Investigating long-term changes in European air quality in the satellite era

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Project partner(s): Rutherford Appleton Laboratory and National Centre for Earth Observation

Project Summary:

Over recent decades, European air quality legislation has led to the reduction of many air pollutants such as nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$ – particles with diameter of less than 2.5 µm). However, several observational studies (Chang et al., 2017; Ordonez et al., 2007; Pope et al., 2018) have shown that in Western Europe the secondary pollutant ozone (O_3), at the surface and in the free troposphere, has been increasing. This project will use atmospheric chemistry modelling and satellite observations of tropospheric O_3 to investigate which processes (e.g. emission of precursor gases and/or long range transport) are forcing these increases in Western European O_3 concentrations. The results will help quantify to what extent anthropogenic activities (e.g. emissions) are driving the trend in O_3 and how much can be explained by natural processes (stratospheric-tropospheric exchanges).

This PhD project will be supervised in Leeds by Prof Martyn Chipperfield, who leads an atmospheric chemistry modelling group, and by Dr Richard Pope, a researcher with the NERC National Centre for Earth Observation. The project will be co-supervised by Dr Brian Kerridge who leads the Remote Sensing Group at the Rutherford Appleton Laboratory. You will work with state-of-the-art models and satellite data.

Objectives:

The primary aim of this project is to improve our understanding of tropospheric ozone and how it influences European air quality using state-of-the-art satellite ozone products, produced by the Rutherford Appleton Laboratory (RAL – Case partner), and the TOMCAT chemistry transport (CTM) model. The research will:

1. **Analyse long-term trends in tropospheric ozone (and other related gases such as NO_2) using data from multiple satellite sensors.** Use multiple satellite records of different air pollutants (e.g. NO_2, carbon monoxide (CO) and O_3) to investigate long-term changes in European composition. Then evaluate the TOMCAT CTM to see if the model can reproduce the satellite observations (e.g. seasonal cycles) and observed trends.

2. **Perform model experiments to underpin the key processes governing trends in European ozone.** Undertake model sensitivity experiments to investigate what processes are driving changes in European ozone. For instance, 1) using artificial tracers to track inter-annual variability of stratospheric ozone influx into the troposphere, 2) perturbing surface emissions of precursor gases to quantify the sensitivity on tropospheric O_3 and/or 3) run the model with no chemistry to see the importance of transport over long time periods on the European O_3 distribution.

3. **Investigate the impact of European pollutant emission legislation of air quality and the associated health burden.** Run TOMCAT with a "no European emission legislation" scenario as in Turnock et al., (2015) and quantify the impact emissions legislation has had on European O_3. Health response functions, as used by Doherty et al., (2017), can be implemented to estimate the impact of European emission legislation on human premature mortality and morbidity.

Background:
Society is becoming increasingly aware of the dangers of poor air quality. Air pollutants, such as ozone (O_3), nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$ and $_{10}$—particles with diameter of less than 2.5 and 10 µm, respectively), can have significant impacts on human health. Exposure to significantly elevated levels of surface ozone can cause reduced respiratory function and cardiovascular problems. It is estimated that poor UK air quality results in approximately 40,000 premature deaths annually and costs society £8.5–20.2 billion per year.

A good understanding of air quality – to inform the public and policy makers - depends on extensive and accurate observations. However, measurements at the surface are sparse and do not provide information on how pollutants are transported at higher altitudes. Observations from satellite can provide this information but an important challenge is how to make use of the data that they provide. With the recent launch of TROPOMI on the Copernicus Sentinel 5P (13/10/2017), the use of satellite observations for air quality studies is set to increase significantly. **Figure 1** shows a map of satellite observed NO_2 concentrations over Europe highlighting how air quality can be monitored from space (i.e. detection of highly polluted regions such as London, Benelux and Po Valley).

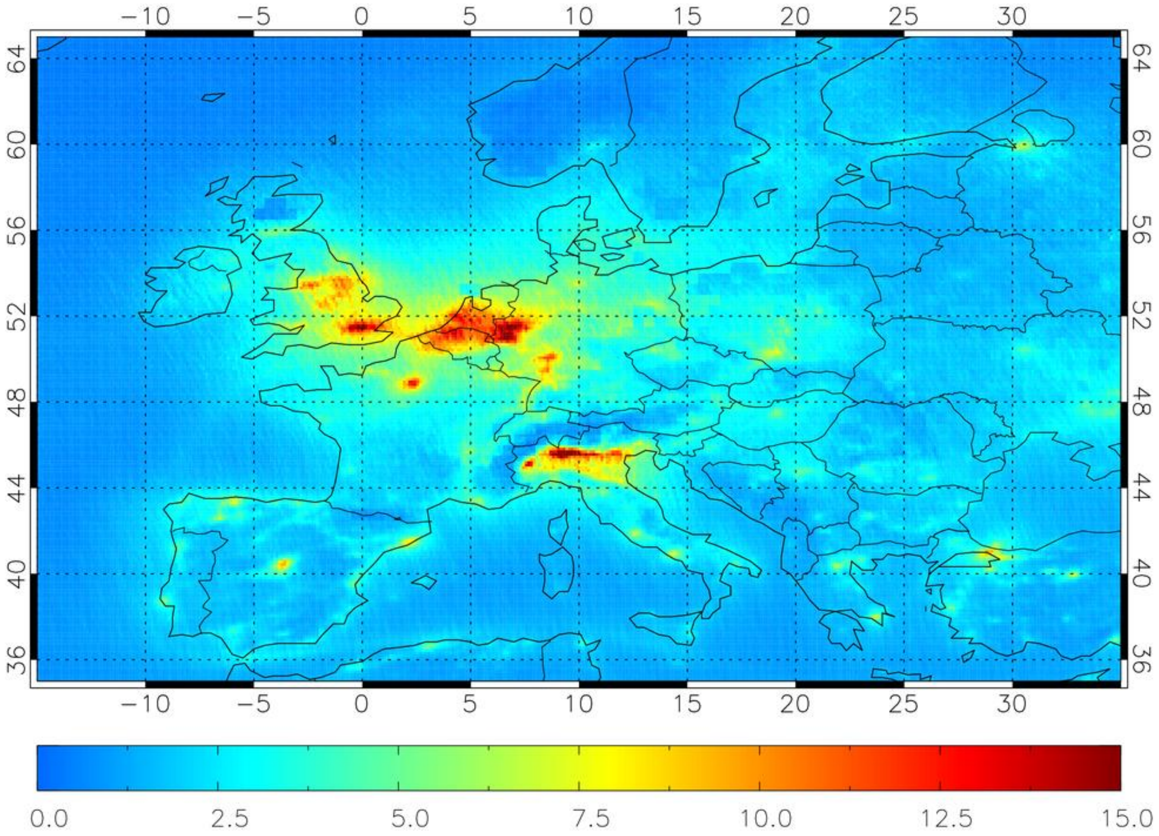

Figure 1: Satellite map of tropospheric column NO_2 (10^{15} molecules/cm^2), 2005-2013 average, over Europe measured by the Ozone Monitoring Instrument (OMI) on-board NASA's AURA satellite.

Multiple observational studies (Chang et al., 2017; Ordonez et al., 2007; Pope et al., 2018) have shown that (O_3) at the surface and in the free troposphere has been increasing in Western Europe. By using satellite observations, it possible to detect changes in air quality over a large region with good spatial coverage. Chemistry transport models (CTM), such as our in-house TOMCAT model, can be used to investigate the processes governing changes in surface tropospheric and surface O_3

(**Figure 2**) through model sensitivity experiments (e.g. perturbing model emissions of precursor gases).

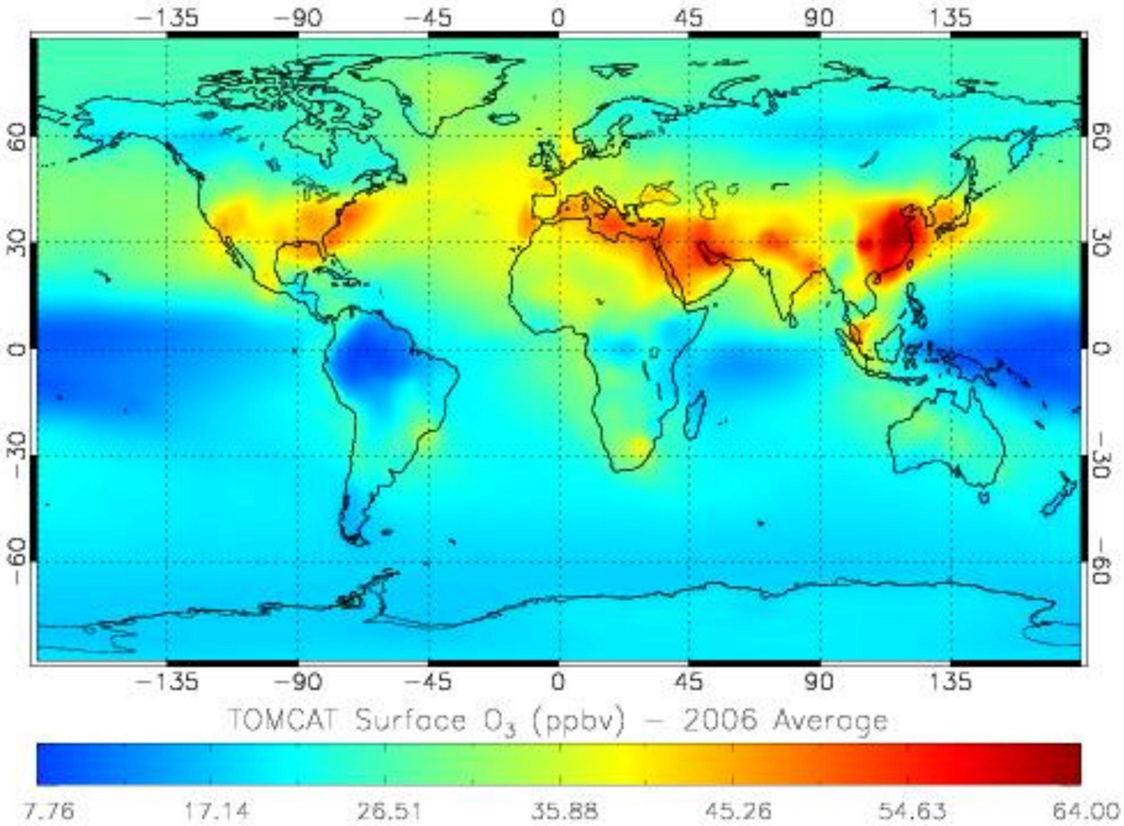

Figure 2: TOMCAT map of global surface O_3 (ppbv) for 2006.

References:

Chang et al., (2017) https://www.elementascience.org/article/10.1525/elementa.243/

Doherty et al., (2017) https://ehjournal.biomedcentral.com/articles/10.1186/s12940-017-0325-2

Ordonez et al., (2007) https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2006GL029113

Pope et al., (2018) https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/asl.817

Turnock et al., (2015) http://iopscience.iop.org/article/10.1088/1748-9326/11/2/024010/meta