February 28, 2022
Contact: gustaf.hugelius@natgeo.su.se
+46 70 797 29 52

Global Stocktake Submission: "Country" of Permafrost

Submission from Stockholm University, Sweden.

Supported by the International Cryopshere Climate Initiative, the Bolin Centre for Climate Research, the Woodwell Climate Research Centre and the Permafrost Carbon Network.

The above-named Observer and supporting institutions appreciate the opportunity to raise, for Parties and the Co-chairs, an essential missing element in the Global Stocktake (GST) process on progress towards fulfilment of the Paris Agreement goals: the need to include estimated permafrost emissions in assessing said progress. Current and future permafrost emissions have clear implications for needed emissions reductions to 2100, as well as the need for negative emissions once anthropogenic carbon neutrality is achieved. These emissions estimates, which are dependent on global mean temperature rise, should be taken into account in any valid Stocktake process. The submitting Observer and supporting organisations offer to arrange presentations or other inputs to the GST process to address this omission.

Background

Permafrost is ground that remains frozen through the year. It underlies 15% of the Northern Hemisphere land area, primarily Arctic tundra and taiga forest; it also affects many high mountain regions globally, with the largest extent in the Tibetan Plateau. Permafrost holds large amounts of organic carbon formed over tens of thousands of years. Observations confirm that permafrost is rapidly warming, and releasing part of that thawed carbon into the atmosphere as both carbon dioxide (CO_2) and methane (CH_4). **Significantly for GST purposes, thawed permafrost can continue emitting carbon into the atmosphere for centuries.**

Unlike direct emissions from human activity, **permafrost emissions are regulated almost entirely by global mean temperature levels**, but cannot be considered fully "natural" as they are a direct consequence of rising temperatures caused by anthropogenic emissions. Permafrost thaw is projected to add as much greenhouse gas forcing as a large current emitter, depending on just how much the planet warms.

Today, at approximately 1.2°C of warming above pre-industrial (WMO, 2021), permafrost emissions are about the same as Japan's annually, 0.3-0.6 Pg per year (NOAA, 2019). This scale of emissions should be considered a minimum estimate of emissions from the "Country of Permafrost" for at least the next century. Some members of the scientific community believe even this to be an under-estimate, due to improvements in understanding of abrupt permafrost thaw events (primarily involving rapid land subsidence, lake formation and impacts of wildfires on tundra and permafrost forest emissions).

At today's 1.2°C, we are already committed to losing about 25% of pre-industrial surface permafrost. Scientists anticipate that 40% of permafrost area will be lost, even if we hold temperatures close to 1.5°C globally. Over 70% of the pre-industrial surface permafrost will thaw should temperatures exceed 4°C.

Emissions Estimates and Related Adaptation Needs

Projected permafrost emissions under scenarios of Very Low and Low Emissions (SSP1-1.8 and SSP2-2.6) would equal carbon emissions of around 200 (range **100-400) Gt eCO_2[*] by 2100**. Surface permafrost will largely disappear below the Arctic Circle, and from nearly all mountain regions globally, with extensive infrastructure damage in the Arctic and Tibetan Plateau.

Should temperatures reach between 2-3°C in 2100 (SSP3), permafrost thaw will add carbon dioxide and methane emissions totaling around 300 (**150-600) Gt eCO_2 by 2100**. Permafrost soils will disappear in extensive regions above the Arctic Circle, as well as below, and nearly all existing infrastructure built on vulnerable permafrost soils will require repair or replacement. In adaptation terms, extensive coastal and riverine erosion due to permafrost thaw, sea ice-free conditions and more violent storms will require extensive replacement of coastal and riverside Arctic infrastructure, especially in Russia, Canada and the U.S. state of Alaska.

These permafrost emissions will continue for one–two centuries, approximately doubling the cumulative 2100 carbon emissions by 2300. Over time permafrost emissions would cease, assuming stabilized global temperature. However, this does mean that subsequent generations, until approximately 2300 and perhaps beyond, will need to implement and continue carbon dioxide removal strategies equal to these long-term permafrost emissions until they cease, in order to hold temperatures steady.

Conclusion

Although there remains uncertainty regarding the scale of emissions, these are not dissimilar to the uncertainty levels surrounding reported emissions from national entities. Measurement of emissions through both remote satellite observation, and on-the-ground monitoring sites continue to improve in both scale, and accuracy. It is the opinion of this Submission therefore that estimates are sufficiently accurate to be include in this GST process, with a mind towards improving this estimate in future Stocktake rounds. The submitting Observers, perhaps in

---

[**] CO_2-e) -- carbon emissions coming from permafrost as both CO_2 and methane, with their climate forcing converted to the same impacts that would come from these emissions as CO_2 alone.

Stockholm University

concert with the IPCC, would welcome the opportunity to present the scientific basis of these estimates at future GST technical meetings and dialogues, and/or to organize special sessions together with the Secretariat and IPCC AR6 authors at the upcoming SB meetings in June.

These finding also have relevance for the Second Periodic Review, as the means to reduce emissions is to keep as much permafrost soil as possible in its current frozen state, holding global temperature increases to 1.5°C, which also minimizes negative emissions efforts required by future generations. This will greatly decrease the amount of additional carbon entering the atmosphere from permafrost thaw, and minimize the long-term burden of negative emissions laid on future generations.

References

Chadburn, S., Burke, E., Cox, P., Friedlingstein, G., & Westermann, S. (2017). An observation-based constraint on permafrost loss as a function of global warming. Nature Climate Change, 340–344. https://doi.org/10.1038/nclimate3262

Comyn-Platt, E., Hayman, G., Huntingford, C., Chardburn, S., Burke, E., Harper, A., . . . Sitch, S. (2018). Carbon budgets for 1.5 and 2 °C targets lowered by natural wetland and permafrost feedbacks. Nature Geoscience, 11, pages 568–573. https://doi.org/10.1038/s41561-018-0174-9

de Vrese, P., & Brovkin, V. (2021). Timescales of the permafrost carbon cycle and legacy effects of temperature overshoot scenarios. Nature Communications. https://doi.org/10.1038/s41467-021-23010-5

Gasser, T., Kechiar, M., Ciais, P., Burke, E., Kleinen, T., Zhu, D., . . . Obersteiner , M. (2018). Path-dependent reductions in CO2 emission budgets caused by permafrost carbon release. Nature Geoscience, 830-835. https://doi.org/10.1038/s41561-018-0227-0

Hugelius, G., Loisel, J., Chadburn, S., Jackson, R., Jones, M., MacDonald, G., . . . Yu, Z. (2020). Large stocks of peatland carbon and nitrogen are vulnerable to permafrost thaw. Proceedings of the National Academy of Sciences of the United States of America, 20438-20446. https://doi.org/10.1073/pnas.1916387117

Hugelius, G., Strauss, J., Zubrzycki, S., Harden, J., Schuur, E., Ping, C.-L., . . . Kuhry, P. (2014). Estimated stocks of circumpolar permafrost carbon with quantified uncertainty ranges and identified data gaps. Biogeosciences, 6573–6593. https://doi.org/10.5194/bg-11-6573-2014

IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty[V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R.Shukla,A. Pirani, W. Moufouma-Okia, C.Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield(eds.)].

IPCC, 2019: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)].

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

Juhls, B., Antonova, S., Angelopoulos, M., Bobrov, N., Grigoriev, M., Langer, M., . . . Overduin, P. (2021). Serpentine (Floating) Ice Channels and their Interaction with Riverbed Permafrost in the Lena River Delta, Russia. Frontiers in Earth Science. https://doi.org/10.3389/feart.2021.689941

Lawrence, D., Slater, A., & Swenson, S. (2012). Simulation of Present-Day and Future Permafrost and Seasonally Frozen Ground Conditions in CCSM4. Journal of Climate, 2207–2225. https://doi.org/10.1175/JCLI-D-11-00334.1

Li, H., Väliranta, M., Mäki, M., Kohl, L., Sannel, A., Pumpanen, J., . . . Bianchi, F. (2020). Overlooked organic vapor emissions from thawing Arctic permafrost. Environmental Research Letters. https://doi.org/10.1088/1748-9326/abb62d

MacDougall, A., Avis, C., & Weaver, A. (2012). Significant contribution to climate warming from the permafrost carbon feedback. Nature Geoscience, 719–721. https://doi.org/10.1038/ngeo1573

McCarty, J., Smith, T., & Turetsky, M. (2020). Arctic fires re-emerging. Nature Geoscience. https://doi.org/10.1038/s41561-020-00645-5

Natali, S., Holdren, J., Rogers, B., Treharne, R., Duffy, P., Pomerance, R., & MacDonald, E. (2021). Permafrost carbon feedbacks threaten global climate goals. Proceedings of the National Academy of the United States of America. https://doi.org/10.1073/pnas.2100163118

Obu, J. (2021). How Much of the Earth's Surface is Underlain by Permafrost? Journal of Geophysical Research Earth Surface. https://doi.org/10.1029/2021JF006123

Stockholm University

Richter-Menge, J et al (2019). Arctic Report Card 2019. https://arctic.noaa.gov/Portals/7/ArcticReportCard/Documents/ArcticReportCard_full_report2019.pdf

Romanovsky, V., Isaksen, K., Anisimov, O., & Drozdov, D. (2017). Changing permafrost and its impacts. In AMAP, Snow, Water, Ice and Permafrost in the Arctic (SWIPA) (pp. 65-102).

Sayedi, S., Abbott, B., Thornton, B., Frederick, J., Vonk, J., Overduin, P., . . . Demidov, N. (2020). Subsea permafrost carbon stocks and climate change sensitivity estimated by expert assessment. Environmental Research Letters. https://doi.org/10.1088/1748-9326/abcc29

Schädel, C., Bader, M.-F., Schuur, E., Biasi, C., Bracho, R., Čapek, P., . . . Wickland, K. (2016). Potential carbon emissions dominated by carbon dioxide from thawed permafrost soils. Nature Climate Change, 950–953. https://doi.org/10.1038/nclimate3054

Schaefer, K., Lantuit, H., Romanovsky, V., Schuur, E., & Witt, R. (2014). The impact of the permafrost carbon feedback on global climate. Environmental Research Letters. https://doi.org/10.1088/1748-9326/9/8/085003

Schneider von Deimling, T., Lee, H., Ingeman-Nielsen, T., Westermann, S., Romanovsky, V., Lamoureux, S., . . . Langer, M. (2021). Consequences of permafrost degradation for Arctic infrastructure – bridging the model gap between regional and engineering scales. The Cryosphere, 2451–2471. https://doi.org/10.5194/tc-15-2451-2021

Schuur, E., McGuire, A., Schädel, C., Grosse, G., Harden, J., Hayes, D., . . . Vonk, J. (2015). Climate change and the permafrost carbon feedback. Nature, 171–179. https://doi.org/10.1038/nature14338

Turetsky, M., Abbot, B., Jones, M., Anthony, K., Olefeldt, D., Schuur, E., . . . McGuire, A. (2020). Carbon release through abrupt permafrost thaw. Nature Geoscience, 138–143. https://doi.org/10.1038/s41561-019-0526-0

Turetsky, M., Abbott, B., Jones, M., Anthony, K., Olefeldt, D., Schuur, E., . . . Sannel, A. (2019). Permafrost collapse is accelerating carbon release. Nature. http://doi.org/10.1038/d41586-019-01313-4

Zhuang, Q., Melillo, J., Sarofim, M., Kicklighter, D., McGuire, A., Felzer, B., . . . Hu, S. (2006). CO_2 and CH_4 exchanges between land ecosystems and the atmosphere in northern high latitudes over the 21st century. Geophysical Research Letters. https://doi.org/10.1029/2006GL026972