Atmospheric blocking and impacts on ozone air quality in Europe: Present-day and under Climate Change

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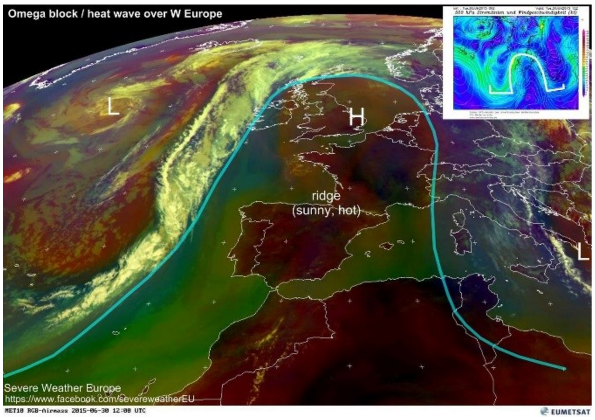
Project background

Atmospheric blocking occurs when the same weather pattern repeats for several days and even weeks. This persistence can lead to extreme weather conditions, such as heatwaves in summer and cold spells in winter. Blocking typically occurs over large regions associated with anticyclonic high-pressure, since high pressure systems cover a large spatial area and move very slowly. Anticyclones can evolve into blocking highs as they “block” the path of mid-latitude low pressure systems (storms). Besides affecting temperatures, blocking high pressure systems create favourable stagnant weather conditions for air pollution episodes - in particular, stagnation in combination with clear sunny weather in summer can lead to elevated surface ozone levels. Both air pollution and heat waves have severe impacts on human health from heat and air pollution related mortality. The figure below shows an atmospheric block, diagnosed by patterns in the large-scale meteorology - here the geopotential height (GPH) field at 500 hPa - bringing warm air from the southern Atlantic to Western Europe that led to heatwave conditions in Europe on July 6th 2015[1].



Recent work by Webber et al. (2016)[2] quantified the relationship between Rossby Wave Breaking (RWB) events (that lead to blocking through the generation of an anomalously high pressure system over Western Europe) and Particulate Matter (PM_{10}) levels over the UK in winter. However, the relationship between regional air pollution ozone episodes and large-scale blocking in summer has not yet been examined.

Future changes in the frequency of these blocking high pressure systems will also have consequences for human health effects due to changes in weather and air quality extremes. Masato et al. (2013)[3] report a decrease in European blocking frequency in summer in the late twenty-first-century from simulations performed with 12 Global Climate Models (GCMs). However, using a “stagnation” metric based on local meteorology (surface and 500 hPa winds), Horton et al. (2014)[4] report no-change/increase in annual-mean stagnation frequency in the late twenty-first-century from 15 GCM simulations over Europe. Hence, the relationship between changes in blocking and stagnation episodes due to climate change remains uncertain[5].

The aim of this project is to provide new understanding of the relationship between summer blocking frequency and duration, stagnation and ozone pollution episodes over Europe.

Key Research Questions

1. What atmospheric processes are the drivers of present-day blocking in summer in the Northern Hemisphere?
2. How are summer blocking statistics (frequency and duration) related to ozone air pollution episodes across Europe for present-day?
3. How are blocking and stagnation likely to change in the future and how are these related?
4. Are changes in ozone air pollution episodes driven by changes in blocking and stagnation?

Methodology

The project will make use of a range of observational datasets for present-day analyses, including meteorological and chemical reanalysis data from ECMWF and CAMS (formerly MACC) as well as a novel gridded dataset by Schnell et al. (2015)[6] of ozone air quality extremes for 2000-2009, and EMEP monitoring station measurements. For studying climate change impacts the project will utilise a suite of available GCM experiments, such as those from the IPCC CMIP5 and ACCMIP archives (already acquired by or available to the supervisors). The project will involve several phases which may vary depending on the student's interest:

Phase 1: diagnosing summer blocking in present-day reanalyses data based on previous research experience and the literature and producing frequency and duration statistics.

Phase 2: analysing ozone extremes gridded data and ozone station data and linking these to blocking results to establish relationships between blocking and ozone air pollution.

Phase 3: evaluating summer blocking and stagnation in CMIP5 models, and ozone episodes from ACCMIP models. The latter will benefit from ongoing collaborations with ACCMIP modellers.

Training

A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The student will attend relevant atmospheric science courses in GeoSciences as part of their PhD-specific training as well as Fortran/IDL/Python courses. From their supervisors, the student will develop expertise in atmospheric dynamics and climate analysis especially in understanding and investigating the mechanisms associated with blocking formation as well as atmospheric chemistry relating to ozone and climate-chemistry interactions. The student will be an active component of the Contemporary Climate group and, as such, will be provided and trained in using state-of-the-art observational datasets, models, and analysis tools. With an external supervisor at the University of Reading the student will benefit from leading expertise and ongoing research in the area of large-scale atmospheric processes related to blocking and the mid-latitude jet-streams. The student will be encouraged to attend relevant NERC summer schools (e.g. NCAS Introduction to atmospheric science, NCAS climate modelling) and to present results at national/international scientific meetings. Several current PDRAs/PhD students at both universities use these atmospheric datasets hence the students will benefit from their peers.

Requirements

The project would suit a student with a strong physical sciences background (Physics, Maths, Chemistry, Engineering), familiarity with programming, and interest in atmospheric and climate science and climate-air pollution interactions.

References

1. http://theconversation.com/explainer-the-omega-shaped-jet-stream-responsible-for-europes-heatwave-44268
2. Webber, C. P., Dacre, H. F., et al.(2016) *Atmos. Chem. Phys. Discuss.*, doi:10.5194/acp-2016-571.
3. Masato, G., B. J. Hoskins, T. Woollings, 2013: *J. Climate*, **26**, 7044–7059.
4. Horton et al. (2014), Nature Climate Change 4,698–703 (2014) doi:10.1038/nclimate2272.
5. Kirtman, B., et al., 2013: Near-term Climate Change: Projections and Predictability. In: Climate Change 2013: IPCC. Cambridge University Press, Cambridge, UK and NY, USA.
6. Schnell, J. L.,et al., *Atmos. Chem. Phys.*, 15, 10581-10596, doi:10.5194/acp-15-10581-2015, 2015.

Project Summary

This project will examine the drivers of atmospheric blocking in summer and its relationship with ozone pollution episodes in Europe for present-day, as well as the impacts of climate change.