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Climatic triggers for peatland initiation

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Peatlands are carbon-dense wetlands characterised by waterlogged, organic-rich soils. Modern-day peatlands have formed mainly since the Last Glacial Maximum (LGM), and despite covering only 3 % of the Earth's land surface are thought to store more than a third of all global soil carbon in the form of poorly decomposed plant detritus. Concern exists that this globally important carbon store may be vulnerable to near-future warming and changes in precipitation patterns, although the links between peatland development and climate are contested. The climatic and other environmental conditions that facilitate the initiation of peat are particularly poorly understood. We present the results of a novel, global study into the climate space of peat initiation since the LGM. We compiled a catalogue of radiocarbon dates of peat initiation from 942 sites that span a range of latitudes and biomes. We used the locations and ages of these peatlands to interrogate downscaled climate hindcasts at 500-yr intervals from a coupled atmosphere-ocean-vegetation general circulation model, HadCM3. This powerful combination of modelling and observational data provides a globally-consistent, temporally-extensive estimate of the climate spaces of peat initiation. In particular, it allows us to identify local and regional climatic changes that may have acted as triggers for peat formation. Peatlands in mid- and high-latitudes of both hemispheres, particularly in maritime locations, developed shortly after local increases in the time integral of growing season temperatures, and were seemingly not influenced by rainfall regime. Peat initiation at such sites appears to have been stimulated by temperature-driven increases in plant productivity in cold, postglacial landscapes, and was not water limited. The exception is the large peatland complex of the Western Siberian Lowlands, which was not glaciated during the last glacial period, and which appears to have been prompted instead by a strong increase in effective precipitation, leading to extensive paludification. Peat initiation in the tropics appears only weakly related to climate, suggesting that other environmental factors such as drainage network evolution and relative sea level change due to tectonic subsidence were more important there. Our model-data fusion also provides valuable context for projected future climate change. In particular, projected temperature increases for the 21^{st} Century, even under modest emissions scenarios, far exceed those experienced by current peatland locations during the course of peat development, and therefore seem likely to exceed these ecosystems' capacities for resistance and resilience.