

Assessing heat wave characteristics across North Africa

Albenis Pérez-Alarcón¹, Rogert Sori¹, Amal El-Sehwagy², Ricardo M. Trigo^{3,4}, Raquel Nieto^{1,5}, Luis Gimeno^{1,5}, Zeinab Salah², Milica Stojanovic¹,

¹*Centro de Investigación Mariña, Universidade de Vigo, Environmental Physics Laboratory, Spain* | ²*Egyptian Meteorological Authority, Cairo, Egypt* | ³*Instituto Dom Luiz (IDL), Universidade de Lisboa, Portugal*. | ⁴*Departamento de Meteorologia, Universidade Federal do Rio de Janeiro, Brazil*. | ⁵*Climate System Research Unit, UVigo-CESGA, Santiago de Compostela, Spain*

Summary

Dominated by arid and semi-arid climates, North Africa (Morocco, Algeria, Tunisia, Libya, and Egypt) is recognised as a climate change hotspot, characterised by rising mean temperatures that exacerbate the region's vulnerability to extreme thermal events. On average, the annual frequency of HWs ranged from 2.8 to 5 events per year, with the highest frequency observed in Morocco. Results also indicate a statistically significant positive trend in HW frequency, ranging from 1.2 to 1.9 events per decade. Egypt exhibits the strongest trend, while Tunisia and Morocco show the lowest rates of increase. The application of a Lagrangian diagnostic allowed for the attribution of sensible heat sources associated with the HWs. Outcomes indicate that temperature increases are predominantly driven by local sensible heating, fostered by intense solar radiation, with secondary contributions from sources close to the target region.

Motivation

- Across the globe, heat waves (HWs) represent a category of climatic extremes that has grown increasingly intense as a direct consequence of global warming. ^[1].
- If global emissions continue at their current trajectory, projections suggest that the world will face HWs that are not only more frequent but also more powerful and persistent ^[2].
- The North Africa (NA) region is considered a climate change hotspot with strong temperature increases and rainfall reductions since the middle of the twentieth century ^[3]
- The risks associated with heat extremes require a further understanding of HW in the region

This work aims to examine the characteristics of HWs across NA during the extended summer season (May–September) from 2000 to 2024

Data and Methods

Data Source

- The study period was set from 2000 to 2024.
- The high-resolution ERA5-Land reanalysis was used to detect HWs
- Global FLEXPART simulations.



Methods

- An extreme temperature event is classified as an HW when both daily maximum and minimum temperatures surpass their respective calendar-day 99th percentiles for at least three consecutive days and affect more than 10% of the area
- Heat sources were identifying using LATTIN ^[4].

Acknowledgements

A.P-A., R.S., M.S, Z.S and A.E-S thank to MARINA (04_MARINA_EG_ES_EOAC3) project funded by the European Space Agency. A.P-A. and M.S acknowledge support from the Xunta de Galicia (ED481B-2023/016, ED481D-2024/017), R.S. acknowledges the support of the Ramón y Cajal (RYC2021-034044-I) fellowship. EphysLab members acknowledge the support from the APAL-PADOR project (PID2024-155515NB-I00), funded by the Ministerio de Ciencia, Innovación y Universidades, Spain (MICIU/AEI/10.13039/501100011033) and by 'ERDF/EU'. This work has been also possible thanks to Centro de Supercomputación de Galicia and Red Española de Supercomputación.

References

- [1] IPCC (2021) doi: 10.1017/9781009157896.001.
[2] Seneviratne et al. (2023). doi: 10.1017/9781009157896.013.1514. [3] Ntoumos et al. (2020). doi: 10.3390/ATMOS11080813.
[4] Pérez-Alarcón et al. (2024). doi: 10.1016/j.simpa.2024.100638.

Results

- Marrocco exhibits the highest annual HW frequency, achieving more than 3 HWs/year
- Statistical analysis confirms that HW are becoming more frequent at a rate of 1.2–1.9 events per decade. Egypt records the highest trend, whereas Morocco and Tunisia showed the lowest rates of increase.
- The HW life cycle revealed that these events are relatively short-lived, with a mean duration of approximately 6 days across the region

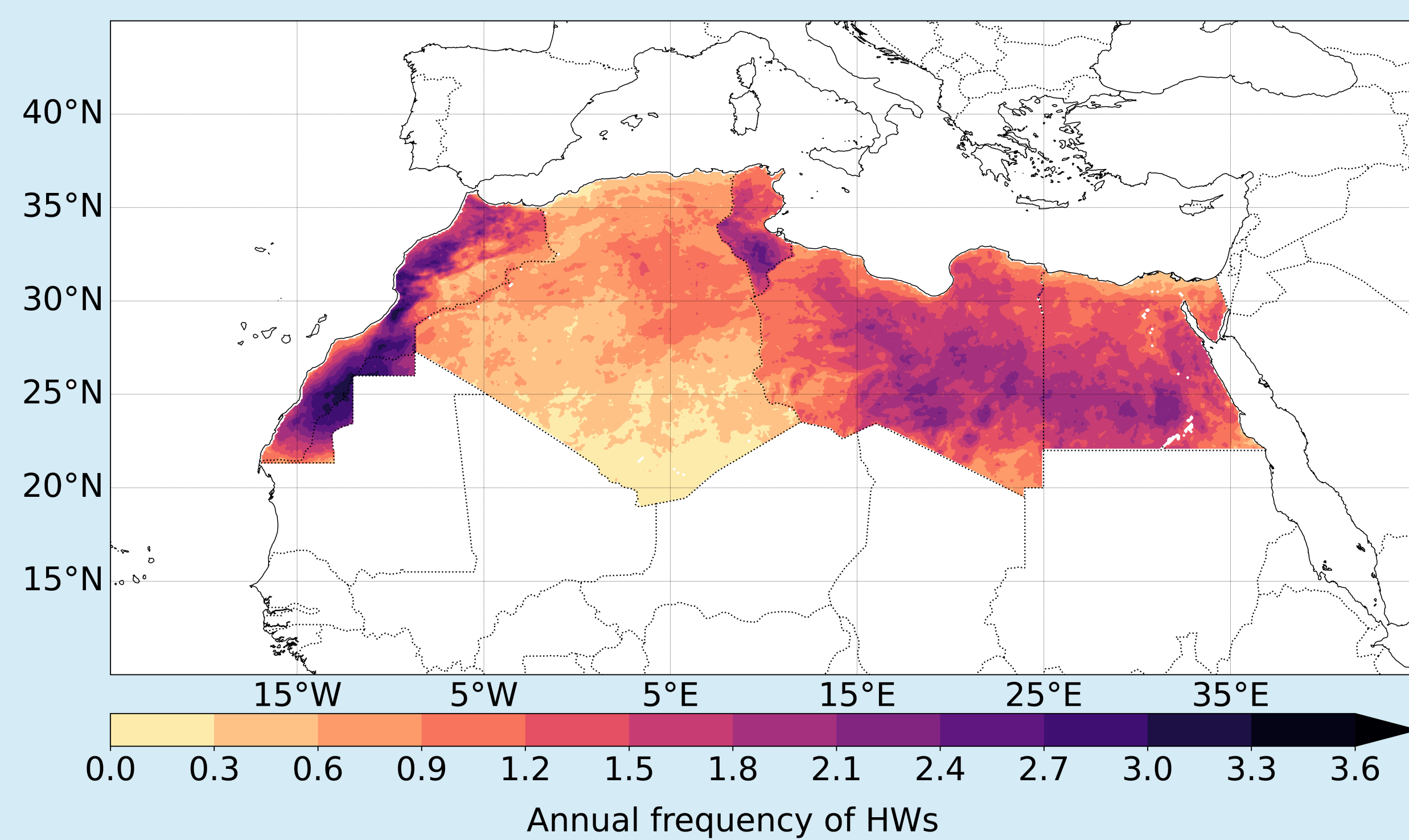


Figure 1. Annual frequency of HWs across North Africa

Heat sources

- Local-origin Heat Soures:** HWs in NA are primarily driven by local-origin sensible heat generation. The highest flux intensities are centered directly within the target region, suggesting that extreme temperatures are first and foremost a result of intense local land-atmosphere coupling and solar heating.
- Secondary Heat Soures:** Secondary contributions originate from near sources located in the immediate vicinity of the target regions.

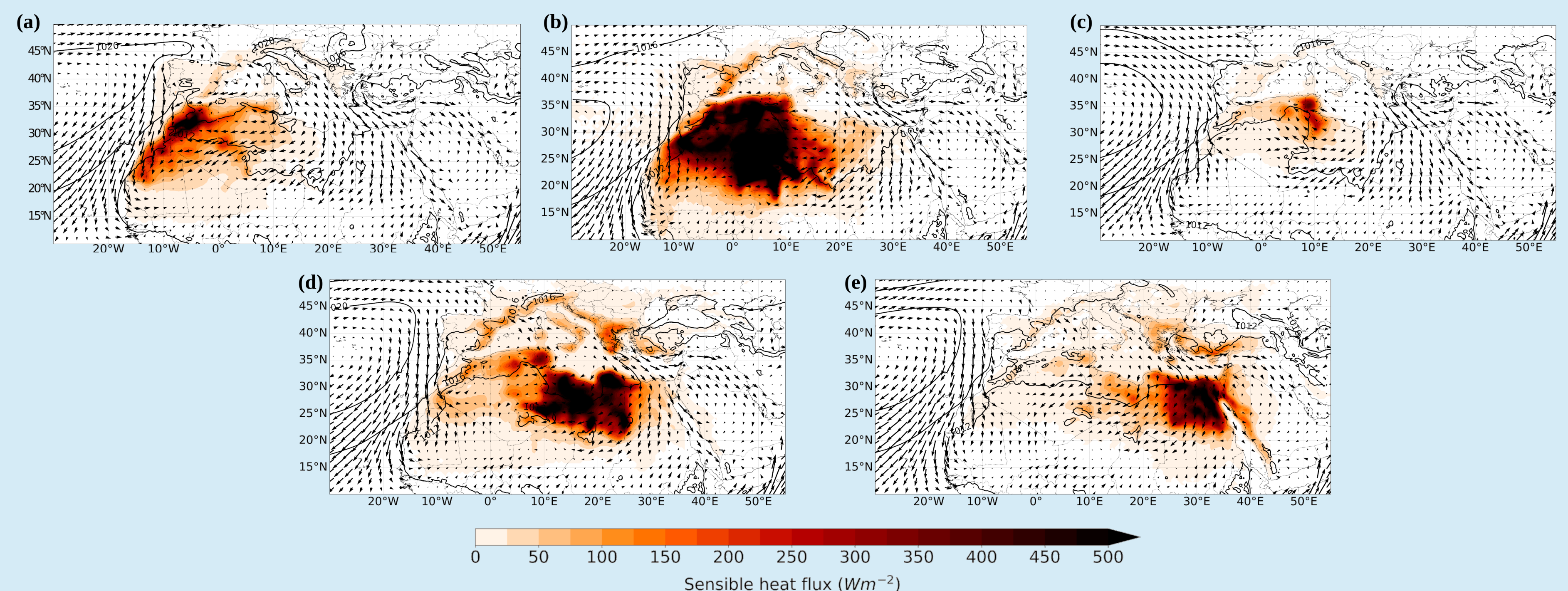


Figure 2. 6-hourly climatological sensible heat source contributions to heat wave events in NA (a) Morocco (b) Algeria (c) Tunisia (d) Libya (e) Egypt. Heat sources were identified by applying a Lagrangian heat tracking framework during the dates of each heat wave event from 2000 to 2024. Arrows and contours show the climatological wind vectors and mean sea level pressure during the same dates of HWs.

- West-to-East Intensity Gradient:** The spatial extent and intensity of the heat sources appear most pronounced in the central and eastern sectors (Algeria, Libya, and Egypt), where the deepest "hotspots" suggest more significant thermal loading compared to the more Atlantic-influenced area.
- Regional Connectivity of Heat Sources:** The spatial distribution shows that heat sources are not isolated; they extend into neighboring Saharan sectors. This suggests that the events are also supported by a broader regional heat reservoir that provides a continuous supply of sensible heat.
- Heat Advection:** A small fraction of sensible heat is advected from southern Europe, particularly during HWs in Libya and Egypt.

Conclusions

These results underscore the critical need for further in-depth analysis to contextualise recent extremes within the framework of future climate projections, thereby aiding in the development of robust regional adaptation strategies.

