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Impressum

This report was written by the TCRE and ZEC Workshop Organizing Committee: Chris Jones, Pierre Friedlingstein, Tatiana Ilyina, Roland Seferian.

The TCRE and ZEC Assessment is a joint activity of the Safe Landing Climates Lighthouse Activity and the Earth System Modelling and Observations Core Project of the World Climate Research Programme.

Disclaimer

TCRE and ZEC Assessment Workshop

1. Background

This WCRP-sponsored activity will provide an assessment of Transient Climate Response to cumulative carbon Emissions (TCRE) ahead of the next Intergovernmental Panel on Climate Change (IPCC) reporting cycle. TCRE and its partner quantity – the Zero Emissions Commitment (ZEC) - are the main determinants of the remaining carbon budget and also provide crucial information on how the world's climate will respond to both net zero emissions and its potential reversibility under net-negative emissions. This activity will provide a much-needed synthesis of state-of-the-science knowledge on these quantities, bringing together multiple lines of evidence and expert elicitation.

Building on past workshops, both in-person and online, we convened a European Geosciences Union (EGU) session to collect the latest science on TCRE and ZEC and held an in-person workshop in Vienna on the Sunday afternoon preceding EGU (27 April 2025). This report gives a brief recap of both events.

The EGU session (see Annex 4) was available for groups and individuals to present scientific work. The workshop was aimed at establishing activities and teams to work on specific aspects of the assessment. 46 people attended the workshop, 36 in person and 10 online. The list of participants is provided in Annex 2. We noted with regret that several US colleagues were unable to attend, but we hope they will still be able to provide input into the assessment process.

2. Workshop Aims and Sessions

The workshop goal was to move forward on the TCRE and ZEC assessment process, aiming to refine the scope of a report and agree on the main concepts. After a short overview and introduction, the half-day workshop covered the main sections of the assessment:

- Frameworks and analysis
- Processes
- Constraints
- Synthesis

By necessity, each section was covered very briefly to enable this to fit into a 2.5-hour time slot in a hybrid format which allowed online attendance. The in-person participants then went into a short, circa 1-hour, breakout format to discuss the ideas and next steps. The workshop agenda can be found in Annex 3 and an overview of the EGU Session in Annex 4.

3. Assessment Focus

Chris Jones explained some decisions made by the steering group after earlier online meetings to more closely define the scope of the assessment. Namely:

1. Our focus is on global temperature, and not regional climate or impacts.
    - While we acknowledge that some things continue to change, for example after zero-emissions (sea-level, forest cover etc.), this is not the main goal of this assessment. We are looking at global temperature response to emissions/zero-emissions/negative-emissions
2. Focus is primarily on CO_2.

- We will assess TCRE as a physical quantity. We need to discuss issues about non-CO_2 forcing and effective-TCRE too, especially if constraints on eff-TCRE let us say things about TCRE. But the primary focus is on the CO_2 forced response.

3. We explicitly DO want to cover reversibility.
    - The symmetry of TCRE under negative emissions is vital. It may or may not be the same as TCRE or TCRE+ZEC. We will draw on as much evidence as we can to assess this. To date, in the literature, there is less evidence than for positive or zero emissions.
4. Our focus is on the direct (radiative) effects of CO_2 rather than the bio-physical effects of particular emissions/removal techniques.
    - To the first order we do not treat land-use as anything other than a source of CO_2, nor various carbon dioxide removal techniques other than as a removal. Consequences of different techniques can be acknowledged in the discussion, but we avoid lengthy quantitative analysis of technique-dependent effects.
5. To first order we separate TCRE and ZEC and assess individually.
    - This simplifies assumptions, although we acknowledge it is an approximation. It will allow different levels of assessment on each quantity – e.g. if a Bayesian probabilistic constraint is possible for TCRE but not ZEC. We define TCRE as warming up to 1000 PgC, ZEC is subsequent warming after emissions suddenly stop. The discussion can cover the role of ZEC as deviation from TCRE, and treatment of negative emissions will explicitly cover their dual role in reversibility/symmetry.

4. Results and Frameworks

Here we break analysis down into three phases. These can simplistically be thought of as:

- How the climate system (meaning here global temperature, T) responds to positive emissions "T-up"
- Zero-emissions "T-stable"
- Negative emissions "T-down"

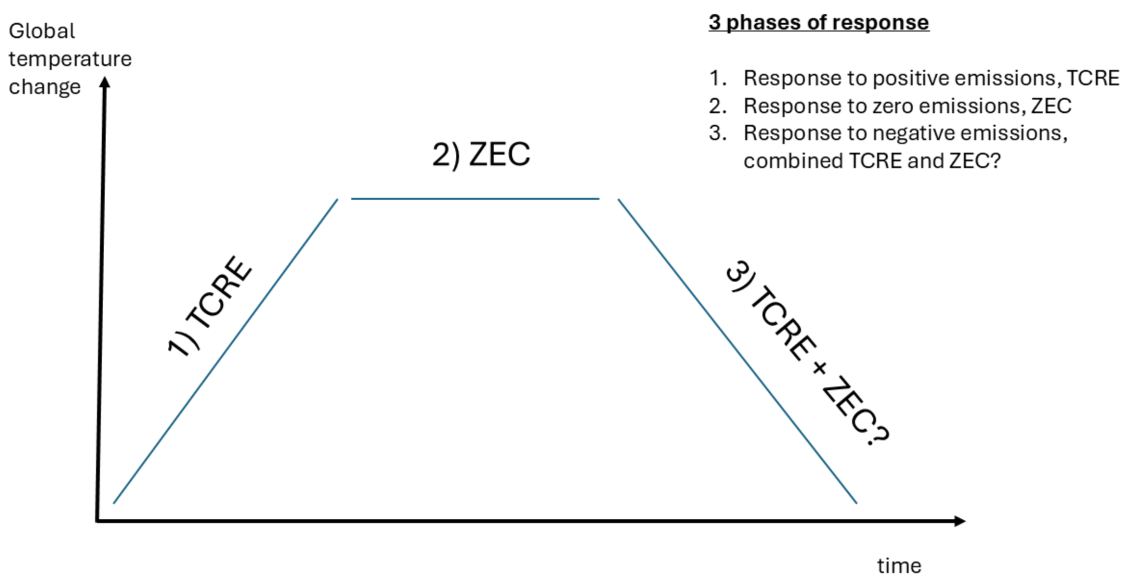

Figure 1: The three phases of climate responses to emissions: positive, zero and negative.

This provides a way to present TCRE and ZEC as partner quantities and then bring in the reversibility/symmetry analysis. We will assemble any/all model output over past generations and synthesise how things have changed over time.

4.1. TCRE

Chris showed how past generations of Earth System Models (ESMs) and IPCC reports have quantified TCRE (Figure 2).

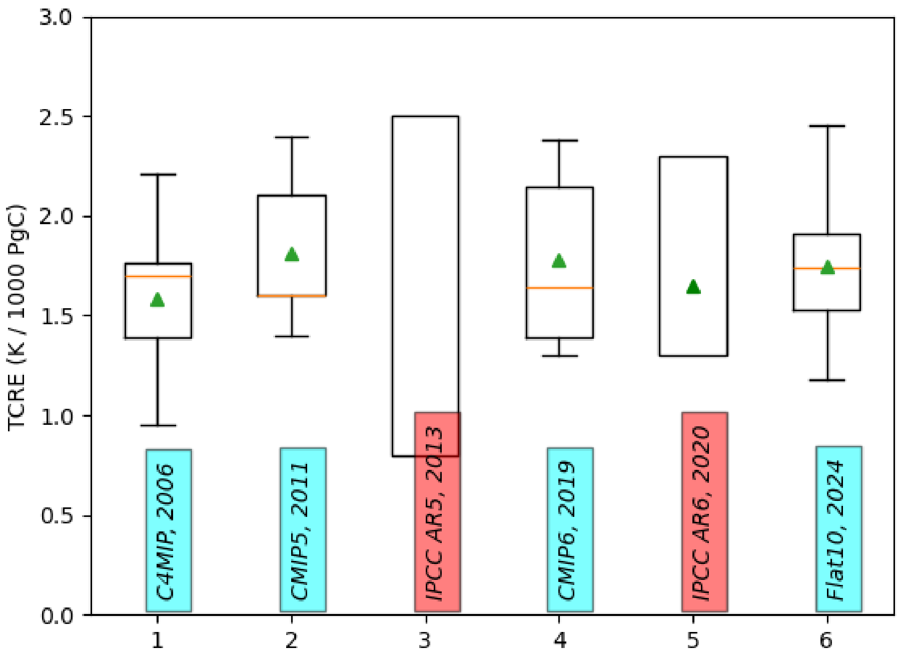

Figure 2. Coupled Model Intercomparison Project (CMIP) and IPCC generations of TCRE

There was a discussion on the definition of TCRE and whether to use 1% runs, flat-10, to quantify at 1000 PgC or $2xCO_2$. We decided that the definition should not prescribe the way of measuring it. So TCRE is defined as the global T response to CO_2-only emissions.

We define TCRE as the global T response to emissions of CO_2.

The definition is not prescriptive over the experiment used to measure it, but we suggest the following should be used:

- Steadily rising CO_2 concentrations/positive emissions. The 1% concentration run or flat-10 emissions run are the best choices.
- Diagnose at or close to 1000 PgC. In flat-10 1000 PgC should be used (noting that in all cases for ESMs we choose a 20-year meaning period centred on the time point of interest – which means that flat-10 runs may need to extend beyond 100 years therefore to at least 110). In 1% runs, it can be diagnosed at 1000 PgC (which gives parallel to flat-10 but requires different levels to be

diagnosed for each model), or at 2xCO_2 which gives parallel to TCR,[1] but may not be exactly at 1000 PgC.

- Use CO_2 only runs, as non-CO_2 forcing complicates diagnosis and may affect carbon sinks in ways which are not intended to be part of the diagnosis of TCRE.

We hope it will be possible to get a quantitative constraint on TCRE, using a Bayesian approach, with an interpretive model not yet fully agreed, but maybe that uses alpha/beta/gamma terms. A quantified pdf of TCRE would be a useful outcome. See later section on synthesis.

4.2. ZEC

Stuart Jenkins, with input from Charlie Koven and Andrew MacDougall, presented thoughts on ZEC and aspects such as RAZE (Rate of Adjustment to Zero Emissions) and the framework from Ric Williams (Williams et al., 2025), which help understand it. Experiments to quantify ZEC going forward include the flat10 (Figure 3) and TIPMIP ensembles (Figure 4), which explore the response to zero emissions at a range of Global Warming Levels (GWLs).

ZEC is a manifestation of deviation from TCRE as a perfect relationship between cumulative emissions and warming.

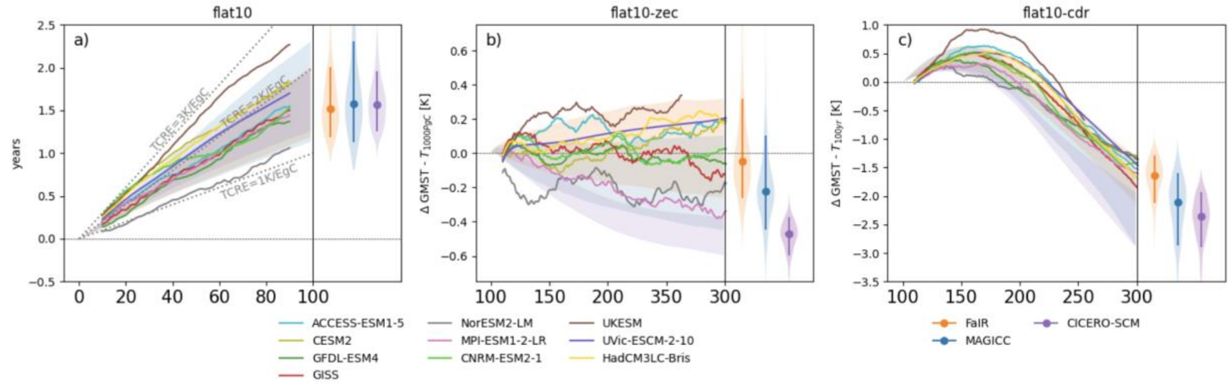

Figure 3. Flat10 experiments. Global temperature response to zero emissions (flat10-zec) is in panel b (Sanderson et al., 2024).

[1] TCR, the transient climate response, is the global temperature change under steadily increasing radiative forcing, due to 1% per year increase in CO_2 concentration. It is defined and measured at 2xCO_2.

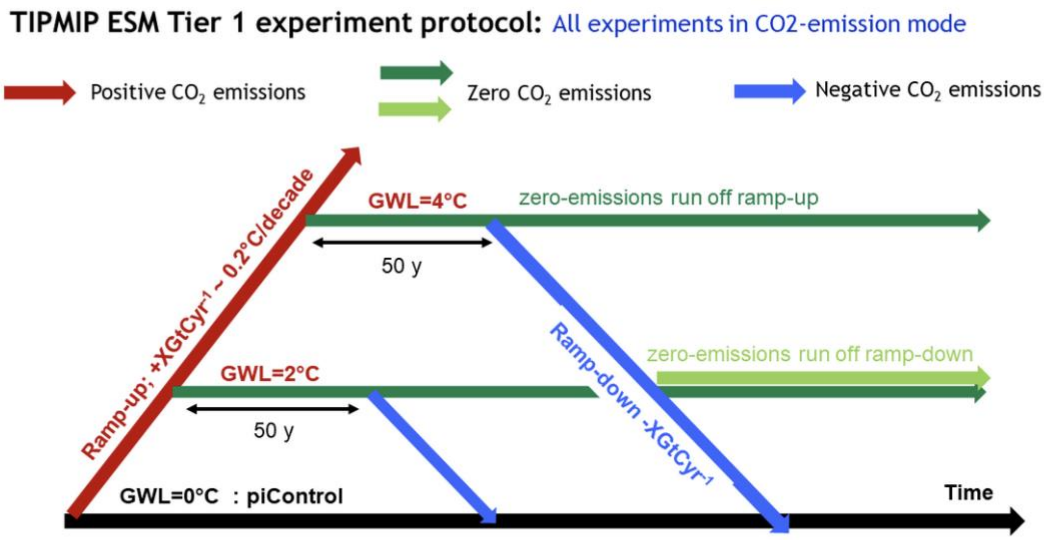

Figure 4. TIPMIP[2] experiment design. Intended to explore system stability and tipping points at different warming levels, the experiments are ideal for also exploring state dependence of ZEC at a range of warming levels achieved at a common rate across ESMs.

There is increasing evidence for and interest in the state dependence of ZEC, and hence we note that ZEC is not a fundamental physical property of the system. As a fine balance between strong opposing behaviour (committed warming/thermal response vs committed CO_2 reduction and carbon sinks), it varies both in time and is state dependent. But ZEC remains a useful concept as a correction term to TCRE in determining Remaining Carbon Budgets (RCBs).

Here, we define ZEC as the change in global T after cessation of emissions. For use in remaining carbon budget estimation, ZEC and TCRE should be measured consistently. A sudden cessation makes this easiest, as per the Zero Emissions Commitment Model Intercomparison Project (ZECMIP) (1%) or flat-10/flat10-zec.

As an update from previous uses of ZEC, we suggest that state dependence is explicitly included in analysis and so, for example, the cessation branch point should be chosen as relevant as possible to the temperature target for the carbon budget. E.g. for 1.5 or 2 degrees, the 1000 PgC branch point may be best. For 4 degrees, a ZEC from 2000 PgC is more appropriate.

We suggest that a good practice for ZEC is to always quote the time period and also the GWL or cumulative emissions associated with it. MacDougall et al. (2020) adopted the former, showing ZEC_50 and ZEC_90. We recommend going beyond this, so ZECMIP results would now be referred to as ZEC_50_1000PgC for example (and hence ZEC_50_2000PgC for ZECMIP variants). TIPMIP runs would diagnose ZEC_50_2K, ZEC_50_3K etc.

In this assessment we will try to map out a phase space of how ZEC varies over time and warming level. With some key points in this space (such as ZEC_50 for 1.5 or 2 degrees) analysed more quantitatively. We only consider CO_2 for ZEC, as inclusion of non-CO_2 and/or sudden cessation of non-CO_2 is out of scope. We also do not consider land use (LU) here as there is still lacking a consensus on how to define a sudden cessation of LU-CO_2-emissions.

[2] https://tipmip.org/

It is possible we may be more qualitative with ZEC than TCRE, as a full Bayesian approach might not be possible or even desirable given the non-constancy of ZEC.

4.3. Reversibility

Kirsten Zickfeld, with input from Charlie Koven, laid out existing status of knowledge on reversibility and symmetry, and led discussion on plans to assess this (Figure 5).

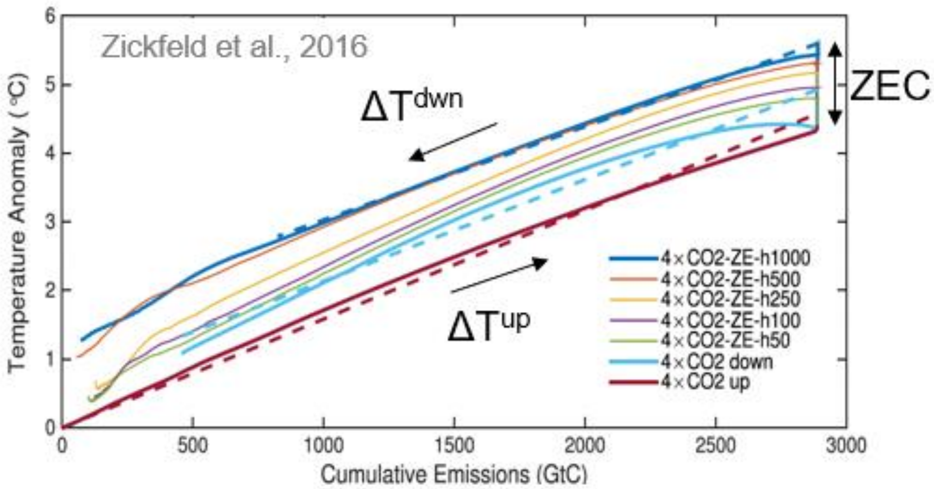

Figure 5. Example of how ZEC affects reversibility. From Zickfeld et al. (2016).

Here we can introduce the concept of the system sensitivity to removals of carbon compared with emissions. So we can define a Transient Climate Response to cumulative carbon Removal (TCRR) and address how it differs from TCRE.

- Due to return from a non-steady state, TCRR can be thought of as TCRE combined with ZEC (or at least the legacy deviation from TCRE).
- Issues to be addressed include symmetry vs reversibility. Studies have shown asymmetry about a state, but this is not the same as reversibility between two states.

If TCRE is defined as ΔT_{up} / CE, then TCRR = ΔT_{down} / CR =TCRE + ZEC/CR, where CE and CR are cumulative emissions and removals respectively. This helps draw an assessment of TCRE and ZEC but we know ZEC is scenario/state dependent which means that so will be TCRR.

We discussed that pulse experiments might be useful additions, and Rachel Chimuka's talk at EGU (Chimuka et al., 2025) showed results from 1% ramp-down experiments branching from an equilibrated $2xCO_2$ baseline. These can feed into future plans. We noted that pulse experiments can be valuable but the signal-to-noise is weak and so ensembles may be required.

5. Processes

5.1. Land

Norman Steinert, with input from Tilo Ziehn and Rosie Fisher, led a discussion around land processes which may affect TCRE and ZEC and presented a draft table (Table 1) which could help assemble and quantify the responses.

Relevant processes include: CO_2 fertilization, permafrost carbon feedback (CO_2 and CH_4), wildfire dynamics, vegetation dynamics and biome shifts, Biogenic Volatile Organic Compounds (BVOC), direct vs. diffuse light, nutrient limitation, soil carbon, and climate feedbacks (e.g., vapor pressure deficit, drought/heat waves, tipping points (interactions)). These can be broadly split to look at how land responds to CO_2 and to climate or how it affects climate. Land use and afforestation, and land management were also discussed as forcings to the system which may affect the response.

Process	Effect on TCRE (°C)	Effect on ZEC (°C)	Confidence	Scenario phases	Drivers and linkages to ocean and atmosphere	Ref.
CO_2 fertilization	-0.86 to -1.70	?	Medium	1, 2	Increases land carbon storage leading to biogeochemical cooling; effect stronger in models without nitrogen limitation	1
Permafrost carbon feedback	+10–20% rate-dependent	+0.1–0.3°C	Medium	1, 2, 3	Creates rate dependence in the land-borne fraction of carbon; stronger effect with slower emission rates; involves time lag between warming and carbon release	2, 3
Wildfire dynamics	+14.6%	?	Low	1, 2, 3	Fire-induced convection creates feedback processes between atmosphere and fire; can affect wind patterns and ignite new fires	4, 7
Vegetation dynamics and biome shifts	-1.5%	?	Low	1, 2, 3	Changes in tree cover and biome distribution affect carbon storage; transitions between forest and savanna biomes	7
BVOC emissions	-1.4%	?	Medium	1, 2	Affects tropospheric ozone concentrations (>10% contribution in urban areas); impacts atmospheric oxidative capacity; contributes to secondary organic aerosol formation	5, 7
diffuse radiation on vegetation	+8.5%	?	Medium	1, 2	Diffuse light increases canopy photosynthesis (~30.5%) through more even light distribution; enhances carbon uptake especially in middle and lower canopy	7
Nutrient limitation	+9.7% (+0.84)	?	Medium	1, 2	Nitrogen-limited models show less land carbon storage and smaller cooling effect (-0.86 vs -1.70°C); constrains CO_2 fertilization	7, 1
Land use and management	?	?	Low	1, 2, 3	-	?
Physical climate feedbacks	Small deviations ?	?	High	1, 2, 3	Encompasses Planck feedback, lapse rate, relative humidity, surface albedo, and cloud feedback; responds to forcing on short time-scales	6
Vegetation disturbances	?	?	Low	1, 2	-	-

Table 1. Example summary table of land processes.

5.2. Ocean

Jorg Schwinger, Natassa Romanou (online) and Hongmei Li led a discussion on ocean processes and responses.

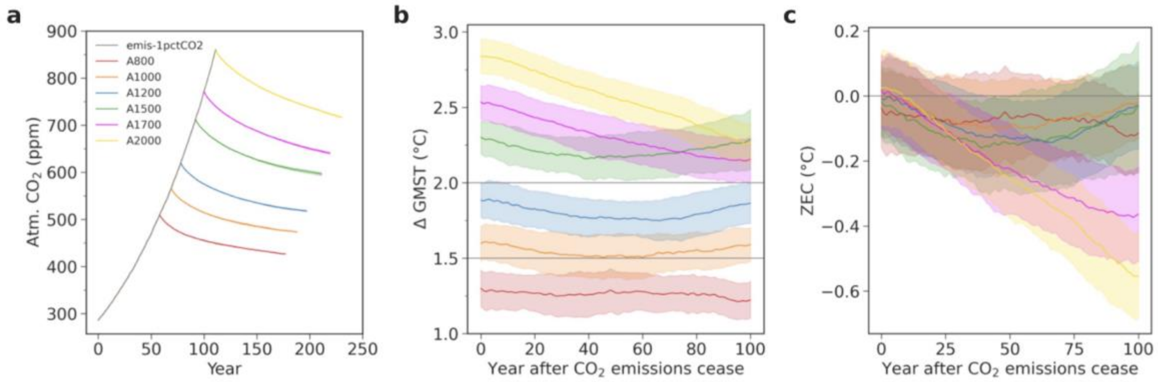

Figure 6. Results from NASA Goddard Institute for Space Studies (GISS) model ZEC runs at a range of branch points

Results from GISS model runs at different warming levels suggest ZEC is dependent on the warming level, but unlike other models (see e.g. Laura Gibbs's EGU talk on UKESM (Gibbs et al, 2025)), the GISS model appears to have increasingly negative ZEC at higher warming levels (Figure 6). Analysis of this, and the role of the Atlantic Meridional Overturning Circulation (AMOC), is ongoing.

5.3. Atmosphere

Thorsten Mauritsen, Hugo Lambert, and Paulo Ceppi were not able to attend. This aspect will be followed up at a Cloud Feedback Model Intercomparison Project (CFMIP) workshop in Exeter this summer. In a possible Bayesian framework, existing Transient Carbon Response (TCR) distribution could be used as a prior.

6. Constraints

6.1. Emergent constraints

Roland Seferian presented some perspectives on emergent constraint techniques for TCRE and the Airborne Fraction (AF) (Figure 7). These can complement other existing constraints such as on tropical gamma (Cox et al., 2013) and extra-tropical beta (Wenzel et al., 2016). Kriging or Bayesian approaches offer much to reduce uncertainty (e.g. based on Ribes et al., 2021).

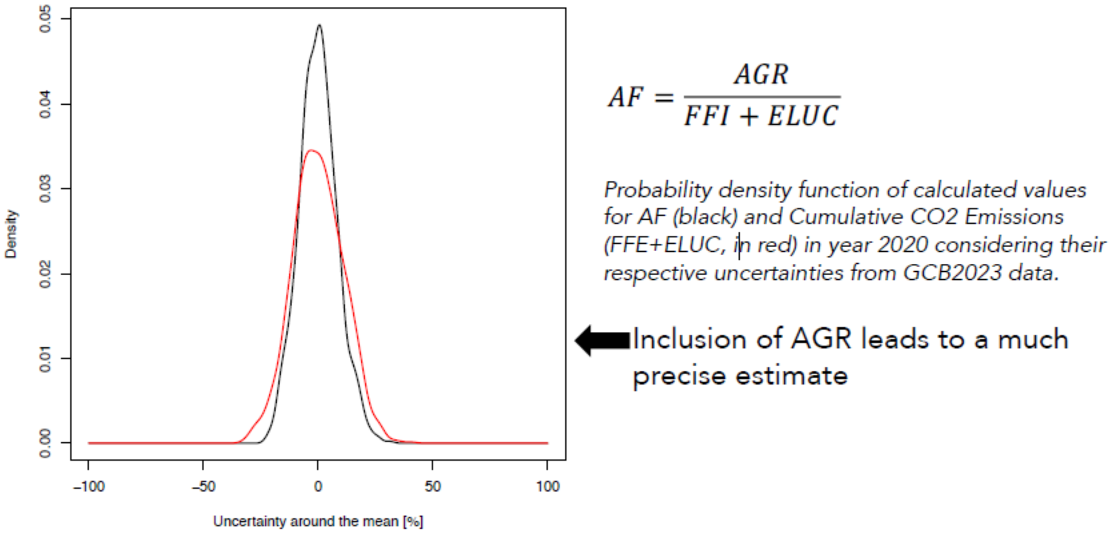

Figure 7. Potential constraint on AF based on atmospheric growth rate observations.

A high priority is to determine how to construct a Bayesian framework and identify the interpretive model and lines of evidence that will be used. See the Synthesis section for a discussion on this point.

6.2. Simple models and history matching

Chris Smith, with input from Alex Romero Prieto and Phil Goodwin, presented aspects of history matching as used for simple models and emulators in the IPCC Sixth Assessment Report (AR6) and the wider literature. TCRE and ZEC as emergent properties in FaIR[3] (Table 2), for example, can be constrained this way.

	5%	50%	95%
TCRE (K PgC^{-1})	1.11	**1.49**	1.96
ZEC50 (K)	-0.21	**-0.04**	0.26
ZEC100 (K)	-0.32	**-0.06**	0.39

Table 2. Example range and distribution of TCRE and ZEC from a constrained FaIR ensemble.

It is not yet clear if/how this approach can be used to combine evidence from a range of simple models (e.g. FaIR, WASP[4], MAGICC[5]), or if all such models are fully suited or capable of representing the behaviour required. However, it is a very powerful technique and will be pursued as part of the next generation of the Reduced Complexity Model Intercomparison Project (RCMIP).

We noted Roland's paper (Figure 8) on the robustness of simple models, showing the non-linear response of ocean heat and carbon as models are pushed beyond the extent from the observational period.

[3] Finite amplitude Impulse Response (FaIR)
[4] Warming Acidification and Sea-level Projector (WASP)
[5] Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)

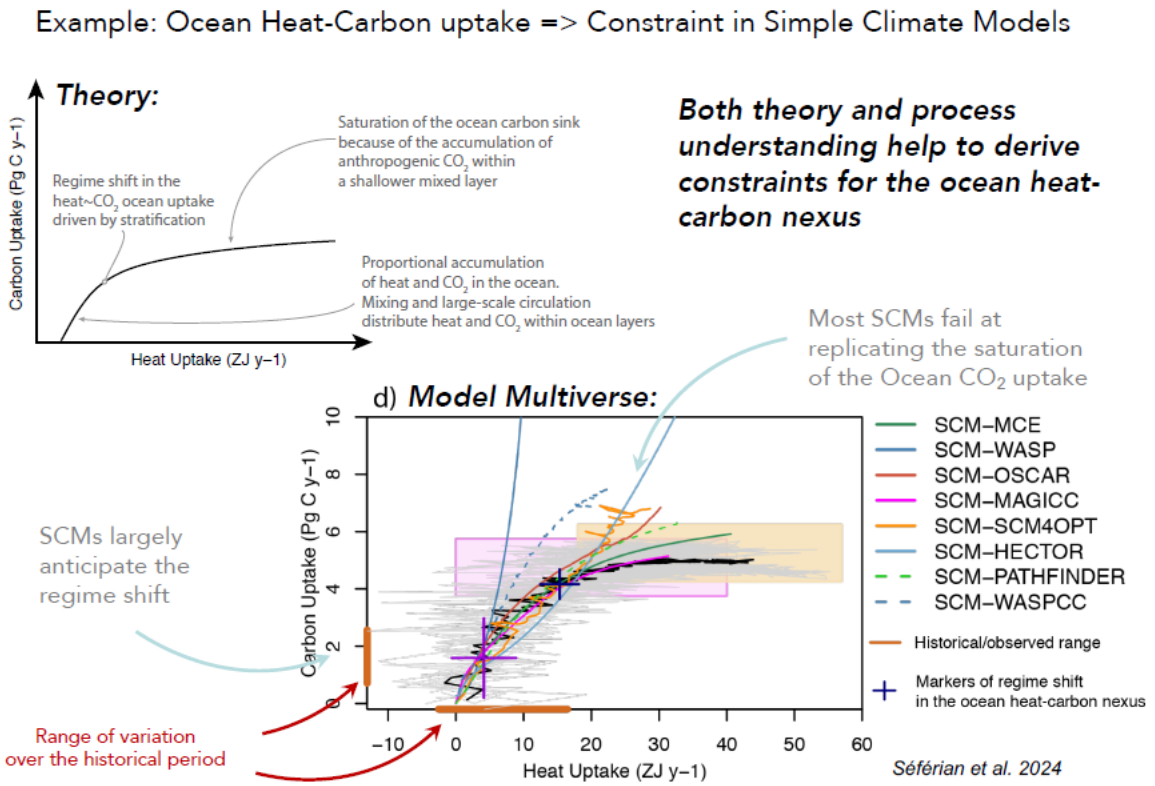

Figure 8. The relationship between ocean heat and carbon in complex and simple models (Séférian et al., 2024).

Sofia Palazzo Corner's EGU talk (Palazzo et al., 2025) offered some exciting new prospects of a constrain on ZEC in MAGICC simulations using only information from the behaviour up to the branch point. This could be a first suggestion of an emergent constraint potential for ZEC.

7. Synthesis

7.1. Bayesian approaches

Chris presented a very crude sketch of how an interpretive model based on alpha, beta and gamma could be a possible basis to combine lines of evidence on TCRE. This was based on discussion with Mark Webb and Kate Marvel, but neither of them could attend. Discussion in the room helped develop the concept and a follow up led to a revised flowchart figure suggestion.

Following up this avenue of thought with Mark Webb and Kate Marvel is a priority next step. Things learned from the Equilibrium Climate Sensitivity (ECS) Assessment (Figure 9) process include the importance of agreeing on the framework early and also identifying what we can/will include as "evidence" in this context.

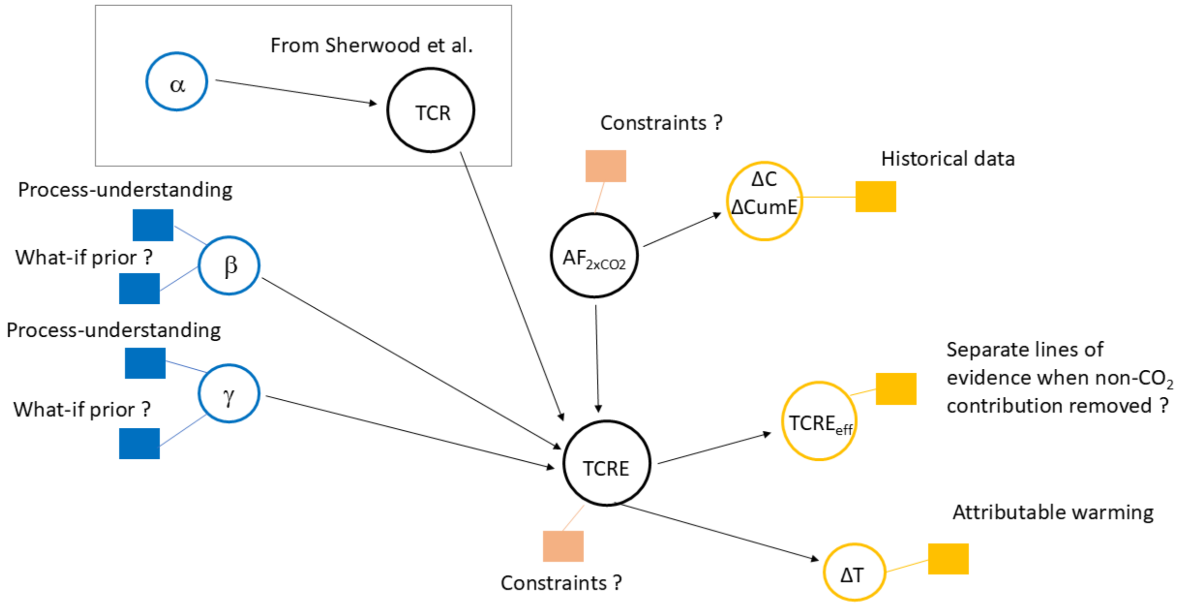

Figure 9. An analogy to Figure 2, Sherwood and Webb et al., 2020.

7.2. Narratives

This aspect remains without content or plans, and we ran out of time at the workshop to cover it. The goal here is to ask the question of what the consequences of a very high TCRE (or ZEC) would be and what would be required for this outcome. Even if we do not know precisely the shape of the TCRE distribution, we can ask how high it could plausibly be. This may be useful information even if we cannot robustly quantify likelihoods.

As an example, we could ask what the TCRE would be in the case where ECS turned out to be close to 5, and there was large scale loss of the Amazon forest and thawing of permafrost.
Remaining carbon budgets (e.g. as per the carbon budget annual update paper[6]), often quote a budget for a temperature target with 50% or sometimes 66% likelihood. However, what if we care about the tails of the distribution? Even considering the 17-83% range (based on IPCC assessment) makes a massive difference to remaining carbon budgets for 1.5 degrees, for example.

6 https://www.globalcarbonproject.org/carbonbudget/

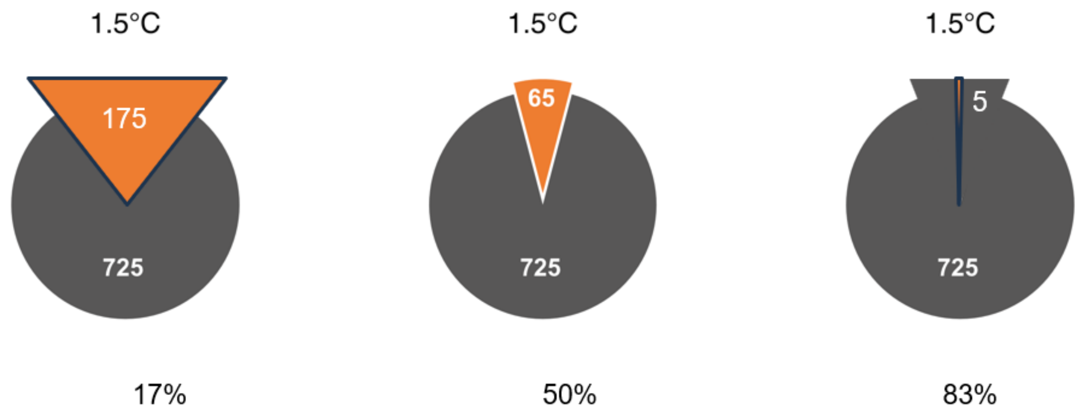

Figure 10. Remaining Carbon Budget for different confidence levels. Based on Friedlingstein et al (2024), but with adjustments from the IPCC table. Simply taking AR6 Chapter 5 range – 17% to 83% RCB for 1.5 is +110 to -60 PgC relative to 50% estimate.

7.3. TCRE vs eff-TCRE

Damon Matthews presented perspective on why we might want to include non-CO_2 or not.

We noted:

- Effective-TCRE is "observable"; TCRE is not.
- TCRE is mostly scenario-independent; Effective-TCRE is not.
- TCRE and Effective-TCRE can be related via non-CO_2 forcing fraction, which may allow for constraints if we can assess the relevant forcings.

We also discussed questions such as:

- If Effective-TCRE is more directly policy relevant.
- What about ZEC vs. Effective-ZEC? (aka non-CO_2 ZEC).

Previous work from Damon Matthews and Peter Cox has been able to constrain (eff)TCRE from observations using these assumptions (Figure 11).

There was a clear consensus in the room that our focus should be on CO_2-only TCRE. But that eff-TCRE might also allow additional constraint as this is what can be measure in the historical record.

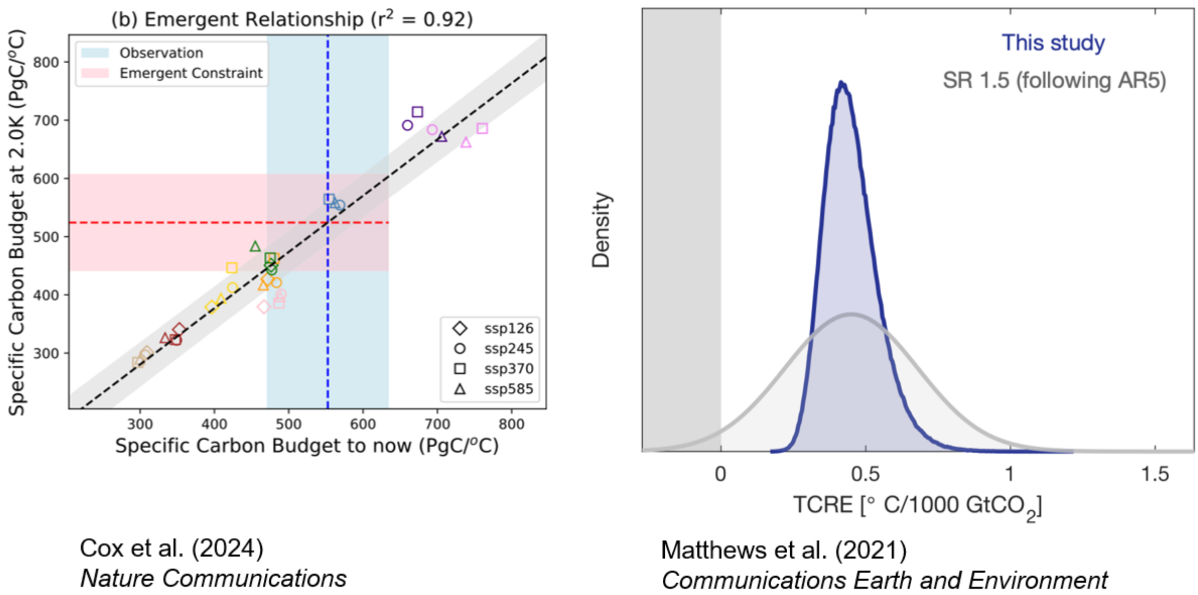

Figure 11. Example constraints from previous work of Cox et al. (2024) and Matthews et al. (2021).

7.4. Carbon budget framework

Joeri Rogelj presented an overview of what IPCC reports need to know and how information on TCRE and ZEC is used (Figure 12). We saw how a literature assessment of TCRE was assembled, and information from TCR and AF values combined. The ZEC assessment from IPCC Chapter 4 was also used. The AR6 also assessed “missing” feedbacks (Chapter 5).

A wish list for the IPCC Seventh Assessment Report (AR7) includes for a TCRE assessment:

- Update TCR
- Beyond CMIP spread for AF

And for a ZEC assessment:

- Beyond ZECMIP spread
- Internally consistent with TCRE assessment
- Fully integrated in carbon budget estimation

Non-CO_2 contributions and implicit (CO_2-fe) consistent with integrated scenarios is also important, but out of scope for this TCRE assessment.

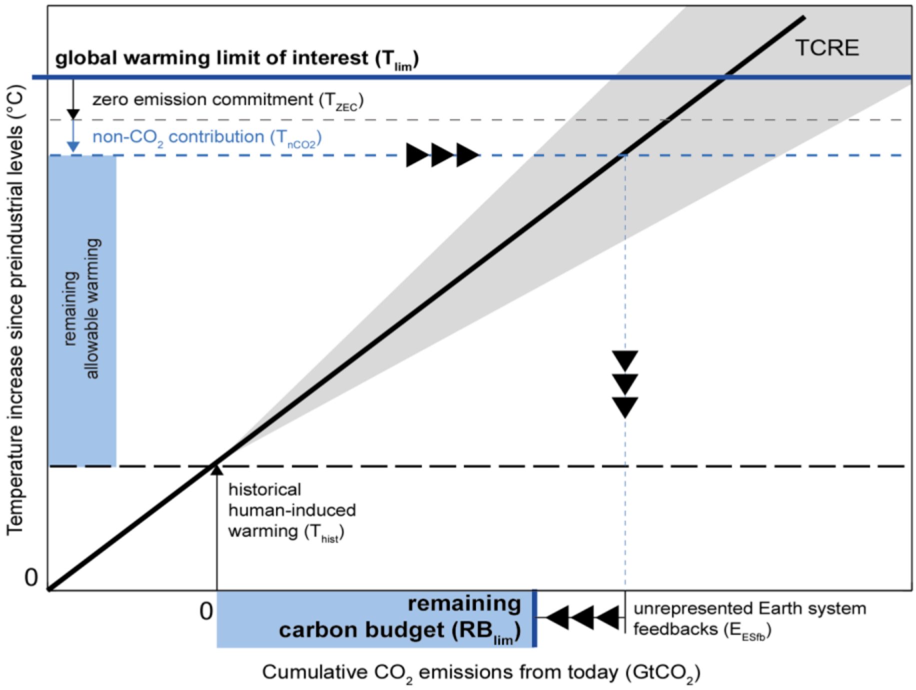

Figure 12. Schematic of how to derive remaining carbon budget estimates from five key components. IPCC SR1.5 (Canadell et al., 2021, Figure 5.31).

However, we can and will provide evidence towards quantifying unrepresented Earth system feedbacks. An issue here is that not all processes are "binary" in being represented or not in CMIP. Some processes are in some models and not others which makes a correction term impossible unless it can be applied model-by-model depending on what processes they contain. This situation is unlikely to be resolved for the Seventh Phase of CMIP (CMIP7), so a means to deal with it is required. See Spencer Liddicoat's EGU poster (Liddicoat et al., 2025).

Beyond the requirement for AR6-type remaining carbon budget assessment, AR7 will likely face the fact that the remaining carbon budget for key temperature limits (e.g., 1.5°C – 50%, 1.6°C – 66%) will be zero or negative. Hence, although the current carbon budget definition served its purpose well until net-zero, it is not designed to quantify negative budgets. A new concept of a "carbon debt" would require:

- An assessment of reversibility of TCRE
- Integrating ZEC (50?)
- Potentially an integration of a temporal aspect.

8. Next steps

Specific next steps include establishing weekly meetings of the workshop convenors and more regular engagement with the different sections of the report. Developing the framework to enable a Bayesian assessment of TCRE is a high priority and that will then enable plans to combine multiple strands of evidence. We will arrange meetings as required with the strand leads. We hope that the individual topic areas will also begin to meet regularly. The committee will be in touch to initiate and facilitate this.

To facilitate information and communication, a mailing list will be set up. This will avoid issues of people accidentally missing information due to reliance on "reply-all". To request to be added to the mailing list please contact Peter Abbott (pabbott@wmo.int) or Narelle van der Wel (nvanderwel@wmo.int).

Although IPCC timelines for AR7 are still emerging, it is clearer what requirements are likely to be from Working Group I for their assessment of TCRE, ZEC and carbon budgets. We will ensure plans for this assessment meet those requirements and will keep an eye on potential literature cut-off dates to guide our activity.

Future activities include a session at the ESM2025 final meeting in Toulouse in October 2025 and a proposed session at the CMIP7 workshop in Japan in March 2026. Please see the website for details: https://www.wcrp-climate.org/slc-activities/tcre

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Annex 1 - Acronym List

AMOC	Atlantic Meridional Overturning Circulation
AR6, AR7	Sixth and Seventh Assessment Report (IPCC)
BVOC	Biogenic Volatile Organic Compounds
CFMIP	Cloud Feedback Model Intercomparison Project
CMIP	Coupled Model Intercomparison Project (WCRP)
CMIP7	CMIP Phase 7
ECS	Equilibrium Climate Sensitivity
EGU	European Geosciences Union
ESM	Earth System Model
FaIR	Finite amplitude Impulse Response
IPCC	Intergovernmental Panel on Climate Change
GISS	Goddard Institute for Space Studies (NASA)
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
RAZE	Rate of Adjustment to Zero Emissions
RCB	Remaining Carbon Budget
RCMIP	Reduced Complexity Model Intercomparison Project
TCR	Transient Climate Response
TCRE	Transient Climate Response to cumulative carbon Emissions
TCRR	Transient Climate Response to cumulative carbon Removals
WASP	Warming Acidification and Sea-level Projector
ZEC	Zero Emissions Commitment
ZECMIP	Zero Emissions Commitment Model Intercomparison Project

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Annex 3 – Workshop Agenda

Remit - We have had two very productive and interesting workshops (in person in Bristol, online in December). We saw lots of great work and ideas. The job now is to begin work on the assessment process and plan what is required in the coming 1-2 years. So this workshop will be on planning structure and activity, rather than showing results. We have the EGU session in the week for that.

- Workshop begins at 13:00 (Vienna time / CEST).
- We would recommend picking up your EGU badge from the Austria Center Vienna before the workshop as the desk is open between 12:00-18:00. Then you will have your transport card for Monday morning and can use the badge for the workshop!
- Allow 30 minutes gather/meet-and-greet. Grab drinks and fruit. Basic catering, with snacks in the coffee break, will be available, but we're not providing lunch specifically.
- Need to be strict with timing – as people will be joining online. 13:30 start of meeting itself.

13:30 – 13:45. Overview of latest plans and structure

- Chris plus Roland/Tatiana/Pierre. Recap of what we planned, outcomes of the video calls, emerging structure and section outlines as a result. Definitions and scope of report.

13:45 – 16:00. Plenary discussion for each section. Approx 4x 30 minutes

a) Short prepared talks as overview of sections
b) Focus is on developing the structure and content for the report and plan to move forward.

- Each to give very brief overview, recap of key questions. Identify any gaps – what knowledge exists, where is new work/analysis required? Try to assemble a team – we will need people who can actually work on this. E.g. applying existing frameworks to new ensembles etc.

16:00. Brief recap and then close for online participants
16:00. Coffee break with snacks
16:30-17:30. Reconvene

- Breakouts for an hour. Local logistics mean we can't have online easily – will be ad-hoc depending on the room space. Form around sections or sub-section level. Decide these ad-hoc on the day.

17:30. Plenary feedback from Break Out Groups
18:00. Close
18:30. Welcome reception at EGU venue

Annex 4 – EGU Session 2025

Session CL4.13 / BG9: **Assessing the Transient Climate Response to Emissions (TCRE) and Zero Emissions Commitment (ZEC)**

For completeness we list here the EGU session presentations, as these are complementary to, and necessary for, the assessment. More details and the presentation abstracts can be found on the EGU website[7] or by contacting the authors directly.

Organisers: Chris Jones, Tatiana Ilyina, Roland Séférian, Pierre Friedlingstein

Oral presentations and posters took place on the afternoon of Tuesday 29th April 2025

- AERA-MIP: TCRE, emission pathways and remaining budgets compatible with 1.5 and 2 °C global warming stabilization, Yona Silvy and Thomas Frölicher and the AERA-MIP author team
- Effect of land carbon accounting methods on the climate response to cumulative CO2 emissions, H. Damon Matthews, Kirsten Zickfeld, Alexander MacIsaac, and Mitchell Dickau
- The reforestation-TCRE: A metric to quantify the effect of reforestation on global temperature, Alexander MacIsaac, Kirsten Zickfeld, Damon Matthews, and Andrew MacDougall
- Implications of permafrost carbon cycle feedbacks for TCRE: evidence from Earth system modelling, Rémi Gaillard, Patricia Cadule, Philippe Peylin, Nicolas Vuichard, and Bertrand Guenet
- Asymmetric carbon-climate responses to cumulative emissions under different CO2 pathways, Hongmei Li, Lennart Ramme, Chao Li, and Tatiana Ilyina
- TCRE, ZEC and ocean heat uptake efficacy response to AMOC, Anastasia Romanou, presented by Jorg Schwinger
- Knowing what we know now: predicting ZEC with observables in a simple climate model, Sofia Palazzo Corner, Joeri Rogelj, Zebedee Nicholls, Chris Jones, and Chris Smith
- A normalised framework for the Zero Emission Commitment: competing controls by thermal and carbon processes, Ric Williams, Phil Goodwin, Paulo Ceppi, Chris Jones, and Andrew MacDougall
- Understanding the Mechanisms Behind Zero Emissions Commitment (ZEC) at Different Warming Levels, Laura Gibbs, Andy Wiltshire, Chris Jones, Colin Jones, Spencer Liddicoat, Ric Williams, Timothy Andrews, Eddy Robertson, Andrea Dittus, Ranjini Swaminathan, Lee DeMora, Jeremy Walton, Paulo Ceppi, and Till Kuhlbrodt
- Constraining uncertainties of the Zero Emissions Commitment with a large ensemble of UVic 2.10 climate model simulations, David Hohn, Giang Tran, Makcim De Sisto, and Nadine Mengis

Posters:

- Toward an observational constraint on the Transient Climate Response to Cumulative Emission, Roland Séférian, Aurélien Ribes, and Saïd Qasmi
- After 'Net Zero': Tracing uncertainties in the Zero Emissions Commitment signal, Tabea Rahm, David Hohn, and Nadine Mengis
- The role of simple models in understanding the low CO2 emissions regime and the ZEC, Ashwin K Seshadri
- Linking carbon cycling to climate feedbacks in a simple climate model for decarbonization, Greta Shum, Abigail Swann, Dargan Frierson, and Charles Koven
- Understanding the mechanisms driving the ocean's anthropogenic carbon reservoir under changing emissions, Hwa-Jin Choi, Bo Liu, and Tatiana Ilyina
- Southern Ocean heat burp in a cooling world, Ivy Frenger, Svenja Frey, Andreas Oschlies, Julia Getzlaff, Torge Martin, and Wolfgang Koeve
- The double emergence of TCRE, Andrew MacDougall and Alexander MacIsaac

[7] https://meetingorganizer.copernicus.org/EGU25/session/51903

- Role of Earth system processes in the Transient Climate Response to cumulative Emissions, Spencer Liddicoat, Chris Jones, Lina Mercado, Eddy Robertson, Stephen Sitch, and Andy Wiltshire

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