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## Attribution of irreversible loss to anthropogenic climate change

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The Paris Agreement (2015) under the UNFCCC has anchored loss and damage in a separate article which specifies that understanding and support should be enhanced in areas addressing loss and damage such as early warning, preparedness, insurance and resilience. Irreversible loss is a special category under loss and damage but there is still missing clarity over what irreversible loss actually includes.

Many negative impacts of climate change may be handled or mitigated by existing risk management, reduction and absorption approaches. Irreversible loss, however, is thought to be insufficiently addressed by risk management. Therefore, countries potentially or actually affected by irreversible loss are calling for other measures such as compensation, which however is highly contested in international climate policy. In Paris (2015) a decision was adopted that loss and damage as defined in the respective article of the agreement does not involve compensation and liability.

Nevertheless, it is likely that some sort of mechanism will eventually need to come into play for irreversible loss due to anthropogenic climate change, which might involve compensation, other forms of non-monetary reparation, or transformation. Furthermore, climate litigation has increasingly been attempted to address negative effects of climate change. In this context, attribution is important to understand the drivers of change, what counts as irreversible loss due to climate change, and, possibly, who or what is responsible.

Here we approach this issue by applying a detection and attribution perspective on irreversible loss. We first analyze detected climate change impacts as assessed in the IPCC Fifth Assessment Report. We distinguish between irreversible loss in physical, biological and human systems, and accordingly identify the following candidates of irreversible loss in these systems: loss of glaciers and ice sheets, loss of subsurface ice (permafrost) and related loss of lake systems; loss of land area due to coastal and hillslope erosion and sea level change; loss of plant and animal species, loss of ecosystems and biodiversity; loss of human lives, homelands, and cultural identity.

Attribution to anthropogenic climate change is analyzed based on recent progress following from the IPCC AR5. Generally, high confidence in attributing irreversible loss to anthropogenic climate change is found in physical systems and more specifically in cryosphere environments, both in mountain and polar regions. Detected loss in terrestrial ecosystems has typically low confidence in attribution whereas loss in some ocean ecosystems (corals) has high confidence. Impacts in human systems that may be classified as irreversible loss are of low confidence in terms of attribution except for the Arctic where higher confidence for a relation with anthropogenic emissions was found.

Our analysis suggests that scientific progress in detection and attribution is now at a level that would likely allow policy, or courts, to define mechanisms, or take decisions, as related to irreversible loss in many cryosphere systems. On the other hand, policy may need to consider that at least in the near future it will be difficult to establish clear tracks between irreversible loss in most human systems and anthropogenic climate change, a domain, which however is at the forefront of discussions. We end our discussion with setting out ideas for further clarification of different categories of irreversible loss, including in human systems, and the role of attribution in any policy or legal mechanism in order to help in the development of just and sensible solutions.