

Planetary Boundary Initiative

Newsletter

FIFTH EDITION · Q4 2025



Planetary Boundaries
Science



PIK

POTS DAM INSTITUTE FOR
CLIMATE IMPACT RESEARCH



While Planetary Boundary science has advanced tremendously over the past decades, we still lack a deep understanding of the intricate, yet pivotal connections between many biological and physical functions of the Earth system.

In late 2023, the **Potsdam Institute for Climate Impact Research** and its partners launched a major scientific effort to improve both our ability to model how the Earth system evolves under the pressure of human activity, as well as our ability to measure the state of the Earth system at a high temporal resolution: **Planetary Boundaries Science (PBScience)**.

WELCOME TO THIS FIFTH NEWSLETTER OF THE PLANETARY BOUNDARY INITIATIVE (PBI).

Here, you find updates on **Planetary Boundaries Science** and related research efforts conducted at the Potsdam Institute for Climate Impact Research (PIK) and beyond. Read on for news on our steadily growing science initiative, cutting-edge Planetary Boundaries (PB) research results, and exclusive insights into the PBScience effort.





UNFCCC

COP30 AND THE PLANETARY SCIENCE PAVILION

Text: Bruce Phillips | Visuals: UNFCCC

The Potsdam Institute for Climate Impact Research highlighted the Planetary Health Check 2025 as part of the **Planetary Science Pavilion at COP30** in co-operation with multiple partners including the Planetary Guardians, Future Earth, the Max-Planck Institute for Geoanthropology, Stanford, Exeter and São Paulo Universities among others.

From November 10–20 2025, the **Planetary Science Pavilion** was hosted inside the blue zone, the beating heart of negotiations at COP30, hosting a dynamic lineup of sessions that connected cutting-edge research with real-world solutions. The opening day featured well known scientists Johan Rockström and Carlos Nobre, who kicked off discussions on how science can guide urgent climate action. Throughout the week, sessions like "Amazon day" and "Biodiversity day" dove into the latest evidence on tipping points, carbon sinks, and strategies to keep us moving back inside the planet's Safe Operating Space. Amazon Day brought powerful voices from the region, highlighting the social, ecological, and health impacts of climate change in Brazil.

Midweek, the Pavilion shifted focus to solutions and accelerating "positive tipping points" that support nature while reducing climate impacts. Sessions explored how emerging technologies, equitable policies, and Indigenous knowledge can reshape economies and restore Earth's life-supporting systems. As the summit closed, the Pavilion turned toward the future: strengthening the science-policy interface, the roles of local communities, justice and showcasing Global South leadership. Next year's COP will be held in Turkey.



EARTH ENERGY IMBALANCE WORKSHOP

Text: Levke Caesar | Visuals: Bruce Phillips

In October 2025, PIK brought together leading scientists from Europe, the US, and Asia for the first **Earth Energy Imbalance (EEI) Workshop**. The meeting was driven by a shared scientific concern: *over the last few years, the Earth has been taking up more excess energy than ever recorded – and the rise is faster than current climate models can explain.*

The Earth's Energy Imbalance is the difference between the energy the planet receives from the Sun and the energy it radiates back into space. Under a stable climate, these flows are roughly equal. Today, however, the planet retains more of this energy, primarily in the ocean, which accelerates warming, ice melt, and sea-level rise.

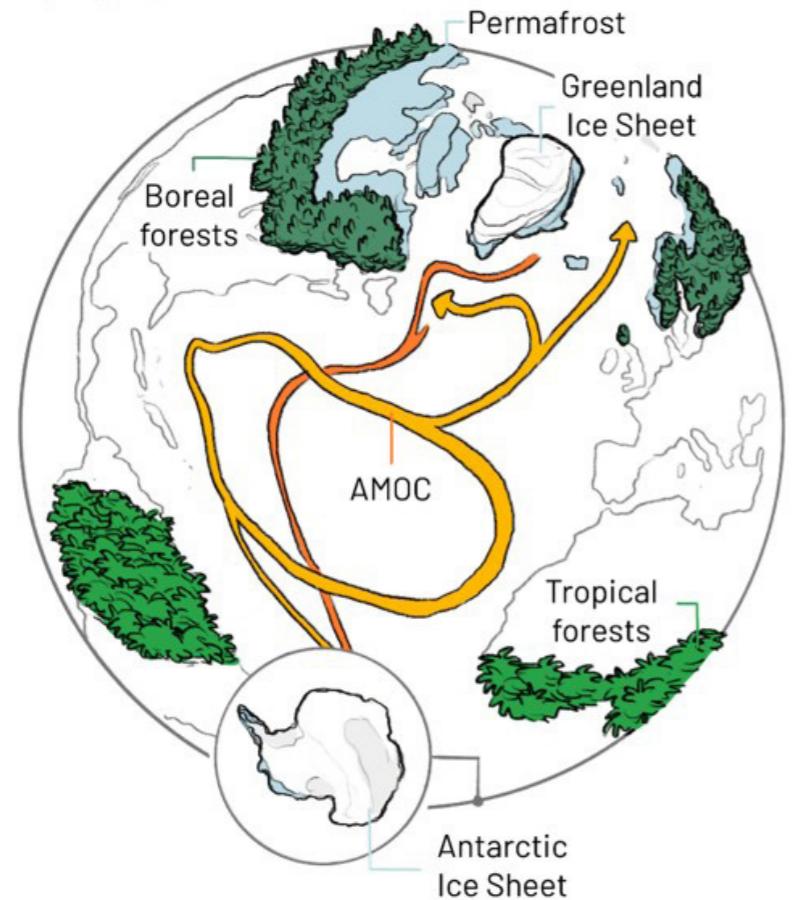
What triggered the workshop is that since around 2020, this imbalance has increased unusually rapidly. Observational datasets – from satellites, ocean measurements, and the Earth Heat Inventory – all show a sharp upward trend. Yet the underlying causes remain partly unclear. Participants discussed several possible contributors:

- a decline in aerosols, leading to clearer skies and more absorbed sunlight,
- changes in cloud cover and planetary reflectivity,
- and natural variability, including the recent strong El Niño.

The central question remains: Are we witnessing an extreme but natural fluctuation - or an early indication of a more structural shift in the Earth system? The workshop brought together, for the first time, experts from observational science, climate modelling, and Earth-system resilience research. The outcome was a strong consensus that this signal is unusual enough to warrant sustained joint investigation.

This is of great importance, as the EEI is the planet's most fundamental "vital sign": it reveals whether Earth is still gaining heat, even when surface temperatures appear to stabilize. Understanding this imbalance – and what drives recent changes – is essential for anticipating long-term climate risks and safeguarding planetary resilience.

Continued support will be crucial to maintain this new scientific collaboration and ensure that we can track and understand this emerging and potentially highly important signal. This workshop kicked off an important collaboration which PIK aims to continue into 2026.



TIPMIP PROTOCOL PAPERS PUBLIC AND IN REVIEW

Text & Visual: TIPMIP

The pre-print for the [TIPMIP framework paper](#) is now out! This is the overarching TIPMIP paper, outlining the entire project and aiming to bring together the international modelling community's understanding of tipping points. To this end, we described TIPMIP's key scientific research questions and the state of tipping points modelling. The paper is currently undergoing public peer review in an open access journal, meaning that the reviewer comments and replies to them are fully transparent.

The fundamental principle of a modelling intercomparison project (MIP) is the following: Each model (simulation) is different, and has its pros and cons in terms of resolution, the processes it captures and complexity. We learn a lot about the Earth system — and the models aiming to describe it — by comparing what different models do under the same scenario. The scenario is defined by the research question(s) under consideration, and comes with a set of instructions that each participating model needs to follow (think of a recipe). This set of instructions is commonly referred to as the “protocol” of the MIP.

TIPMIP can be thought of as a “MIP of MIPs”, with protocols (detailed guidelines that ensure consistency across multiple modeling efforts) for each individual domain. The domains correspond (roughly) to different components of the Earth system (i.e., icesheets, the global biosphere, oceans, etc.). After a long community engagement process, the team converged on the TIPMIP-ESM protocol, now also [published as a preprint](#). This “recipe” will be followed by all participating Earth system models, which are instructed to warm the Earth by 0.2°C per decade, stay at selected warming levels for a prescribed period of time (50-200 years) and then cool again at the same rate. This will not only allow the team to study how, say, a 2°C world looks across models (and which tipping points are to be expected), but also outputs can be used as forcing for the other domains. Concretely, this means that the team can study how the ice sheet models in TIPMIP-ICE respond to being exposed to these 2°C worlds from TIPMIP-ESM.

The protocol papers for the other domains are under active development.



PLANETARY SOLUTIONS AND NOVEL ENTITIES WORKSHOP WITH UFZ LEIPZIG

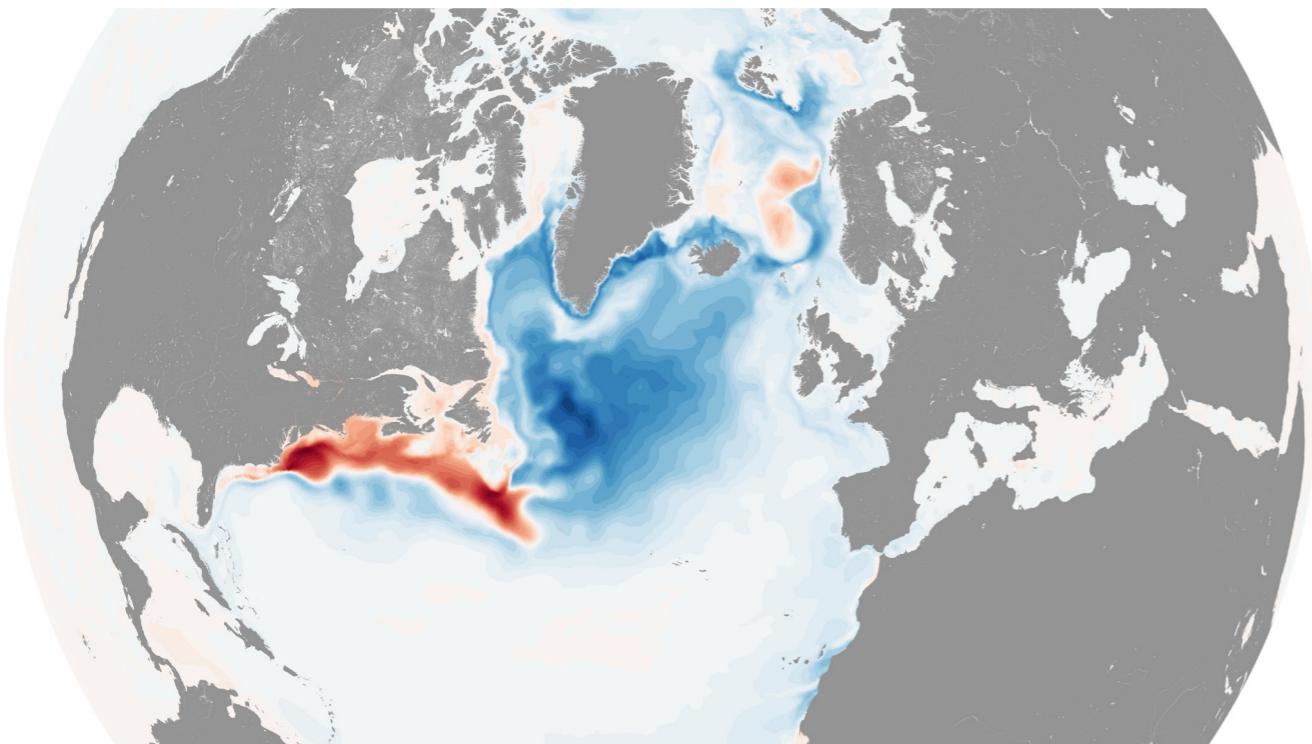
Text & Visual: Yuge Bai

At the end of November, more than twenty participants from five countries gathered in Leipzig to take part in the **Planetary Solutions Expert Workshop**, bringing together a broad range of perspectives from senior representatives of environmental ministries to early-career researchers working on plastics, pollution assessment, and regulatory science. The central focus of the workshop was the mounting global challenge of chemical pollution and novel entities, and the urgent need to shift from describing the problem to shaping coherent, future-oriented governance strategies. With expertise spanning policy, toxicology, earth system science, sociology, and industrial practice, the group set out to explore how current regulatory structures can adapt to the accelerating introduction of new chemicals and materials into the biosphere.

Across two days of structured discussions and breakout groups, participants explored why current approaches to chemical management remain mostly reactive. In many cases, harmful substances are regulated only after they have already entered our food, water, air and ecosystems. The group reflected on how to build a more forward looking approach that can identify

risks before harm occurs. Ideas included improving scientific screening of new chemicals, creating clearer rules that work across national borders and making knowledge easier to access across scientific and political communities. Although the scientific community already has strong evidence on pollution impacts, meaningful action still depends on cooperation, shared responsibility and clear communication between researchers and decision makers.

A key outcome of the workshop was the recognition that *protecting the planet from harmful substances is not only a scientific or political task but also a shared public mission*. Participants discussed how to communicate more clearly with society about risks and responsibilities, and how to support citizens in making informed choices that reduce pressure on natural systems. The meeting closed with a renewed commitment to work together across institutions and countries to establish stronger global controls on novel entities and to shift from managing damage after it happens to preventing it before it begins. The Leipzig workshop was an encouraging step toward a cleaner and safer future for all.

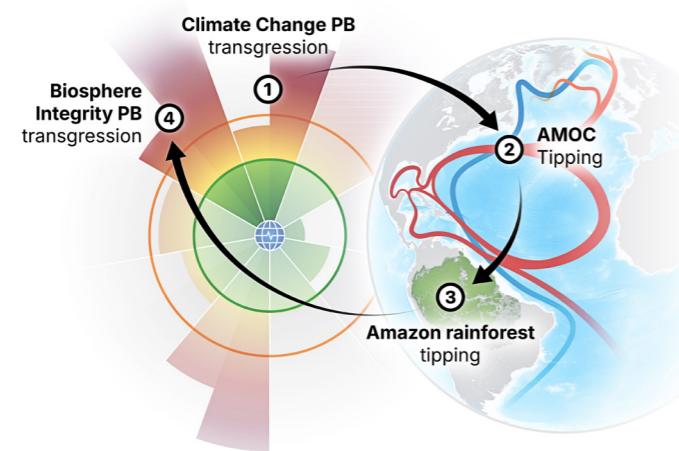


PRESENTING AMOC TIPPING AT DMG EVENT IN BONN

Text: Levke Caesar | Visuals: van Westen et al., 2025 · Globaïa

At the end of November, Dr. Levke Caesar, Co-lead of the Planetary Boundaries Science Lab was invited to present the latest science on the stability of the **Atlantic Meridional Overturning Circulation (AMOC)** at a tipping point workshop in Bonn. The AMOC is like a giant conveyor belt in the Atlantic Ocean that moves warm water north and cold water south, helping regulate Earth's climate. There are major concerns about the AMOC slowing down due to climate change which would have significant impacts on Europe and the Eastern USA. In preparing this talk, Levke reviewed all new studies published over the past two to three years, and the overall picture has become clearer: although there

remain substantial uncertainties, several independent lines of evidence now indicate that the risk of an AMOC shutdown can no longer be considered remote or theoretical. Observational analyses, new model generations, and physics-based early-warning indicators all point to an increasingly vulnerable system. For us, this reinforces why advancing robust Earth-system science and early-warning capabilities is so essential. The AMOC is a cornerstone of climate stability, and understanding its resilience is critical for informed decision-making and long-term planetary stewardship.



Sustainable Development in the Face of Global Urgency and Polycrises



KEYNOTE ON PLANETARY BOUNDARIES TO THE SWISS AGENCY FOR DEVELOPMENT AND COOPERATION (SDC)

Text: Levke Caesar | Visuals: van Westen et al., 2025 · Globaïa

In November, the PBScience Lab's coordinator Clara Nicolai delivered an online keynote at the webinar *Bridging Themes for Greater Impact: Enhancing Collaboration in Times of Global Crises* for the Swiss Agency for Development and Cooperation (SDC). In her keynote, Clara introduced the audience to the Planetary Boundaries Framework and, drawing from her own previous work experience in the development sector, related it to the working reality of the participants. This keynote was used to kick off an SDC-internal learning journey meant to span several months to enhance collaboration within the organization, with the ultimate goal to increase the impact of SDC's development interventions.

In practice, this means (more) closely relating climate, disaster risk reduction, environmental concerns, agriculture and food, as well as water in concrete projects. Following Clara's keynote, several staff members from SDC's various participating thematic networks reported back on their current projects.

The recording of the full seminar as well as some reflections on the event's outcome can be found [here](#).



TIPMIP DOMAIN LEADS MEETING IN POTSDAM

Text: TIPMIP | Visuals: TIPMIP

In the first week of December, PIK's Earth Resilience Science Unit was delighted to welcome a subset of the TIPMIP Domain Leads to Potsdam for what proved to be a highly productive meeting. Unfortunately, only some of the TIPMIP members in person, as several (seven, by our count!) were simultaneously participating in the IPCC Lead Author Meeting in Paris marking the commencement of work on the IPCC's Seventh Assessment Report. More on that in one of the next issues of the newsletter!

Our sectoral coordination team based at PIK and the Max-Planck Institute for Geoanthropology facilitated an exchange across the various domains. Through a series of focused discussions, the domain leads were able to identify shared priorities, align ongoing efforts, and sketch a preliminary roadmap for the coming years. These discussions laid the groundwork for stronger cross-domain collaboration and will help guide the strategic development of our activities moving forward in 2026 and 2027. In particular, the team agreed on delivery dates for the various data products, and responsibilities for the assessment papers.

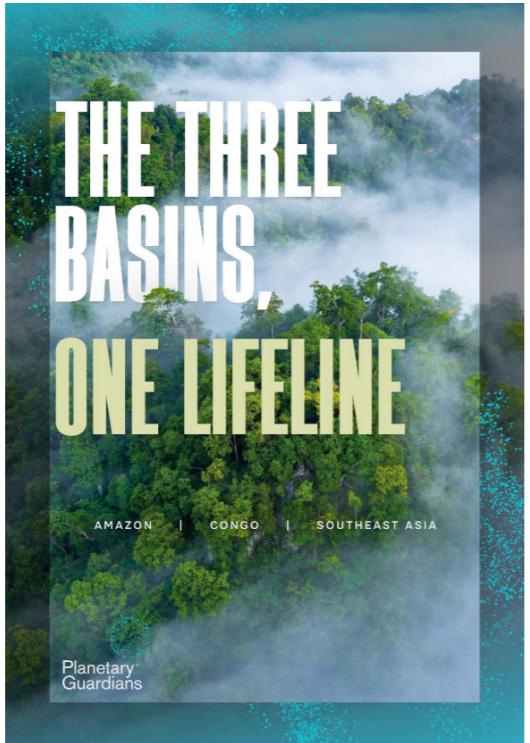


TIPPING POINT RISKS UNDER GLOBAL WARMING OVERSHOOT TRAJECTORIES ASSESSED AT FIRST OVERSHOOTS CONFERENCE IN LAXENBURG

Text: TIPMIP | Visuals: TIPMIP

ERSU deputy-lead Jonathan Donges (second from the left) co-organized the first and very well attended Overshoots Conference that took place in Laxenburg/Vienna in October 2025 and led the conference theme on "Overshoot legacy and tipping elements". The participants came to the agreed conclusion that "Overshoot risks triggering tipping dynamics and cascades that cannot be fully stopped by reversing warming, causing additional and severe planetary changes to climate and the biosphere for centuries, some being irreversible.

The only way to mitigate most tipping point risks is to minimize overshoot amplitude and duration." Our research through TIPMIP will make relevant contributions to better assess and mitigate these overshoot risks.

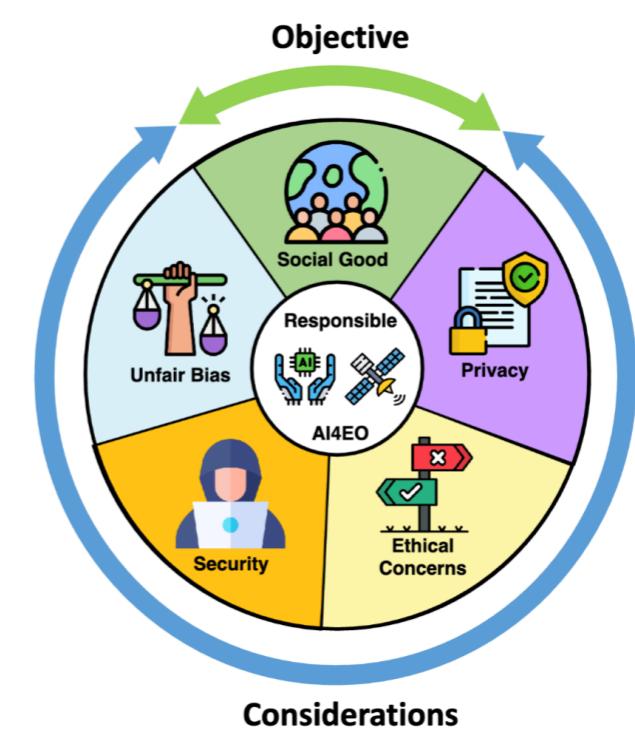


THREE BASINS, ONE LIFELINE

Text: Bruce Phillips | Visual: Planetary Guardians

The **Planetary Guardians** commissioned the sustainability advisory *Systemiq* to write the [Three Basins, One Lifeline](#) report, which explains that the tropical forests of the Amazon, the Congo, and of Southeast Asia are not only the beating heart of the global climate system: they are also essential macroeconomic infrastructure providing indispensable services in regulating rainfall patterns, storing carbon, sustaining biodiversity, and underpinning food and water security worldwide.

These forests impact rainfall and weather conditions across the globe, underpinning 50% of global food production and up to 8% of global GDP. Their degradation places at risk not only nature, but the resilience of economies, the stability of societies, and the health of people everywhere. The TFFF is a good solution to long term support, maintenance and protection of standing forests. Finance Ministers of all countries, as well as independent banking and other financial institutions, are strongly encouraged to invest in this vehicle.



RESPONSIBLE AI FOR EARTH OBSERVATION (RAI-EO)

Text: Bruce Phillips | Visual: Ghamisi et al., "Responsible Artificial Intelligence for Earth Observation: Achievable and realistic paths to serve the collective good," IEEE Geoscience and Remote Sensing Magazine (2025).

Recently, Dr Kasra Rafiezadeh Shahi of the PBScience Lab was appointed as the co-lead of the newly established **Responsible AI for Earth Observation (RAI-EO)** working group within the IEEE Geoscience and Remote Sensing Society (GRSS) Image Analysis and Data Fusion (IADF) Technical Committee. The RAI-EO working group advances Responsible AI (RAI) practices in Earth Observation by integrating methodological innovation (e.g., interpretable machine/deep learning, uncertainty quantification, bias detection and mitigation, AI security, and geoprivacy preservation) into applied EO solutions addressing urgent environmental and societal challenges.

Operating as a globally coordinated hub, the group brings together researchers, engineers, practitioners, industry partners, NGOs, educators, and policy experts to develop, evaluate, and promote ethical, transparent, and fair AI methodologies. Through this effort, the working group strengthens accountability and trustworthiness across the EO/AI ecosystem and supports the community in building responsible, operationally relevant AI capabilities.

OUTLOOK

UPCOMING EVENTS, ACTIVITIES AND PUBLICATIONS RELATED TO THE PLANETARY BOUNDARY INITIATIVE AND RELATED RESEARCH TEAMS.

2026 WILL SEE SOME EXCITING NEW DEVELOPMENTS, INCLUDING:

JANUARY & FEBRUARY 2026

As part of our outreach program, Bruce Phillips (*Planetary Boundaries Science Communicator*) and Aeon Alvarado Amaro (*Masters Student in the PBSScience Lab*) will present lessons on the Planetary Boundaries to a leading UK school. It gives us the opportunity to ask, and be asked, what young people know and are concerned about which in turn helps us direct our energy into raising public awareness and action on sustainable solutions. Science communication will be a key part of our upcoming Planetary Boundaries Initiative (see below).

2026

THE DEVELOPMENT OF THE PLANETARY BOUNDARY INITIATIVE

The initiative is bringing together international expert groups on Earth system analysis, sustainable solutions and communication to bring us back into a safe operating space within the Planetary Boundaries. It will combine global expertise, accessible datasets, cutting edge science, AI and innovative communication to provide local, regional and globally tailored solutions that are fair and just. More to follow in the next Newsletter.

MARCH 2026 TIPPING POINTS GO BIG IN JAPAN

PB-Tip scientists Drs. Jonathan Donges, Donovan Dennis, Ricarda Winkelmann and Sina Loriani are co-convenors in the plenary session "Understanding climate system responses, feedbacks and thresholds" at the CMIP Community Workshop in Kyoto, March 9-13th, where the international climate modelling community convenes in the final year before the closing deadline of the next IPCC report. This session, as well as the [TIPMIP General Assembly 2026](#) taking place the week before in Tokyo, received an overwhelming amount of abstracts on state-of-the-art tipping points modelling – including many first results of the TIPMIP-ESM Tier 1 experiments!



THANK YOU...

for your interest in Planetary Boundaries science. By providing us with feedback on our activities, you can help us to continuously improve our outreach efforts:
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