Geophysical Research Abstracts
Vol. 21, EGU2019-1916-1, 2019
EGU General Assembly 2019

The local nature of the water cycle associated with marine cold air outbreaks

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Marine cold air outbreaks (CAOs) are the dominant weather systems injecting moisture into the mid- and high latitude atmosphere - yet their role in the water cycle is not well understood. We present here a numerical process study of an intense, basin-scale CAO in the Nordic Seas. To that end, we perform simulations with the limited area weather prediction model COSMO at resolutions from coarse to convection resolving. Using tagged water tracers transported within a secondary water cycle built into the model, we follow the moisture that evaporates into the CAO air mass from evaporation to precipitation.

Based on these simulations we characterize the water cycle associated with the CAO. Specifically, we show that the CAO is associated with a net injection of moisture of about 7% of the hemispheric mid- to high latitude water content. Thus, we analyse the footprint of the CAO in surface evaporation and precipitation, as well as moisture pathways. Most importantly, we show that the CAO is associated with a highly local water cycle where rapid turnover leads to a residence time of water vapour on the order of only one day. These characteristics of the water cycle are in strong contrast to that of other weather systems that are associated with the long-range transport of moisture, such as frontal systems.

The close linkage of CAO formation and the storm track as well as the important contribution of CAOs to the mid- to high latitude moisture budget suggest that CAOs may be an important contributor of latent energy to the diabatic intensification of individual storms. The local nature of the water cycle during CAOs and the decoupling of a cyclone‘s cold sector from the dynamical ascent regions in its warm sector question, however, to what extent this can be effective. As we demonstrate, the tagging approach provides a promising avenue in addressing this specific question and, more generally, in pinpointing the role of CAOs in the energy budget of a storm track.