Zhicong Xie

Spatial-temporal responses of Arctic amplification to carbon-concentration and carbon-climate feedbacks in CMIP6 simulations

The Arctic is experiencing a phenomenon called Arctic amplification (AA) which has caused a rapid warming rate two to three times greater than that of the Northern Hemisphere (NH) or global in both observed and modelled data over the past few decades. Previous studies focused mostly on temperature and sea ice albedo feedbacks; however, the impacts of biosphere feedbacks especially from carbon cycle feedbacks, are largely underexplored. In this study, different coupling experiments simulated by 11 Earth system models (ESMs) were used to assess the spatial and temporal changes of AA, as well as to identify potential causes related to carbon cycle feedbacks.

The results show that in the model experiments considering two carbon cycle feedbacks (carbon-climate, related to the responses to the changes of temperature, and carbon-concentration, caused by the changes of atmospheric CO_2 concentration) and considering only carbon-climate feedback, the speed of warming in the Arctic is ~2 times faster than the NH over the whole simulated period. AA is notable in the Arctic Ocean and maintains a consistent spatial pattern over the experiment period under aforementioned experiments. By contrast, the experiment only considering carbon-concentration feedback shows stronger but fluctuating AA index, ranging from 1 to 4 (the mean value is 2.5), and its primary manifestation was found in the Barents Sea. The interaction between the two carbon cycle feedbacks intensified the increase in temperature and sea ice melting and mitigated the reduction of evapotranspiration (ET) caused by the response of plants to CO_2 forcing (CO_2 physiological effect). In addition, heat from decreased ET at lower latitudes may be transported to higher latitudes, accelerating sea ice melting, and thereby exacerbating AA.

While the CMIP6 models generally agree on the long-term temperature trends as well as the changes in sea ice area and ET, they exhibit greater uncertainties at high latitudes and in the experiment that quantifies the carbon-concentration feedback. This highlights the need to constrain CO_2 physiological effects in ESMs to facilitate an accurate evaluation of AA and the effects of carbon cycle feedbacks.

Keywords: Geography, Physical Geography, Ecosystem Analysis, Arctic amplification, Carbon cycle feedbacks, CO2 physiological effect, CMIP6

Advisors: Wenxin Zhang and Hans Chen
Master degree project 30 credits in Physical Geography and Ecosystem Science, 2023
Department of Physical Geography and Ecosystem Science, Lund University. Student thesis series INES nr 609