# Factores meteorológicos e incertidumbres en las proyecciones climáticas del ozono superficial en Europa


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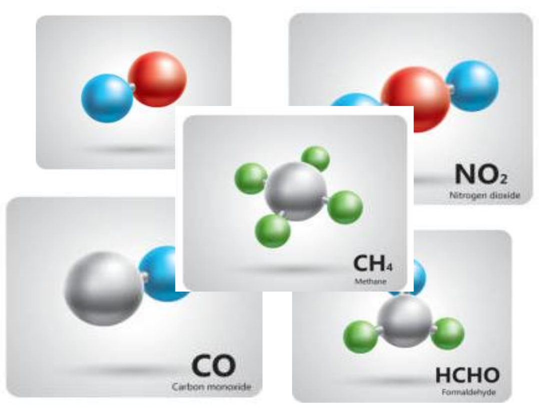
## MOTIVATION

Tropospheric ozone ($O_3$) forms through complex photochemical reactions involving precursors such as nitrogen oxides, non-methane volatile organic compounds, carbon monoxide, and methane in the presence of sunlight.

$O_3$ is highly dependent on solar radiation, temperature (Otero et al., 2016) and land use changes.




### CURRENT SCIENTIFIC CONSENSUS

Future ozone concentrations will be determined by changes in both climate and precursor emissions:

- A warmer atmosphere can lead to local $O_3$ increases during the peak season in polluted regions.
- Efforts to control precursor emissions are expected to yield $O_3$ reductions.

## DATA & METHODS

**Chemical data:**
- CAMS reanalysis
  - 1.0° x 1.0° horizontal resolution
  - Daily (April–May 2003–2022)
- CAMS global emission inventory dataset

**Semi-Lagrangian algorithm**

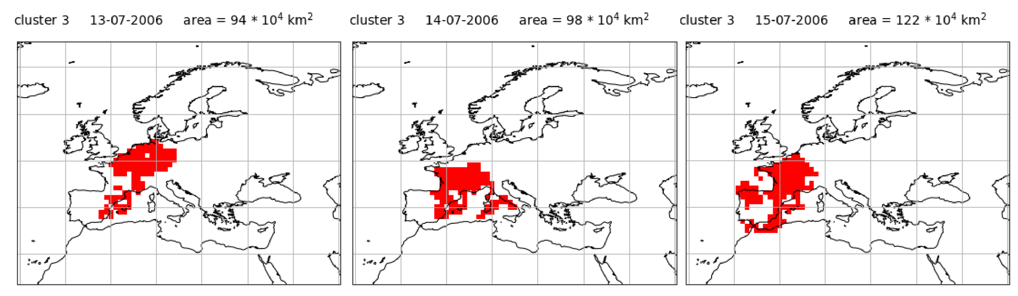
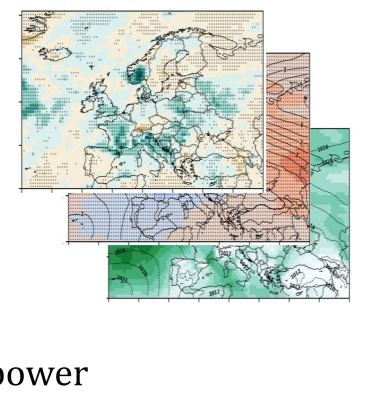


Fig. 1: Output of the ozone episode detection algorithm

**Meteorological data**
- ERA5 reanalysis
- T2M, Z500, precipitation, wind speed, ω500
- Same horizontal and temporal resolution



**Additional data:**
- GFAS → Wildfire radiative power

**Flow analogues**
- (e.g. Yiou et al. 2014)

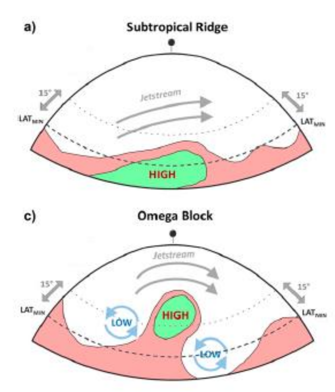
**Air stagnation Index (ASI)**

- < 1 mm
- 10-m < 3.2 m/s
- 500 hPa < 13.0 m/s

**Regional projection index**

$$I(Z500)^R = \frac{\langle Z500_{daily}, Z500^R \rangle}{\langle Z500^R, Z500^R \rangle}$$

**Blocks and ridges algorithm**




(Sousa et al. 2021)

## PAST

### Meteorological conditions and dynamical processes contributing to high ozone levels vary across regions

**SOUTHERN HALF OF BRIT:**
- **Advection** of clean air masses.
- Strong winds ventilate the region, reducing precursors levels, thereby limiting ozone titration by NO.

**EEU:**
- **Anticyclonic conditions**
- **High emissions of ozone precursors** from wildfires.

**NORTHERN PART OF CEU:**
- **anticyclonic conditions**
- high Z500 and T2M anomalies
- reduced wind and precipitation deficits

**SOUTHERN PART OF CEU:**
- modest positive anomalies of T2M and Z500
- weak winds
- **enhanced subsidence.**

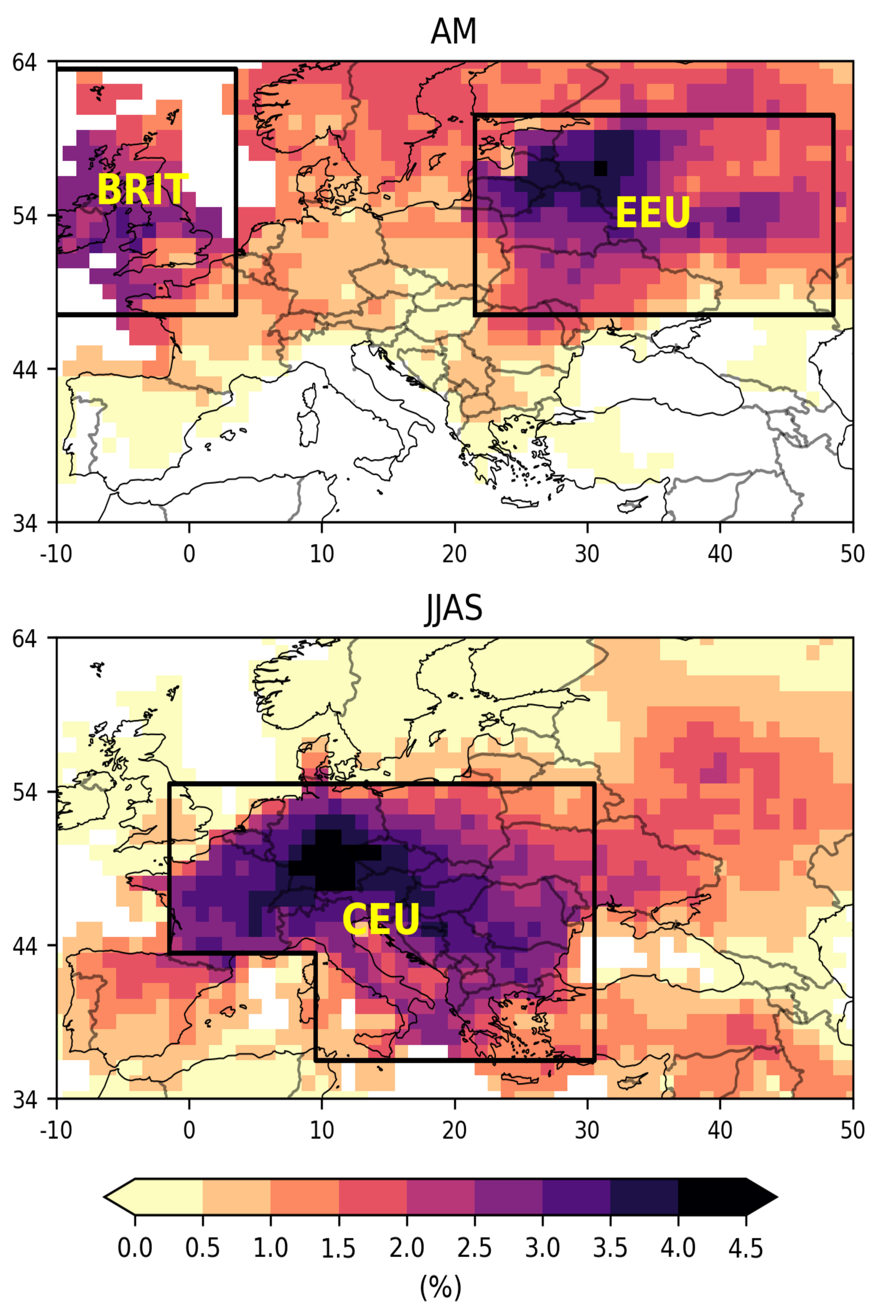
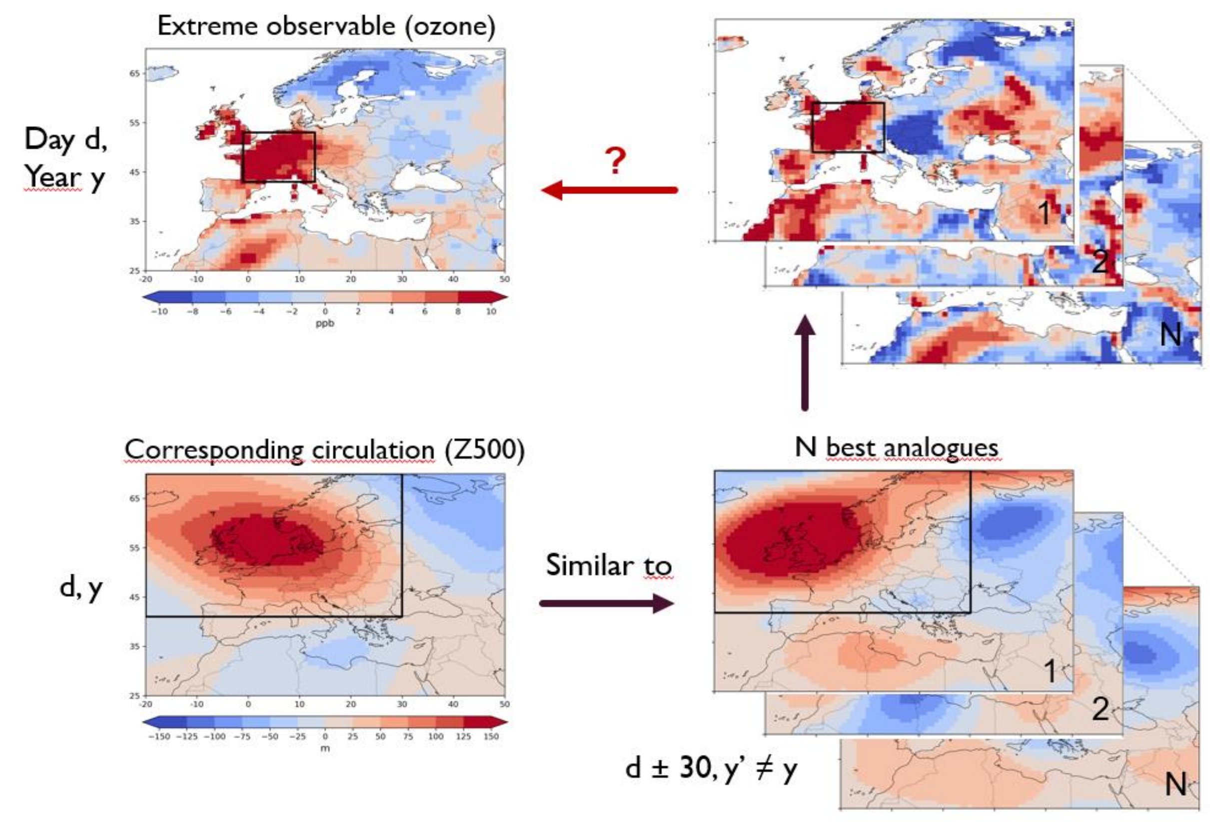



Fig. 1: Frequency of occurrence (% over the total number of days) of the 100 largest European ozone episodes during April–May (AM, top) and June–September (JJAS, bottom) of 2003–2022. The boxes indicate the location of the regions with the highest incidence of episodes: British Isles (BRIT) and eastern Europe (EEU) in AM and central Europe (CEU) in JJAS.

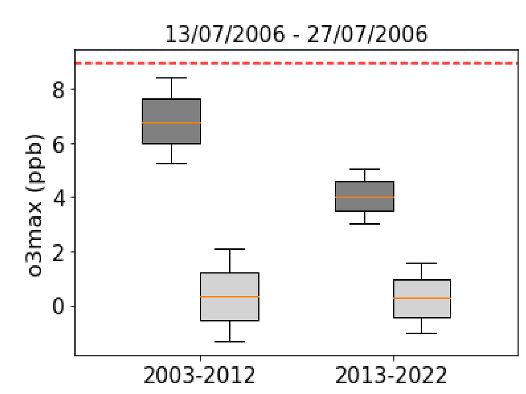
### As we understand the associated mechanisms of regional ozone episodes ...

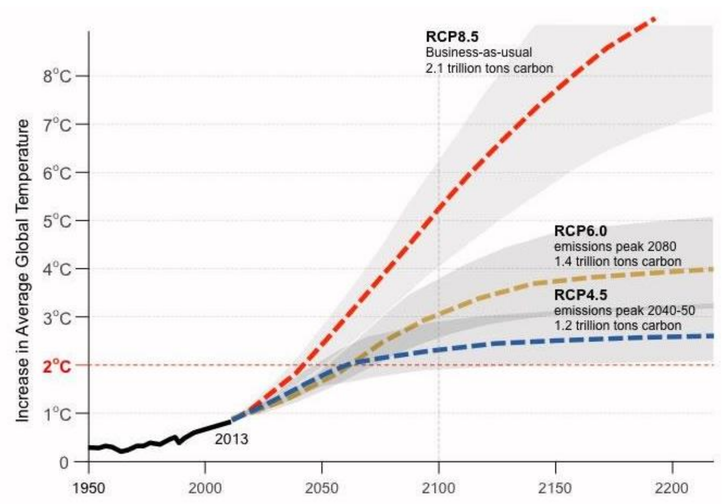
## FUTURE

### ... we can better estimate the evolution of ozone in the future based on different climate scenarios?




Under similar meteorological forcing, ozone has decreased over time in line with the decrease in pollutant emissions.




**Open questions**

- Which process will control the occurrence of ozone extremes in the future: climate change or precursor emissions?
- How extreme will ozone levels be in the future?

## HIGHLIGHTS

- The processes contributing to high ozone levels vary across regions in Europe.
- Weather forcing plays an important role in the occurrence of ozone episodes.
- For similar weather conditions, ozone concentrations have decreased in line with the reduction in precursor emissions.
- Using the analogue method, we can estimate the role of climate change and precursor emissions in the occurrence of ozone extremes in the future.

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