EGU26-17246, updated on 07 Nov 2026
https://doi.org/10.5194/egusphere-egu26-17246
EGU General Assembly 2026
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Climate change modifies atmospheric river precipitation: a global storyline approach

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The intensification of the global water cycle under climate change is amplifying precipitation extremes, with disproportionate impacts on societies and ecosystems. Atmospheric rivers (ARs) are among the most important atmospheric drivers of extreme precipitation events, yet how climate change modifies AR-related precipitation remains poorly constrained, particularly at process level and for individual events.

Here we study the thermodynamic contribution to the intensification of AR precipitation by combining spectrally-nudged, kilometre-scale global storyline simulations (IFS-FESOM, 2017-2024) with a recently published state-of-the-arts AR catalogue (PIKART). The high spatial resolution of the simulations enables a physically interpretable attribution of precipitation changes to thermodynamic effects, while spectral nudging keeps large-scale circulation approximately fixed. This allows us to compare how AR precipitation unfolds under different levels of climate forcing. Precipitation responses are characterised using multiple complementary metrics, including total and extreme precipitation, precipitation rate, and spatial localizedness of precipitation.

We find an overall net intensification of AR-driven precipitation with almost global spatial extent (average intensification ~8%/K). The storyline framework further reveals the nature of precipitation changes at the event scale (where some events intensify by >20%/K), highlighting which ARs produce enhanced or reduced precipitation and through which mechanisms. To systematically assess these responses, ARs and precipitation are classified based on geometric properties and lifecycle characteristics (e.g. long- versus short-lived, oceanic versus inland-penetrating). I will present which constellations of AR/precipitation classes robustly produce more hazardous precipitation extremes.

This work represents one of the first global applications of a storyline approach focused explicitly on atmospheric rivers and provides a process-based perspective on how climate change modifies AR-driven precipitation extremes.