Climate change and future scenarios in the Arctic Region
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Impacts of Climate Change on Arctic permafrost

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What is permafrost?

Permafrost is defined as ground (soil or rock and included ice or organic material) that remains at or below 0°C for at least two consecutive years.

Why permafrost can warming of cooling?

Permafrost state depends from the ground surface temperature (GST).

GST depends mainly by 4 factors:

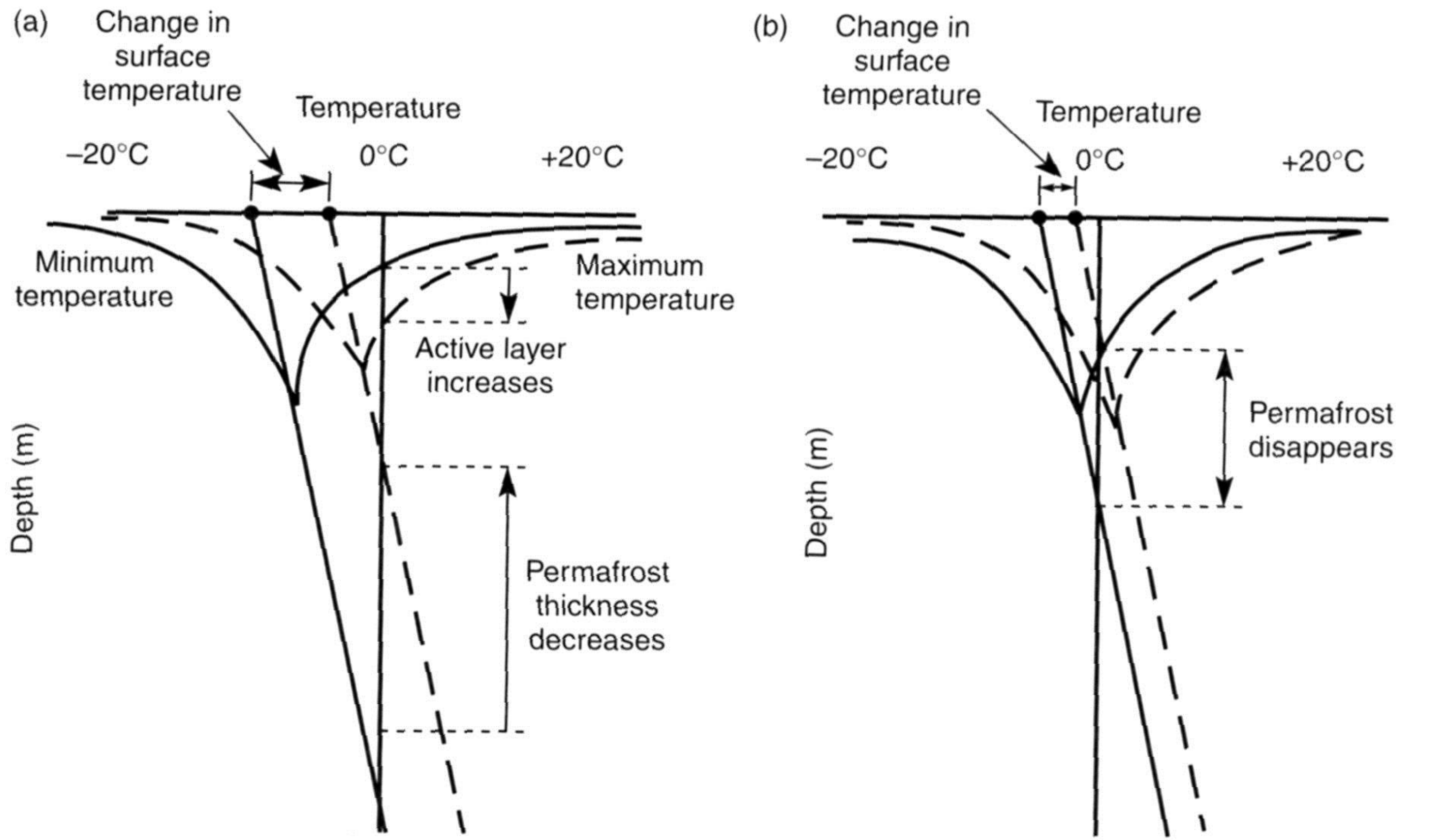
- Air temperature
- Solar radiation
- Snow cover
- Vegetation cover

Why permafrost can thawing or aggrading?

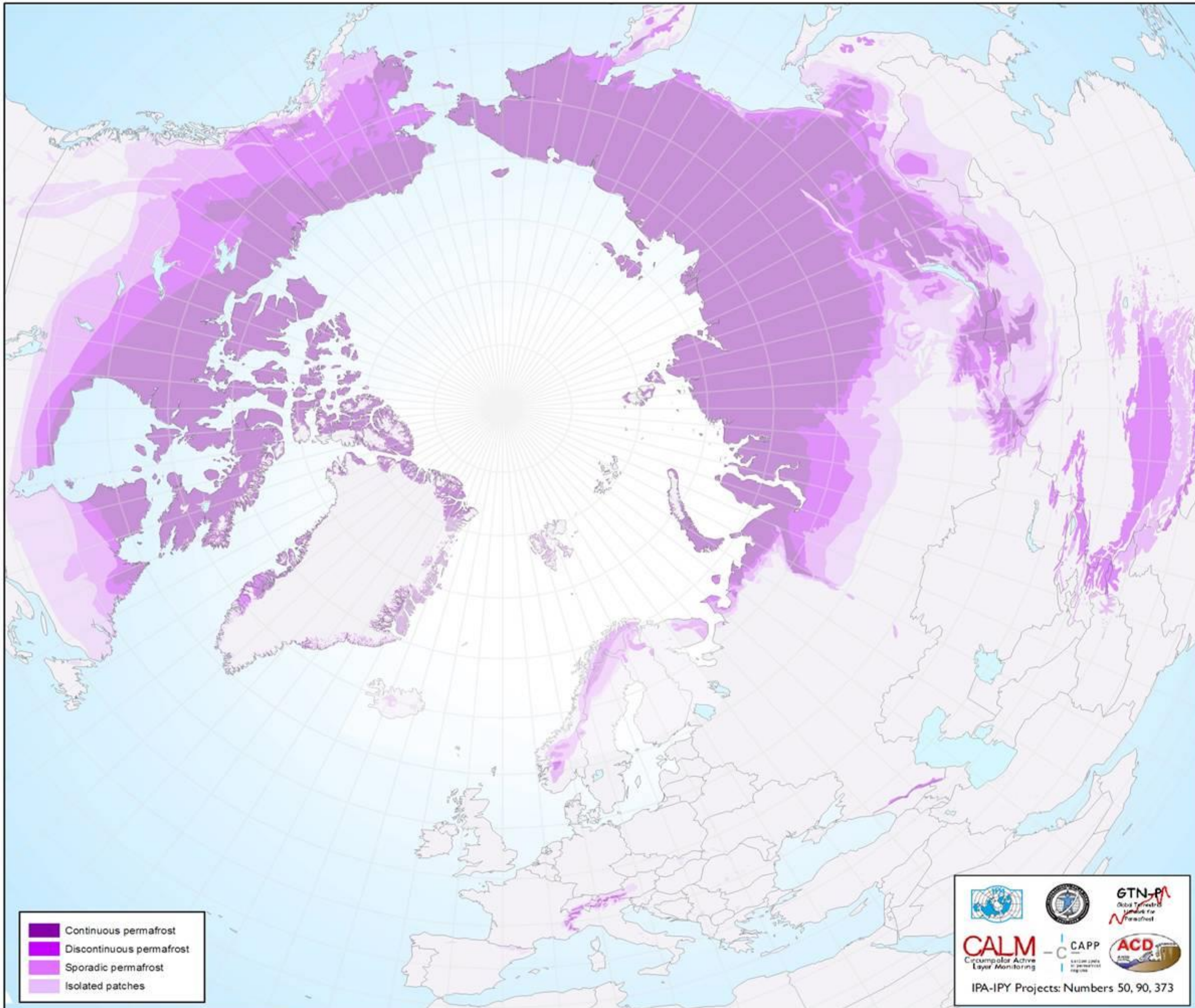
Permafrost can have different percentage of ice within (from 0% in Dry Permafrost to 100% in some massive buried ice mass). From the amount of ice content, the thermal properties of the deposit or rock and from GST pattern depends if permafrost can thawing or not.

What is the active layer?

Active layer is the surface layer of ground that freezes in the winter (seasonally frozen ground) and thaws in summer

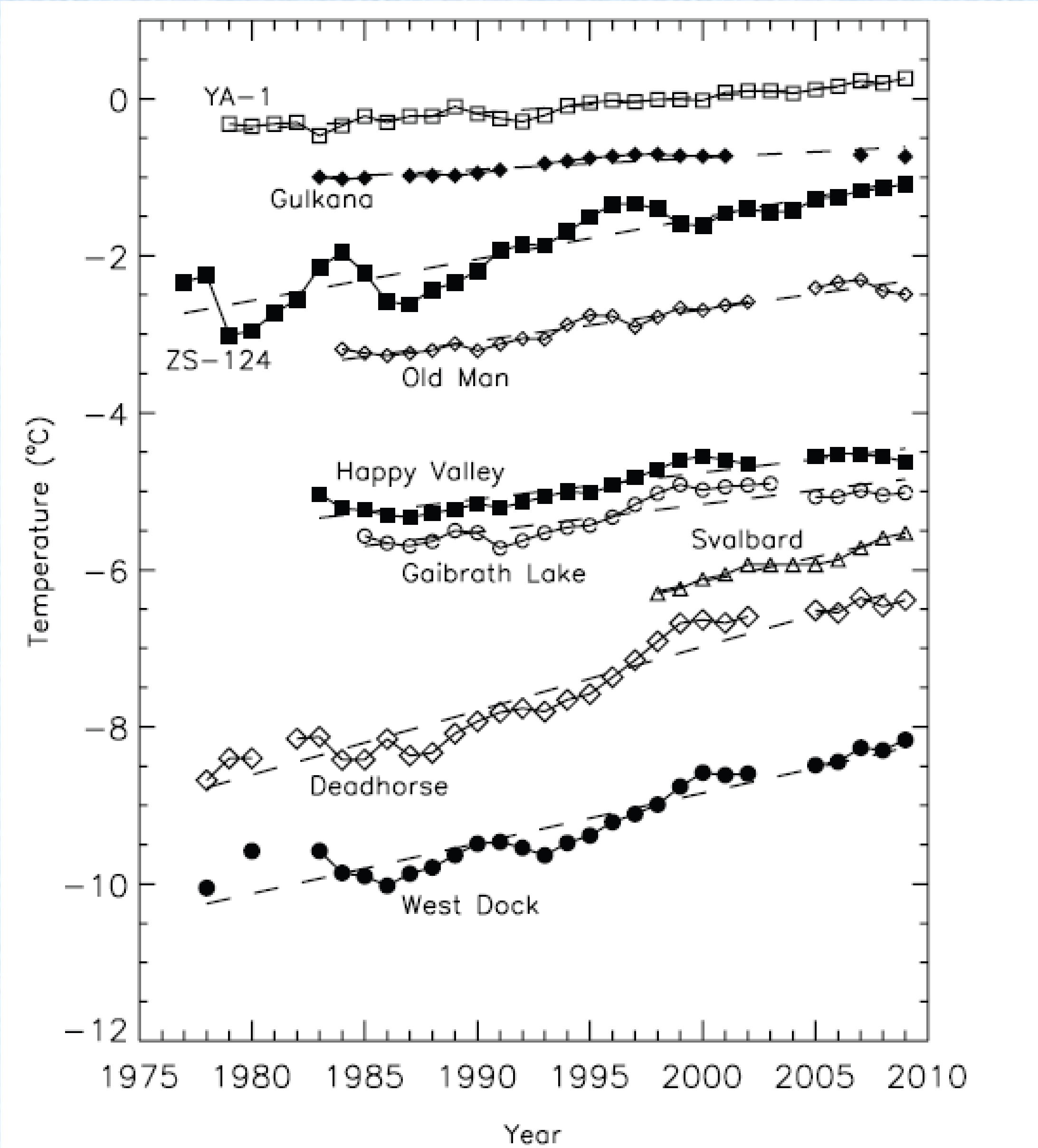


Effects of GST changes on permafrost (Da French, 1997)

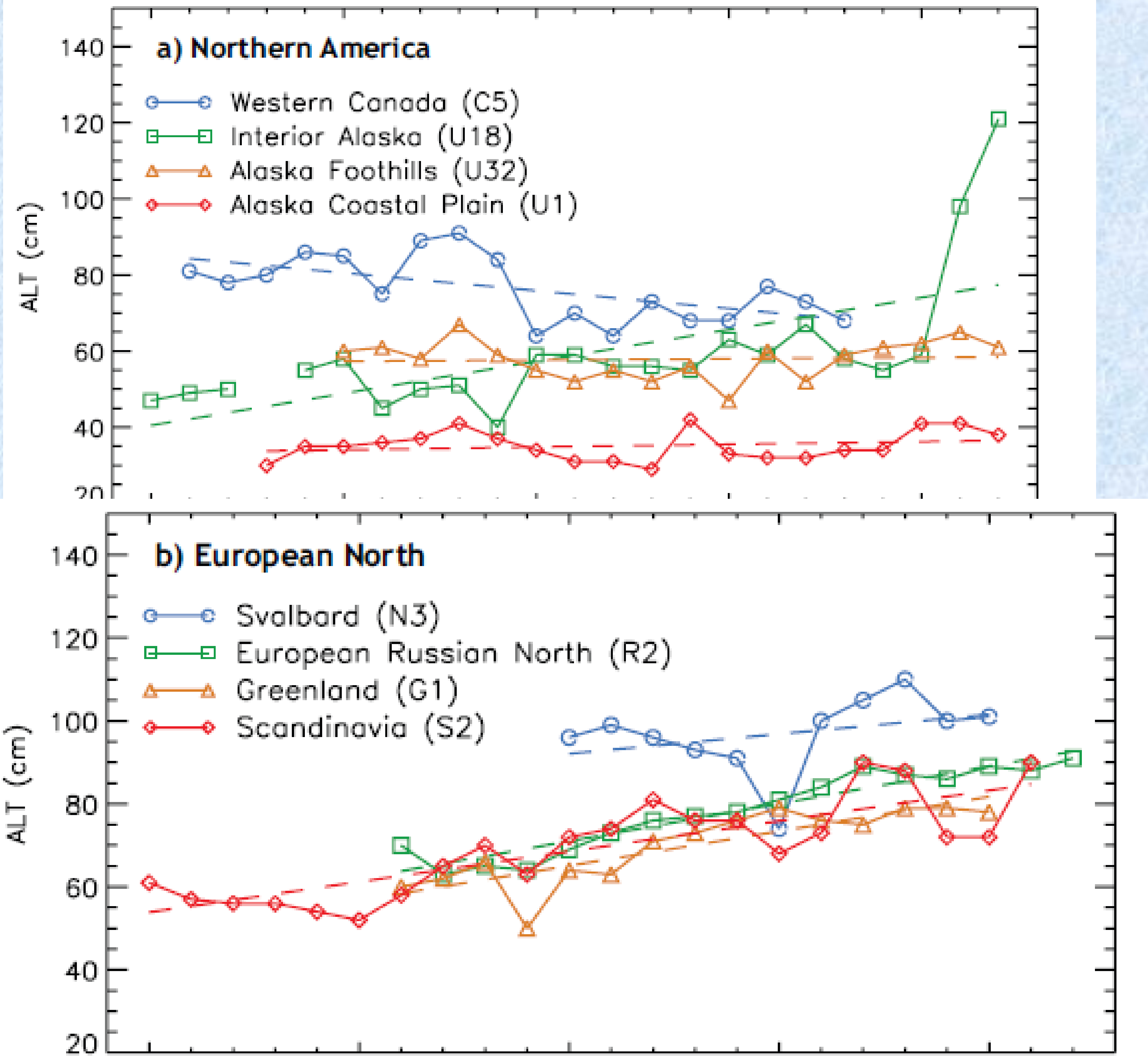


Continuous permafrost
Discontinuous permafrost
Sporadic permafrost
Isolated patches
GTN-P
CALM
Circumpolar Active Layer Monitoring
CAPP
ACD
IPA-IPY Projects: Numbers 50, 90, 373

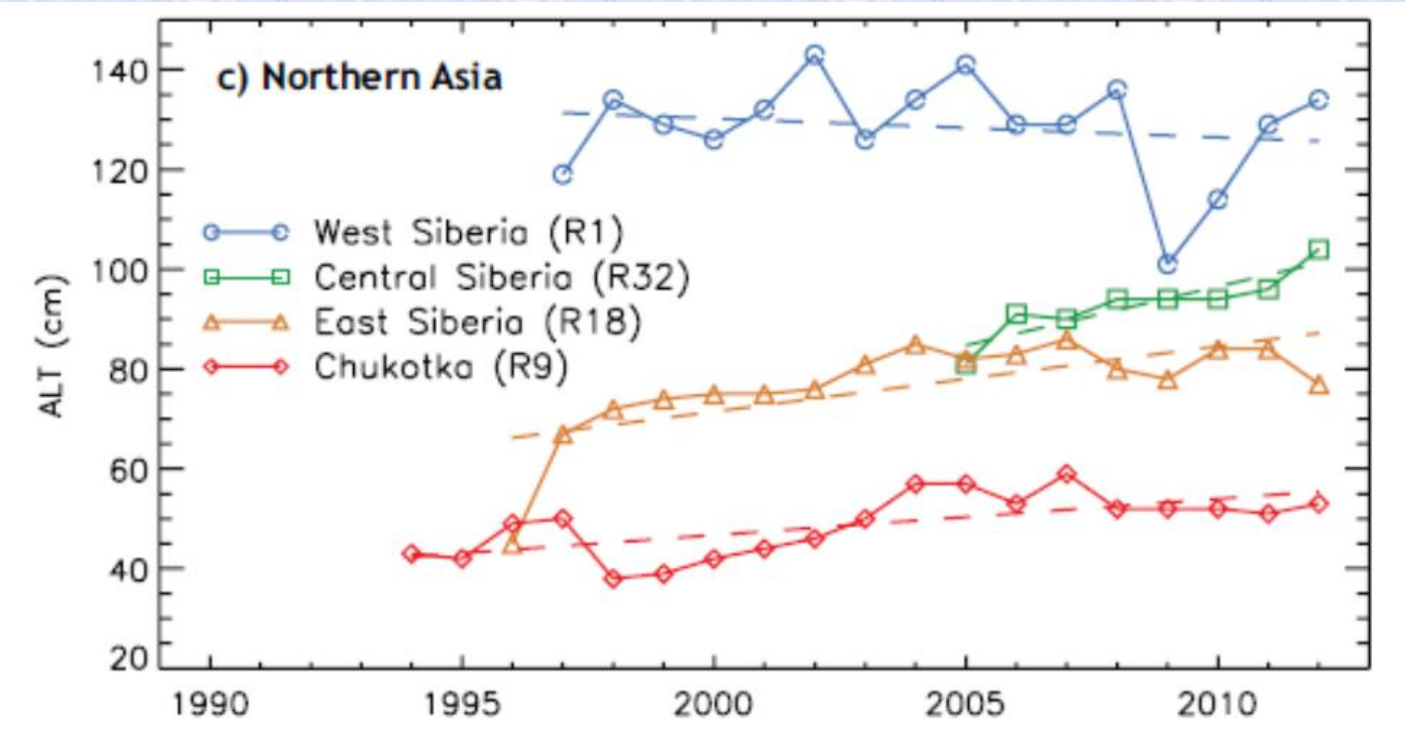
In Violet the subsea permafrost area according to Brown et al 1998



From IPCC, 2013



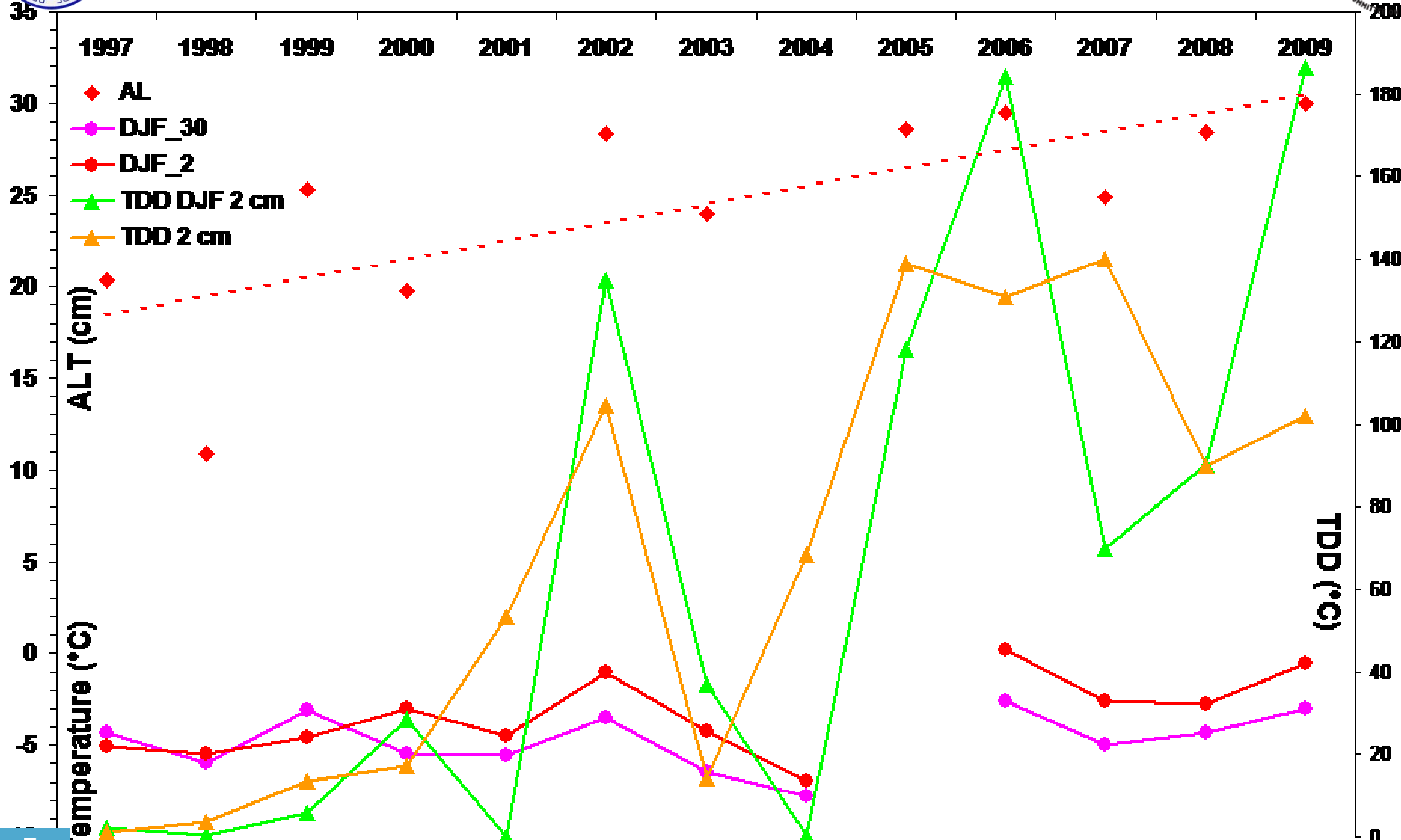
From IPCC, 2013



From IPCC, 2013

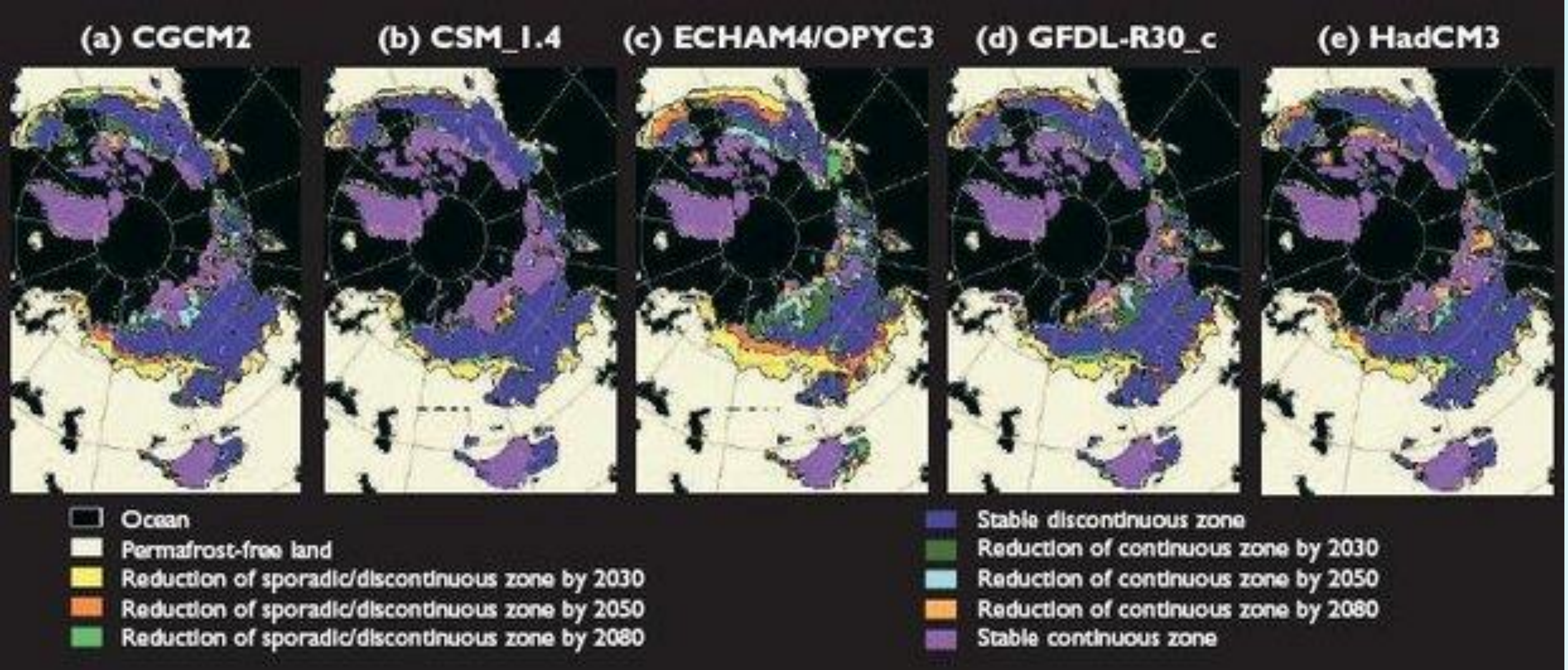
ALT= 2.25*SummerGST+30.6; =0.0241

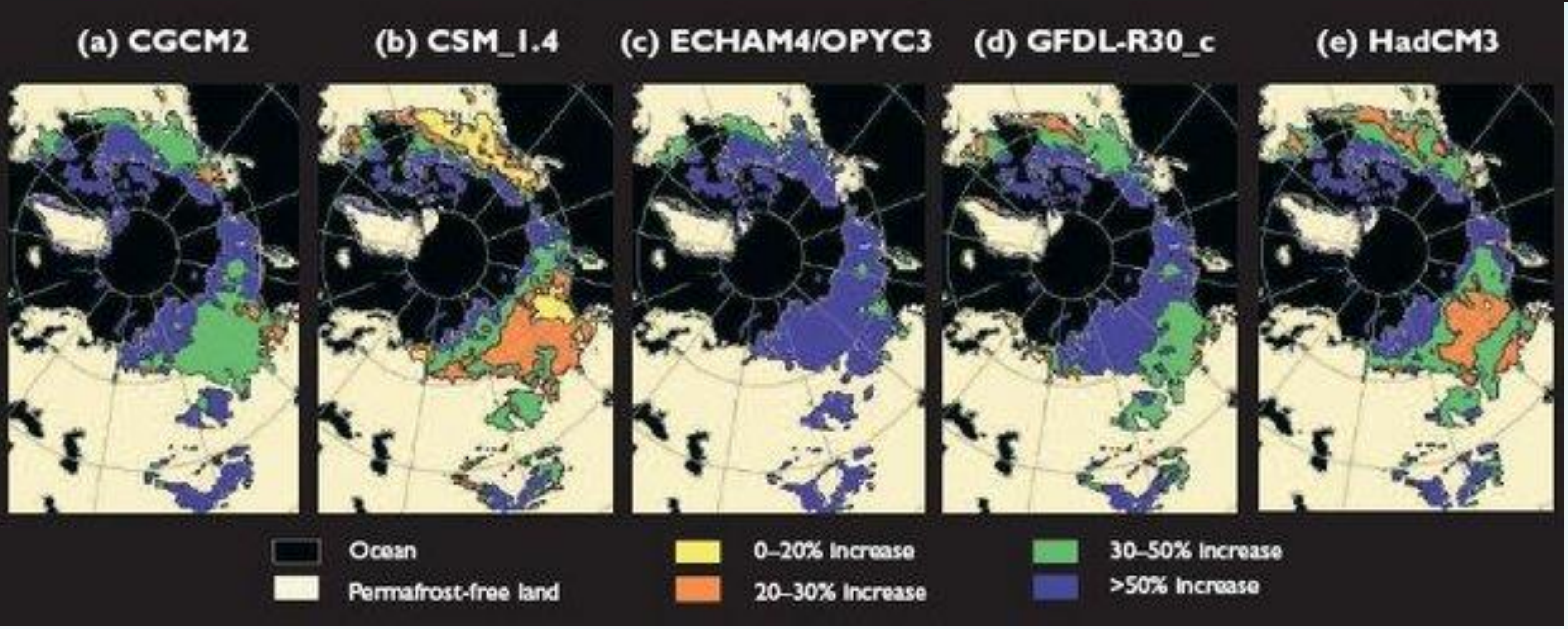
The increase of ALT is 1 cm per year ; p = 0.0099



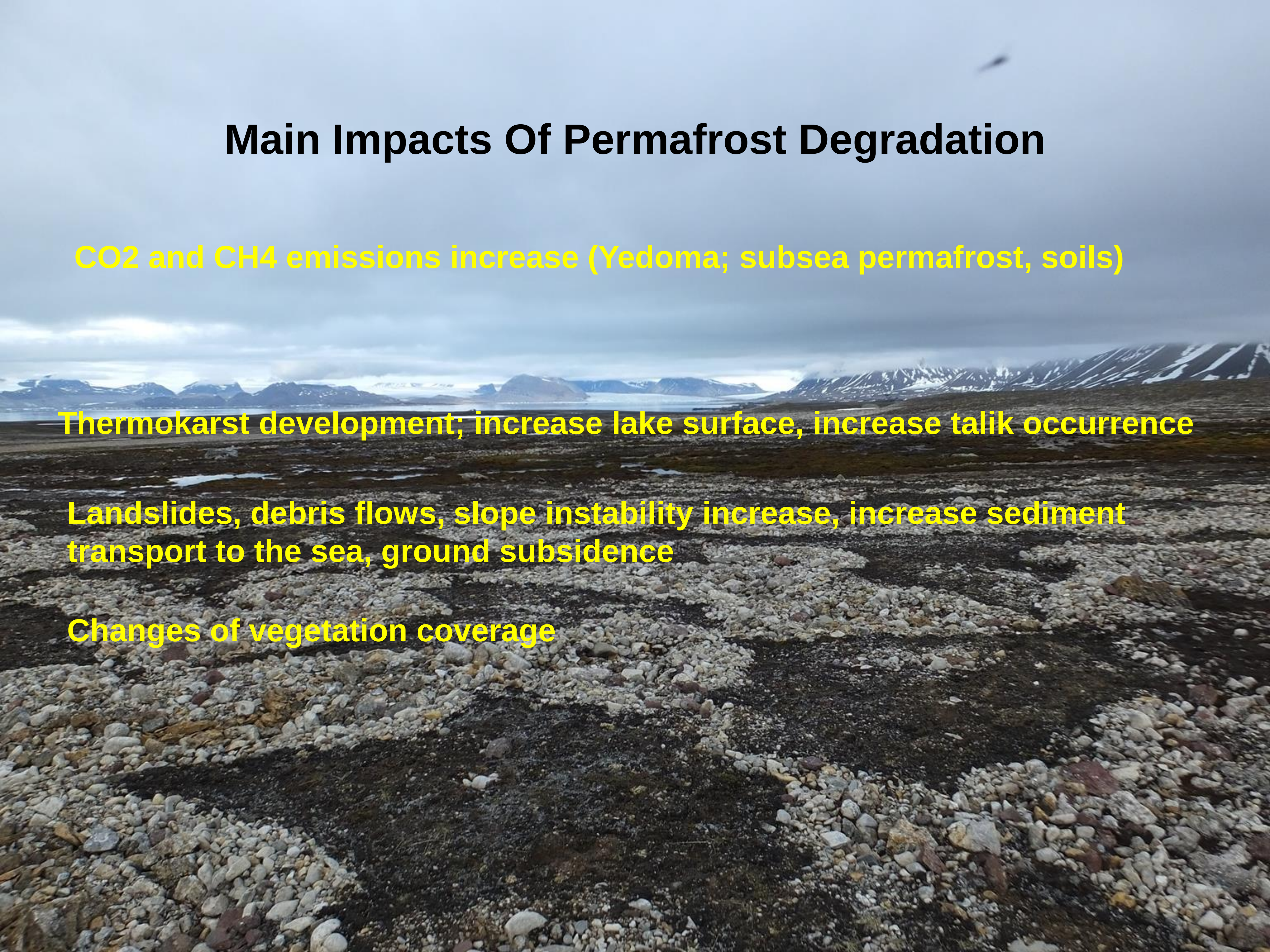
Relationships among Active Layer thickness (AL) and : Mean Summer GST (DJF_GST); Mean Summer Temperature at 30 cm of depth (DJF_30); Summer Thawing Degree Days at 2 cm of depth (TDD DJF); Total Thawing Degree Days at 2 cm of Depth (TDD). From **Guglielmin and Cannone 2011 (Climatic Change)**

XXXII SCAR


(a) CGCM2
(b) CSM_1.4
(c) ECHAM4/OPYC3
(d) GFDL-R30_c
(e) HadCM3
Ocean
Permafrost-free land
Reduction of sporadic/discontinuous zone by 2030
Reduction of sporadic/discontinuous zone by 2050
Reduction of sporadic/discontinuous zone by 2080
Stable discontinuous zone
Reduction of continuous zone by 2030
Reduction of continuous zone by 2050
Reduction of continuous zone by 2080
Stable continuous zone


(a) CGCM2
(b) CSM_1.4
(c) ECHAM4/OPYC3
(d) GFDL-R30_c
(e) HadCM3
Ocean
Permafrost-free land
0–20% increase
20–30% increase
30–50% increase
>50% increase

Main Impacts Of Permafrost Degradation



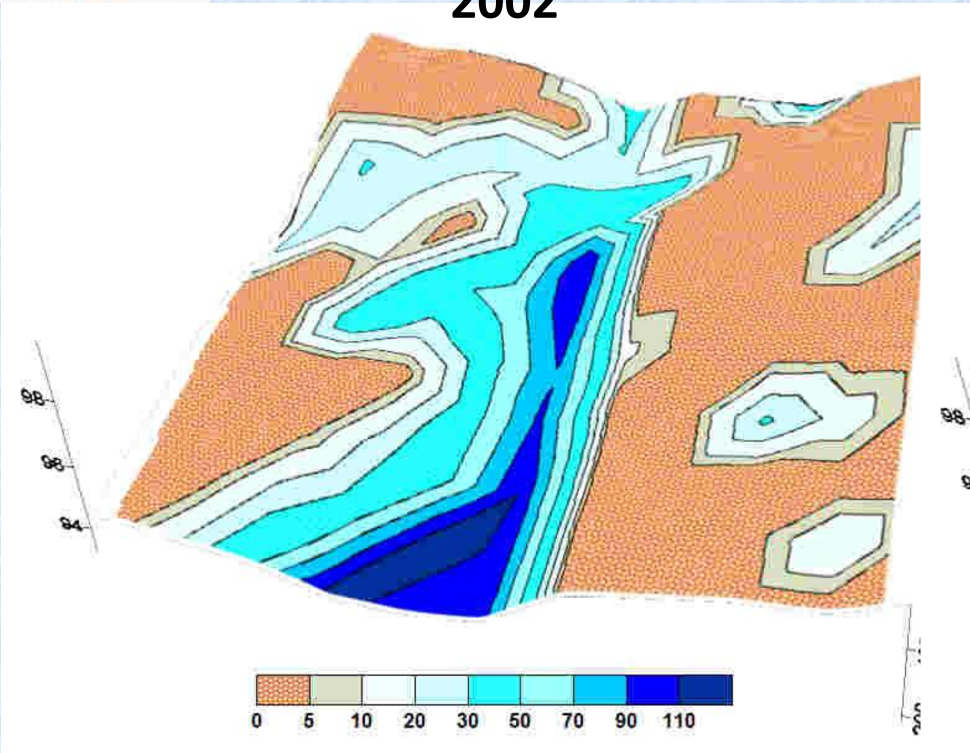
CO_2 and CH_4 emissions increase (Yedoma; subsea permafrost, soils)

Thermokarst development; increase lake surface, increase talik occurrence

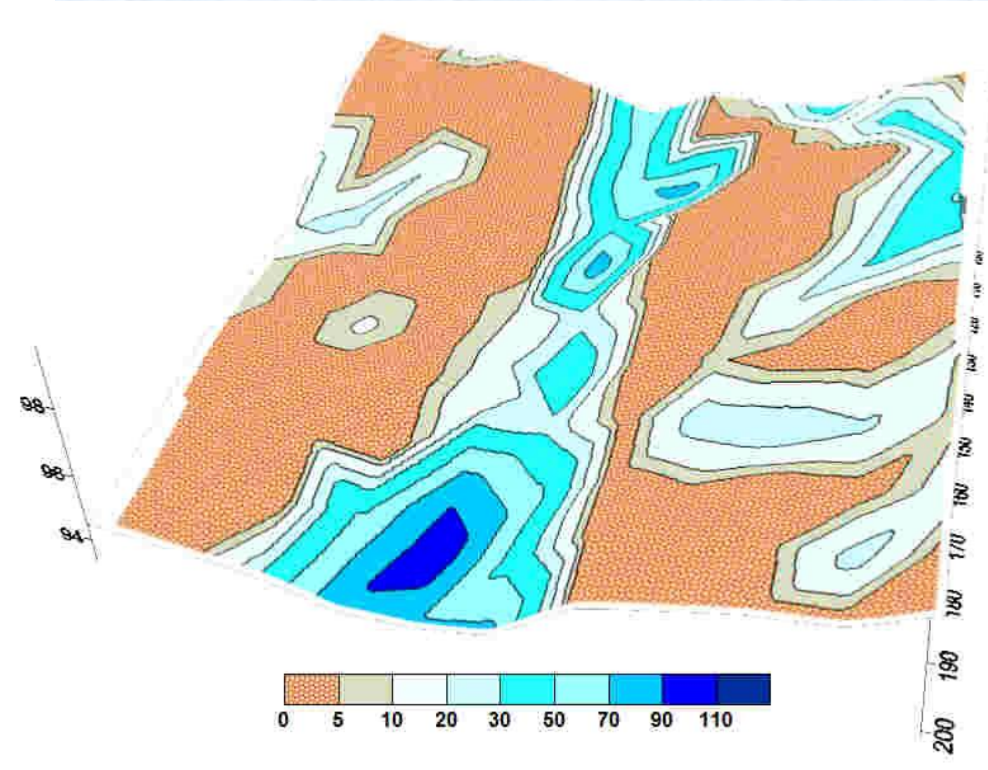
Landslides, debris flows, slope instability increase, increase sediment transport to the sea, ground subsidence

Changes of vegetation coverage

2002



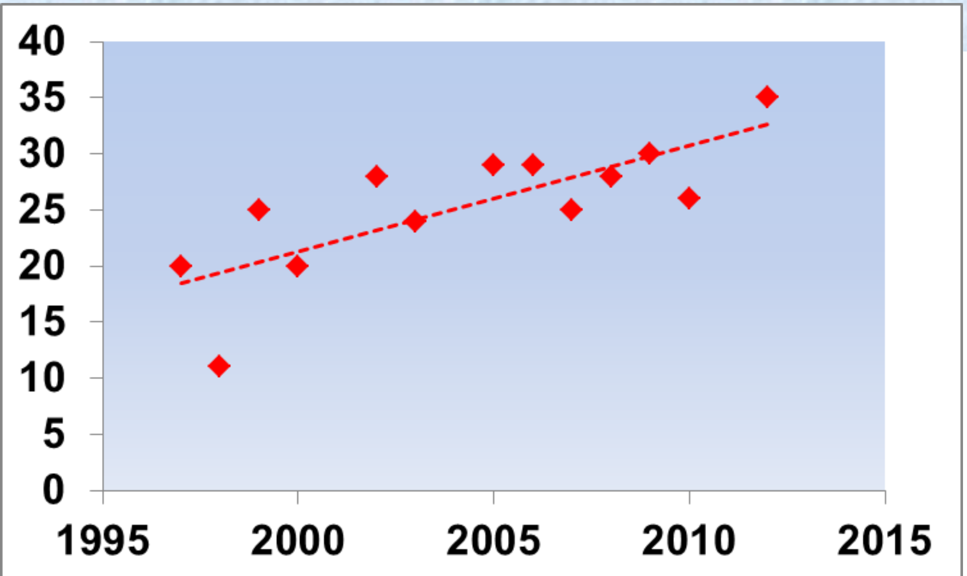
2013



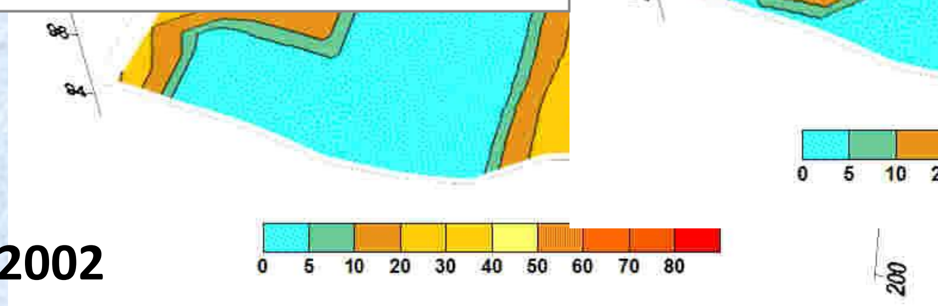
Snow cover distribution is strongly controlled by the ground morphology.
Features as the central E–W oriented depression that acts always as the main accumulation zone . Other spatial variations are related to features (<10 m), such as big boulders, small concavities and convexities that produce snow accumulation, mainly N–S or NE–SW oriented, when the prevailing wind blows from the NW, as it did in 2013.

Results

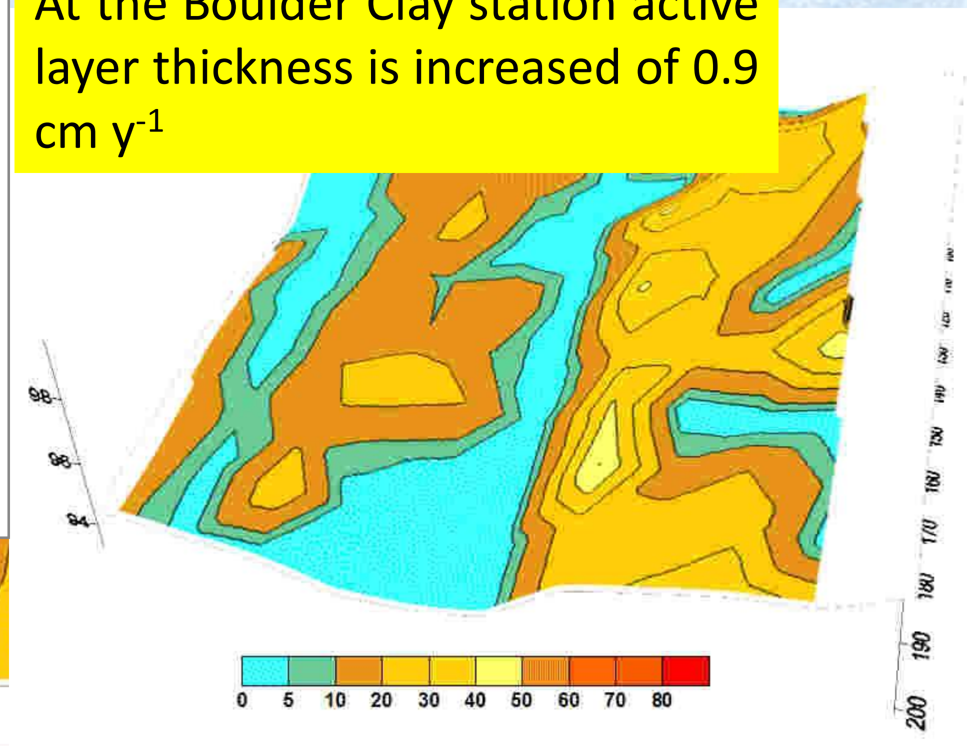
Permafrost Change



At the Boulder Clay station active layer thickness is increased of 0.9 cm y^{-1}



2002



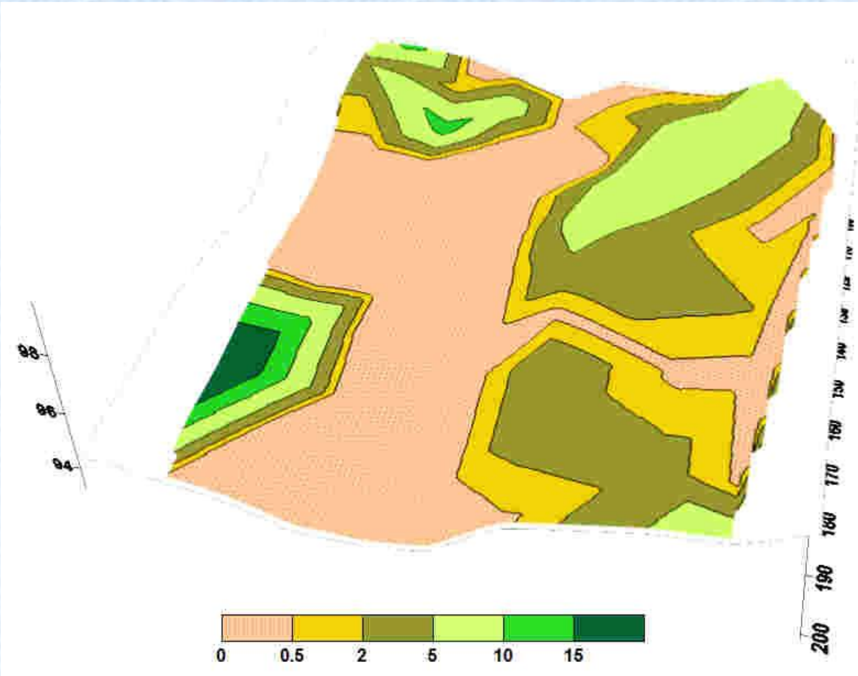
2013

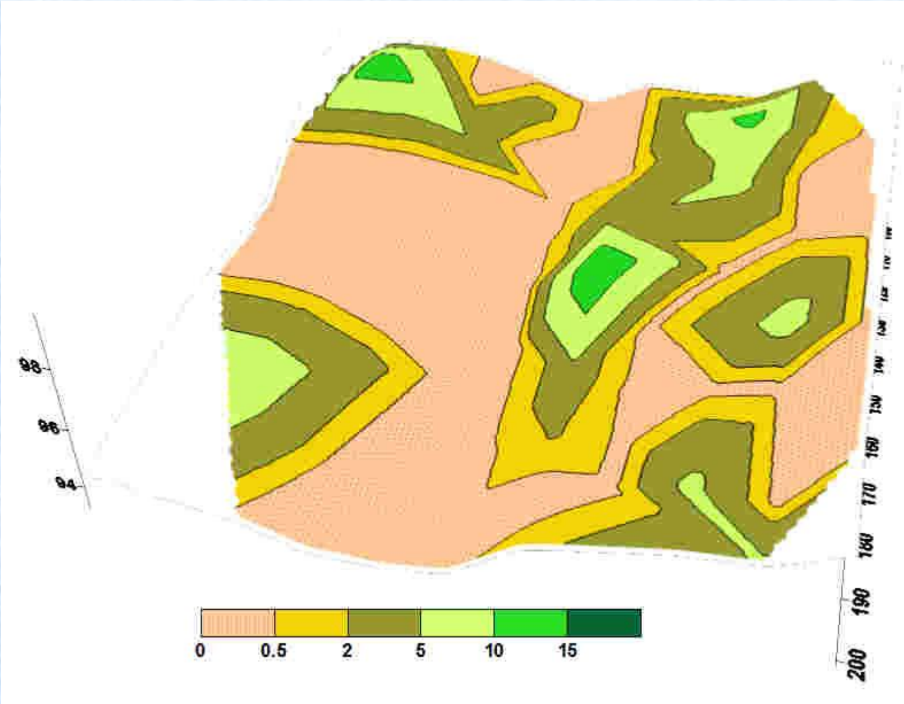
Spatial variability of the active layer thickness at Boulder clay CALM grid, showed a large variability of mean values (from 2 to 18 cm) and its ranges (between 0-23 and 0-92 cm), with a slight increasing trend (0.3 cm y^{-1}, $p < 0{:}05$).

Results

Vegetation Change

Total Coverage





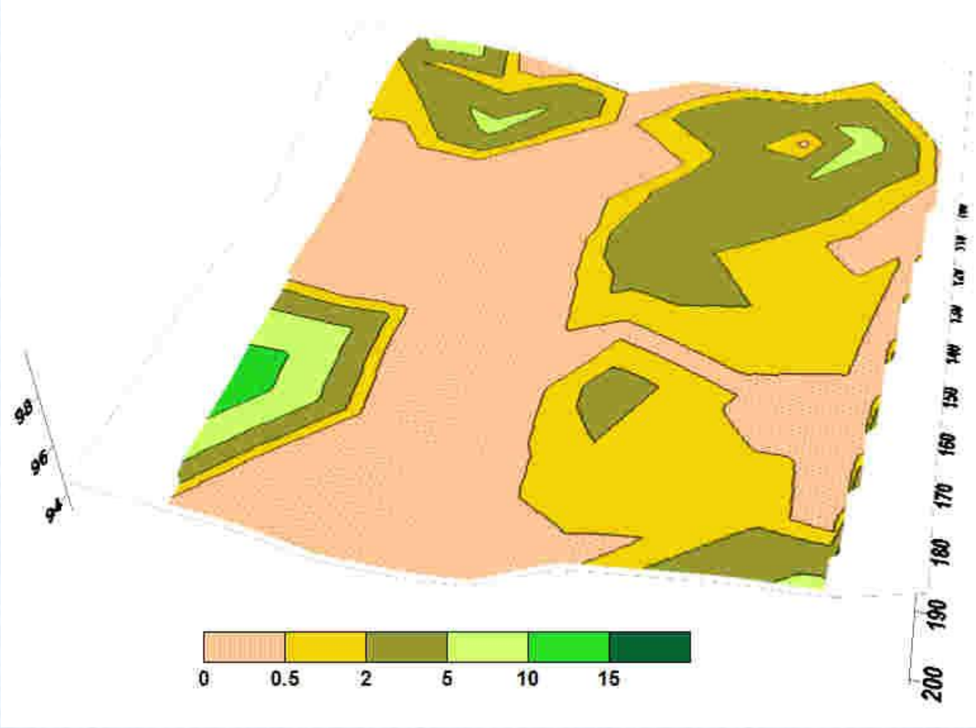
2002 **2013**

The spatial distribution of vegetation within the selected 25 CALM grid nodes showed that the vegetated areas almost coincide between 2002 and 2013 and that their coverage was almost stable

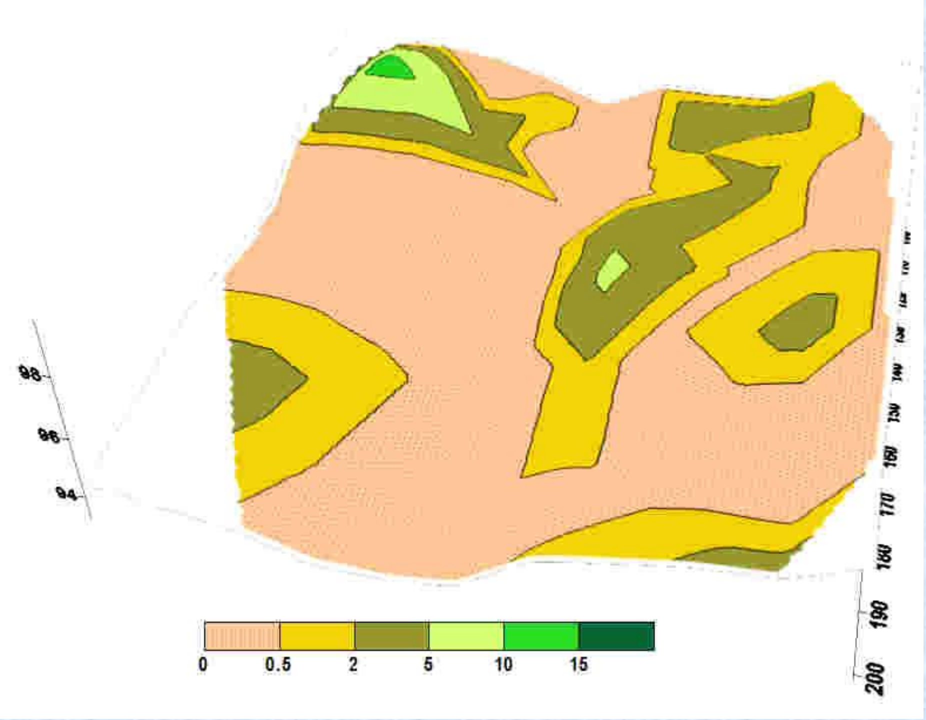
Results

Vegetation Change

Mosses



2002



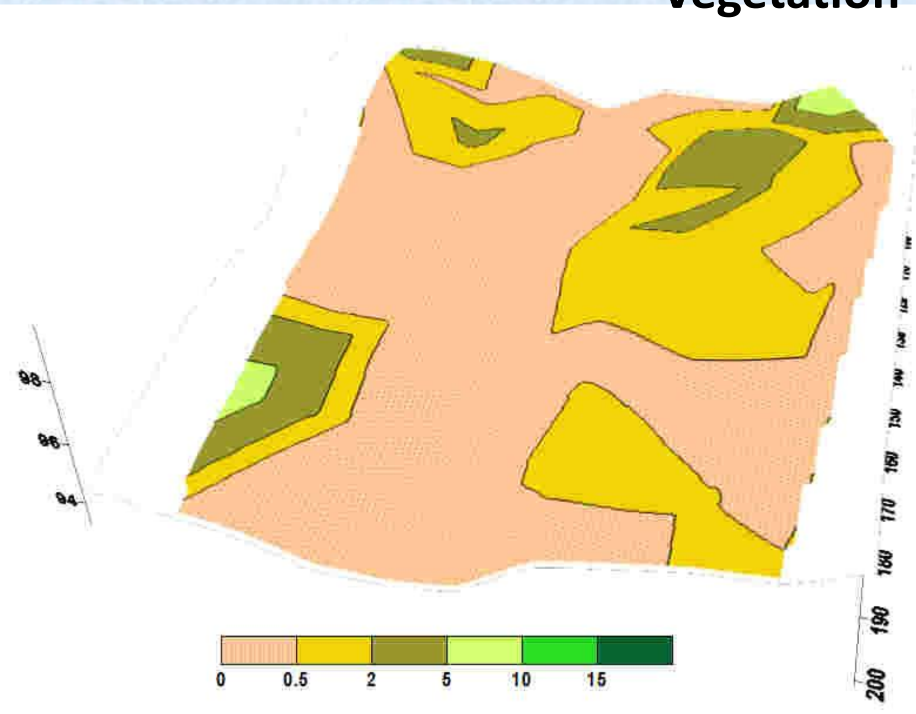
2013

Mosses showed a slight decrease in coverage

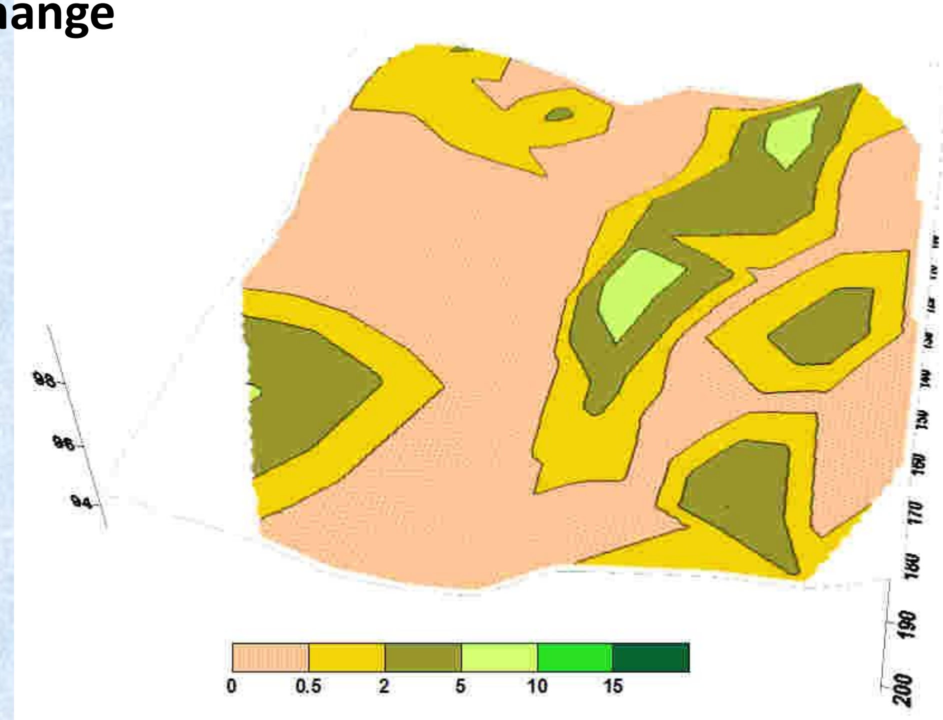
Lichens

Results

Vegetation Change



2002



2013

Conversely Lichens showed a slight increase in coverage especially on the highest elevations (on the reliefs)

HIGH ARCTIC
SVALBARD ISLANDS – NY ALESUND

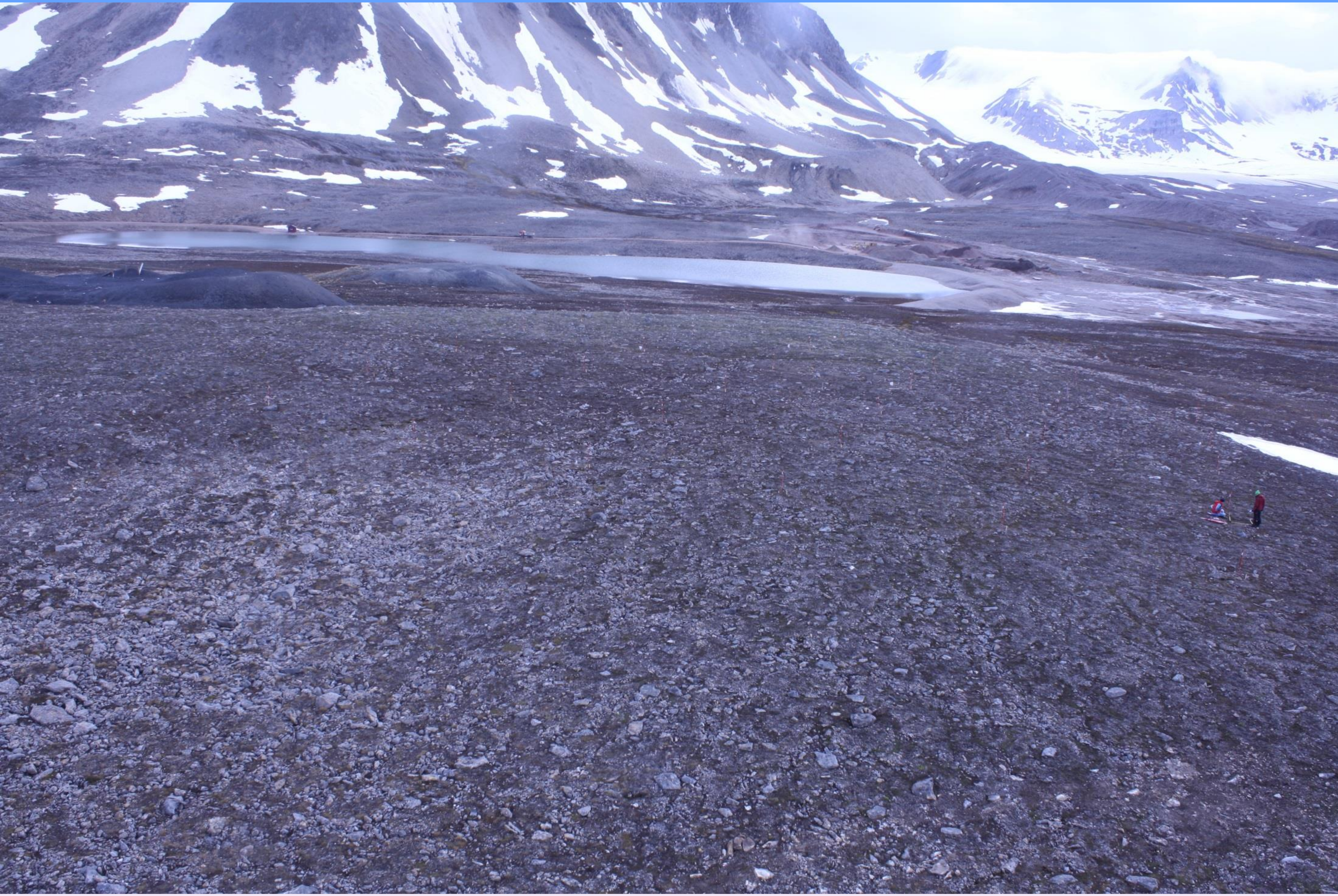
Main aims of the field campaign 2012 :

a) Estimate the spatial variability of active layer thickness and permafrost distribution around the Climate Change Tower (CCT) and, for comparison, in one site along the coast;

b) estimate the variability of CO_2 fluxes in relation with vegetation types and active layer thickness.

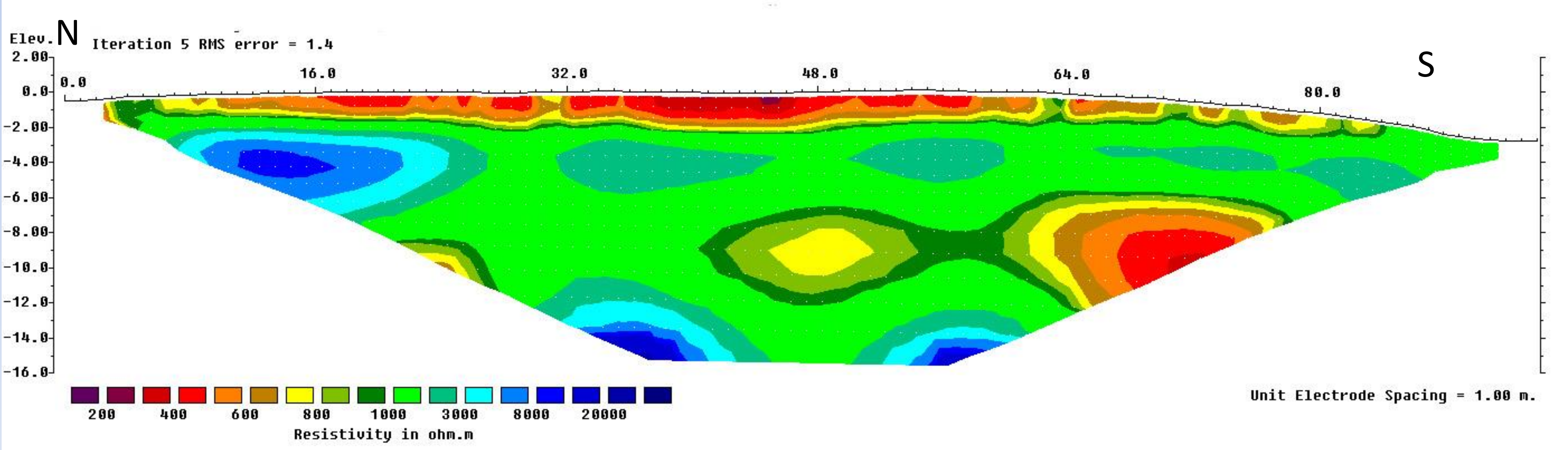
Two main study sites:

- **CALM grid close to the CCT Tower**
- **Coastal site along a transect close to Strandvatnet**



CCT tower site

1) Installed the CALM grid (50 x 50 m) located immediately southward to the CCT tower with 24 dataloggers (48 thermistors at different depths on 12 nodes)
2) Analyzed the spatial variability of the active layer thickness (AL) by performing 830 m of electrical tomografies (ERT) of which 6 lines (3 lines N-S and 3 E-W oriented, with a span of 2 m) placed at a distance of 25 m each other and centred on the CALM grid of 50x50 m
Resistivity values above 2000 ohmm should represent frozen ground.
AL is extremely variable from a few dm up to more than 3 m
Detected the existence of some taliks

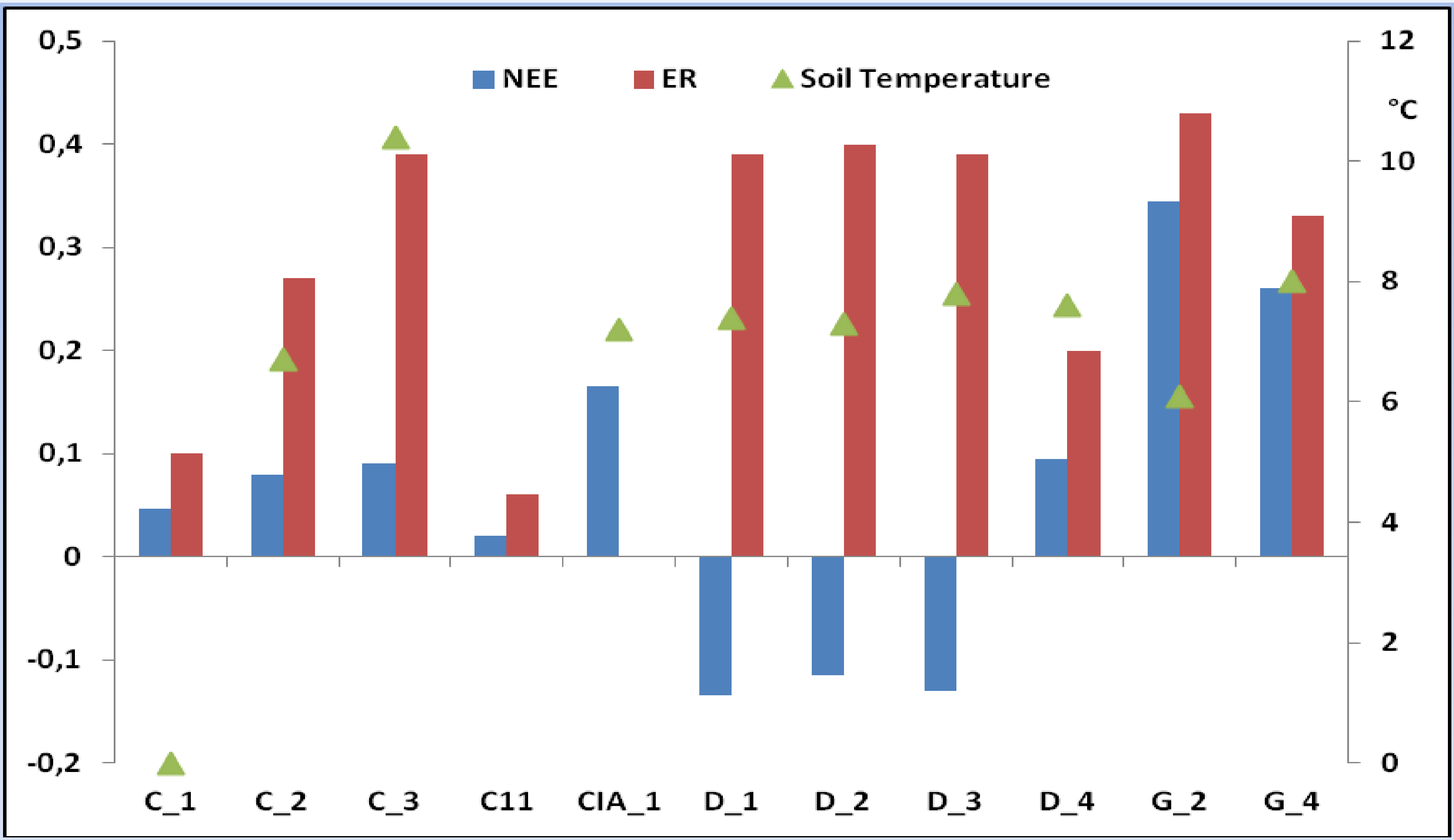


Example of ERT within the CALM grid

CO_2 fluxes

Both sites show by a spatial variability of CO_2 fluxes in relation to vegetation types

The advanced senescence of leaves may have influenced NEE values (in most cases positive, resulting in a CO_2 release to the atmosphere)



Example of the spatial variation of CO_2 fluxes in relation to different vegetation types measured in one date at the CCT site. Legend: NEE = Net Ecosystem Exchange; ER = Ecosystem Respiration; C (1, 2, 3, 11) = Cassiope tetragona vegetation; CIA = cryptogamic crust with Cyanobacteria; D (1, 2, 3, 4) = Dryas octopetala vegetation; G (1, 2, 3, 4) = graminoid barren dominated by Carex rupestris.


Thanks for the attention