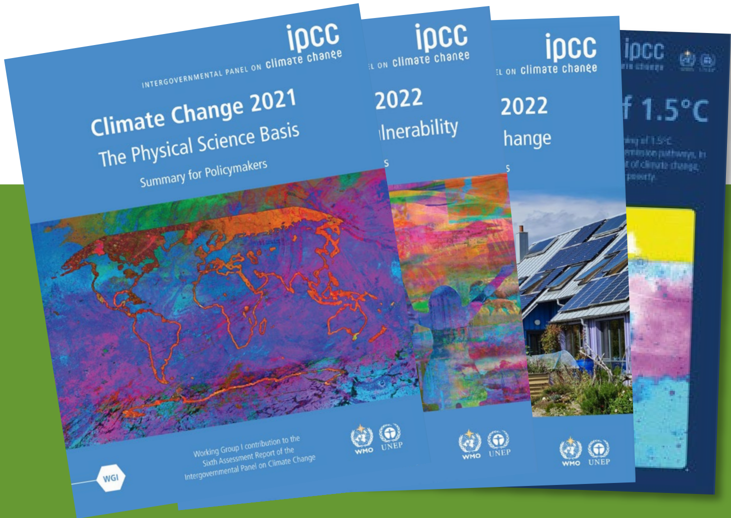

BOOST YOUR FUTURE

DIENSTAG,
26. SEPTEMBER 2023
TU GRAZ

Wegener Center

UNI GRAZ

Climate Change Graz

Field of Excellence
University of Graz

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Weblink-IPCC Science supporting policy & society to cope with the climate crisis:
https://ipcc.ch/ar6 **Physical Climate Science Basis, Impacts, Adaptation, Mitigation, etc.**

Weblinks-News: Carbon Management to achieve Paris-compliant climate goals:
https://carbmanage.earth, https://www.uni-graz.at/en/news/uni-graz-zeigt-vor

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Globaler Klimawandel und Klimaschutz – Auswirkungen und Handlungsbedarfe in Österreich

Gottfried Kirchengast

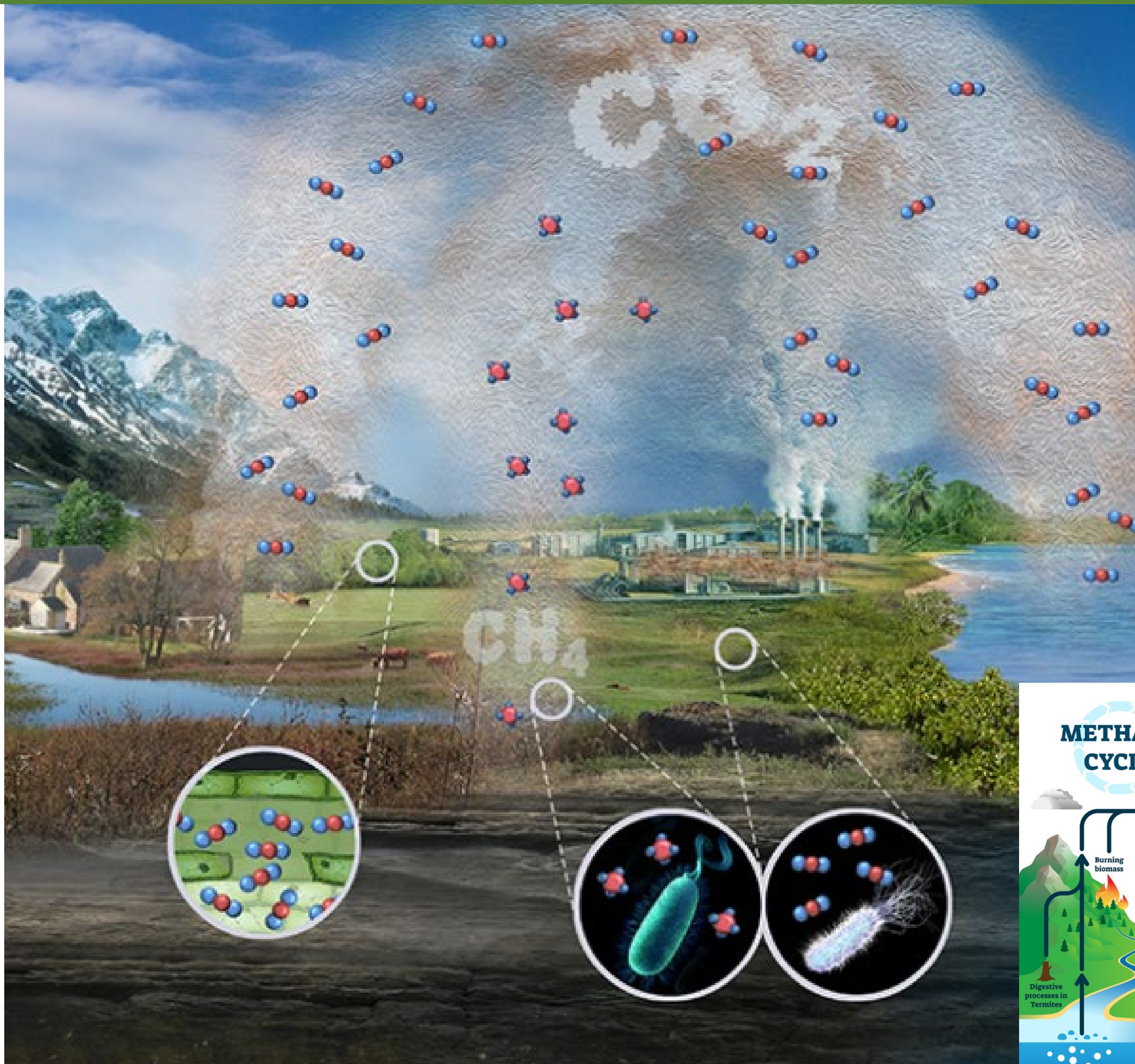
Founding Director & Lead Scientist Wegener Center for Climate and Global Change (WEGC)
and Head Atmospheric and Climate Physics/Institute of Physics, University of Graz, Austria

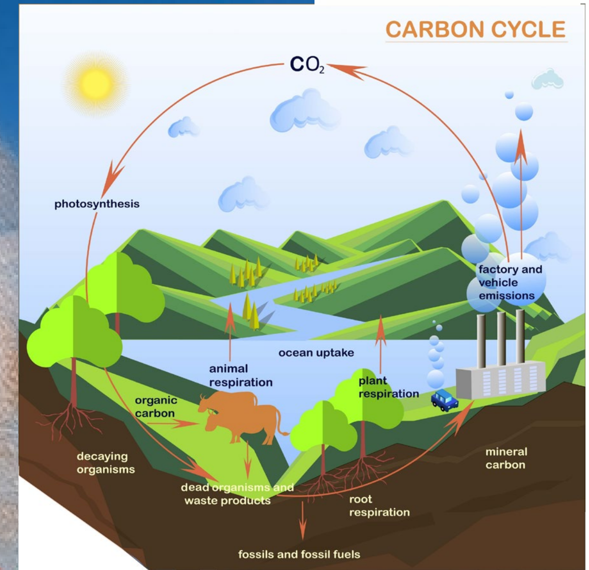
Speaker Field of Excellence Climate Change Graz and EO & Climate Strategies, University of Graz

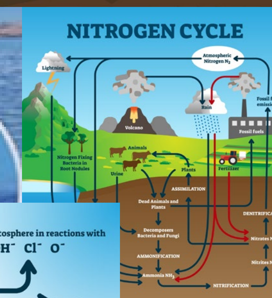
Member in the Field Environment & Climate of the Austrian Academy of Sciences (ÖAW)

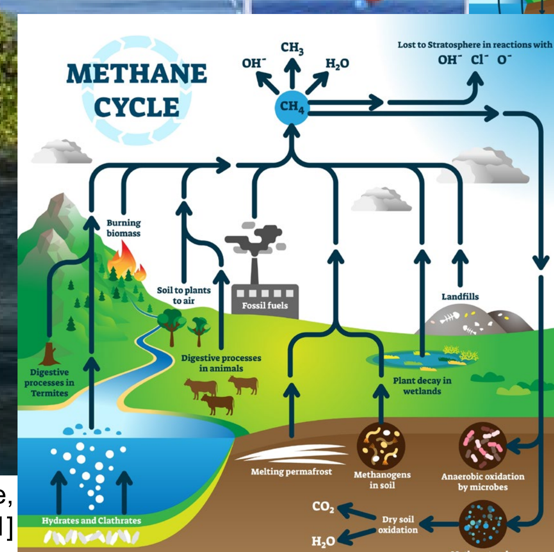
Representative of Science in the Austrian National Climate Committee (NKK)

Low Carbon Transition – *a planetary management challenge 2023 to 2050…*







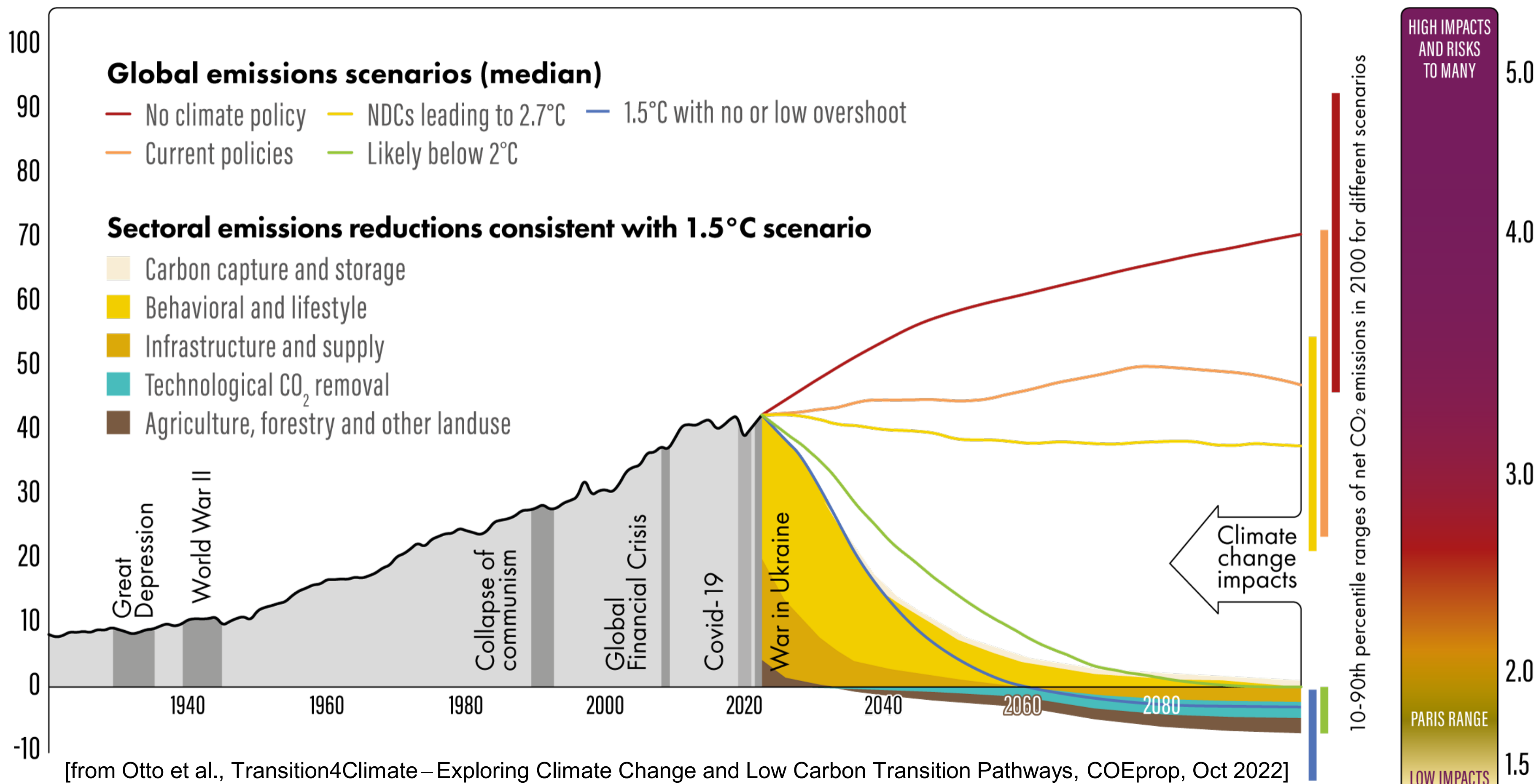


[Kaushik et al., Carbon Cycle & Changing Climate, EOS, 2020; insert figs: dreamstimepics-dl.2021]

Low Carbon Transition – *a planetary management challenge 2023 to 2050…*

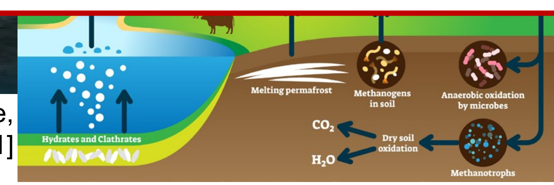
CARBON CYCLE

A more quantitative intro look at the challenge of low carbon transition pathways…



[from Otto et al., Transition4Climate – Exploring Climate Change and Low Carbon Transition Pathways, COEprop, Oct 2022]

[*Note:* Kirchengast et al., WEGC, 2023: such emissions data, and carbon budget-based 'path2Paris' scenarios, are part of GCCIv2 in gcci.earth/gem]



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GHG drivers, radiative forcing, Earth energy imbalance (EEI), global warming, climate change,...

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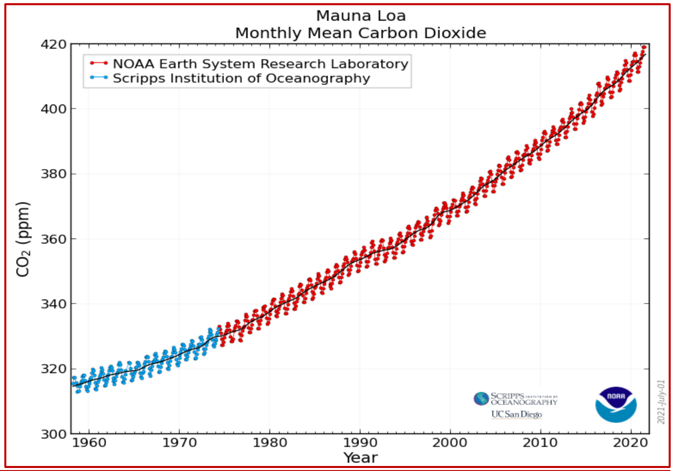

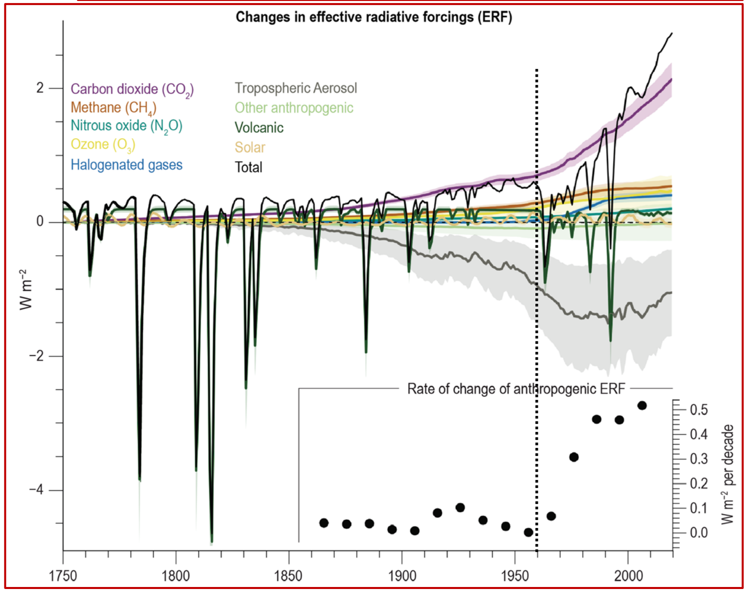

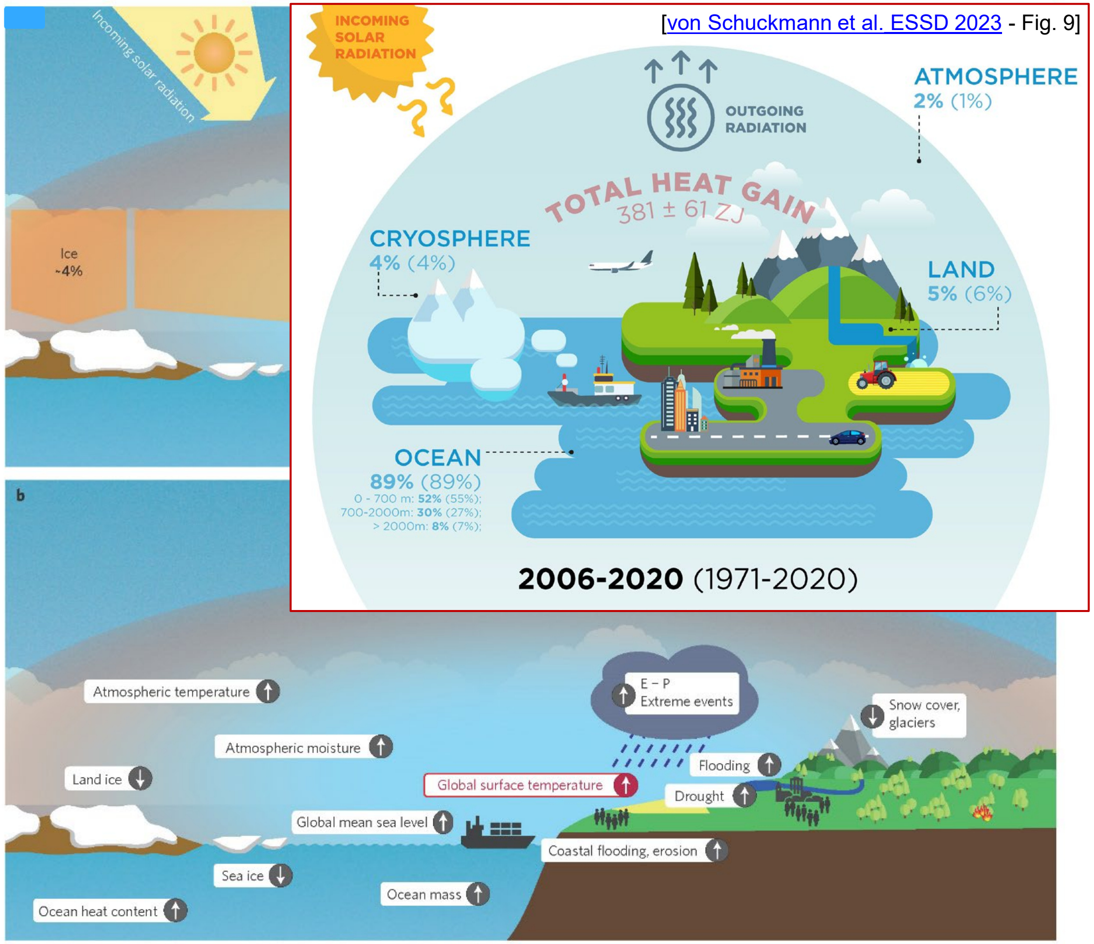

[upper left: NOAA-ESRL, 2022; lower left: IPCC-AR6-WGI, 2021; other panels: v.Schuckmann et al., 2016 & 2023; more info online > Kirchengast et al., WEGC, 2023 - GCCI-Climate Warming Monitoring: gcci.earth/cwm]

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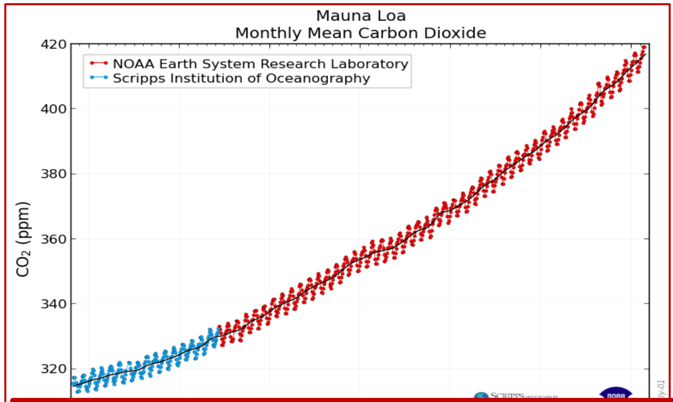

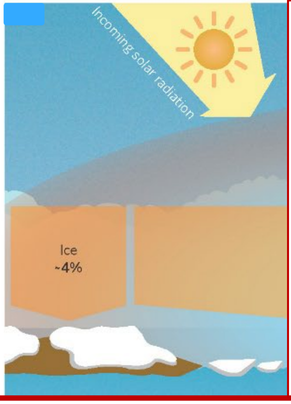

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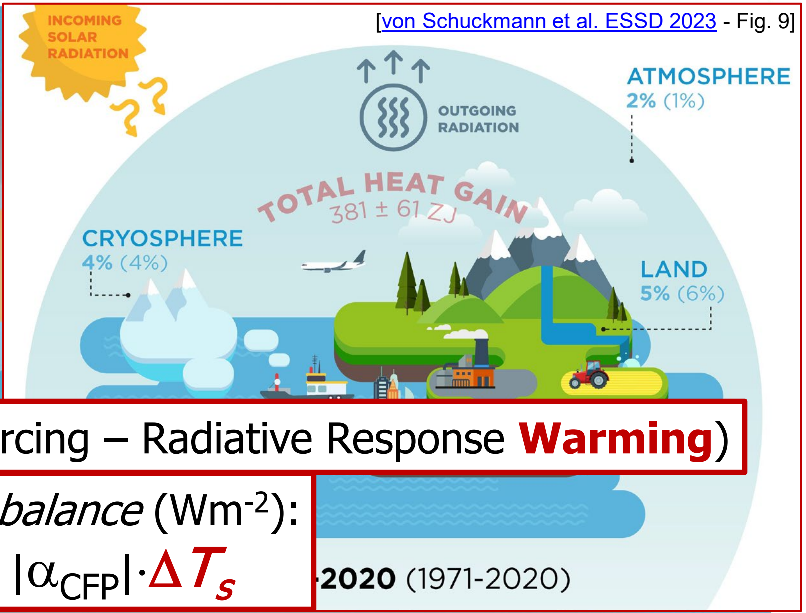
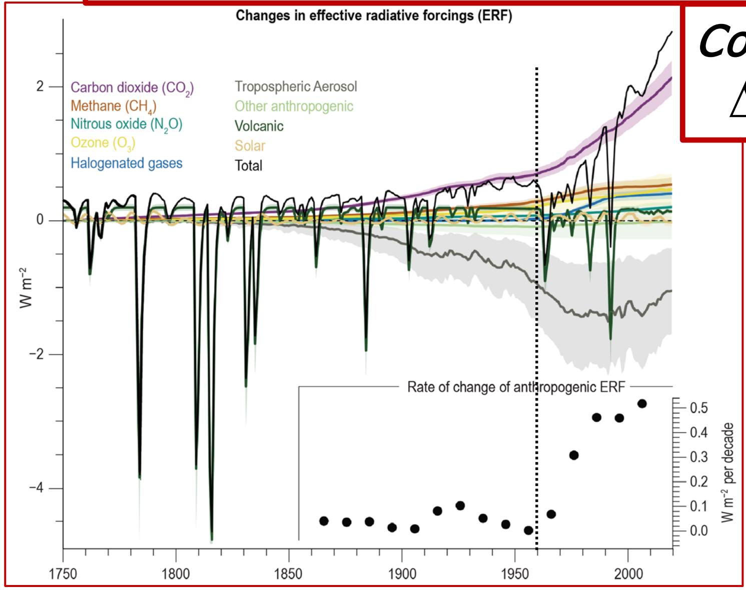
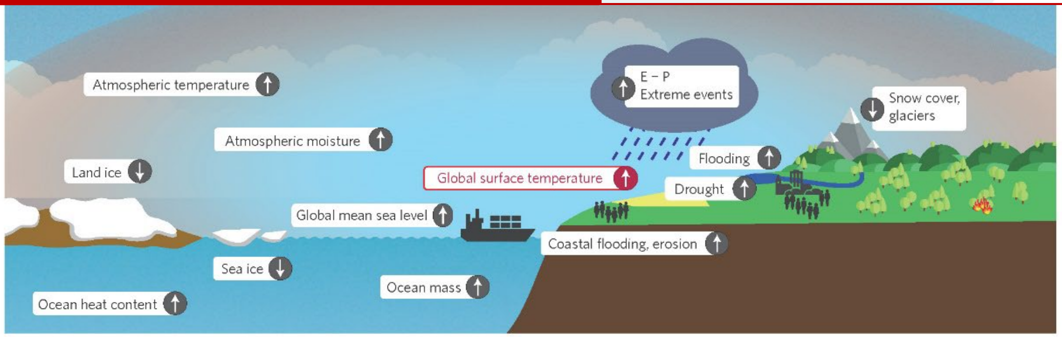


Earth Energy Imbalance = (Effective Radiative Forcing – Radiative Response **Warming**)

Core–the TOA imbalance (Wm^{-2}):

$$\Delta N_{EEI} \cong F_{ERF} - |\alpha_{CFP}| \cdot \Delta T_s$$





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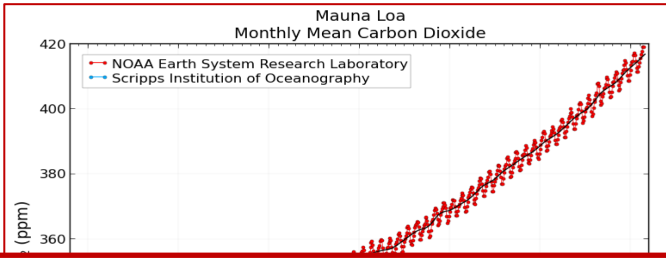

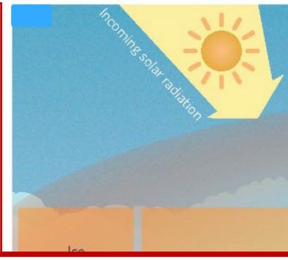

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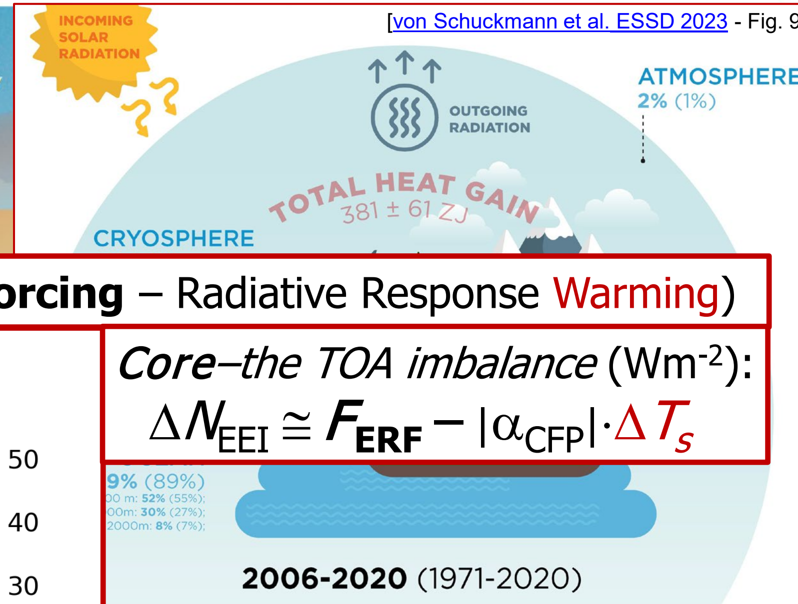

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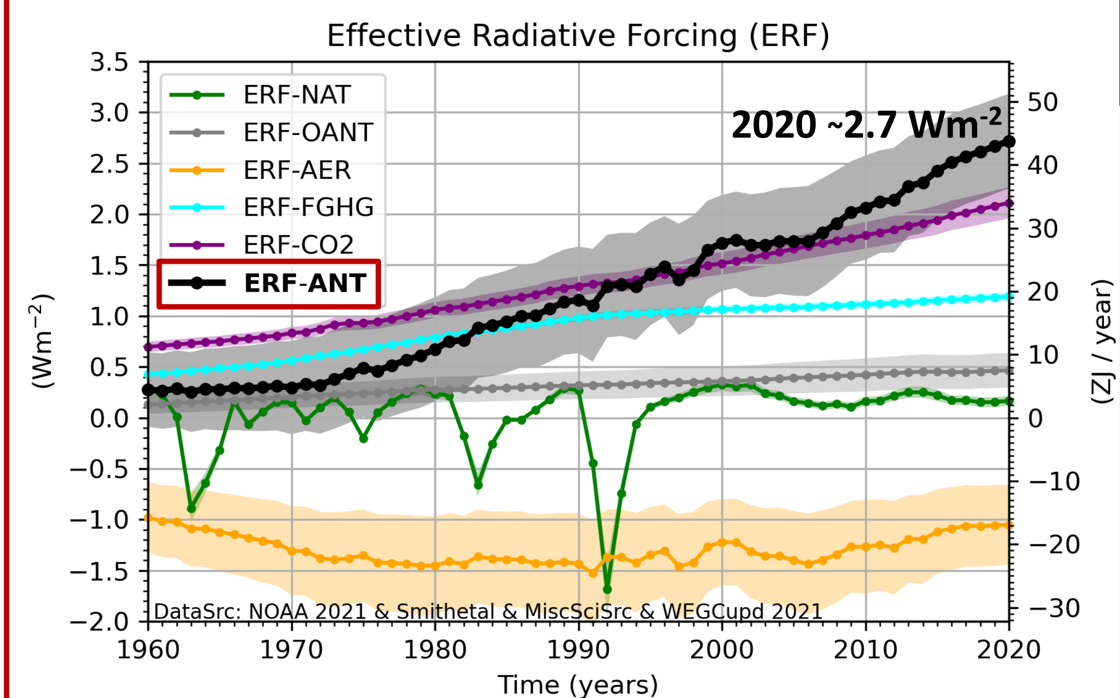
[Kirchengast & Thalassinos, AGU Pres, 2021; adapted]



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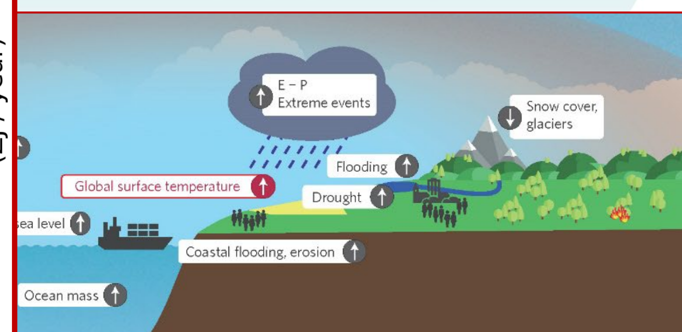

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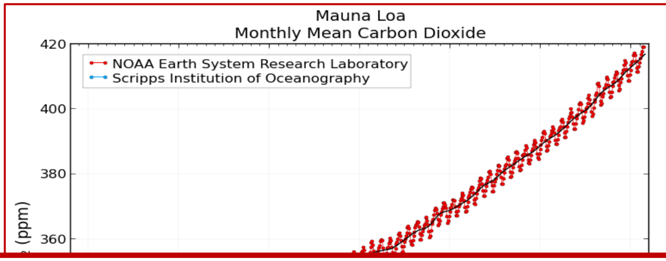

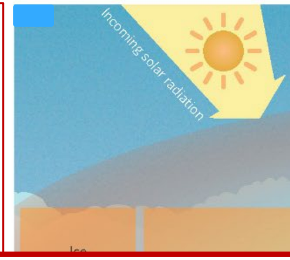

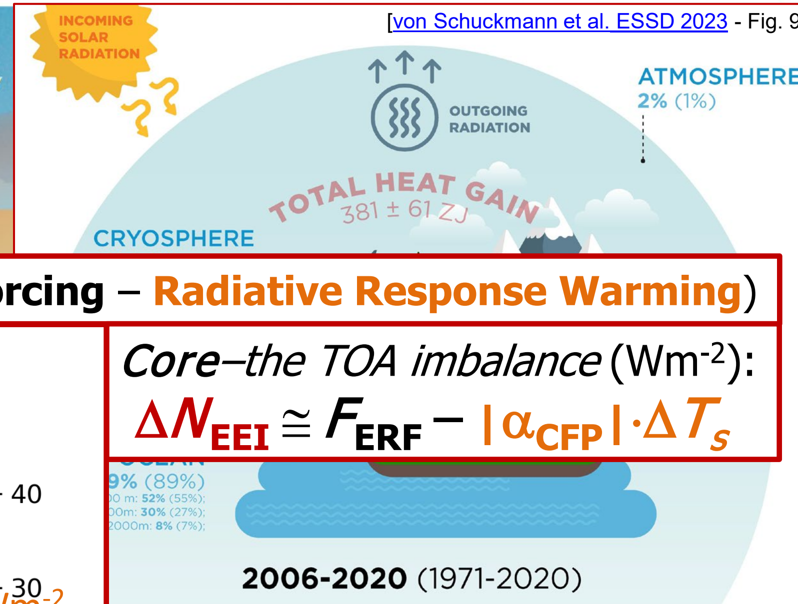

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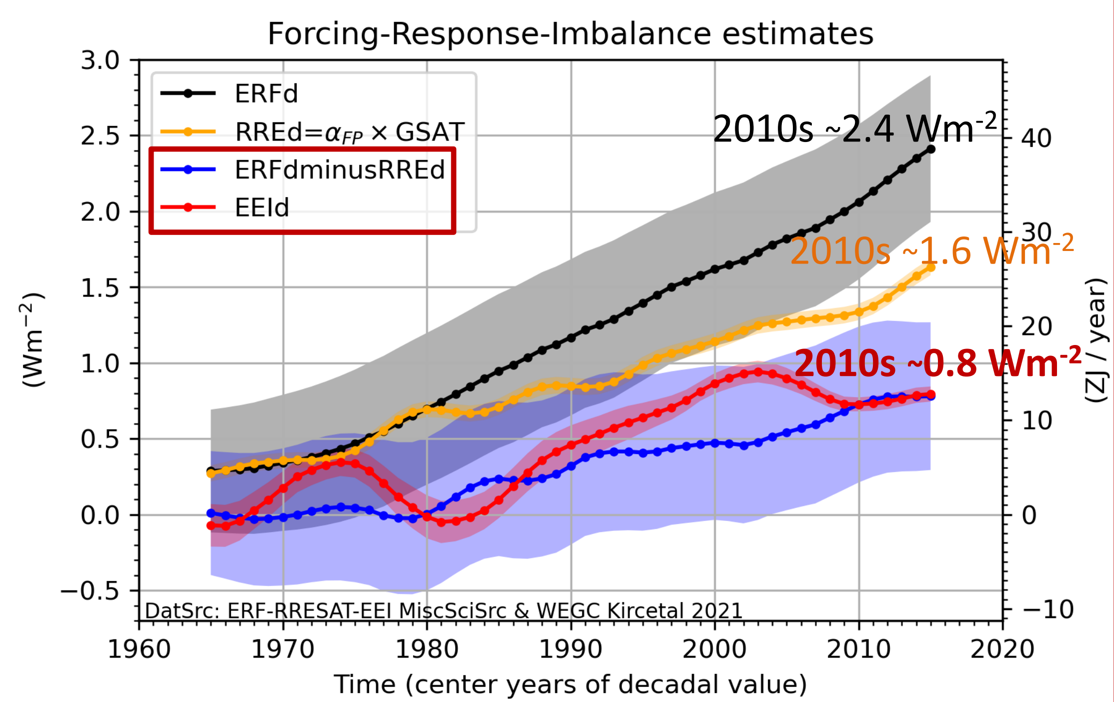

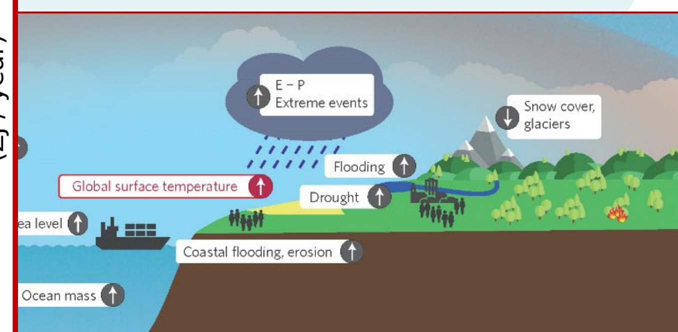

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A three layer view: from TOA energy imbalance to surface layer and deeper ocean...

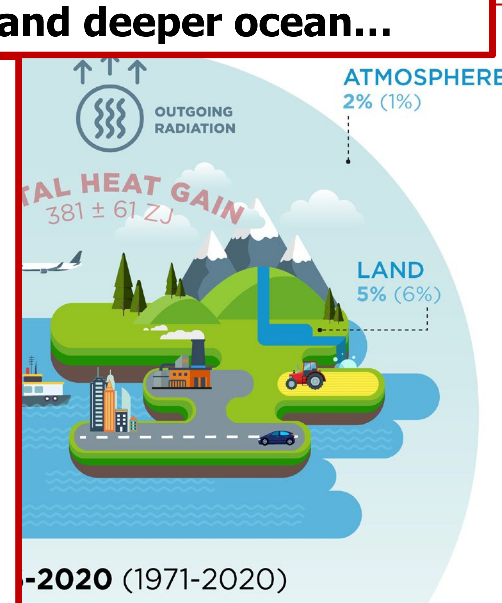
Top-of-Atmosphere (TOA) energy imbalance drives ΔT_s

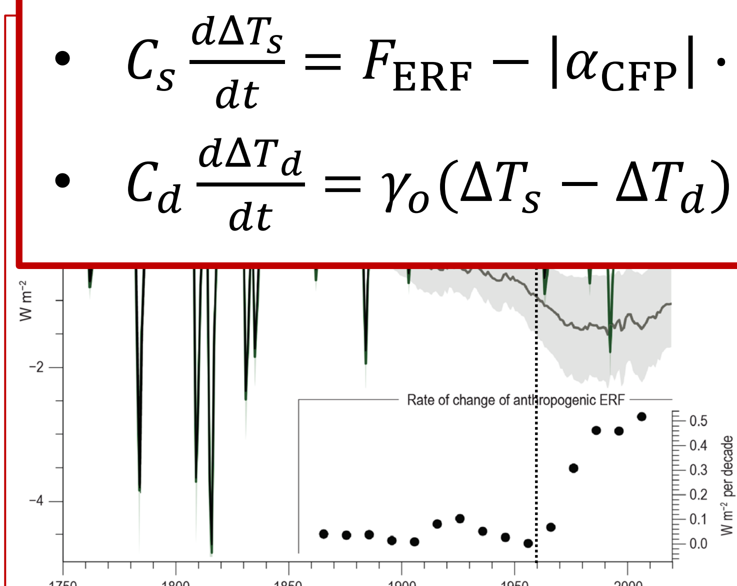
Earth-surface-layer energy imbalance => ΔT_s (GSAT)

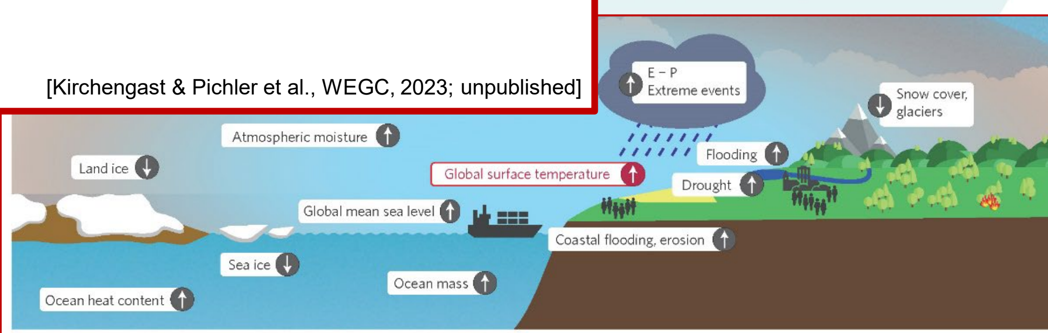
Deeper-ocean energy imbalance => ΔT_d (GDOT)

- $\Delta N_{\mathrm{EEI}} = F_{\mathrm{ERF}} - |\alpha_{\mathrm{CFP}}| \cdot \Delta T_s$
- $C_s \dfrac{d\Delta T_s}{dt} = F_{\mathrm{ERF}} - |\alpha_{\mathrm{CFP}}| \cdot \Delta T_s - \gamma_o(\Delta T_s - \Delta T_d)$
- $C_d \dfrac{d\Delta T_d}{dt} = \gamma_o(\Delta T_s - \Delta T_d)$

[Kirchengast & Pichler et al., WEGC, 2023; unpublished]







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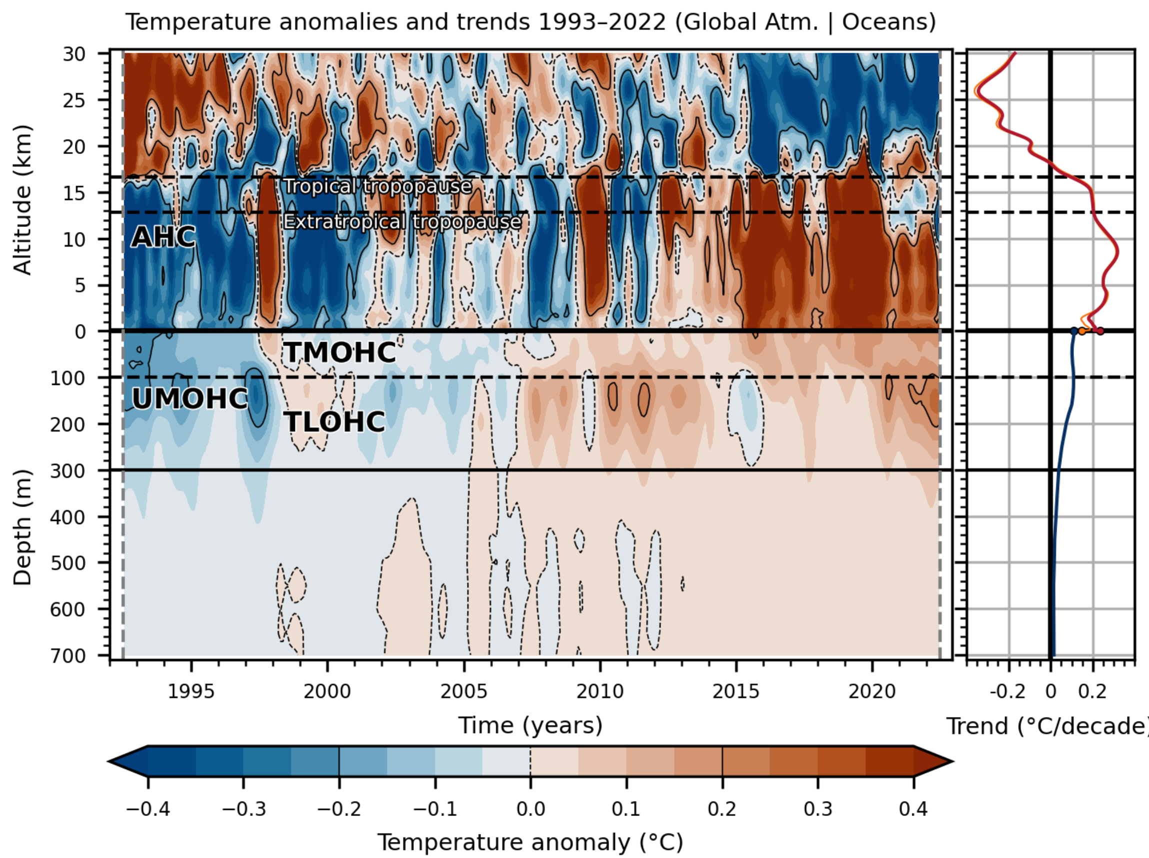
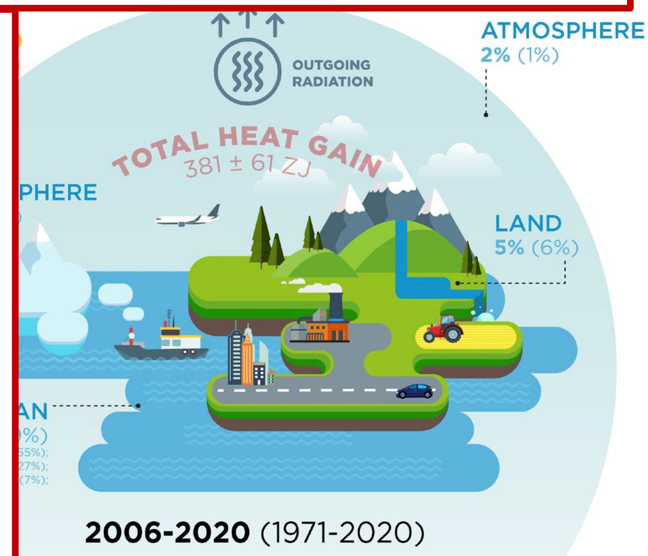
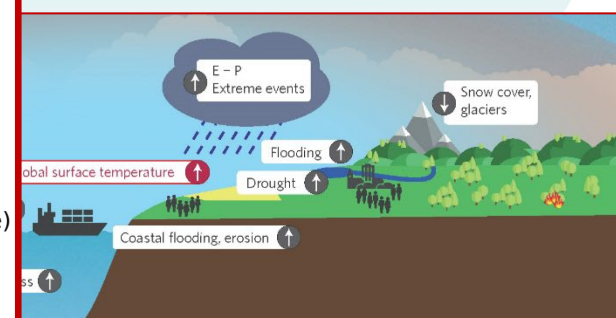
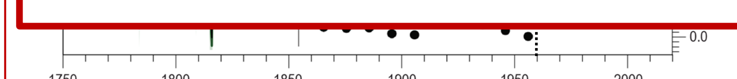
A vertically resolved view: trends & variability in the atmosphere and upper ocean...

[Kirchengast & Gorfer et al., WEGC, 2023; unpublished]









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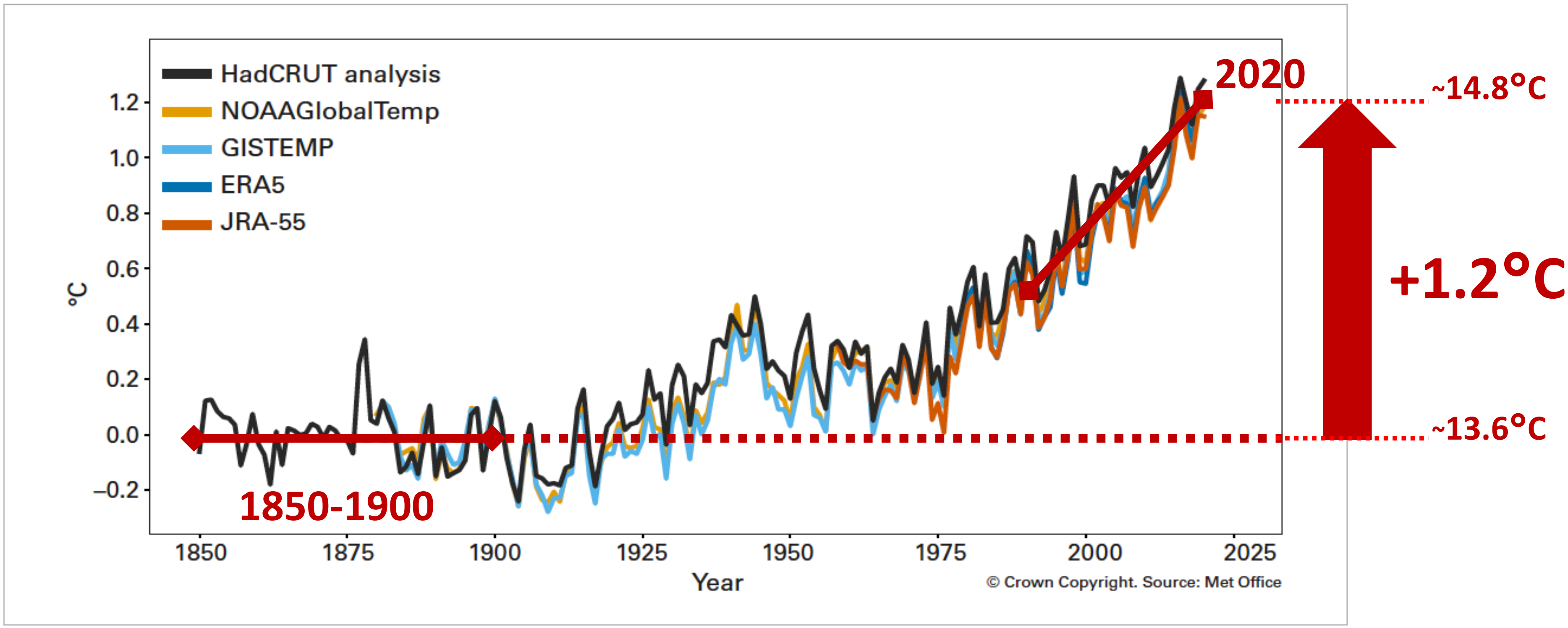
Facts–global warming is going on and on strongly…

*Memorable year 2020: **Mean surface temperature (GMST)** reaches **~1.2°C***

- **Global Warming:** Increase of the **global mean surface temperature (GMST)** ΔT_s **by ~1.2°C** near 2020, relative to preindustrial times (represented by Mean[1850–1900])

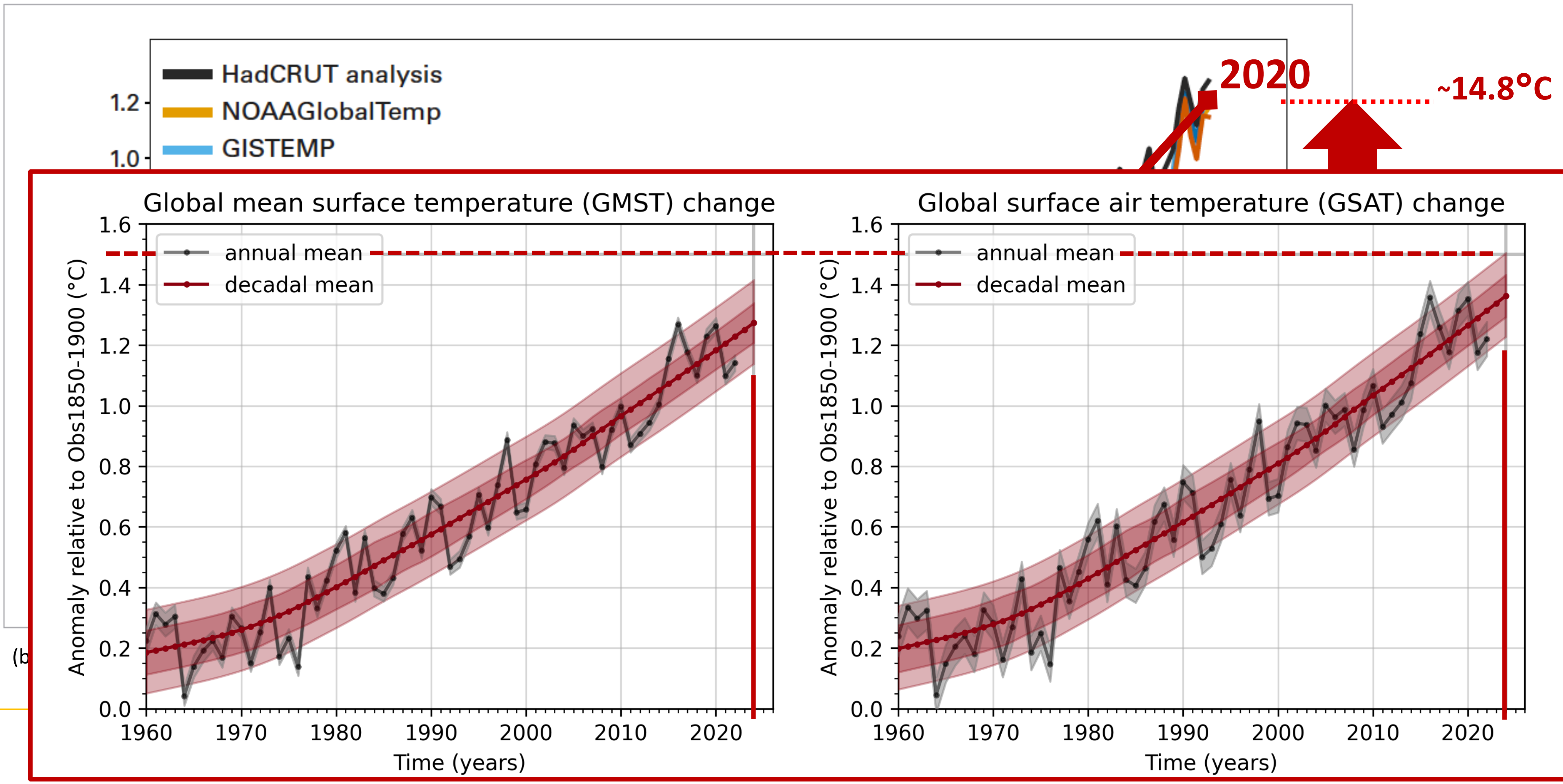


(based on https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate, WMO, 2021; annotations, WEGC, 2021)

Facts–global warming is going on and on strongly…

Memorable year 2024? ***Surface air temperature (GSAT)*** *may reach* ***~1.5°C***

- **Global Warming:** Increase of the mean **global surface air temperature (GSAT)** ΔT_s **by ~1.35°C** in 2024; a strong El Niño (similar to 1998, 2016) could make the annual ΔT_s exceed 1.5°C

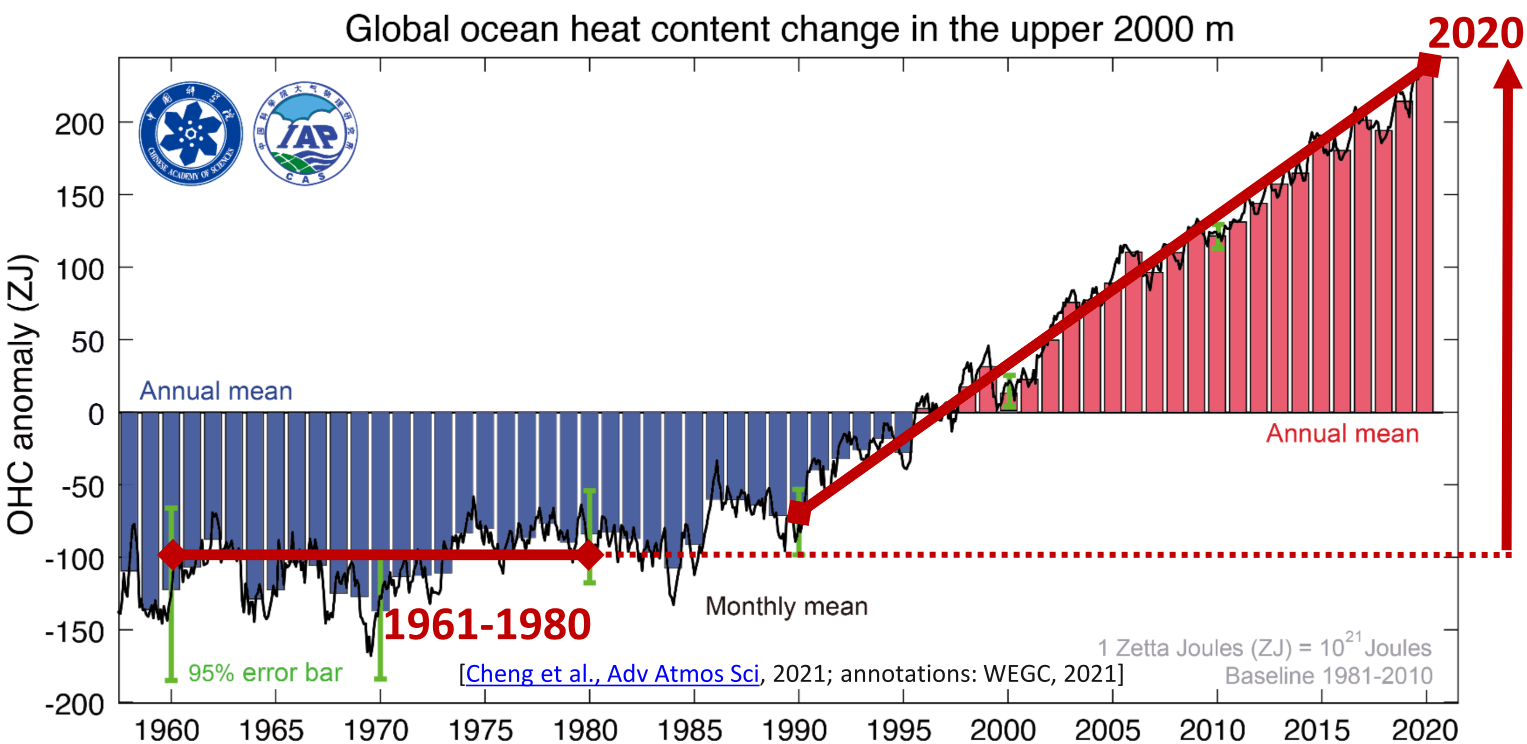


[Kirchengast & Pichler et al., WEGC, 2023; unpublished/data will be part of GCCIv2.1 in gcci.earth/cwm]

Facts–the clearest fingerprint of climate change…

Memorable 2020: ***Ocean heat content*** *(to 2 km depth) reaches* ***~350 ZJ***

- **Ocean warming:** 2020 again more than 13 ZJ excess heat added into the Earth system; about 90 % of the **excess energy ΔN_{EEI} is stored in the oceans** (about 350 ZJ in 0-2000m since 1960)

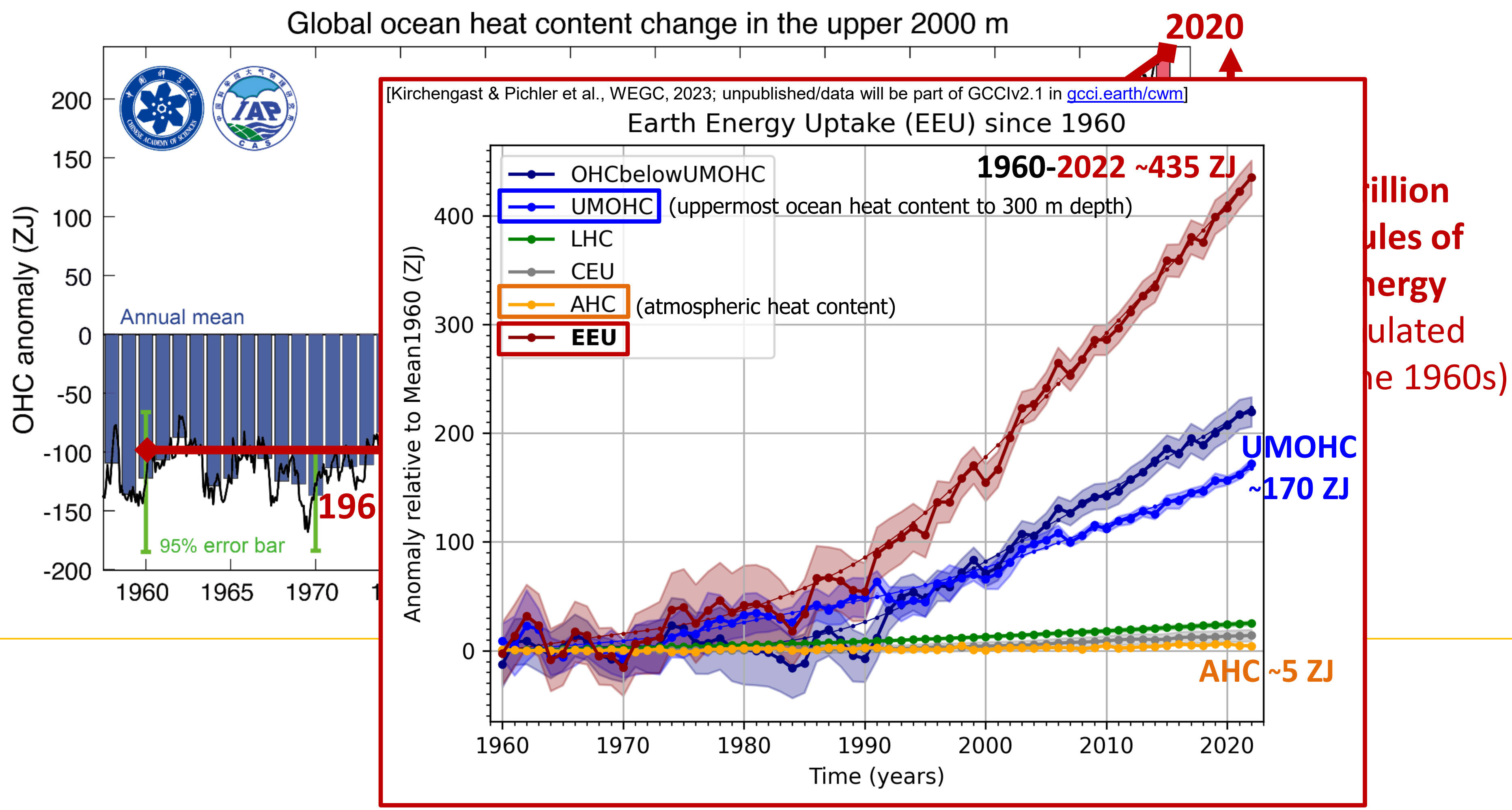


+350 Trillion GigaJoules of Heat Energy (accumulated since the 1960s)

Facts–the clearest fingerprint of climate change…

*Memorable 2022: **Ocean heat content** (all depths) reaches **~400 ZJ***

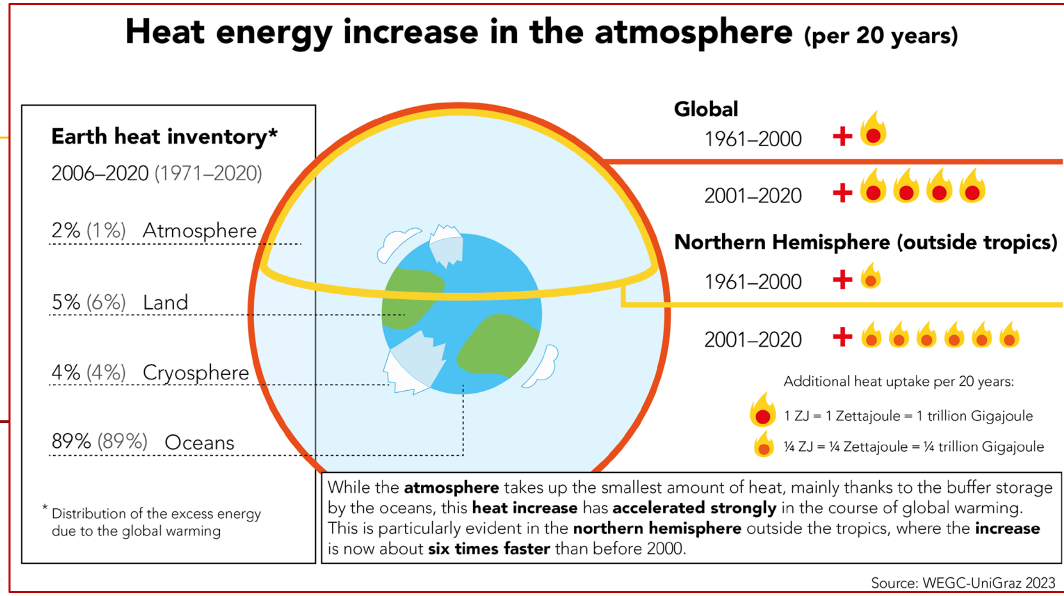
- **Ocean warming:** 2022 again more than 13 ZJ excess heat added into the Earth system; about 90 % (~89 %) of the **excess energy ΔN_{EEI} is stored in the oceans** (near 400 ZJ since 1960)



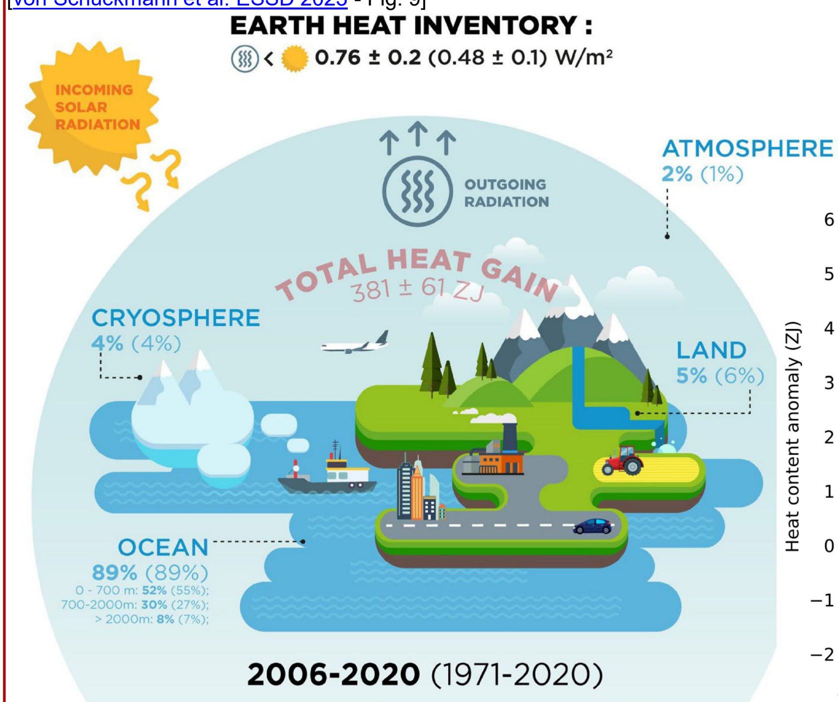
Facts–the clearest fingerprint of climate change…

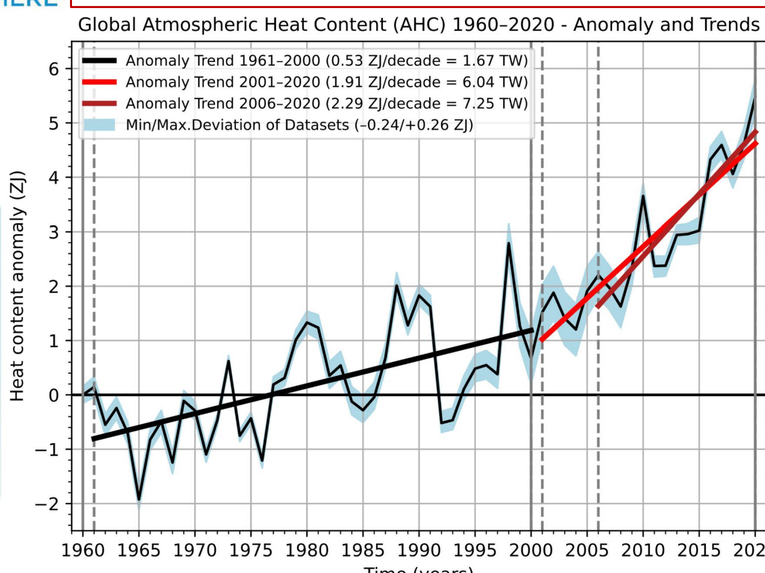
Memorable 2020: ***Atmospheric heat content*** *has increased four-fold…*

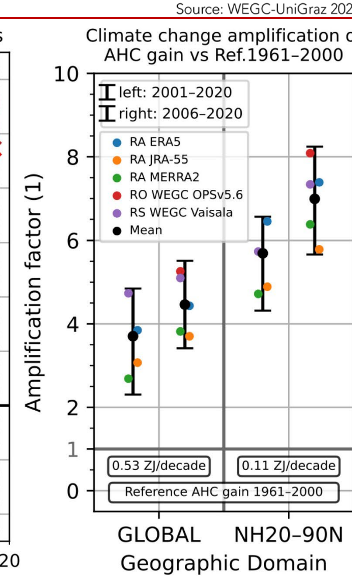
- **Atmospheric warming:** AHC gain over 2001-2020 was **globally four-fold** vs the decades before since 1960
  (intro info: www.uni-graz.at/en/news > Running hot…, UniGraz, 2023)



[von Schuckmann et al. ESSD 2023 - Fig. 9]







(Sources: image left MercatorOcean/ESSD 2023; adaptation&charts WEGC-UniGraz/ESSD 2023)

Facts–the clearest fingerprint of climate change…

*Oceans & **Atmospheric heat content** recently featured frontpage in AT…*

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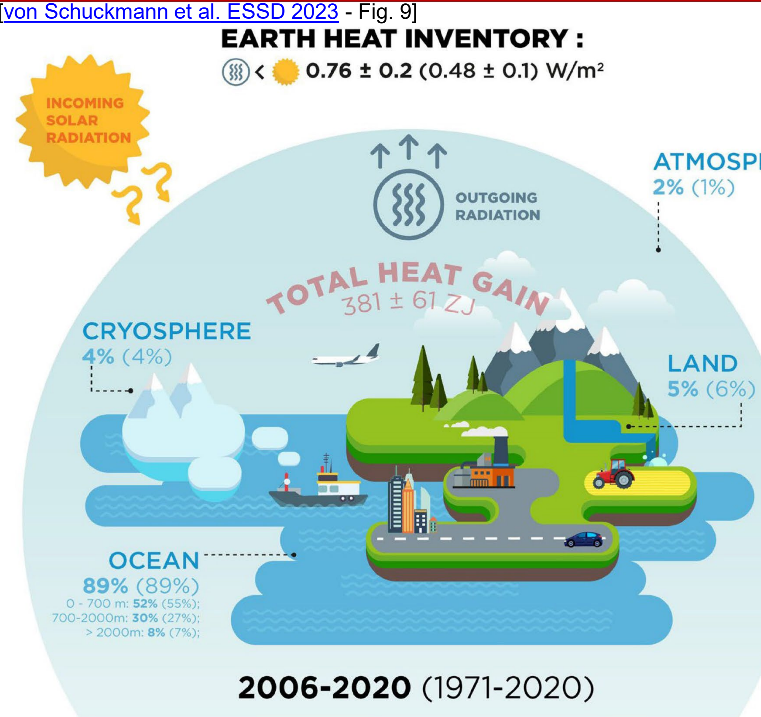

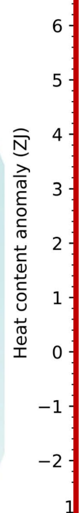

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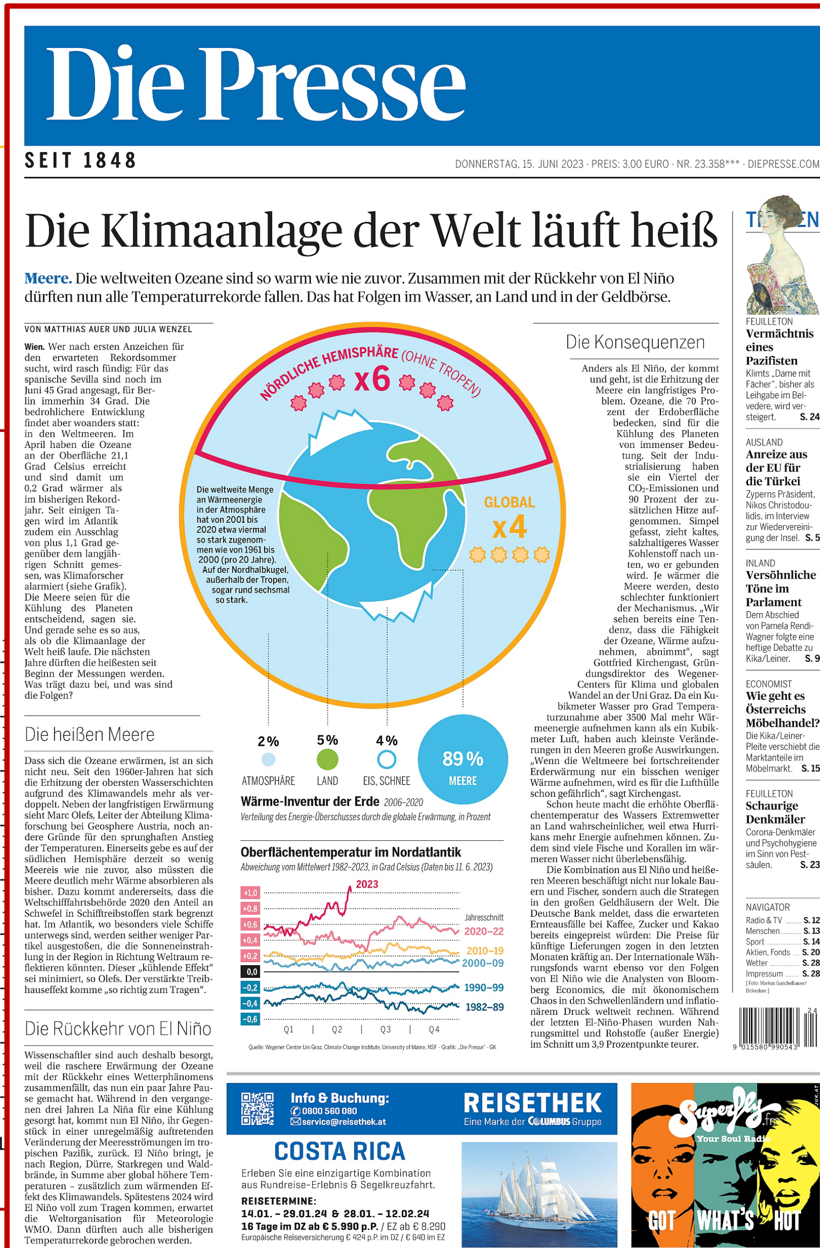

Die Presse

SEIT 1848

DONNERSTAG, 15. JUNI 2023 · PREIS: 3,00 EURO · NR. 23.358*** · DIEPRESSE.COM

Die Klimaanlage der Welt läuft heiß

Meere. Die weltweiten Ozeane sind so warm wie nie zuvor. Zusammen mit der Rückkehr von El Niño dürften nun alle Temperaturrekorde fallen. Das hat Folgen im Wasser, an Land und in der Geldbörse.

VON MATTHIAS AUER UND JULIA WENZEL

Wien. Wer nach ersten Anzeichen für den erwarteten Rekordsommer sucht, wird rasch fündig: Für das spanische Sevilla sind noch im Juni 45 Grad angesagt, für Berlin immerhin 34 Grad. Die bedrohlichere Entwicklung findet aber woanders statt: in den Weltmeeren. Im April haben die Ozeane an der Oberfläche 21,1 Grad Celsius erreicht und sind damit um 0,2 Grad wärmer als im bisherigen Rekordjahr. Seit einigen Tagen wird im Atlantik zudem ein Ausschlag von plus 1,1 Grad gegenüber dem langjährigen Schnitt gemessen, was Klimaforscher alarmiert (siehe Grafik). Die Meere seien für die Kühlung des Planeten entscheidend, sagen sie. Und gerade sehe es so aus, als ob die Klimaanlage der Welt heiß laufe. Die nächsten Jahre dürften die heißesten seit Beginn der Messungen werden. Was trägt dazu bei, und was sind die Folgen?

Die heißen Meere

Dass sich die Ozeane erwärmen, ist an sich nicht neu. Seit den 1960er-Jahren hat sich die Erhitzung der obersten Wasserschichten aufgrund des Klimawandels mehr als verdoppelt. Neben der langfristigen Erwärmung sieht Marc Olefs, Leiter der Abteilung Klimaforschung bei Geosphere Austria, noch andere Gründe für den sprunghaften Anstieg der Temperaturen. Einerseits gebe es auf der südlichen Hemisphäre derzeit so wenig Meereis wie nie zuvor, also müssten die Meere deutlich mehr Wärme absorbieren als bisher. Dazu kommt andererseits, dass die Weltschifffahrtsbehörde 2020 den Anteil an Schwefel in Schiffstreibstoffen stark begrenzt hat. Im Atlantik, wo besonders viele Schiffe unterwegs sind, werden seither weniger Partikel ausgestoßen, die die Sonneneinstrahlung in der Region in Richtung Weltraum reflektieren könnten. Dieser „kühlende Effekt" sei minimiert, so Olefs. Der verstärkte Treibhauseffekt komme „so richtig zum Tragen".

Die Rückkehr von El Niño

Wissenschaftler sind auch deshalb besorgt, weil die raschere Erwärmung der Ozeane mit der Rückkehr eines Wetterphänomens zusammenfällt, das nun ein paar Jahre Pause gemacht hat. Während in den vergangenen drei Jahren La Niña für eine Kühlung gesorgt hat, kommt nun El Niño, ihr Gegenstück in einer unregelmäßig auftretenden Veränderung der Meeresströmungen im tropischen Pazifik, zurück. El Niño bringt, je nach Region, Dürre, Starkregen und Waldbrände, in Summe aber global höhere Temperaturen – zusätzlich zum wärmenden Effekt des Klimawandels. Spätestens 2024 wird El Niño voll zum Tragen kommen, erwartet die Weltorganisation für Meteorologie WMO. Dann dürften auch alle bisherigen Temperaturrekorde gebrochen werden.

Wärme-Inventur der Erde *2006–2020*

Verteilung des Energie-Überschusses durch die globale Erwärmung, in Prozent

Oberflächentemperatur im Nordatlantik

Abweichung vom Mittelwert 1982–2023, in Grad Celsius (Daten bis 11. 6. 2023)

Quelle: Wegener Center Uni Graz, Climate Change Institute, University of Maine, NSF · Grafik: „Die Presse" · GK

Die Konsequenzen

Anders als El Niño, der kommt und geht, ist die Erhitzung der Meere ein langfristiges Problem. Ozeane, die 70 Prozent der Erdoberfläche bedecken, sind für die Kühlung des Planeten von immenser Bedeutung. Seit der Industrialisierung haben sie ein Viertel der CO_2-Emissionen und 90 Prozent der zusätzlichen Hitze aufgenommen. Simpel gefasst, zieht kaltes, salzhaltigeres Wasser Kohlenstoff nach unten, wo er gebunden wird. Je wärmer die Meere werden, desto schlechter funktioniert der Mechanismus. „Wir sehen bereits eine Tendenz, dass die Fähigkeit der Ozeane, Wärme aufzunehmen, abnimmt", sagt Gottfried Kirchengast, Gründungsdirektor des Wegener-Centers für Klima und globalen Wandel an der Uni Graz. Da ein Kubikmeter Wasser pro Grad Temperaturzunahme aber 3500 Mal mehr Wärmeenergie aufnehmen kann als ein Kubikmeter Luft, haben auch kleinste Veränderungen in den Meeren große Auswirkungen. „Wenn die Weltmeere bei fortschreitender Erderwärmung nur ein bisschen weniger Wärme aufnehmen, wird es für die Lufthülle schon gefährlich", sagt Kirchengast.

Schon heute macht die erhöhte Oberflächentemperatur des Wassers Extremwetter an Land wahrscheinlicher, weil etwa Hurrikans mehr Energie aufnehmen können. Zudem sind viele Fische und Korallen im wärmeren Wasser nicht überlebensfähig.

Die Kombination aus El Niño und heißeren Meeren beschäftigt nicht nur lokale Bauern und Fischer, sondern auch die Strategen in den großen Geldhäusern der Welt. Die Deutsche Bank meldet, dass die erwarteten Ernteausfälle bei Kaffee, Zucker und Kakao bereits eingepreist würden: Die Preise für künftige Lieferungen zogen in den letzten Monaten kräftig an. Der Internationale Währungsfonds warnt ebenso vor den Folgen von El Niño wie die Ökonomen von Bloomberg Economics, die mit ökonomischem Chaos in den Schwellenländern und inflationärem Druck weltweit rechnen. Während der letzten El-Niño-Phasen wurden Nahrungsmittel und Rohstoffe (außer Energie) im Schnitt um 3,9 Prozentpunkte teurer.

THEMEN

FEUILLETON
Vermächtnis eines Pazifisten
Klimts „Dame mit Fächer", bisher als Leihgabe im Belvedere, wird versteigert. **S. 24**

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Zyperns Präsident, Nikos Christodoulidis, im Interview zur Wiedervereinigung der Insel. **S. 5**

INLAND
Versöhnliche Töne im Parlament
Dem Abschied von Pamela Rendi-Wagner folgte eine heftige Debatte zu Kika/Leiner. **S. 9**

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Wie geht es Österreichs Möbelhandel?
Die Kika/Leiner-Pleite verschiebt die Marktanteile im Möbelmarkt. **S. 15**

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[Foto: Markus Guschelbauer/Belvedere]

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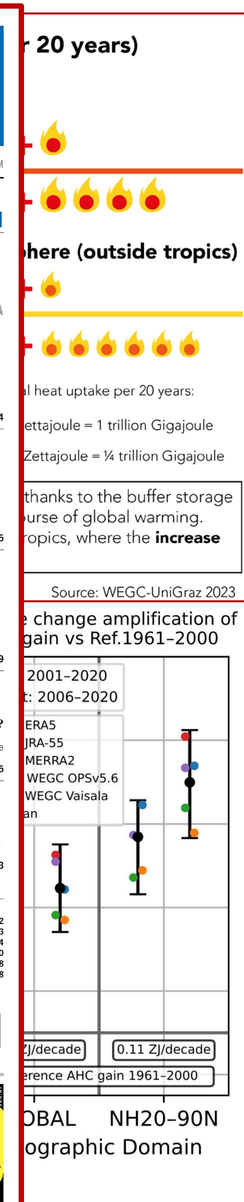


Perspectives–what do we learn for CC mitigation?

The IPCC-AR6 was very clear that reaching the Paris goals needs strong action

A key statement in the recent IPCC(-AR6-WGI) assessment report:

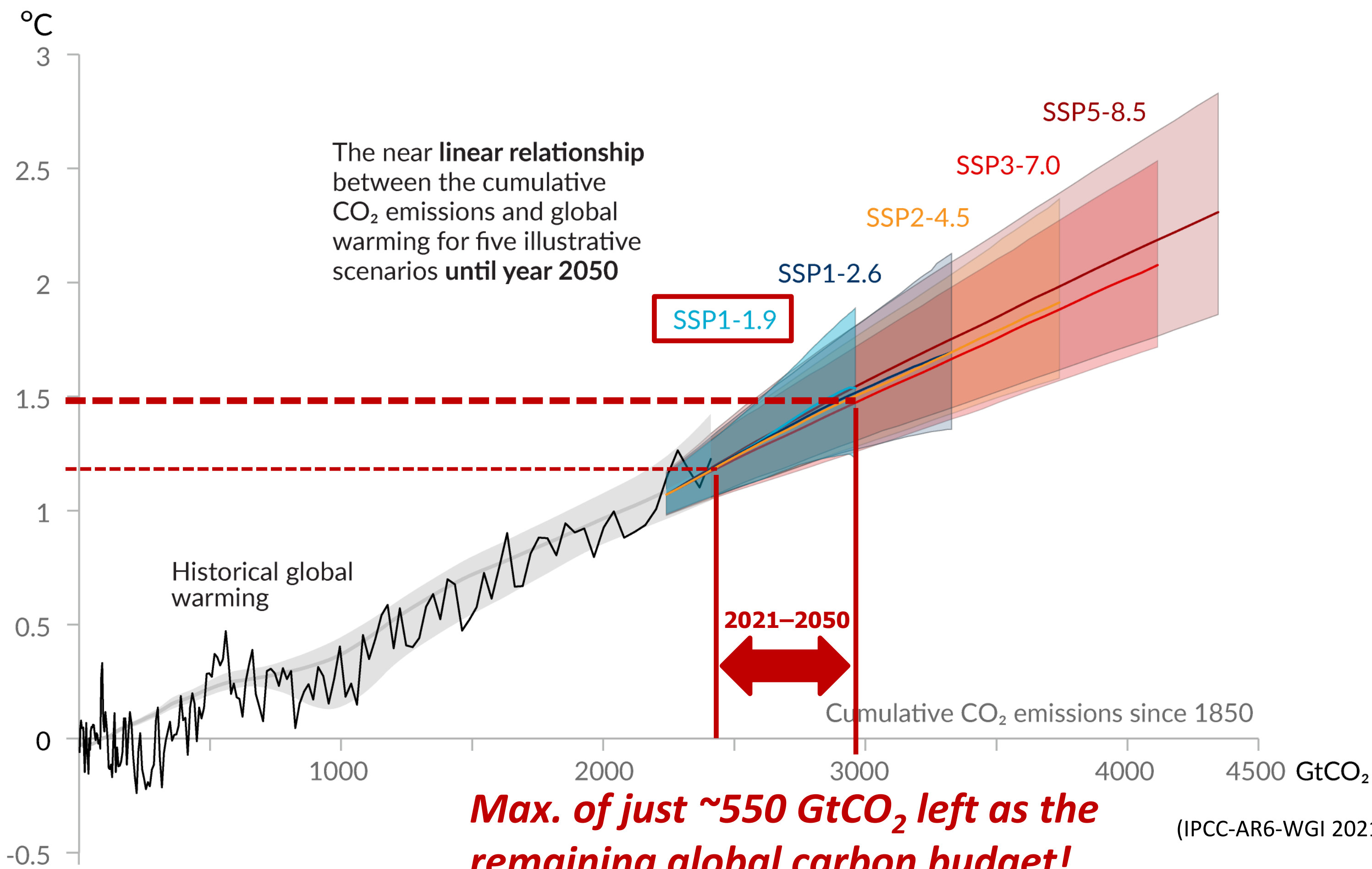
Perspectives–what do we learn for CC mitigation?

"Emissions & global warming: novel cause-effect relationships modeling…"

Time to act – Cumulation of CO_2 emissions needs to end near 2050

- **Every additional ton of CO_2 (and other GHG) emissions contributes to global warming**

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Max. of just ~550 $GtCO_2$ left as the remaining global carbon budget!

(IPCC-AR6-WGI 2021, Fig. SPM.10)

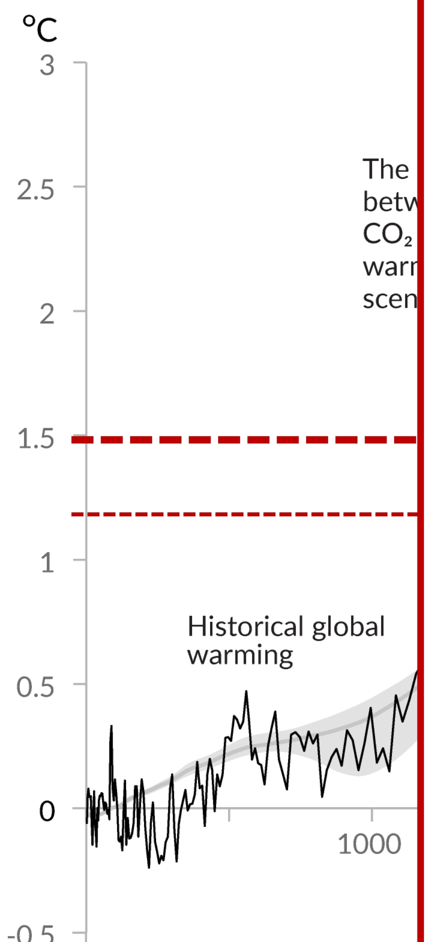
Perspectives–wh

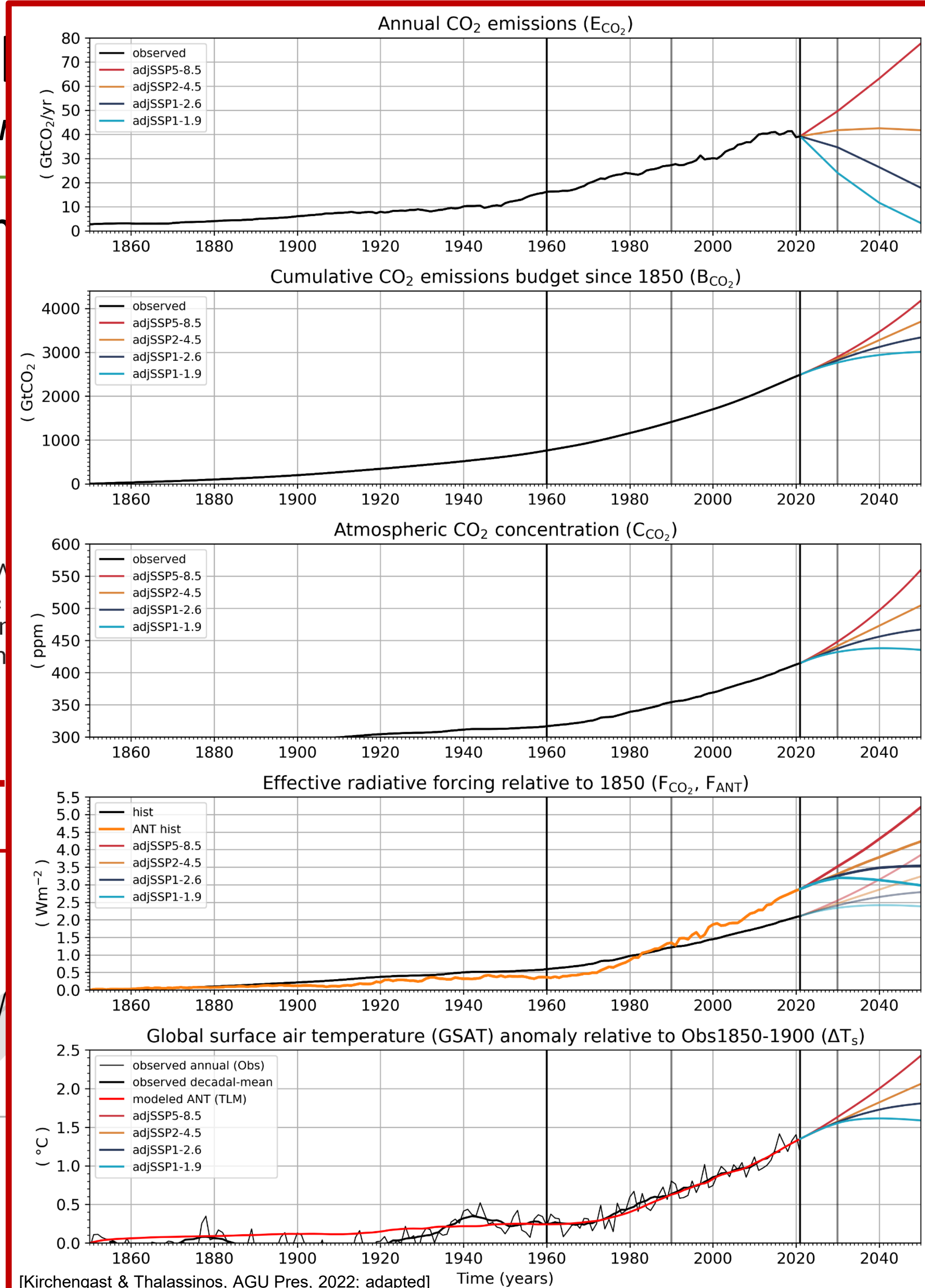
"Emissions & global warr

Time to act – Cur ... near 2050

- **Every additional ton ... bal warming**

Global surface temperature ... missions (GtCO₂)





[Kirchengast & Thalassinos, AGU Pres, 2022; adapted]

CO₂

2021, Fig. SPM.10)

Persp

“Emissio

Core–*the TOA imbalance* (Wm[-2]):

$$\Delta N_{EEI} \cong F_{ERF} - |\alpha_{CFP}| \cdot \Delta T_s$$

Top-of-Atmosphere (TOA) energy imbalance drives ΔT_s

Earth-surface-layer energy imbalance => ΔT_s (GSAT)

Deeper-ocean energy imbalance => ΔT_d (GDOT)

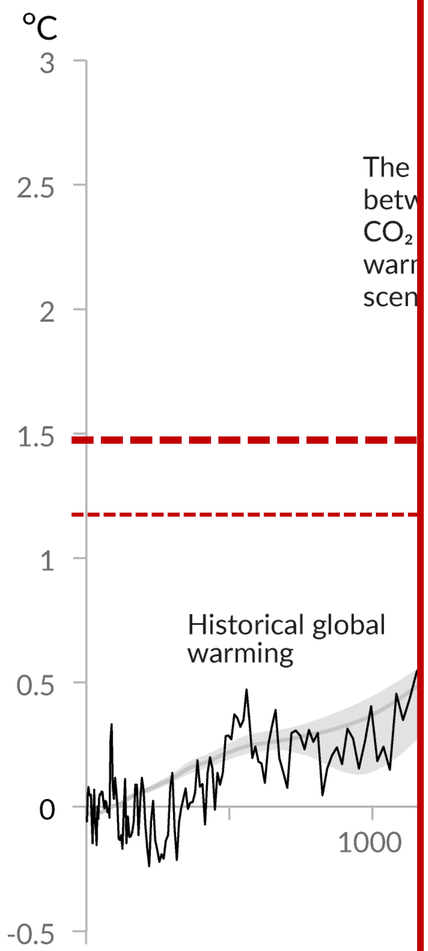
- $\Delta N_{EEI} = F_{ERF} - |\alpha_{CFP}| \cdot \Delta T_s$
- $C_s \frac{d\Delta T_s}{dt} = F_{ERF} - |\alpha_{CFP}| \cdot \Delta T_s - \gamma_o(\Delta T_s - \Delta T_d)$
- $C_d \frac{d\Delta T_d}{dt} = \gamma_o(\Delta T_s - \Delta T_d)$

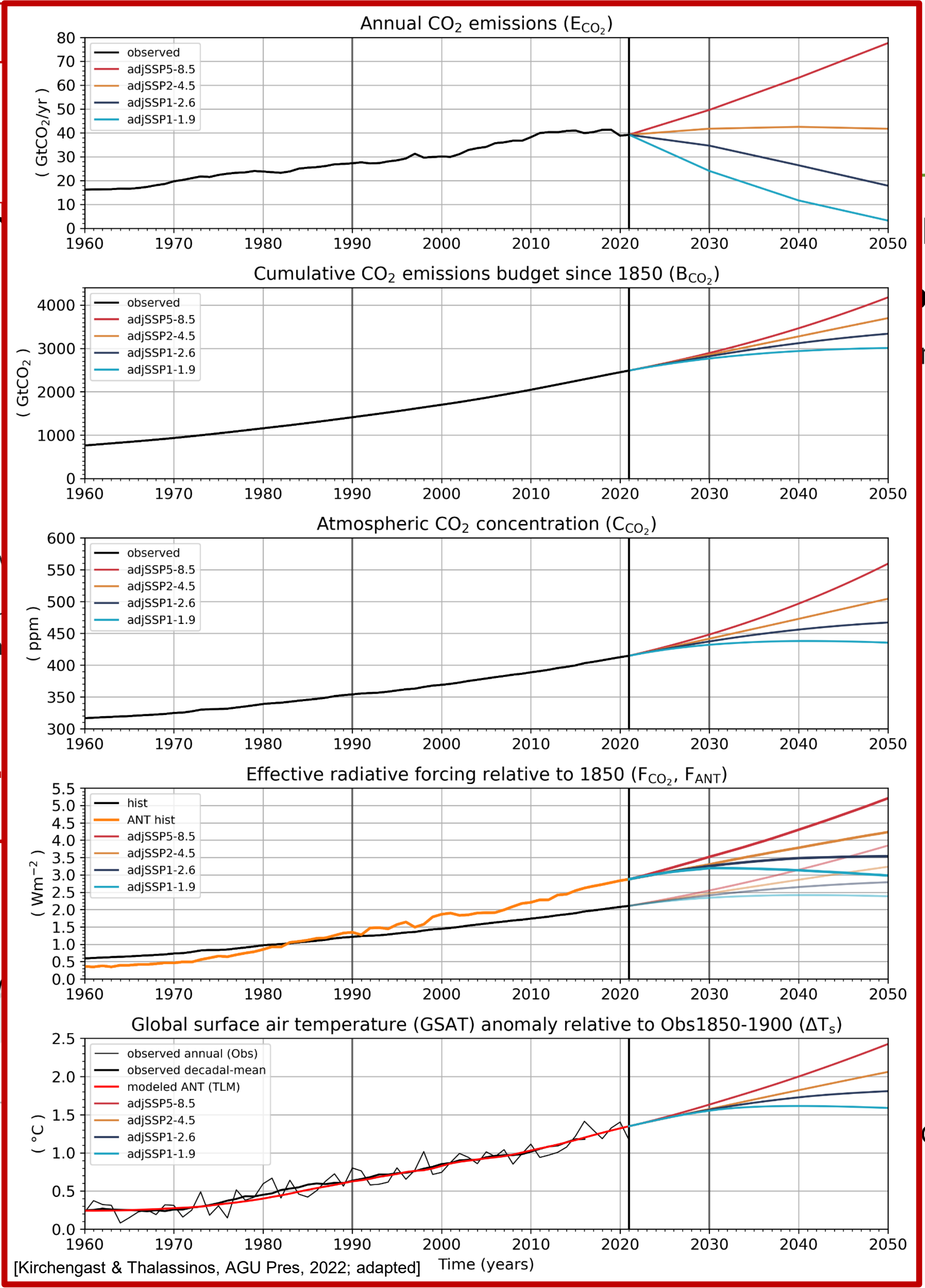
[Kirchengast & Pichler et al., WEGC, 2023; unpublished]

Time to act – Cur ... near 2050

- **Every additional ton ... bal warming**

Global surface temperature ... missions (GtCO₂)





[Kirchengast & Thalassinos, AGU Pres, 2022; adapted]

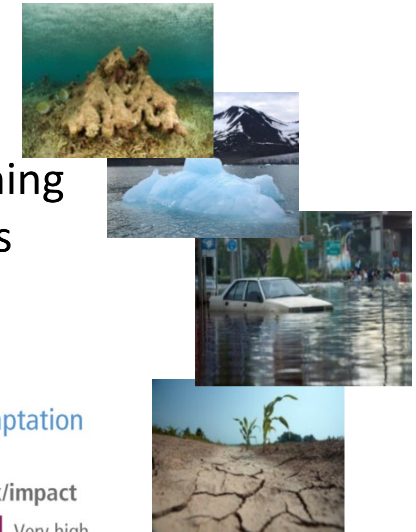
CO_2

2021, Fig. SPM.10)

Perspectives–what do we learn for CC mitigation?

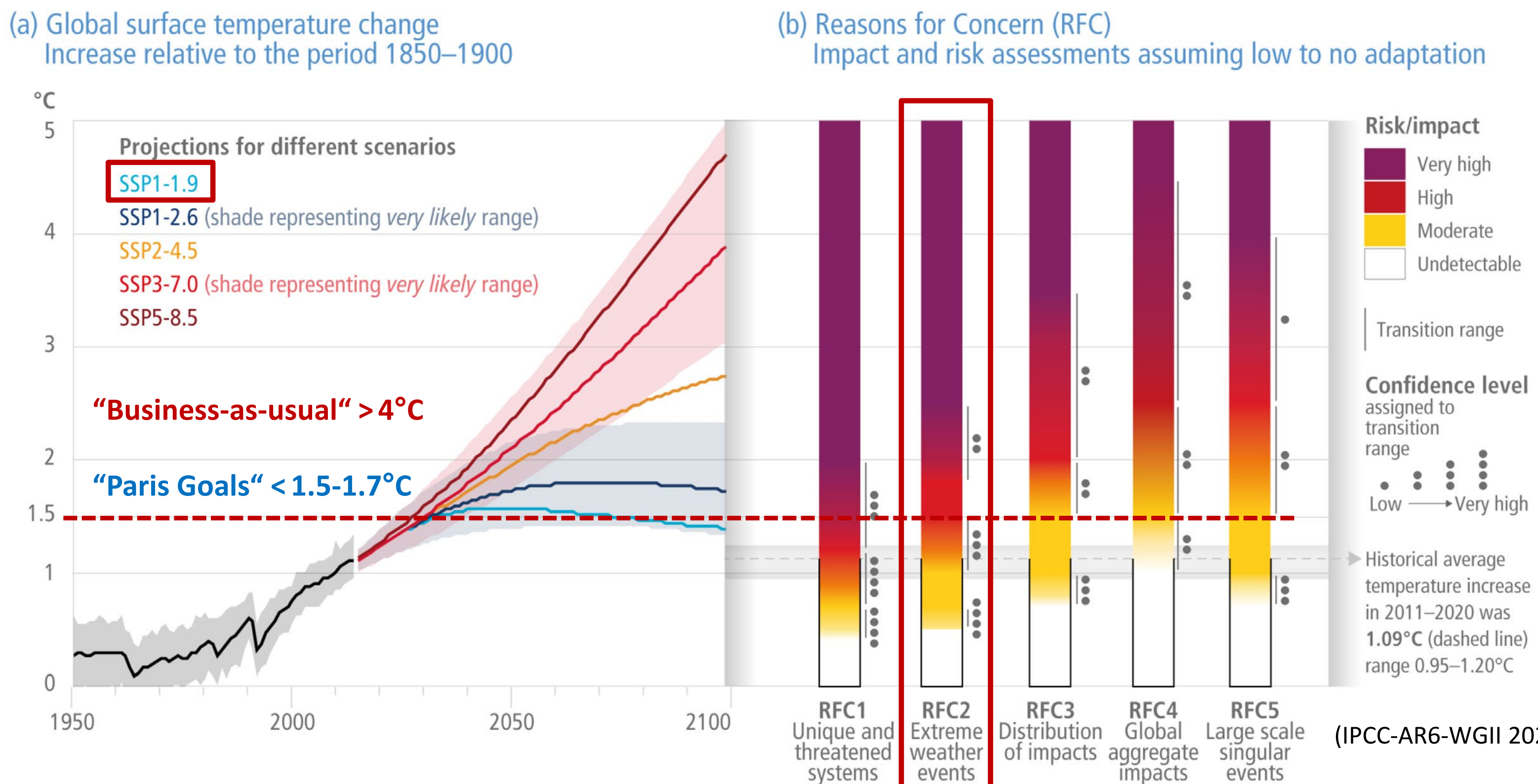
“Global warming & extremes: novel compound extreme event indicators…”

Time to act! Avoid High Risks and Irreversible Changes



- **Paris 2015 Climate Agreement** – Countries pledge to keep global warming well below 2°C, aiming for 1.5°C to avoid risks & irreversible disruptions

Global and regional risks for increasing levels of global warming

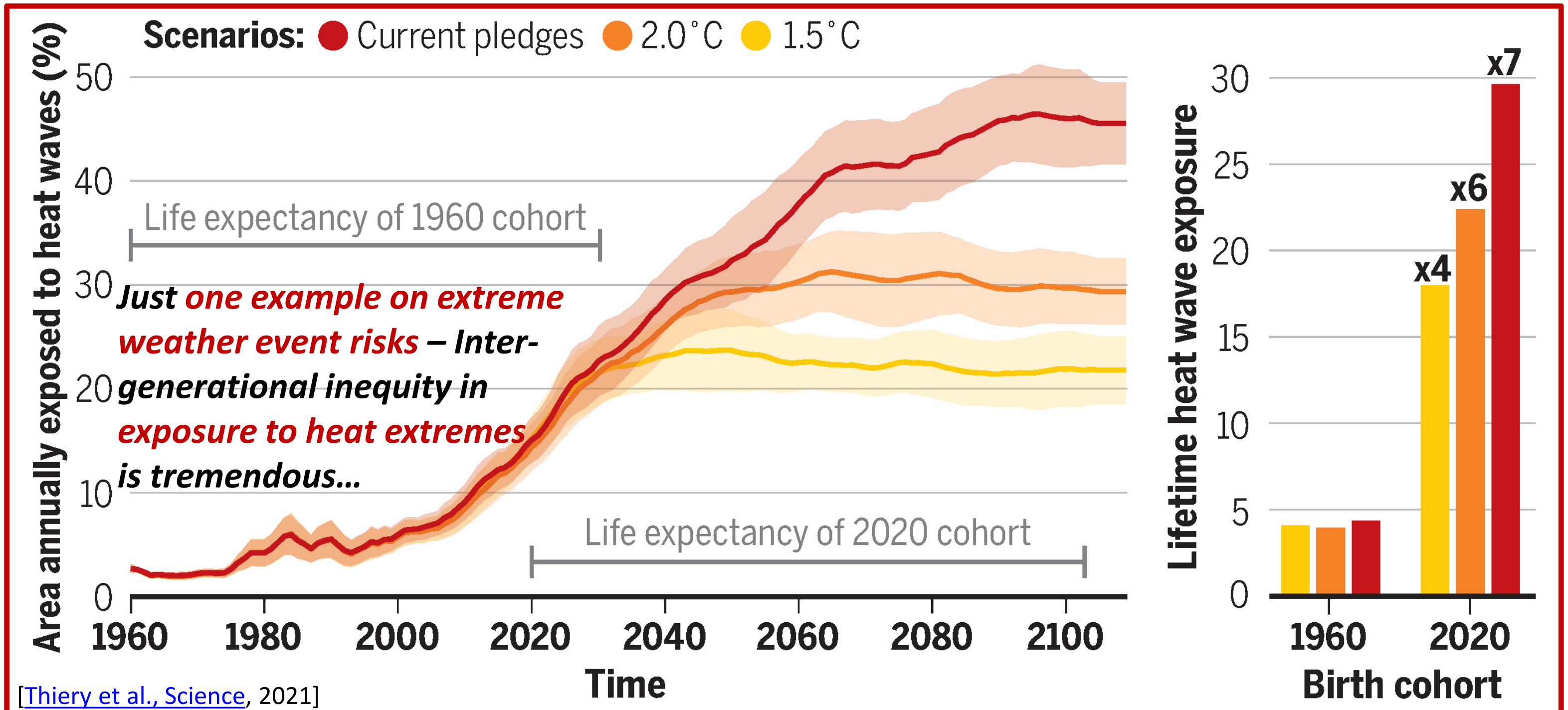


(IPCC-AR6-WGII 2022, Fig. SPM.3/1)

Time to act! Avoid High Risks and Irreversible Changes

- **Paris 2015 Climate Agreement** – Countries pledge to keep global warming well below 2°C, aiming for 1.5°C to avoid risks & irreversible disruptions

Global and regional risks for increasing levels of global warming



[Thiery et al., Science, 2021]

RFC1 Unique and threatened systems | RFC2 Extreme weather events | RFC3 Distribution of impacts | RFC4 Global aggregate impacts | RFC5 Large scale singular events

(IPCC-AR6-WGII 2022, Fig. SPM.3/1)

Perspective

“Global warming &

Time to act!

- **Paris 2015 Clin**
  well below 2°C

Global and regional r

(a) Global surface temperatu
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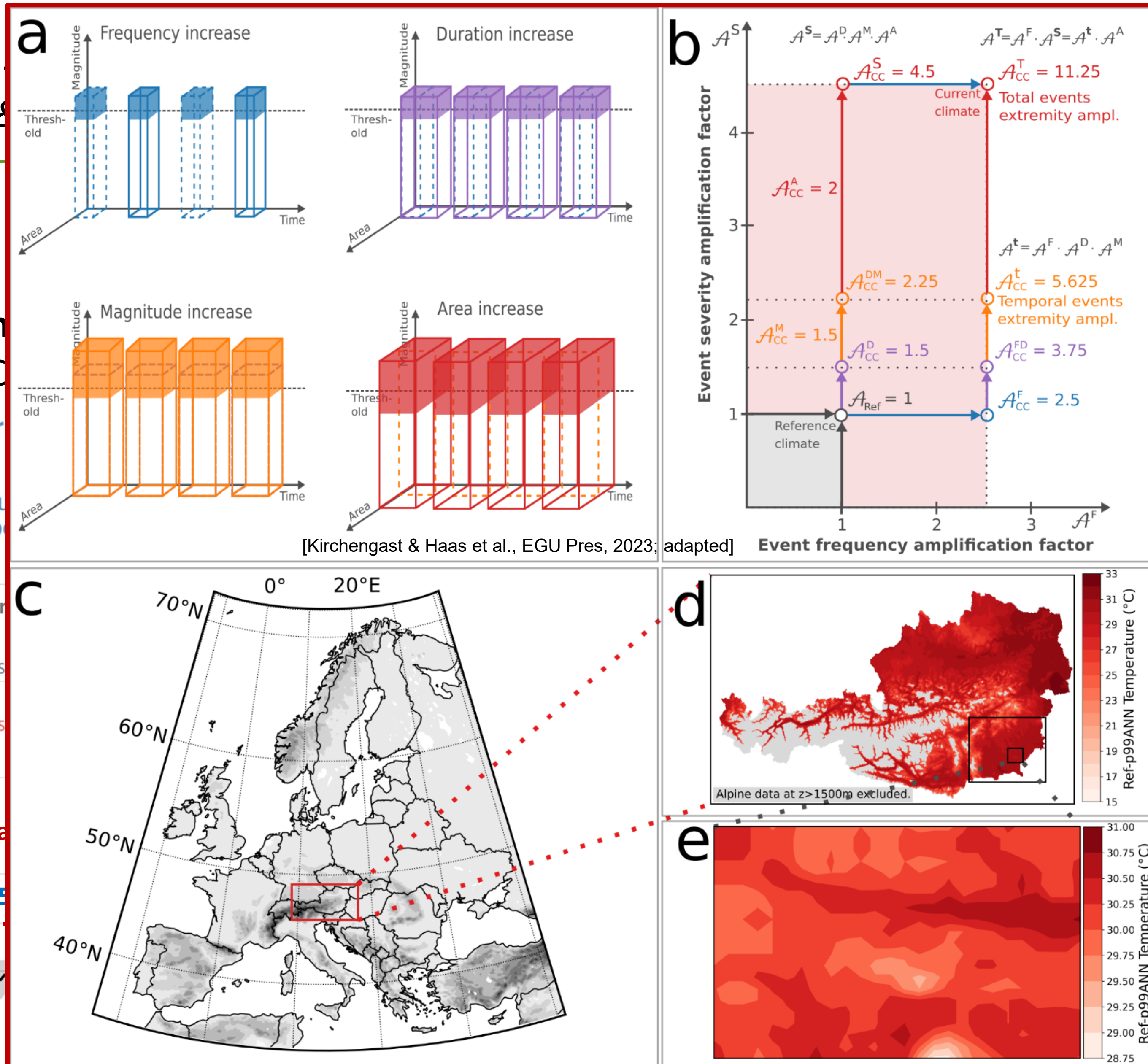

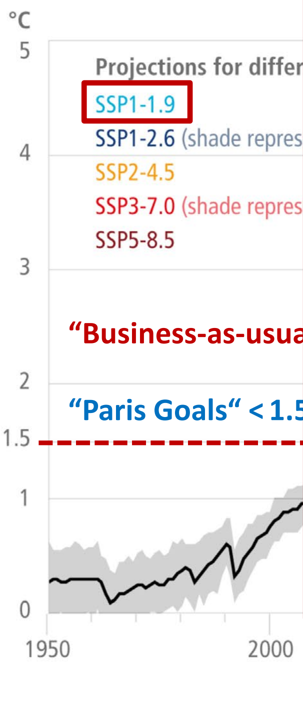

(IPCC-AR6-WGII 2022, Fig. SPM.3/1)

Perspectives–

“Global warming & ex

Time to act! Av

- **Paris 2015 Climat**
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Global and regional risks

(a) Global surface temperature ch
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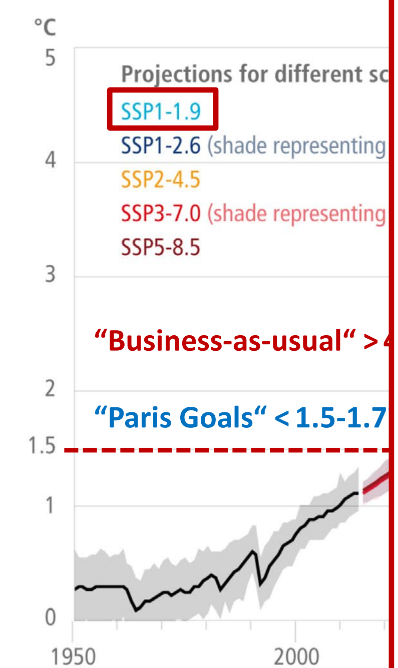

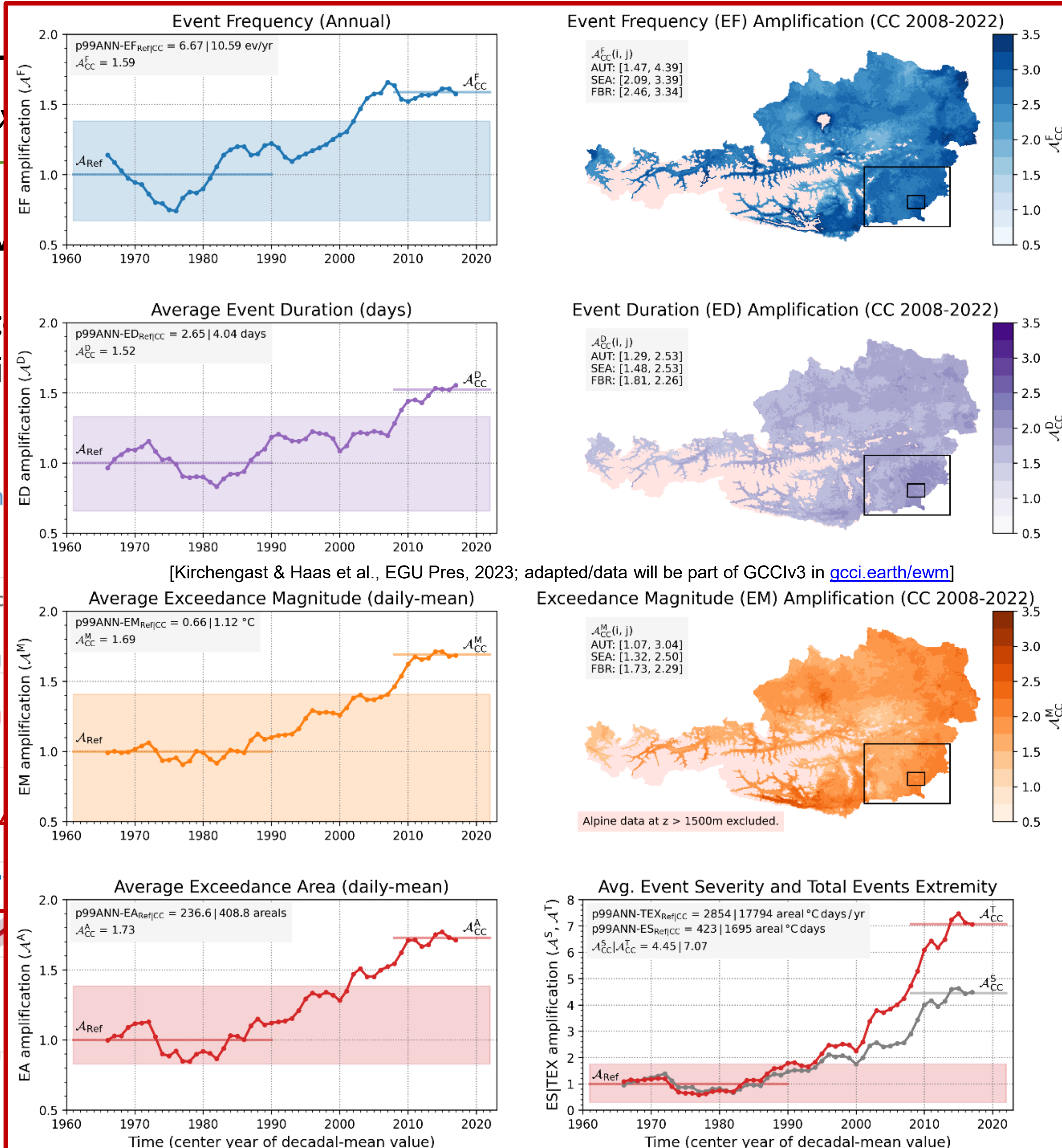

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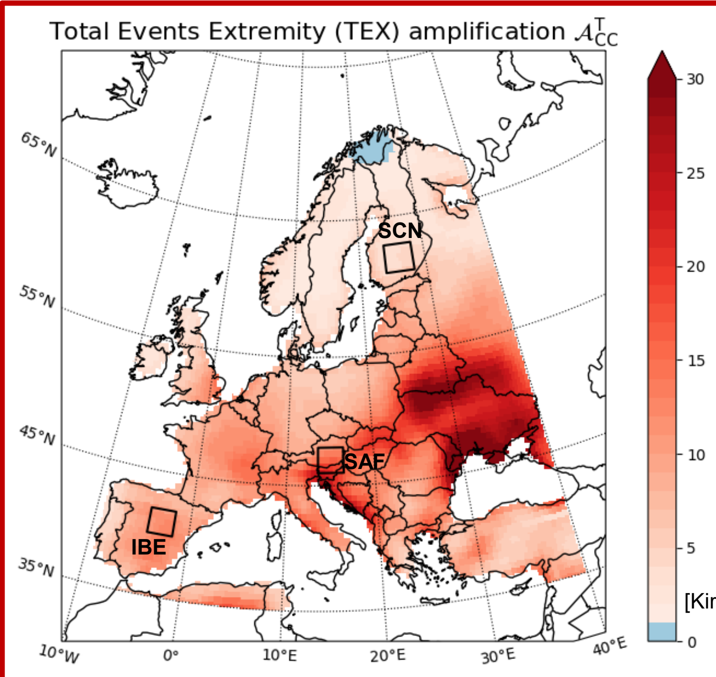
we learn for CC mitigation?

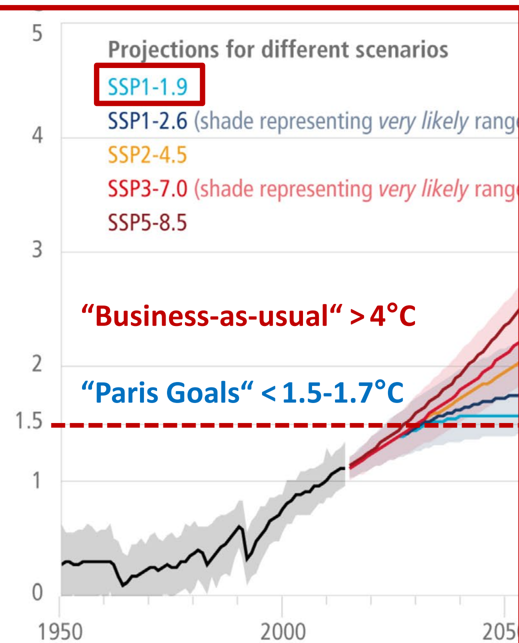
compound extreme event indicators…”

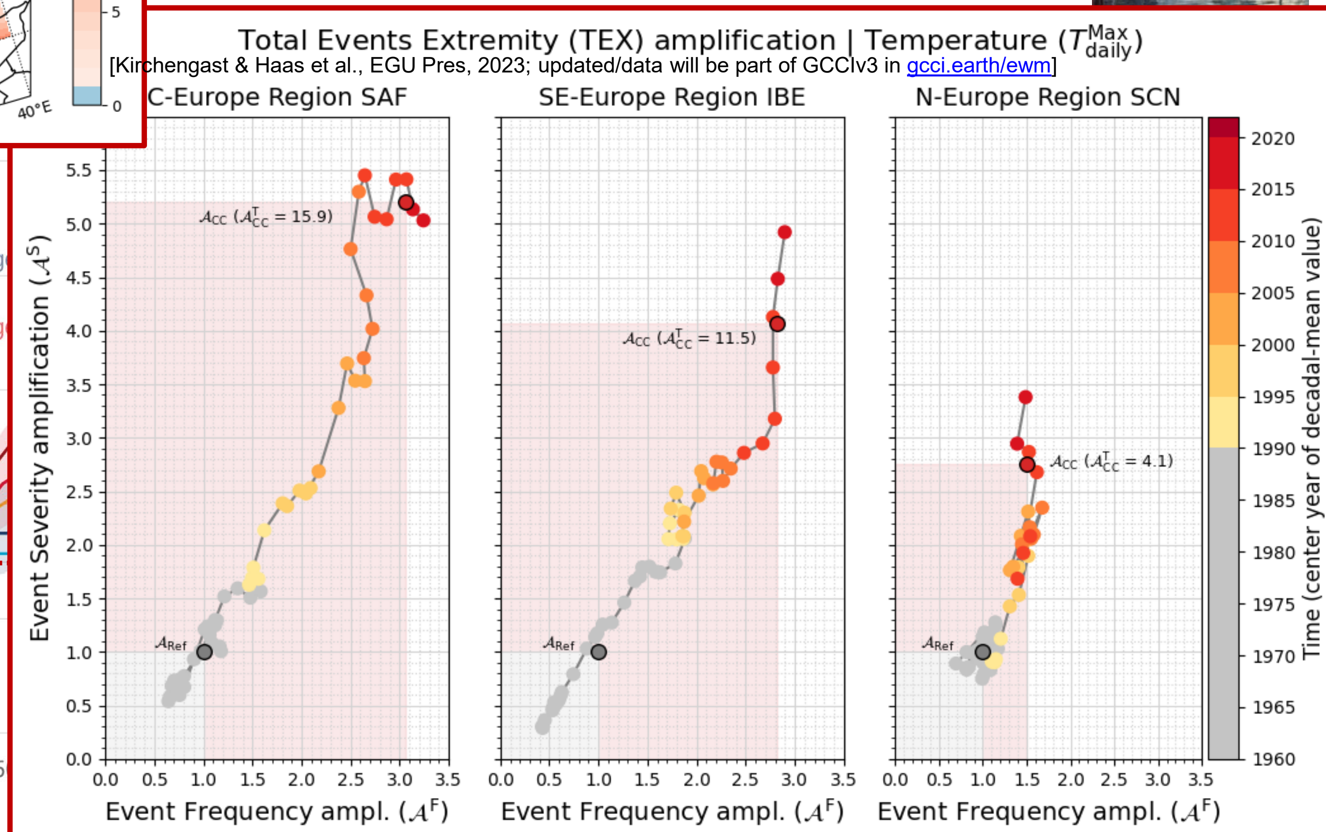


isks and Irreversible Changes

- Countries pledge to keep global warming to avoid risks & irreversible disruptions

ls of global warming





Perspectives–what do we learn for CC mitigation?

"Climate action: novel approach to fair contributions to reach the Paris goals…"

Wegener Center

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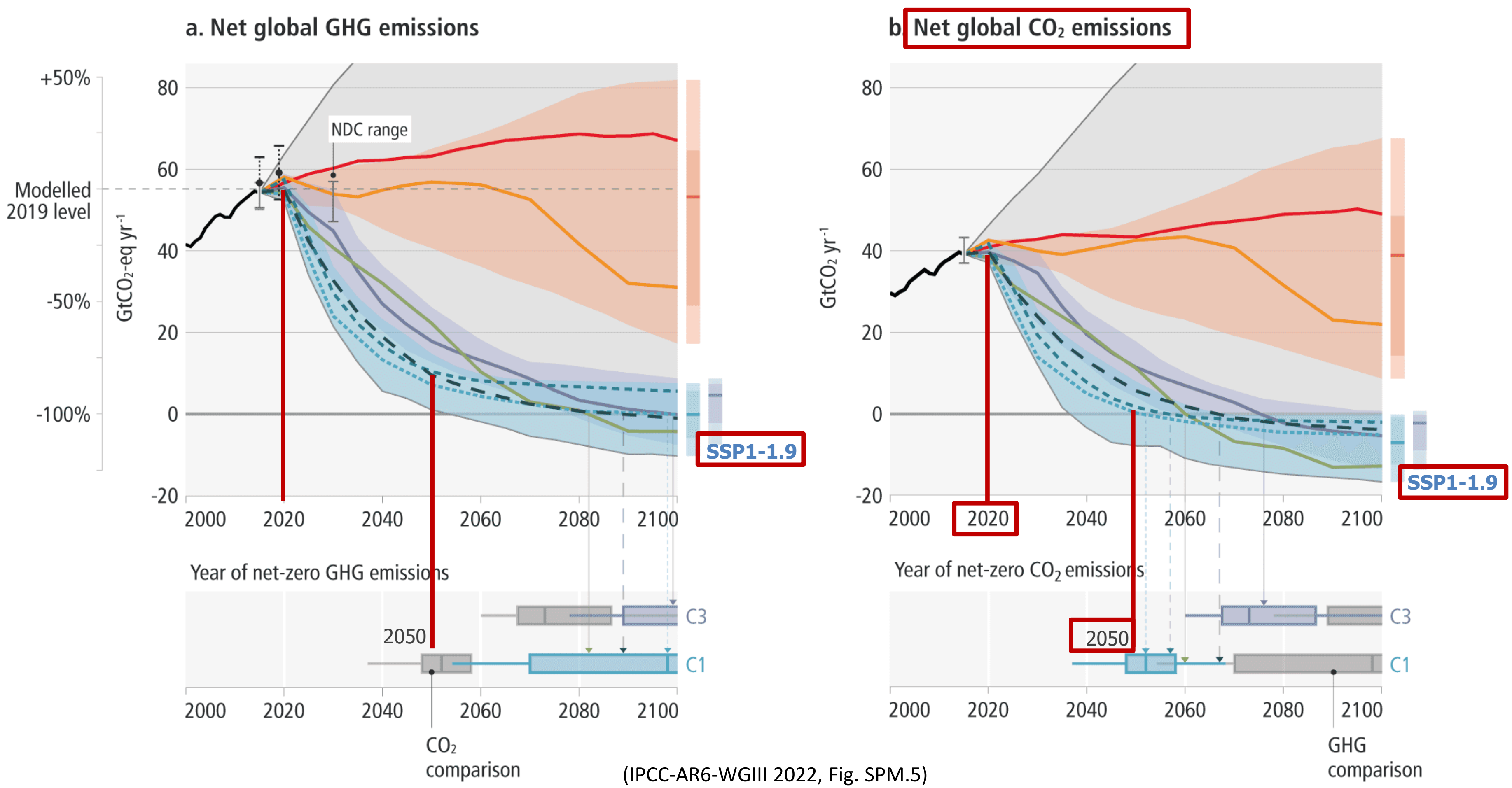
Turning to action: CO_2 emissions need to reach *Net-Zero near 2050*

Modelled mitigation pathways that limit warming to 1.5°C, and 2°C, involve deep, rapid and sustained emissions reductions.



(IPCC-AR6-WGIII 2022, Fig. SPM.5)

Perspectives–what do we learn for CC mitigation?

"Climate action: novel approach to fair contributions to reach the Paris goals…"

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Frame the action: Carbon budgets need be *allocated in a fair manner*

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

ELSEVIER

Fairness critically conditions the carbon budget allocation across countries

https://doi.org/10.1016/j.gloenvcha.2022.102481 (March 2022)

Keith Williges [a,c,*], Lukas H. Meyer [c,*], Karl W. Steininger [a,b], Gottfried Kirchengast [a,d]

[a] Wegener Center for Climate and Global Change, University of Graz, Brandhofgasse 5, Graz A-8010, Austria
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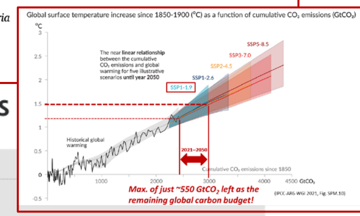
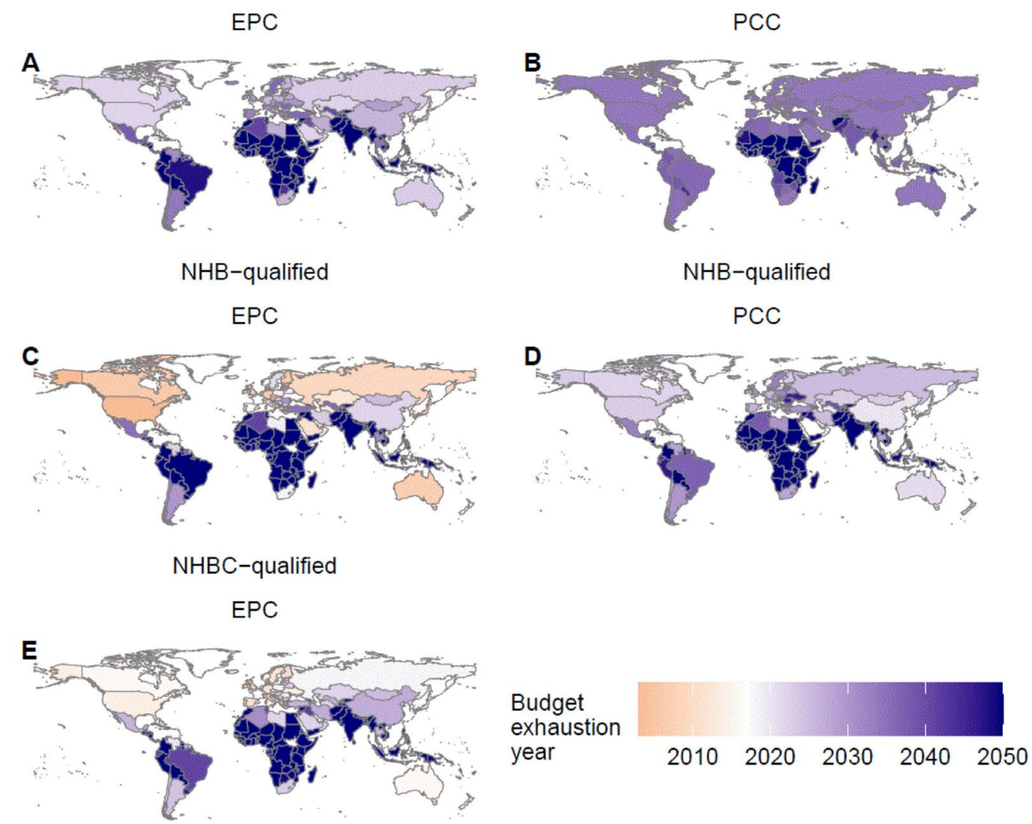
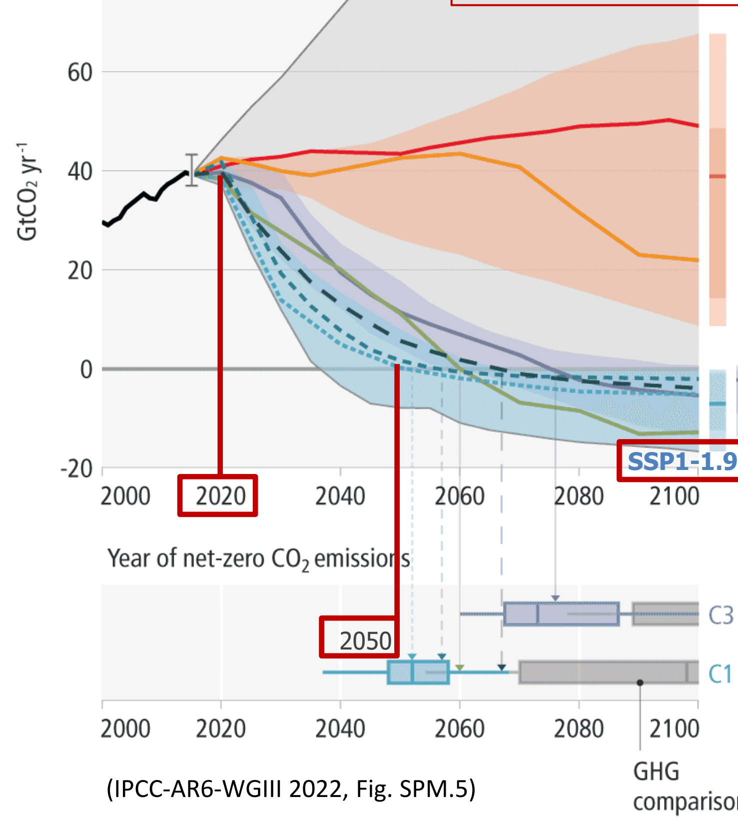
[c] Department of Philosophy, University of Graz, Attemsgasse 25, Graz A-8010, Austria
[d] Institute of Physics, University of Graz, Universitaetsplatz 5, Graz A-8010, Austria



Remaining CO_2 budget availability across countries** **for different sharing principles *(EPC…Equal-per-capita, PCC…Per-capita-convergence)*

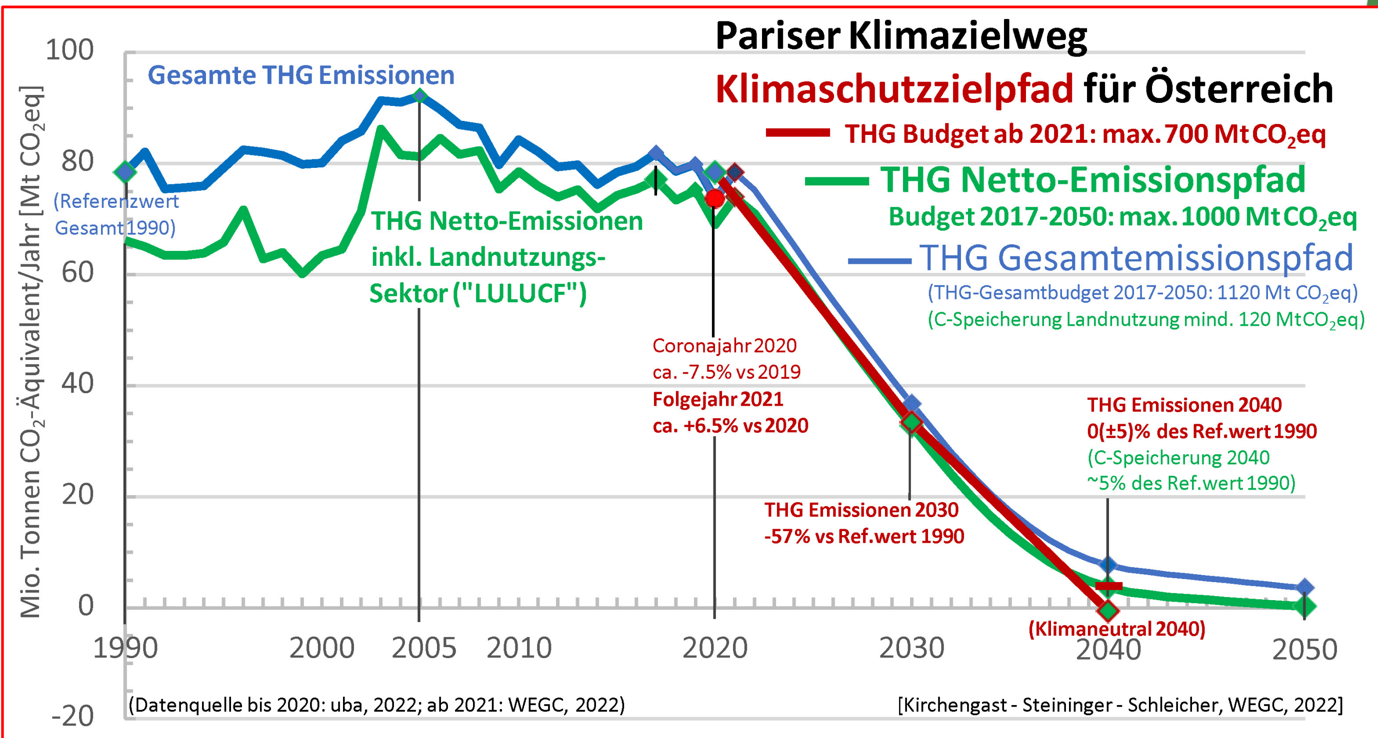


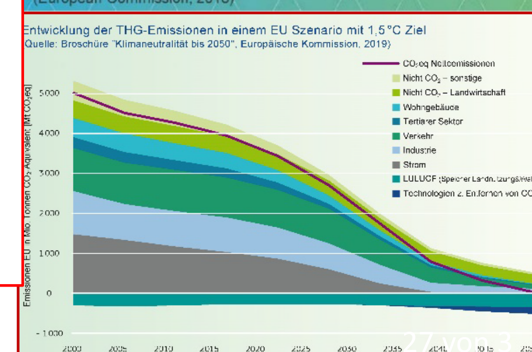


(IPCC-AR6-WGIII 2022, Fig. SPM.5)

[*Note:* Kirchengast et al., WEGC, 2023: such carbon budget-based 'paths2Paris' are part of GCCIv2 in gcci.earth/gem]

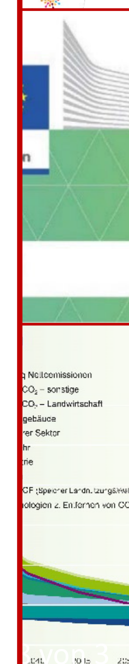
Go for the Action–example country Austria: Which reduction targets here? *A 1.5°C-oriented max.1000 $MtCO_2eq$ 2017-2050 budget requires GHG emissions reductions of more than 55% until 2030 and over 90% to be achieved near 2040, in accordance with the European Green Deal climate goals…*

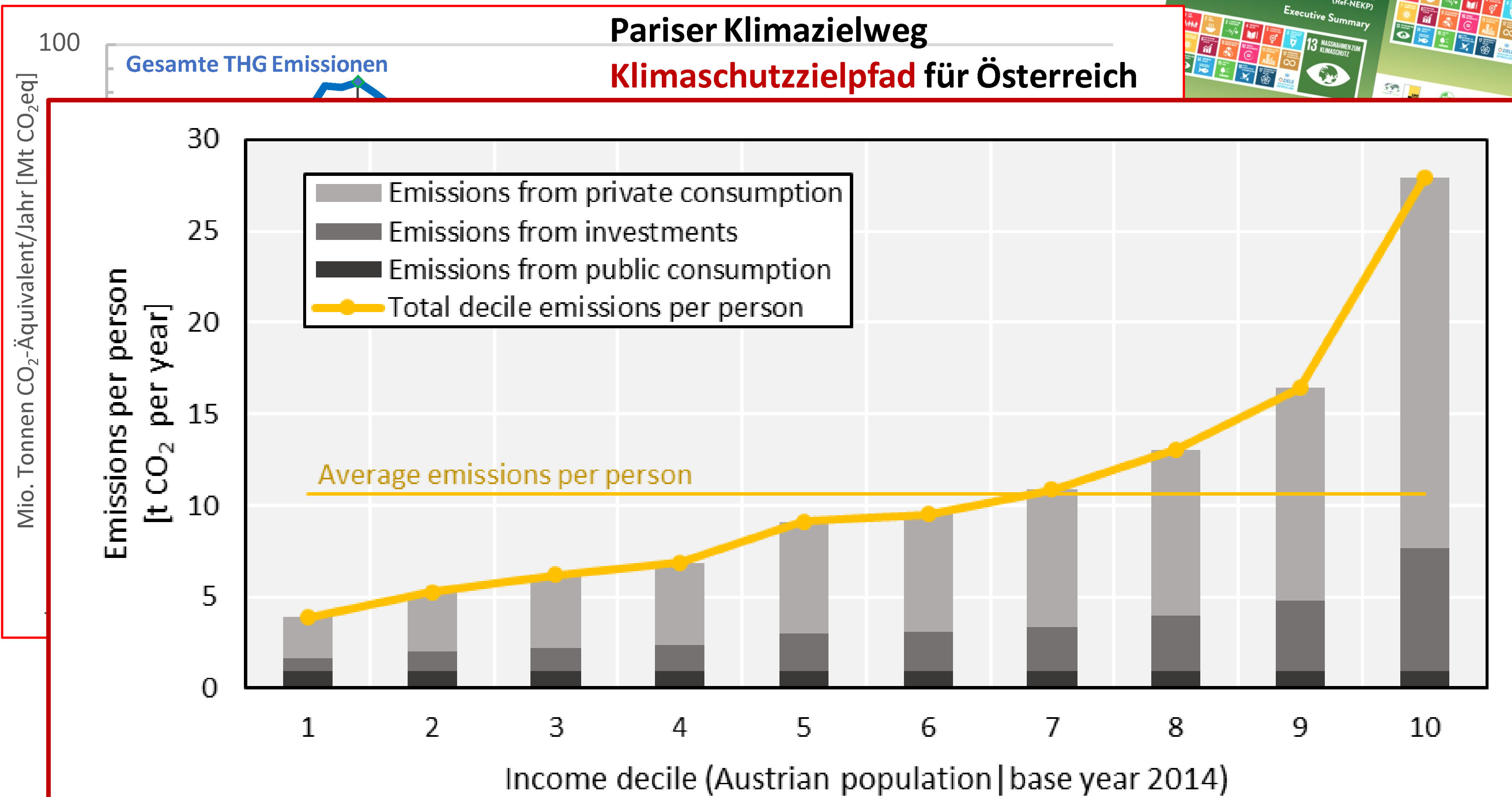




[Kirchengast et al., Ref-NEKP, 2019; online via ccca.ac.at/refnekp; Kirchengast-Steininger THG statement online via wegcenter.uni-graz.at/downloads/2022]
(Kirchengast et al. WEGC RB1-2021; online via carbmanage.earth, direct-link https://doi.org/10.25364/23.2021.1)

Go for the Action–example country Austria: Which reduction targets here? *A 1.5°C-oriented max.1000 $MtCO_2eq$ 2017-2050 budget requires GHG emissions reductions of more than 55% until 2030 and over 90% to be achieved near 2040, in accordance with the European Green Deal climate goals…*





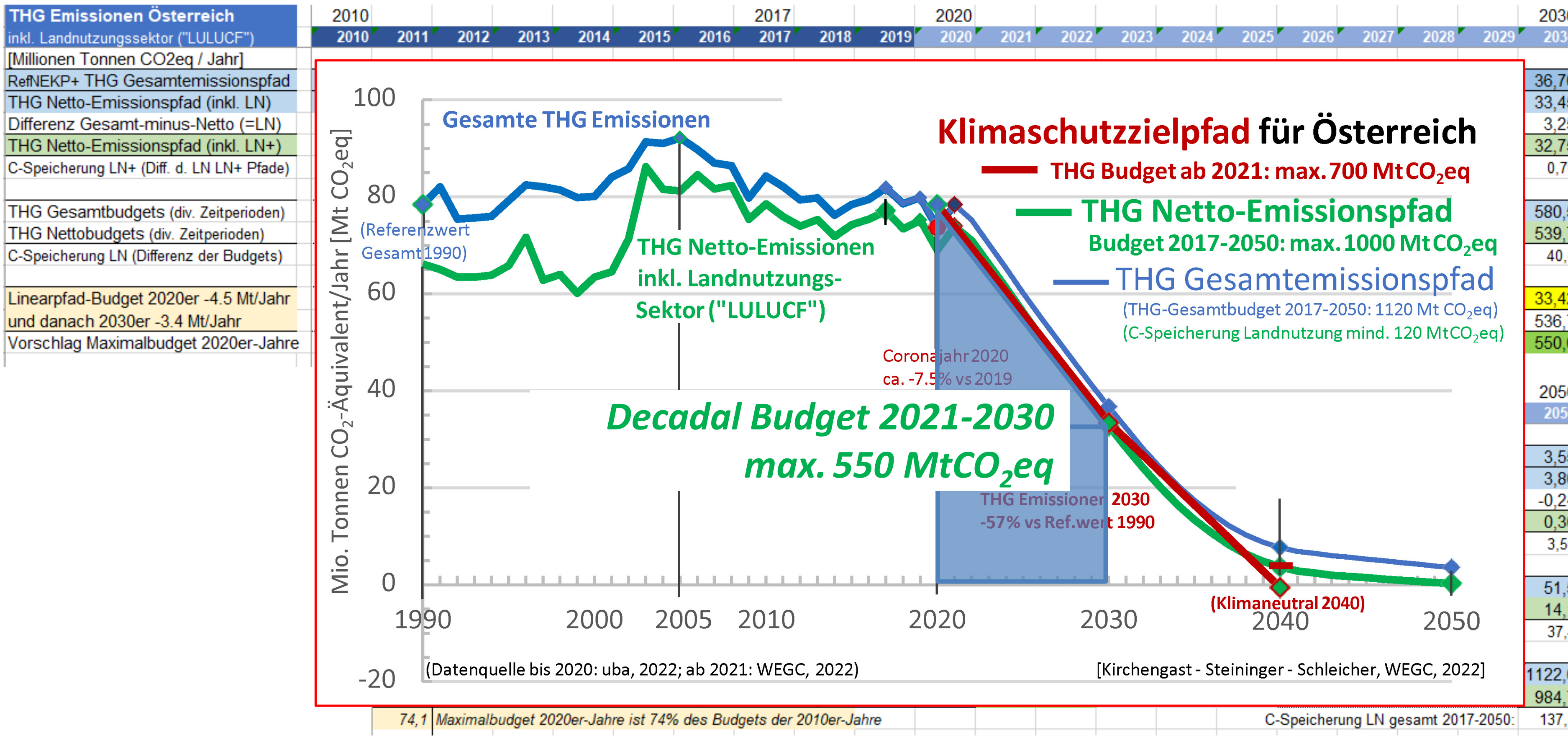
(Nabernegg et al., WEGC SciRep 100-2023|upcoming Oct.2023; adapted)

[*Note:* Kirchengast et al., WEGC, 2023: such socio-econ data will become part of GCCI in gcci.earth/gem and beyond]

What can support effective Action in Austria and any other country?

Carbon Management (CM) at all public and private action levels

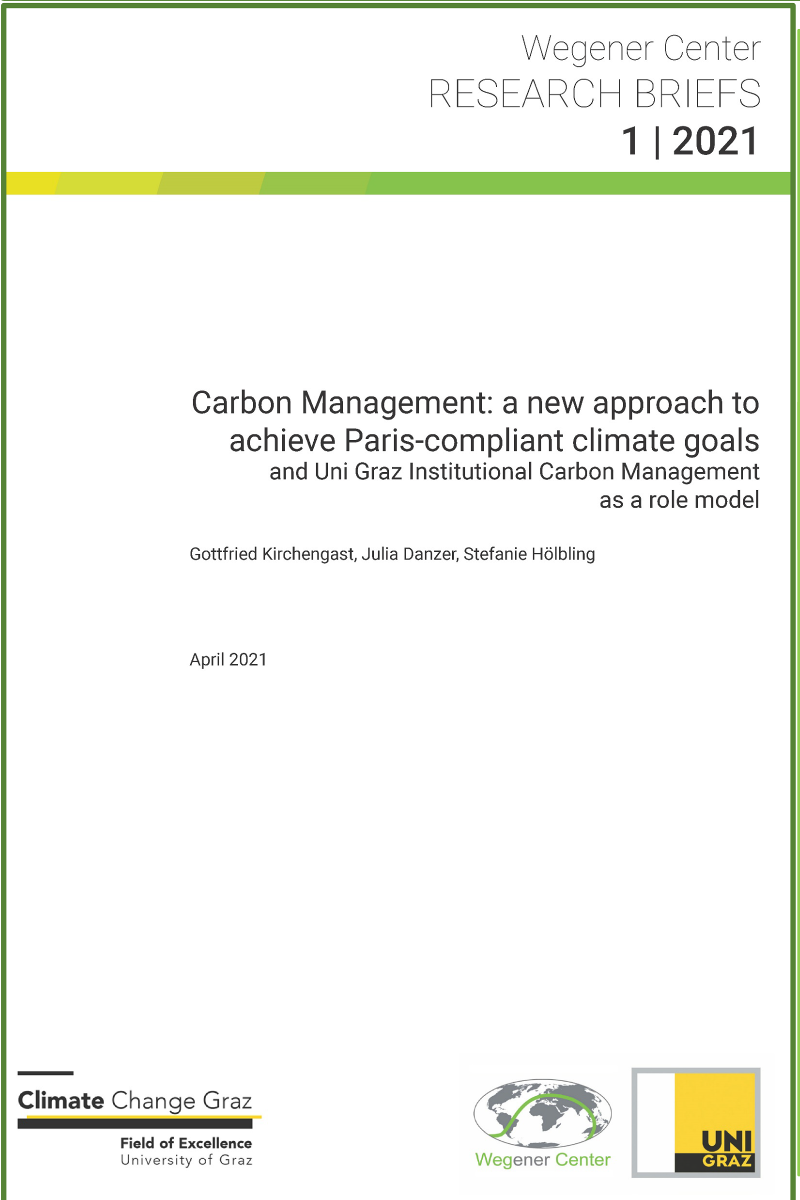
The 1000 $MtCO_2eq$ AT total leads to manage a decadal 2021-2030 budget of max. 550 $MtCO_2eq$ => reduction by at least 57% in 2030 (vs Ref.2020)



[Kirchengast-Steininger, WEGC, 2022; statement on THG budget at wegcenter.uni-graz.at/downloads/2022]

(Kirchengast et al. WEGC RB1-2021; online via carbmanage.earth, direct-link https://doi.org/10.25364/23.2021.1)

Carbon Management – *a new solution framework to help meet the Paris challenge*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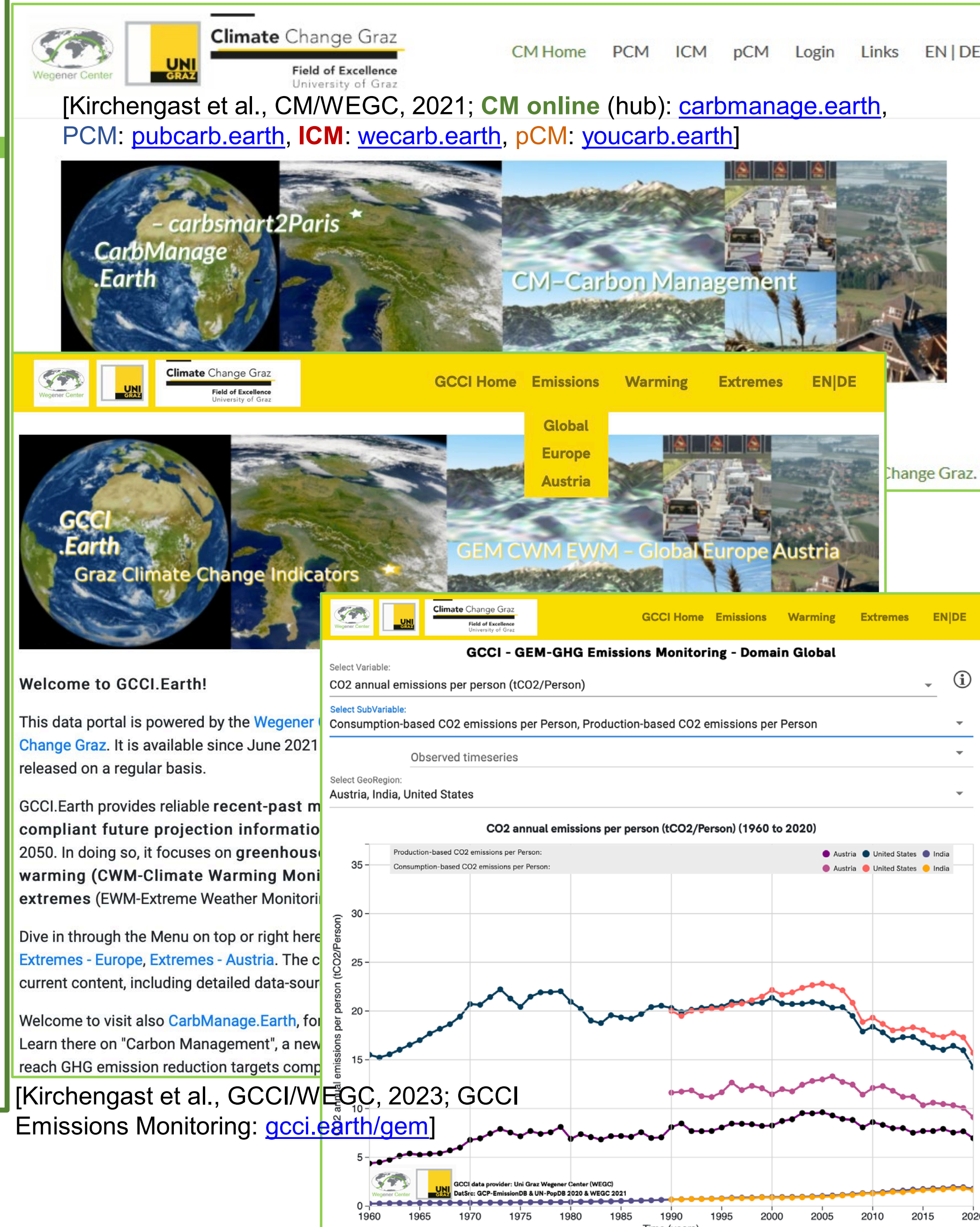
Carbon Management: a new approach to achieve Paris-compliant climate goals
and Uni Graz Institutional Carbon Management as a role model

Gottfried Kirchengast, Julia Danzer, Stefanie Hölbling

April 2021

Climate Change Graz
Field of Excellence
University of Graz
Wegener Center
UNI GRAZ

[Kirchengast et al. WEGC RB1-2021; accessible online (including individual-sections access) via https://doi.org/10.25364/23.2021.1]



[Kirchengast et al., CM/WEGC, 2021; **CM online** (hub): carbmanage.earth, PCM: pubcarb.earth, **ICM**: wecarb.earth, pCM: youcarb.earth]

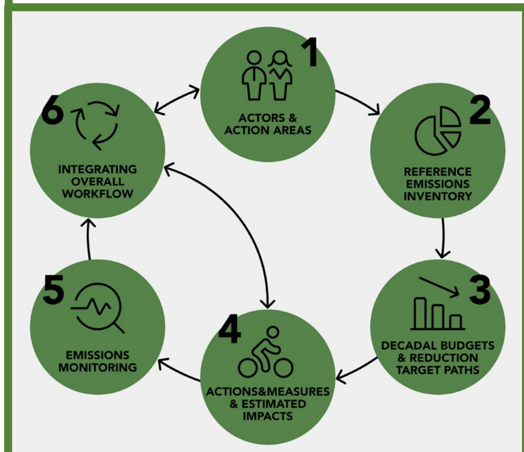
[Kirchengast et al., GCCI/WEGC, 2023; GCCI Emissions Monitoring: gcci.earth/gem]

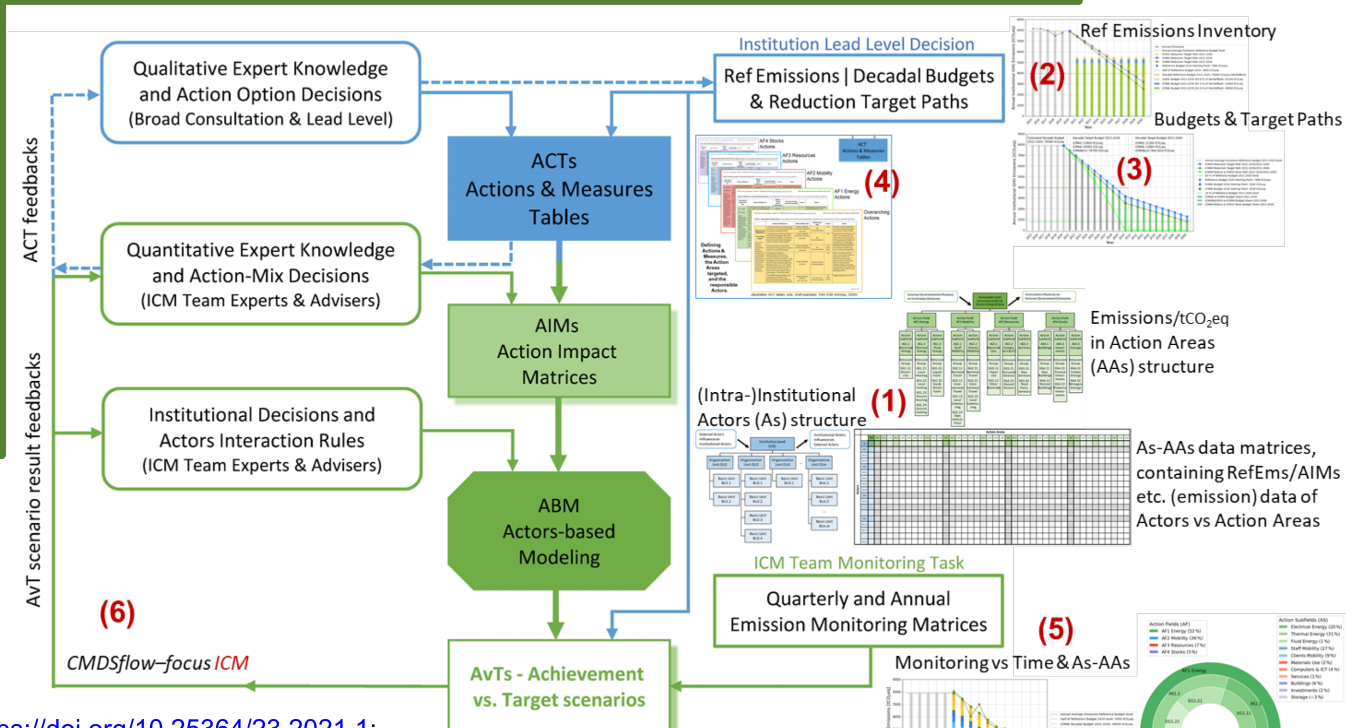
Carbon Management (CM) summary: intro explanations

The CM approach and overall Decision Support workflow (CMDSflow)

***Carbon Management** supports public and private entities to:*

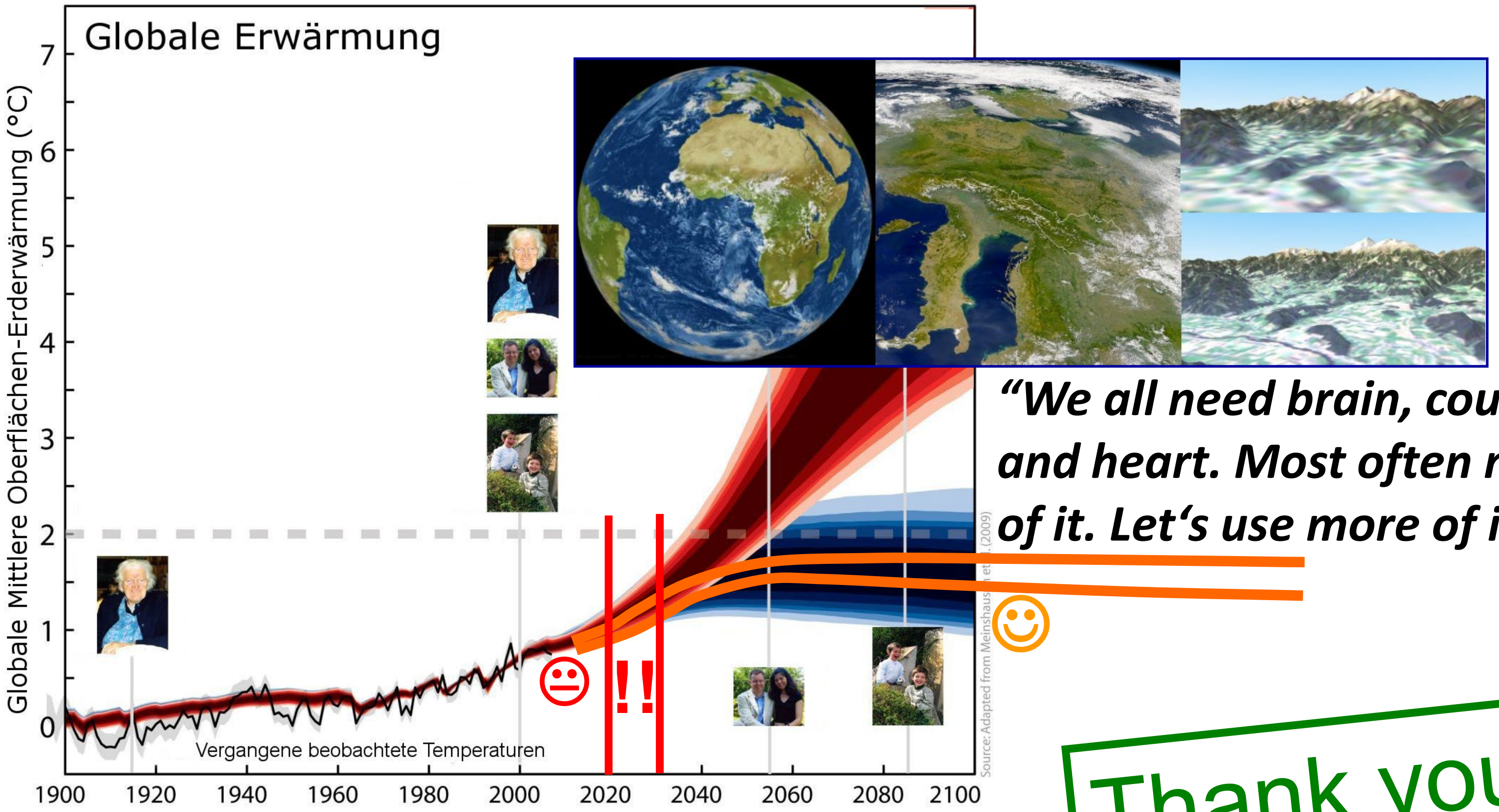
(1) Define Actors & Action Areas (countries, institutions, persons; GHG emission areas)
(2) Compute a Reference Emissions Inventory (serving as "Reference Emissions 2020")
(3) Adopt Decadal Budgets & Reduction Target Paths (setting goals to 2030 and 2040…)
(4) Prepare Actions & Measures and quantify their Estimated Impacts ("ACTs and AIMs")
(5) Set up and carry out Emissions Monitoring (tracks progress and underpins decisions)
(6) Implement an Integrating Overall Workflow (Decision Support Workflow - CMDSflow)





[Kirchengast et al. WEGC RB1-2021, link https://doi.org/10.25364/23.2021.1;
for brief overview intro see klimaneutral.uni-graz.at/carbon-management; direct-link (I)CM core intro RB1-2021 p.27-37]

=> FACT: Climate physics results provide strong climate change facts – hence it is time to act: reaching the Paris climate goals is essential!



"We all need brain, courage, and heart. Most often more of it. Let's use more of it!"

Thank you for your Attention! ☺