

Tracing Moisture and Heat in a 2012 Mediterranean Compound Event: a Lagrangian Analysis

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Introduction

- The simultaneous occurrence of droughts and heatwaves (compound events) represents one of the greatest climate-related threats to society, agriculture, and energy grid resilience, as during these episodes, impacts do not simply add up, they multiply.
- Between **June 28 and July 21, 2012**, a compound event of extreme spatial extent severely affected Central Europe, the Balkan Peninsula, and western Turkey (Fig1).
- Unraveling the mechanisms that sustained this event requires looking beyond surface anomalies and tracing the atmospheric history of the air masses.

Objectives

- Characterize the thermodynamic mechanisms driving the 2012 Mediterranean compound event and their contribution to the observed temperature anomalies.
- Identify source regions as well as heat and moisture trajectories using the LATTIN software to assess atmosphere-surface coupling.

Methodology

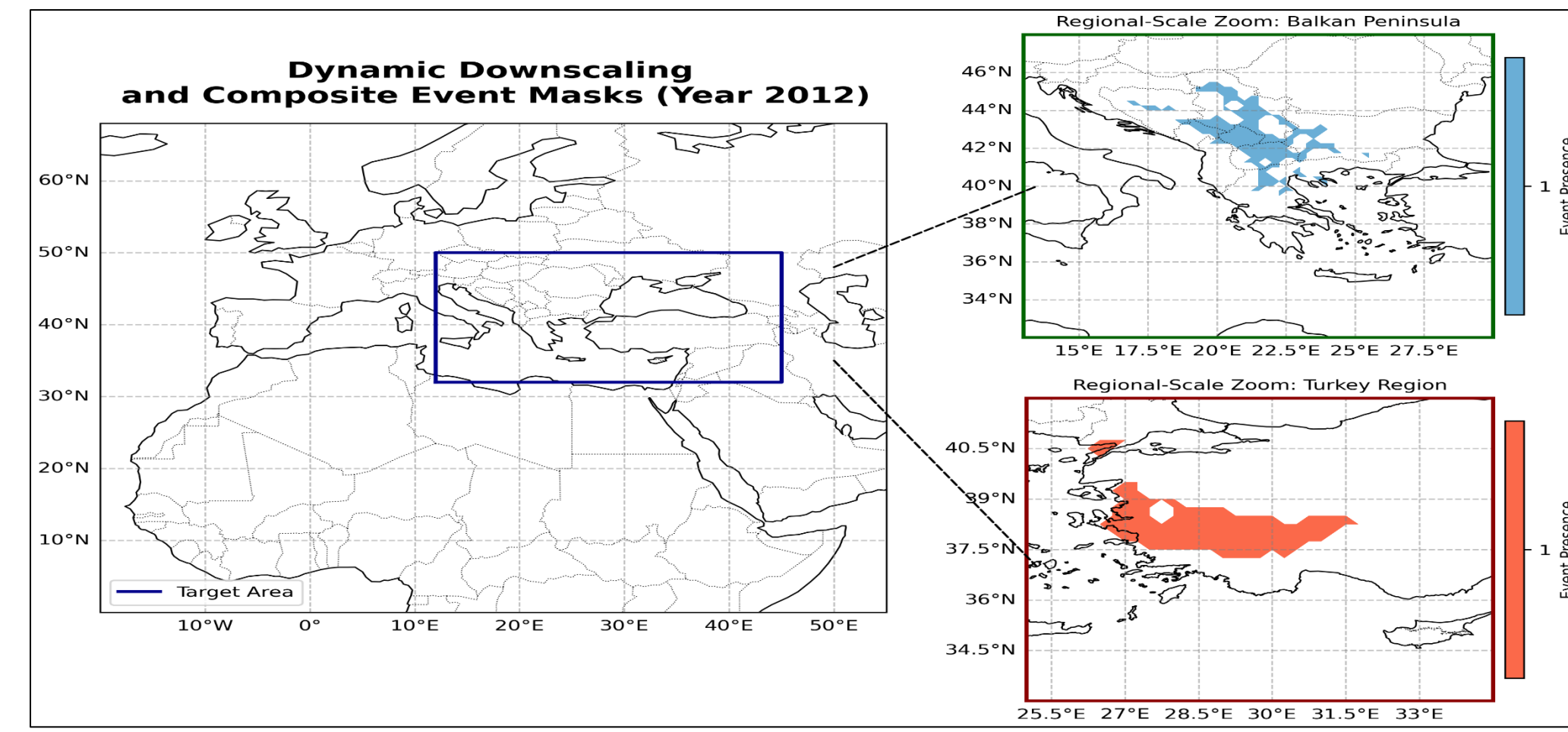


Figure 1. Geographic location and spatial masks defining the 2012 compound event across its two main sub-regions: Balkan Peninsula (blue) and Turkey Region (red).

Data:

- The Dheed database
- ERA5 reanalysis.
- FLEXPART v10.4.

Methodology:

- LATTIN software.

LATTIN

$$E - P = \frac{m \sum_{i=1}^N \Delta q_i}{A} = (MU)$$

(Moisture) →

(T. Anomaly) → $T' = \int \left[\frac{K}{p} T - \frac{\partial T}{\partial p} \right] w d\tau + \int \left(\frac{p}{p_0} \right)^K \frac{D\theta}{Dt} d\tau - \int \vec{u} \nabla_h \bar{T} d\tau - \int \frac{\partial \bar{T}}{\partial t} d\tau$

↑ Anomalia Adiabática ↑ Anomalia Diabática ↑ Anomalia Adectiva ↑ Climatología

Röthlisberger y Papritz (2023)

The Balkan Peninsula

Results

Western Turkey

Heat

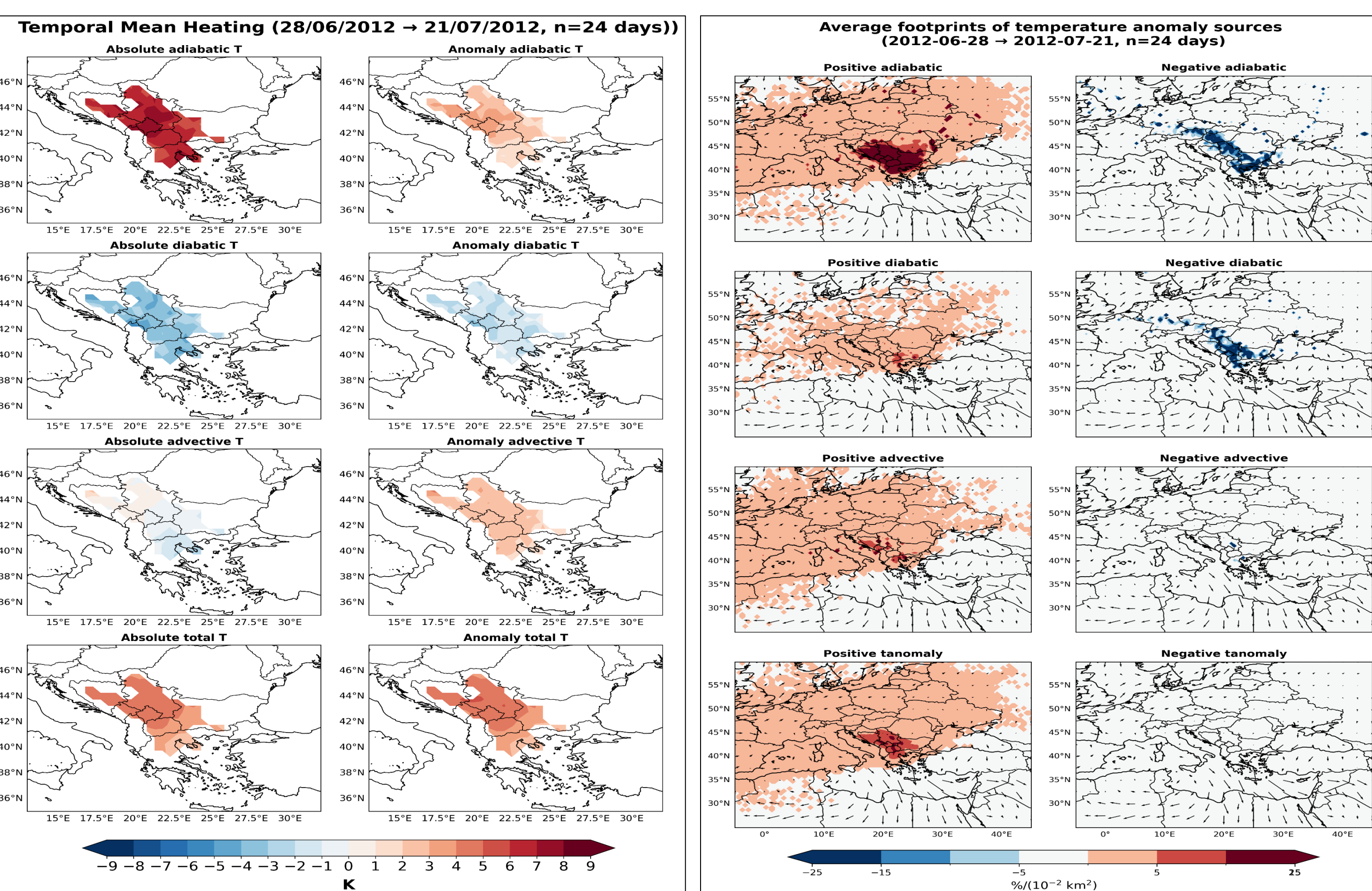


Figure 2: Mean atmospheric temperature decomposition (K) for the Balkans target region during the extreme heat event (28/06/2012 → 21/07/2012, n=24 days). Left column: Absolute mean contributions of adiabatic warming, diabatic heating, advective transport, and total temperature perturbation. Right column: Corresponding anomalies relative to climatology (1980–2020).

Figure 3: Spatial contribution (%) of surrounding grid cells to the temperature anomaly components within the Balkans target region, overlaid with the 10-m mean wind field during the 2012 heatwave event. Left column: Positive anomaly contributions. Right column: Negative anomaly contributions for adiabatic, diabatic, advective, and total temperature terms.

Heat

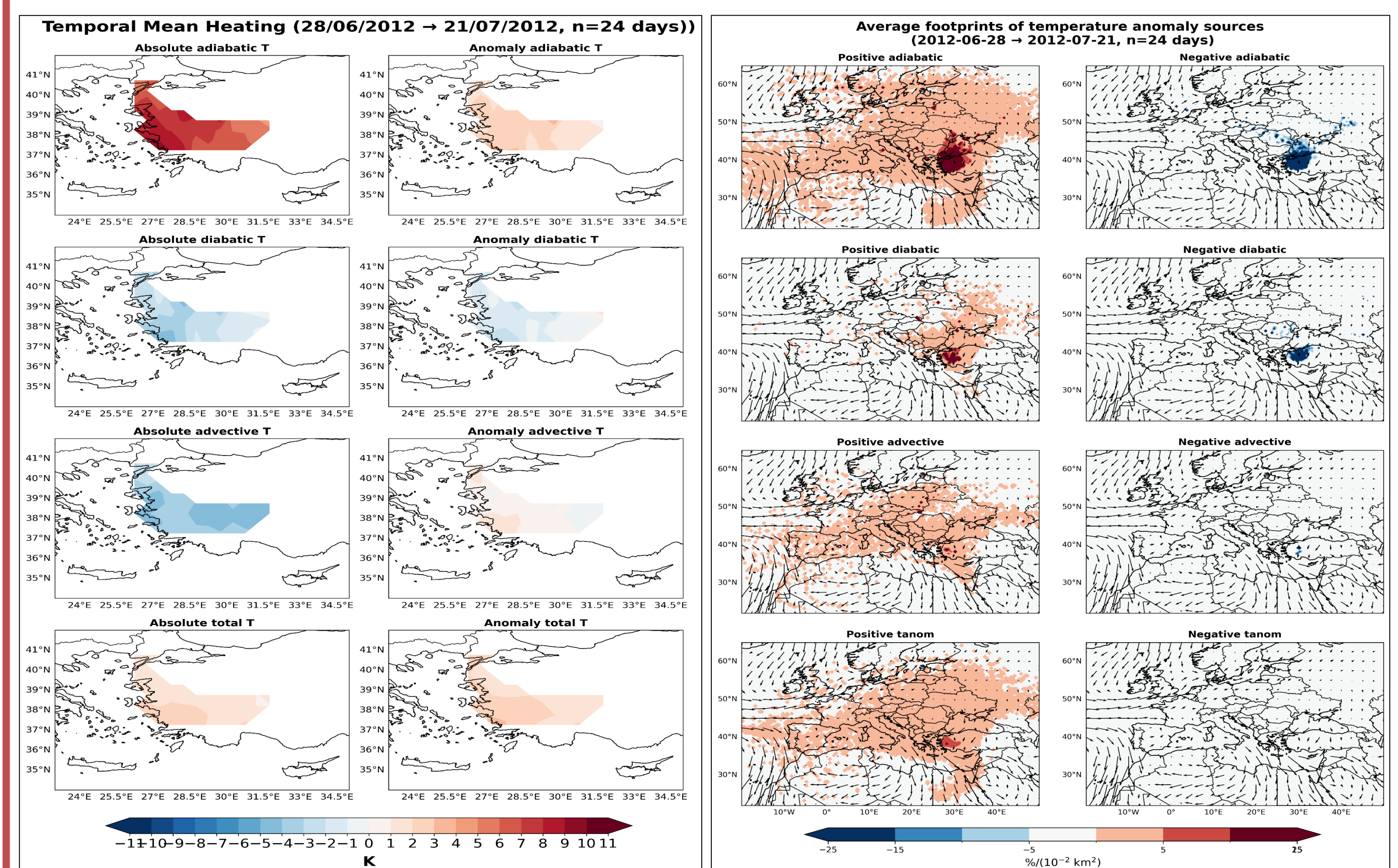


Figure 5: Mean atmospheric temperature decomposition (K) for the Turkey target region during the extreme heat event (28/06/2012 → 21/07/2012, n=24 days). Left column: Absolute mean contributions of adiabatic warming, diabatic heating, advective transport, and total temperature perturbation. Right column: Corresponding anomalies relative to climatology (1980–2020).

Figure 6: Spatial contribution (%) of surrounding grid cells to the temperature anomaly components within the Turkey target region, overlaid with the 10-m mean wind field during the 2012 heatwave event. Left column: Positive anomaly contributions. Right column: Negative anomaly contributions for adiabatic, diabatic, advective, and total temperature terms.

Moisture

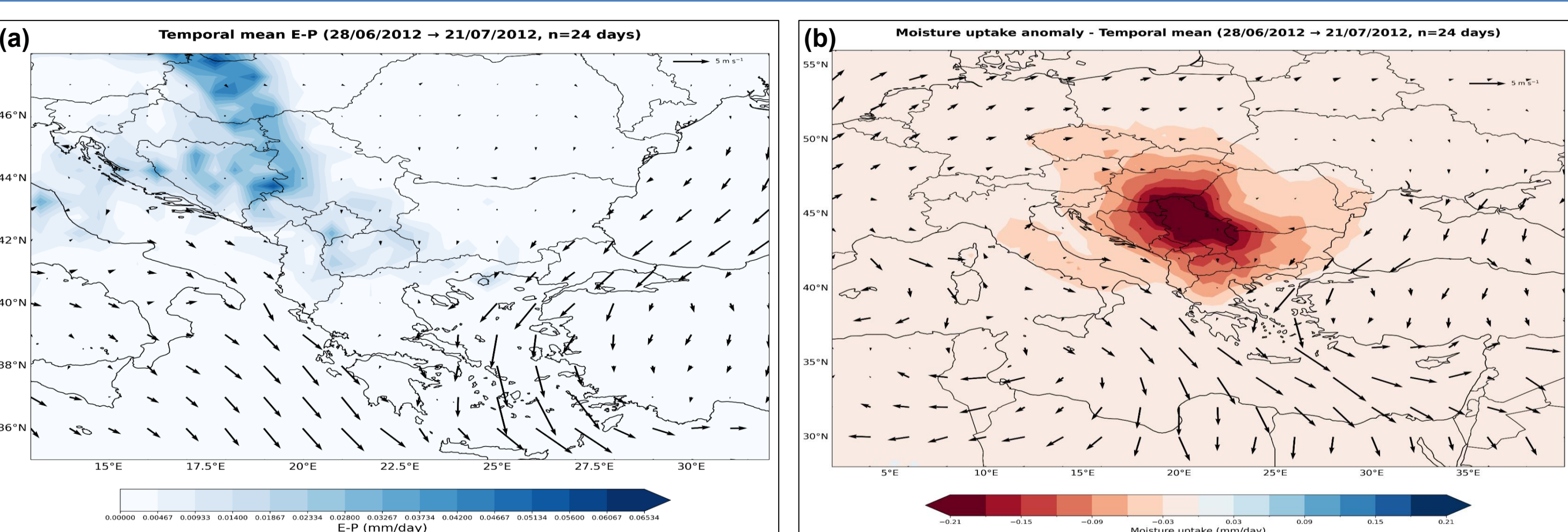


Figure 4: Atmospheric moisture transport and moisture uptake patterns for the Balkans target region during the compound extreme event (28/06/2012–21/07/2012, n = 24days). (a) Temporal mean moisture uptake ($E - P$, mm/day), and (b) Moisture uptake anomaly (mm/day) relative to the 1980–2020 climatology. Black vectors represent the 10-m mean wind field ($m \cdot s^{-1}$). Blue shading indicates regions of net moisture gain/positive anomalies, while red shading indicates negative anomalies.

Moisture

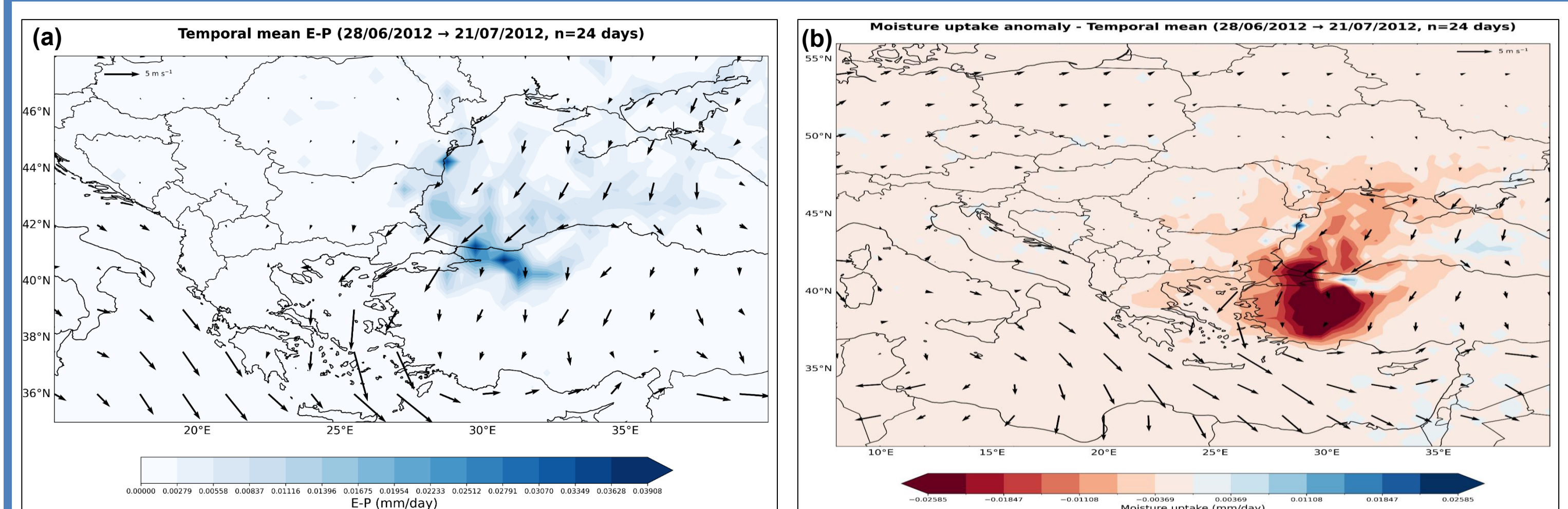


Figure 7: Atmospheric moisture transport and moisture uptake patterns for the Turkey target region during the compound extreme event (28/06/2012–21/07/2012, n = 24days). (a) Temporal mean moisture uptake ($E - P$, mm/day), and (b) Moisture uptake anomaly (mm/day) relative to the 1980–2020 climatology. Black vectors represent the 10-m mean wind field ($m \cdot s^{-1}$). Blue shading indicates regions of net moisture gain/positive anomalies, while red shading indicates negative anomalies.

Synoptic Analysis

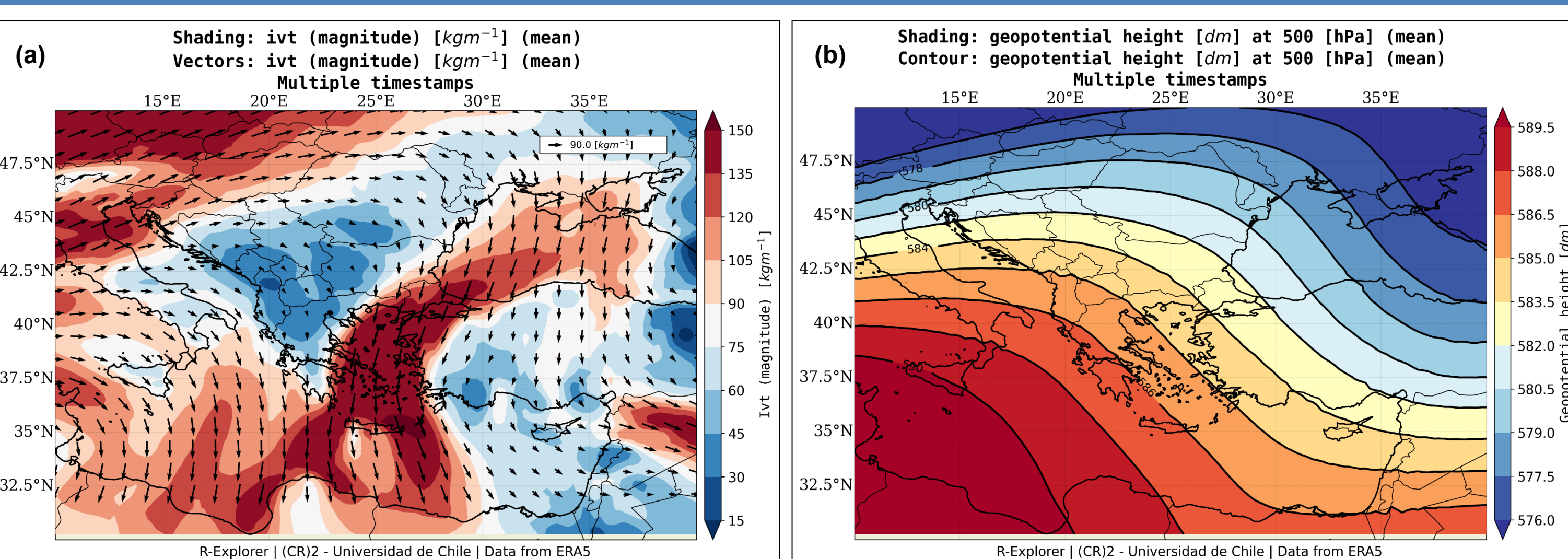


Figure 8: Atmospheric synoptic context during the event. (a) Mean geopotential height at 500 hPa (Z_{500} , dm) showing a prominent upper-level ridge anchored over the central-eastern Mediterranean. (b) Integrated Water Vapor Transport (IVT, $kg \cdot m^{-1} \cdot s^{-1}$; magnitude and direction vectors), highlighting anticyclonic flow peripheral transport and an extended dry/low-IVT core under the blocking structure. Data derived from ERA5 reanalysis.

Conclusions

- The 2012 Mediterranean compound event was driven and maintained *in situ* primarily by adiabatic processes. Strong subsidence associated with a persistent blocking pattern acted as the main thermodynamic driver across both the Balkan Peninsula and western Turkey.
- Horizontal advective transport played a secondary or negligible role due to strong spatial isolation under the blocking high.
- Rapid suppression of local evapotranspiration and soil moisture depletion inhibited moisture recycling, feeding back into the dry-warm compound event.
- The influence of adjacent water bodies was confined to narrow coastal fringes, failing to mitigate adiabatic warming in continental areas.

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References

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