



Global Attribution of Precipitation to Weather Features – Present and Future Climate and the Role of Fronts for Extreme Precipitation

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Weather features, such as extratropical cyclones (ETCs), atmospheric rivers (ARs), and fronts, contribute to substantial amounts of precipitation globally. We introduce a robust attribution method applicable at all latitudes present the first global climatology of the contributions from extratropical cyclones (ETCs), fronts, moisture transport axes (MTAs; AR-like features), and cold air outbreaks, as well as their combinations, to summer and winter precipitation as well as extreme precipitation using ERA5 and 10 ensemble members of the CESM2-LE. For the present climate, most of the precipitation in the midlatitudes relates to the combination of ETC, fronts, and MTAs (28%), while in polar regions most precipitation occurs within the ETC-only category (27%). Extreme precipitation events in all extratropical regions are predominantly associated with the combination of ETCs, fronts, and MTAs (46%). In the midlatitudes, the combination of ETCs, fronts, and MTAs occurs almost 4 times as often during extreme events compared to regular events.

For the period 1960-2100 under the SSP3-7.0 scenario, we find that CESM2-LE adeptly represents the precipitation characteristics associated with the different combinations of weather features. The combinations of weather features that contribute most to precipitation in the present climate also contribute the most to future changes, both due to changes in intensity as well as frequency. While the increase in precipitation intensity dominates the overall response for total precipitation in the storm track regions, the precipitation intensity for the individual weather features does not necessarily change significantly. Instead, approximately half of the increase in precipitation intensity in the storm track regions can be attributed to a higher occurrence of the more intensely precipitating combinations of weather features, such as the co-occurrence of extratropical cyclones, fronts, and moisture transport axes.

Given that most of the extreme precipitation in the extratropics is associated with cyclones, fronts, and moisture transport axes, we also analyse the changes in precipitation characteristics associated with these weather features, as well as their combinations. We find that extreme precipitation associated with fronts increases substantially in the extratropics. Extreme precipitation associated with non-frontal conditions, on the other hand, does not increase and even decreases in some regions. Hence, atmospheric fronts are the main driver of future extreme precipitation changes in the extratropics.