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Deliverable 4.2. POLARIN Graphic products package for multiple audiences and gap analysis

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SUMMARY

Our ability to observe, understand, and predict polar change relies on our combined observational capacity, including remote sensing, modeling, and in situ observations. In situ observations are crucial but often scarce in polar regions due to logistical challenges and harsh environments. This deliverable developed a framework for graphical products related to the six POLARIN themes, providing insights into current state of knowledge that will be used in WP1 to identify potential knowledge gaps and the potential for POLARIN infrastructures to cover these. The graphical products will compare remote observations, CMIP models, and in situ data for the themes Carbon balance and permafrost, and Polar ecosystems and biodiversity – more specifically Soil Organic Carbon and Biomass. The deliverable thus aims to enhance understanding and inform future research efforts.

1. Introduction

Our ability to observe, understand and predict polar change depends on our combined observational capacity. Remote sensing, modelling and in situ observaitons all add to our knowledge of current state and dynamics in polar areas. In situ observaitons are often scarce in polar areas challenges by logistics, costs of operations and a remote and harsh environment, yet these are important fpr verifying remote sensing observations and feeding into modelling efforts. The geographical distribution of in-situ observations and level of standardisation have implication for the representativity of our observaitons.

This deliverable is developing a framework for graphical products related to the six POLARIN themes, providing information about our current knowledge of specific varaibles related to the six themes. The graphical products will also be used by WP1 to identify potential observational gaps that can be filled by POLARIN infrastructures part of the POLARIN Transnational Access programme.

This deliverable will include variables related to the themes Carbon balance and permafrost and Polar ecosystems and biodiversity. It will be followed by additional deliverables adding variables related to other POLARIN themes.

2. Main Objectives

The purpose of the graphical products is to showcase comparisons of remote observations, CMIP models and in situ observations of selected variables in polar regions. The products will be used by WP1 to evaluate the representativeness of existing in situ observations and the potential for POLARIN infrastructures to fill potential observational gaps.

Deliverables under this task will provide graphical products related to POLARIN themes:

1. Sea-Ice and Polar Oceans
2. Sea level, glacier stability and melt
3. Carbon Balance and permafrost
4. Polar Ecosystems and biodiversity
5. Atmosphere dynamics
6. (Paleo)climate processes

Selection of key variables will be inspired by *Deliverable 1.4 - Overview report of existing science priorities by major Arctic and Antarctic organisations and validation/calibration needs by in-situ observation, remote sensing, and modelling communities*. Variables are also selected based on the available data from remote sensing and in situ observations.

Data sources: Remote sensing data are obtained from the ESA Climate Change Initiative https://climate.esa.int/en/data/#/dashboard. CMIP6 model is applied using the same unit and geographical coverage. In situ data are gathered from existing open access thematic repositories.

2.1. Description of graphical products

The figures provide a comparative analysis of observed and modelled data across the polar regions. The products contain 1) two maps (Remotes sensing and CMIP Model) using similar units and geographical coverage, and 2) box plots comparing variability between maps, in-situ observations (existing thematic repositories) and terrestrial infrastructure locations.

2.2. Graphical products 2025

POLARIN themes and selected variables

Theme 3: Carbon Balance and permafrost:

a. Variable: Soil Organic Carbon

Theme 4: Polar Ecosystems and biodiversity:

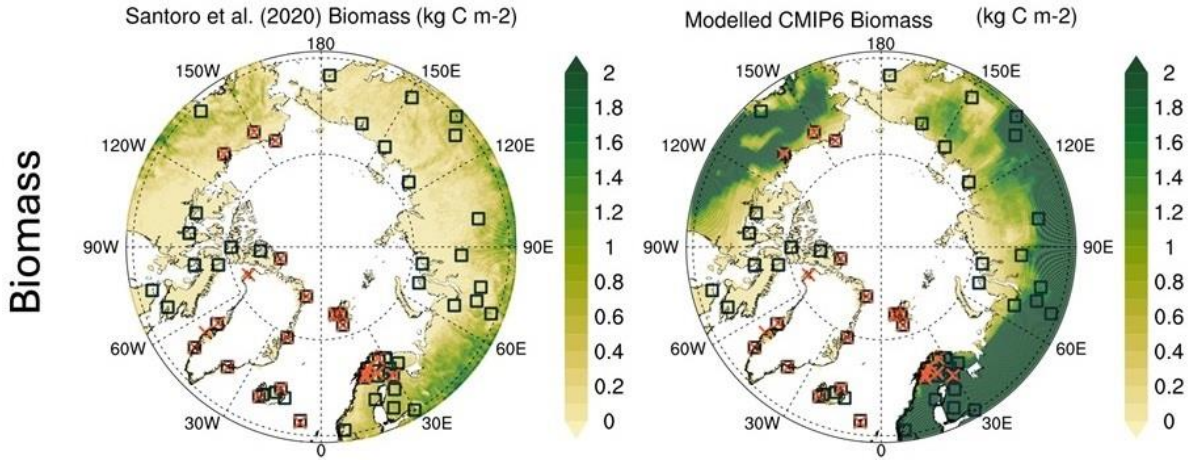
b. Variable: Above Ground Biomass

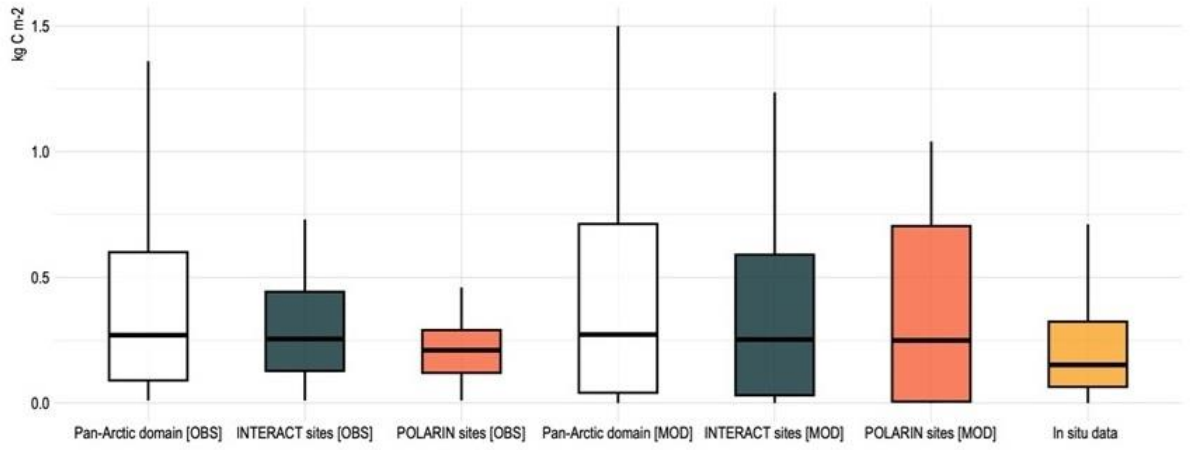
Above Ground Biomass

Vegetation biomass changes can indicate shifts in climate patterns. For example, increased biomass might suggest warming temperatures, which can lead to greening that impact habitat suitability for various species. Vegetation also plays a crucial role in the carbon cycle by absorbing carbon dioxide during photosynthesis. Monitoring biomass helps scientists understand how much carbon is being sequestered in polar regions and how changes in vegetation affect global carbon dynamics.

Variable: Above Ground Biomass - $kgCm^{-2}$

Remote sensing **Model**





Key insights: Remote sensing (OBS) and modelling (MOD) show similar average for Above Ground Biomass, but with higher variability in the model data. POLARIN infrastructure locations (pink) also show similar averages but lower variability. In-situ observations (orange) have lower average and lower variability indicating that the data set could be underrepresented in areas with high Above Ground Biomass.

Data sources:

- Remote sensing data (left map (OBS)): Santoro *et al.* (2020) https://dx.doi.org/10.5285/af60720c1e404a9e9d2c145d2b2ead4e
- Modeled data (right map (MOD)): CMIP6 Biomass
- In-situ data: Berner *et al.* (2014) https://doi.org/10.1038/s41597-024-03139-w

Terrestrial infrastructure locations: Maps include markers for POLARIN sites (crosses) and INTERACT sites (squares), indicating opportunities for data collection points.

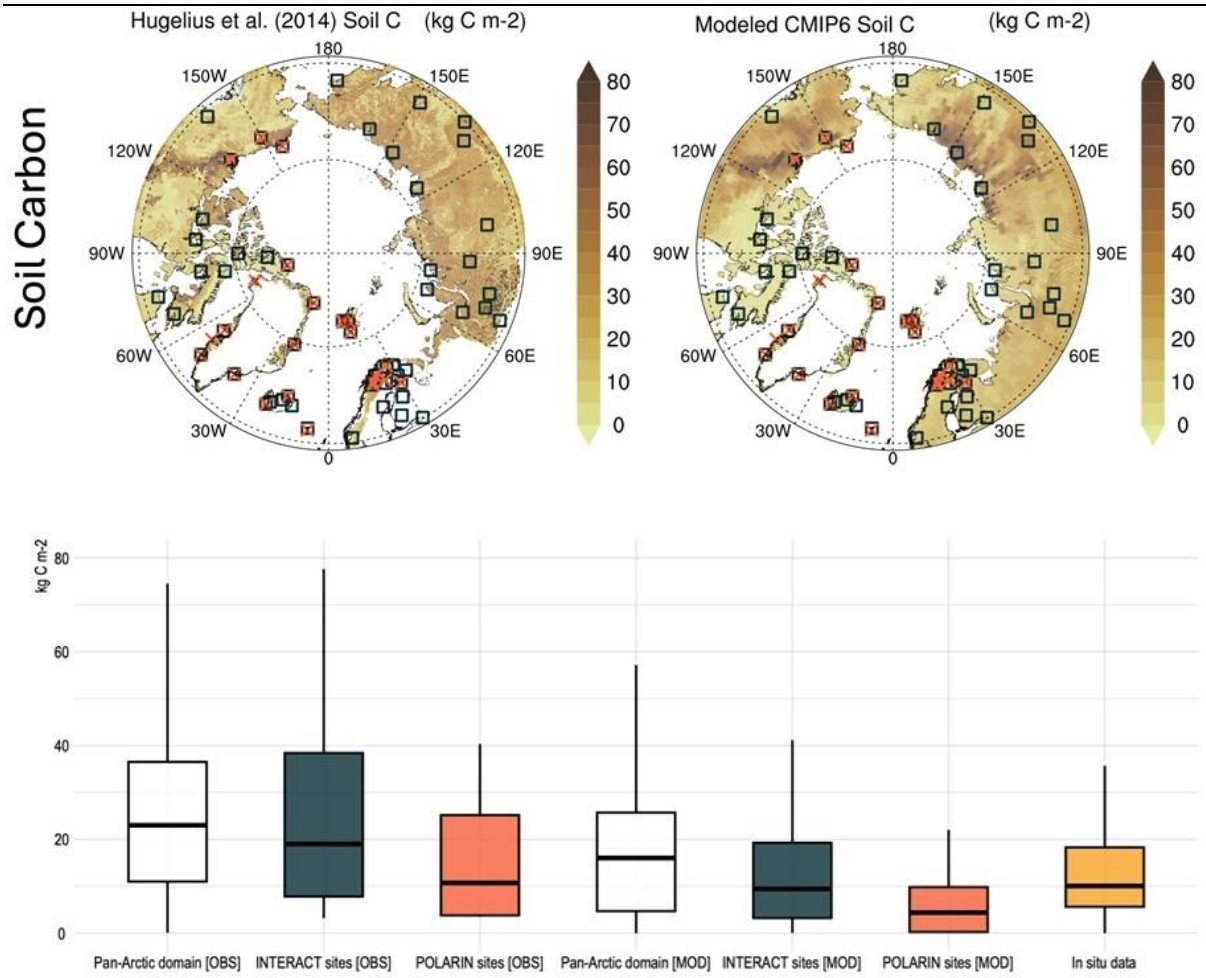
References:

Berner, L.T., *et al.* (2014). The Arctic Plant Aboveground Biomass Synthesis Dataset. *Sci Data* 11, 305 (2024).
Santoro, M., *et al.* (2020). The global forest above-ground biomass pool for 2010 estimated from high-resolution satellite observations. Earth System Science Data, 13, 3927-3950.

Soil Organic Carbon

Polar regions (especially the Arctic) store vast amounts of carbon in their soils. As the climate warms, permafrost thaws, releasing stored carbon into the atmosphere as carbon dioxide and methane, potent greenhouse gases. Monitoring Soil Organic Carbon helps track these emissions and understand their impact on global climate change. Soil Organic Carbon is also a key indicator of soil health, influencing soil structure, fertility, and biodiversity that are shaping polar ecosystems.

Variable: Soil Organic Carbon - $kgCm^{-2}$



Key insights: Modelled Soil Organic Carbon (MOD) show lower values and reduced variability compared to remote sensing estimates (OBS). POLARIN infrastructure locations (pink) and in-situ data show (orange) lower averages and lower variability indicating that they are underrepresented in areas with high Soil Organic Carbon values.

Data sources:

- Remote sensing data (left map (OBS)): Hugelius *et al.* (2014) https://doi.org/10.5194/bg-11-6573-2014
- Modeled data (right map (MOD)): CMIP6
- In-Situ data: Zinke *et al.* (2024) https://doi.org/10.3334/ORNLDAAC/221.

Terrestrial infrastructure locations: Maps include markers for POLARIN sites (crosses) and INTERACT sites (squares), indicating opportunities for data collection points.

References:

Hugelius, G., Strauss, J., Zubrzycki, S., Harden, J. W., Schuur, E. A. G., Ping, C.-L., Schirrmeister, L., Grosse, G., Michaelson, G. J., Koven, C. D., O'Donnell, J. A., Elberling, B., Mishra, U., Camill, P., Yu, Z., Palmtag, J., and Kuhry, P.: Estimated stocks of circumpolar permafrost carbon with quantified uncertainty ranges and identified data gaps, Biogeosciences, 11, 6573–6593, https://doi.org/10.5194/bg-11-6573-2014, 2014.

Zinke, P. J., Stangenberger, A. G., Post, W. M., Emanuel, W. R., & Olson, J. S. (1998). Global Organic Soil Carbon and Nitrogen. Oak Ridge National Laboratory, ORNL/CDIC-18; NDP-018.

3. Conclusions

Both biomass and soil organic carbon show discrepancies between observed data (OBS) and model outputs (MOD), with models generally underestimating variability. POLARIN sites demonstrate distinct characteristics compared to INTERACT sites, which often shows higher values in both observations and models. The inclusion of in situ data provides additional context for evaluating model performance against ground truth measurements. The developed template proved useful for depicting the current state of knowledge for selected variables and for informing WP1 task related to gap analysis.

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