Popular science abstract

Thunderstorms and their accompanying phenomena such as heavy precipitation with flash flooding, damaging wind gusts, large hail and tornadoes pose a significant hazard to communities, infrastructure and various sectors of the economy. Across Europe and the United States alone, around 30 billion USD in damage has been reported each year over the last decade. Reports and observations of storms are strongly related to the population density. The local nature of convective events causes their significant underestimation over sparsely populated areas. The available remote sensing data (meteorological radars, lightning detection networks) have still too short operating periods, and their uneven detection efficiency and biases makes it impossible to create reliable estimates of storm hazards on a global scale. However, such opportunities are possible within the so-called meteorological reanalyses, which are multi-year numerical simulations based on assimilation of historical data. With their use, it is possible to model the frequency of atmospheric conditions that lead to dangerous thunderstorm hazards.

The main goal of the project is to use global data from ECMWF ERA5, NOAA 20CR and NASA MERRA2 meteorological reanalyses over a period of over 70 years, and assess the impact of the observed globally warming climate on the occurrence of thunderstorms and their accompanying hazards. Additionally, global rawinsonde measurements will be used to assess the reliability of each of aforementioned reanalyses. In order to better evaluate, which atmospheric environments are conducive to the formation of specific storm hazards, we will use the so-called machine learning techniques. These algorithms will be numerically trained to properly identify storm environments on a set of over 1 million severe weather reports (large hail, tornadoes, severe wind gusts) and over 1 billion lightning detections from databases across Europe, United States and Australia. Significant emphasis will be placed on the aspect of storm development (convective initiation) and environmental variables that significantly limit this process (e.g. dry air in the middle troposphere). The models created in this way will be applied on previously developed global reanalysis databases and will allow for a better estimation of long-term changes in atmospheric conditions conducive to severe thunderstorms and the role of global climate warming in this process.

Research on convective climatologies has been so far conducted mainly on a regional basis, and almost none considered historical changes on the global scale. Initial studies in Europe and the United States have shown that the increase in temperature, although it affects the increase in low-level moisture, does not necessarily result in an increasing frequency and intensity of thunderstorms. Changes in the atmospheric components leading to increases in convective inhibition play a much greater role in modeling thunderstorm climatologies than it was previously expected.

This project will result in the development of a global thunderstorm climatology and an assessment of the relationship between globally warming climate and the changing risk of convective hazards across various regions of the world. The developed machine learning models will have a possibility to be applied in climate projections and operational forecasting of thunderstorms. In addition, comparison of rawinsonde observations with reanalyses will allow to assess credibility of the latter, which can be a useful result for future studies using these reanalyses. The successful implementation of the project will contribute to the development of the current state of knowledge in the fields of mesoscale meteorology, climatology, risk assessment, climate change and numerical weather prediction.