

# Abstract

The climate has always been changing but the current speed under human influences greatly exceeds past warming events. This has consequences for thermodynamic and dynamic processes in the climate system and implications for the hydrological cycle. Extreme weather events, like heat waves and heavy rainfall, have increased in intensity and frequency in recent decades. Thermodynamic drivers behind changes in extremes are reasonably well understood but dynamic mechanisms much less so. There is an urgent need for an improved understanding of their relative importance. Successful adaptation strategies will strongly depend on better information on how climate variability and in particular extremes events will change in the future.

Extratropical storm tracks play a central role in understanding the Earth's climate and its variability. They are a major component of the large-scale atmospheric circulation and their position and strength account for much of the day-to-day weather variability in the mid-latitudes. Moreover, extreme rainfall is often associated with strong storm activity. However, changes in simulated extratropical storm activity still reveal large uncertainties and knowledge about their influence on weather extremes is limited. This thesis aims at improving the understanding of these processes. It is based on two different approaches including record-statistics of rainfall extremes and the analysis of the storm track activity.

First, I show that worldwide the number of record-breaking daily rainfall events from 1981 to 2010 is 12 % higher than expected in a stationary climate. The long-term increase has reached 26 % by 2010. I show that this increase is consistent with the thermodynamically expected increase in the atmosphere's water holding capacity. Regional changes in rainfall extremes differ markedly across the globe with a tendency of wet regions seeing an over proportional increase and dry regions less so. This pattern is also reflected at monthly timescales where my analyses reveal substantial drying over Central Africa and significant increases in observed record-wet months in tropical monsoon climates as well as in the northern mid- to high latitudes.

In the second part of my thesis I show that in the mid-latitudes such monthly rainfall extremes are strongly coupled to extratropical storm track activity as measured by the eddy kinetic energy (EKE). Moreover, EKE modulates continental temperatures, because storms bring relatively moist and moderate temperatures from the ocean to the continents. I show that summer EKE has declined over 1979-2014, which likely favors the buildup of heat and drought conditions over the continents. Likewise, cold spells in winter are associated with low EKE over parts of North America, Europe, and central- to eastern Asia.

The observed weakening of summer EKE is associated with a weakening of the zonal wind related to a reduction in the equator-to-pole temperature gradient. This gradient reduces due to Arctic amplification. Consistently, I show that climate models project a robust weakening in summer EKE for the 21st century under a high-emission scenario which will further increase the risk of prolonged heat and dry periods over mid-latitude land regions.