Beitrag ID: **3** Typ: **Oral**

Disentangling North Atlantic ocean-atmosphere coupling using circulation analogues

Donnerstag, 11. April 2024 12:20 (20 Minuten)

The coupled nature of the ocean-atmosphere system frequently makes understanding the direction of causality difficult in ocean-atmosphere interactions. This study presents a method to decompose turbulent heat fluxes into a component which is directly forced by atmospheric circulation, and a residual which is assumed to be primarily 'ocean-forced'. This method is applied to the North Atlantic in a 500-year pre-industrial control run using the Met Office's HadGEM3-GC3.1-MM model. The method shows that atmospheric circulation dominates interannual to multidecadal heat flux variability in the Labrador Sea, in contrast to the Gulf Stream where the Ocean primarily drives the variability. An empirical orthogonal function analysis identifies several residual heat flux modes associated with variations in ocean circulation. The first of these modes is characterised by the ocean warming the atmosphere along the Gulf Stream and North Atlantic Current and the second by a dipole of cooling in the western subtropical North Atlantic and warming in the sub-polar North Atlantic. Lead-lag regression analysis suggests that atmospheric circulation anomalies in prior years partly drive the ocean heat flux modes, however there is only a weak atmospheric circulation response in years following the peaks of the modes. Overall, the heat flux dynamical decomposition method provides a useful way to separate the effects of the ocean and atmosphere on heat flux and could be applied to other ocean basins and to either models or reanalysis datasets.

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Sitzung Einordnung: Conference