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Characterization of Edge States as Gateway to a Collapse of the Atlantic Ocean Circulation

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There is growing concern that various large-scale elements of the Earth system may undergo catastrophic transitions under future climate change. But already at present-day conditions there is a risk of spontaneous transitions to an undesired state induced by stochastic fluctuations, given that any of those elements occupy a multi-stable regime. For many climate sub-systems this potential present-day multi-stability is still uncertain. For instance, it cannot be ruled out that there is a regime of a collapsed Atlantic Meridional Overturning Circulation (AMOC) that is stable under present-day conditions. Assuming such an undesired stable state exists, there also exists an additional unstable state called the edge state. This state anchors the basin boundary separating the desired and undesired regimes, and it lies at the heart of the path taken by the system during a noise-induced transition between the two stable states.

In this work such an edge state lying between the stable regimes of a vigorous and a collapsed AMOC is computed for the first time in a global ocean model using an edge tracking algorithm. The physical characteristics that set this state apart from the usually observed stable regimes are analyzed. This can be useful to detect if a spontaneous collapse of the AMOC induced by stochastic climate variability is underway, or to detect so-called rate-induced tipping. It may be especially helpful if the system is close to the tipping point where the desired state loses stability. Here the desired stable state and the edge state become increasingly similar, but a transition towards the undesired state may nevertheless be detected early-on if specific signatures of the edge state are recognized.