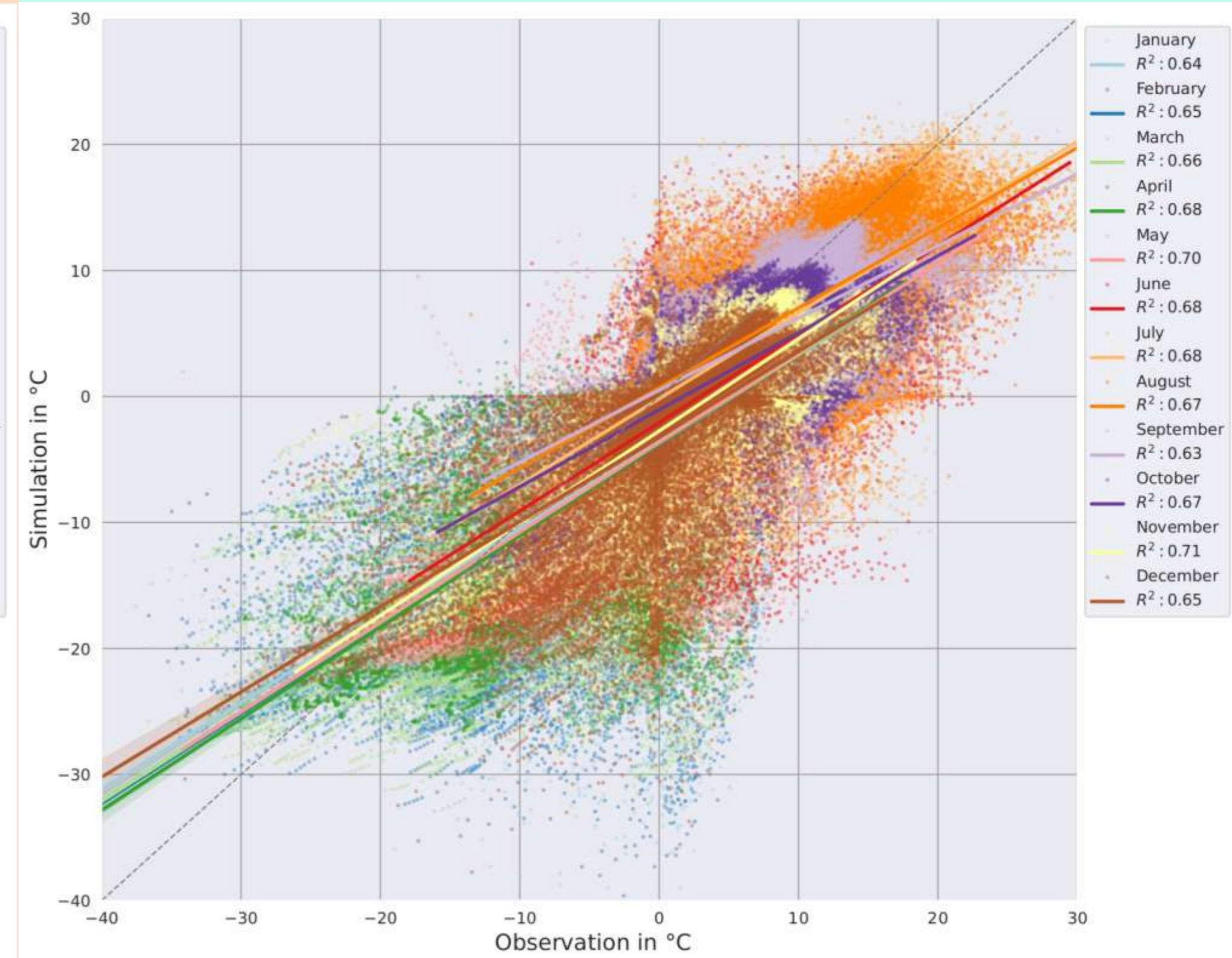
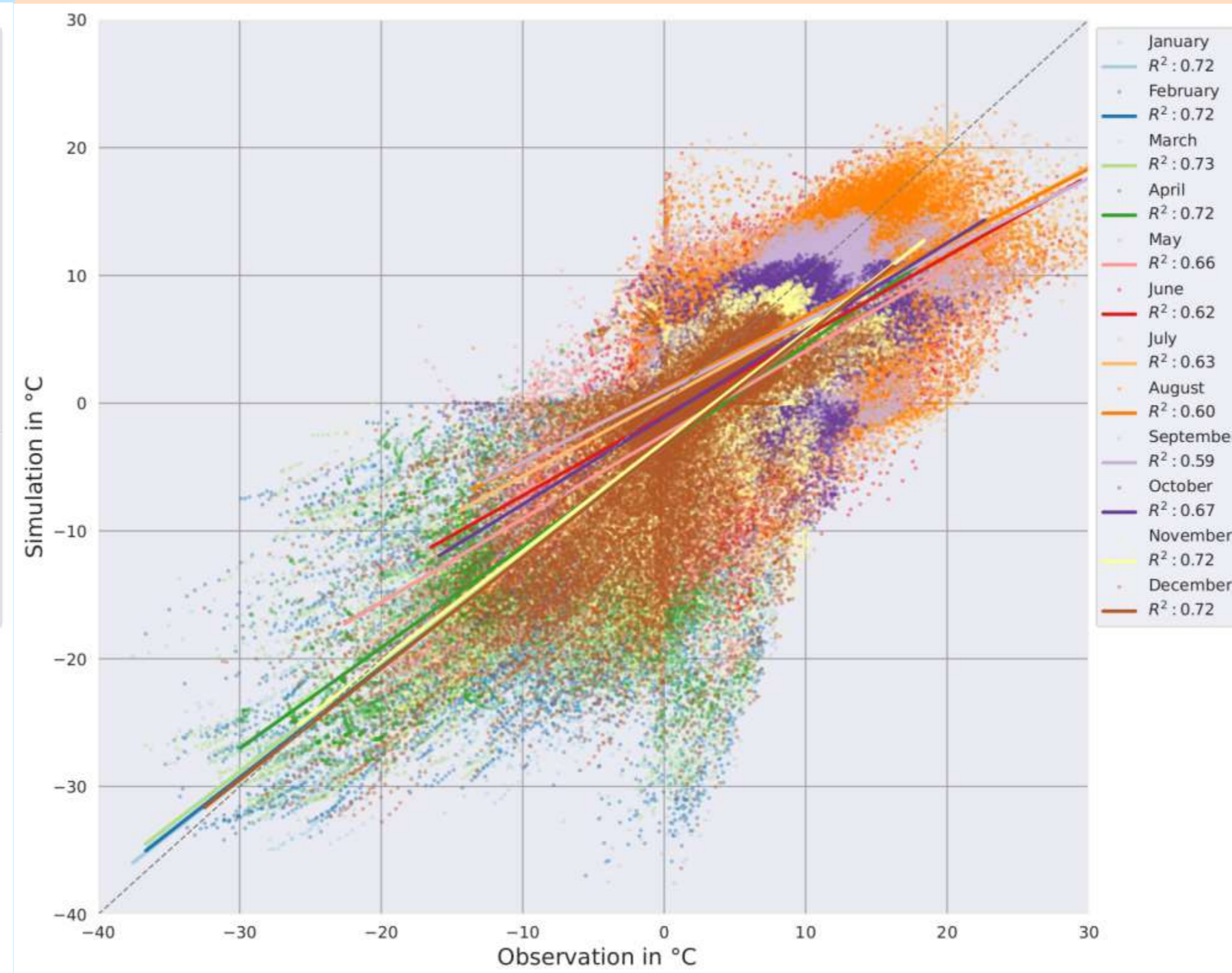
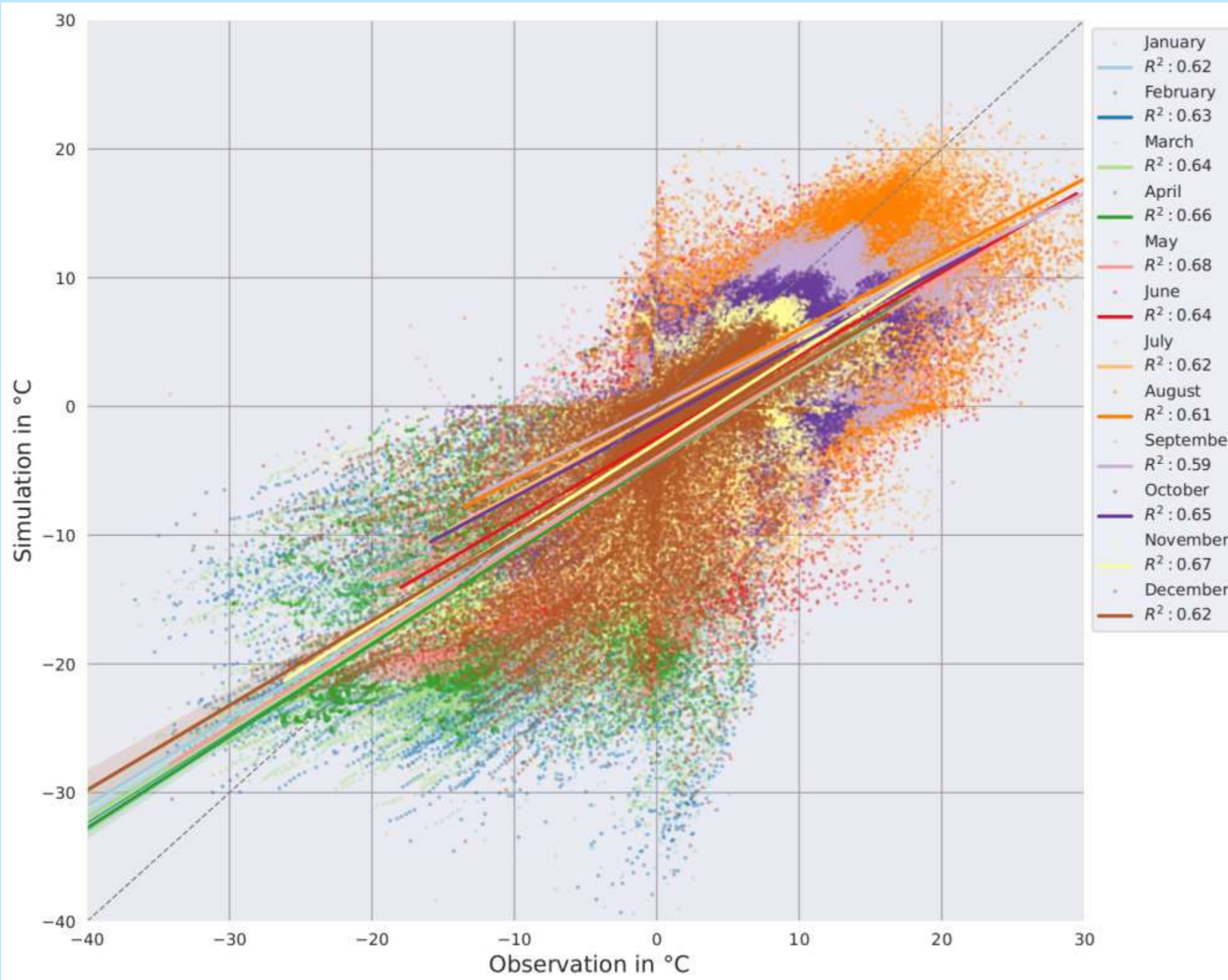


Run 001
ERA5
Default soil
1980-2021

Run 002
GSWP3
Default soil
1980-2014

Run 005
ERA5
New soil
1980-2021

Soil temperature bias CTSM vs 274 stations

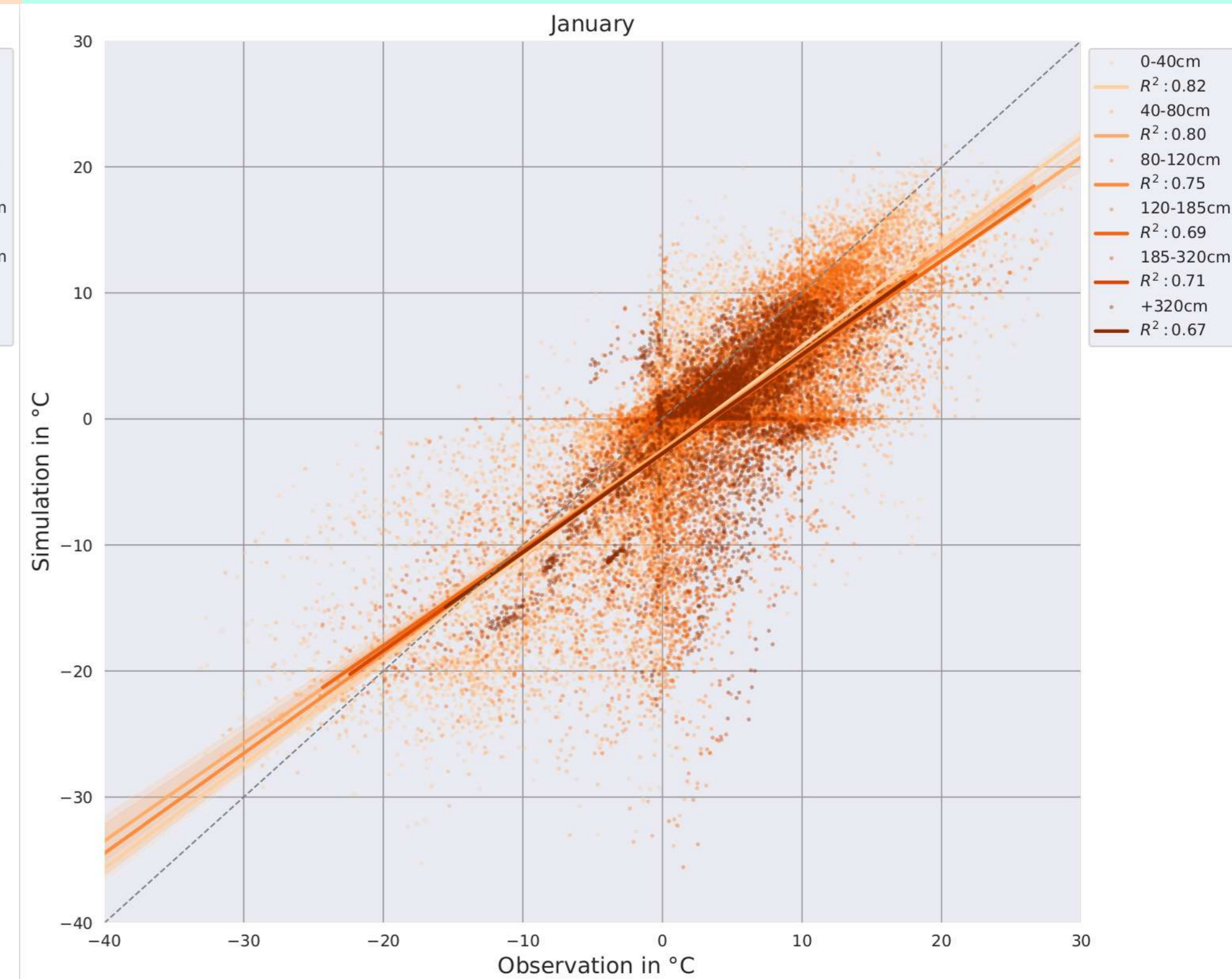
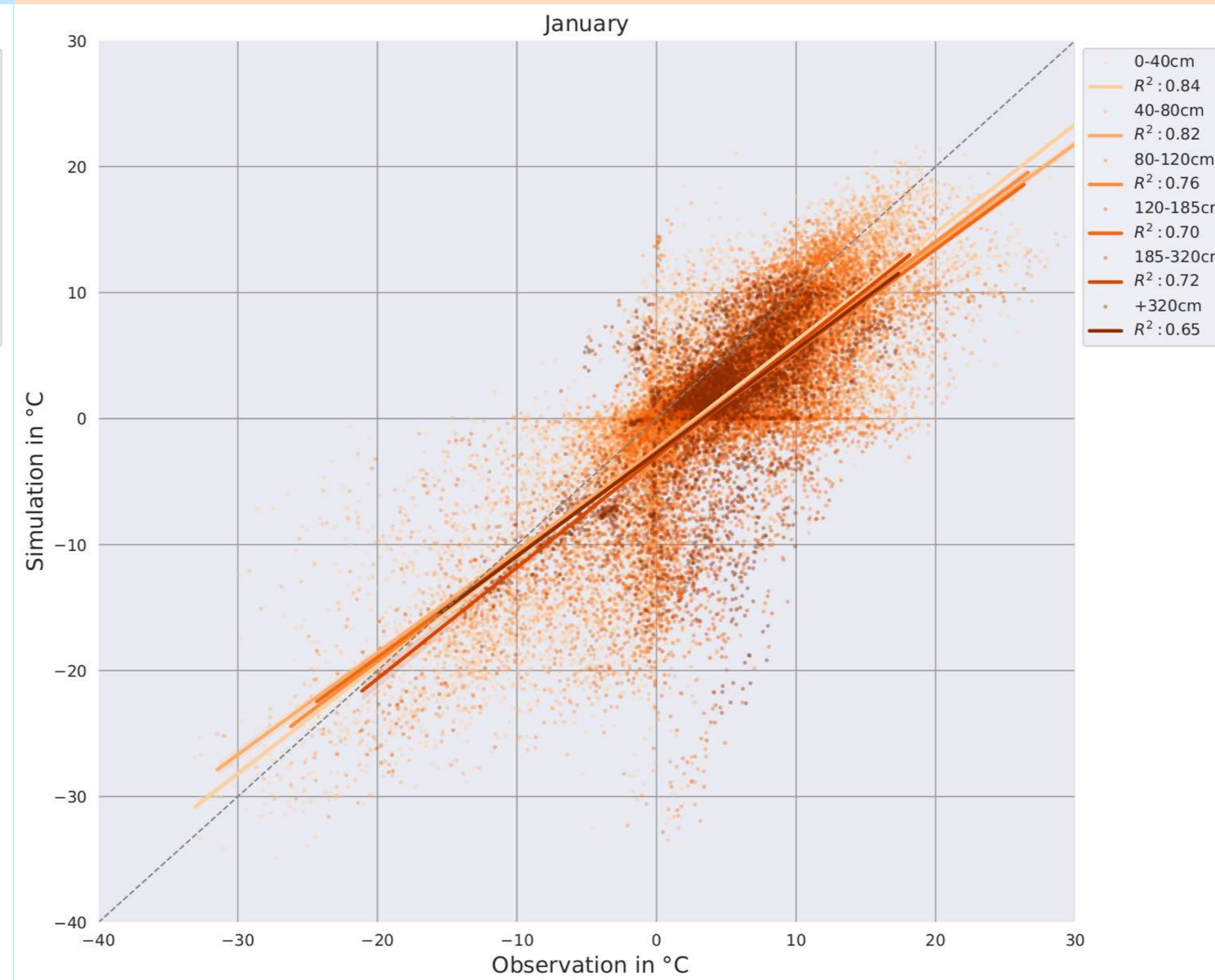
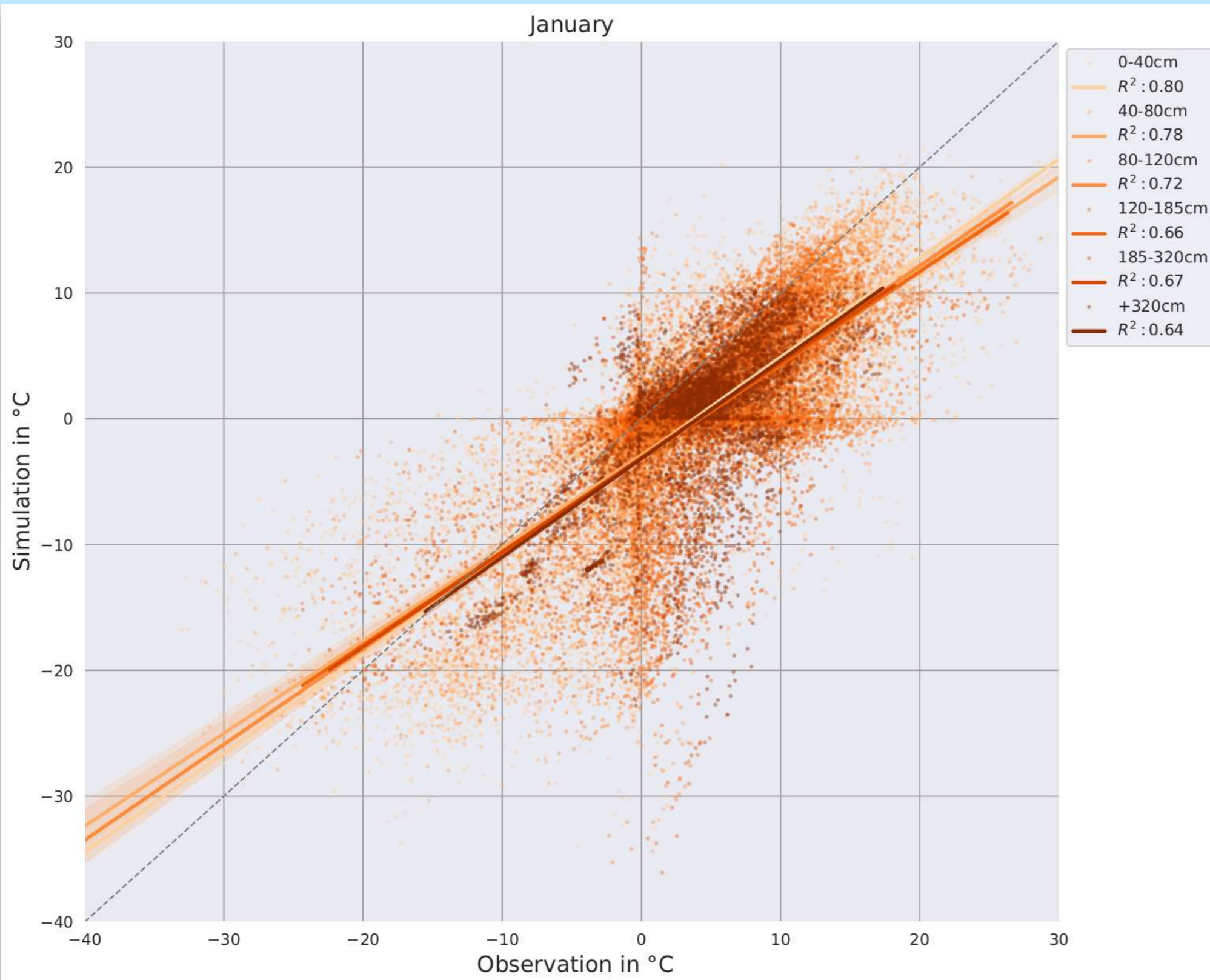


Run 001
ERA5
Default soil
1980-2021

Run 002
GSWP3
Default soil
1980-2014

Run 005
ERA5
New soil
1980-2021

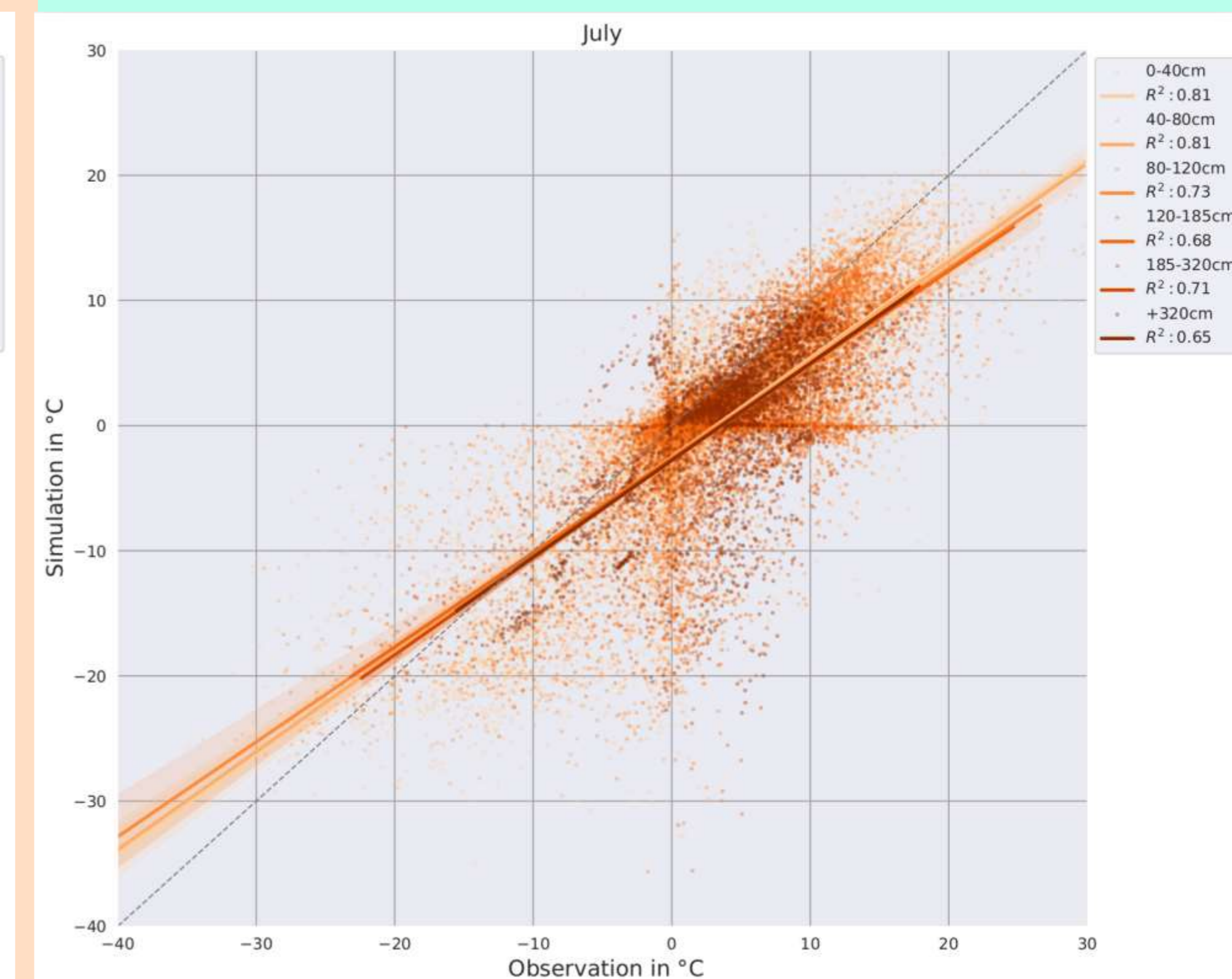
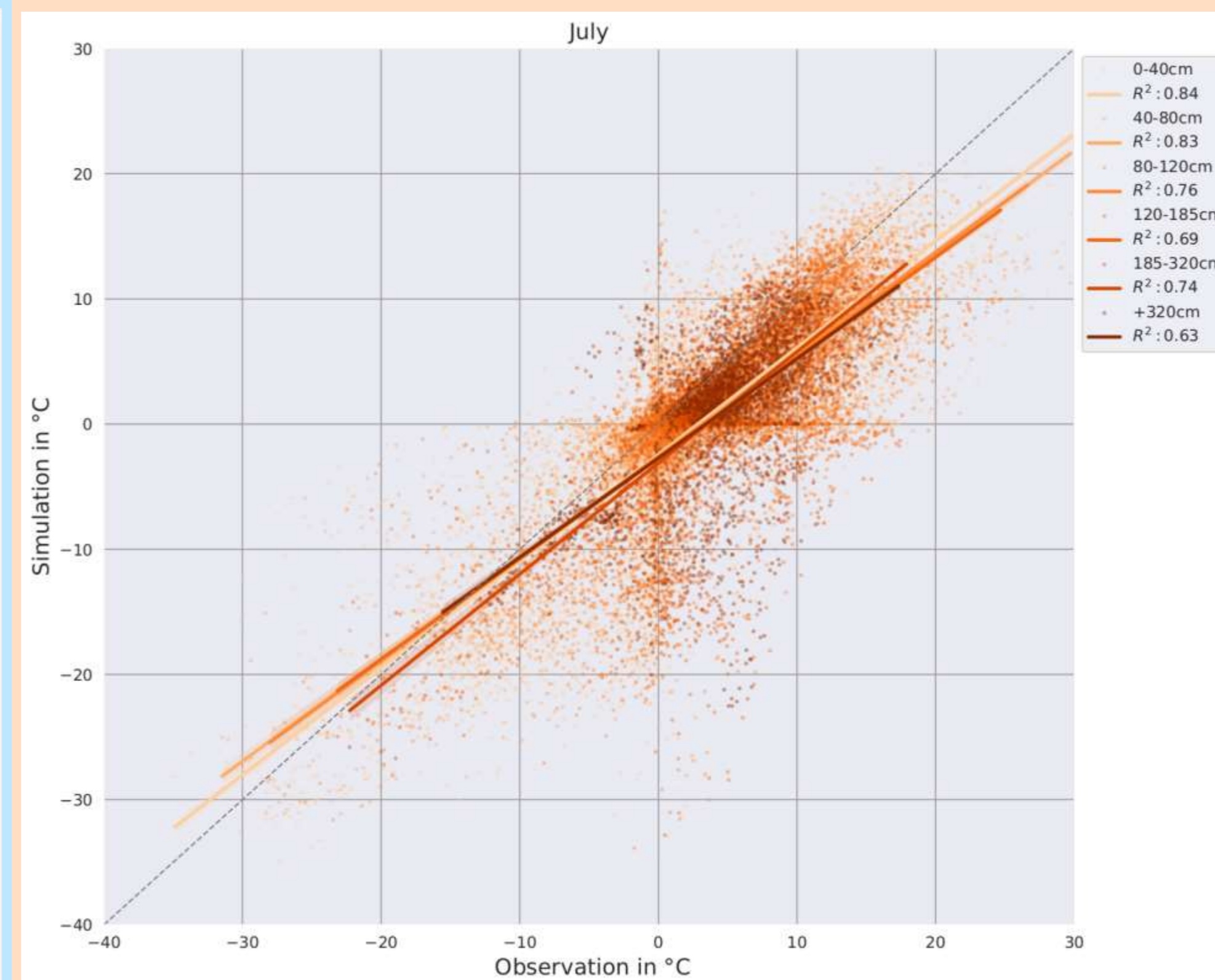
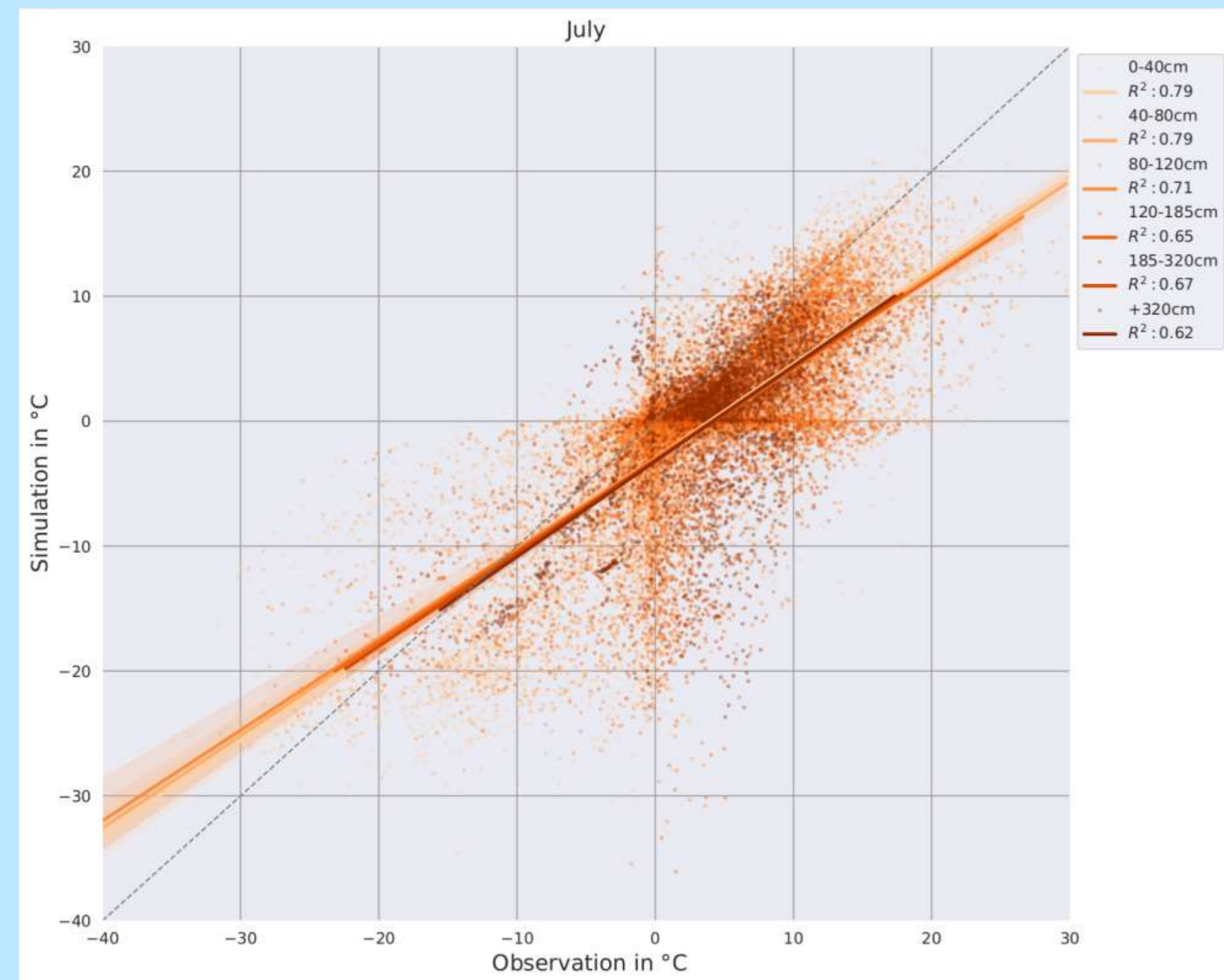
Soil temperature bias CTSM vs 274 stations
in January - Depths clustering



Run 001
ERA5
Default soil
1980-2021

Run 002
GSWP3
Default soil
1980-2014

Run 005
ERA5
New soil
1980-2021

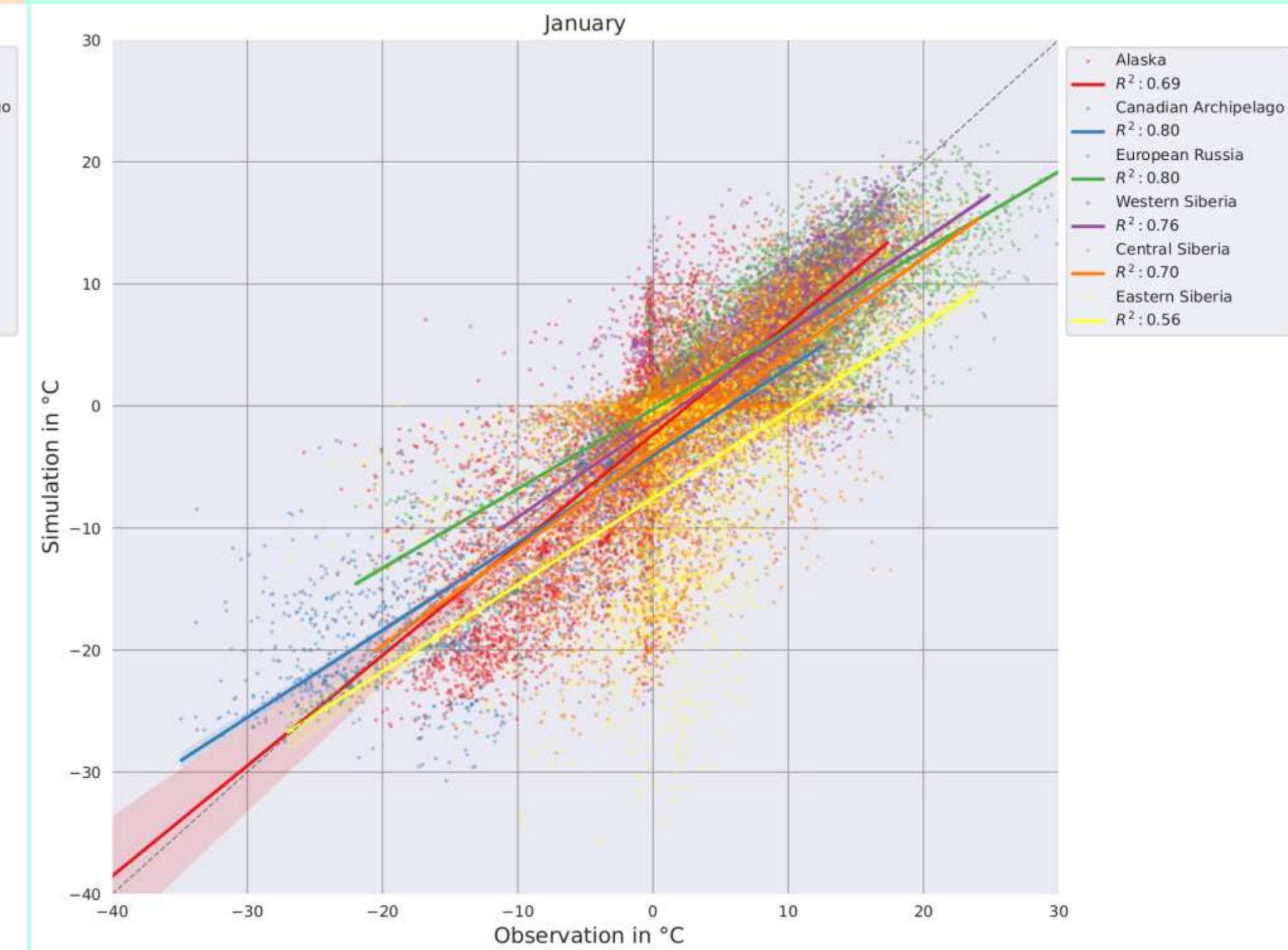
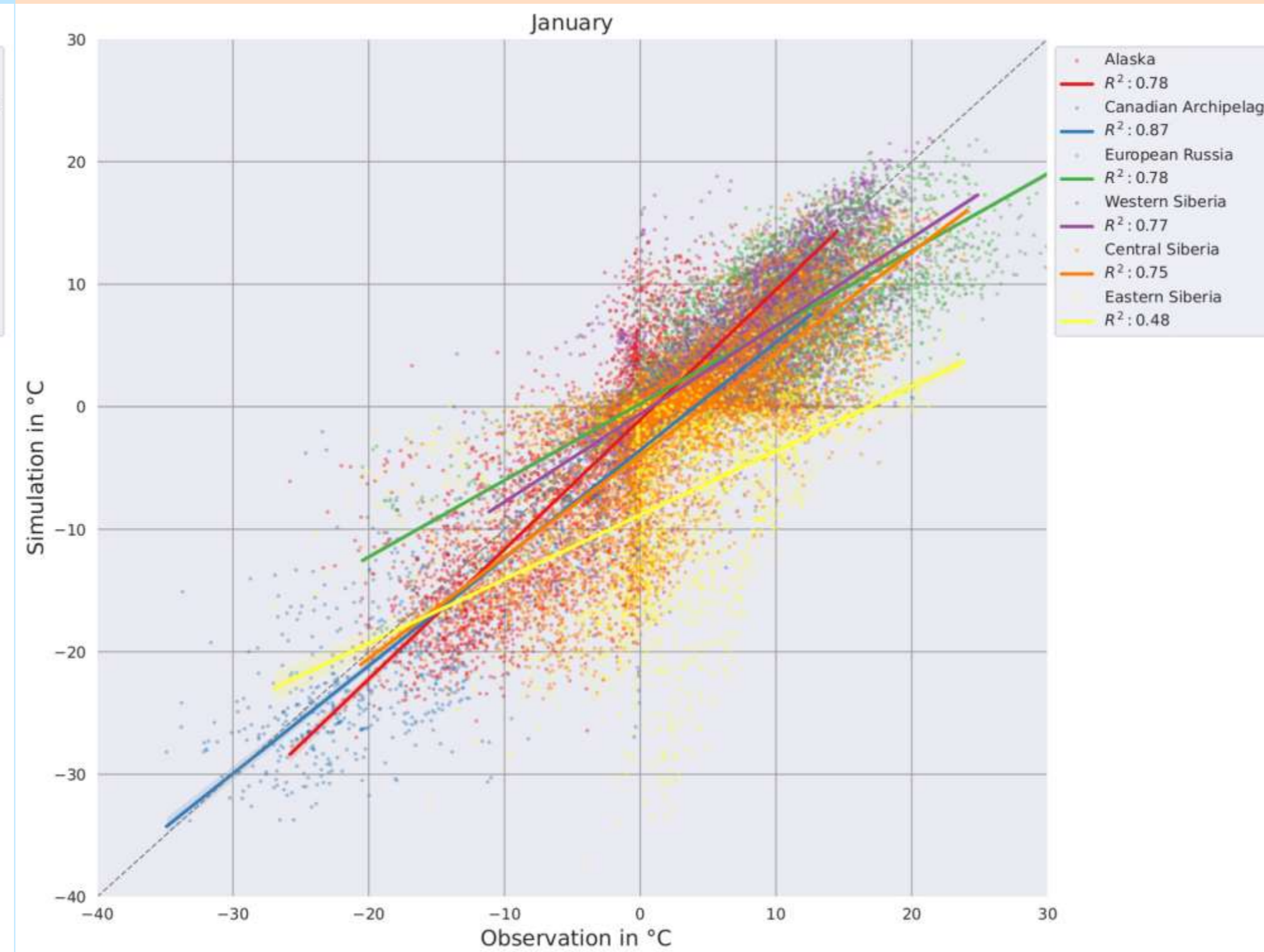
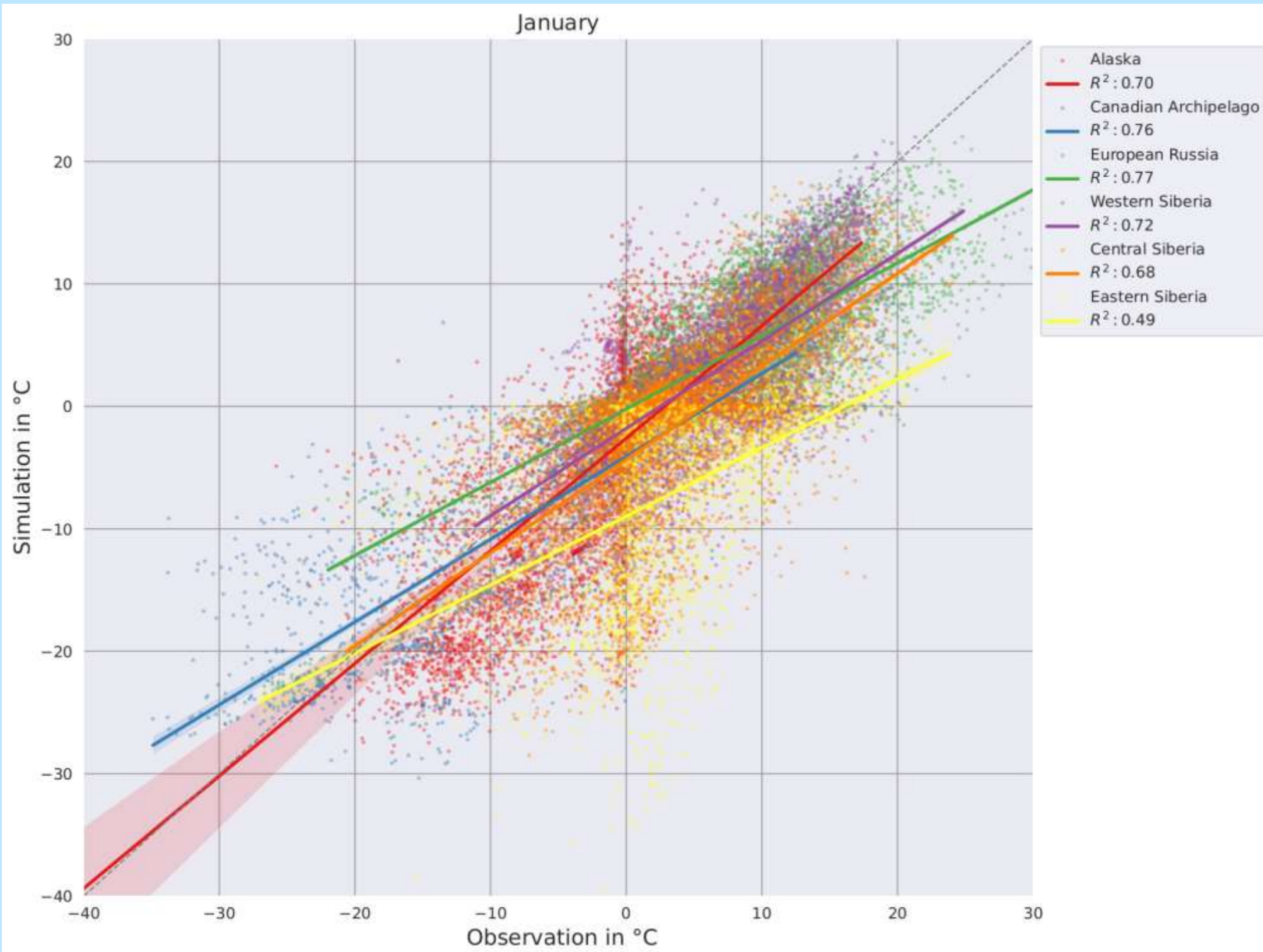


Run 001
ERA5
Default soil
1980-2021

Run 002
GSWP3
Default soil
1980-2014

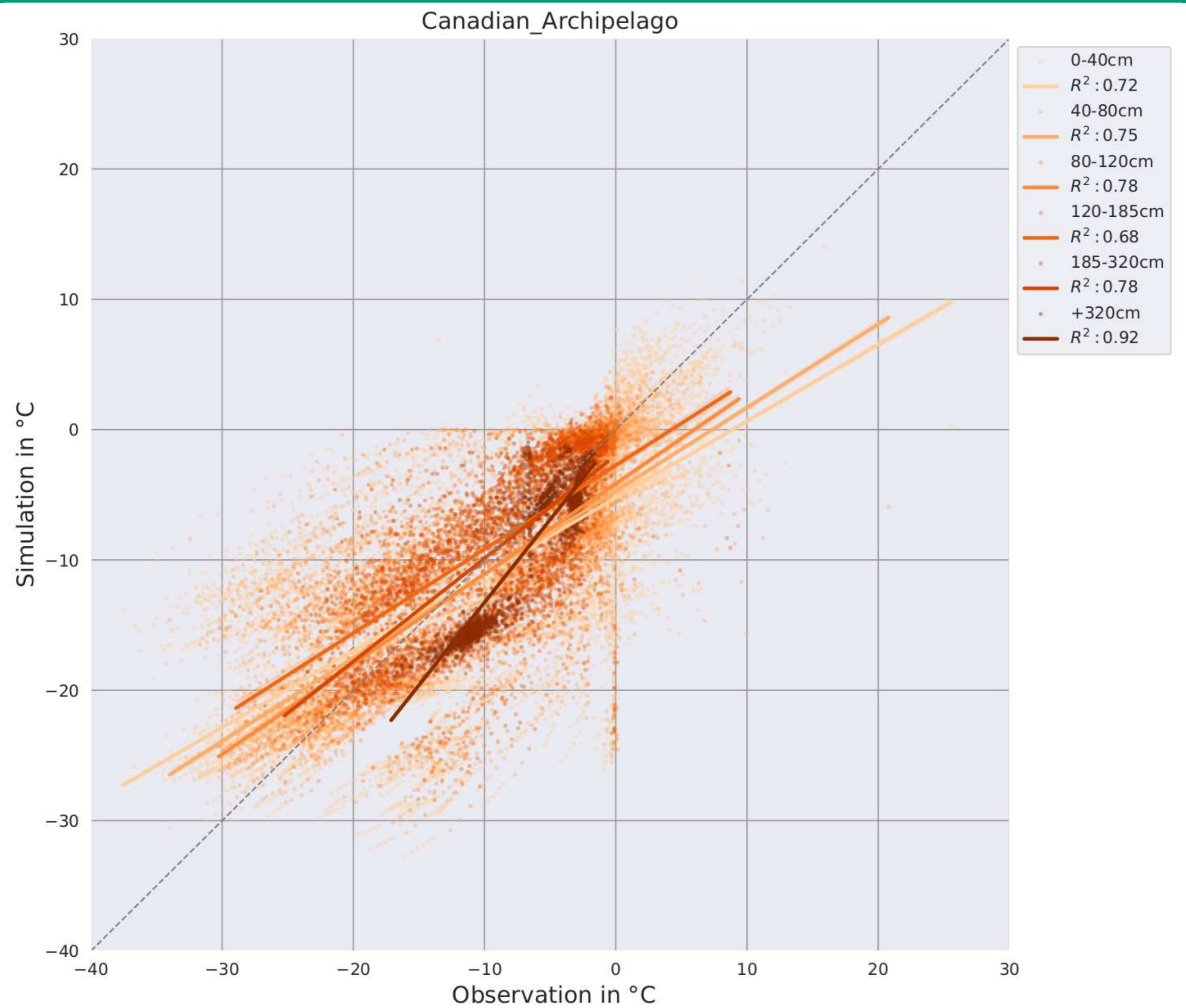
Run 005
ERA5
New soil
1980-2021

Soil temperature bias CTSM vs 274 stations
in January - Regions clustering

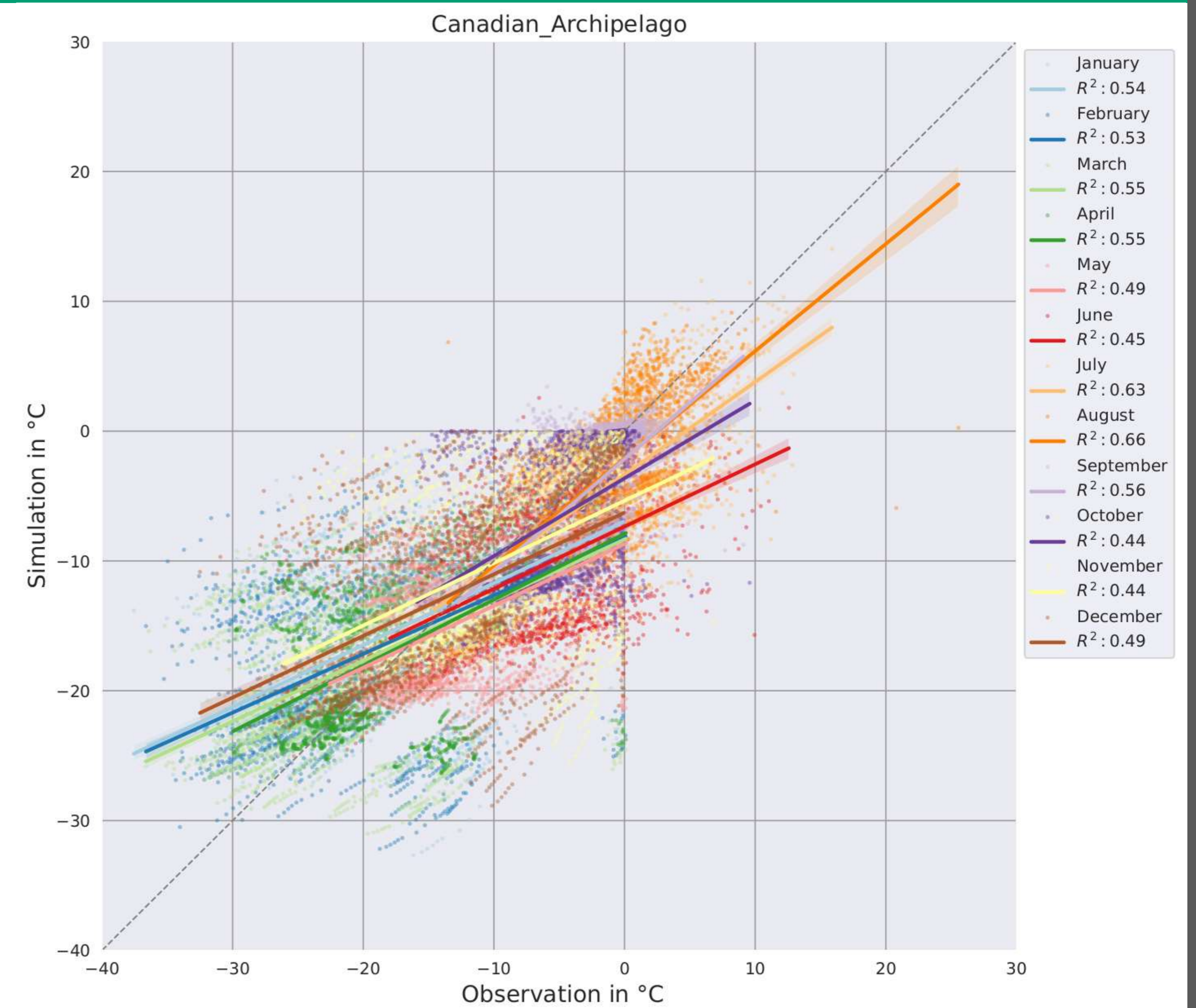


Soil temperature bias - only for Canada

Depth clustering

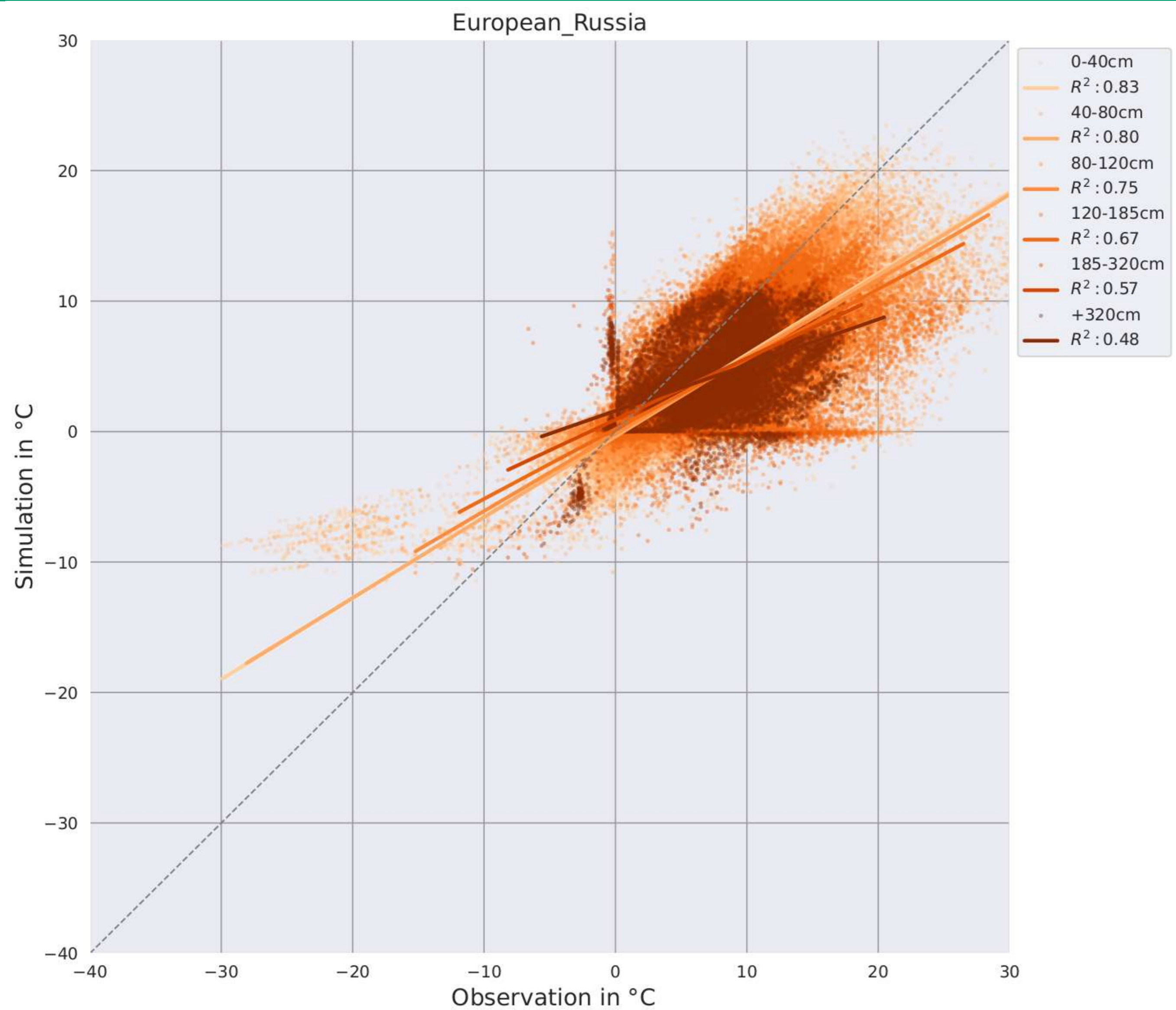


Month clustering

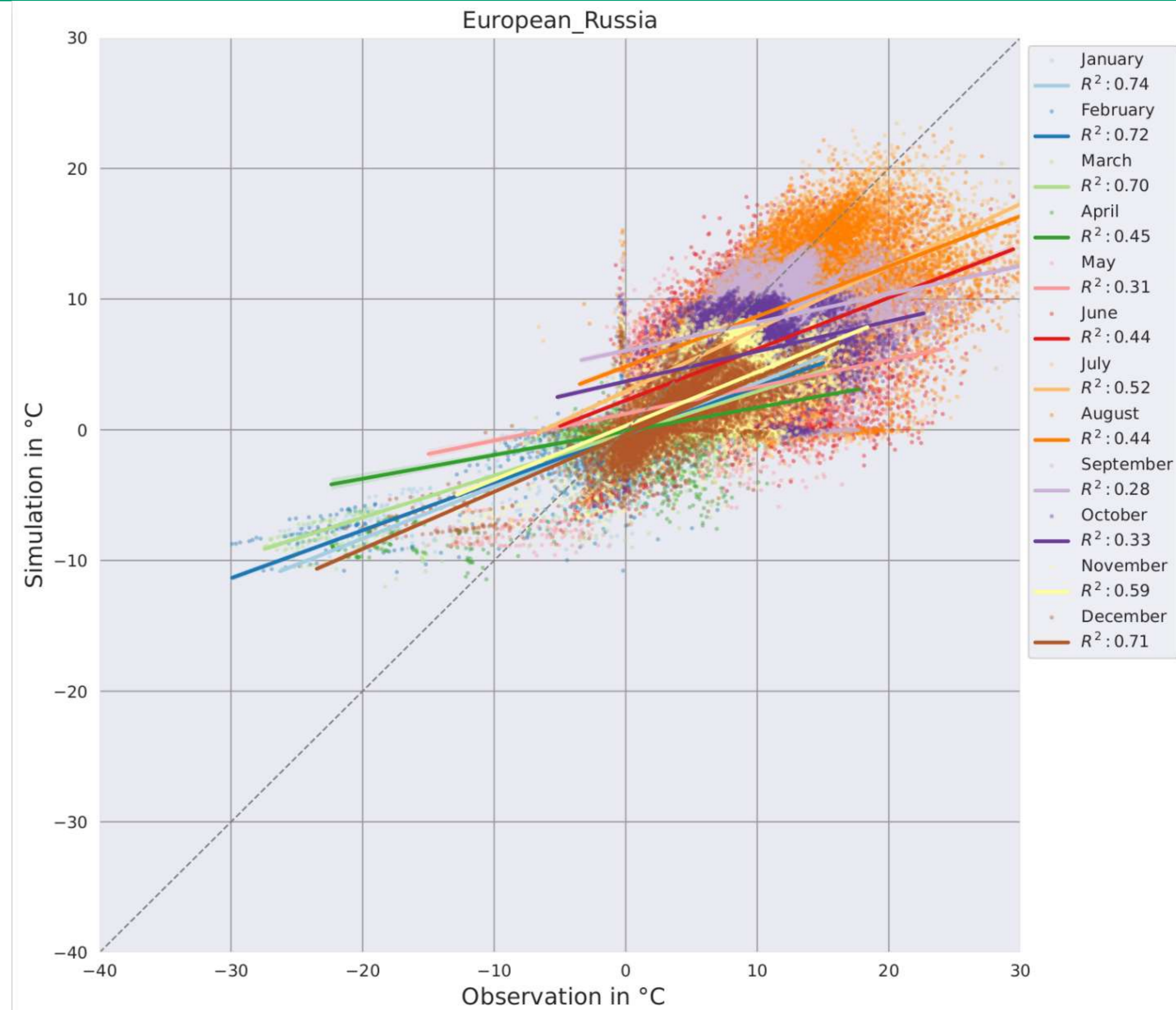


Soil temperature bias - only for European Russia

Depth clustering

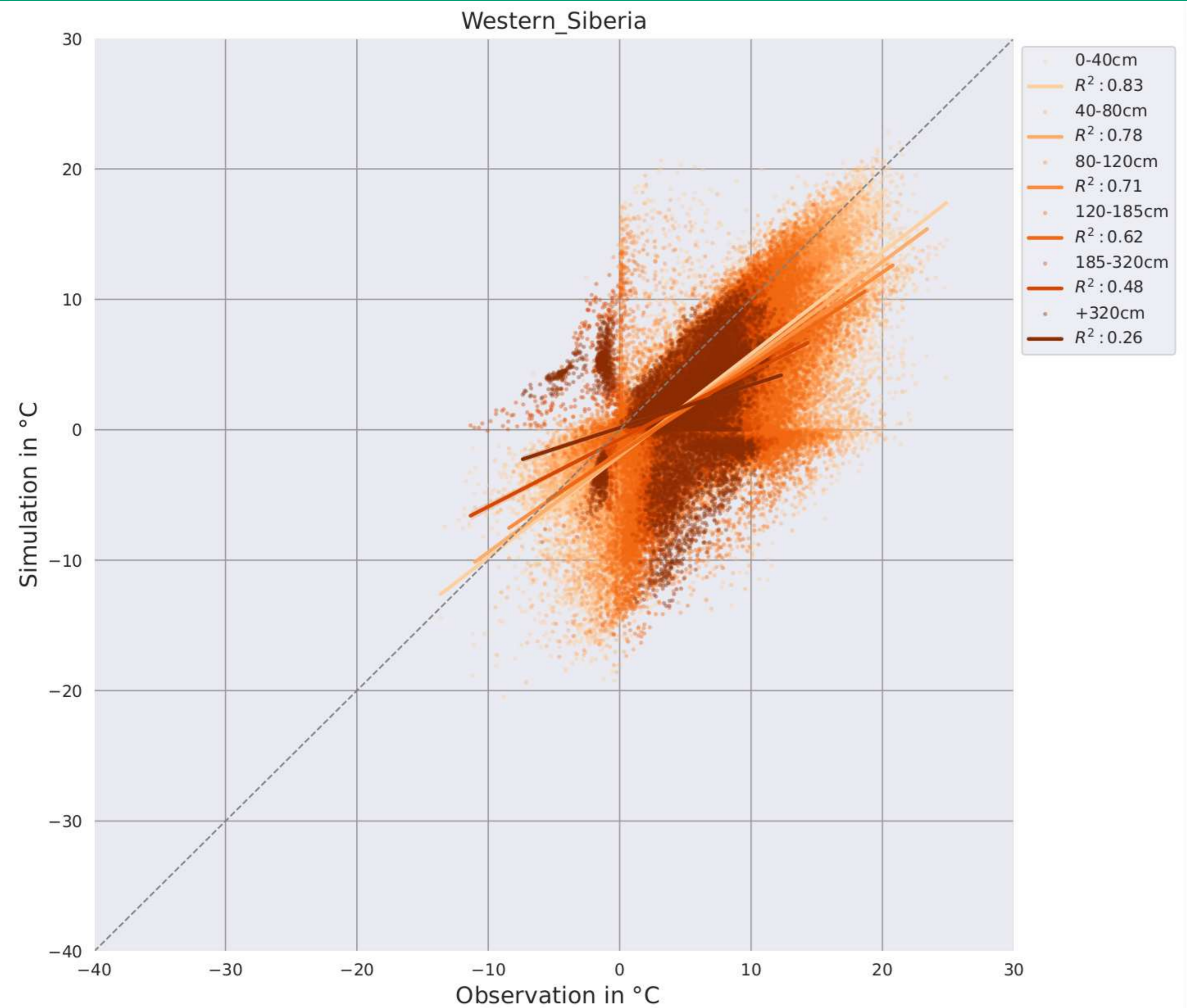


Month clustering

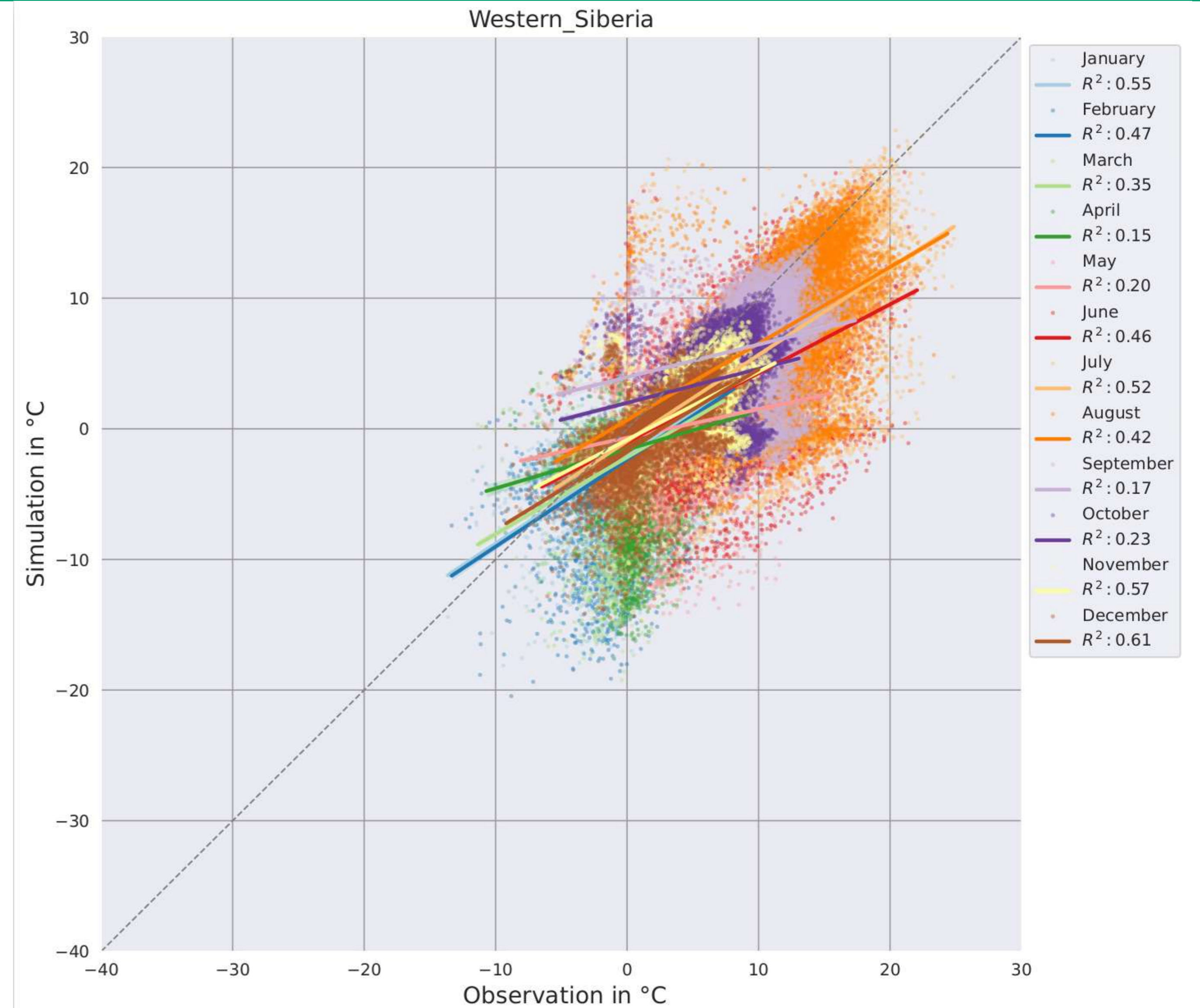


Soil temperature bias - only for Western Siberia

Depth clustering

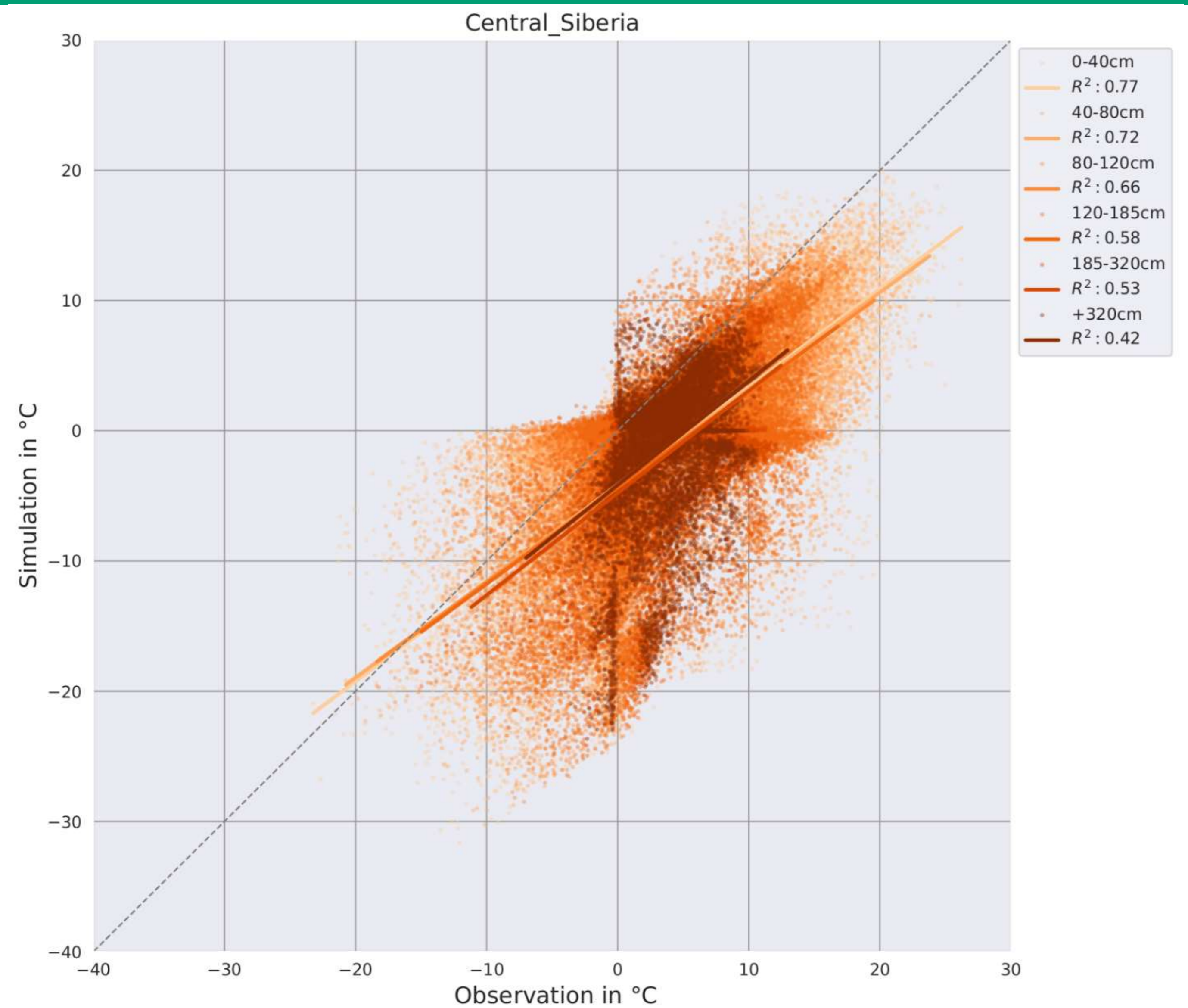


Month clustering

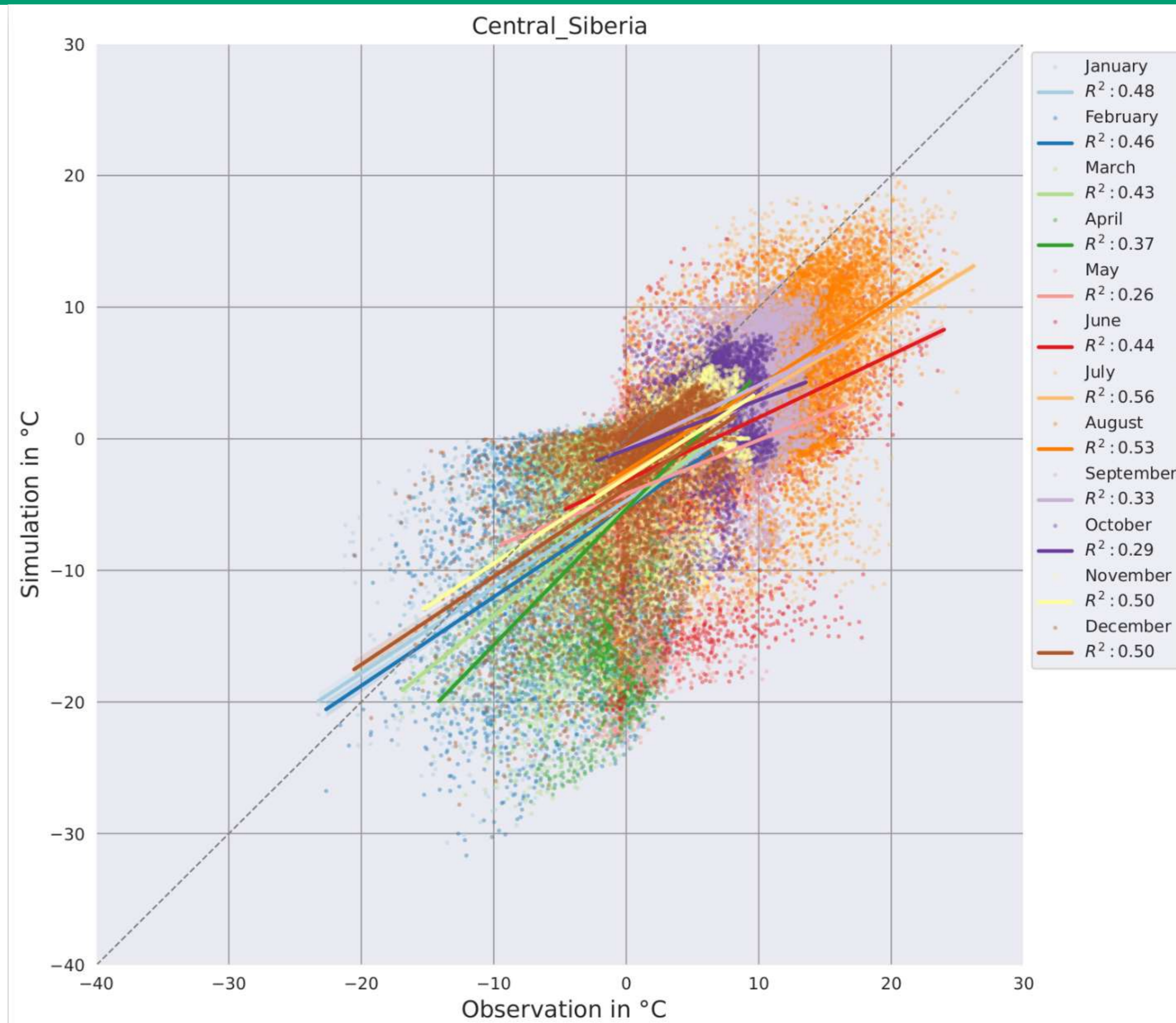


Soil temperature bias - only for Central Siberia

Depth clustering



Month clustering

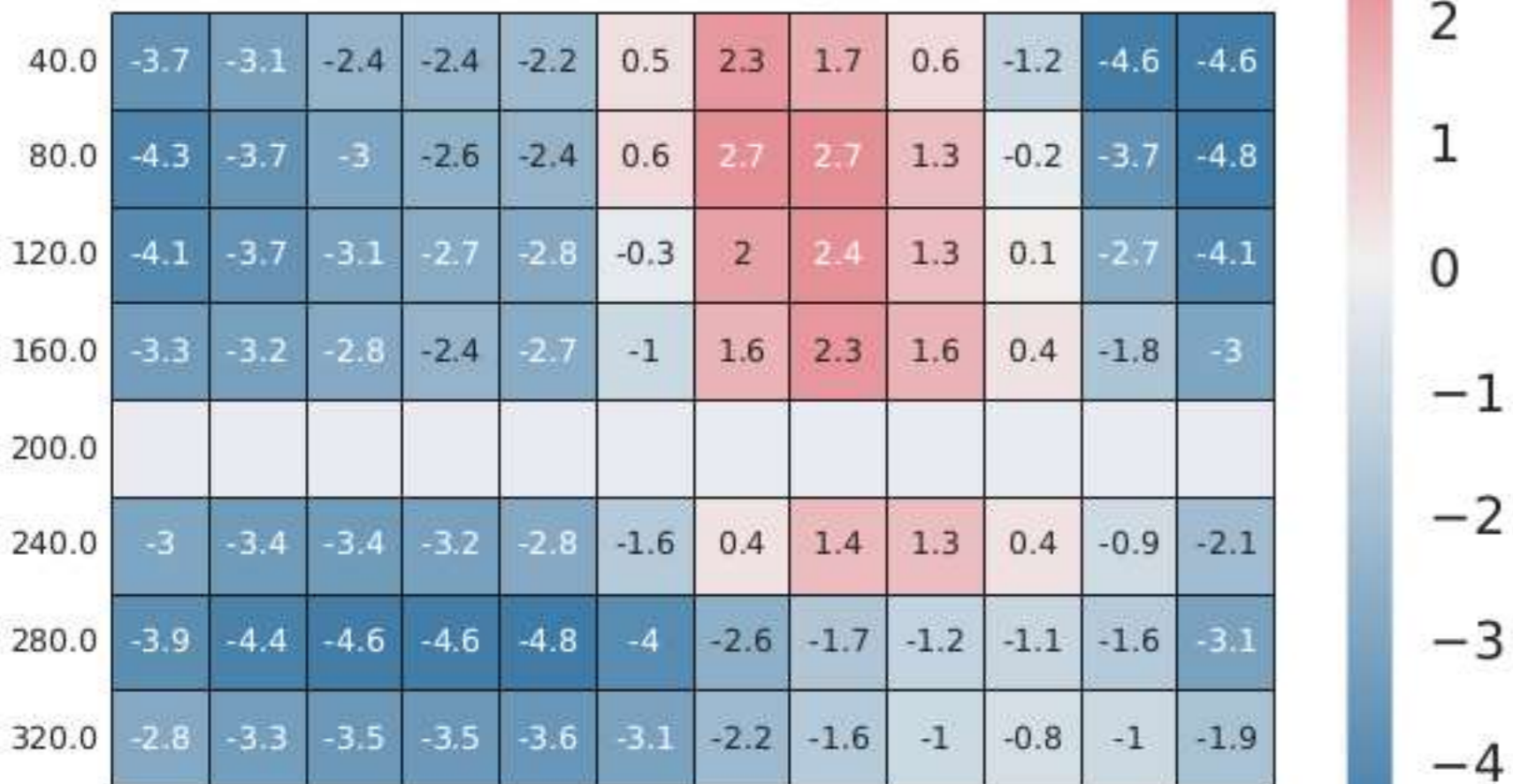


Run 001
ERA5
Default soil
1980-2021

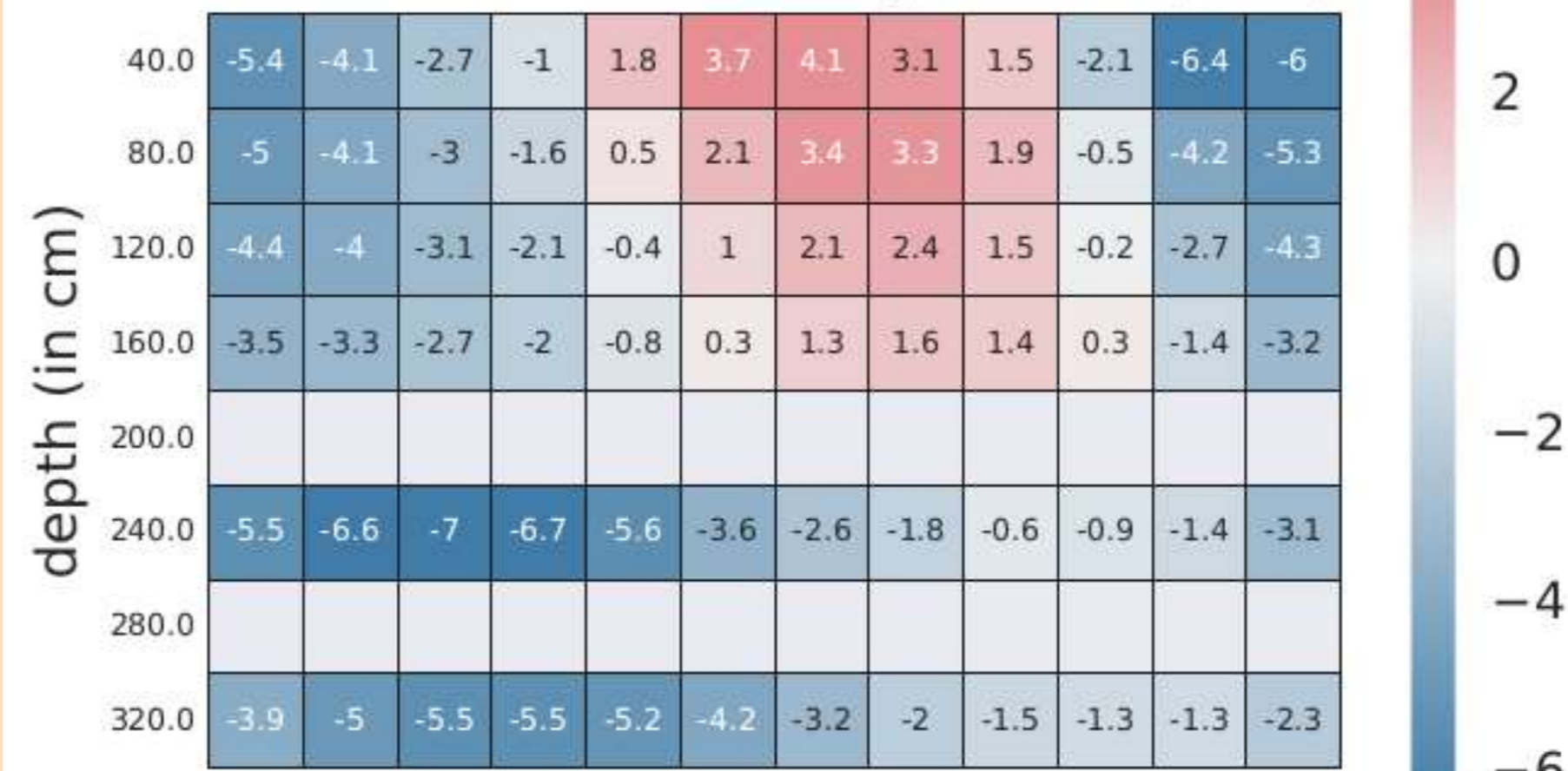
Run 002
GSWP3
Default soil
1980-2014

Run 005
ERA5
New soil
1980-2021

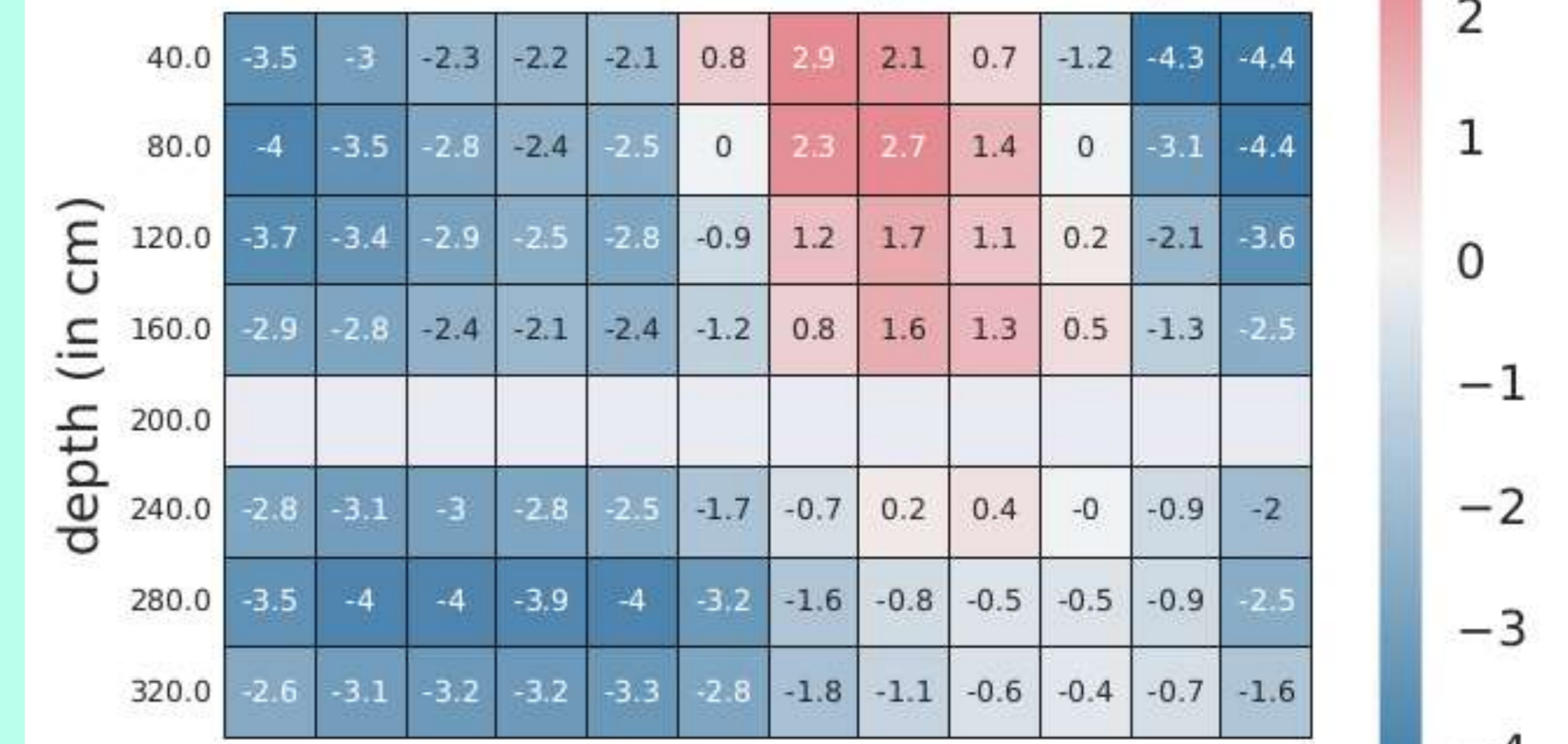
ctsm-stations soil temperature (in C)



ctsm-stations soil temperature (in C)



ctsm-stations soil temperature (in C)



RMSE ctsm-stations



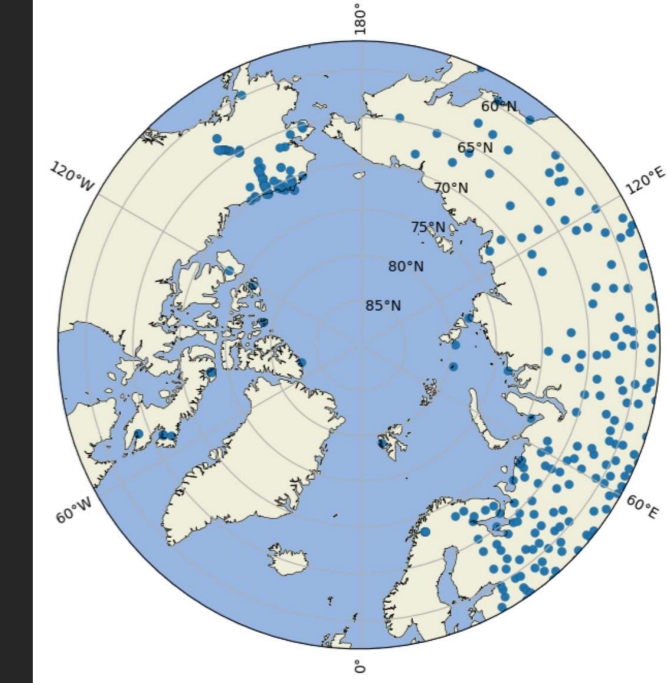
RMSE ctsm-stations



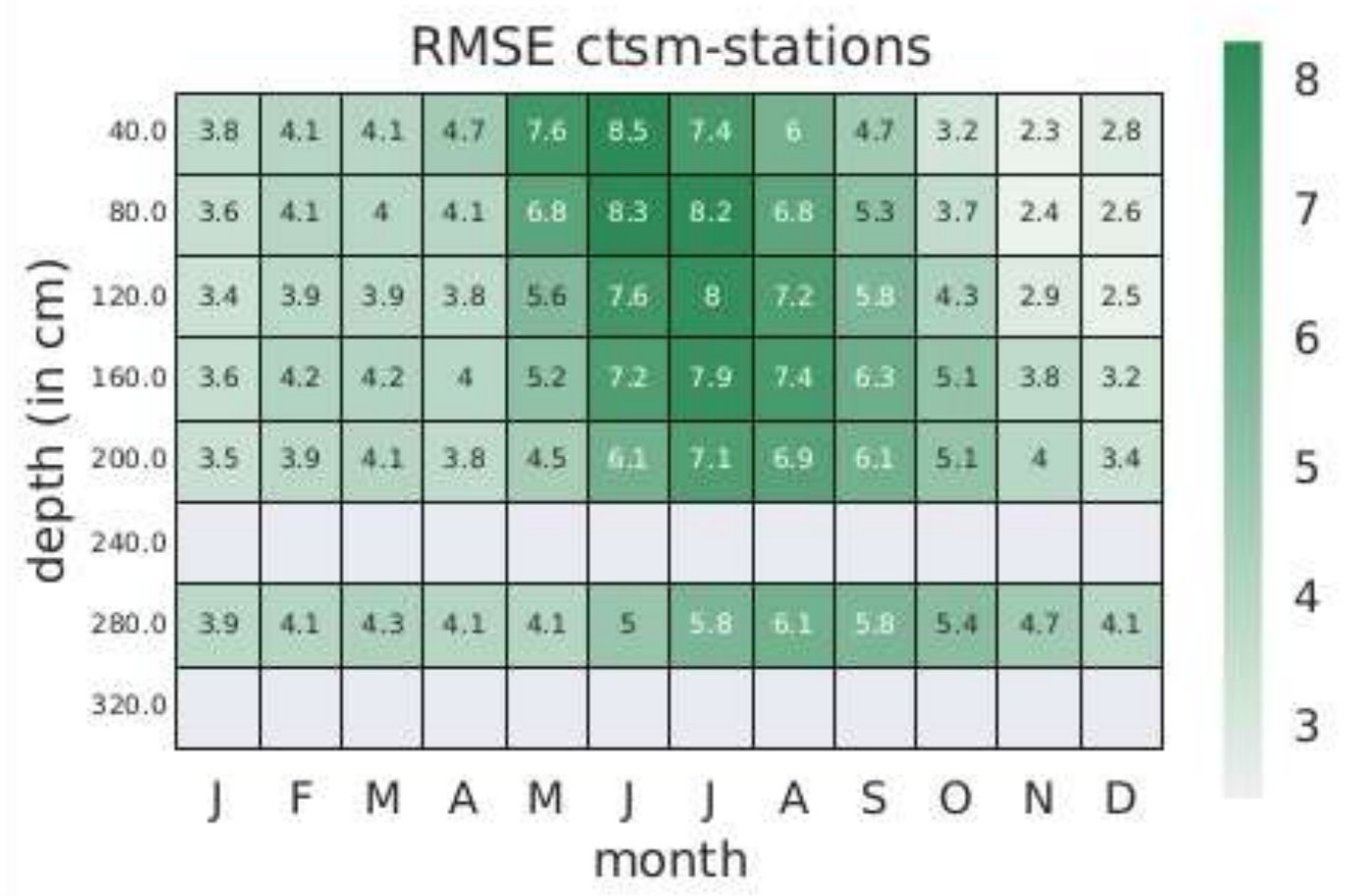
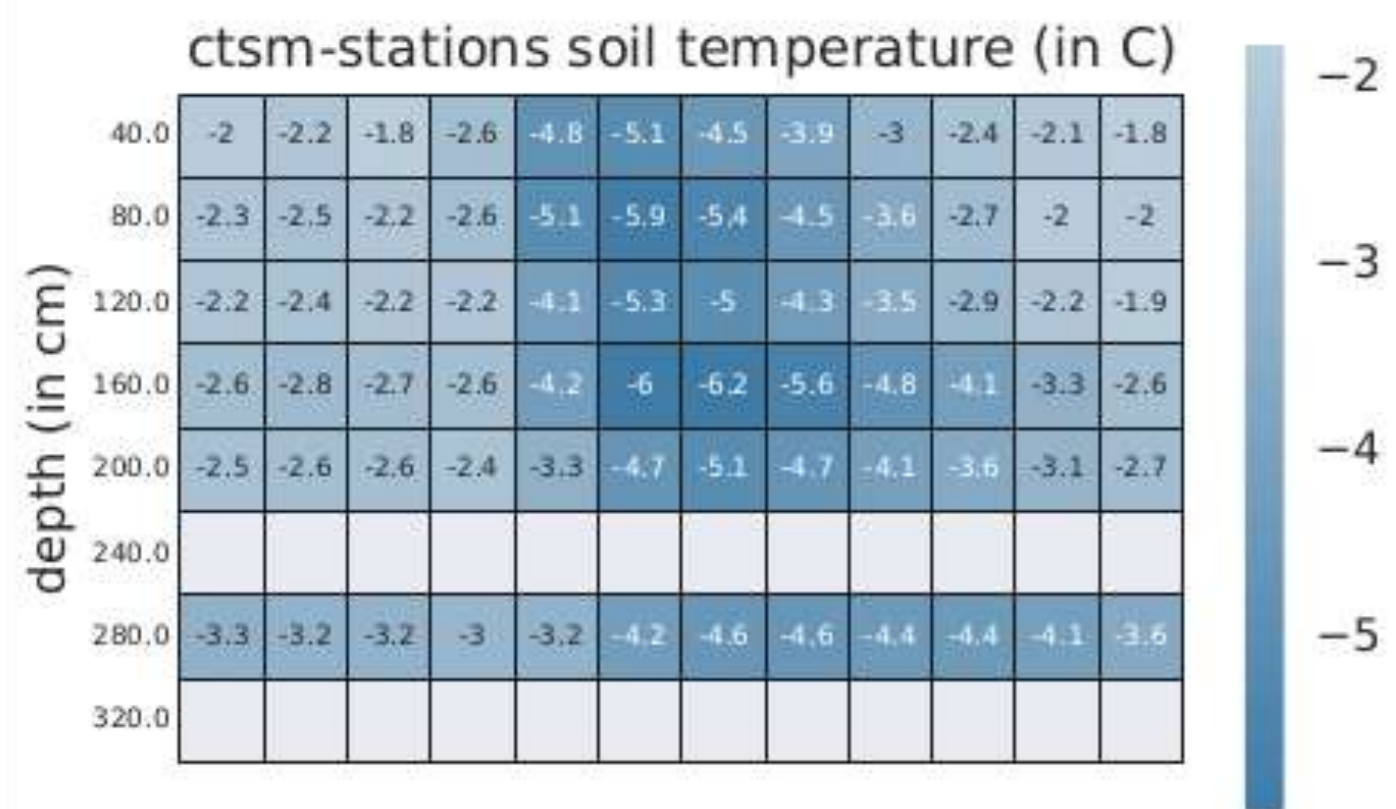
RMSE ctsm-stations



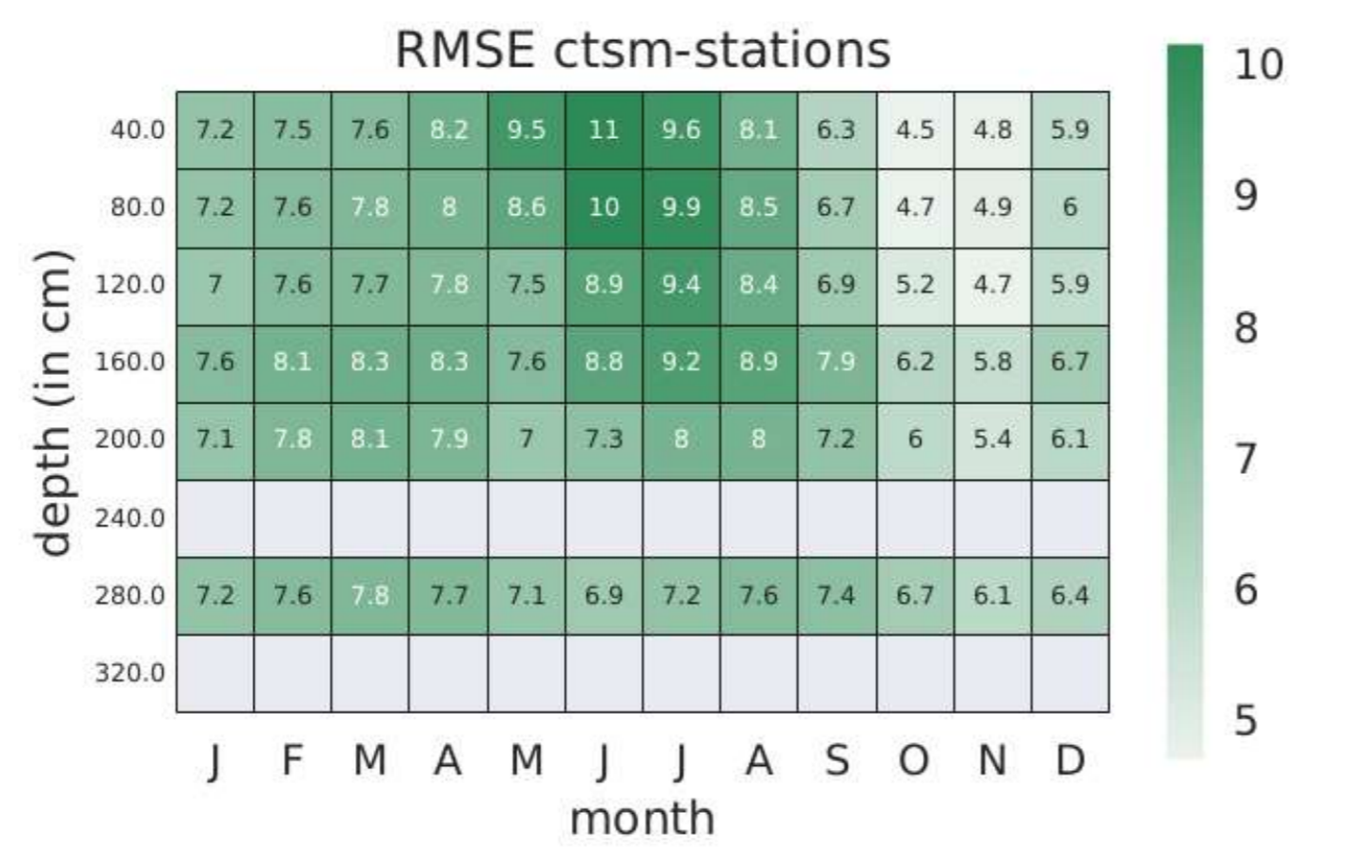
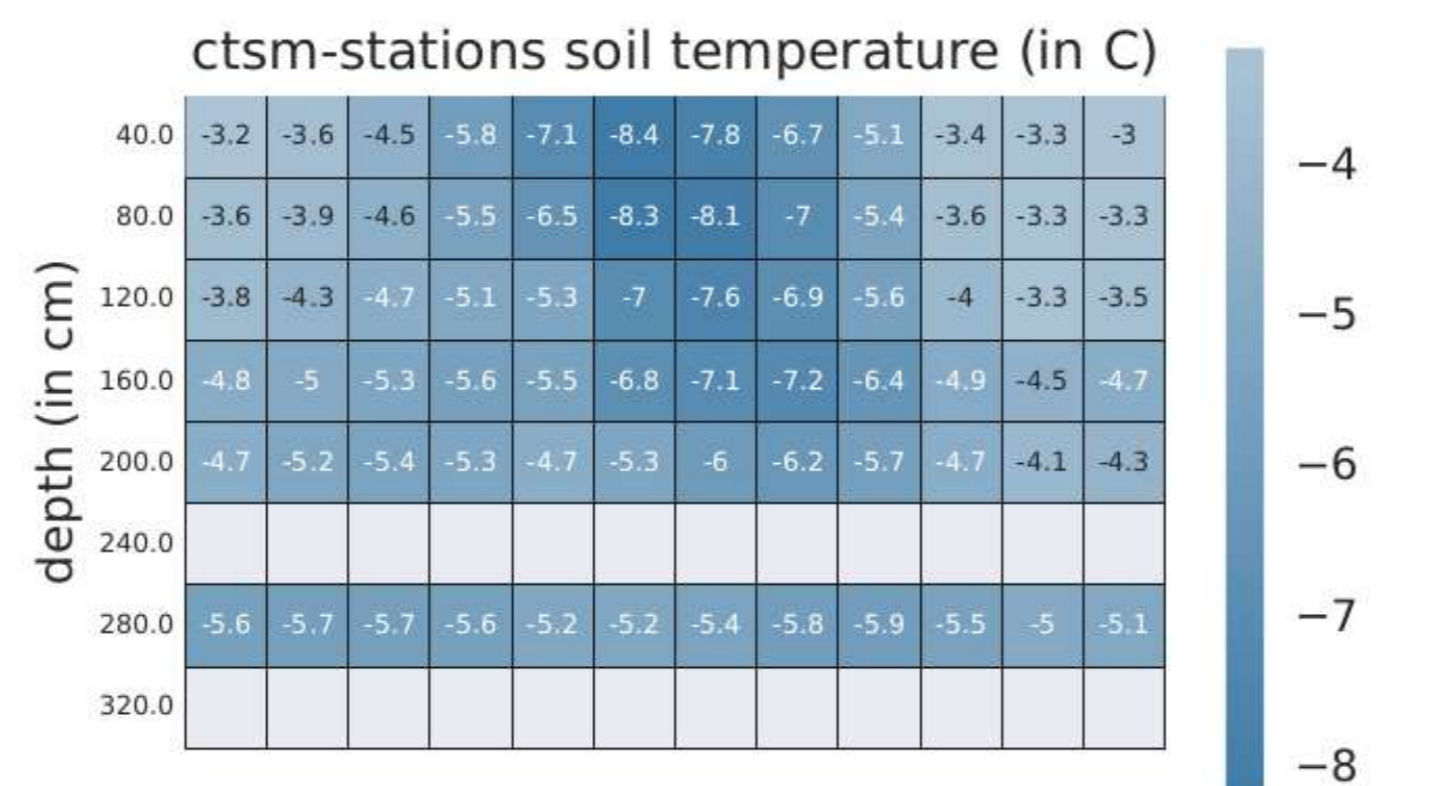
Heatmap of soil temperature bias



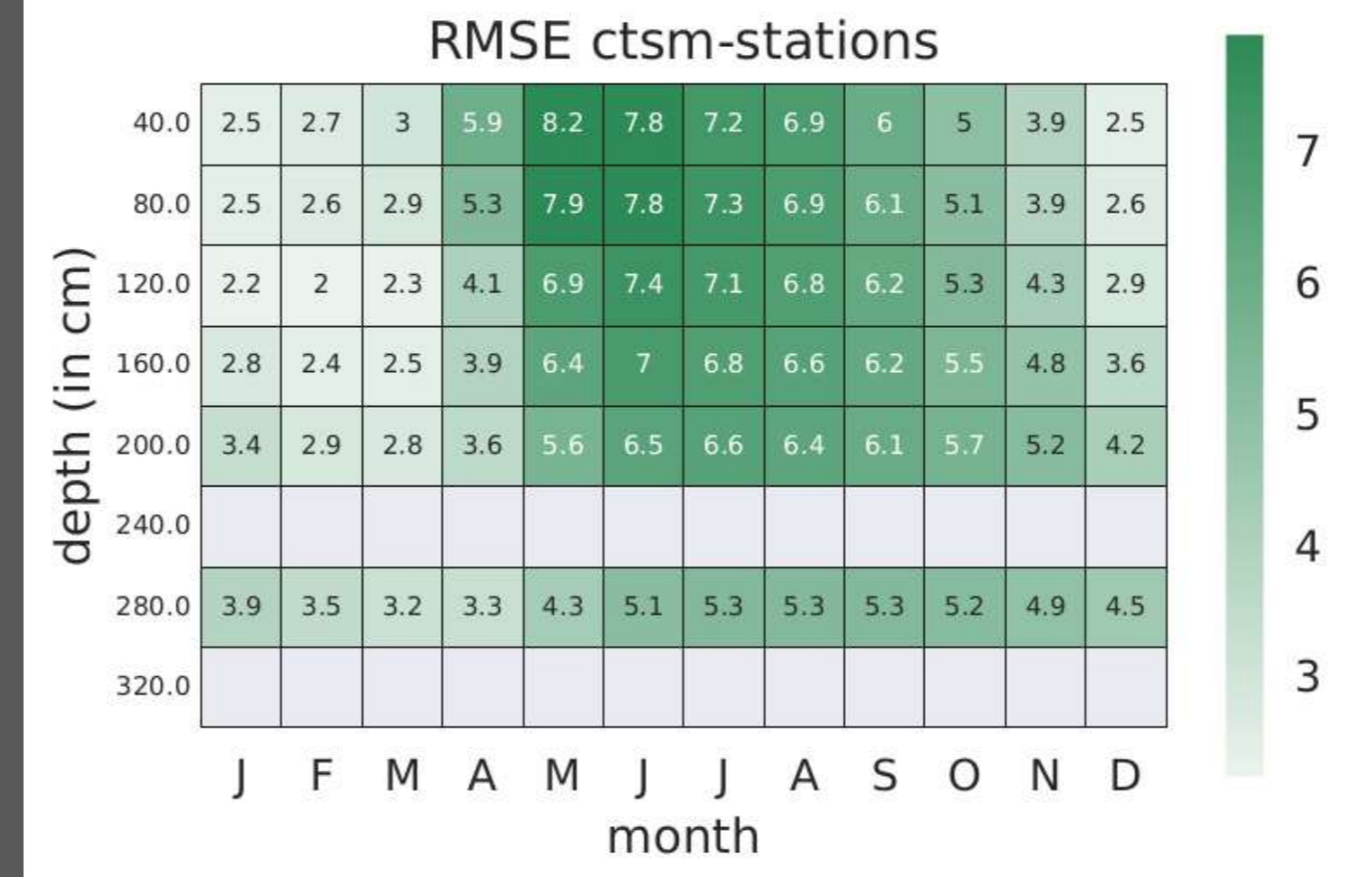
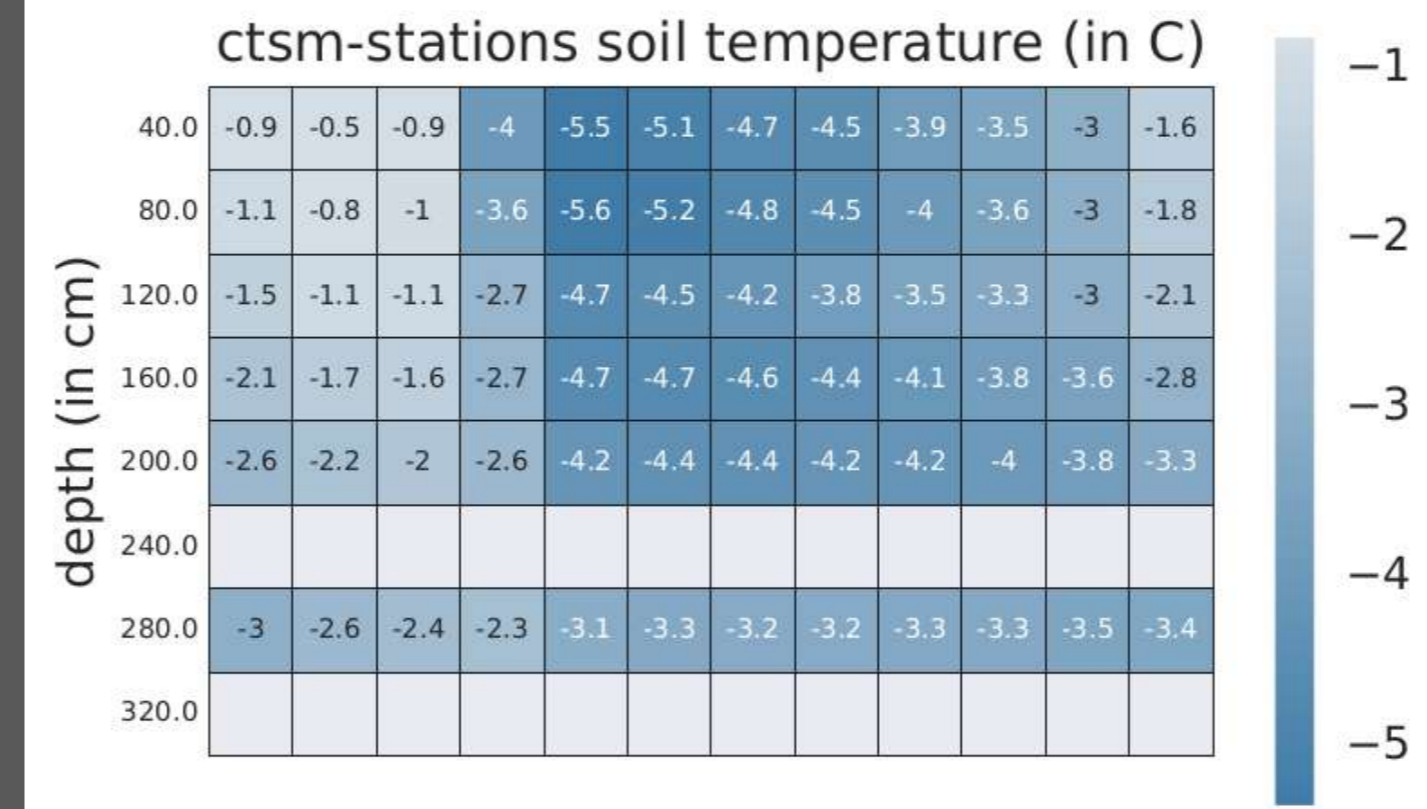
Western Siberia



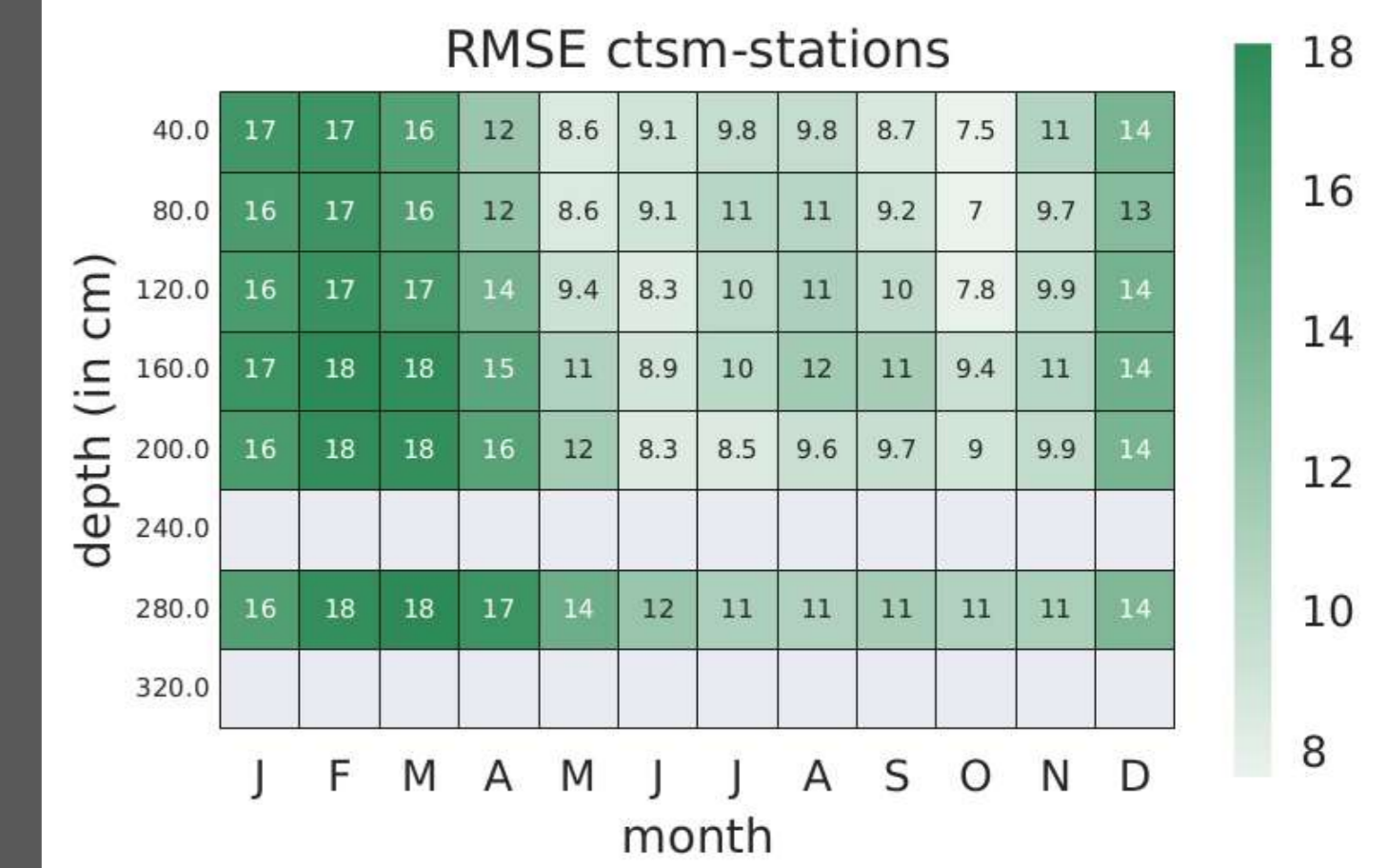
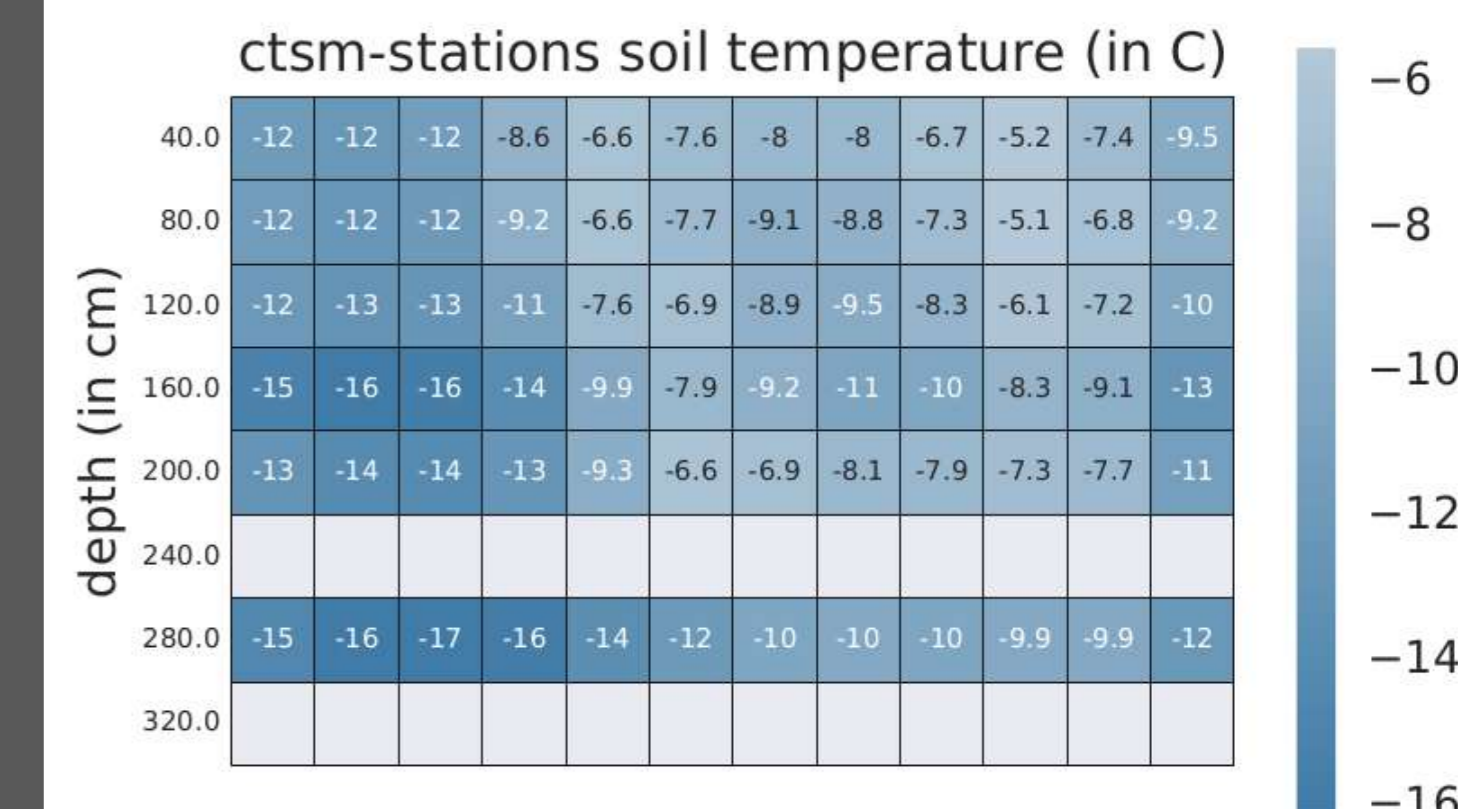
Central Siberia



European Russia



Eastern Siberia

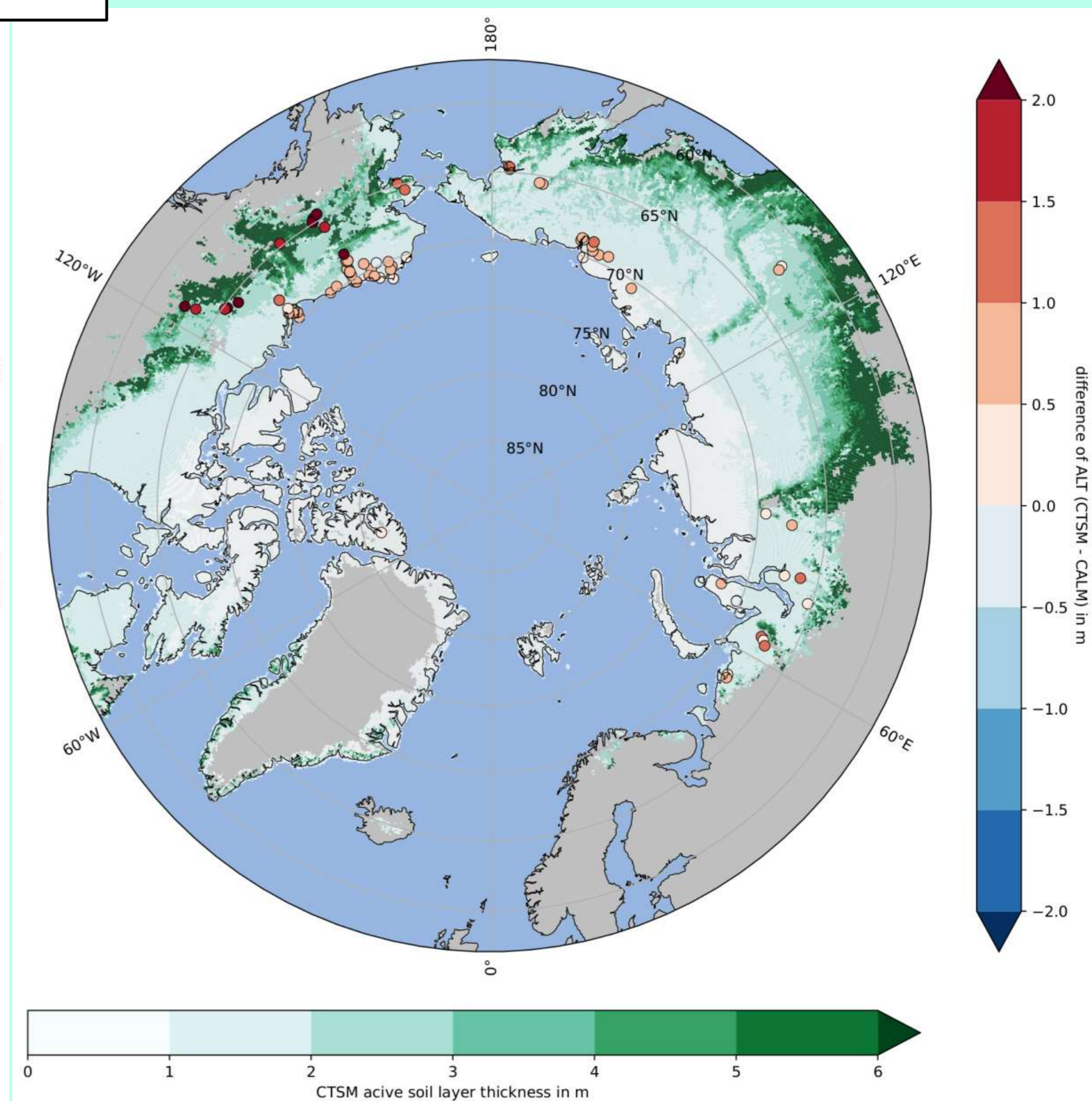
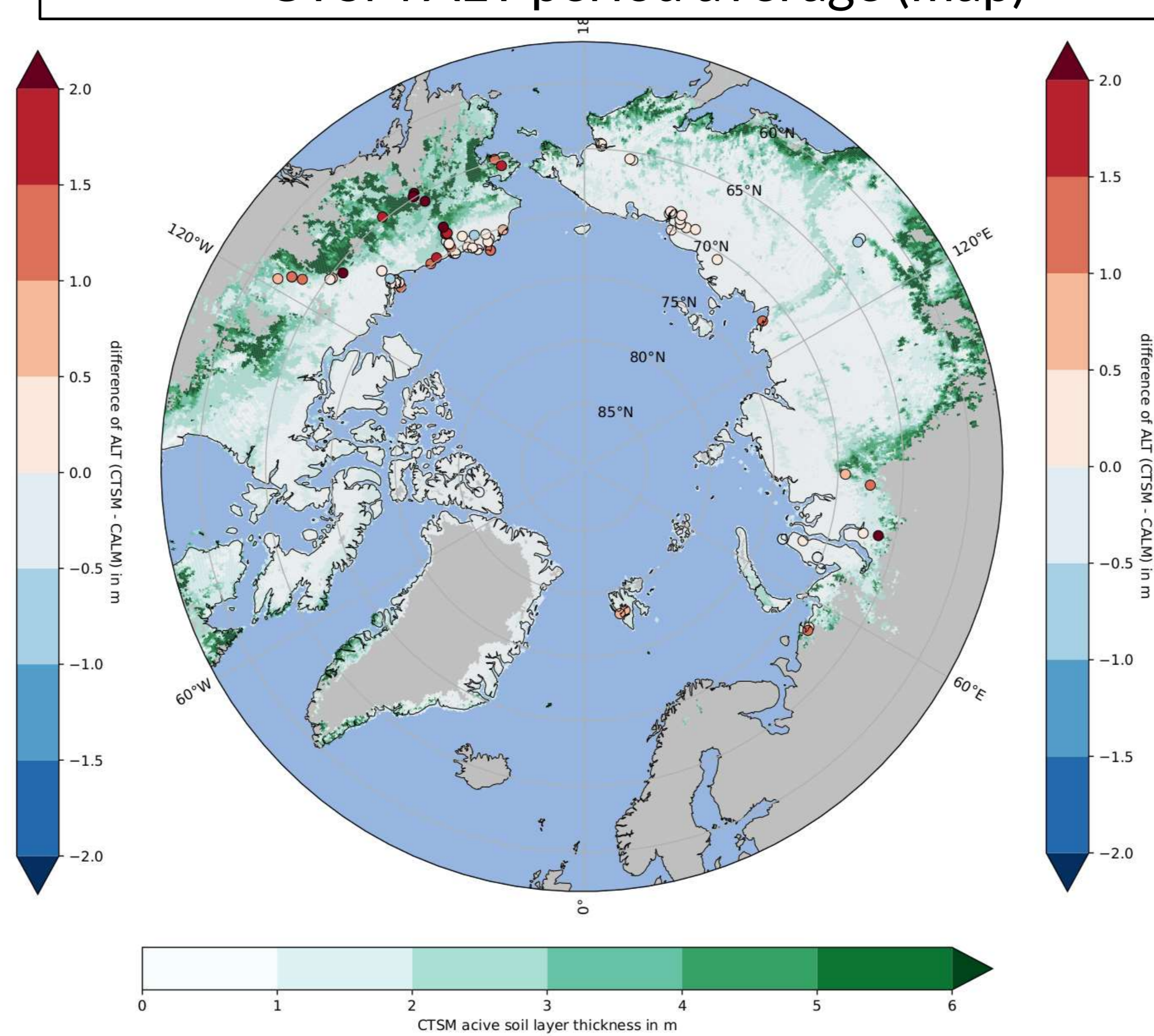
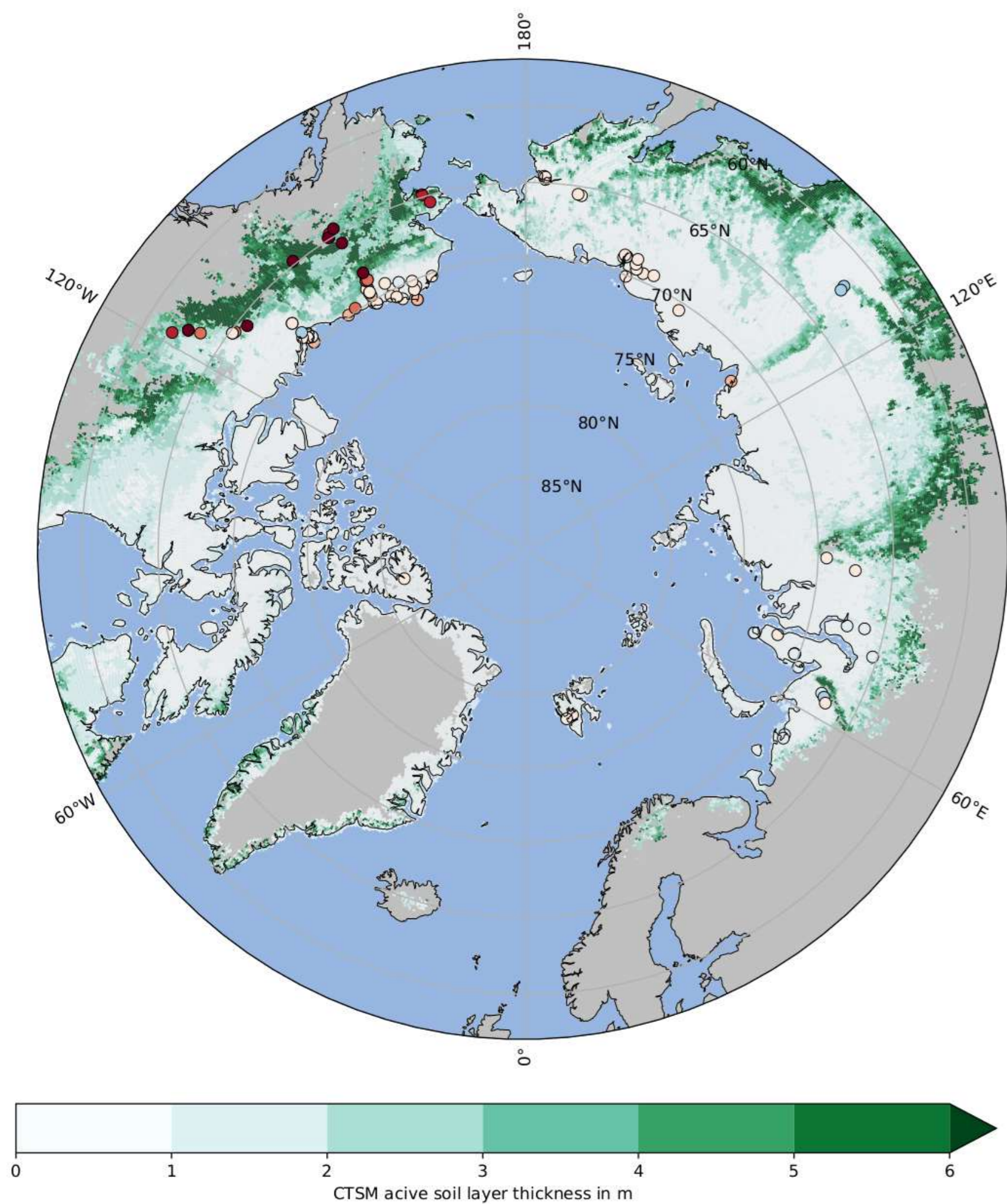


Run 001
ERA5
Default soil
1991-2021

Run 002
GSWP3
Default soil
1991-2014

Run 005
ERA5
New soil
1991-2021

ALT bias CTSM - CALM (dots)
CTSM ALT period average (map)

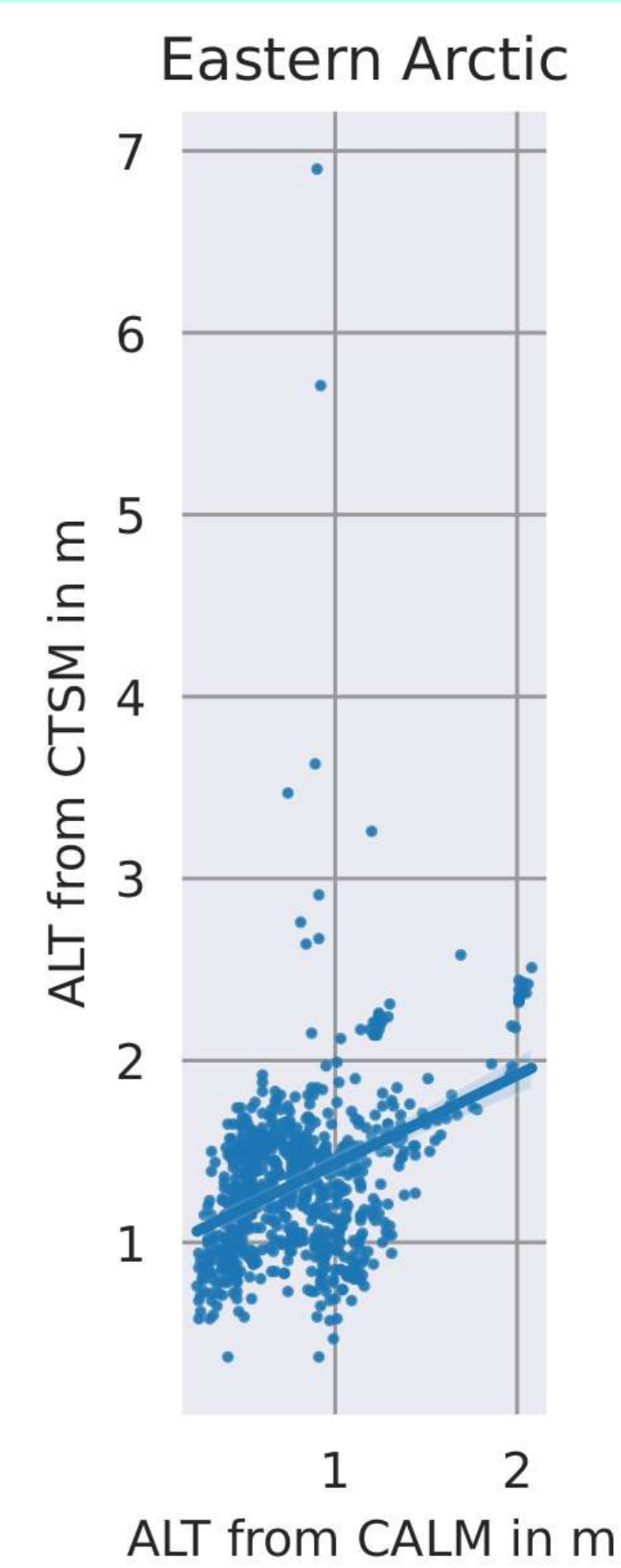
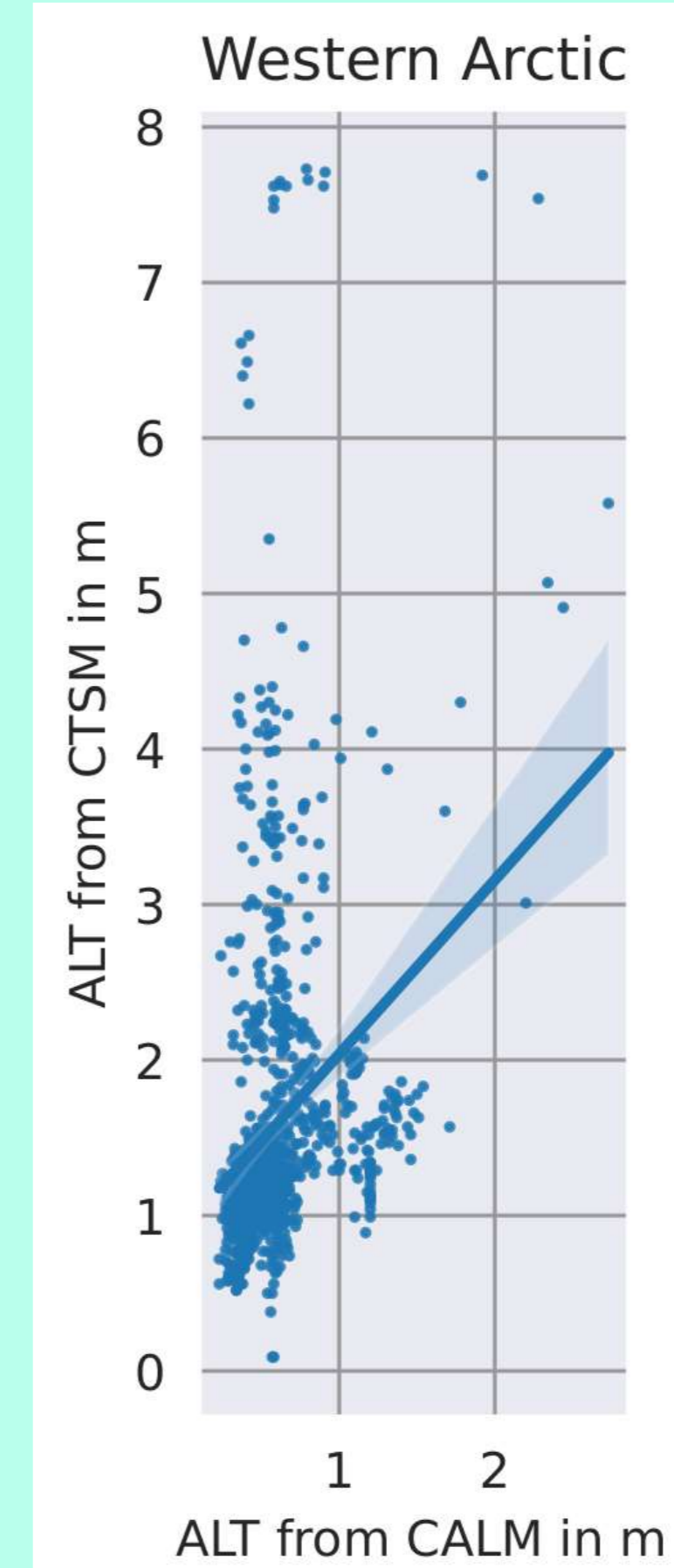
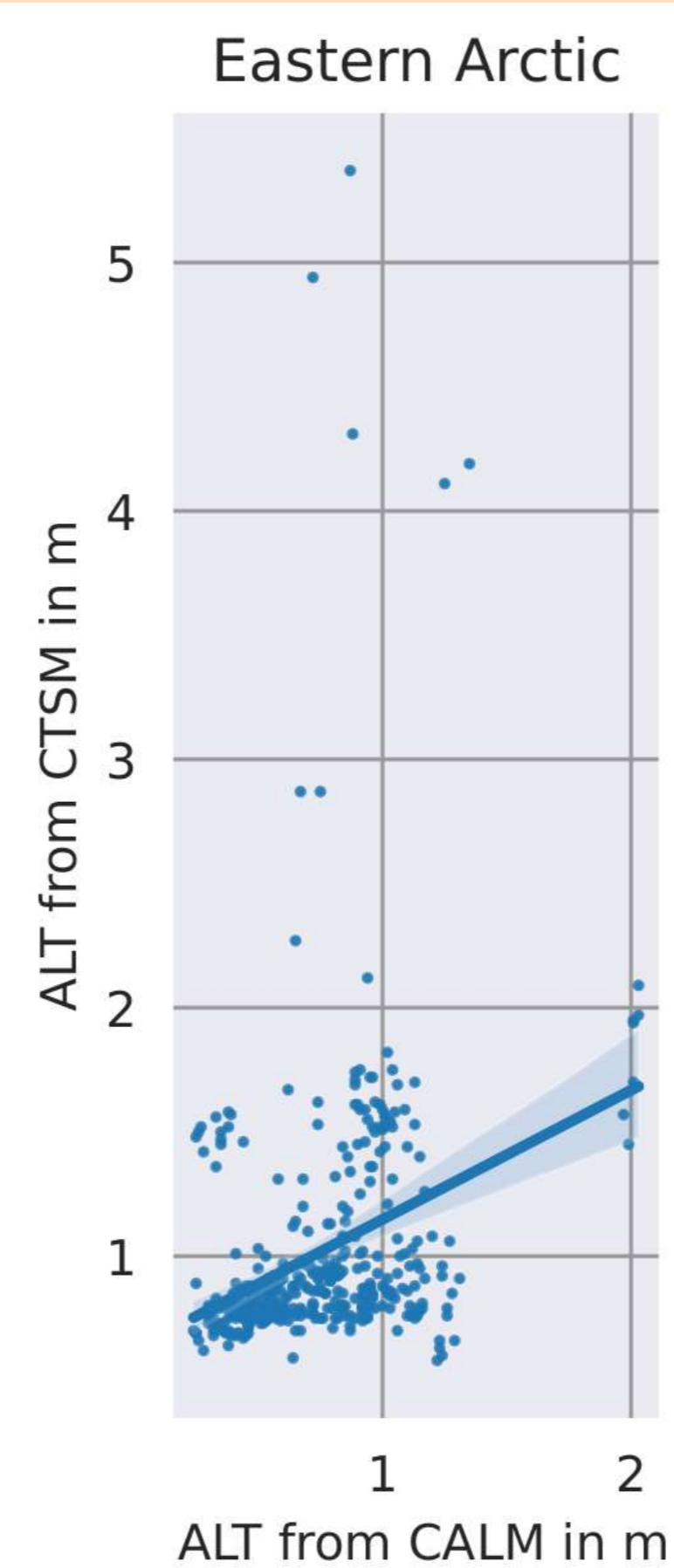
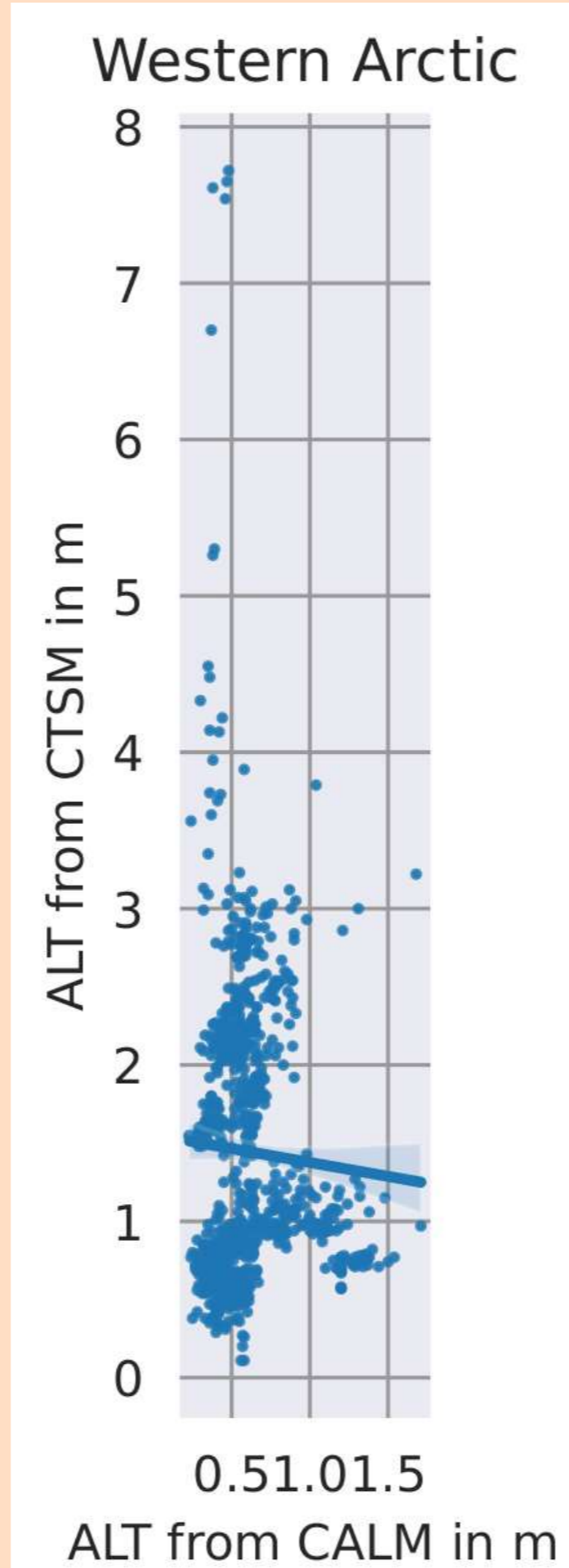
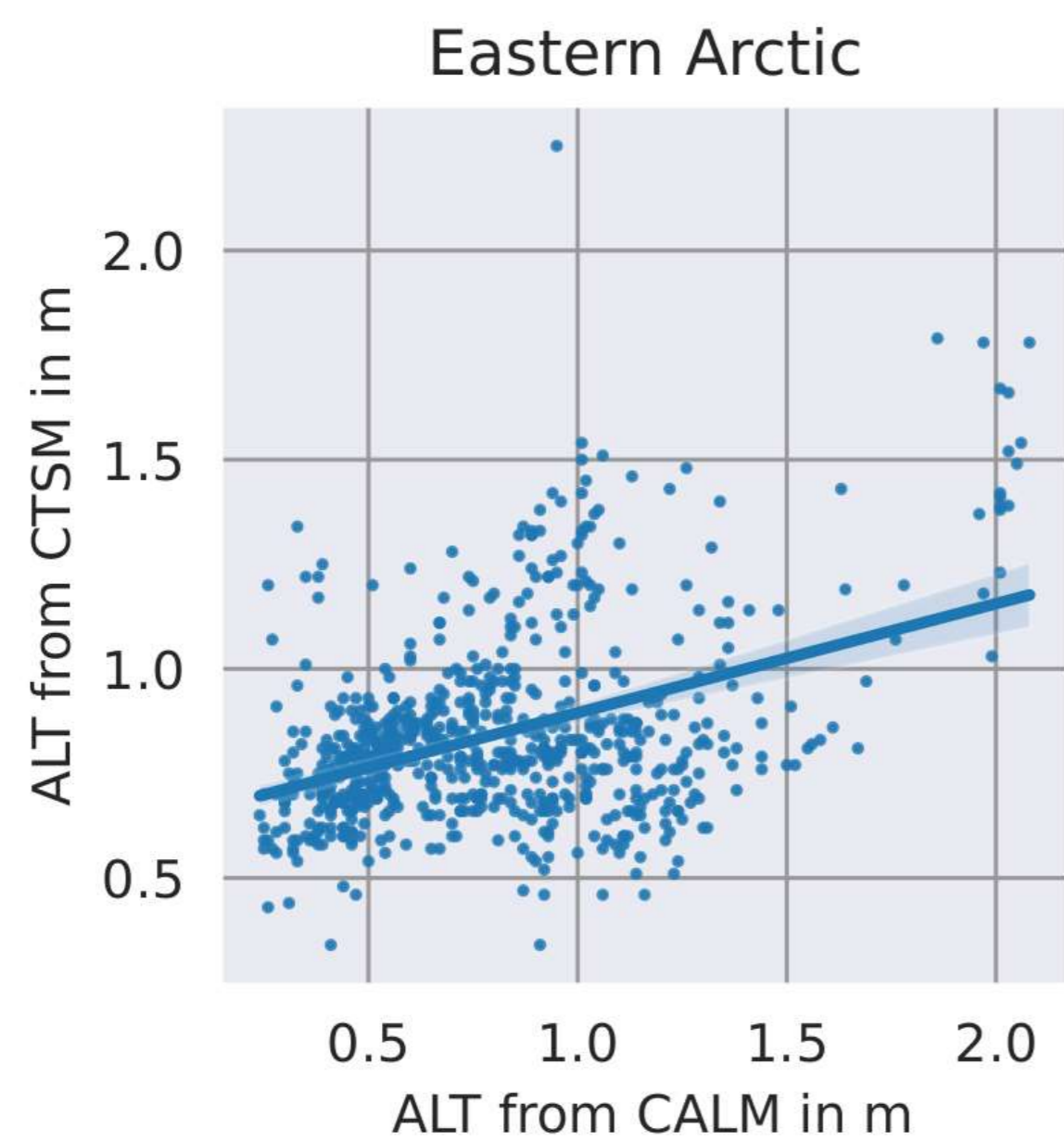
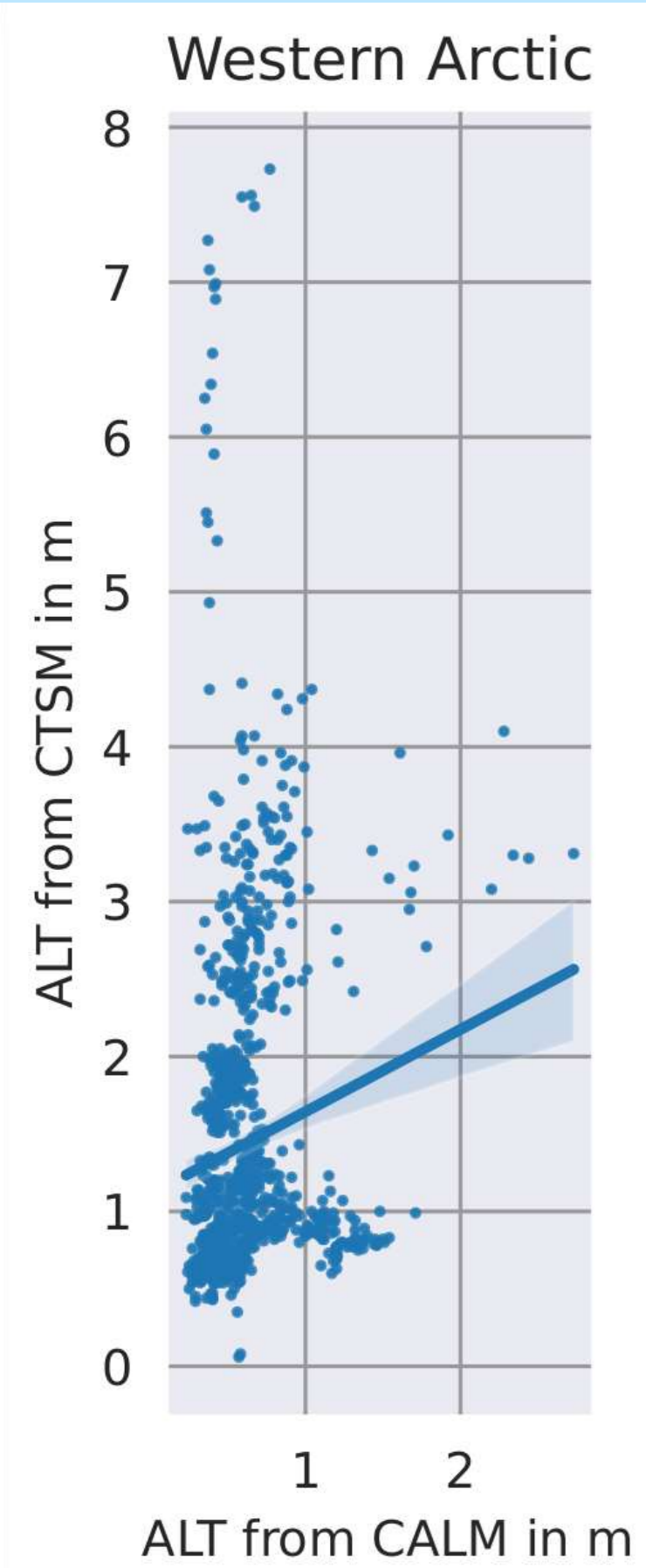


Run 001
ERA5
Default soil
1991-2021

Run 002
GSWP3
Default soil
1980-2014

Run 005
ERA5
New soil
1980-2021

ALT bias CTSM – CALM

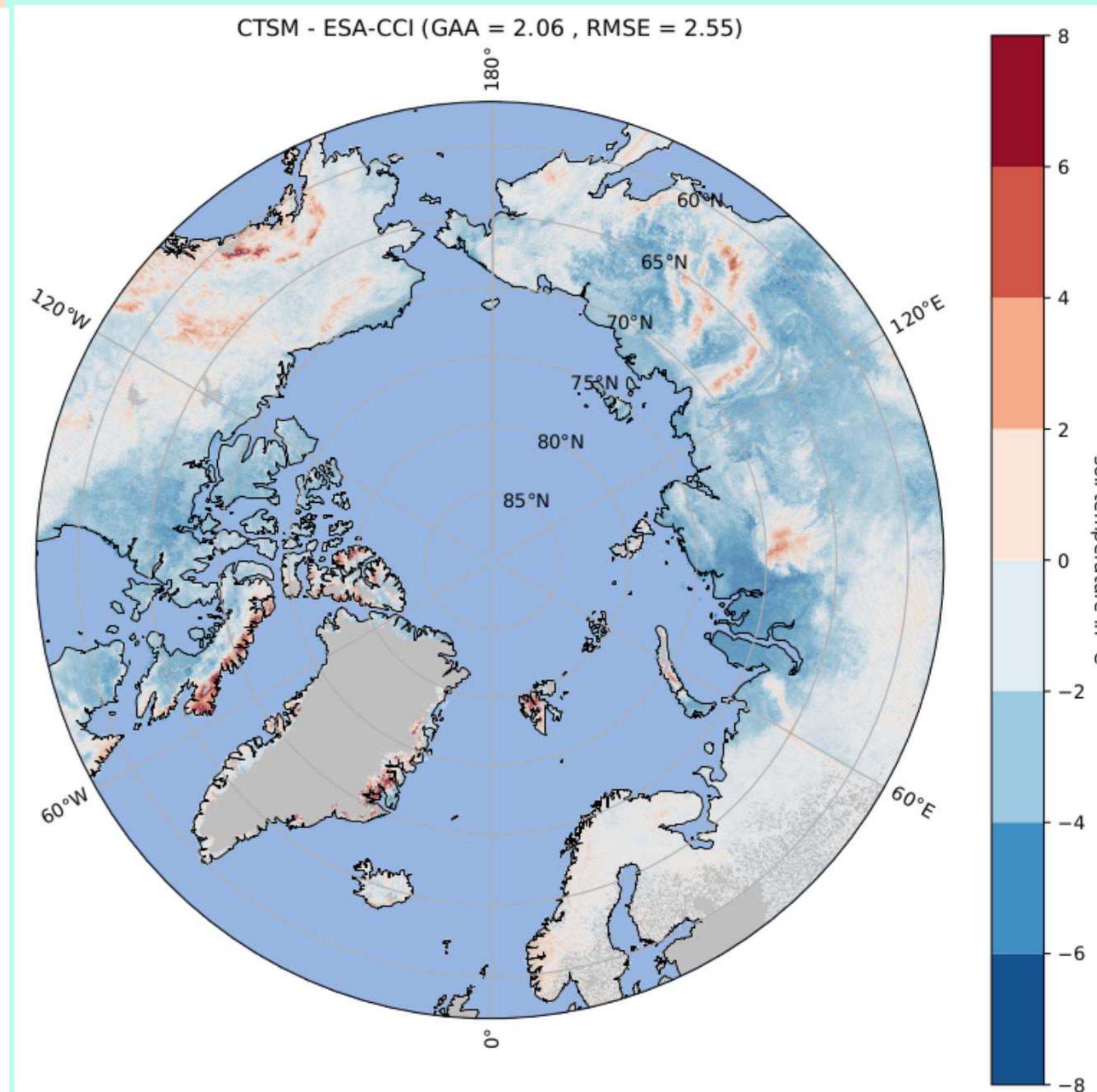
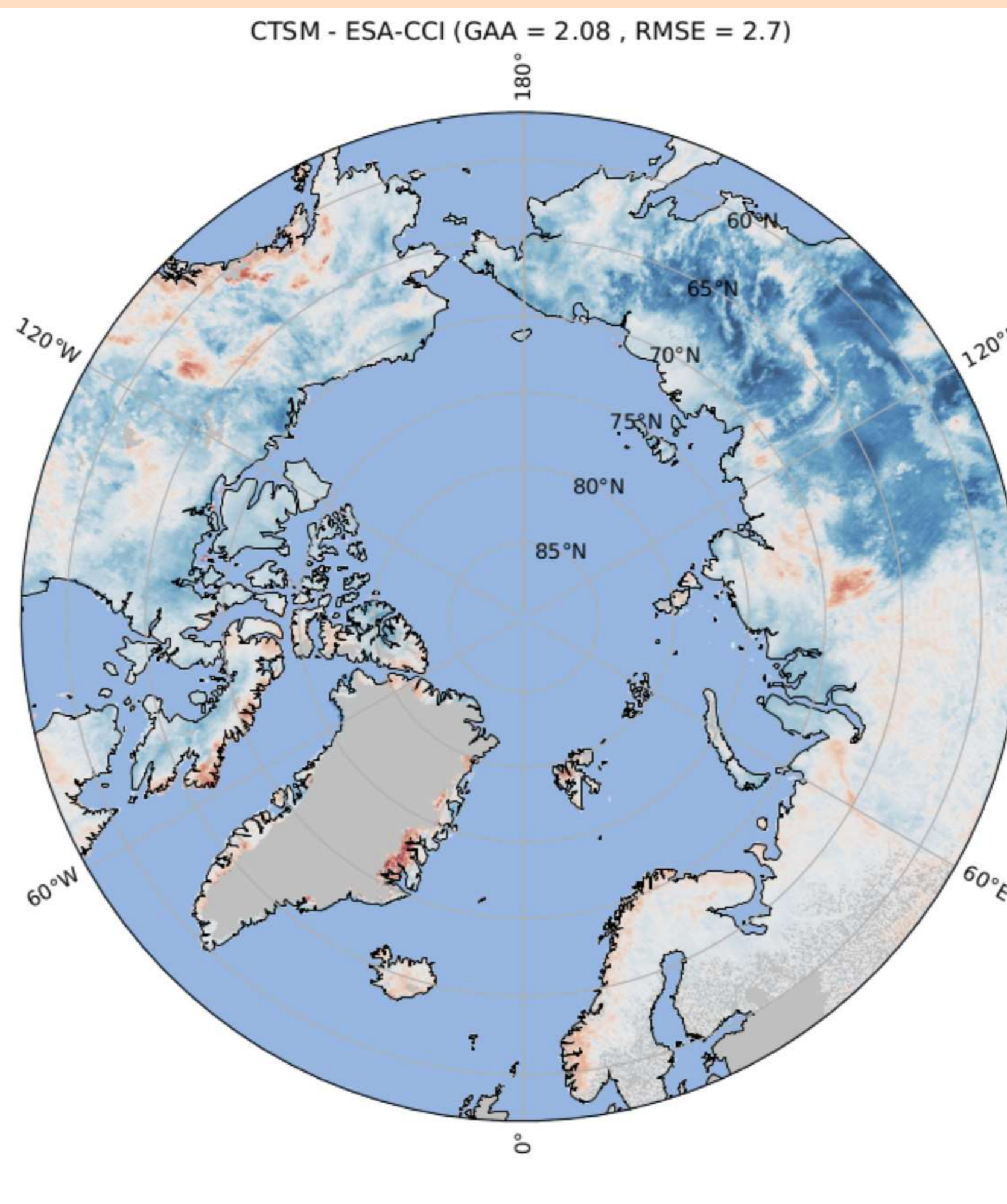
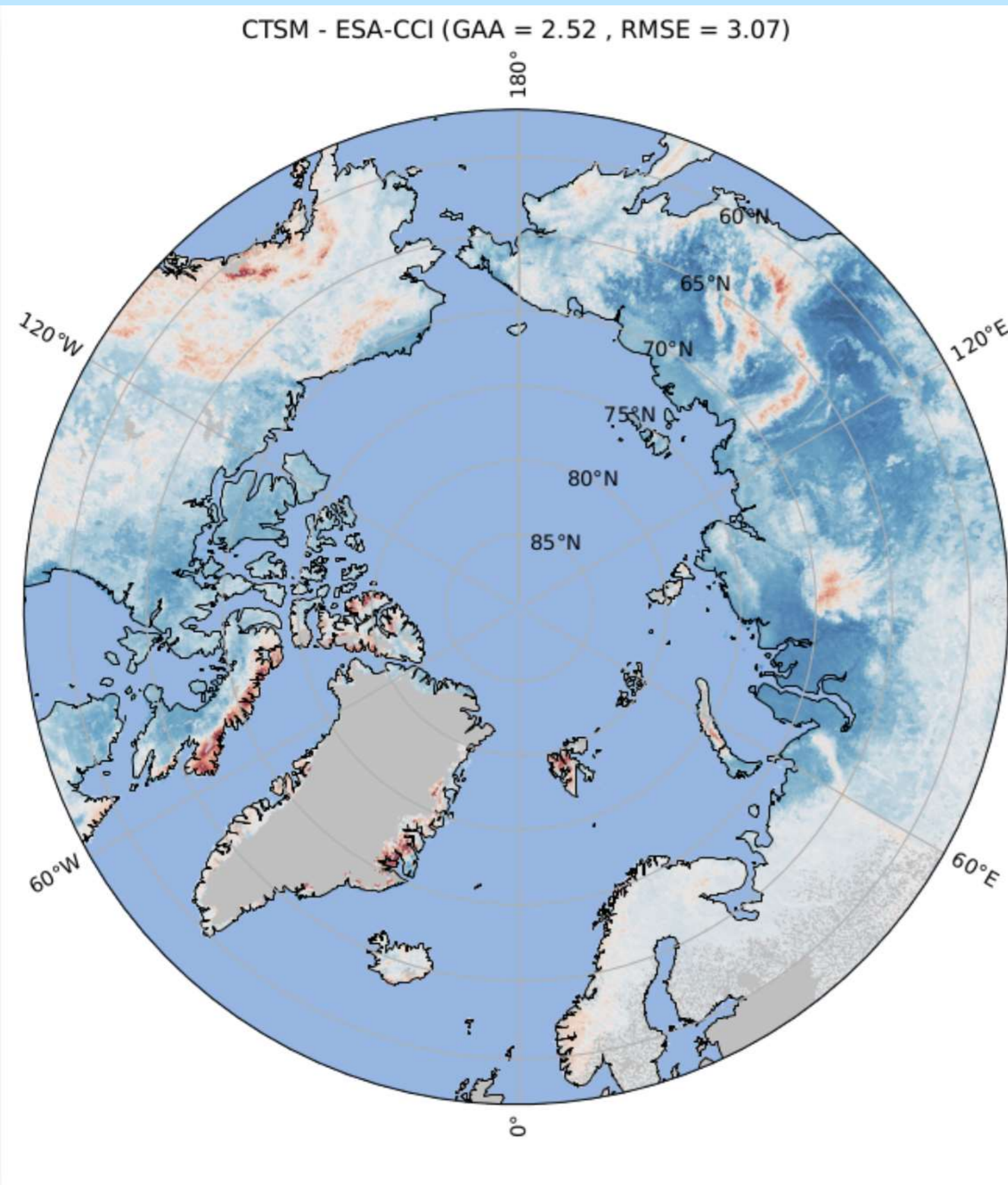


Run 001
ERA5
Default soil
1980-2021

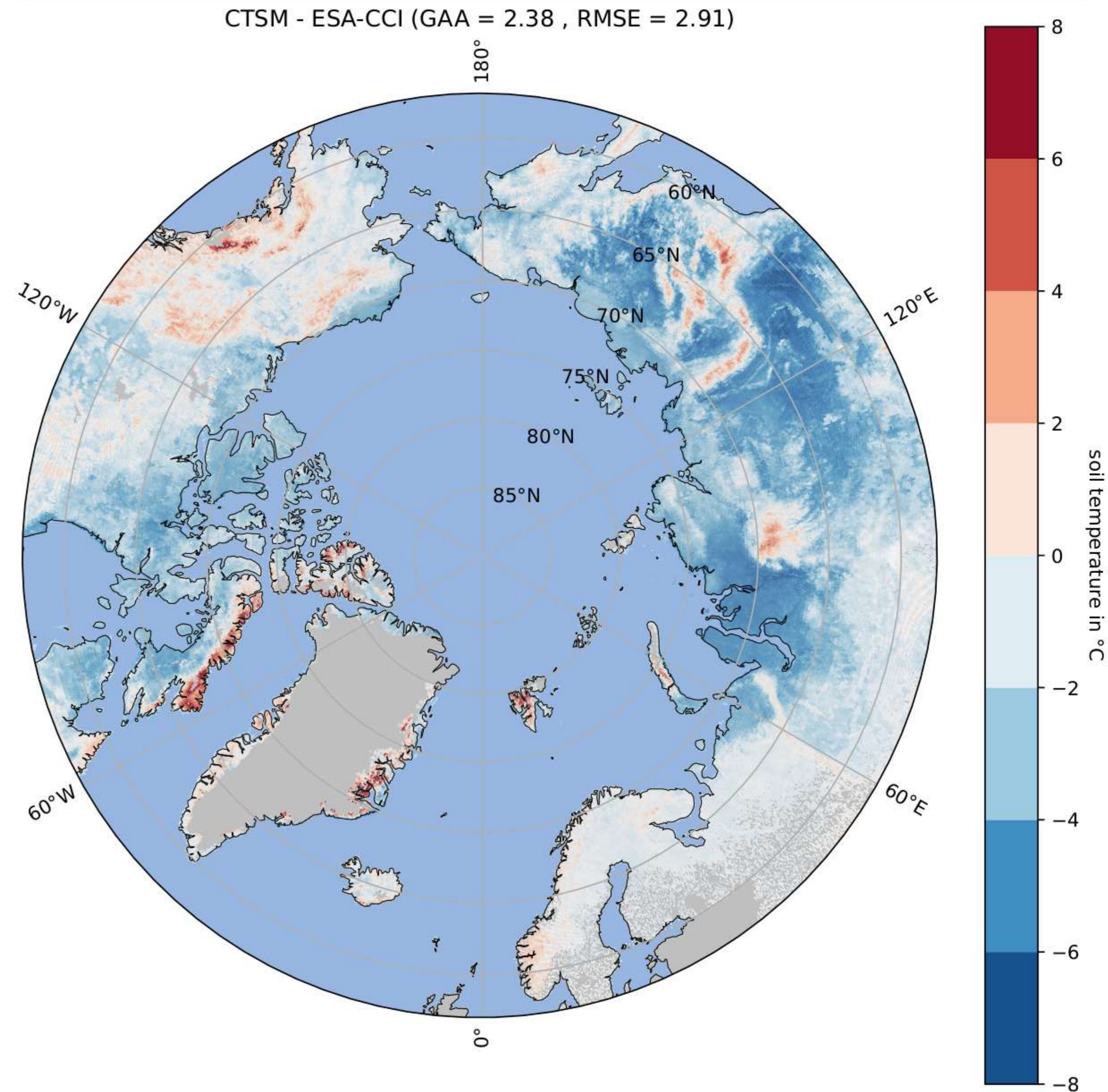
Run 002
GSWP3
Default soil
1980-2014

Run 005
ERA5
New soil
1980-2021

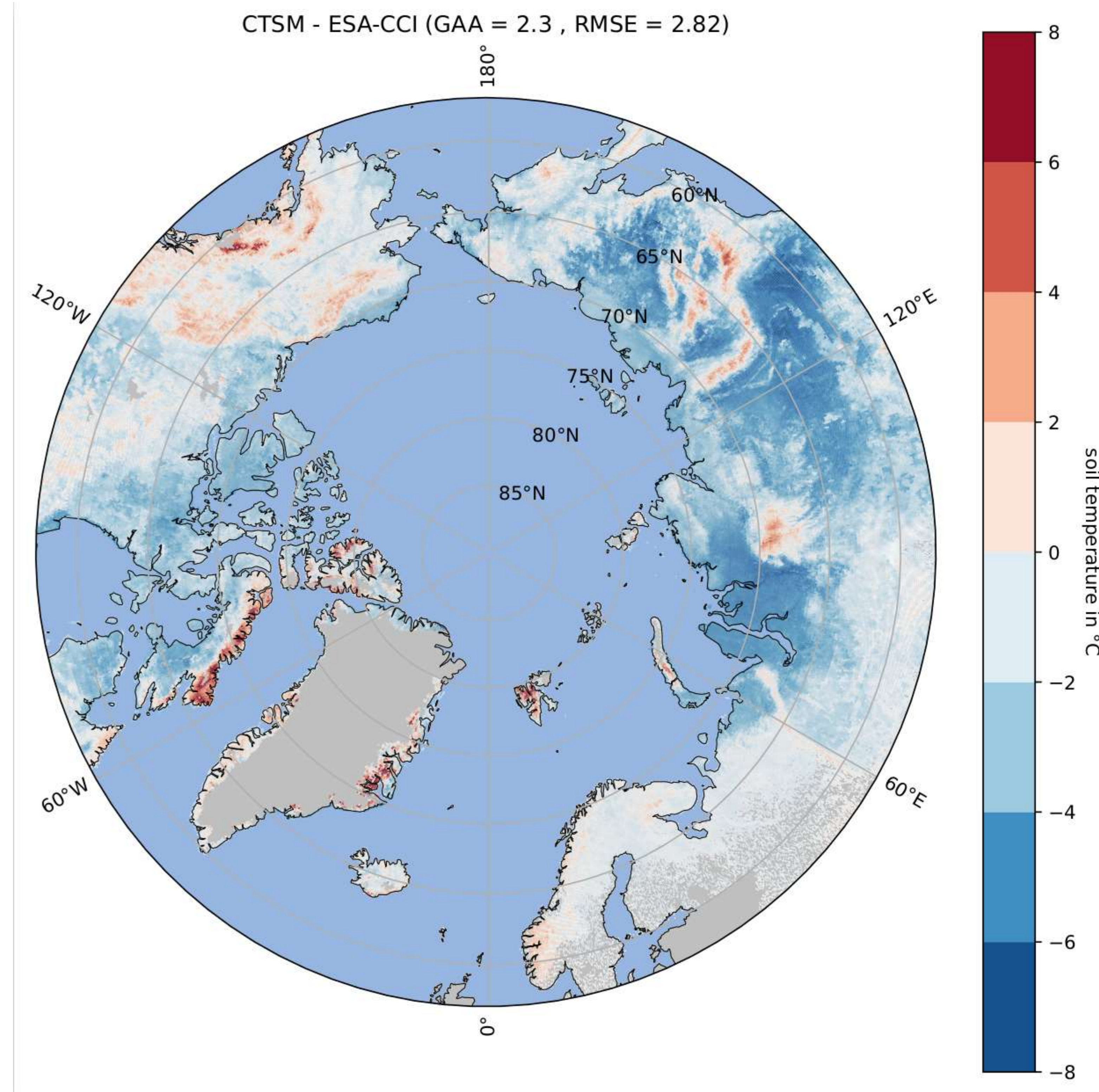
Soil temperature at 1m bias CTSM - ESACCI



Soil temperature bias at -5 m CTSM - ESACCI



Soil temperature bias at -10 m CTSM - ESACCI

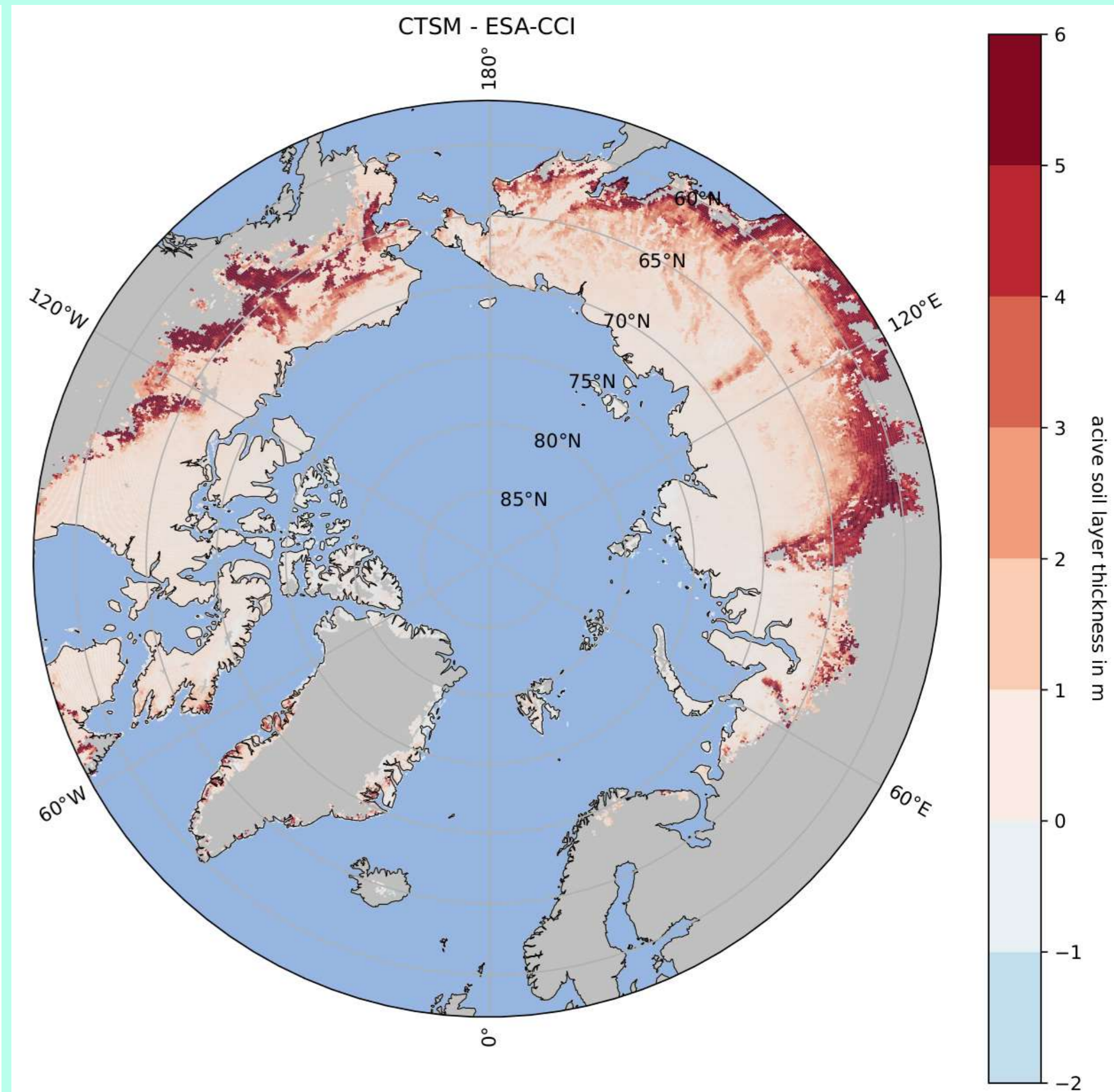
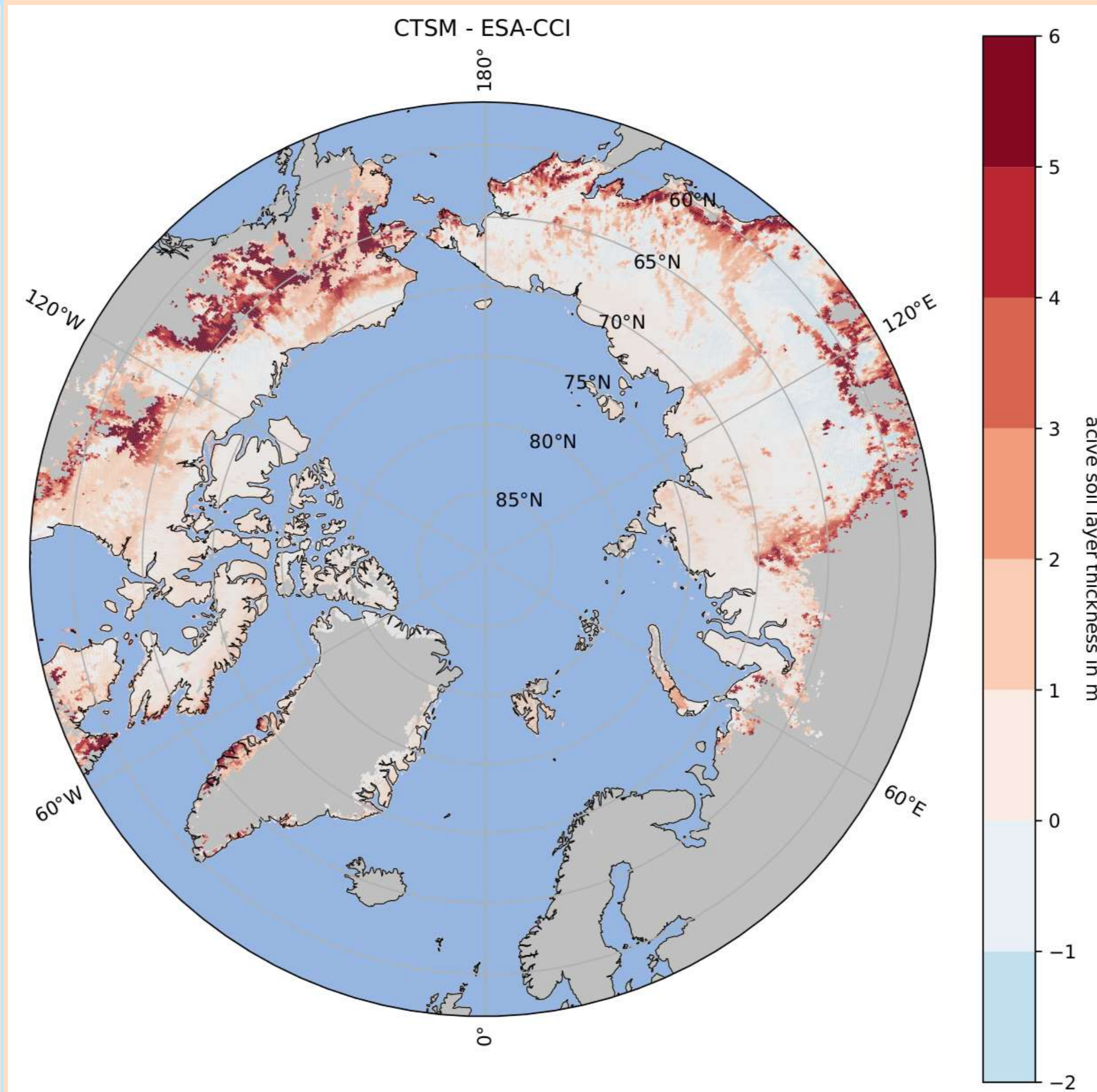
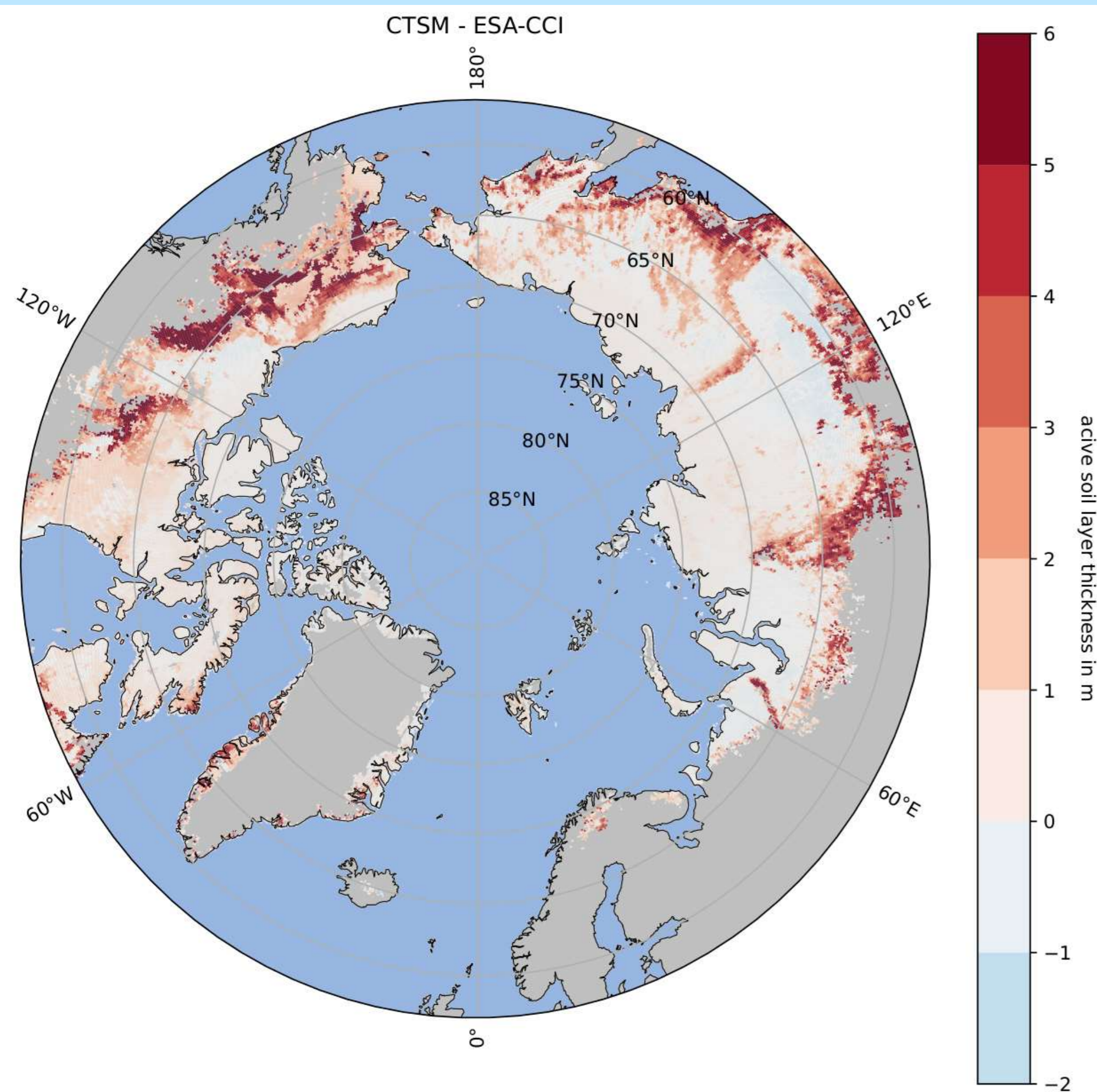


Run 001
ERA5
Default soil
1980-2021

Run 002
GSWP3
Default soil
1980-2014

Run 005
ERA5
New soil
1980-2021

ALT bias CTSM - ESACCI



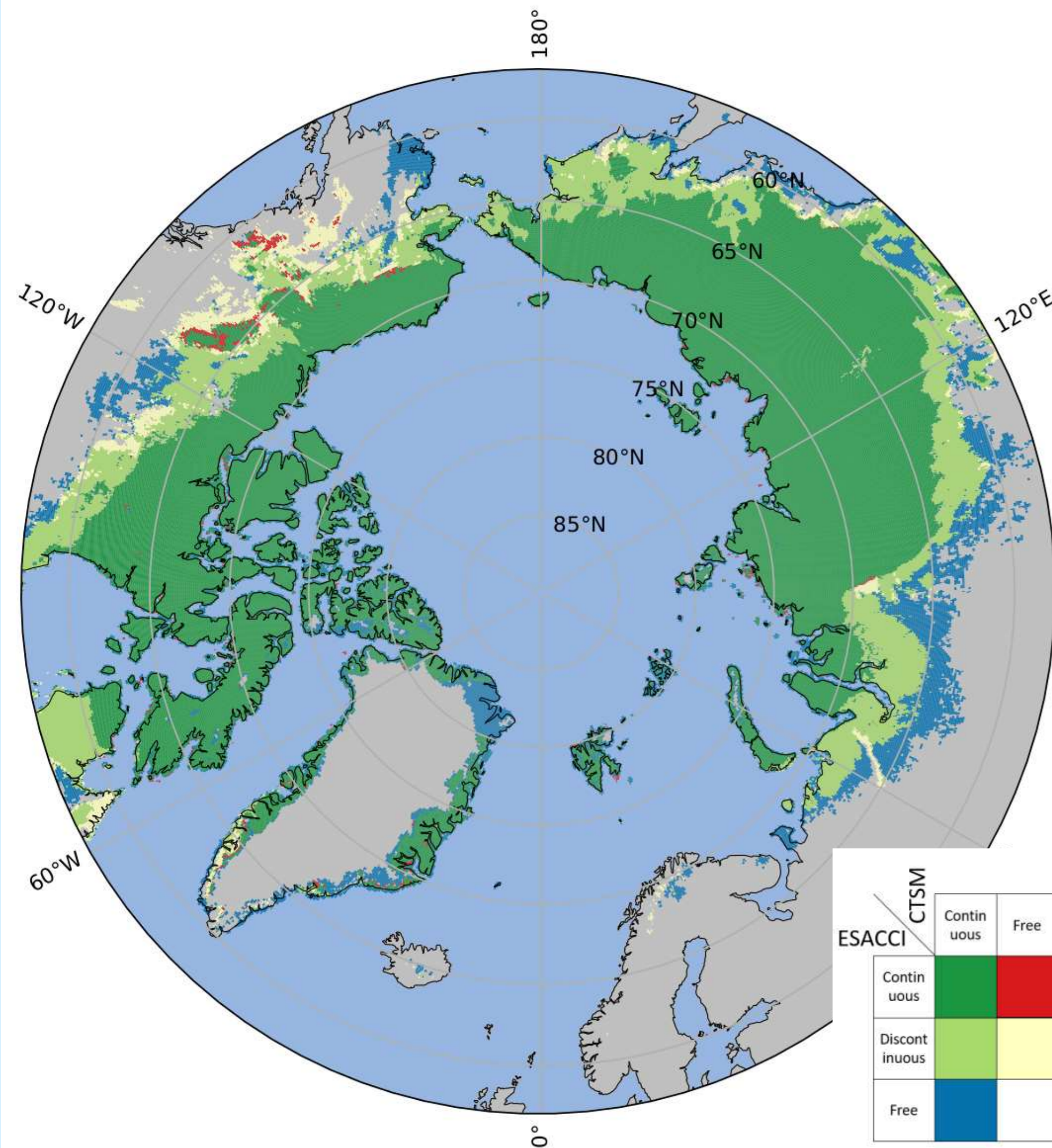
Run 001
ERA5
Default soil
1980-2021

Run 002
GSWP3
Default soil
1980-2014

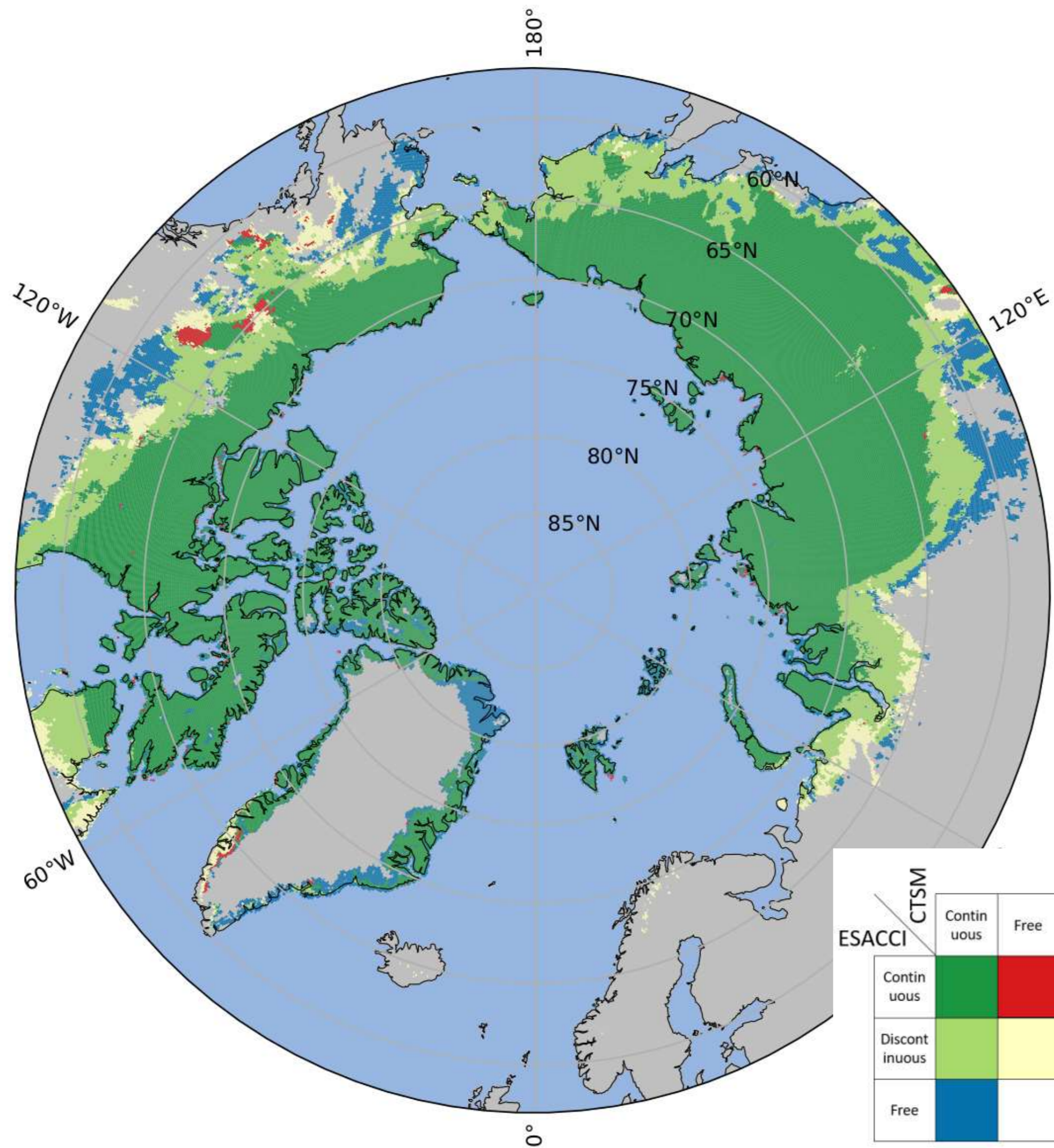
Run 005
ERA5
New soil
1980-2021

PFR extent CTSM – ESACCI

Permafrost extent area:
CTSM = 13.358 - ESACCI = 12.544 10e6km²



Permafrost extent area:
CTSM = 13.063 - ESACCI = 12.544 10e6km²

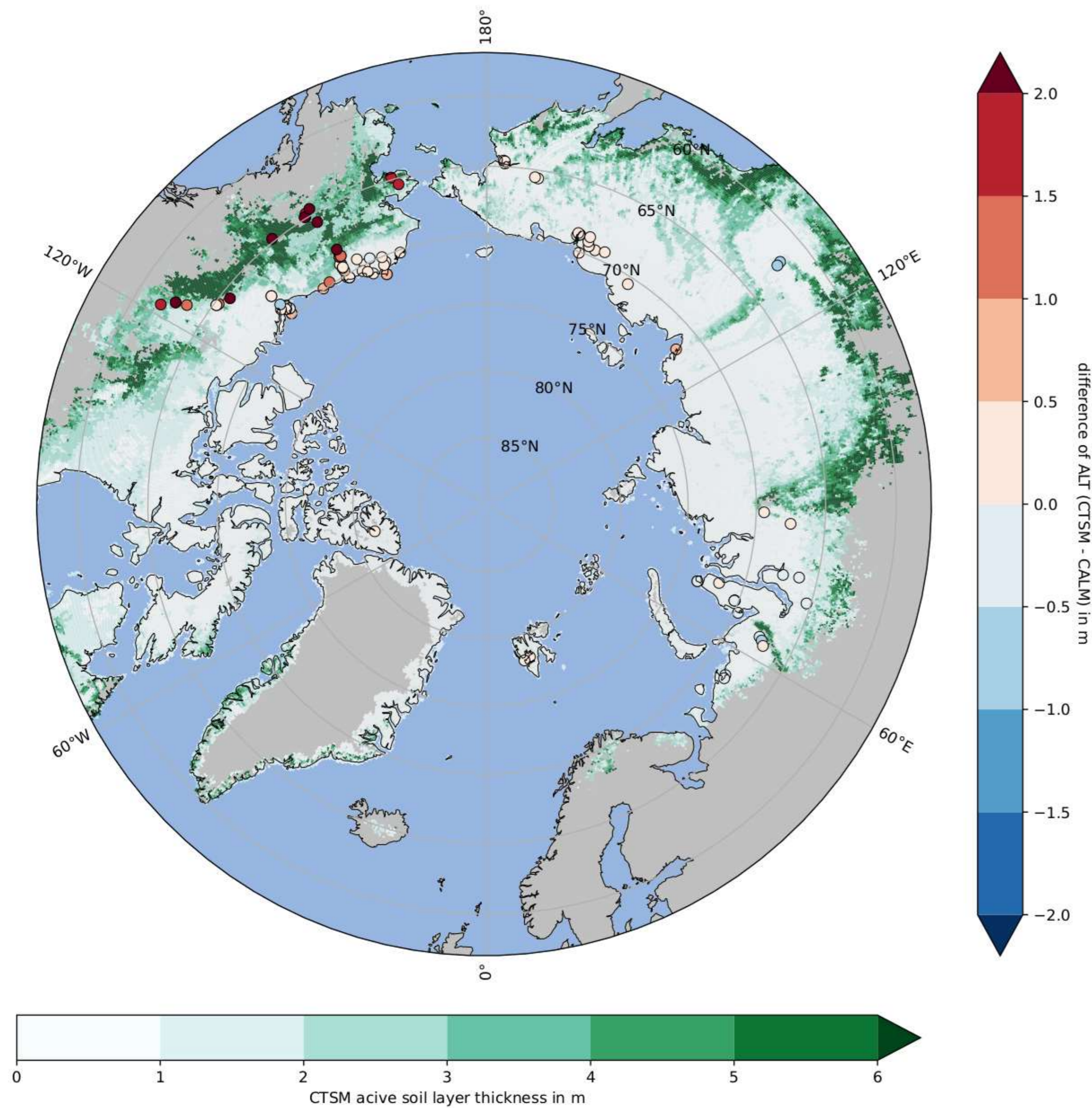


Permafrost extent area:
CTSM = 12.857 - ESACCI = 12.544 10e6km²

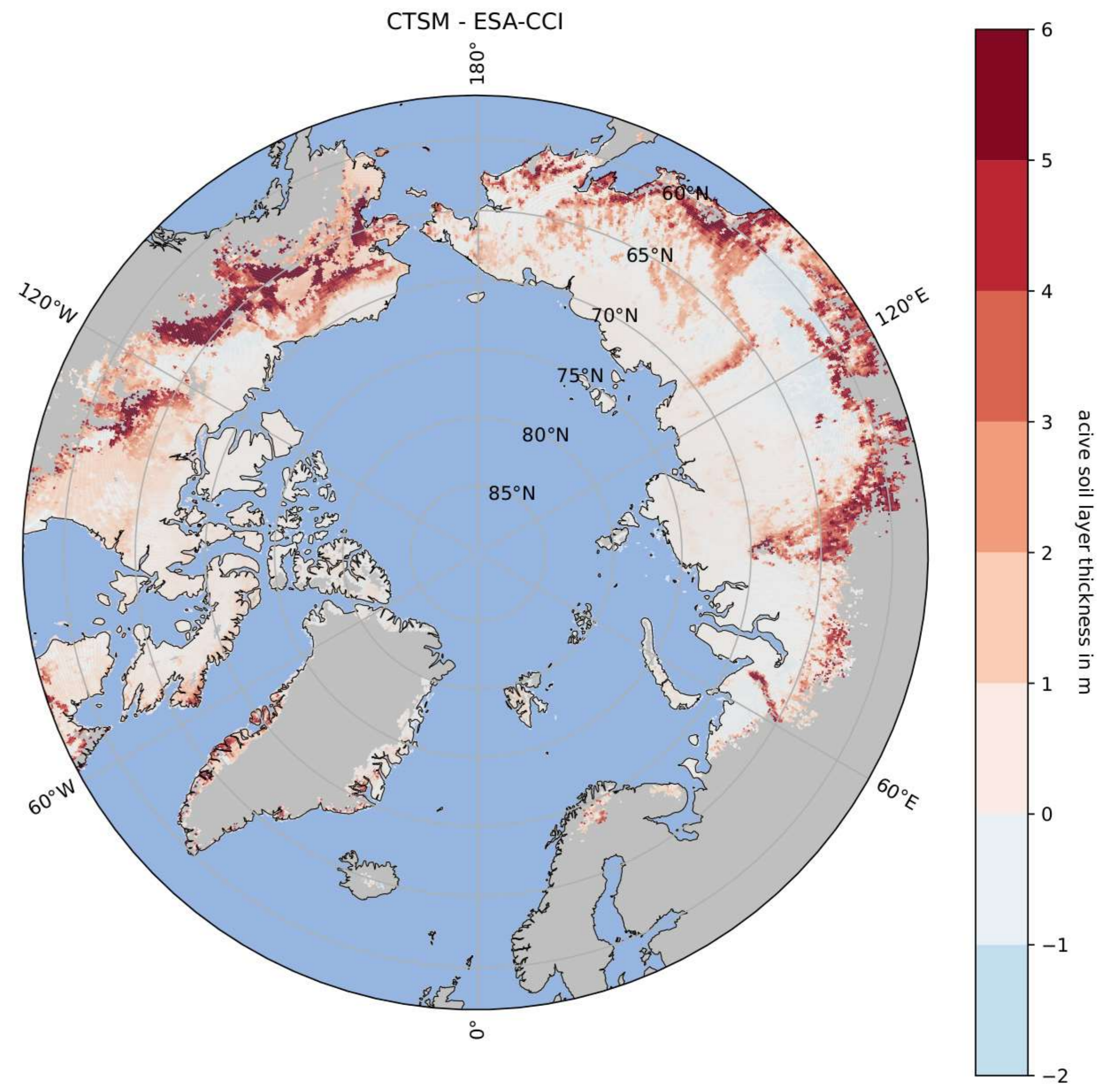


Active Layer Thickness

CTSM - CALM

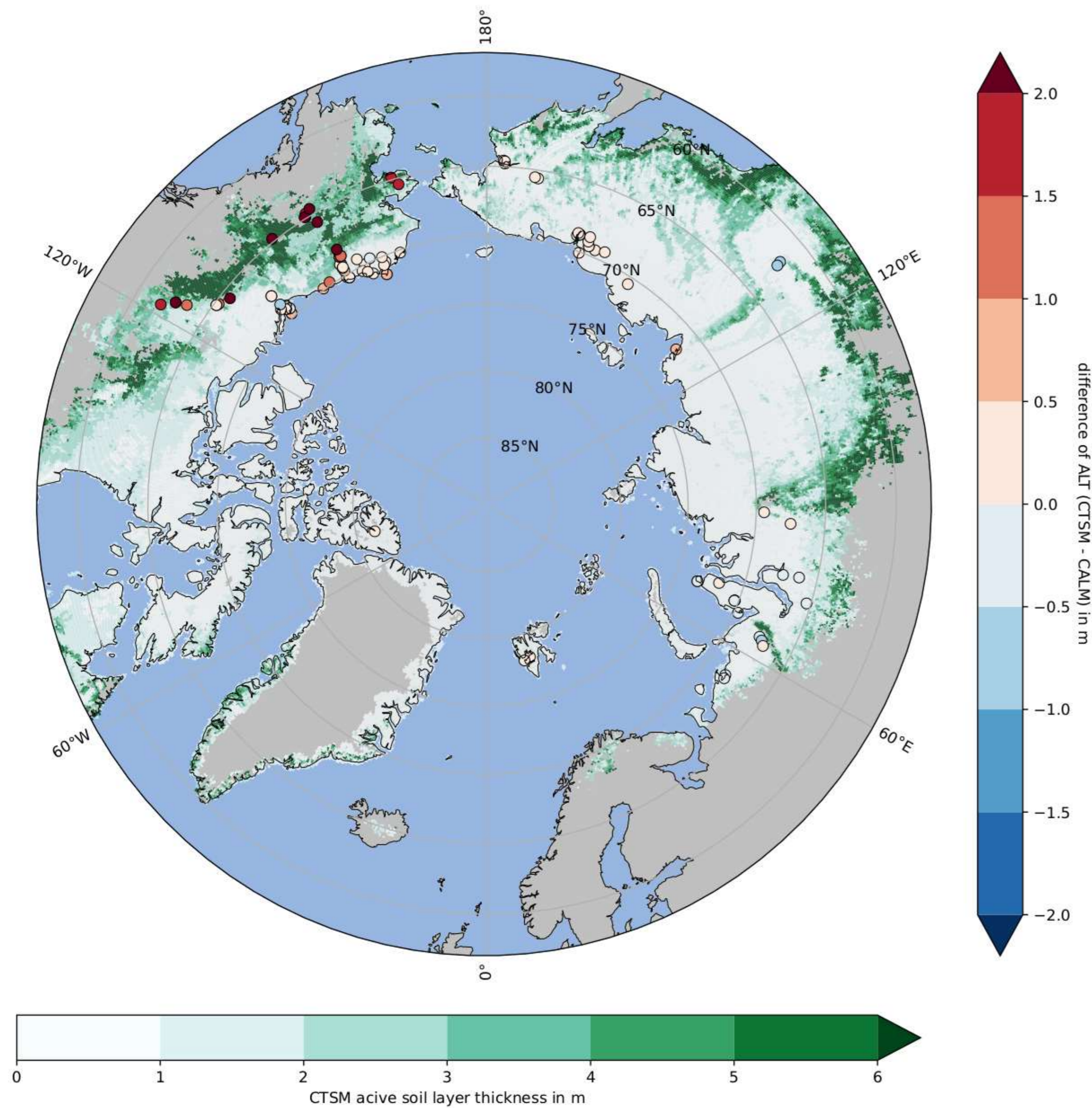


CTSM - ESACCI

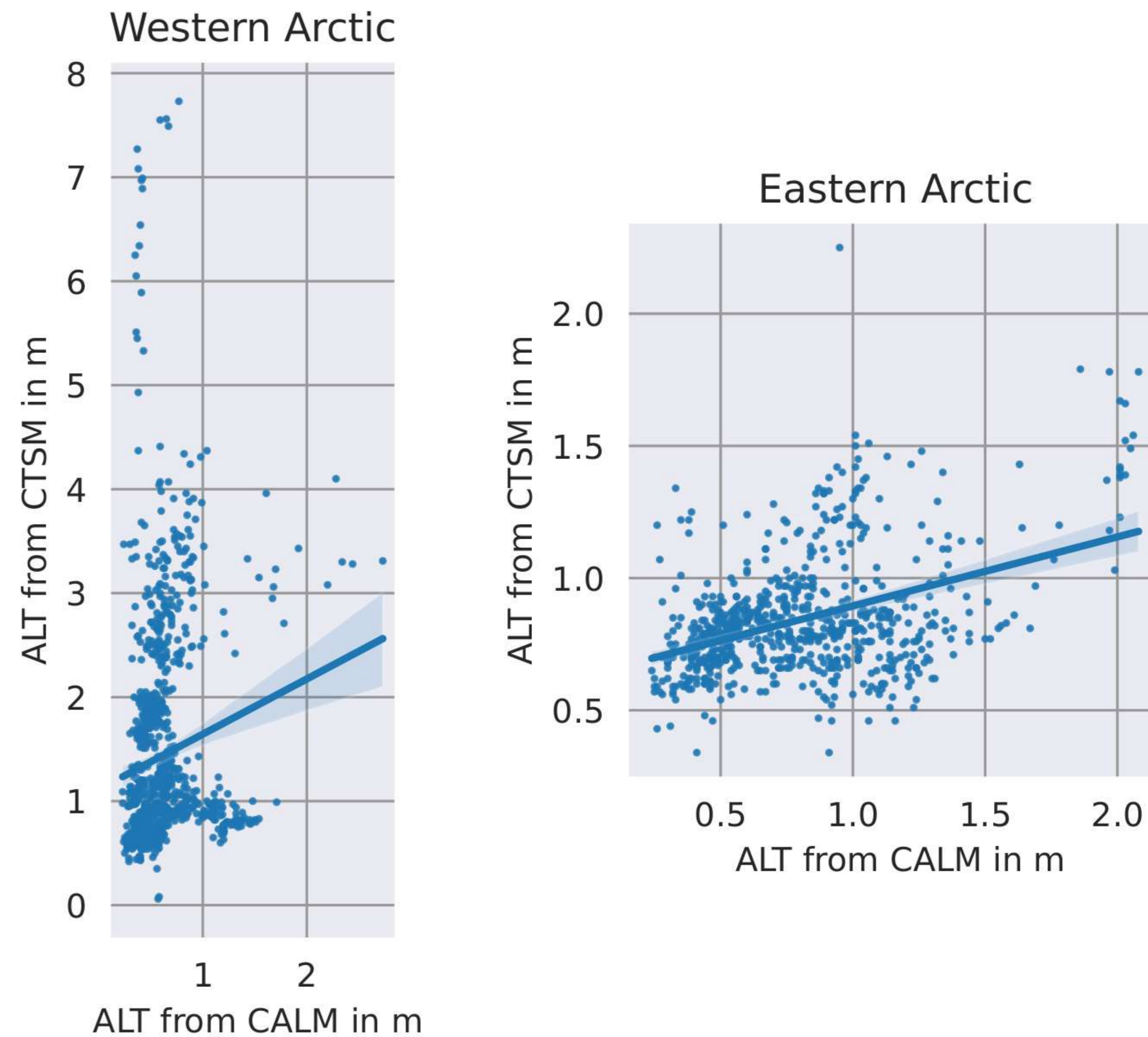


Active Layer Thickness

Period average



Not period average



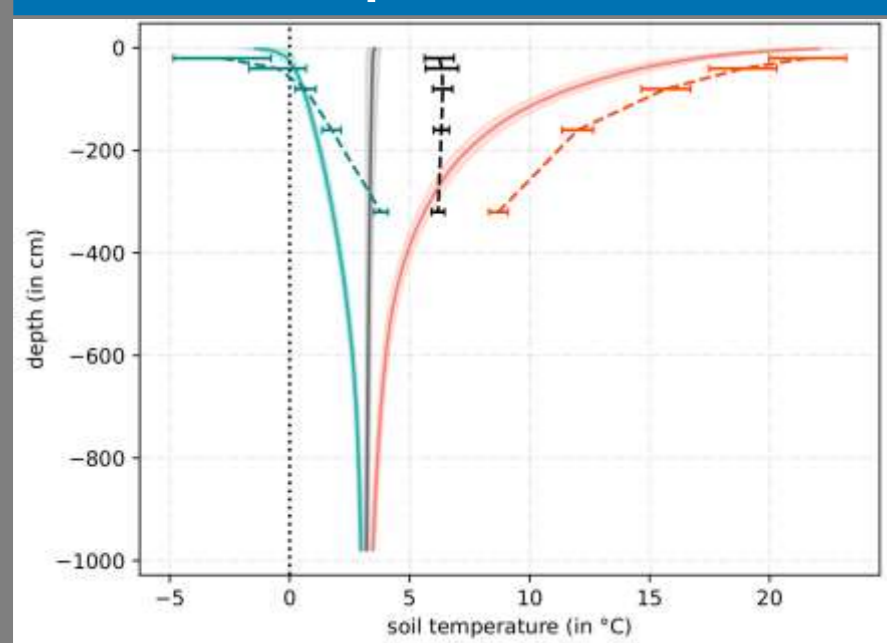
Observation products

554 in-situ stations

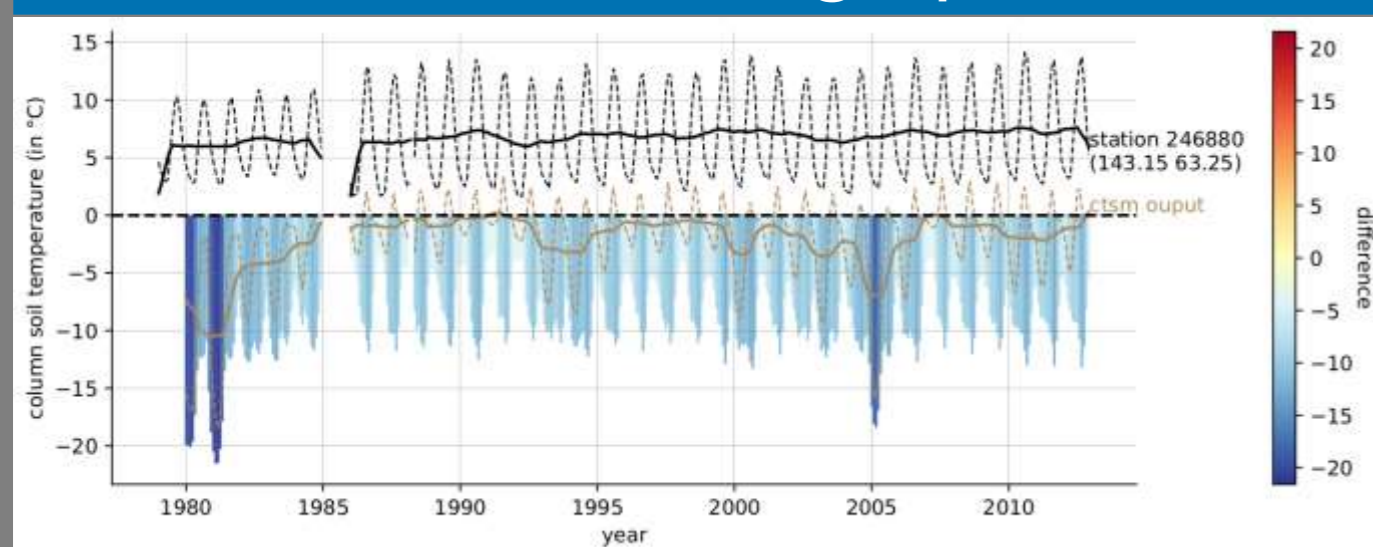
CALM network

ESACCI products

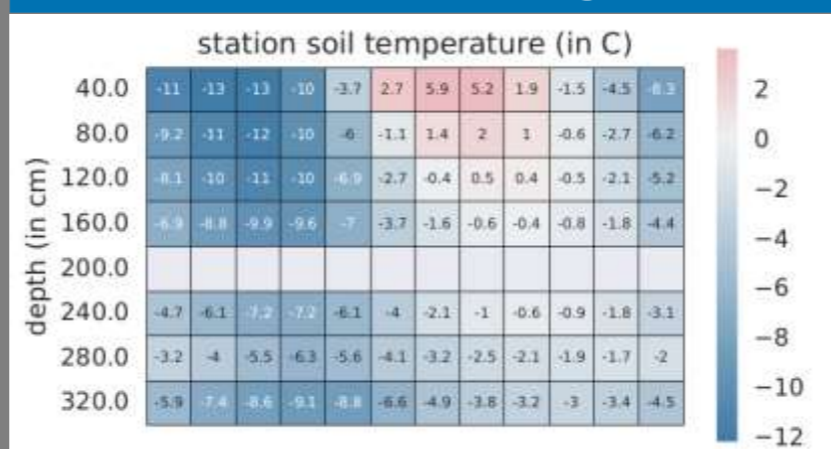
Trumpet curves



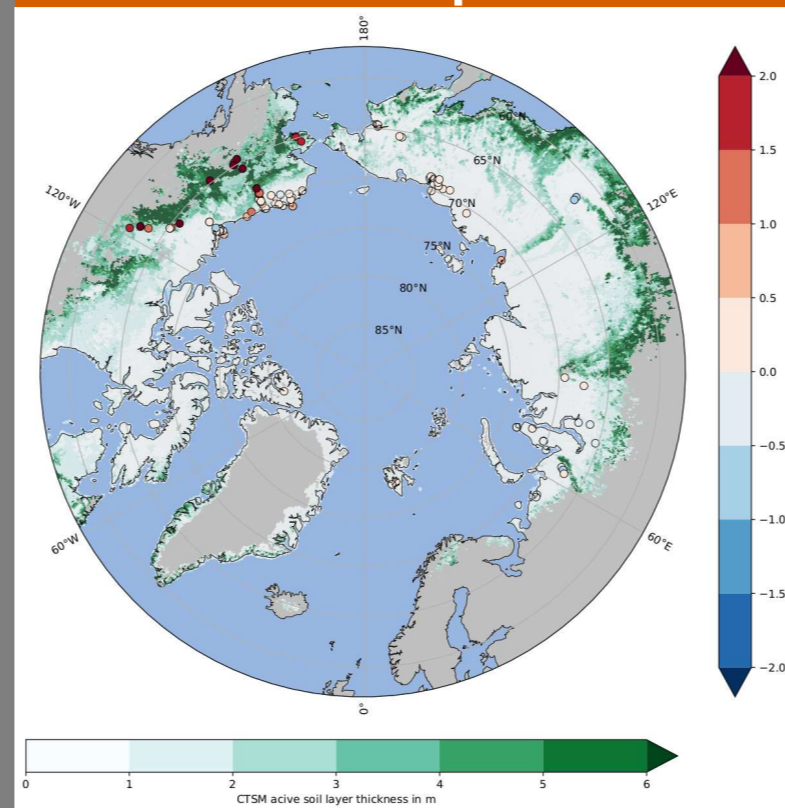
Time series graph



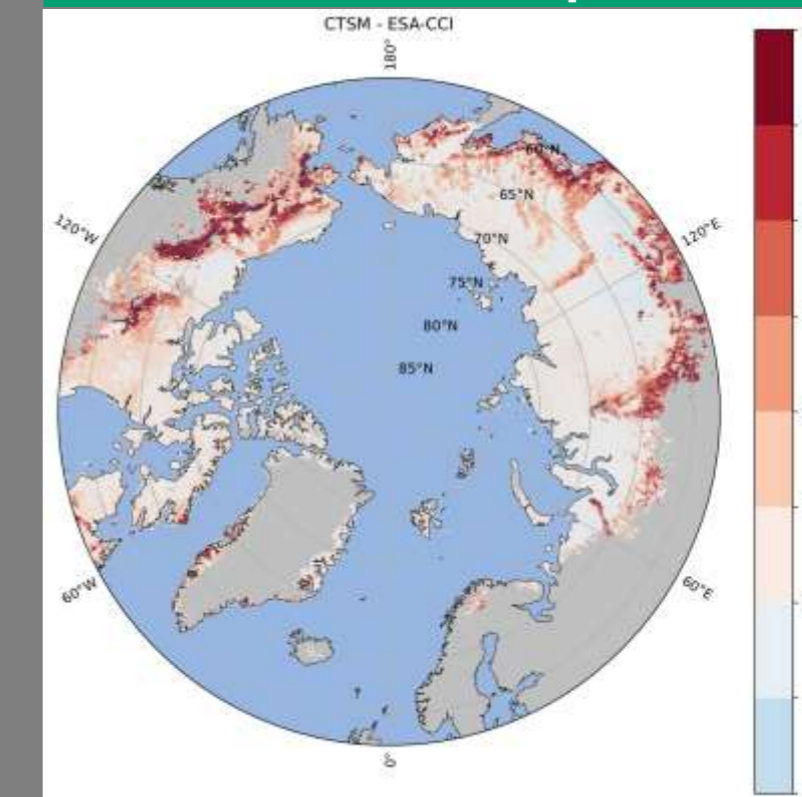
Heatmap region



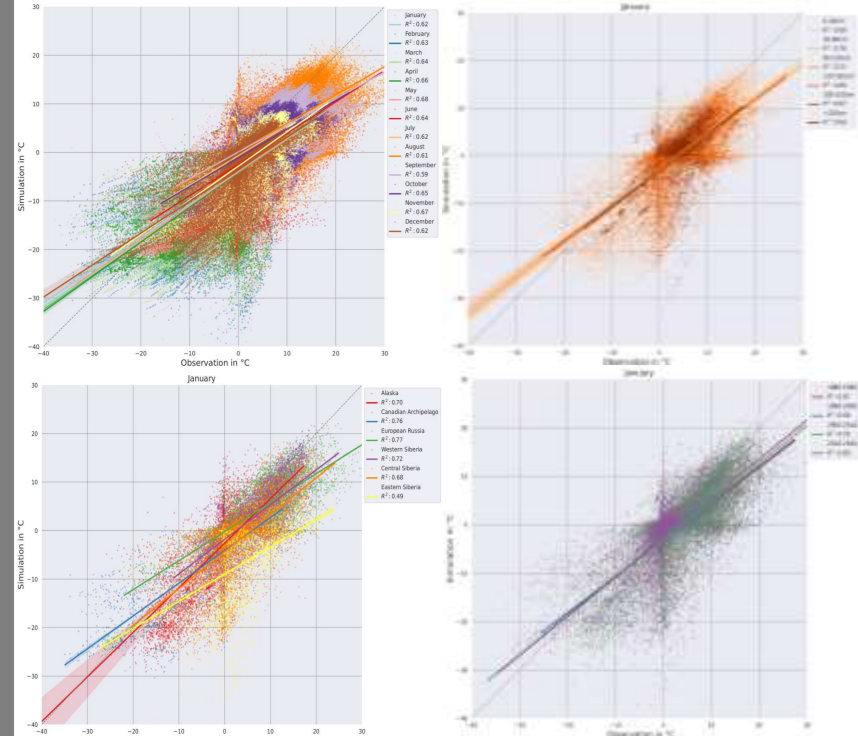
Map



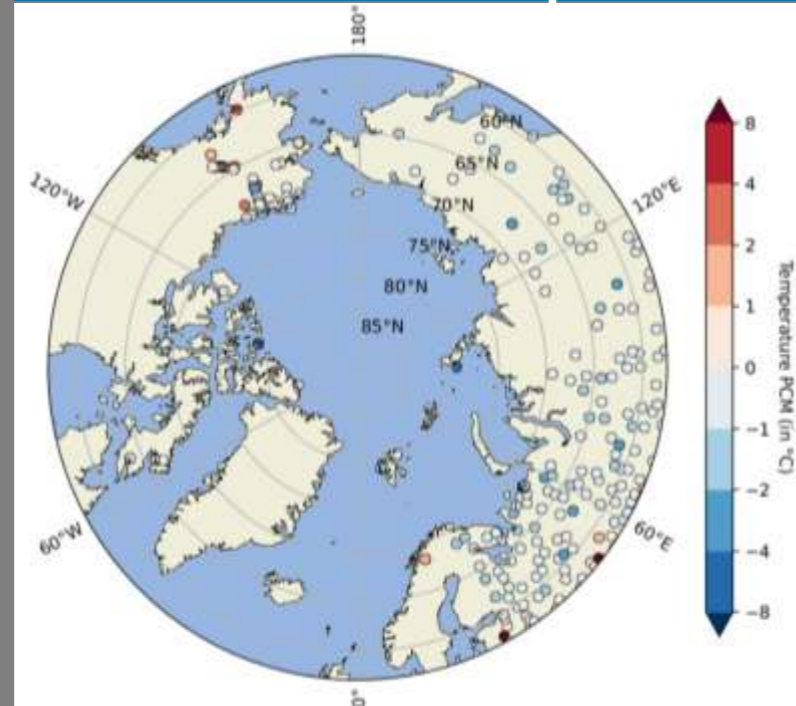
ALT map



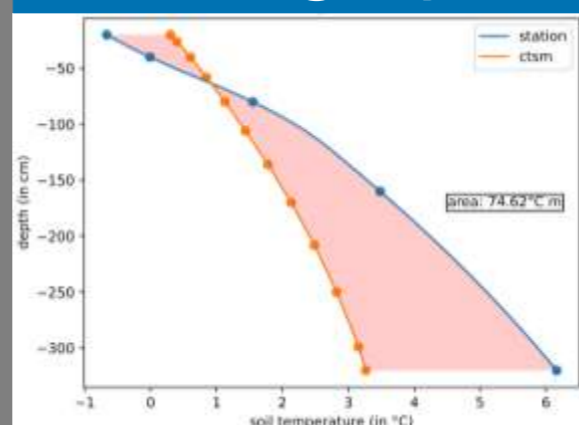
Scatter plot



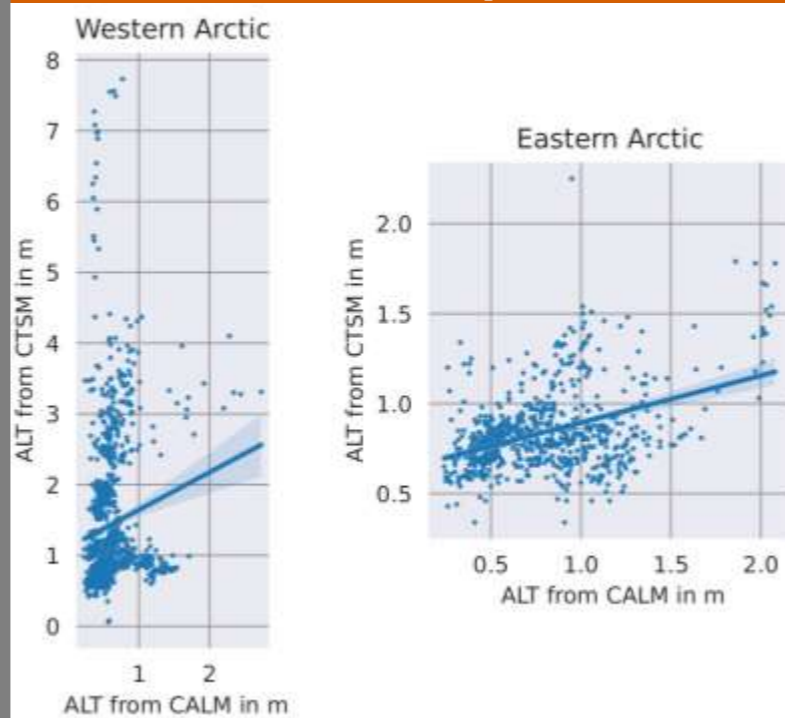
PCM map



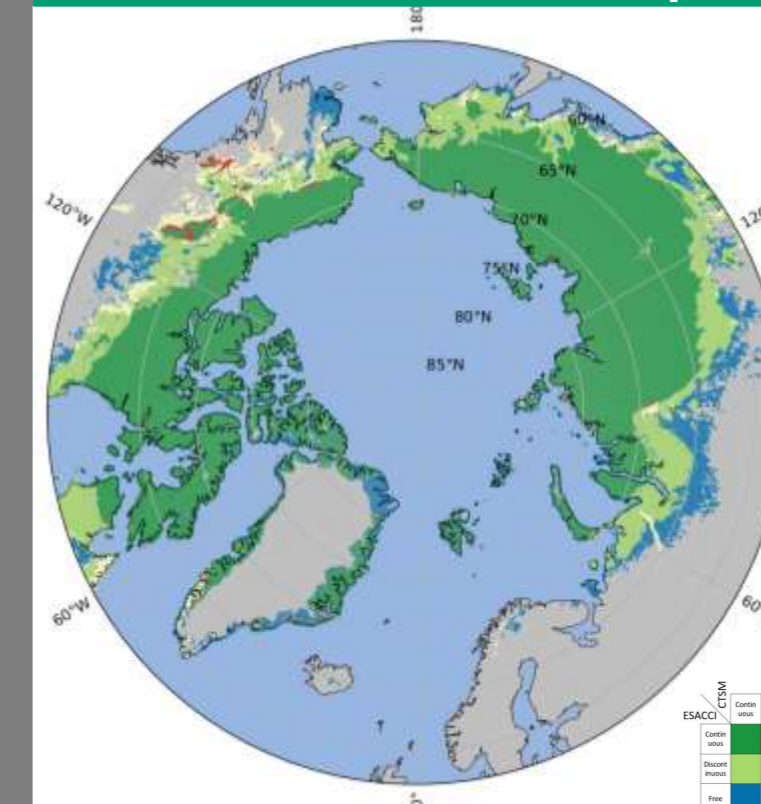
PCM graph



Scatter plot



PFR extent map



TSOI map

