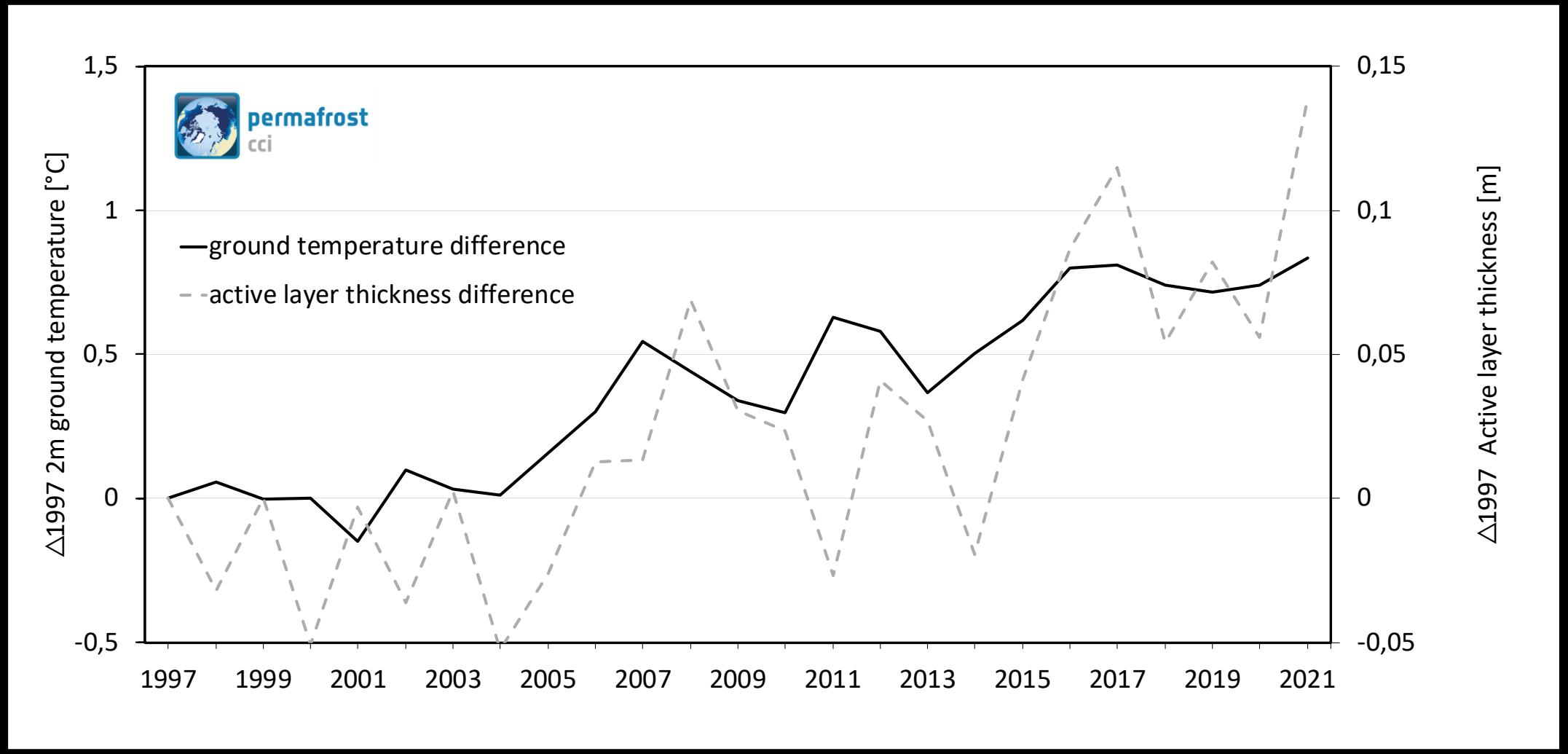
Photo:Q-Arctic.net

Remote sensing supporting the Arctic Methane and Permafrost Challenge (AMPAC)

through esa AMPAC-Net

Annett Bartsch (1), Gustaf Hugelius (2), Guido Grosse (3), Joshua Hashemi (3), Clair Treat (3), Mathias Goeckede (4), Johanna Tamminen (5), Andreas Fix (6), Torsten Sachs (7), Sander Houweling (8), Helena Bergstedt (1), and Barbara Widhalm (1)

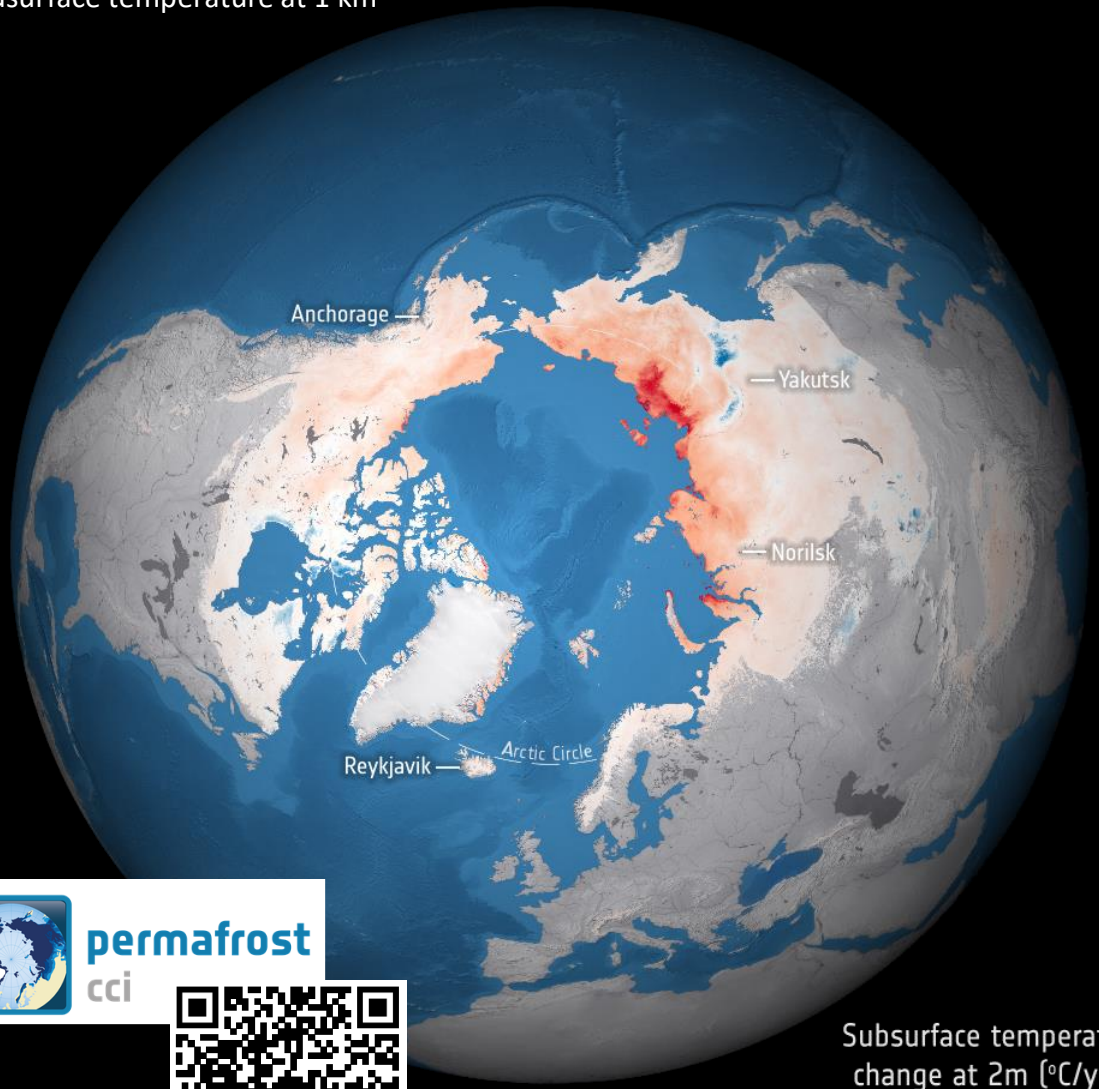
(1) b·geos (2) Stockholm University (3) AWI (4) Max Planck Institute for Biogeochemistry (5) FMI (6) DLR (7) GFZ Helmholtz-Zentrum Potsdam (8) VU Vrije Universiteit Amsterdam

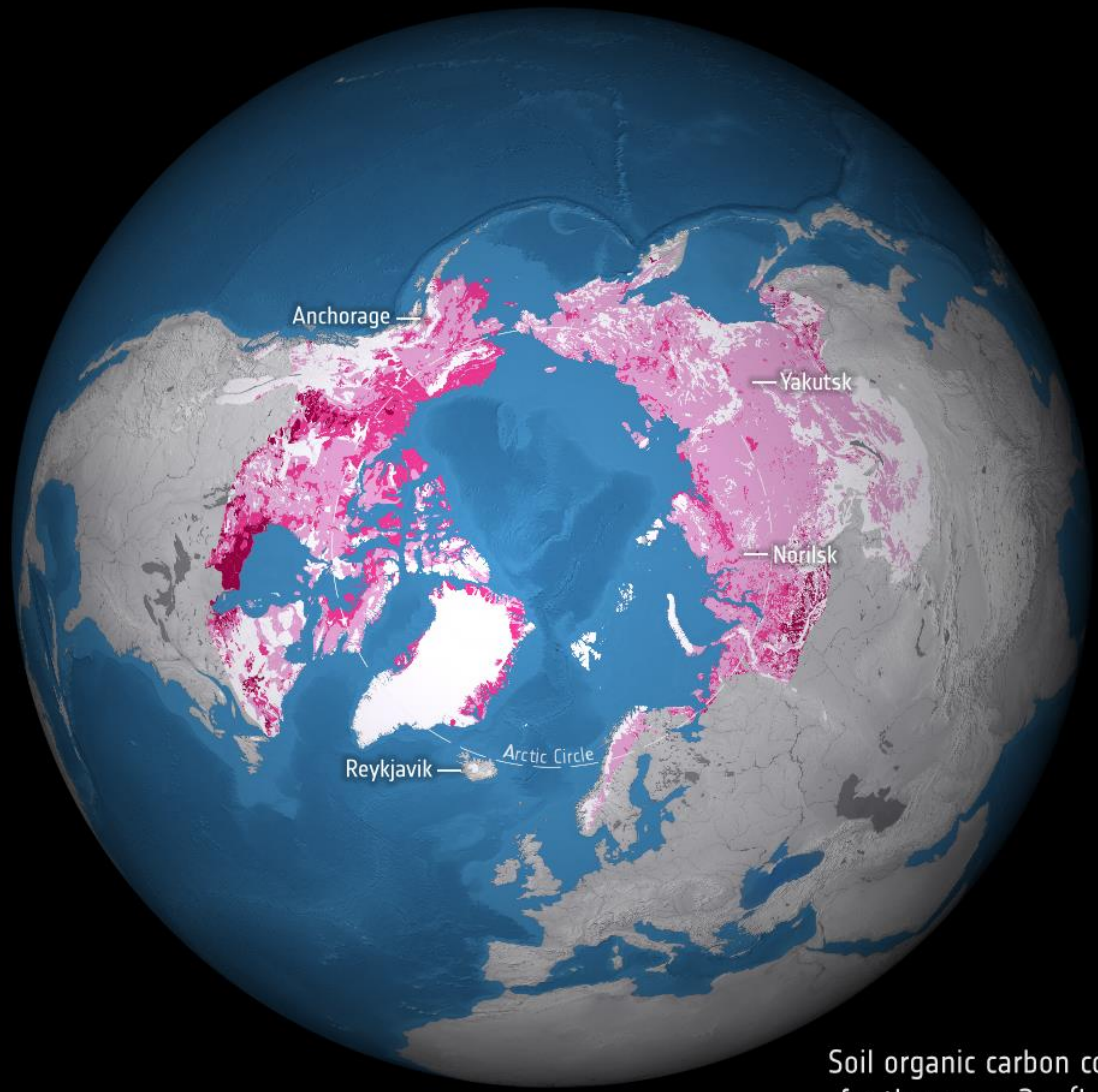


NH Permafrost area average

University of Oslo, CryoGrid modelling using
Landsurface temperature at 1 km

Stockholm University, NSCSD database





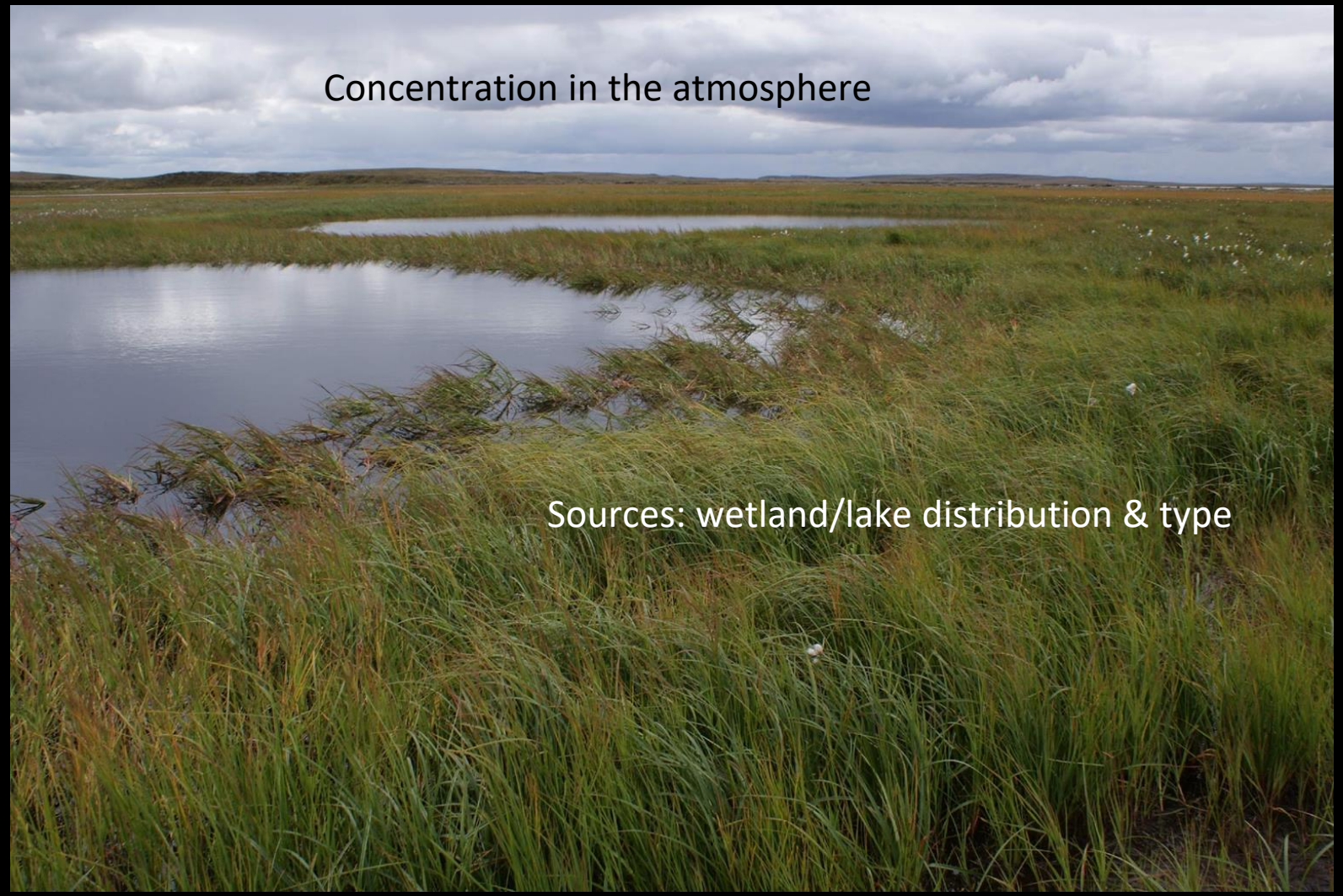
permafrost cci

Subsurface temperature change at 2m (°C/year)
1997-2019
-0,05 0 0,07 0,15 ≥0,2

Soil organic carbon content for the upper 2m (kg/m²)
0-10 10-25 25-50 50-100

AMPACnet CH4

Remote sensing methane across the Arctic



ESA and NASA collaborative community initiative

Working groups:

1. Observations (in situ and remote sensing)
2. Model linkage, bottom-up top-down
3. Future missions

ESA AMPAC related projects 2022-2024

AMPAC-Net
- Networking
- Gap analyses

MethaneCamp
- Atmosphere, improving retrievals

Key event - workshop January 2023

Participants of the AMPAC-Net workshop at FMI, 18.01.2023

more than 40 research topics identified

10 concrete publication ideas

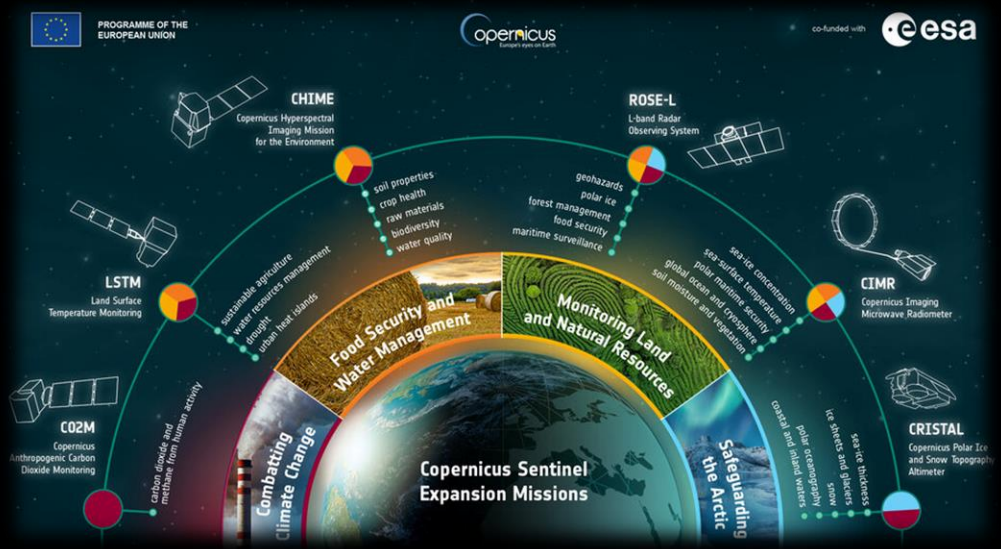
Bartsch, A., Tamminen, J., & Hugelius, G. (2023). AMPAC-Net Workshop Summary, 16.-18.01.2023. Zenodo. https://doi.org/10.5281/zenodo.10369889

Key deliverables - publications and a catalogue with meta data

- Supporting community activities
  - of the Permafrost Carbon Network (PCN, started 2011, coordinated by T. Schuur, NAU)
  - RECCAP2 – Permafrost component (coordinated by G. Hugelius, SU)

RECCAP2 REgional Carbon Cycle Assessment and Processes

- Assessment of EO capabilities in the next decade (including next IPY), considering approved missions of specifically ESA and NASA



Permafrost carbon network – steering committee: all European members part of AMPAC-Net

Abbott, Ben	Brigham Young University, USA	Subsea permafrost, DOC
Ernakovich, Jessica	Univ. of New Hampshire, USA	Microbiome
Grosse, Guido	Alfred-Wegener Institute, Germany	Abrupt thaw
Hugelius, Gustaf	Stockholm University, Sweden	Carbon Pools
Koven, Charlie	Lawrence Berkeley National Lab, USA	Model Integration
Lawrence, Dave	National Center of Atmospheric Research, USA	Model Integration & Development
Loranty, Michael	Colgate University, USA	Vegetation/temp coupling
Natali, Sue	Woodwell Climate Research Center, USA	Non-growing season fluxes
Olefeldt, David	University of Alberta, Canada	Methane, abrupt thaw
Salmon, Verity	Oak Ridge National Laboratory, USA	Nitrogen, belowground
Treat, Claire	Alfred-Wegener Institute, Germany	Anaerobic emissions
Turetsky, Merritt	University of Colorado Boulder, USA	Abrupt thaw

Annett Bartsch | Johanna Tamminen | Andreas Fix | Guido Grosse

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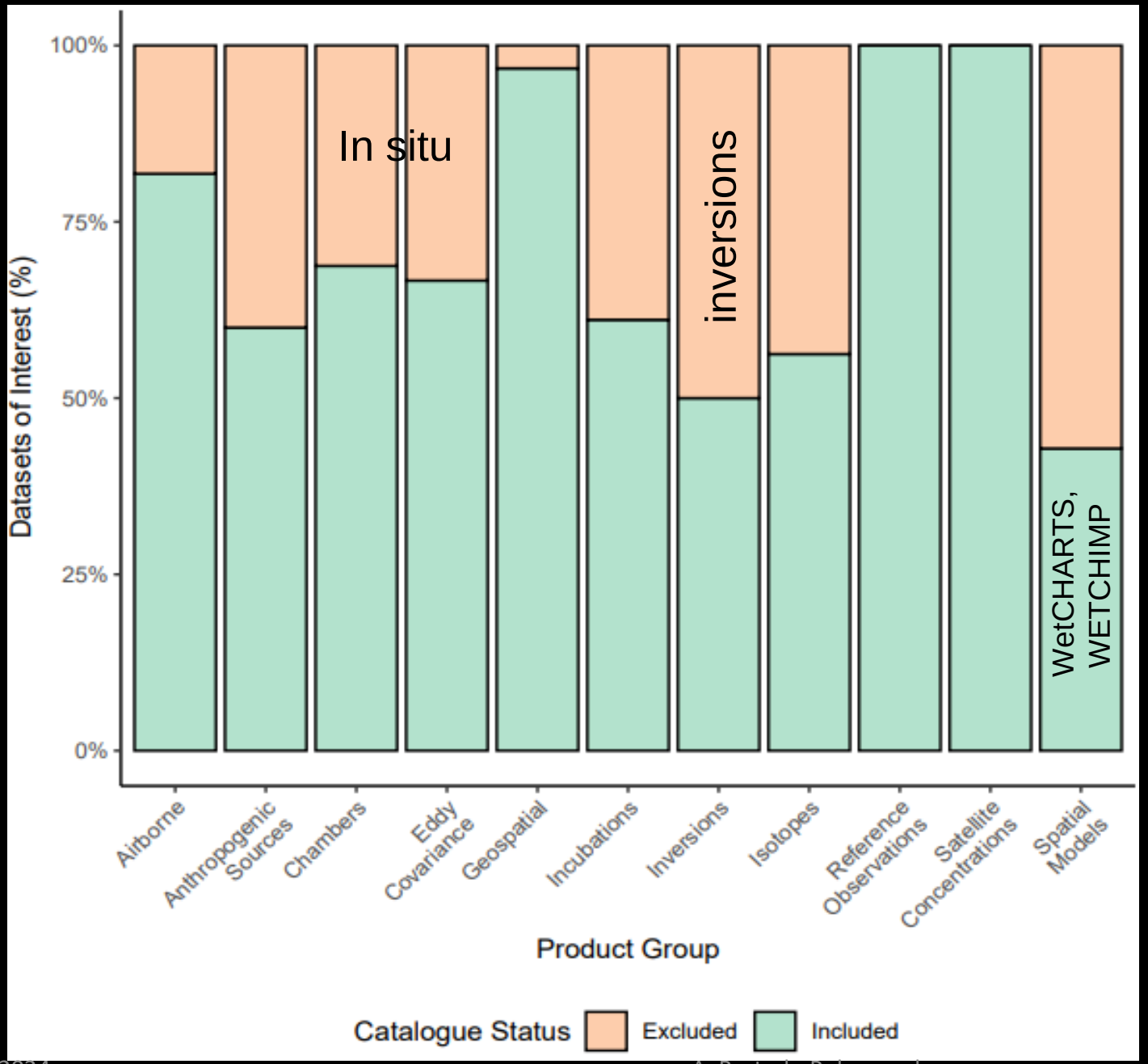
Sub-Catalogue of APGC (Arctic Permafrost Geospatial Centre) which also hosts

- HORIZON2020 ArcticPassion

- H2020 Nunataryuk
- FP7 PAGE21
- ESA GlobPermafrost, CCI Permafrost, DUE permafrost
- NASA CARVE
- …



Data survey for AMPAC catalogue

More than 100 datasets/collections identified, but only 2/3 included

Exclusion due to

- Not published, just mentioned in papers etc
- Published without DOI and meta data

Publications status

January 2023

\+

activities of collaborating projects, e.g. funded through

bottom-up top-down

5/8

land surface remote sensing

2/4

2/3

general topics remote sensing

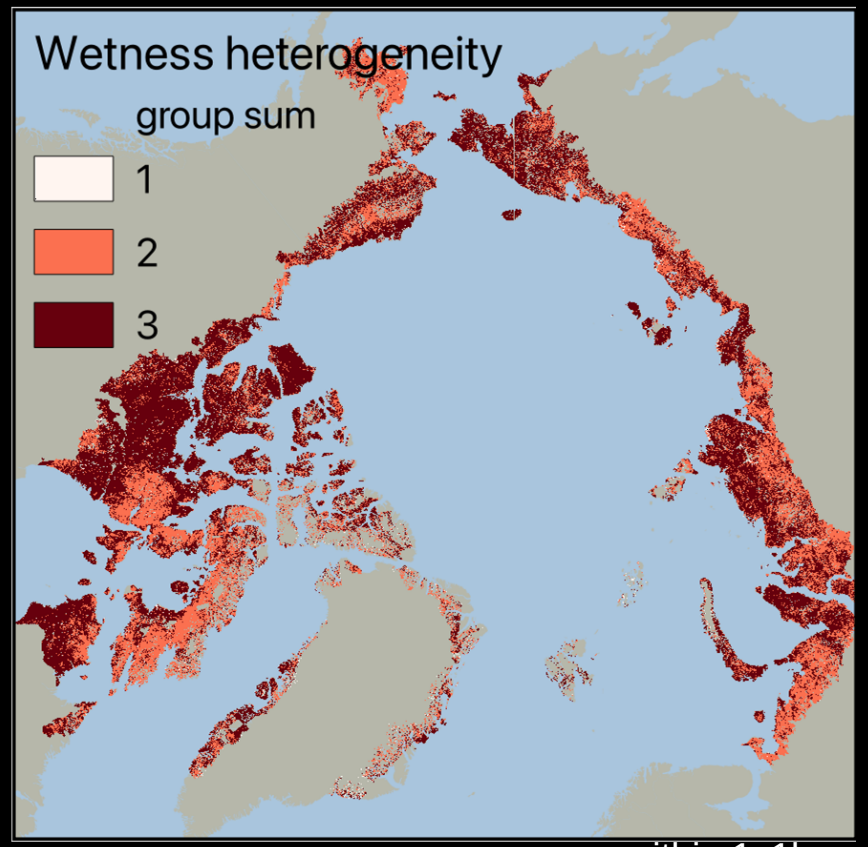
9/15 published or accepted / + in review or final stage

Land surface remote sensing

- Bartsch et al. (2024): Circumarctic landcover diversity considering wetness gradients
- v. Baeckmann et al. (accepted): Landcover succession for recently drained lakes in permafrost regions

- Bartsch et al. (in disc.): Benchmarking passive microwave satellite derived freeze/thaw datasets
- Hashemi et al. (in prep.): Land cover classification resolution requirements for upscaling Methane Emissions

usage of ESA Permafrost_cci landcover (10m) for wetland fraction and heterogeneity analyses



within 1x1km

Bottom-up top-down

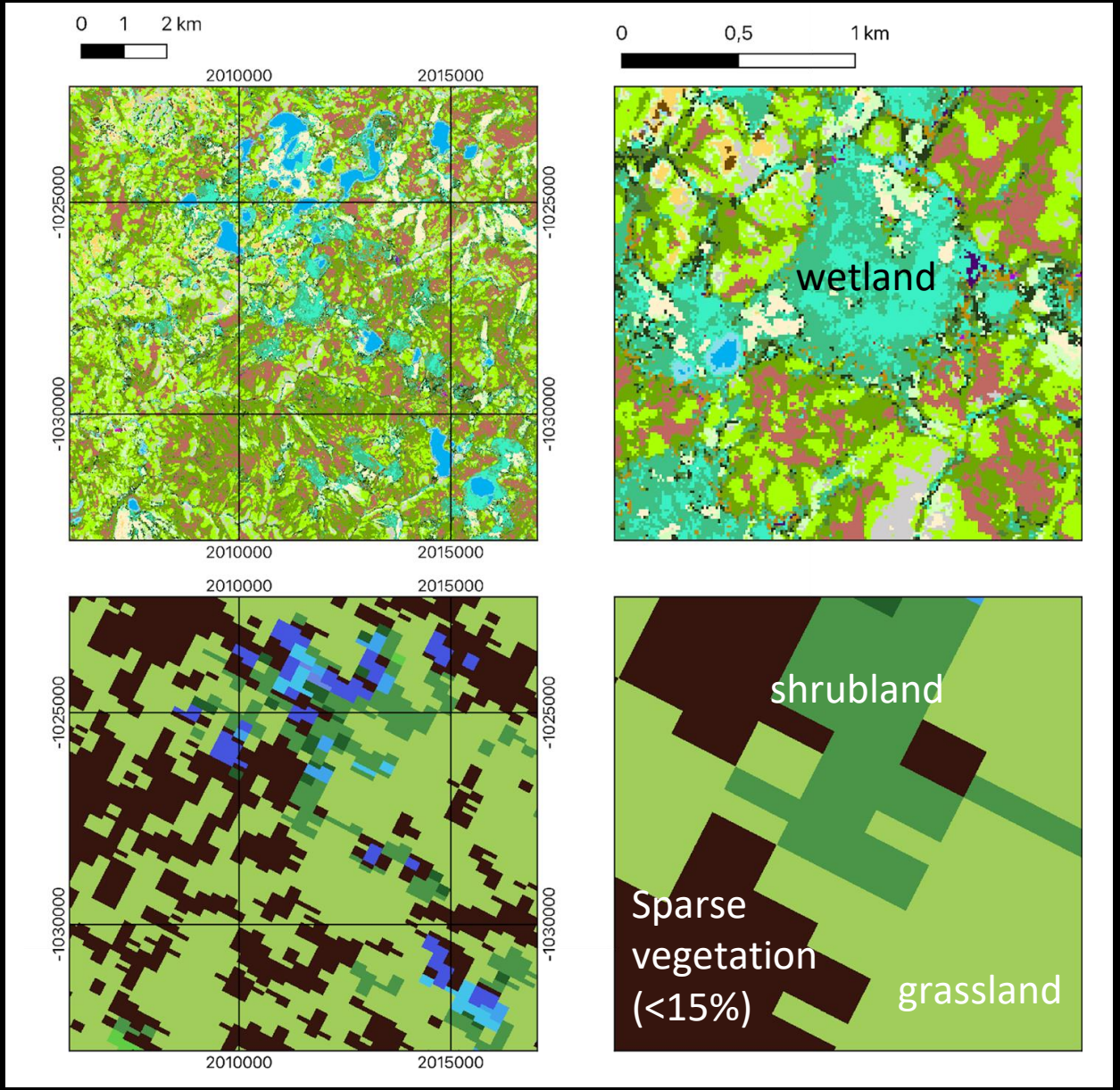
○ Treat et al. (2024): Progress on understanding stocks and fluxes	PCN activity
○ Ramage et al. (2024): Net GHG balance and budget from ecosystem flux upscaling	RECCAP2 permafrost activity
○ **Hugelius et al. (accepted): Two decades of permafrost region CO_2, CH_4, and N_2O budgets**	RECCAP2-permafrost activity
○ Erkkilä et al. (2023): Variability of High Latitude Methane Emissions Based on Earth Observation Data and Atmospheric Inverse Modelling	MethaneCamp
○ Lindquist et al. (2024): New inversions based on TROPOMI improvements from MethaneCamp	MethaneCamp
○ **Ying et al. (in disc.): Machine Learning-based Upscaling of Methane Fluxes**	usage of Permafrost_cci landcover
○ Pallandt et al. (in prep): Quantifying detection limits of top-down methane monitoring infrastructures	
○ Lindquist et al. (in prep): Benchmarking atmospheric methane at high latitudes	

CALU - Circumarctic landcover units

Sentinel-1/2
static, 2017-21
10m
23 unit, with 14 tundra specific

Developed/assessed in Permafrost_cci/AMPAC-Net

Beta version available
Next update 10/24



use in Ying et al.

Landcover_cci (300m)

adapted from Bartsch et al. (2023)

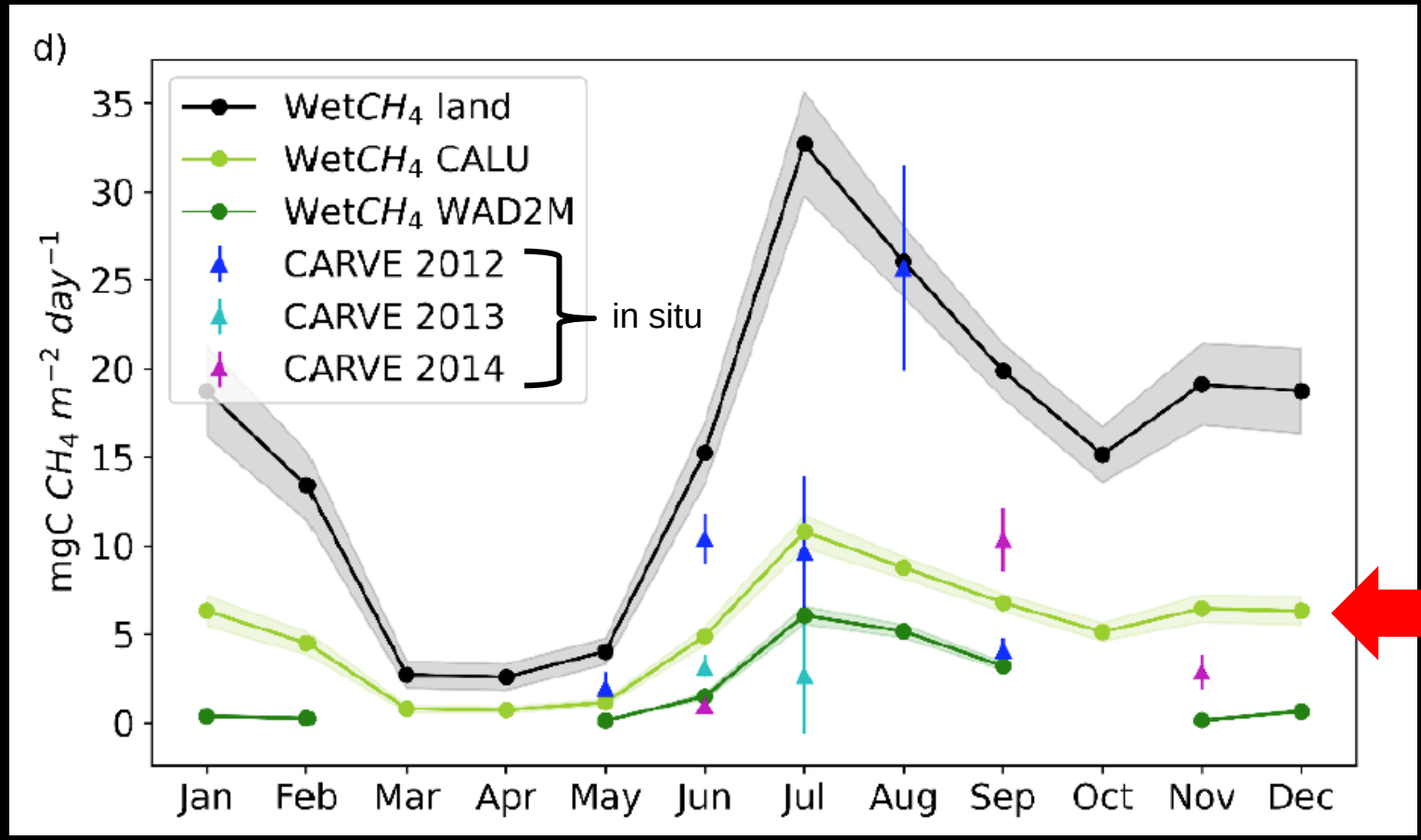
Machine Learning-based Upscaling of Methane Fluxes

test region – Utqiagvik, Alaska

Ying, Q., Poulter, B., Watts, J. D., Arndt, K. A., Virkkala, A.-M., Bruhwiler, L., Oh, Y., Rogers, B. M., Natali, S. M., Sullivan, H., Schiferl, L. D., Elder, C., Peltola, O., Bartsch, A., Armstrong, A., Desai, A. R., Euskirchen, E., Göckede, M., Lehner, B., Nilsson, M. B., Peichl, M., Sonnentag, O., Tuittila, E.-S., Sachs, T., Kalhori, A., Ueyama, M., and Zhang, Z.:

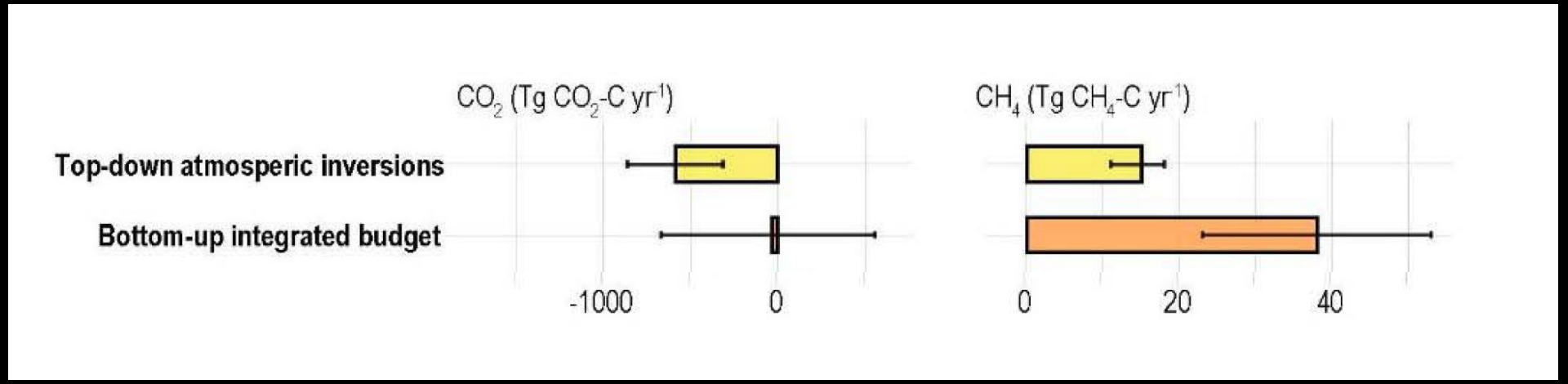
WetCH4: A Machine Learning-based Upscaling of Methane Fluxes of Northern Wetlands during 2016–2022, Earth Syst. Sci. Data Discuss. [preprint],

WAD2M currently used for global methane budget estimation (Saunois et al.)



After the formulation of the first AMPAC-Net workplan and the workshop, several updates and changes were done to the RECCAP2-Permafrost budget study:

- Abrupt thaw representation/double counting, inclusion of anthropogenic emissions …



Hugelius et al. (accepted): Two decades of permafrost region CO2, CH4, and N2O budgets

- 15 inversions (5 from GOSAT)
- For CH4, bottom-up and the top-down show consistent sources, albeit of different magnitudes at **39 and 15** Tg CH4-C yr-1, respectively.
- uncertainty ranges do not overlap, suggesting that there may be a systematic bias between the methods

General - remote sensing status and gaps

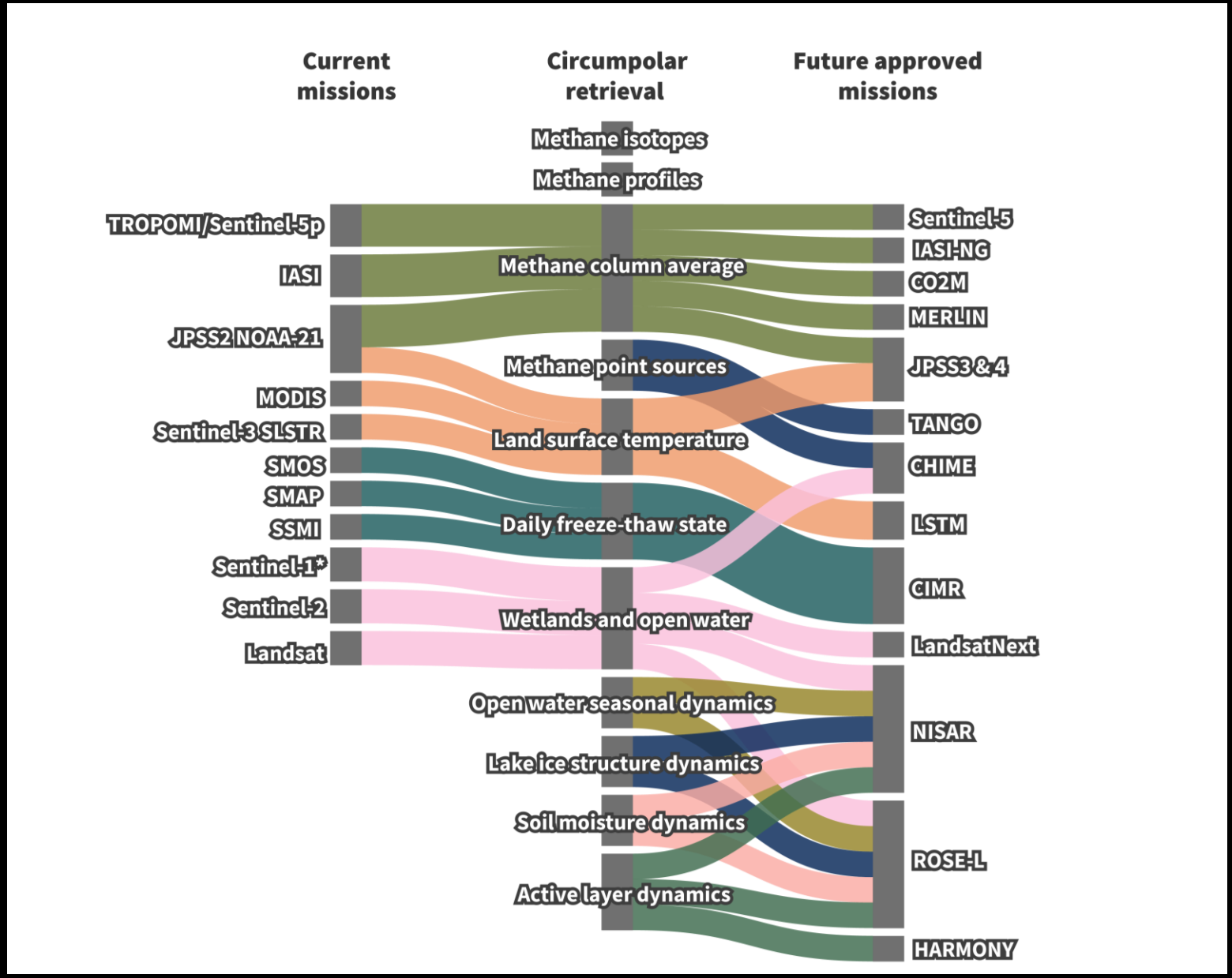
- Bartsch, A., Strozzi, T., Nitze, I. (2023): Permafrost Monitoring from Space. Surveys in Geophysics

- Lenton et al. (2024): Remotely sensing potential climate change **tipping points** across scales. Nat Commun

- Bartsch et al. (in review): Potential of **future satellite missions** for supporting AMPAC

Annett Bartsch, Bradley A. Gay, Dirk Schüttemeyer, Edward Malina, Kimberley Miner, Guido Grosse, Andreas Fix, Johanna Tamminen, Hartmut Bösch, Robert J. Parker, Kimmo Rautiainen, Josh Hashemi, Charles E. Miller (in review)

Advancing the Arctic Methane Permafrost Challenge (AMPAC) with Future Satellite Missions



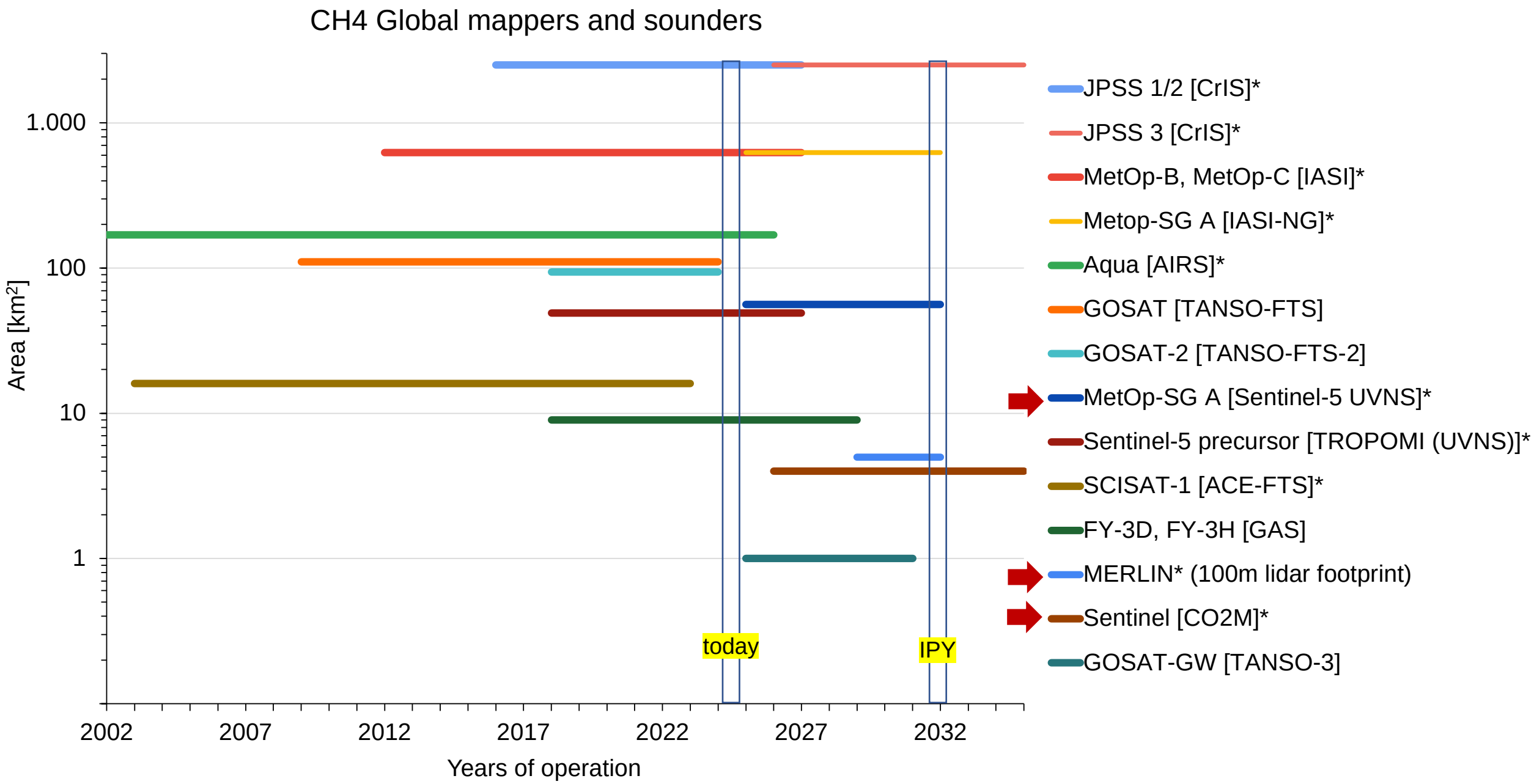

CH4 Global mappers and sounders
1.000
100
10
1
Area [km²]
2002
2007
2012
2017
2022
2027
2032
Years of operation
today
IPY
JPSS 1/2 [CrIS]*
JPSS 3 [CrIS]*
MetOp-B, MetOp-C [IASI]*
Metop-SG A [IASI-NG]*
Aqua [AIRS]*
GOSAT [TANSO-FTS]
GOSAT-2 [TANSO-FTS-2]
MetOp-SG A [Sentinel-5 UVNS]*
Sentinel-5 precursor [TROPOMI (UVNS)]*
SCISAT-1 [ACE-FTS]*
FY-3D, FY-3H [GAS]
MERLIN* (100m lidar footprint)
Sentinel [CO2M]*
GOSAT-GW [TANSO-3]

Photo:Q-Arctic.net

- A high number of issues that need to be addressed for tackling related AMPAC questions has been identified in consultation with the research community
- Many relevant datasets not published, including in situ data, inversions & spatial modelling results
- Novel high resolution landcover provides means to assess heterogeneity and wetness gradients across the Arctic, and can improve bottom-up estimates, but static representation
- Large differences between bottom-up and top-down approaches, probably there is a systematic bias between the methods
- Future SAR missions expected to provide major advance in monitoring polar land surface dynamics
- Several methane missions with higher spatial detail then available today will be operating during IPY
- ….

www.ampac-net.info

Funding:

esa