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Identifying the atmospheric and oceanic contribution to Arctic amplification due to remote sulfate aerosol changes

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Changes in regional European aerosol emissions can have an important role in modifying Arctic climate. Acosta et al (2016) used the Norwegian Earth system model (NorESM) to show that the reduction in sulfate emissions from Europe probably modified the rate of Arctic warming since the 1980s. However, the mechanisms that drove this response were unclear. Specifically, the contribution of changes in ocean heat convergence (OHC) versus those driven by changes through the atmosphere to Arctic warming is poorly understood. Here, we address this question by analyzing a series of idealized simulations. We compare a control case where sulfate aerosol emissions from Europe are taken as year 2000 values with a modified case where sulfur emissions are 7 times higher compared to the control (7xEU). We use both fully coupled ocean-atmosphere simulations and simulations with a mixed-layer ocean where OHC values are specified. To distinguish the role played by the atmosphere and the ocean, we use NorESM in the mixed-layer ocean mode to determine changes when either the atmosphere (with sulfate aerosol changed to reflect 7xEU, but ocean heat transport set to year 2000) or the ocean (ocean heat transport reflecting 7xEU, and year 2000 atmosphere) is modified. Simulations with modified atmospheric heat transport show large changes in Arctic surface temperature, while simulations with modified ocean heat transport show little or no change in Arctic temperatures. This indicates that most of the temperature changes at the Arctic are driven through the atmosphere, or by atmospheric-related processes. Further analysis indicate that the temperature response is clearly modulated by changes in sea-ice extent, mostly between the 60º-70ºN latitudes. Taken together, these results indicate an important link (in NorESM) between changes in anthropogenic aerosol emissions, atmospheric heat transport, the sea-ice extent and the Arctic amplification. We discuss these results within the framework of Arctic energy transport and radiation budgets. This allows us to provide mechanistic explanations for the remote impact of European aerosol emissions on the Arctic.