A reanalysis of air quality in the UK

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Atmospheric Dispersion and Air Quality
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Eleanor Smith · Clean Air Conference · 2nd – 3rd October 2024

Project Overview

Motivation for creating an air quality reanalysis …

Observational Data

Time records are often incomplete
instrument downtime or sites opening / closing

Species records are often incomplete
not all pollutants are measured by all monitoring stations

Spatial coverage is often sparse

Site locations are not always suitable for assessing ambient concentrations
many sites are in roadside / industrial locations

Model Data
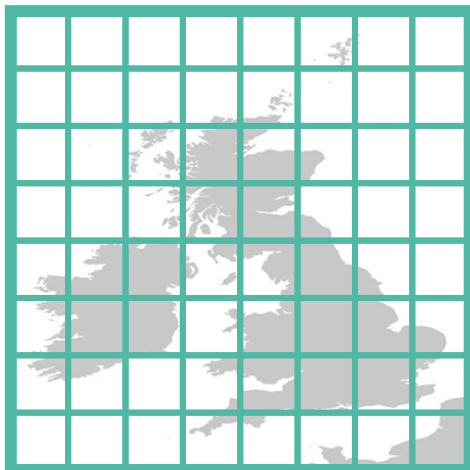
Air quality models are **continually advancing**
advances in scientific knowledge and technological capabilities

Long-term data often **lacks consistency**
models are rarely re-run over long time periods using a consistent configuration

The **accuracy of the models** is dependent on a wide range of inputs
emissions, meteorology, chemical reactions, physics …

Reanalysis Data

The reanalysis combines model output with observations to give …

Coverage of the **whole of the UK**

Hourly time resolution for a **long time period**

**Consistency** in model configuration and input data

Inclusion of **all species** of interest

Enhanced data over just model output alone by incorporating observations through a bias correction method

Model Configuration

The model system is based upon the operational configuration of **Air Quality in the Unified Model (AQUM)**, and **Statistical Post Processing of Observations (SPPO)** method, which is used to generate the national air quality forecast.

Rotated pole coordinate system at 0.11° resolution

Meteorological data from the ECMWF 5th Generation Reanalysis (ERA5)
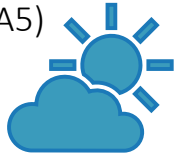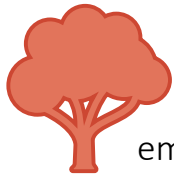
Lateral Boundary Conditions

Chemical composition data from the ECMWF 4th Generation Atmospheric Composition Reanalysis (EAC4)
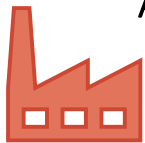
Anthropogenic emissions from the CAMS regional European anthropogenic inventory
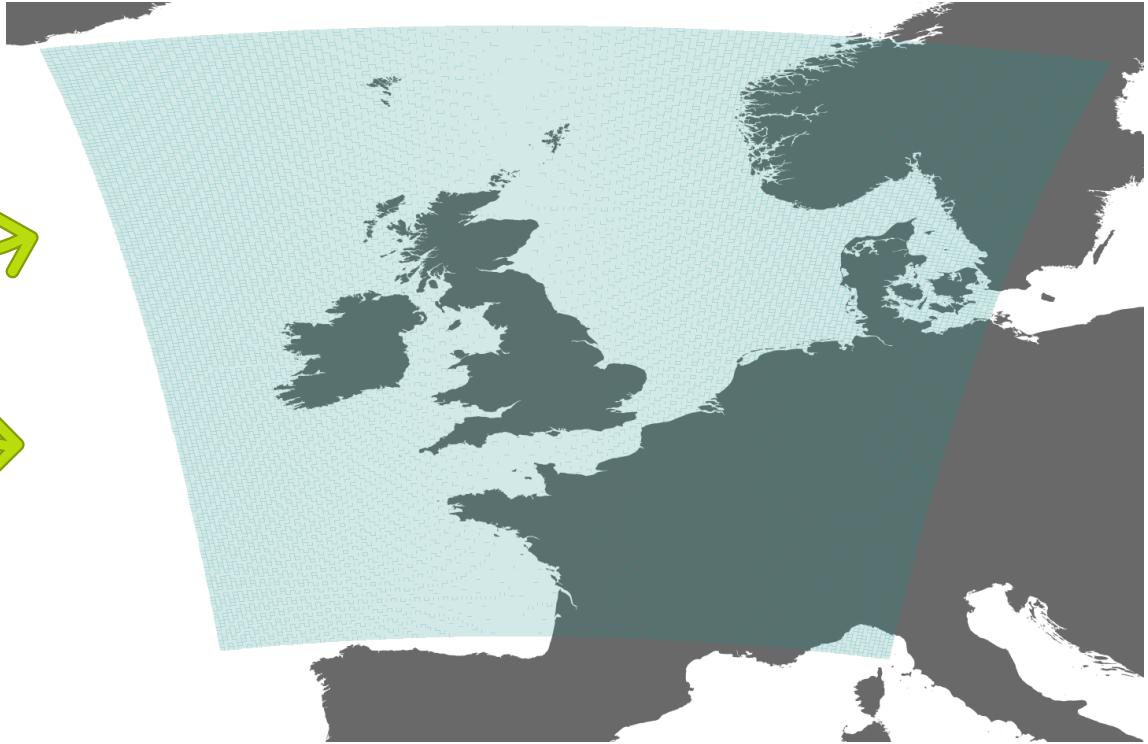
Emissions

Biomass burning emissions from the Global Fire Assimilation System (GFAS) inventory

Biogenic emissions from the CAMS global biogenic inventory

Simulations are run from 00Z as 24-hour forecasts

AQUM Model · *Savage et al, 2013* · https://doi.org/10.5194/gmd-6-353-2013
SPPO Method · *Neal et al, 2014* · https://doi.org/10.1016/j.atmosenv.2014.09.004

Observations of pollutants from monitoring sites in the UK's Automatic Urban and Rural Network (AURN) and some additional monitoring sites in Ireland are used for the bias correction.

Only uses ground-based observations so corrections are applied to the surface level data only

Only uses observations from "background" monitoring stations as 0.1° model cannot represent concentrations near strong emission sources

Biases for urban and rural locations are calculated separately and a weighting method is used to combine the contribution of urban and rural biases for each grid cell
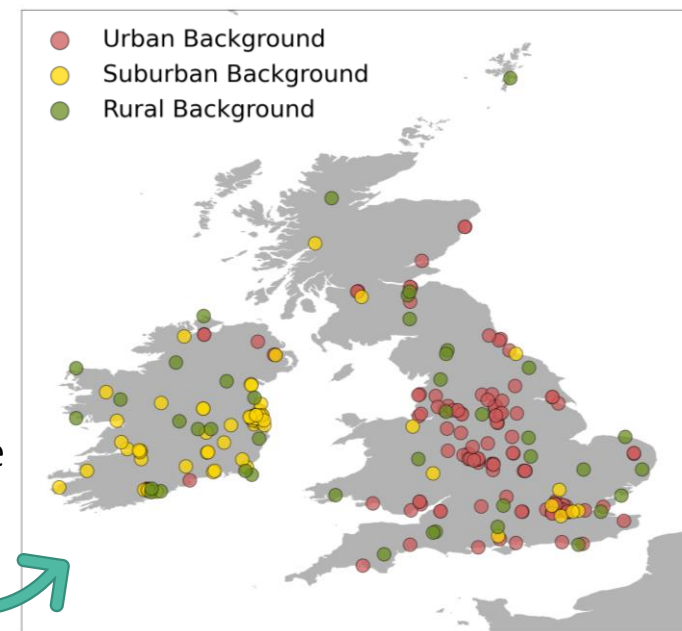
For each pollutant, the number and location of monitoring sites varies over the reanalysis time-period.

Pollutants included in the bias correction:

NO

NO_2

O_3

SO_2

CO

$PM_{2.5}$

PM_{10}
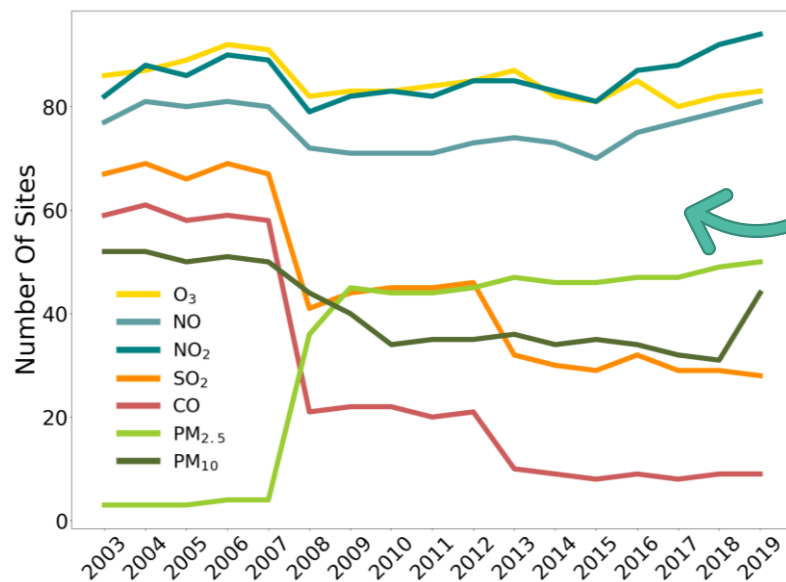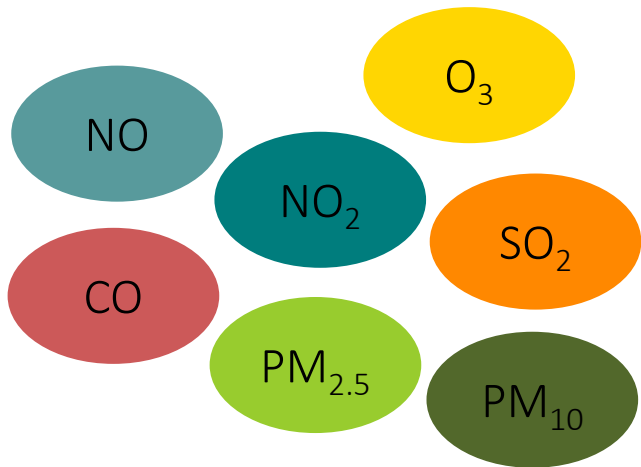
number of available observation sites

"background" monitoring site locations

Data Reformatting

The reanalysis data is re-gridded from the native model rotated pole grid to a WGS 84 coordinate system with a horizontal resolution of 0.1 degree.

All data is saved into monthly NetCDF files containing hourly data.

reanalysis data output domain and resolution
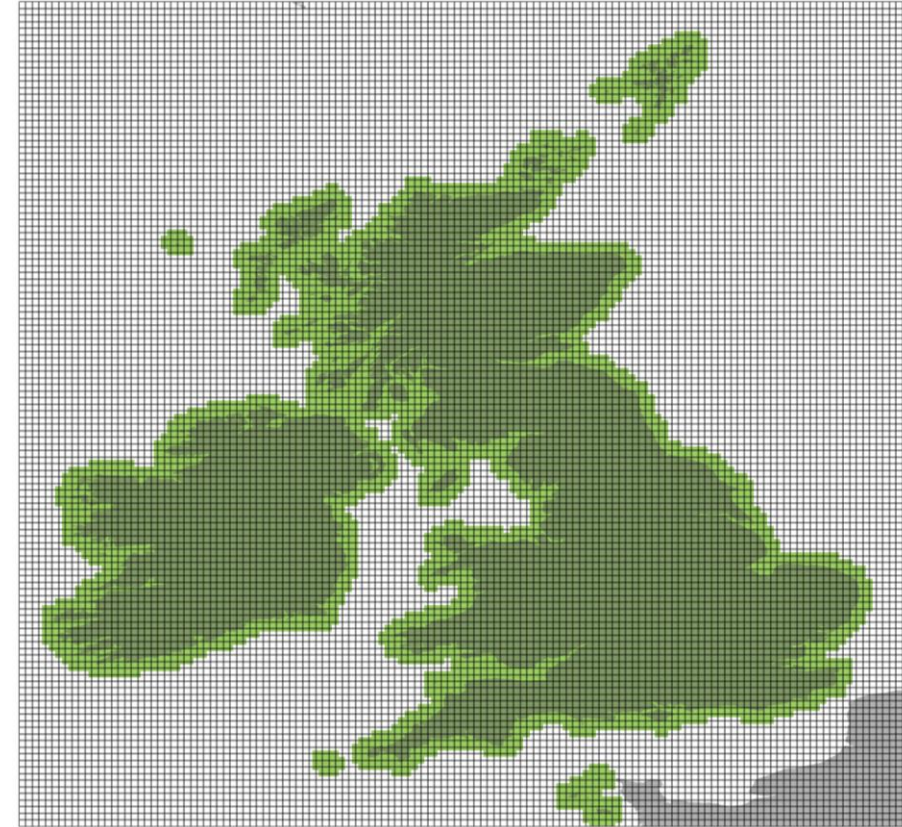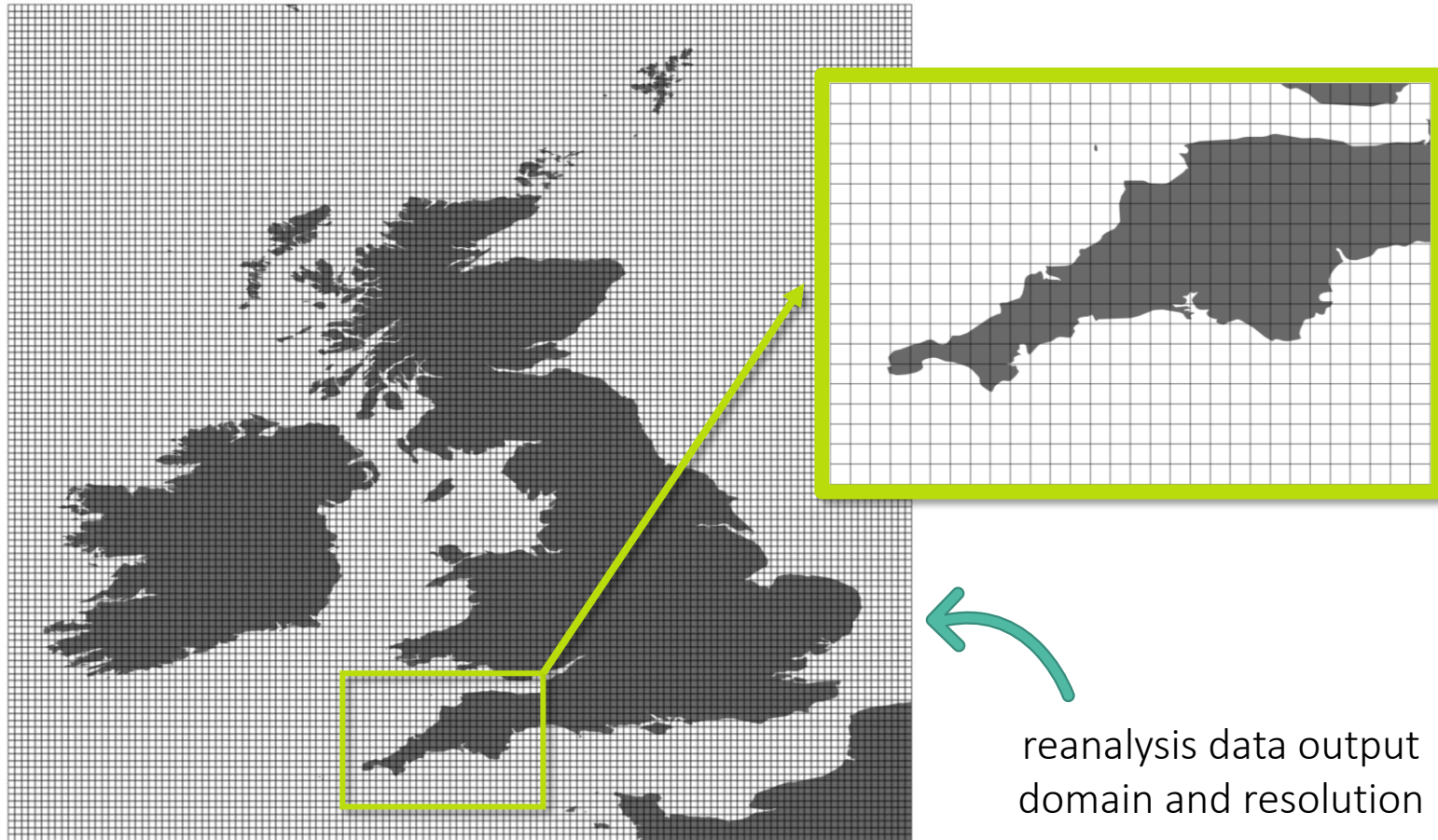
as only land-based observations are used in the bias correction method, the bias corrected data is masked to remove data over the oceans

Dataset Details

The dataset contains the bias-corrected surface level concentrations of key gaseous and particulate pollutants along with calculated daily air quality indices.

Gaseous Pollutants

| Ozone O_3 | Nitric Oxide NO | Nitrogen Dioxide NO_2 | Nitrogen Oxides (as mass of NO_2) NO_x | Sulphur Dioxide SO_2 | Carbon Monoxide CO |

Particulate Pollutants

| Particulate Matter d < 2.5 μm $PM_{2.5}$ | Particulate Matter d < 10 μm PM_{10} |

Daily Air Quality Indices

| Daily Air Quality Index $DAQI$ | Daily Air Quality Index of Ozone O_3 DAQI | Daily Air Quality Index of PM d < 2.5 μm $PM_{2.5}$ DAQI | Daily Air Quality Index of PM d < 10 μm PM_{10} DAQI | Daily Air Quality Index of Nitrogen Dioxide NO_2 DAQI | Daily Air Quality Index of Sulphur Dioxide SO_2 DAQI |

Raw Model Surface Level Data

Contains additional gaseous pollutants (ammonia, isoprene, NMVOC), speciated particulate matter and meteorology (including temperature, humidity, precipitation, cloud, wind speed and direction).

Raw Model Vertical Data

Contains O_3, NO, NO_2, SO_2, CO, NH_3, $PM_{2.5}$, PM_{10}, temperature, pressure, height above sea level.

Strengths and Limitations

Limitations

coverage of the whole of the UK

can provide data where observations are limited

only representative of background pollution levels in outdoor environments

cannot represent sharp gradients in concentrations, such as close to roadsides

coverage of a long time period at hourly time resolution

doesn't account for any indoor pollution

can be used to study short term events, such as pollution episodes

enables long term analysis and longitudinal studies

effectiveness of the bias correction is limited by observation availability

for times or locations where observations are limited, the data will more closely resemble the raw model output

Strengths

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Mean Pollutant Concentrations
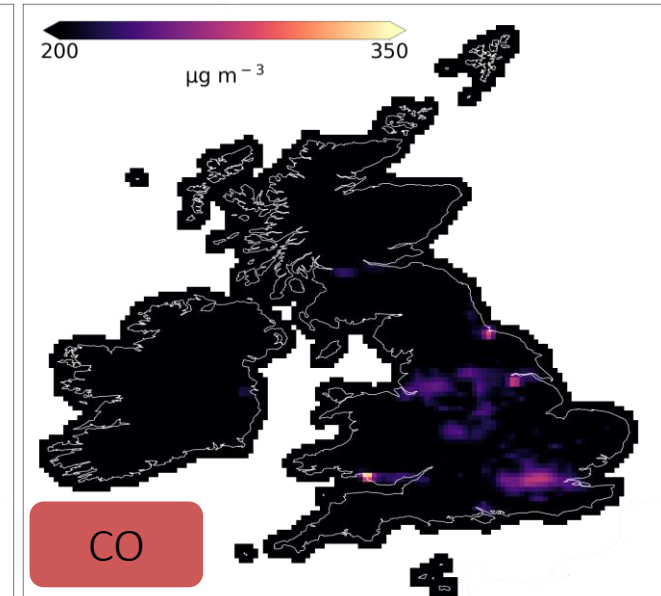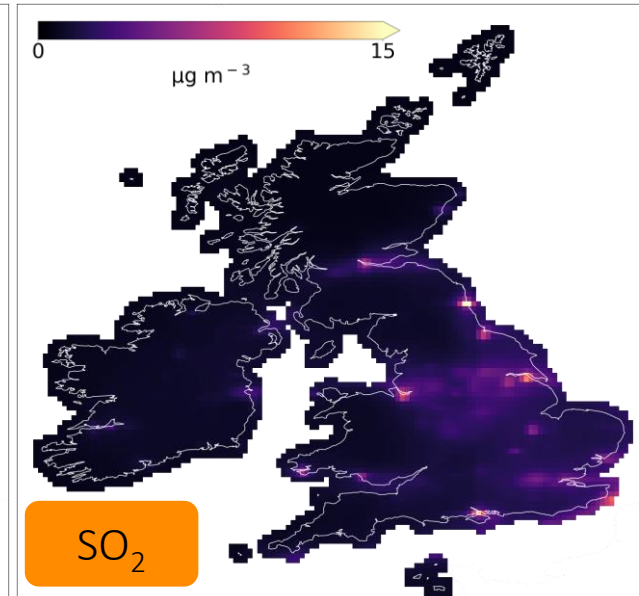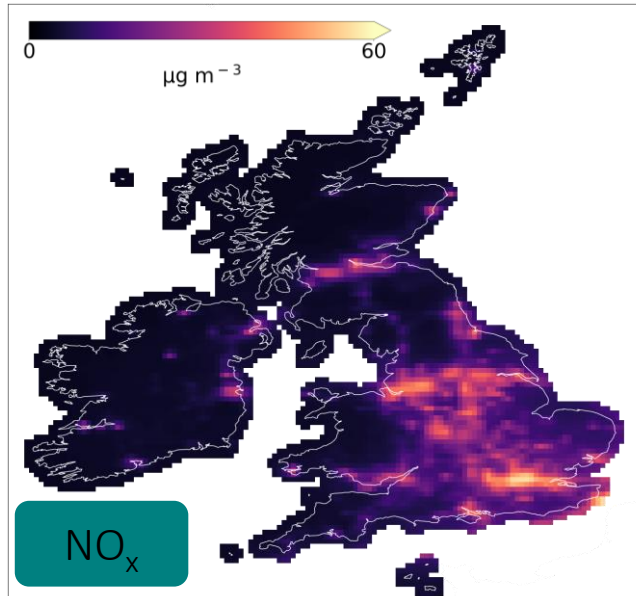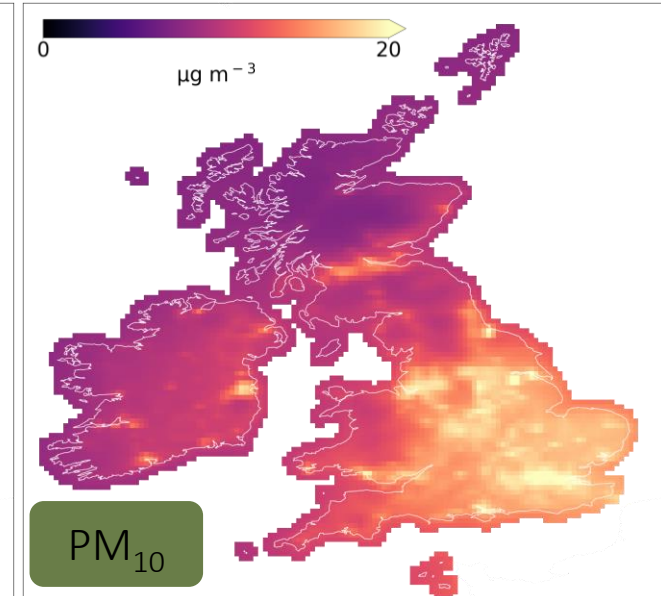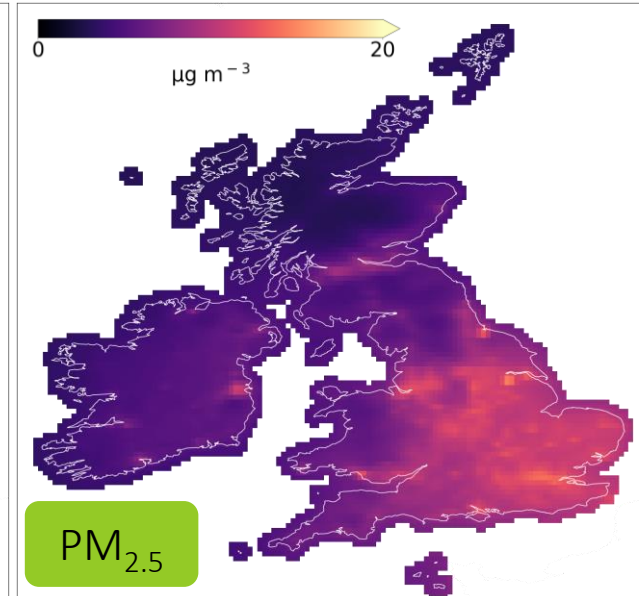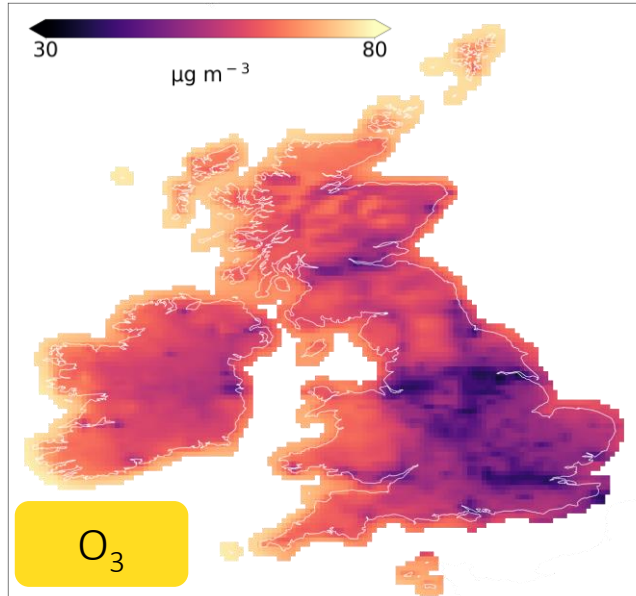
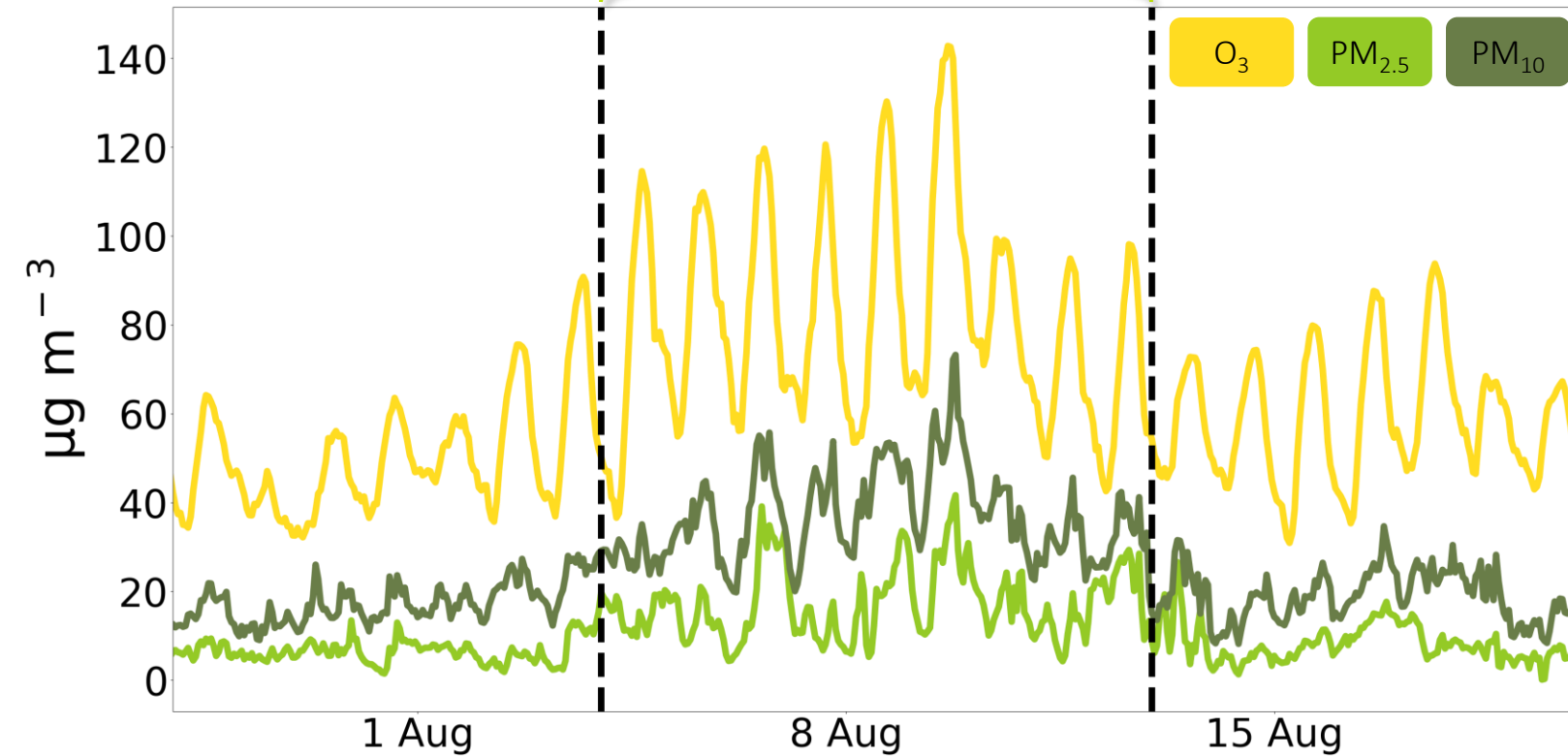averaged from hourly data between 1st January 2003 and 31st December 2019 →

Analysis

Long Term Trends
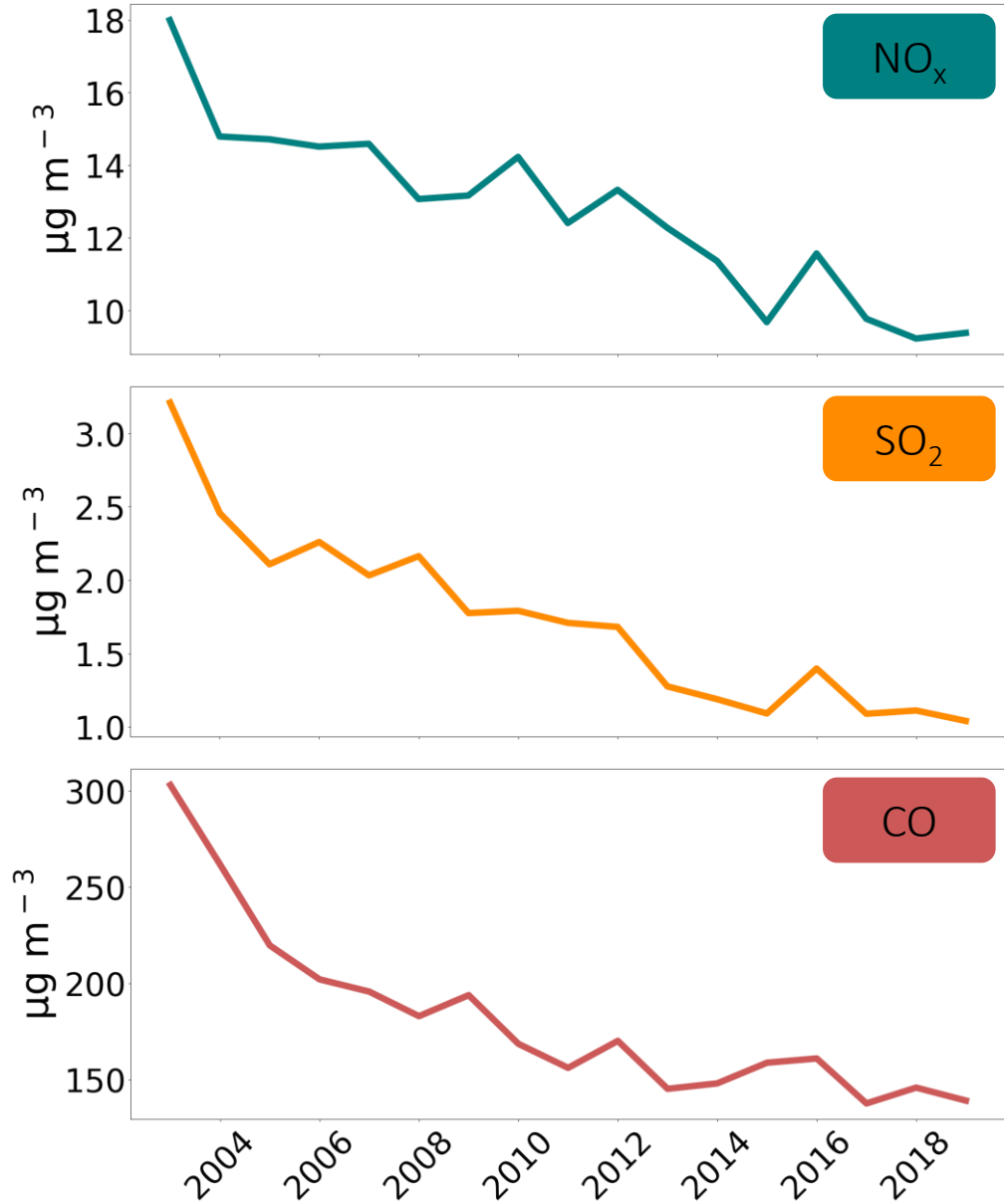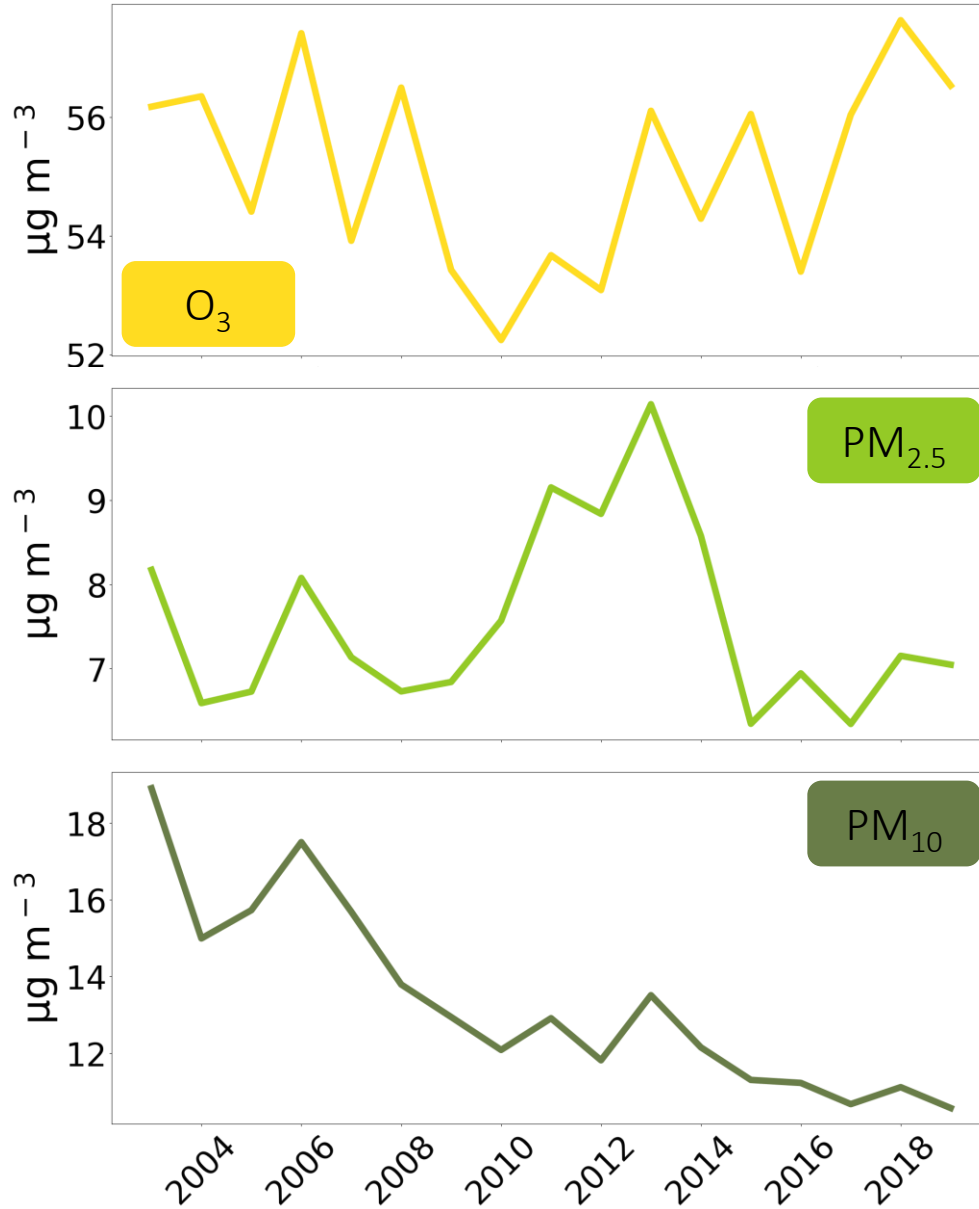
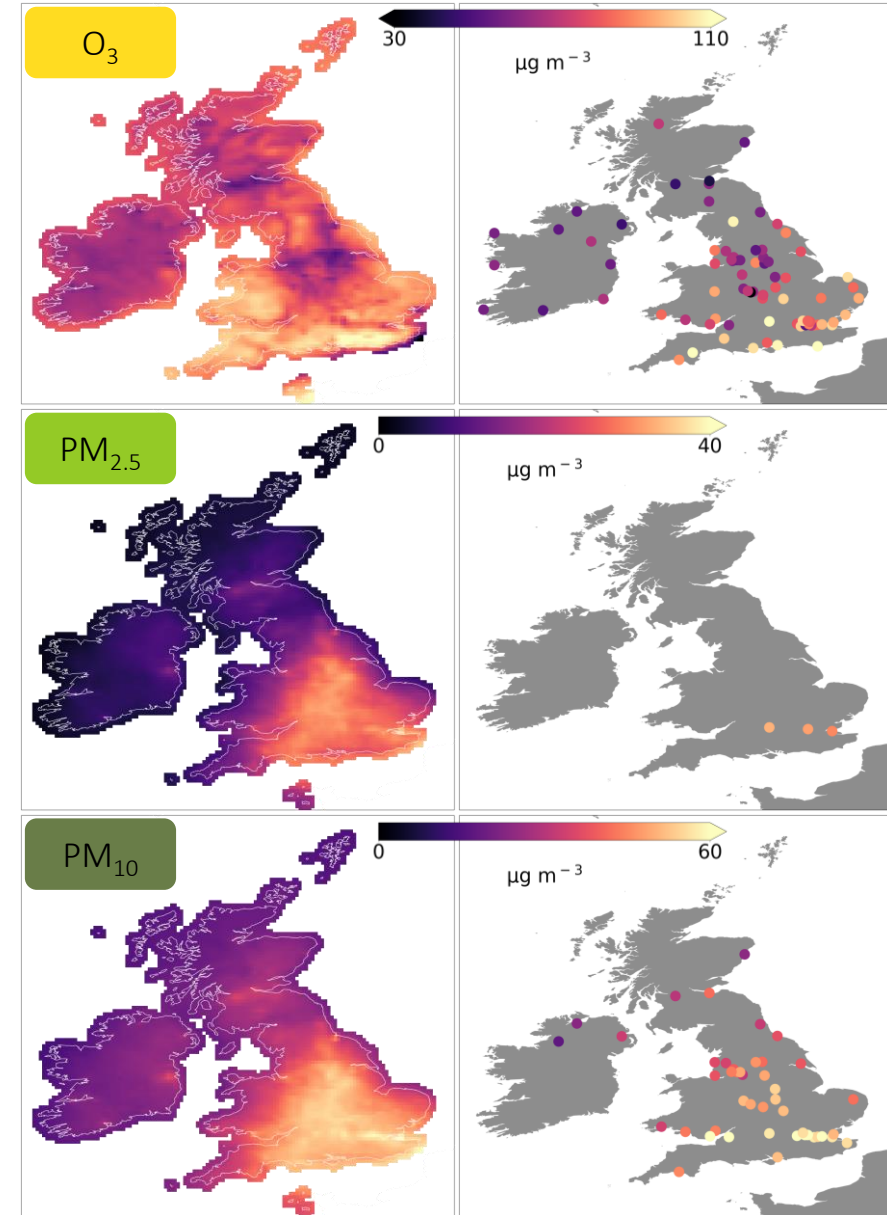annual mean from hourly data averaged over all UK land-based locations →
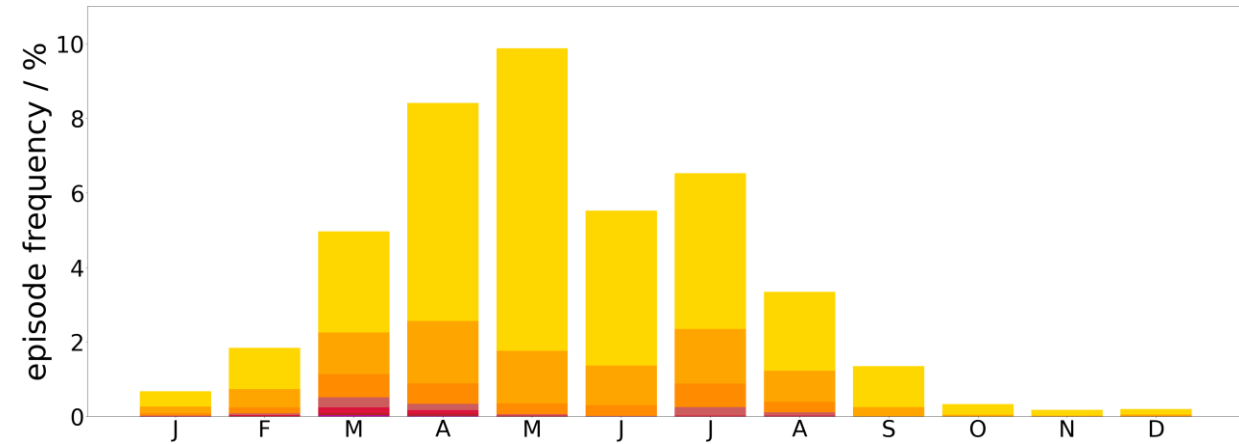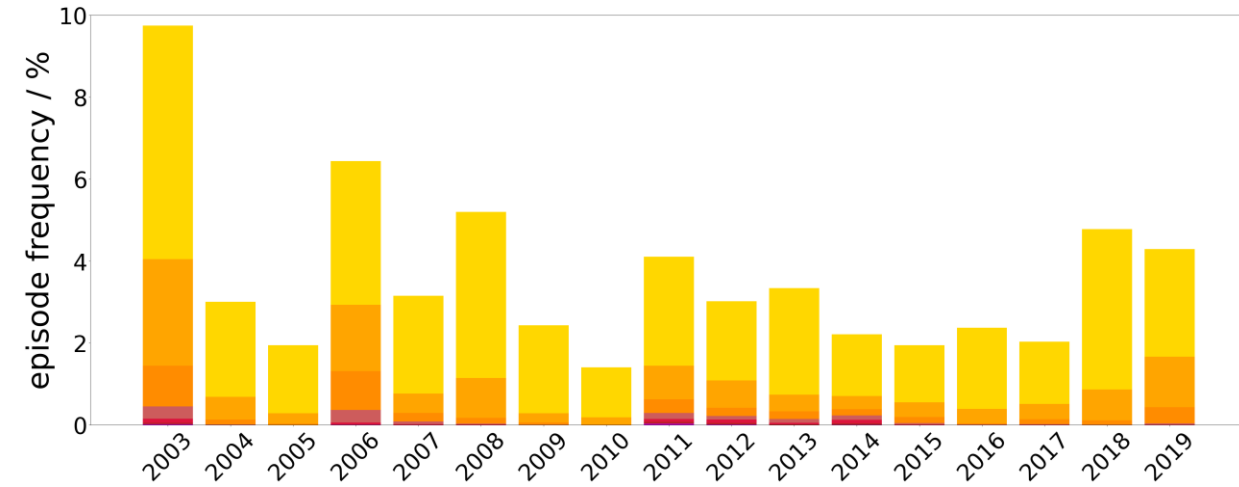
August 2003 Pollution Episode

Pollution Episodes

Daily Air Quality Index

4	5	6	7	8	9	10
	Moderate			High		V. High

↑ average proportion of time that a typical land-based location in the UK experiences these indexes of air pollution

species contributing to the pollution episodes …

O_3

$PM_{2.5}$

PM_{10}
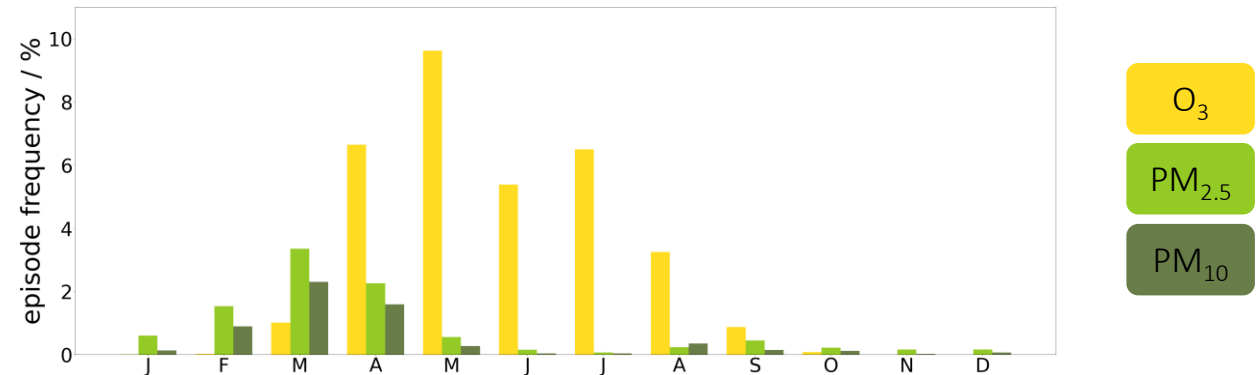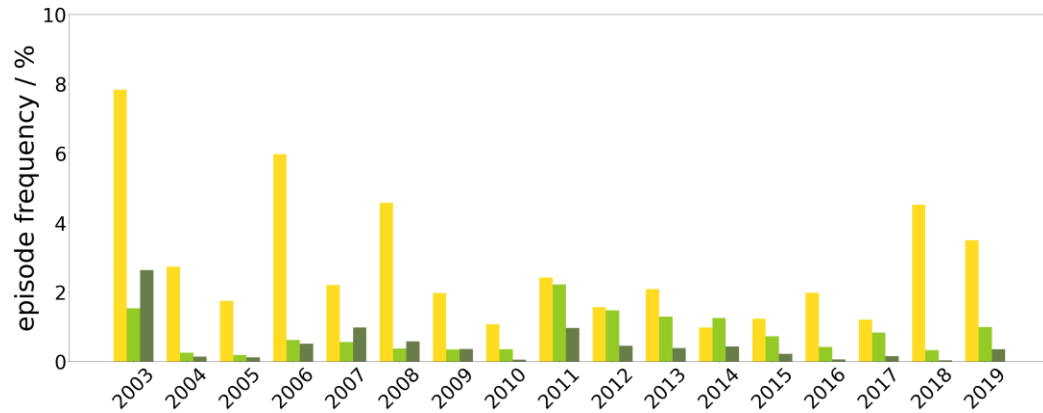
The reanalysis data is available to interact with via the Air Quality Data Portal

https://air-quality-1-themetoffice.hub.arcgis.com/

A paper on the reanalysis dataset is being prepared for submission

The full dataset will soon be available on the CEDA Archive
Data is currently available on JASMIN – please contact us to request access
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