Supplementary material
Ten New Insights in Climate Science 2023

1. Process from ‘call for input’ to ‘10 New Insights’

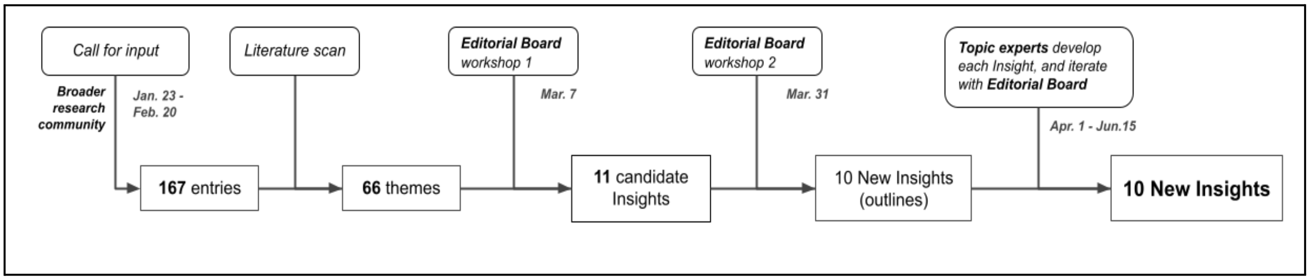

Figure SM1. Flow process and timeline from opening of the ‘call for input’ to final version of the 10 Insights

2. Questionnaire - ‘call for input’

(in separate pdf file)

3. Questionnaire respondents, brief characterisation

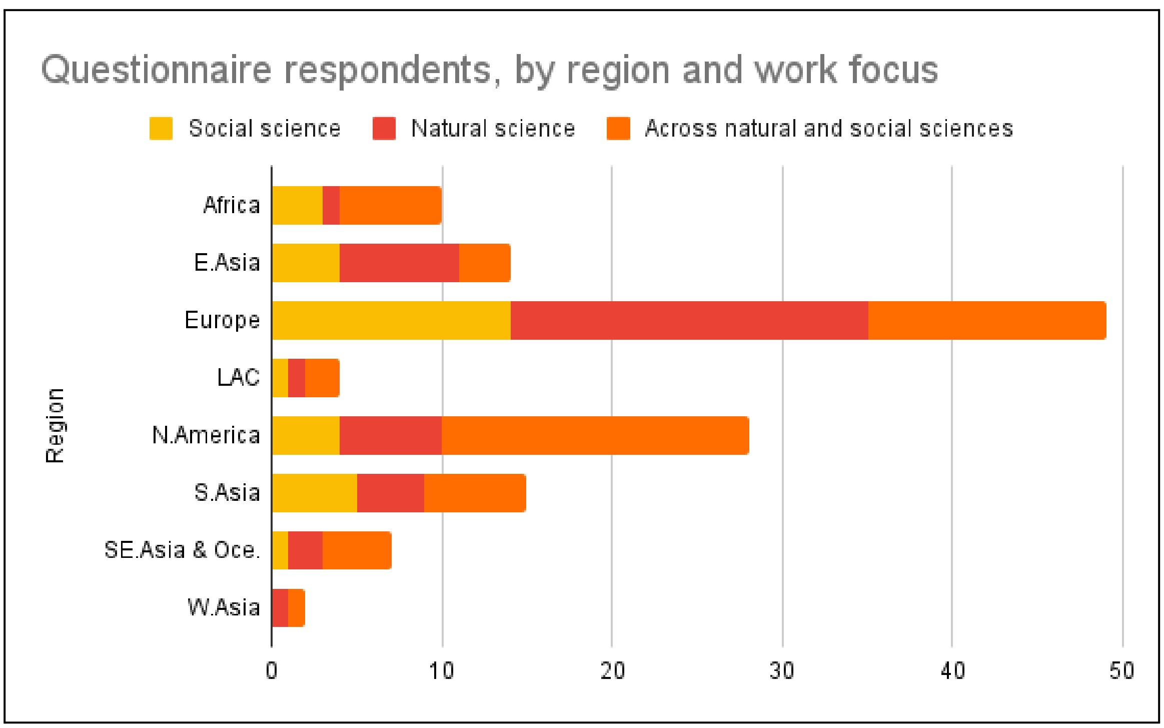

Figure SM2. Respondents to the call for input (131), regional and work focus distribution

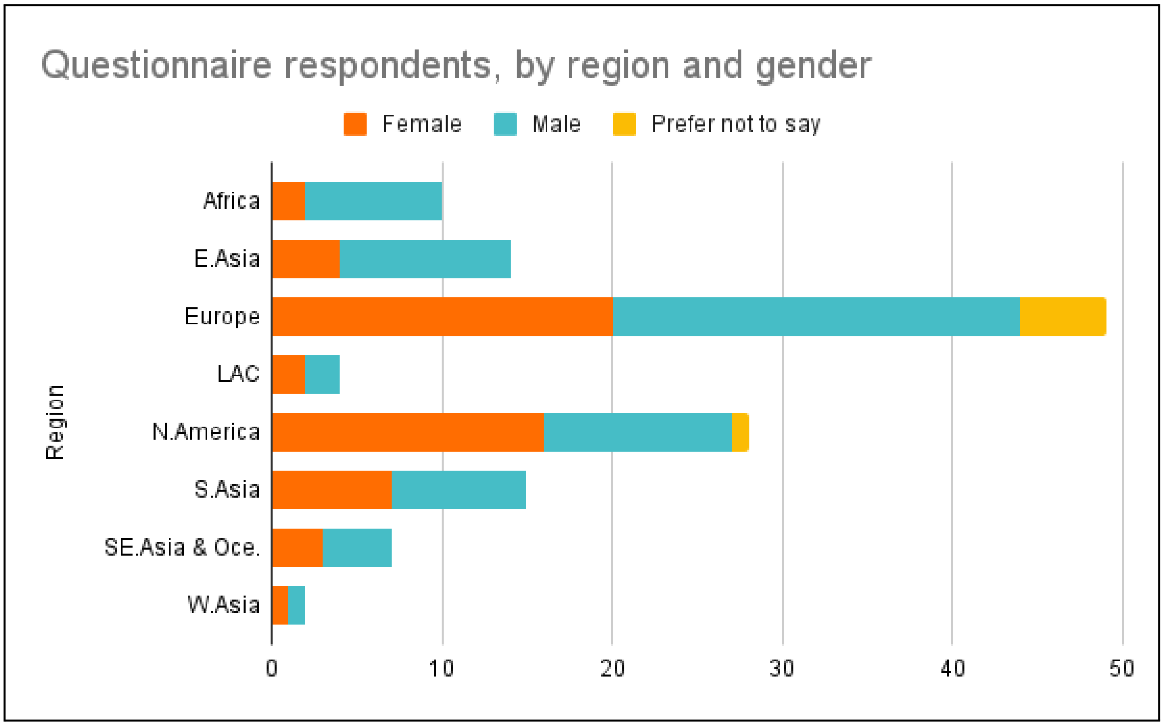

Figure SM3. Respondents to the call for input (131), regional and gender distribution

4. Ranking criteria for screening for entries from questionnaire

- Include - The entry describes a key message relevant to understanding or addressing climate change, and provides at least one recent (2022-2023) supporting reference.

- Exclude - The entry is not directly relevant to understanding or addressing **climate change**, or does not provide any credible supporting references.

- Unclear - The entry appears too broad (perhaps just a *topic*, rather than a potential Insight), or is not recent enough (no supporting reference from 2022 or 2023 is provided).

All entries were assessed by two team members, at least. Discrepancies were further discussed among reviewers to reach a final decision. When necessary project coordinators completed one additional round of screening and made a final decision.

5. Literature scan

The literature scan is intended to complement the results of the open 'call for input', mainly as a way to reduce the chance of missing on highly impactful recent publications; it is not a comprehensive literature review. Three main sources were used:

1) Web of Science Core Collection, using various generic search terms (such as "climate change", "global warming" "climate AND mitigation", "climate AND adaptation" "loss and damage") is the field tag Topic (which includes Title, Keywords, and Abstract), within the period

starting from 2022.01, and filtering with two ‘Essential Science Indicators’: ‘Highly cited papers’ and ‘Hot papers’.

2) Aggregators of science “news”, which compile press releases from universities and research institutes: EurekAlerT -Climate change and ScienceDaily - Climate.
3) Direct recommendations from the Editorial Board and the researchers from the team.

6. Emergent themes from the open call and the literature scan

THE EARTH SYSTEM

Status and trends

1. Overshooting +1.5°C - committed warming, consequences, and reversibility
2. Arctic heating is happening even faster
3. Permafrost release slower than expected
4. Over 25% of glacial mass will disappear (nearly 50% of glaciers by number)

Earth system stability

5. Climate tipping elements beyond +1.5°C
6. Amazon nearing a tipping point
7. Boreal forest transition, even under modest climate change

Climate-Biosphere interactions

8. Potential destabilisation of the coupled carbon–climate system
9. Doubling of gross tropical forest carbon loss (due to forest loss)
10. Loss of and weakened land and ocean carbon sinks
11. The global effect of CO_2 fertilisation might have been overestimated

IMPACTS

Health

12. Rising toll of heat stress on human health
13. Climate change increases pathogenic disease risks
14. Climate trauma and psychological resilience in climate-vulnerable communities

Food/Nutrition and water stress

15. Projected rise in food prices driven by climate change
16. Multiple problems with freshwater resources under climate change

Biodiversity loss

17. Impacts on biodiversity might be irreversible beyond +1.5°C
18. Climate change effects on species sex determination

Socioeconomic vulnerability and loss

19. Climate change reduces global economic growth

20. Compound climate risks and social vulnerability
21. Trapped populations (involuntary immobility)

Extreme weather

22. Self-enhancing wildfire regimes under climate change
23. Attribution science is essential for L&D, adaptation funding, and litigation
24. Increase in unprecedented extreme events and the challenge for risk management

Sea-level rise

25. Sea-level rise committed from ice sheet loss

Oceans

26. Under BAU warming marine systems are likely to experience mass extinctions
27. Marine heatwaves, ocean acidification extremes, and species sensitivity

Forests

(Themes 6 and 7, above)

Glaciers

28. Glacial lake outbursts puts millions of people at risk

ACTION NEEDED AND BARRIERS

Trends and projections: needed action

29. Realisation of Paris Agreement Pledges May Limit Warming Just below 2°C
30. Rates of coal reduction needed for +1.5°C have to be faster than commonly understood
31. GHG emissions from nitrogen fertilisers could be reduce by up to one-fifth by 2050
32. Prospects for mitigation of methane emissions in oil and gas production and agriculture

Corporate actions

33. Speculation-monitoring systems for emissions allowance markets
34. Top 10 financial actors on the fossil fuel economy
35. 'Renewable energy certificates' not delivering
36. D. Emerging technologies can accelerate ESG reporting

Cities

37. Transformations needed in urban construction sector
38. Scenarios of GHG emissions from global cities to 2100 - key regions and implications

Nature-based solutions and wet/land management

39. Rewetting global wetlands has enormous potential for reducing greenhouse gas emissions
40. Global carbon sink potential of terrestrial vegetation can be increased substantially by optimal land management
41. Evidence of synergies between nature-based solutions and health outcomes

42. Afforestation can affect agricultural markets and food security much more than other land-based mitigation measures
43. Temporary nature-based carbon storage can lower peak warming
44. Benefits of “Blue Carbon” are Uncertain/Unreliable, with questionable climatic cost-effectiveness

Carbon management (CCS, CDR, DAC)

45. Gap between proposed and needed CDR to meet Paris goal
46. Alternative allocation methods for setting national quotas for CDR yield vastly different outcomes - challenges for agreement and trade-offs

Other policy measures

47. Carbon pricing is a critical component of policy packages to meet the mid-century net zero target
48. Factors shaping the sociopolitical feasibility of fossil fuel subsidy reforms
49. Early decommissioning of fossil fuel infrastructure is necessary to meet Paris target
50. Climate geoengineering - a risk-risk trade-offs
51. Social cost of carbon is unable to reflect the linkages between climate and economy
52. Post/De-growth perspectives should inform mitigation policies

Co-Benefits

53. Evidence that climate solutions can boost socioeconomic development
54. Demand-side solutions also tend to improve well-being
55. Co-benefits of clean air policies for future of Arctic

Adaptation/Resilience-building

56. Climate Resilient Development Pathways based on ‘adaptation rationales’ (monitoring and evaluation)

Transformations

57. Roadmap for achieving net-zero emissions in global food systems by 2050
58. Organic agriculture is climate-smart, it should be better funded

Justice / Inequality

59. Reducing global poverty without overshooting implies a reduction in inequality (economic and carbon)
60. ‘Adaptation justice’ - Connecting climate justice and adaptation planning

Political feasibility and social movements

61. Youth inclusion means more climate action, more just
62. For climate communication to be impactful it has to be tailored

Climate diplomacy

63. Towards a funding mechanism for L&D - lessons and challenges
64. An intergovernmental body for ocean sustainability is needed to tackle climate change impacts

Litigation

65. The EU Corporate Sustainability Due Diligence Proposal as guide for a broader legal framework for accountability

New proposed topic: New techniques to inform policy decisions

66. Artificial intelligence in climate change research and action - risks and opportunities

We received over 170 entries (from 131 respondents) to our open ‘call for input’. These were classified into 42 specific *themes* (in 21 broad *topics*). This initial list was complemented with a literature scan which led to the addition of 24 distinct *themes* and 7 *themes* that overlapped with those from the call for input. The themes identified through scanning of the literature were classified in 13 of topics used to organise the call for input entries, and 4 additional topics. Of the final 10 Insights highlighted this year, 5 stem from themes identified both from the call for input and the literature scan, 4 stem exclusively from the call for input, and 1 stems exclusively from the literature scan.

7. Additional supporting literature on CDR methods

The list below refers to the CDSR methods listed in Figure 3 that are not described in IPCC WG3 report (2022, Chapter 12):

Bio-oil sequestration:

- Schmidt, H. P., Anca‐Couce, A., Hagemann, N., Werner, C., Gerten, D., Lucht, W., & Kammann, C. (2019). Pyrogenic carbon capture and storage. Gcb Bioenergy, 11(4), 573-591. https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.12553

Direct Ocean Removal:

- Digdaya, I. A., Sullivan, I., Lin, M., Han, L., Cheng, W. H., Atwater, H. A., & Xiang, C. (2020). A direct coupled electrochemical system for capture and conversion of CO2 from oceanwater. *Nature communications*, *11*(1), 4412. https://www.nature.com/articles/s41467-020-18232-y
- Kim, S., Nitzsche, M. P., Rufer, S. B., Lake, J. R., Varanasi, K. K., & Hatton, T. A. (2023). Asymmetric chloride-mediated electrochemical process for CO 2 removal from oceanwater. *Energy & Environmental Science*, *16*(5), 2030-2044. https://pubs.rsc.org/en/Content/ArticleLanding/2023/EE/D2EE03804H

Terrestrial biomass burial:

- Yablonovitch, E., & Deckman, H. W. (2023). Scalable, economical, and stable sequestration of agricultural fixed carbon. *Proceedings of the National Academy of Sciences*, *120*(16), e2217695120. https://www.pnas.org/doi/full/10.1073/pnas.2217695120

- Zeng, N. (2008). Carbon sequestration via wood burial. *Carbon Balance and Management*, *3*, 1-12. https://cbmjournal.biomedcentral.com/articles/10.1186/1750-0680-3-1
- Zeng, N., & Hausmann, H. (2022). Wood Vault: remove atmospheric CO2 with trees, store wood for carbon sequestration for now and as biomass, bioenergy and carbon reserve for the future. *Carbon Balance and Management*, *17*(1), 2. https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-022-00202-0

Terrestrial biomass sinking:

- Strand, S. E., & Benford, G. (2009). Ocean sequestration of crop residue carbon: recycling fossil fuel carbon back to deep sediments. https://pubs.acs.org/doi/10.1021/es8015556
- Raven, M. R., Young, I., Allen, C., Girard, Z., & Crotteau, M. (2022, December). Anoxic Marine Storage of Terrestrial Biomass: Mechanisms and Monitoring Approaches as Informed by the Geologic Record. In *AGU Fall Meeting Abstracts* (Vol. 2022, pp. B25F-1604). https://ui.adsabs.harvard.edu/abs/2022AGUFM.B25F1604R/abstract
- Gomez-Saez, G. V., Dittmar, T., Holtappels, M., Pohlabeln, A. M., Lichtschlag, A., Schnetger, B., ... & Niggemann, J. (2021). Sulfurization of dissolved organic matter in the anoxic water column of the Black Sea. *Science Advances*, *7*(25), eabf6199. https://www.science.org/doi/10.1126/sciadv.abf6199

Marine biomass sinking:

- Wu, J., Keller, D. P., & Oschlies, A. (2023). Carbon dioxide removal via macroalgae open-ocean mariculture and sinking: an earth system modeling study. *Earth System Dynamics*, *14*(1), 185-221. https://esd.copernicus.org/articles/14/185/2023/
- Krause-Jensen, D., & Duarte, C. M. (2016). Substantial role of macroalgae in marine carbon sequestration. *Nature Geoscience*, *9*(10), 737-742. https://www.nature.com/articles/ngeo2790
- Krause-Jensen, D., Lavery, P., Serrano, O., Marbà, N., Masque, P., & Duarte, C. M. (2018). Sequestration of macroalgal carbon: the elephant in the Blue Carbon room. *Biology letters*, *14*(6), 20180236. https://royalsocietypublishing.org/doi/10.1098/rsbl.2018.0236