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Satellite-based Climate Data Records to explore the water cycle

INTRODUCTION

Satellite-based climate data records (CDRs) enable consistent, long-term monitoring of the global water cycle. Their stable and spatially continuous coverage overcomes limitations of sparse in-situ networks, allowing reliable analysis of key variables such as precipitation, water vapor and evapotranspiration. This makes them essential for tracking transboundary hydrological changes across scales and regions.

Atmospheric Rivers and Precipitation

Atmospheric rivers are narrow bands of moisture that can bring heavy precipitation. On 5 December 2015, Storm Desmond delivered exceptional rainfall to northwest England, northern Scotland, and parts of Ireland, largely driven by a powerful atmospheric river that transported vast amounts of moisture from the tropics into the mid-latitudes.

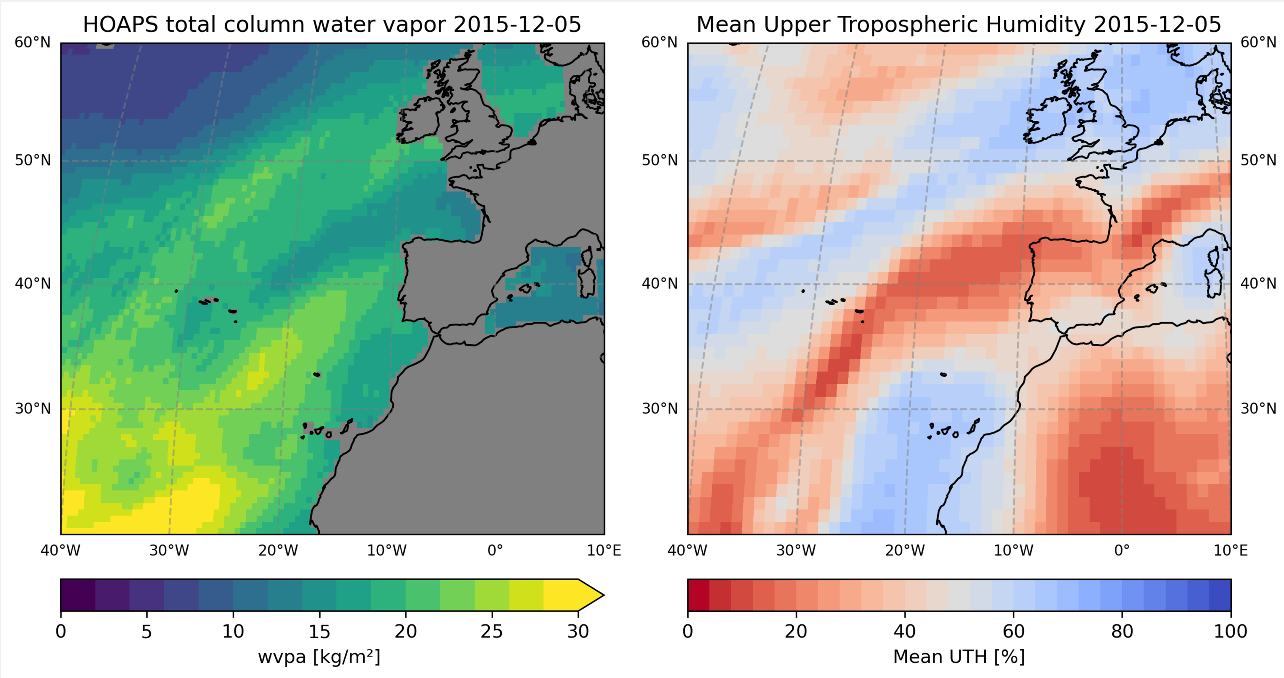


Figure 1: Atmospheric River visible in total column water vapor (HOAPS, left) and – in this case – upper tropospheric humidity (UTH, right) on 5 December 2015

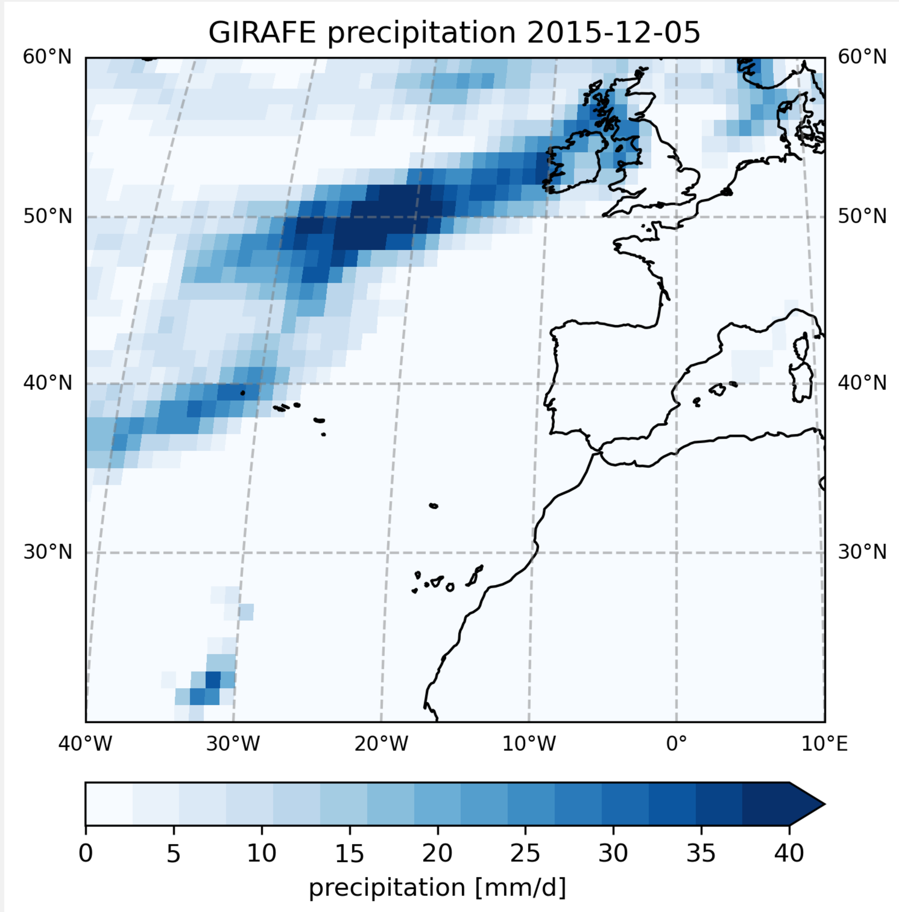


Figure 2: Precipitation on 5 December 2015, Storm Desmond

Anomalies of Precipitation and Evapotranspiration

Comparing anomalies of precipitation and evapotranspiration reveals important insights into ecosystem water balance. Positive anomalies in both indicate wetter-than-average conditions, promoting vegetation growth, while opposite anomalies may signal drought stress or water surplus. Such comparisons help to better understand regional hydrological changes and their impacts on agriculture and climate.

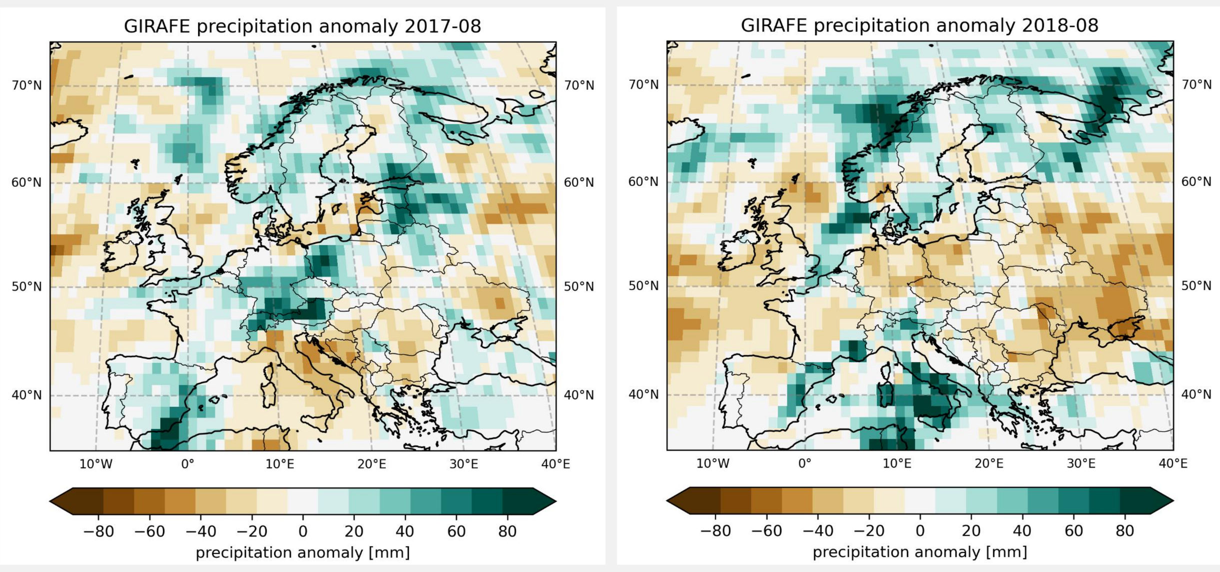


Figure 3: GIRAFE monthly precipitation anomalies. Left: August 2017. Right: August 2018

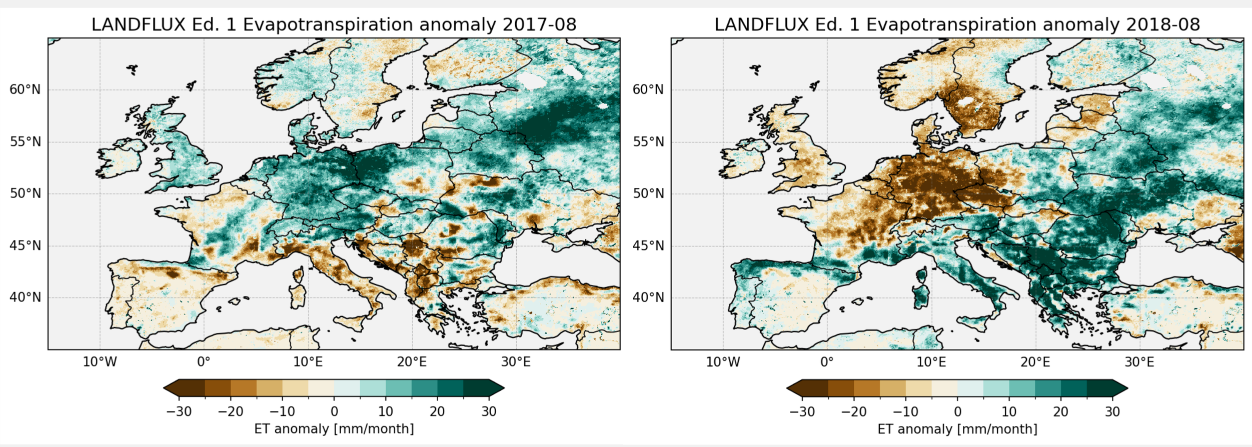


Figure 4: LANDFLUX evapotranspiration anomalies. Left: August 2017, right: August 2018

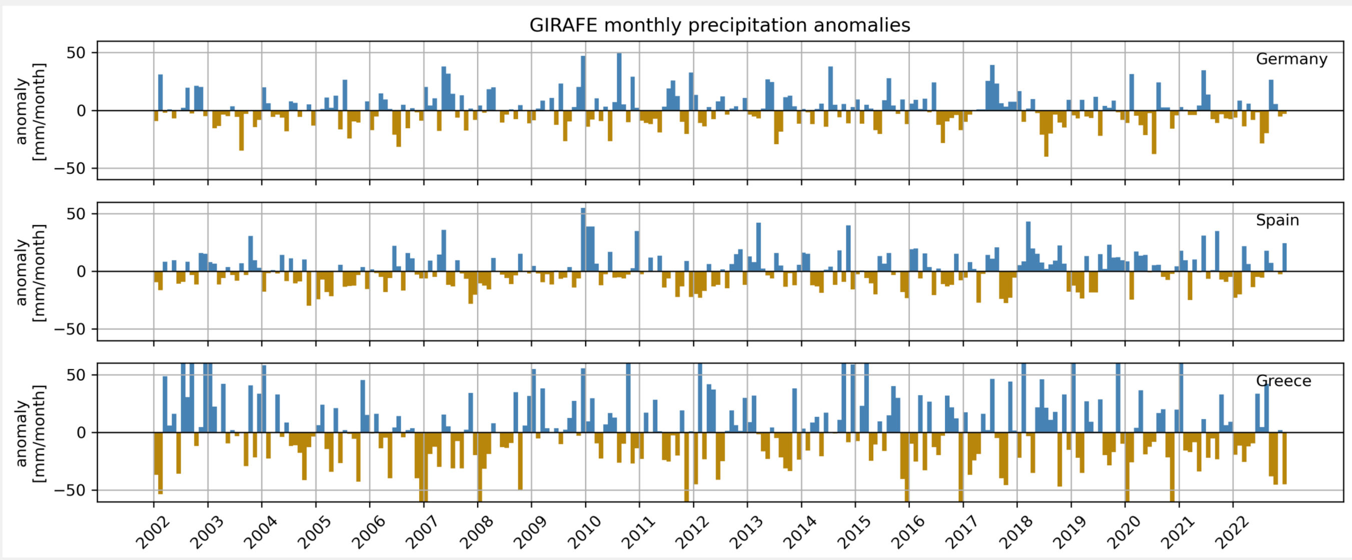


Figure 5: Timeseries of GIRAFE monthly precipitation anomalies of several Countries

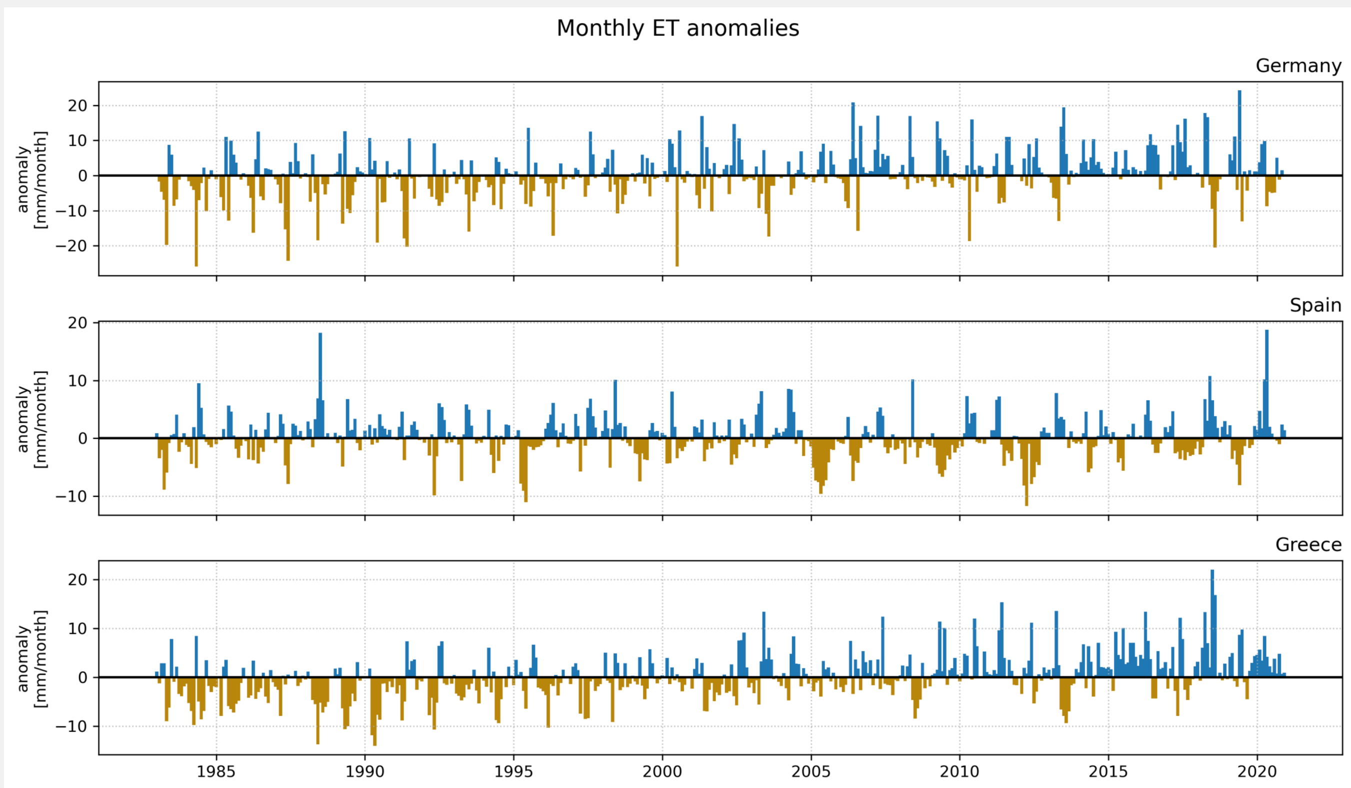


Figure 6: Timeseries of LANDFLUX monthly evapotranspiration anomalies of several Countries

Filling the Gaps in Ground-Based Measurements

Ground-based stations measure precipitation much more directly compared to satellite observations, but in regions with sparse station coverage, satellite observations provide valuable, consistent data to fill gaps.
Example (Figure 7): Precipitation event on 16 November 2019 (contributing to the 2019/20 Congo river floods). In relevant precipitation area no ground-based observation were available, so a station-based dataset like the Global Precipitation Climatology Centre (GPCC) dataset is „blind" to this event.

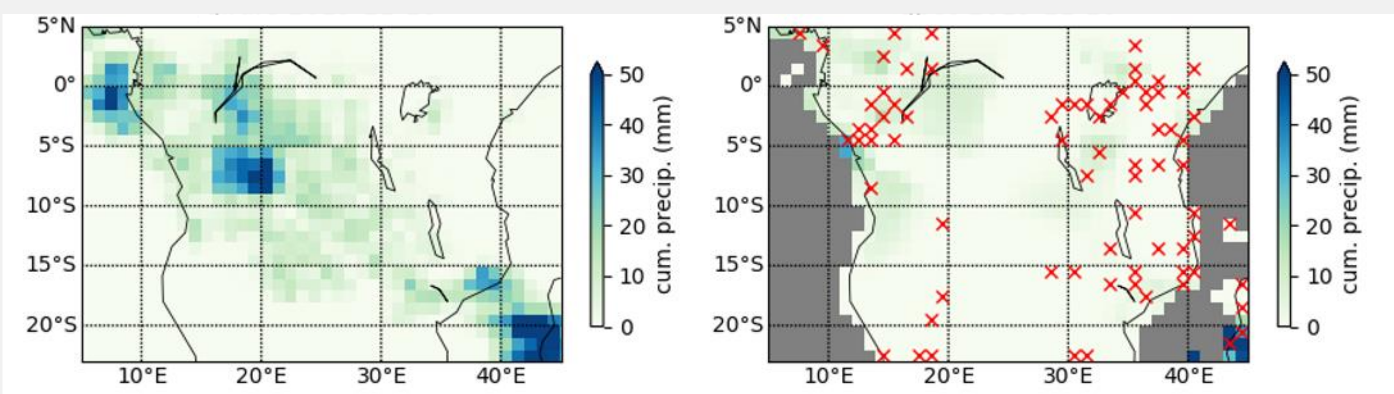
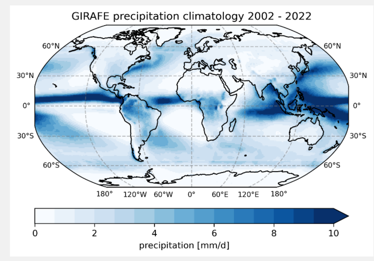


Figure 7: Precipitation on 16 Nov 2019. Left: GIRAFE (satellite-based). Right: GPCC v2022 (station-based). Red crosses mark GPCC station locations.

Dataset Overview

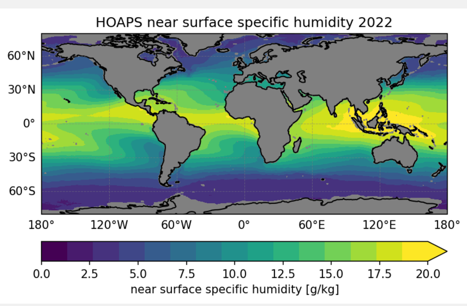
GIRAFE

Global Interpolated RAinfall Estimation
- Parameters: Precipitation and related daily sampling uncertainty
- Coverage: Global
- Temporal Coverage: 2002 - 2022
- Spatial Resolution: 1°
- Temp. Resolution: daily and monthly
- Continuous extension in preparation (release 2026)



HOAPS

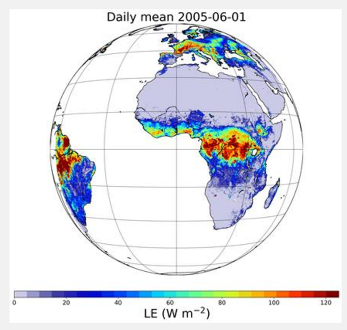
Hamburg Ocean Atmosphere Parameters and fluxes from Satellite data
- Parameters: Total column water vapor, wind speed, evaporation, freshwater budget, near surface specific humidity, latent heat flux, (liquid water path*)
- Coverage: Global ice-free oceans
- Temporal coverage: 1987-2014(2024*)
- Spatial Resolution: 0.5°
- Temporal Resolution: monthly and 6-hourly (hourly*) composites



*upcoming version: release 2026

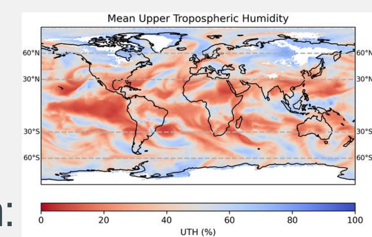
LANDFLUX

Surface Radiation and Fluxes from Meteosat First and Second Generation
- Coverage: Meteosat disk (60°N - 60°S, 60°E - 60°W)
- Parameters: Latent heat flux, evapotranspiration, sensible heat flux
- Temporal coverage: 1983 - 2020
- Spatial Resolution: 0.05°
- Temp. Resolution: hourly, daily, monthly



UTH

Passive Microwave Upper Tropospheric Humidity
- Coverage: Global
- Temp. Coverage: 1994 – 2018
- Spatial Resolution: 1°
- Temporal Resolution: hourly and daily



References

[1] Rustemeier Elke; Hänsel, Stephanie; Finger, Peter; Schneider, Udo; Ziese, Markus (2022): GPCC Climatology Version 2022 at 1.0°: Monthly Land-Surface Precipitation Climatology for Every Month and the Total Year from Rain-Gauges built on GTS-based and Historical Data. DOI: 10.5676/DWD_GPCC/CLIM_M_V2022_100