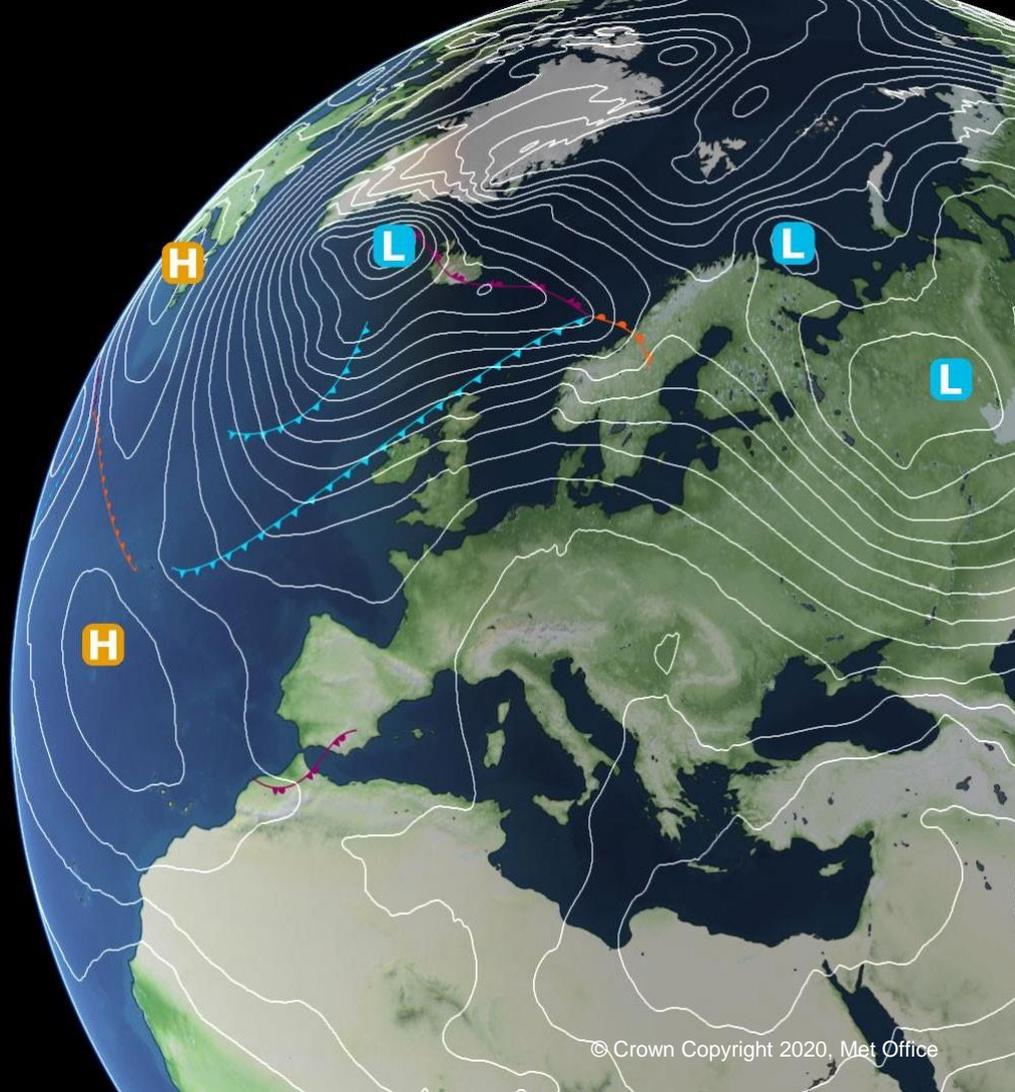


Permafrost in CMIP6

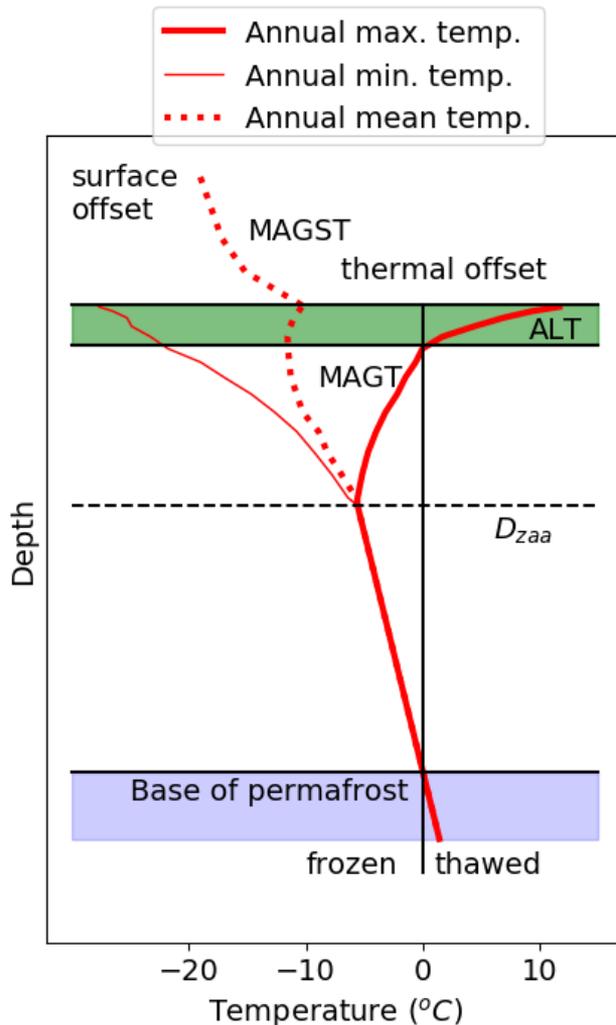
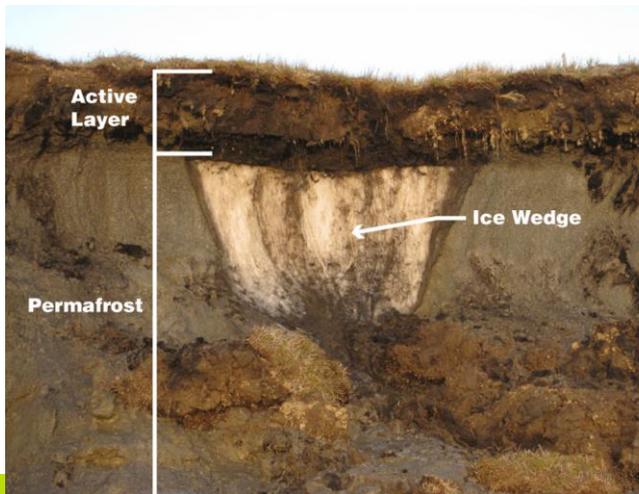
Eleanor Burke



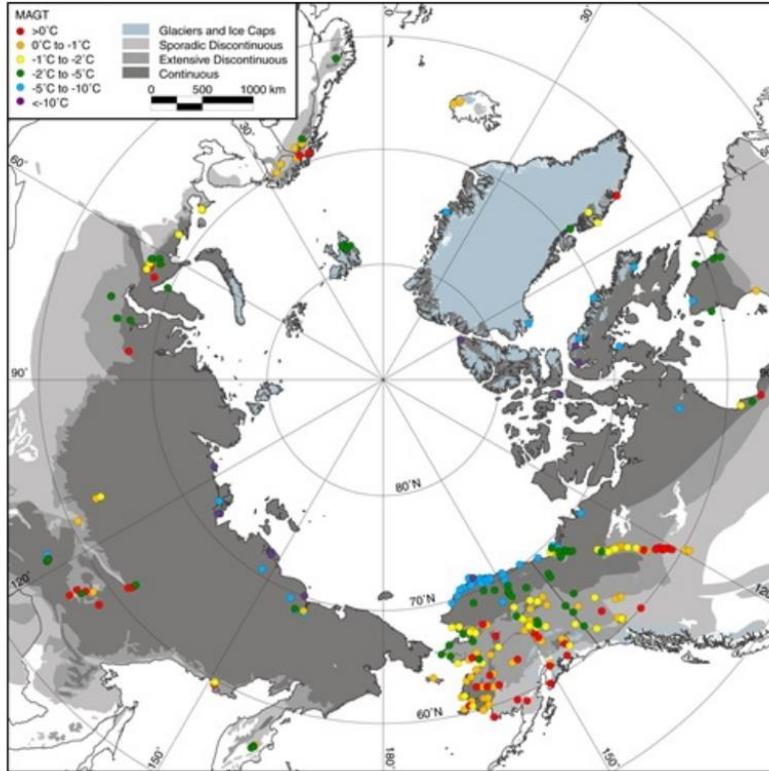


Permafrost in CMIP6

Alaska (NPS Alaska Region)



Observations are sparse

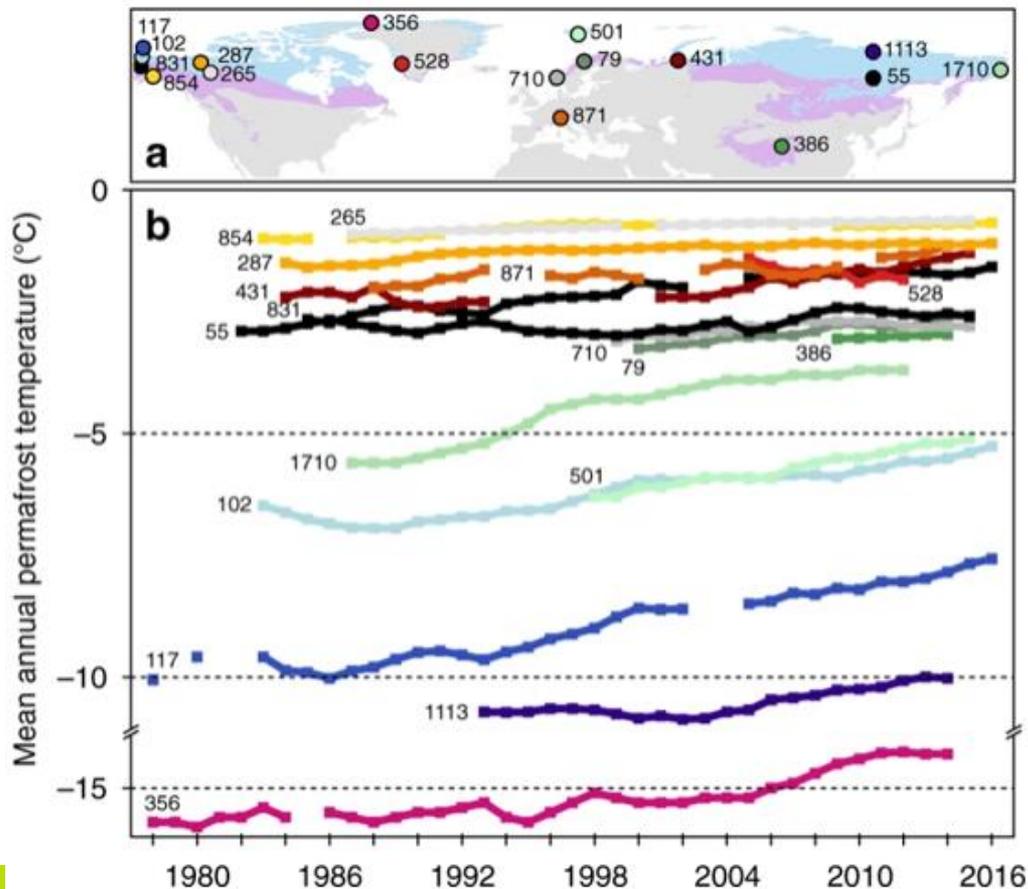


What are the problems?

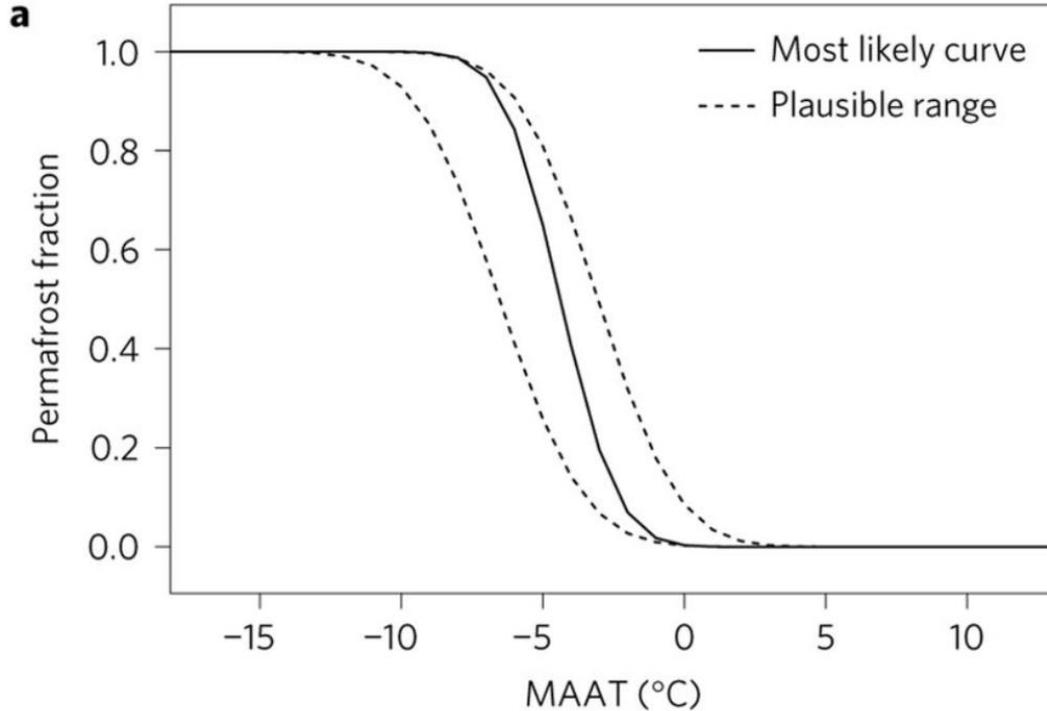
- Permafrost is under ground.
- Most of the Arctic is uninhabited (very hard to get there!)
- Batteries do not work at -40°C .

Circum-Arctic view of mean annual ground temperature (MAGT) in permafrost during the International Polar Year (IPY 2007-2009; from Romanovsky et al., 2010).

Borehole temperatures



Air temp. vs probability of permafrost

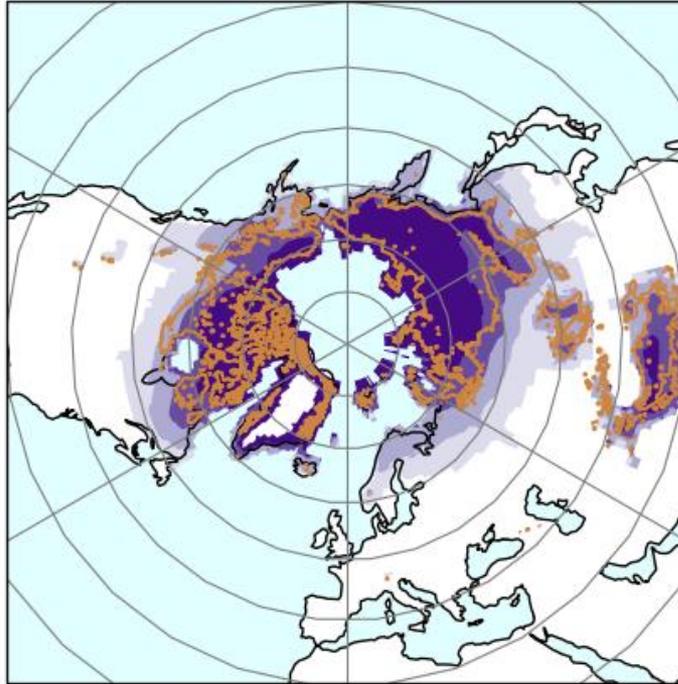


Observed relationship between probability of permafrost and local mean annual air temperature.

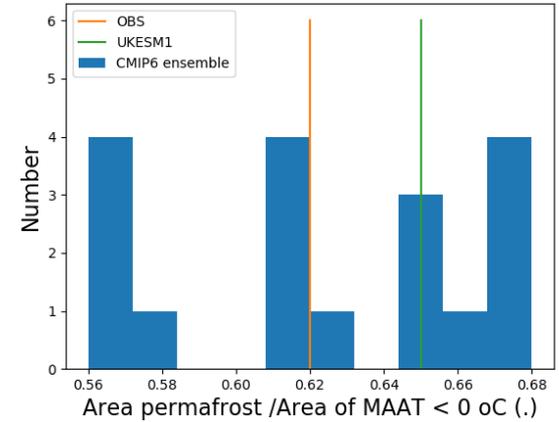
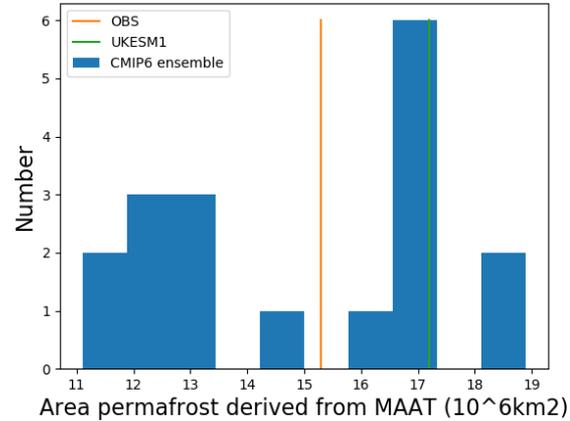
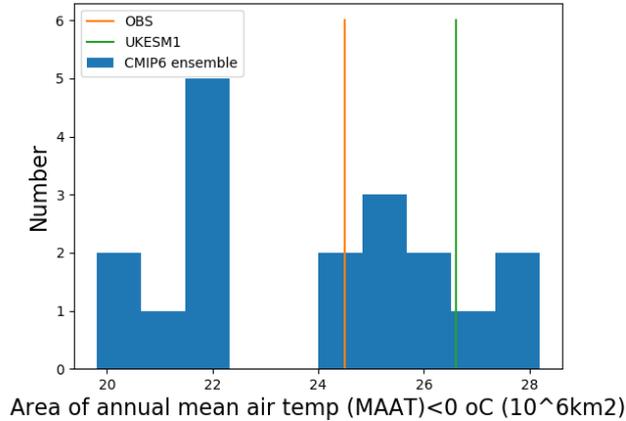
Estimates of permafrost and permafrost loss derived using this method do not require a land surface model.

Permafrost from air temperature

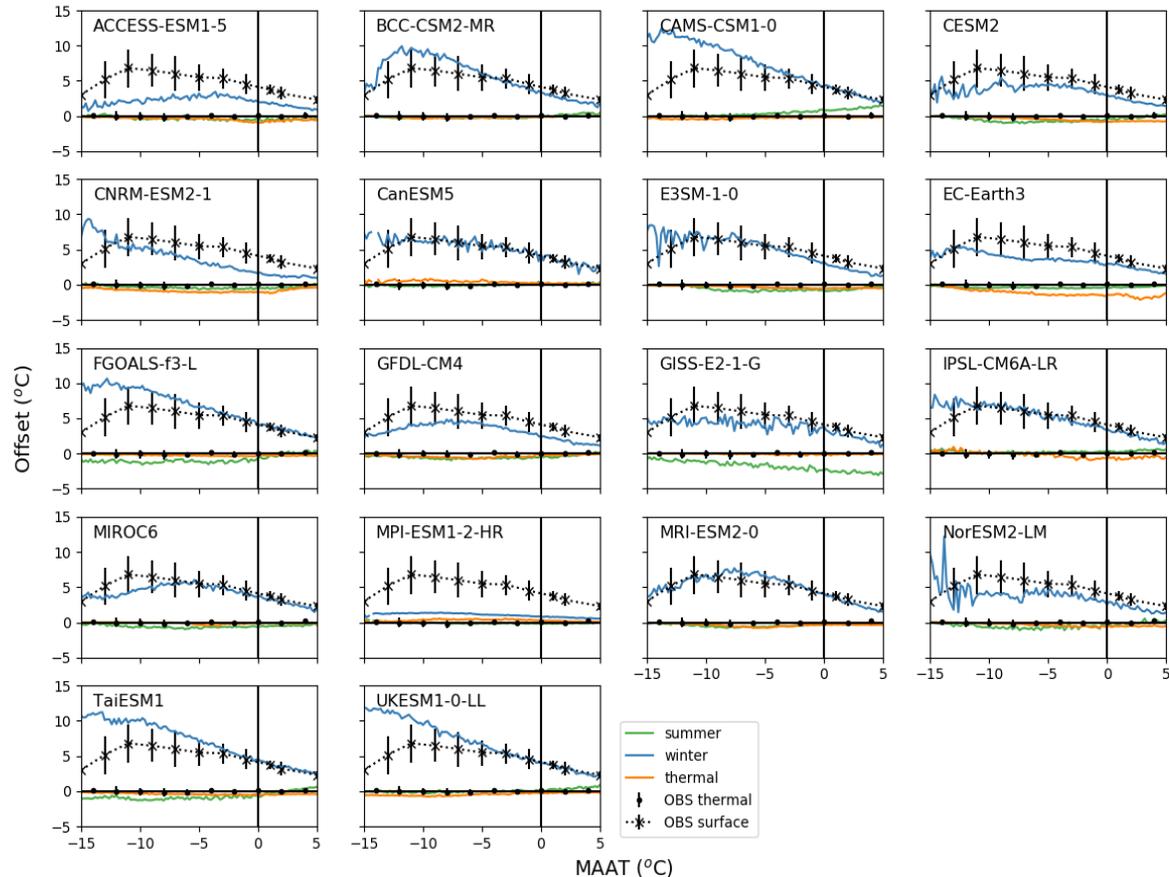
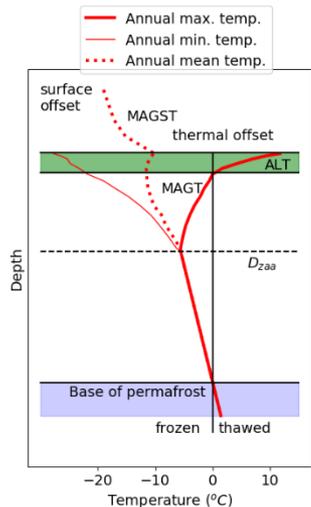
Ensemble: Chadburn



Permafrost from air temperature

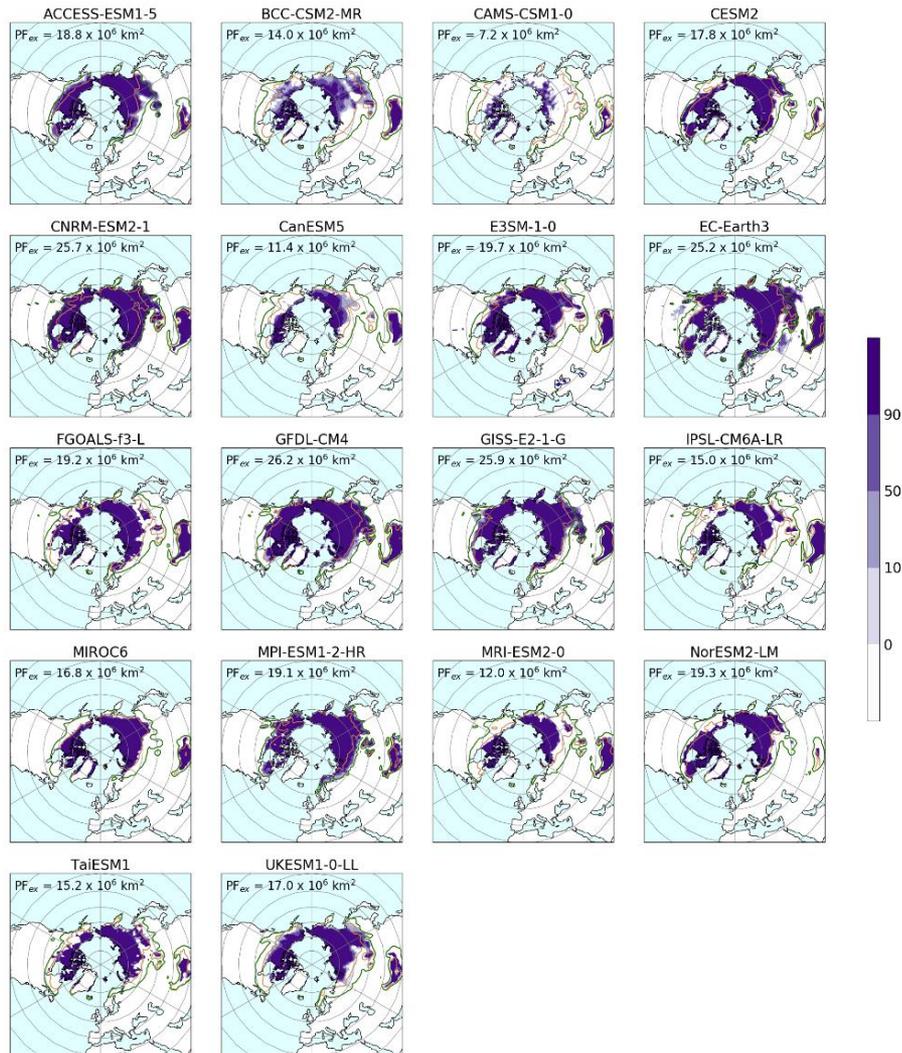


Land surface offsets

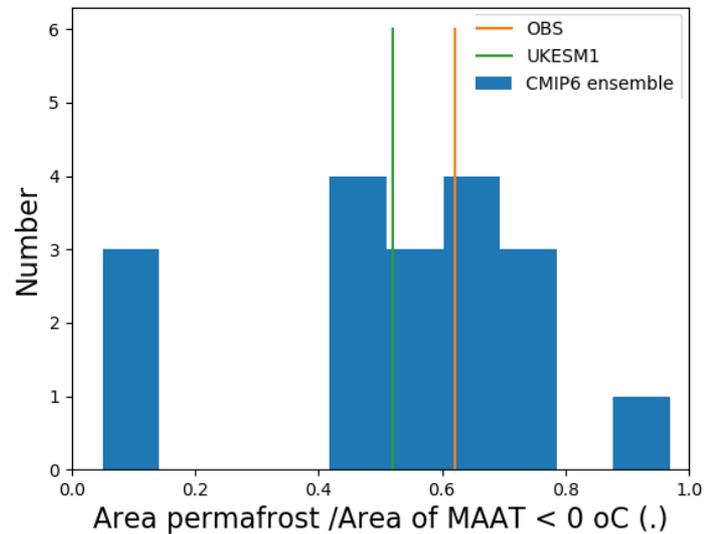
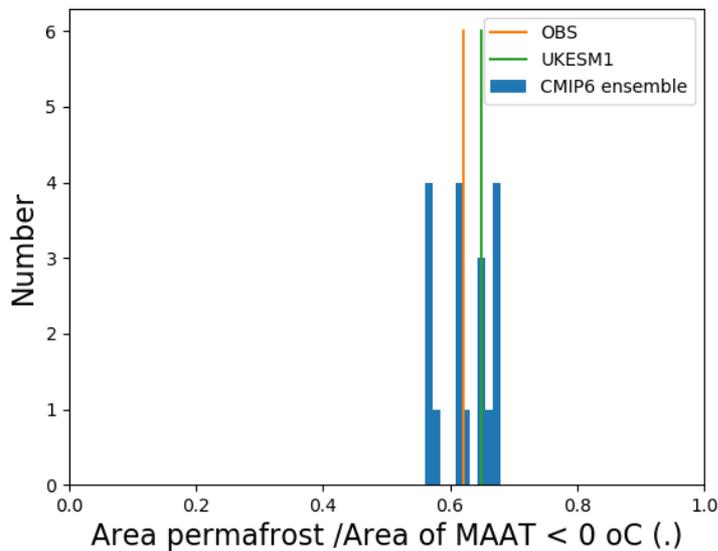


Snow insulation is important for presence/absence of permafrost

Permafrost area



Permafrost area



Land surface components

| Model | Institute | Land model | No. layers | Soil depth (m) | $D_{z_{aa}}$ (m) |
|-----------------|-------------------------------|--|------------|----------------|------------------|
| BCC-CSM2-MR | BCC | BCC_AVIM2 | 10 | 2.9 | - |
| BCC-ESM1 | BCC | BCC_AVIM2 | 10 | 2.9 | - |
| CESM2 | NCAR | CLM5 | 25 | 42.0 | 19.4 |
| CESM2-WACCM | REF | CLM5 | 25 | 42.0 | 19.9 |
| CNRM-CM6-1 | CNRM-CERFACS | Surfex 8.0c | 14 | 10.0 | - |
| CNRM-ESM2-1 | CNRM-CERFACS | Surfex 8.0c | 14 | 10.0 | - |
| CanESM5 | CCCma | CLASS3.6/CTEM1.2 | 3 | 4.1 | - |
| EC-Earth3 | EC-Earth-Consortium | HTESEL | 4 | 1.9 | - |
| GFDL-CM4 | NOAA-GFDL | GFDL-LM4.0.1 | 20 | 8.8 | - |
| GISS-E2-1-G | NASA-GISS | GISS LSM 6 | 2.7 | - | - |
| GISS-E2-1-H | NASA-GISS | GISS LSM 6 | 2.7 | - | - |
| HadGEM3-GC31-LL | MOHC, NERC | JULES-HadGEM3-GL7.1 | 4 | 2.0 | - |
| IPSL-CM6A-LR | IPSL | ORCHIDEE (v2.0, Water /Carbon/Energy mode) | 18 | 65.6 | 16.0 |
| MIROC6 | MIROC | MATSIRO6.0 | 6 | 9.0 | - |
| MIROC-ES2L | MIROC | MATSIRO6.0+ VISIT-e ver.1.0 | 6 | 9.0 | - |
| MPI-ESM1-2-HR | MPI-M, DWD DKRZ | JSBACH3.20 | 5 | 7.0 | - |
| MRI-ESM2-0 | MRI | HAL 1.0 14 | 8.5 | - | - |
| NorESM2-LM | NCC | CLM | 25 | 42.0 | 18.9 |
| UKESM1-0-LL | MOHC, NERC, NIMS-KMA, NIWA | JULES-ES-1.0 | 4 | 2.0 | - |

More layers in some soil schemes

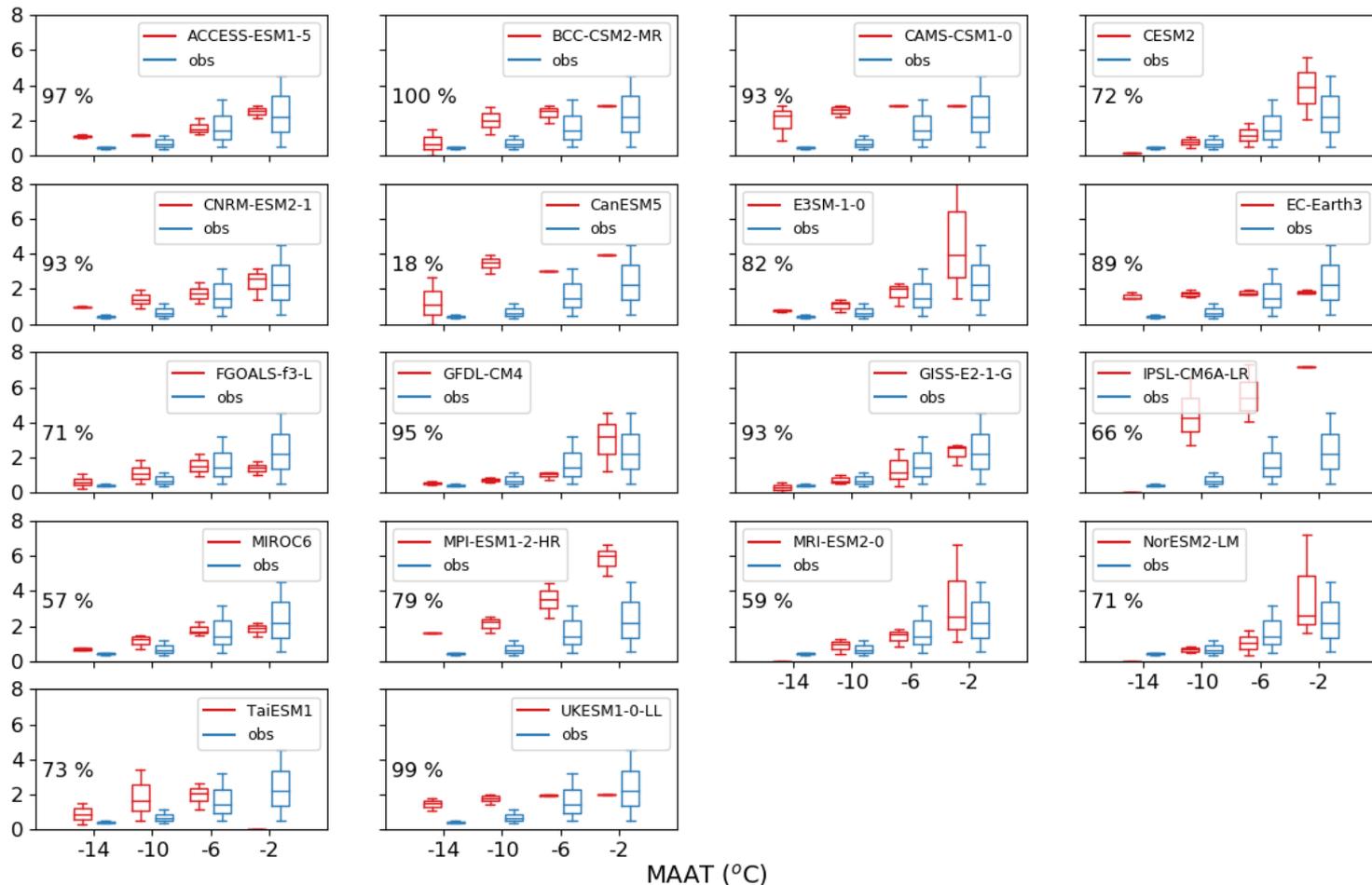
A few models with deeper soils

Still many models with shallow soils and not many layers

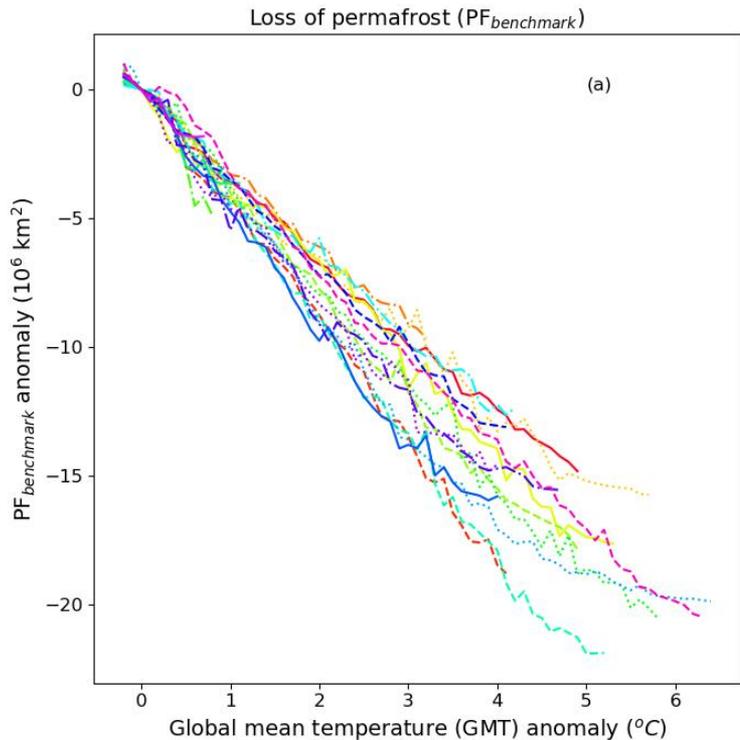
ERRORS IN MAXIMUM SUMMER THAW DEPTH

Maximum summer thaw depth

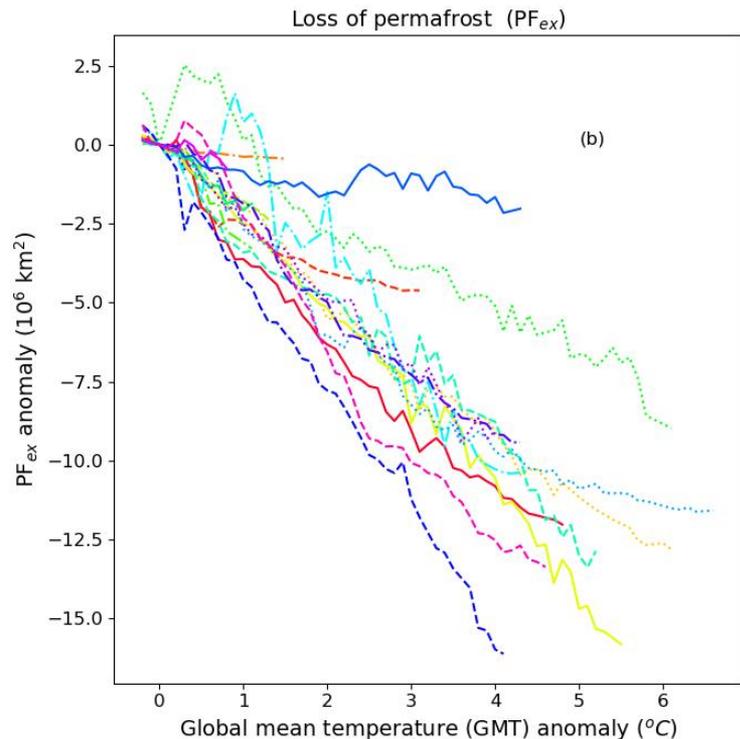
Max. thaw depth (ALT in m)



Future projections

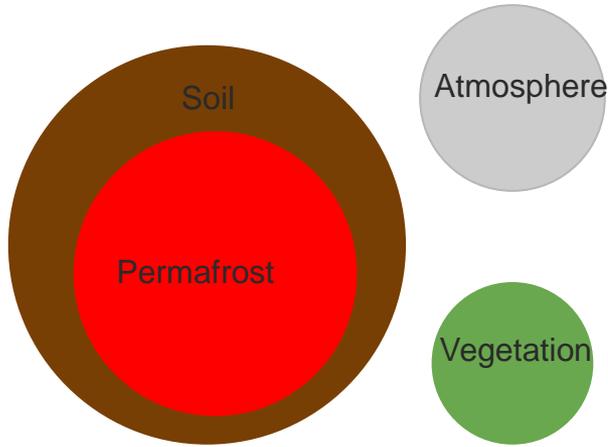


3.3 - 4.1 million km² / degree



1.8 - 3.0 million km² / degree

A massive store of carbon in Arctic permafrost

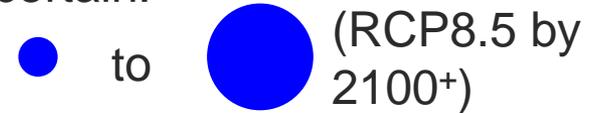


Present day carbon stocks.

Areas represent amounts and uncertainties are not shown.

● Annual fossil fuel emissions

Cumulative permafrost carbon emissions are uncertain:



Comparing CMIP5 and CMIP6

- Many models still have shallow soils and not many layers
- A small number of models have demonstrably better snow insulation in CMIP6 which improves their representation of the permafrost extent
- The simulation of maximum summer thaw depth does not improve in CMIP6
- Only a couple of models in CMIP6 have a representation of permafrost carbon