

# CONTRIBUTION OF EVAPORATIVE SOURCES AND ATMOSPHERIC CIRCULATION TO THE SPATIOTEMPORAL VARIABILITY OF MOISTURE TRANSPORT

Vittorio Giordano<sup>1</sup>, Arie Staal<sup>2</sup>, Marta Tuninetti<sup>1</sup>, Luca Ridolfi<sup>1</sup> and Francesco Laio<sup>1</sup>

<sup>1</sup>Politecnico di Torino, DIATI, Turin, Italy

<sup>2</sup>Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, The Netherlands

## INTRODUCTION & AIM

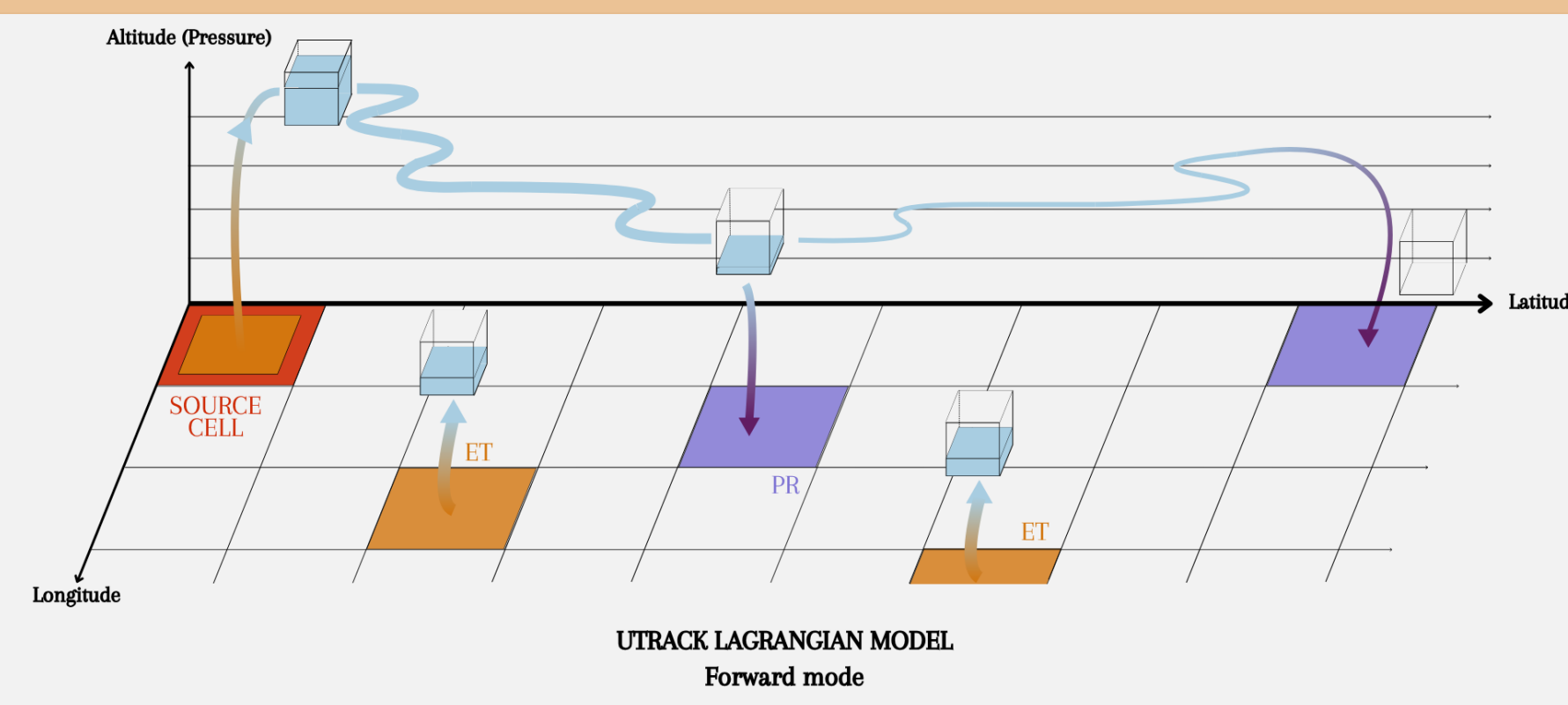
Precipitation variability is influenced by surface evaporation, moisture transport and atmospheric circulation<sup>1</sup>, however its sensitivity to these factors remains unexplored.

We performed multi-annual moisture tracking simulations to:

- Identify **evaporative sources of precipitation**;
- Characterize their **variability over time**;
- Investigate the **sensitivity of precipitation to anomalies** in source evaporation and its transport;

## UTRACK MODEL

UTrack<sup>2</sup> is a **lagrangian (trajectory-based) model** that simulates atmospheric moisture transport. It **tracks moisture parcels through the atmosphere**, from their locations of evaporation to those of precipitation, forced with ERA5 data.



## METHODS

- **Monthly, forward tracking simulations from 1996 to 2025**
- **Surface released** proportional to evaporation
- Probabilistic scheme for **vertical distribution**, based on specific humidity
- **Moisture allocation** method:

$$A_p(x, y, t) = P(x, y, t) \frac{W_p(t-1)}{TCW(x, y, t)}$$

moisture allocated by parcel  $p$ , at time  $t$

$$W_p(t) = W_p(t-1) - A_p(x, y, t)$$

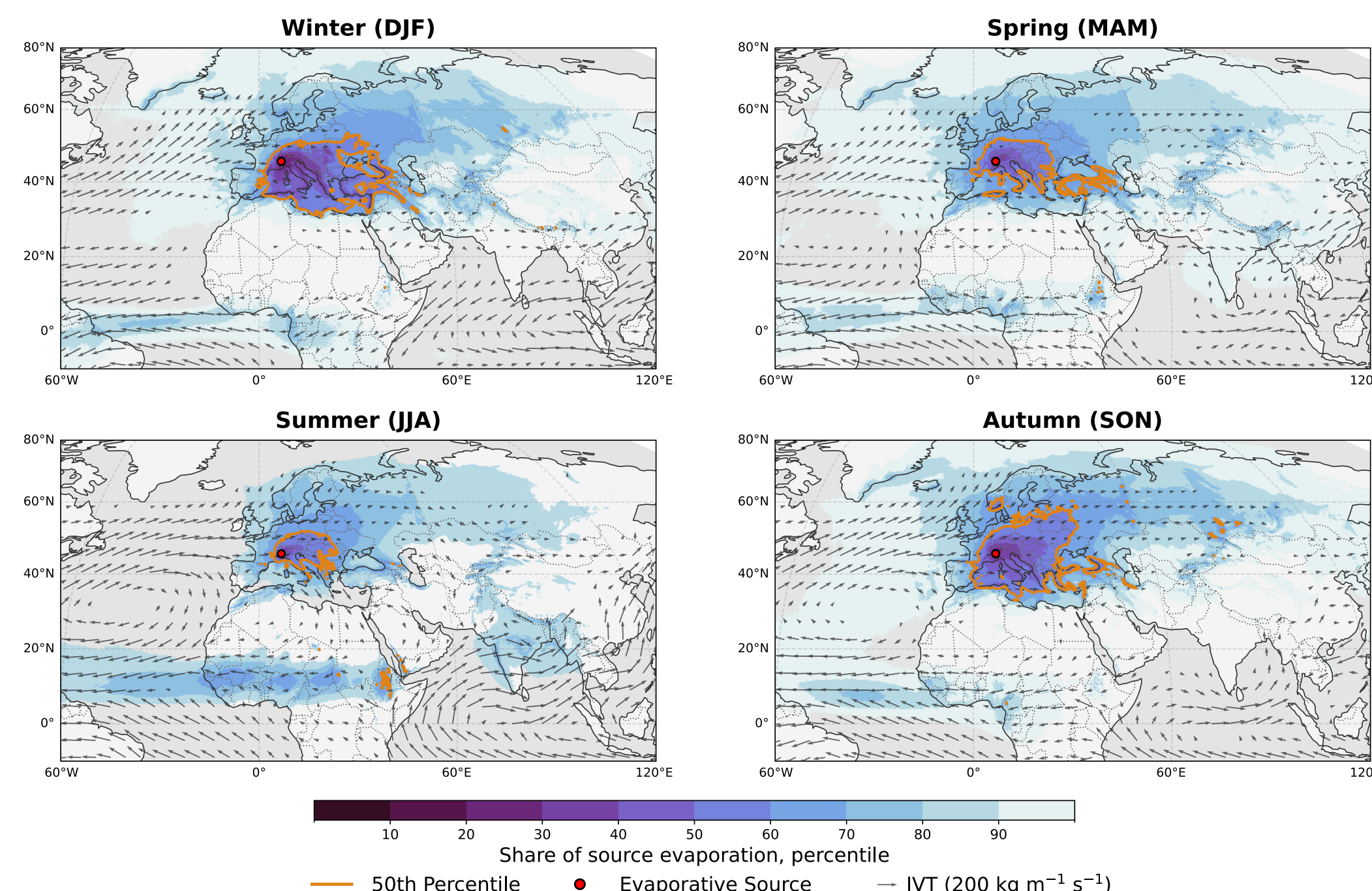
moisture content of parcel  $p$ , at time  $t$

$$R(x, y, T) = \sum_{t=0}^T \sum_{p=1}^n A_p(x, y, t)$$

tracked precipitation from source  $e$

$$q(x, y, T) = \frac{R(x, y, T)}{et_s(T)}$$

share of source evaporation precipitated in  $[x, y]$

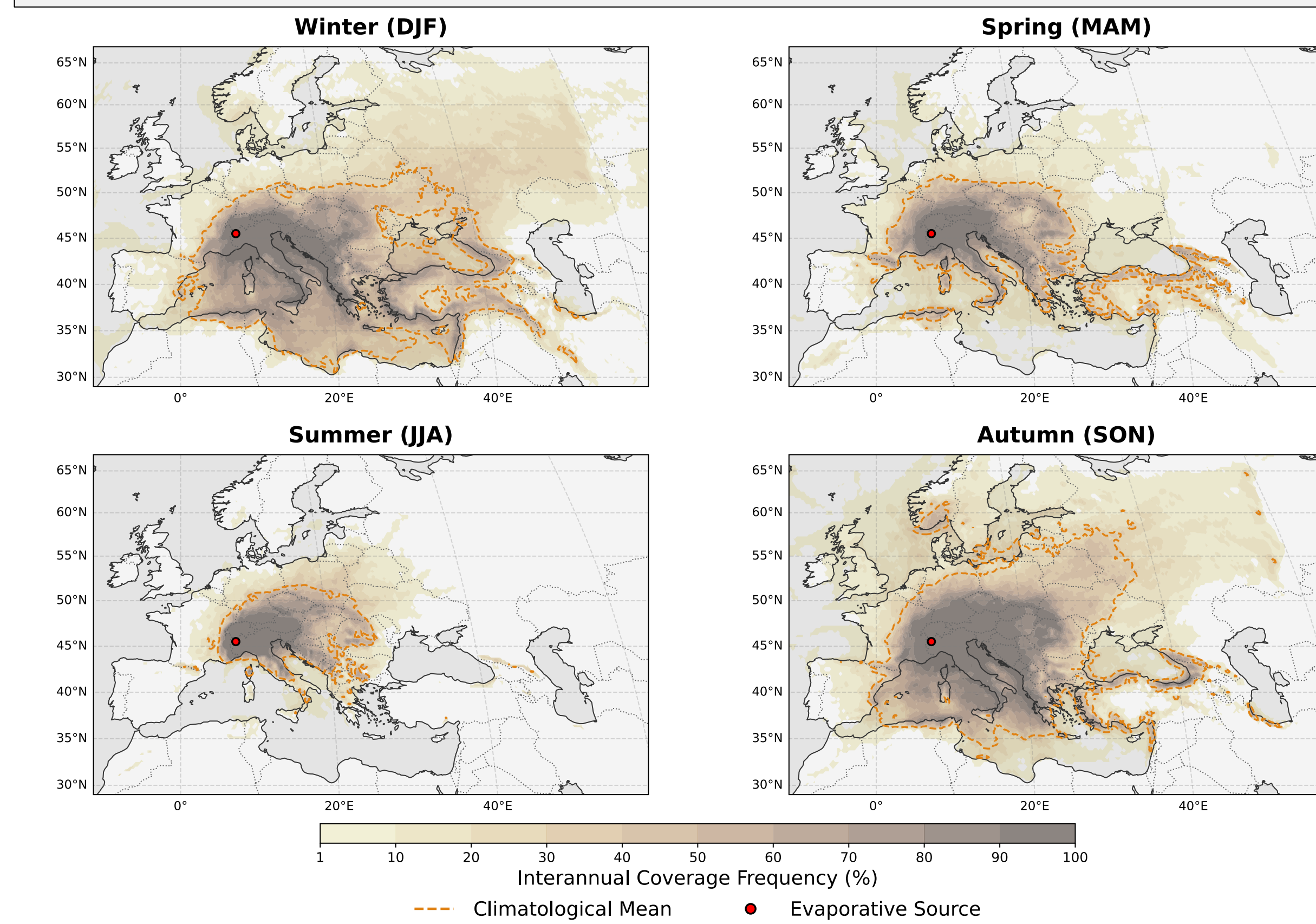


- Time step: **15 min**
- **25 pressure levels**
- **10000 parcels/mm**
- Resolution **0.25°**
- **Kinetic scheme** motion
- Mixing freq. **24h**

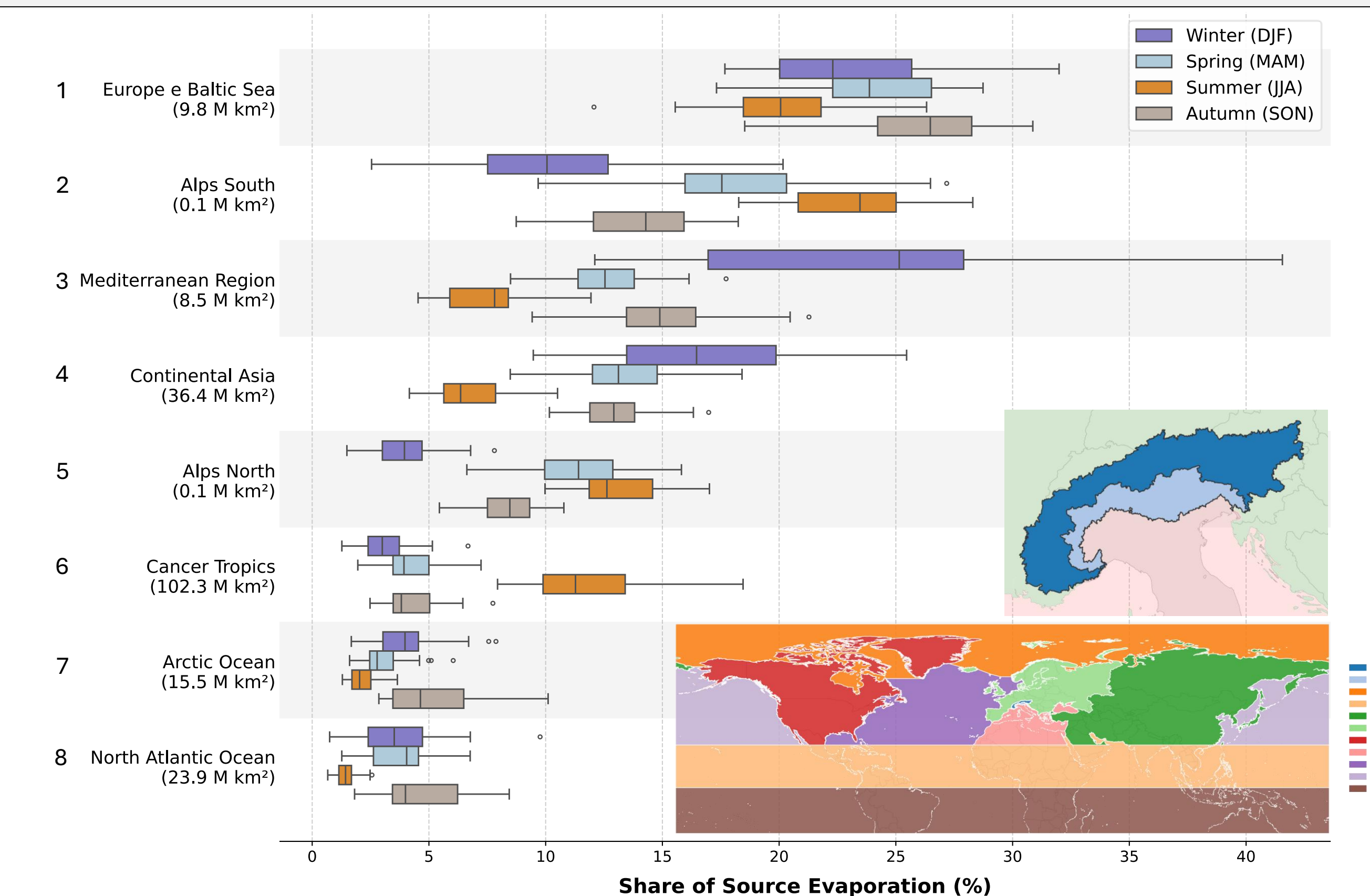
**Figure 1. Seasonal climatologies of Evaporationsheds.** Areas where evaporation from the source (red dot) has precipitated, averaged over 30 years, by season, expressed as share of source evaporation ( $q$ , %). Orange contours show seasonal average 50<sup>th</sup> percentile.

## RESULTS

### Interannual Variability of moisture transport



**Figure 2. Interannual variability of moisture transport.** Shading indicates the frequency of areal coverage by seasonal evaporationsheds over 30 years (50<sup>th</sup> percentiles). Orange contours show seasonal average 50<sup>th</sup> percentile.



**Figure 3. Interannual variability of moisture transport, regional aggregation.** Boxplots indicate the variability in the sink regions of precipitation over 30 years, by season.

### Anomaly decomposition (summer 2015)

Summer 2015 shows the lowest cumulated evaporation over 30 years.

Anomaly decomposition:

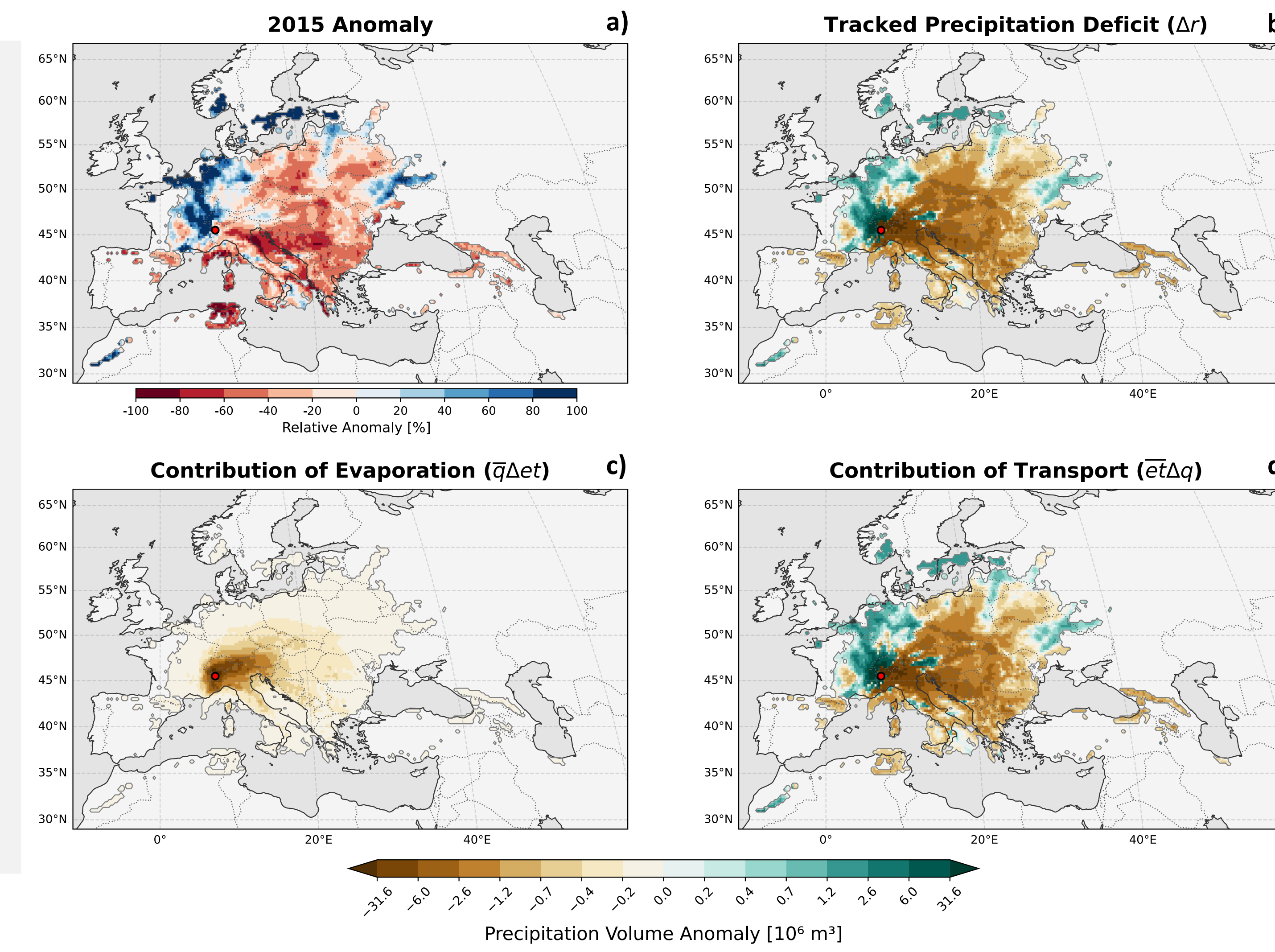
$$R(x, y, T) = et_s(T) \cdot q(x, y, T)$$

$$R(x, y, T) = \bar{R} + \Delta R$$

$$\Delta R \approx \bar{q} \Delta et_s + \overline{et_s} \Delta q + \Delta et_s \Delta q \quad (\bar{R} \approx \overline{et_s} \cdot \bar{q})$$

- $\bar{q} \Delta et_s$  evaporation anomaly term: **13.2%**
- $\overline{et_s} \Delta q$  transport anomaly term: **82.1%**
- $\Delta et_s \Delta q$  interaction term: **4.70%**

**The transport term dominates the anomaly of precipitation in the summer of 2015**



**Figure 4. Summer 2015 anomaly decomposition.** a) relative precipitation anomaly from the seasonal average; b) absolute precipitation anomaly; c) source evaporation contribution to precipitation anomaly; d) moisture transport anomaly contribution to precipitation anomaly

## TAKEAWAYS

- Evaporation contributions to precipitation show **high interannual variability**;
- The mediterranean region, in the winter season, shows the **widest IQR**
- While Europe receives stable seasonal moisture transport shares, the Alps and the Mediterranean show distinct seasonal trends
- Atmospheric moisture **transport** contribution to precipitation variability **dominate, especially in summer**, when evaporation is stable and circulation is subject to strong anomalies<sup>3</sup>;
- The use of average moisture transport fields can introduce systematic biases;

## References:

1. Wei, J., & Dirmeyer, P. A. (2019). Sensitivity of land precipitation to surface evapotranspiration: a nonlocal perspective based on water vapor transport. *Geophys. Res. Lett.*, 46(21), 12588–12597. doi: 10.1029/2019GL085613
2. Tuinenburg, O. A., & Staal, A. (2020). Tracking the global flows of atmospheric moisture and associated uncertainties. *Hydrol. Earth Syst. Sci.*, 24(5), 2419–2435. doi: 10.5194/hess-24-2419-2020
3. Sodemann, H., & Zubler, E. (2009). Seasonal and inter-annual variability of the moisture sources for Alpine precipitation during 1995–2002. *Int. J. Climatol.*, 30(7), 947–961. doi: 10.1002/joc.1932

## Contacts:

vittorio.giordano@polito.it