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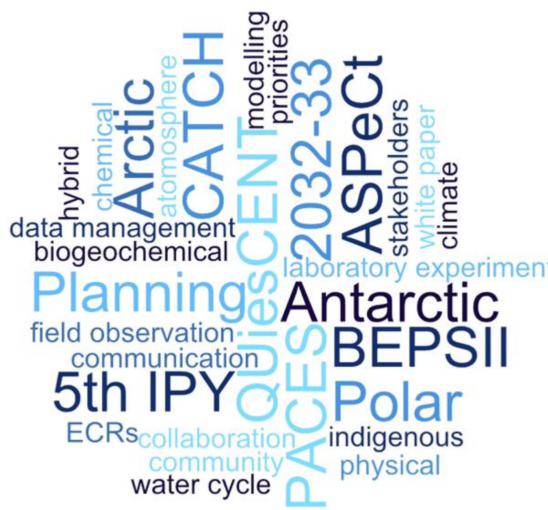

Chemical, Biogeochemical, and Physical Drivers of the Coupled Polar Atmosphere and Climate: An International Polar Year 2032-33 Planning Workshop

17-22 November 2024
Aussois, France & Online

The International Polar Year 2032-33 Planning Workshop on "Chemical, biogeochemical, and physical drivers of the coupled polar atmosphere and climate" took place at the Centre Paul Langevin in Aussois, France from 17 to 22 November. The joint workshop was fully hybrid and co-organised by the international initiatives CATCH, PACES, BEPSII, ASPeCt and QUiesCENT. A total of 99 scientists and stakeholders (44 in person) from 21 countries came together (Figures 1, 2). The group assembled core expertise in chemical, biogeochemical and physical processes in the Arctic and Antarctic with a research focus on the coupled atmosphere-ice-ocean system and links to climate change. The main workshop objectives were to i) present and discuss interdisciplinary 'big picture' science questions and challenges, and ii) jointly identify research priorities and implementation pathways for research activities in field, laboratory and modelling leading up to and during the 5th International Polar Year (IPY) 2032-2033. Planned workshop output includes a white paper to shape IPY32 funding calls, underpin grant applications, and influence the planning of polar research cruises, field campaigns and new long-term measurement capabilities.

In this report

Attendees research profiles

Figure 1: In-person participants of the International Polar Year 2032-33 Planning Workshop in Aussois, France (*Early Career Researcher (ECR), ‡organiser). Left to right - Front row: Adrien Gandolfo*, Nadja Steiner‡, Alexis Lamothe*, Veronica Amoruso*, Patrick Farnole*, Chung Yan Crystal Fu*, Vanessa Selimovic*, Kerri Pratt. Middle row: Bruno Delille, Thorsten Bartels-Rausch, Holly Winton*, Babula Jena, Rajani Mishra, Kathy Law‡, Kate Oglethorpe*, Letizia Tedesco‡, Mittu Walia*, Emma Boland, Ruth Price*, Petra Heil‡, Markus Frey‡. Back: Julia Schmale, Benjamin Rabe, Antoine Haddon*, Penelope Wagner, Marcel Nicolaus, Torsten Kanzow, Elise Droste*, Jennie Thomas, Jessie Creamean, Detlef Helmig, Sabine Eckhardt, Archana Dayal*, Eija Asmi, Stefano Decesari, Steve Arnold‡, Paul Zieger, Rafael Reiss*, Andreas Klocker, Sérgio Gonçalves Junior*. Missing: Marcel Babin, Girish Beedessee*, Gijs de Boer, Fumikazu Taketani. And 55 online participants, including Marie Attard*, Emelia Chamberlain*, Matthew Corkill*, Laura Cimoli*, Peter Effertz*, Jayashree Ghosh*, Libby Jones*, Megan Malpas*, Lisa Matthes*, Lisa Miller‡, Lisa von Friesen*, Alison Webb*, and Cort Zang* (see workshop URL for full list).

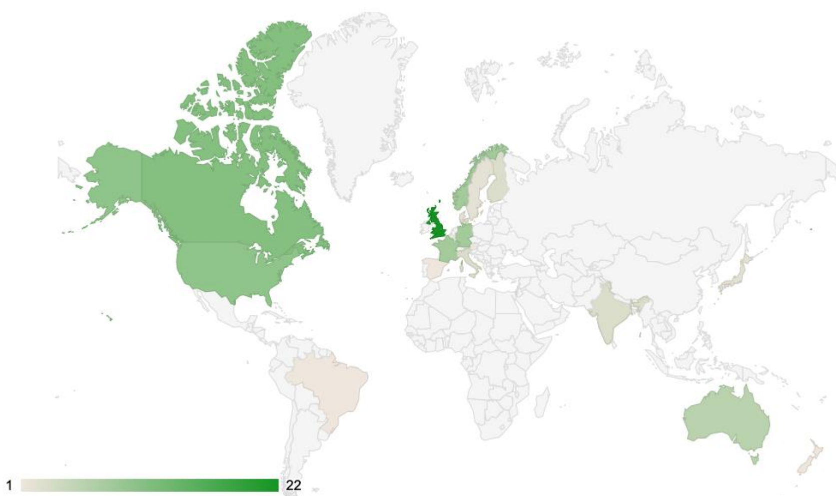

Figure 2: In total 99 participants (44 in-person) from 21 countries in both hemispheres participated in the International Polar Year 2032-33 Planning Workshop.

Programme

On the **first day** plenary orientation sessions with short presentations set the scene regarding current research challenges and gaps for an audience from diverse science backgrounds. The Scientific Committee on Antarctic Research (SCAR) Executive Director Dr. Chandrika Nath and International Arctic Science Committee (IASC) President Henry Burgess provided the high-level context of the next IPY in describing the aims and strategy from the perspectives of Arctic and Antarctic research; for further reading see also the 5th IPY homepage and 5th IPY concept note. This was followed by summaries of research priorities from CATCH, PACES, BEPSII, QUiesCENT and ASPeCt, who had previously consulted their own communities. These were complemented by a series of short talks on recent or ongoing research programs such as 4th IPY project POLARCAT, MOSAiC, AC3 or the Horizon 2020 projects CRiceS and PolarRES. A forward look was provided by presentations on, for example, the Tara Polar Station and Antarctica InSync. Breakout groups then discussed **new science for the 5th IPY**: which major scientific issues need to be tackled by international collaborative and cross-disciplinary efforts under the 5th IPY framework, considering both Poles; how the identified topics address the IPY concept note and its call to action; if there are possibilities for transdisciplinary research to address the identified topics, including co-development of activities with indigenous or local communities; and finally, how outcomes provide new knowledge for international policy agreements.

On the **second day** keynote talks on interdisciplinary '**big picture science**' at the poles followed by discussion provided a larger view on how topics are connected and how processes in the coupled ocean-ice-atmosphere system are linked and potentially driving climate feedback loops. Topics included polar sea ice loss, the role of sea ice in polar biogeochemistry and ecosystems, chemical air-snow exchange, short-lived climate forcers, cloud aerosol interactions, climate interventions and policy and socially relevant research in the Arctic. The participants then broke up into smaller groups to rotate through a series of World Café sessions discussing each a specific topic regarding the **implementation of new science for the 5th IPY**. These topics were: research cruises, modelling experiments, new observation technologies, laboratory experiments, aircraft campaigns and remote sensing, ground observations (short/long term; community involvement).

The **third day** started off with a session on **indigenous and community collaboration** with case studies from the Canadian Arctic, Greenland and New Zealand, and a session on impactful science **communication** with a strategic outlook on the 5th IPY. Brainstorming sessions then followed up on the discussions from the previous days around new science and implementation pathways to define priority research areas and list main research challenges and tools.

The **fourth day** commenced with talks reminding the group of some of the target stakeholders for planned IPY activities, including the International Ice Charting Working Group (IICWG) and Global Cryosphere Watch (GCW)/ World Meteorological Organization (WMO). Breakout groups for each of four identified priority research areas continued to discuss and were tasked to produce overview figures for potential use in the planned white paper.

The **fifth day** concluded the workshop with a public stakeholder session, a workshop synthesis presentation, a talk on perspectives from Climate and Cryosphere (CliC), a core project of the World Climate Research Program, and the final discussion.

Hybrid experience

The workshop was fully hybrid, and on-site participants were encouraged to log into Zoom to level the playing field with the online participants. Online poster sessions in GatherTown allowed for individual science presentations and further discussions.

Workshop feedback

Participants provided feedback in a survey, which was mostly positive, in particular regarding presentation topical range and quality, space provided for discussions, hybrid management, networking and building an IPY community.

Conclusions and next steps

This group with core expertise in chemical, biogeochemical and physical sciences of the polar atmosphere, ice and ocean made a first step in building a conceptual framework for a 5th IPY research program, which will be fed into the wider IPY process. The **four priority research areas** identified were: 1. The Water Cycle; 2. Atmospheric Composition; 3. Biogeochemistry and Ecosystems; and 4. The Energy Budget. These research areas rest on **five supporting pillars** consisting of 1. field observations, 2. laboratory experiments, 3. data management, 4. numerical modelling, and 5. community knowledge and engagement. Together these will enable progress to achieve the larger societal objectives of global weather and climate understanding, polar ecosystem health, global security and resilience, and community health and well-being. A detailed synthesis and overview concept will be published as a white paper in 2025.

It was recognised that rather than duplicating efforts this group will liaise with other existing groups and programmes. Furthermore, collaboration and collaborative projects will already start now in preparation for the 5th IPY. To do this the workshop URL will be used as a digital hub with the video recordings of keynotes and short presentations publicly available, a participant list, and announcements of future meetings and events via the workshop email list.

This group remains open, and anyone interested is welcome to join by emailing ipy2032workshop@univ-grenoble-alpes.fr.

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Chung Yan (Crystal) Fu studied Geology at Imperial College London and specialised in Holocene Climates at the University of Cambridge. She continued to a PhD to investigate Arctic sea ice sensitivity by combing palaeoclimate proxy and model data through physics-based statistical learning methods.

Bayesian calibration for the Arctic sea ice biomarker IP_{25}

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Sea ice plays multiple important roles in the Earth system, enabling the ice-albedo feedback, moderating air-sea heat and gas exchanges, and facilitating deep-water formation and thermohaline circulation. The rapid sea ice loss in the Arctic over the last few decades has far-reaching climatic impacts, yet our understanding of long-term sea ice variability and its feedbacks remains limited by a lack of quantitative sea ice reconstructions beyond the observational period. Various proxies have been used to investigate past sea ice conditions; the biomarker IP_{25} (Ice Proxy with 25 carbon atoms) is one of the most widely applied.

IP_{25} is synthesised by Arctic sea ice diatoms during the spring algal bloom and released when the ice melts in summer (Belt *et al.*, 2007; Brown *et al.*, 2011, 2016); thus, its detection in marine sediments suggests the presence of seasonal sea ice. It is commonly combined with open-water phytoplankton biomarkers, such as brassicasterol and dinosterol, to distinguish between year-round ice-covered and ice-free conditions (Figure 3; Müller *et al.*, 2011). The resultant sea ice index (PIP_{25}) shows potential for quantitative sea ice reconstructions, but its correlation with sea ice varies significantly across different regions (Kolling *et al.*, 2020), hampering spatially consistent proxy interpretation. Furthermore, persisting issues related to a balance factor in the index complicate the proxy's application on geologic timescales (Belt & Müller, 2013).

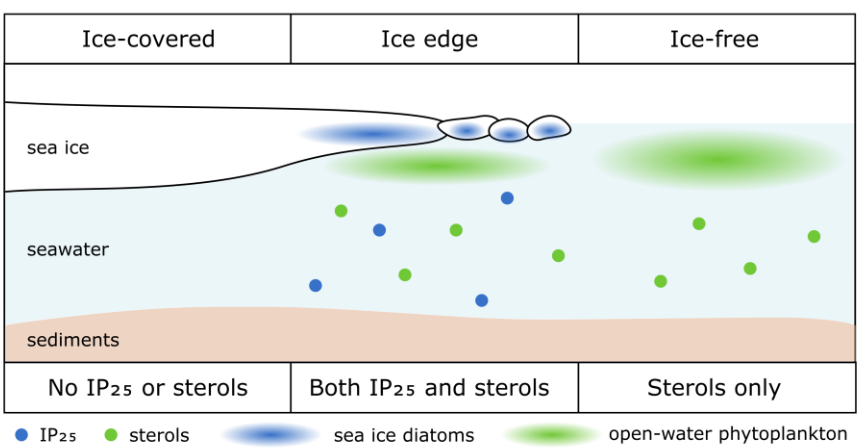

Figure 3: Schematic diagram of the IP_{25} (Ice Proxy with 25 carbon atoms)-sterols proxy system (adapted from Belt & Müller, 2013, modified from Müller *et al.*, 2011).

To achieve fully quantitative sea ice reconstructions, we develop a robust calibration for IP_{25} (and associated phytoplankton biomarkers) using recently compiled core-top biomarker measurements across the Arctic. We calculate a new PIP_{25} index that dispenses with the problematic balance factor, allowing direct comparison across space and time. A Bayesian framework is employed to model the nonlinear association of the proposed PIP_{25} index with sea ice concentration and quantify the uncertainties. The proxy system model accounts for spatial variations and the influence of other environmental factors (e.g. sea surface salinity) for more accurate forward modelling of the PIP_{25} index. An inverse model will also be released to support direct inferences of past sea ice concentrations from biomarker measurements. The new calibration, called BaySIC, presents opportunities for direct comparison between proxy and model data as well as palaeoclimate data assimilation, providing more insights into the evolution of sea ice in the past that may help us better predict its future.

References

Belt, S.T., Massé, G., Rowland, S.J., *et al.* (2007). A novel chemical fossil of palaeo sea ice: IP25. *Org. Geochem.*, 38(1), 16–27. https://doi.org/10.1016/j.orggeochem.2006.09.013

Belt, S.T. & Müller, J. (2013). The Arctic sea ice biomarker IP25: a review of current understanding, recommendations for future research and applications in palaeo sea ice reconstructions. *Quat. Sci. Rev.*, 79, 9–25. https://doi.org/10.1016/j.quascirev.2012.12.001

Brown, T.A., Belt, S.T., Philippe, B., *et al.* (2011). Temporal and vertical variations of lipid biomarkers during a bottom ice diatom bloom in the Canadian Beaufort Sea: further evidence for the use of the IP25 biomarker as a proxy for spring Arctic sea ice. *Polar Biol.*, 34(12), 1857–1868. https://doi.org/10.1007/s00300-010-0942-5

Brown, T.A., Belt, S.T., Gosselin, M., *et al.* (2016). Quantitative estimates of sinking sea ice particulate organic carbon based on the biomarker IP25. *Mar. Ecol. Prog. Ser.*, 546, 17–29. https://doi.org/10.3354/meps11668

Kolling, H.M., Stein, R., Fahl, K., *et al.* (2020). Biomarker distributions in (Sub)-Arctic surface sediments and their potential for sea ice reconstructions. *Geochem. Geophys. Geosyst.*, 21(10), e2019GC008629. https://doi.org/10.1029/2019GC008629

Müller, J., Wagner, A., Fahl, K., *et al.* (2011). Towards quantitative sea ice reconstructions in the northern North Atlantic: A combined biomarker and numerical modelling approach. *Earth Planet. Sci. Lett.*, 306(3), 137–148. https://doi.org/10.1016/j.epsl.2011.04.011

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A Brazilian module Criosfera-1: Studying West Antarctica's climate change, aerosols and extremes events

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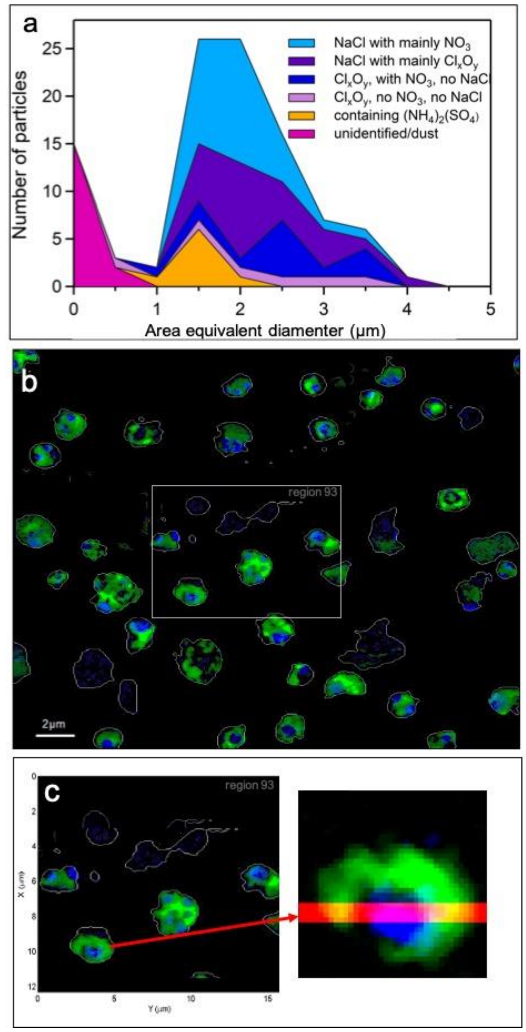
Antarctica's unique geography makes it a key regulator of global climate. Its high albedo, extensive sea ice, and influence on ocean circulation heighten its sensitivity to climate change. As a remote continent, it offers an ideal environment for studying the effects of climate change (Tin *et al.*, 2019). The West Antarctic Ice Sheet (WAIS) warms and melts at a faster rate than East Antarctica due to shifts in atmospheric circulation driven by tropical Pacific sea surface temperatures (Casado *et al.*, 2022). Changes in Antarctic ice and the chemical processes of WAIS aerosols directly influence regional and global warming.

Criosfera-1, a Brazilian research station located in WAIS (84°S 79°29'39"W), investigates how atmospheric dynamics and aerosols, particularly those transported by air masses from the Southern Ocean, impact the ice sheet. My research at Criosfera-1 analyses atmospheric data, particularly aerosols. We study their sources, transport, and transformations within the WAIS atmosphere. My PhD research used advanced synchrotron techniques, including scanning transmission X-ray microscopy (STXM/NEXAFS) and computer-controlled scanning microscopy (CCSEM) with energy dispersive X-ray (EDX) microanalysis. These methods provided detailed insights into the composition of individual aerosol particles, revealing trends of transformation in West Antarctica (Gonçalves Jr *et al.*, 2021; Gonçalves Jr *et al.*, 2023). A key finding is how snowpack photochemistry alters particle composition, affecting aerosol light scattering. We observed a significant portion of internally mixed particles with sea salt (sodium chloride, NaCl) cores coated with nitrate (Figure 4). This nitrate coating, a product of atmospheric processing, reduces scattering efficiency due to the weak hygroscopicity of the resulting mixed particle. This finding is crucial for accurate radiative transfer calculations in climate models, as nitrate over sea salt aerosols needs to be considered (Gonçalves Jr. *et al.*, 2021).

Beyond aerosols, Criosfera-1 also studies extreme events like heatwaves and their connection to atmospheric rivers using integrated vapor transport (IVT) and integrated water vapor (IWV) data. We documented an extreme warm event in central WAIS (Evangelista *et al.*, 2022), highlighting the region's vulnerability to rapid warming (Figure 5).

Figure 4: Single-particle analysis of aerosols using scanning transmission X-ray microscopy (STXM/NEXAFS). (a) Size distribution of 102 analysed particles, classified into six clusters; (b) representative STXM map showing the distribution of nitrate (NO_3, green) and sodium chloride (NaCl, blue) in individual particles; (c) Magnified view of a single particle and corresponding cross-section, illustrating nitrate coating on a sodium chloride particle. Further details on this photochemical transformation are available in Gonçalves Jr *et al.*, 2021. Similar analyses for other clusters can be found in Gonçalves Jr *et al.*, 2023.



The next step is to analyse over ten years of Criosfera-1 temperature data. This data allows us to identify trends and detect extreme events. Combined with atmospheric river information, it will help us understand the changing WAIS climate and its broader Antarctic impacts. The WAIS's vulnerability to melting from warming oceans underscores the importance of such research for future sea-level rise projections. By combining on-site observations with advanced modelling, we aim to improve these projections and inform climate policy and adaptation strategies. All Criosfera-1 data are available at https://www.criosfera1.com/.

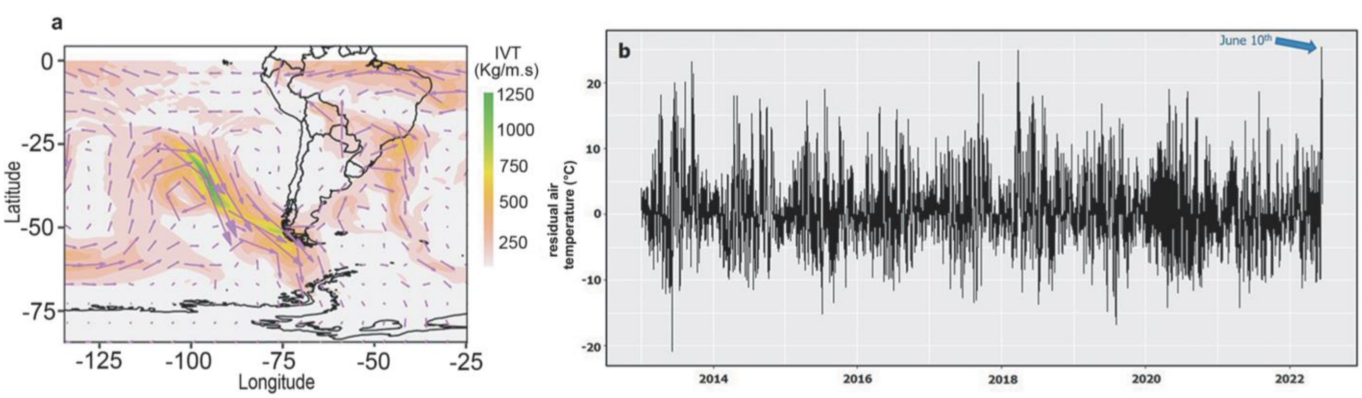


Figure 5: Extreme Warm Event and Atmospheric River (June 10, 2022). (a) Integrated vapor transport (IVT, kg m^{-1} s^{-1}) showing an atmospheric river approaching Antarctica. (b) Near-surface air temperature anomalies (difference from the 2013-2022 median) highlighting the extreme warm event. (Adapted from Evangelista *et al.*, 2022)

References

Casado, M., Hébert, R., Faranda, D., & Landais, A. (2022). The quandary of detecting the signature of climate change in Antarctica. 07 November 2022, PREPRINT (Version 1) available at Research Square. https://doi.org/10.21203/rs.3.rs-2163371/v1

Evangelista, H., Prado, L.F., Gorodetskaya, I.V., *et al.* (2023). The June 2022 extreme warm event in central West Antarctica. *Antarct. Sci.*, 35(5), 319-327. https://doi.org/10.1017/S0954102023000238

Gonçalves Jr, S.J., Evangelista, H., Weis, J., *et al.* (2023). Stratospheric ozone depletion in the Antarctic region triggers intense changes in sea salt aerosol geochemistry. *Commun. Earth Environ.*, 4, 77. https://doi.org/10.1038/s43247-023-00739-z

Gonçalves Jr, S.J., Weis J., China S., *et al.* (2021). Photochemical reactions on aerosols at West Antarctica: A molecular case-study of nitrate formation among sea salt aerosols. *Sci. Total Environ.*, 758(1), 143586. https://doi.org/10.1016/j.scitotenv.2020.143586

Tin, T., Peden, J., O'Reilly, J., *et al.* (2019). Preservation amenity, research laboratory, or mineral reserve? international perspectives on the values of Antarctica. *Polar Rec.*, 55(2), 61-71. https://doi.org/10.1017/s0032247419000214

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