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Detection of the Yorkshire power stations from space: tropospheric column NO_2

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1. Introduction:

Atmospheric pollutants such as NO_2, O_3 and particulate matter (PM_{10} and PM_{25} - atmospheric particles with a diameter of less than 10µm and 2.5µm, respectively) at sufficient surface concentrations are detrimental to human health. The World Health Organisation (WHO) state that O_3 can cause breathing and cardiovascular problems. NO_2 can cause reduced lung function and PM can lead to increased mortality and morbidity (WHO, 2014).

Power station emissions can have a significant impact on regional and local air quality (NO_2, SO_2 and PM). In Beijing, Hao et al. (2007) estimate that power stations emit 49%, 27% and 11% of city SO_2, NO_x (NO + NO_2) and PM_{10}, respectively. Mauzerall et al. (2005) show that emissions of NO_x from larger point sources (power stations) can significantly influence surface O_3 concentrations leeward of the source, which can be detrimental to human health in populated regions. Webb and Hunter (1998) found that between 1992 and 1996 UK power stations in the short term (hourly concentrations) rarely resulted in the exceedance of the WHO safe exposure limit of 104.6 ppb (approximately 200 µg/m^3 – WHO present day safety limit (WHO, 2014)) for NO_2. They suggest the risk of exceeding the WHO NO_2 limit was low and only likely in the case the power station NO_x plume coincided with an extreme ozone event.

In Yorkshire, UK, there are three large power stations; Drax, Eggborough and Ferrybridge. They have generating capacities of 3960 (Drax, 2014), 2000 (Eggborough Power Limited, 2014) and 980 MW (SSE, 2014), respectively. Figure 1a shows average UK tropospheric column NO_2 from the Ozone Monitoring Instrument (OMI) between 2005 and 2011. The peak concentrations are located over London ranging between 12 and 15 x 10^{15} molecules/cm^2. Both Manchester and Birmingham have significant tropospheric column NO_2 around 8-11 x 10^{15} molecules/cm^2. North East Yorkshire has similarly large concentrations, but there are no large cities nearby. We hypothesise that the higher levels of tropospheric column NO_2 here come from these power stations. Emissions data from Drax (Figure 1b) show that between 2008 and 2013 it produces approximately 38-40 kTonnes of NO_x annually (Drax, 2013). For 2012, according to the National Atmospheric Emissions Inventory (NAEI) (NAEI, 2014), Drax was the highest point source emitter of NO_x in the UK (Figure 1c). Ferrybridge C and Eggborough were the 9th and 10th highest point source emitters of NO_x.

Assessing the influence of these power stations on air quality is difficult as there are limited observations of pollutants in the North East Yorkshire region. The Department for Environment, Food and Rural Affairs (DEFRA) Automated Urban and Rural Network (AURN) (DEFRA, 2012) has no nearby sites and measurements from NO_2 diffusion tubes, recorded by local authorities, are limited to monthly sampling and are provided through DEFRA as raw, biased-uncorrected, data (DEFRA, 2015). Particulate matter was monitored around Drax, but stopped in 2008 (Selby Council, 2015). Therefore, satellite observations of air pollutants (OMI tropospheric column NO_2) are used in this study to investigate air pollution sources in the region. The white box in Figure 1a highlights the region of interest.

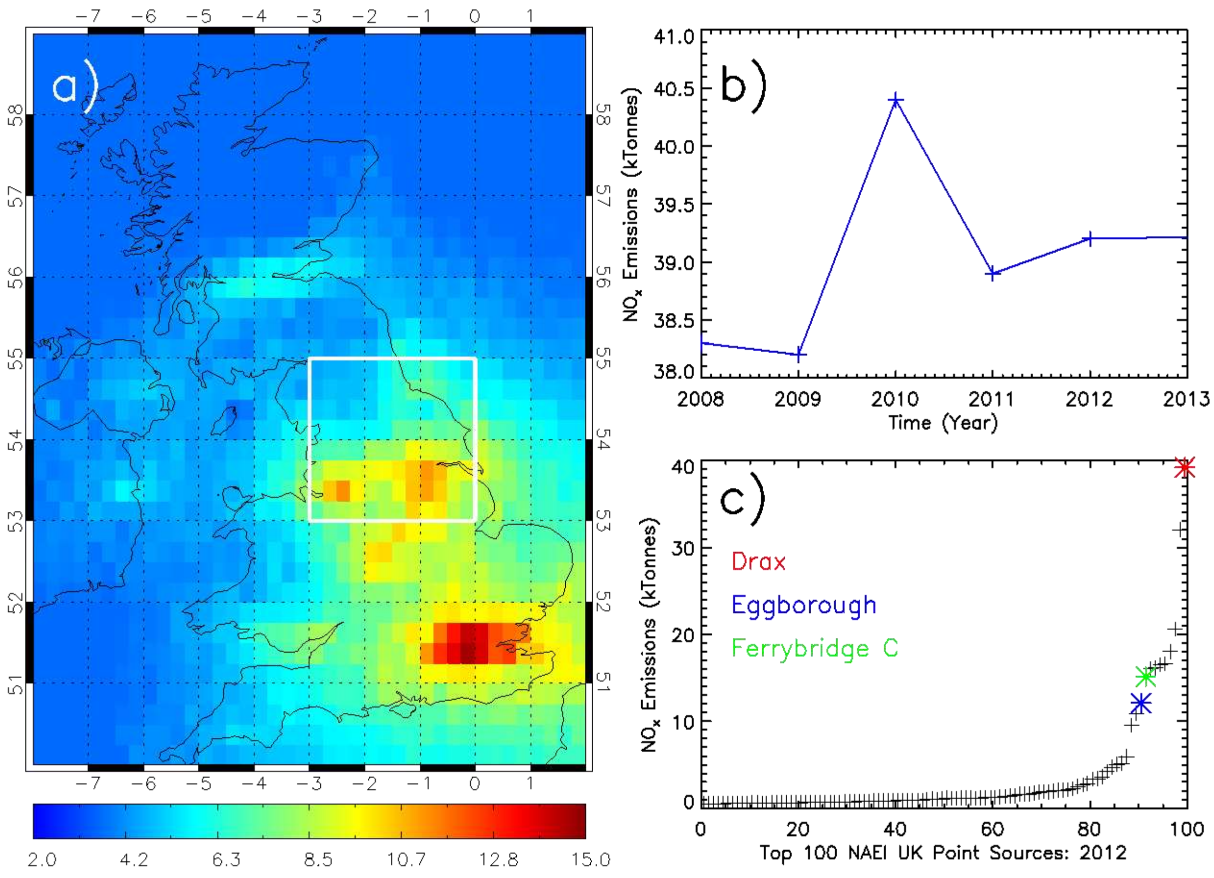

Figure 1: a) OMI tropospheric column NO_2 (x10^{15} molecules/cm^2) between 2005-2011over the UK, b) Drax NO_x emissions between 2008-2013 and c) top 100 NAEI NO_x point source emissions for 2012 (kTonnes).

Multiple studies have looked at the use of satellite data, i.e. NO_2 tropospheric columns, to monitor air quality. Pope et al. (2014) investigated OMI tropospheric column NO_2 over the UK, 2005-2011, and found that under anticyclonic conditions there is an accumulation of tropospheric column NO_2 over source regions, while under cyclonic conditions tropospheric column NO_2 is reduced. Zhou et al. (2012) used OMI tropospheric column NO_2, 2004-2009, to detect the UK days of maximum (Wednesday-Thursday) and minimum (Saturday-Sunday) tropospheric column NO_2. They also show that peak UK tropospheric column NO_2 is in February-March and minimum is in June-July. Beirle et al. (2011) used OMI tropospheric column NO_2 and wind forecasts (below 500m) to analyse NO_2 transport from the isolated megacity Riyadh, Saudi Arabia, detecting leeward NO_2 plume transport. Hayn et al., (2009) undertook a similar analysis of wind direction and tropospheric column NO_2 over Johannesburg, South Africa.

2. Satellite data:

OMI is mounted on NASA's EOS-Aura satellite and has an approximate London daytime overpass at 13:00 local time (LT). It is a nadir-viewing instrument with an average pixel size of 312 km^2.We have taken the DOMINO tropospheric column NO_2 product, version 2.0, from the TEMIS (Tropospheric Emissions Monitoring Internet Service) website, http://www.temis.nl/airpollution/no2.html (Boersma et al., 2011a & b). We have interpolated NO_2 swath data from 1st January 2005 to 31st December

2011 onto a daily 13:00 LT 0.125° × 0.125°grid between 53° – 55°N and 3°W– 0°. All satellite retrievals have been quality controlled for retrievals with cloud cover greater than 20% and poor quality data flags.

3. Results:

Figure 2a shows the 7-year average of OMI tropospheric column NO_2 over northern England. The background tropospheric column NO_2 ranges from below $2x10^{15}$ to $5x10^{15}$ molecules/cm^2 over the rural areas. The peak tropospheric column NO_2 is approximately 10-13 x 10^{15} molecules/cm^2 over the urban regions such as Manchester and North East Yorkshire. The North East Yorkshire peak tropospheric column NO_2 is located over the cluster of large Yorkshire power stations; Drax, Eggborough and Ferrybridge. The location of these power stations has been over plotted in Figure 2, correlating with the OMI peak tropospheric column NO_2. Therefore, this study hypothesises that it is the emissions of NO_x from these power stations, which are primary emitted or chemically converted, which result in the peak tropospheric column NO_2 in the region.

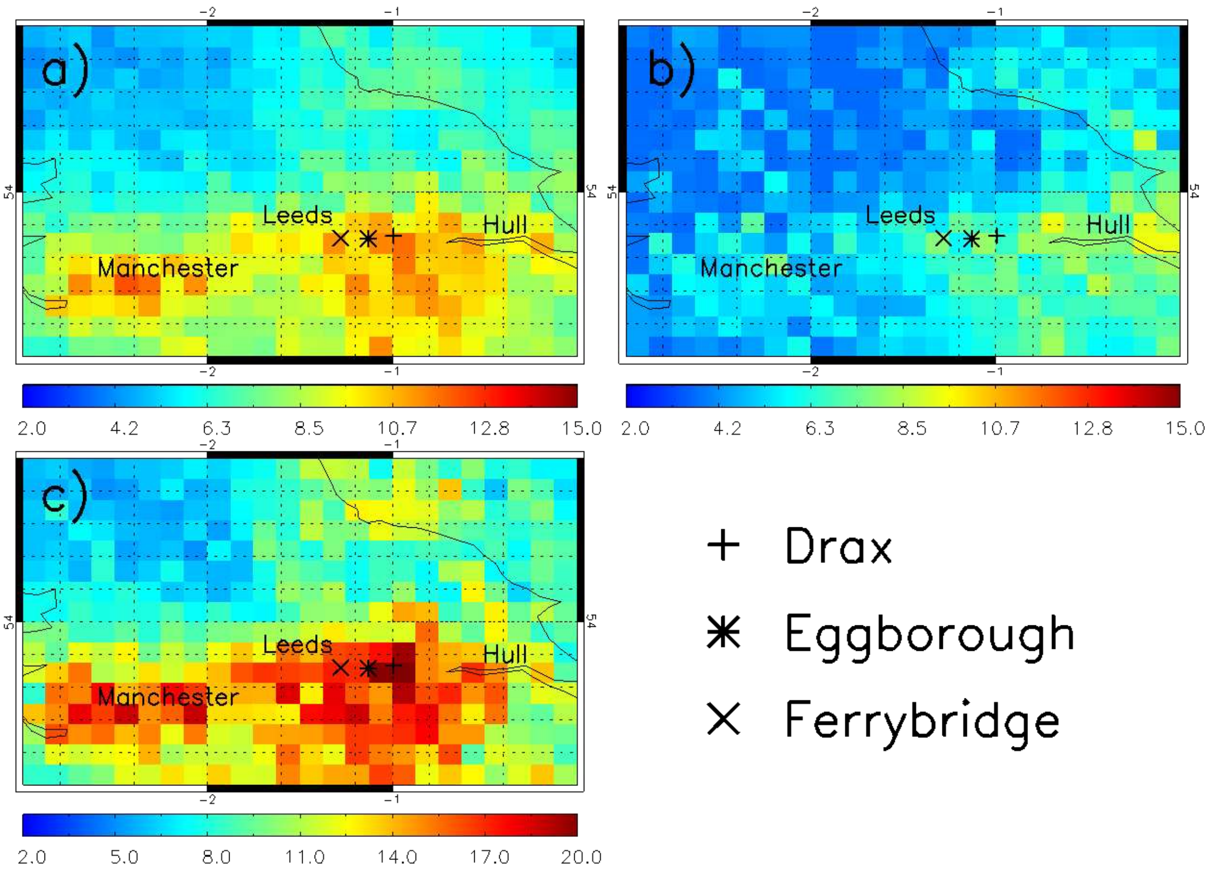

Figure 2: OMI tropospheric column NO_2 (x10^{15} molecules/cm^2), 2005-2011, over northern England: a) 7-year average, b) sampled under high wind speeds (>7.5 m/s) and c) sampled under low wind speeds (<2.5 m/s).

To see if these power stations are the cause of the elevated tropospheric column NO_2 in North East Yorkshire, the OMI data were sampled under days of high and low wind speeds. In the case of high wind speeds, leeward transport of tropospheric column NO_2 from the power stations would be expected. Under low wind speed conditions, accumulation of tropospheric column NO_2 would be expected over the power stations, as there would be limited transport of the pollution. To classify “low” and “high” wind speed days (wind speed sampled at midday to match the OMI overpass), surface wind speed data was taken from the Met Office HadISD database (Dunn et al., 2012 – available at http://www.metoffice.gov.uk/hadobs/hadisd/). Stations between 2°- 0.5°W and 53°-54.5°N were selected (16 stations in total) to approximately represent the average wind speed over Yorkshire each day. Days when the average wind speed was less than 2.5 m/s and greater than 7.5 m/s were classed as "low" and "high" wind speed days, respectively. Over the full time period, there were 242 and 506 days classed as "low" and "high" wind speed days.

Under the high wind speed conditions (Figure 2b), the domain tropospheric column NO_2 decreases to approximately 2-4 $x10^{15}$ and 6-10 $x10^{15}$ molecules/cm^2 in the rural and urban regions, respectively. The concentrations over the power stations range between approximately 6-9 $x10^{15}$ molecules/cm^2 and there appears to be a leeward transport of tropospheric column NO_2 away from the power stations and Hull out into the North Sea and over Lincolnshire. Though this study focuses on wind speed, not direction, climatologically speaking, the UK experiences westerly winds on average (Wheeler, 2013). The elevated NO_2 concentrations downwind of the power stations can also be caused by the reaction of NO with O_3 to produce more NO_2. Depending on the NO/NO_2 emission ratio from the power stations, this can enhance both NO_2 and O_3concentrations downwind of the NO_x source.

As for low wind speed events (Figure 2c), the concentrations are much higher. Over the rural and urban regions, tropospheric column NO_2 ranges between 5-8 $x10^{15}$ and 15-20 $x10^{15}$ molecules/cm^2, respectively. Note that the colour bar range for Figure 2c is larger than the other panels. The peak tropospheric column NO_2 is actually located over the Yorkshire power stations ranging between 18-20 $x10^{15}$ molecules/cm^2. As the transport influences are reduced in this case, the peak values, which are directly over Drax and Eggborough, are unlikely to be linked with transport of tropospheric column NO_2 from elsewhere in the domain. This suggests that these high concentrations are due to power station NO_x emissions. There are no large cities nearby (Doncaster is approximately 20 miles away) and the M62 NO_x emissions will not be as large (in the order of 0-10 kTonnes per year – NAEI, 2014). Therefore, this study suggests that NO_x emissions from Drax and Eggborough power stations are generating the largest regional NO_2 concentrations. Unfortunately, as the satellite product provides column concentrations, it is difficult to comment on surface NO_2 from these results. However, the emission of NO_x from the power stations will be in the boundary layer and quantities will be mixed down to the surface affecting air quality. The impact of power station emissions on local air quality (e.g. in-situ NO_2 and O_3 generated downwind (Mauzerall et al., 2005)) could be assessed in the future if surface measurements near the power stations became available (e.g. DEFRA AURN stations).

4. Conclusions:

This study uses surface wind data from Yorkshire weather stations to composite OMI tropospheric column NO_2 data (satellite data) under low and high wind speeds to investigate the impact of NO_x emissions from the large Yorkshire power stations on regional air quality. On average in the period 2005-2011, peak tropospheric column NO_2 is located over the urban regions (e.g. Manchester and Yorkshire power stations) in the domain. Under high wind speed conditions, reduced tropospheric column NO_2 exists across the domain, including the power stations, as it is transported away from source regions. The low wind speed events show peak tropospheric column NO_2 over Drax and Eggborough, where the lack of transport infers that these peak concentrations are linked to the power stations. These high tropospheric column concentrations of NO_2 from the power stations (largest levels in the domain) have the potential to significantly influence regional air quality. However, surface observations are required to assess the impact of the power stations on surface air quality.

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References:

Beirle S, Boersma KF, Platt U, Lawrence MG, Wagner T. 2011. Megacity Emissions and Lifetimes of Nitrogen Oxides Probed from Space. Science, **333**: 1737–1739.

Boersma K, Eskes H, Dirksen R, Veefkind J, Stammes P, Huijnen V, Kleipool Q, Sneep M, Claas J, Leit˜ao J, et al. 2011a. An improved tropospheric NO_2 column retrieval algorithm for the Ozone Monitoring Instrument. Atmospheric Measurement Techniques Discussions, **4**: 2329–2388.

Boersma K, Braak R, van der A R. 2011b. Dutch OMI NO_2 (DOMINO) data product v2.0. Tropospheric Emissions Monitoring Internet Service on-line documentation, http://www.temis.nl/docs/OMI_NO2_HE5_2.0_2011.pdf.

DEFRA. 2012. Automatic Urban and Rural Network (AURN). http://ukair.defra.gov.uk/networks/network-info?view=aurn (last accessed June 2014).

DEFRA. 2014. Diffusion Tubes. http://laqm.defra.gov.uk/diffusion-tubes/datacentre (last accessed June 2014).

Drax. 2013. Annual review of Environmental Performance. http://www.drax.com/media/56551/Environmental-Performance-Review-2013.pdf (last accessed June 2015).

Drax. 2014. Our history. http://www.drax.com/about-us/our-history/ (last accessed May 2014).

Dunn R, Willett K, Thorne P, Woodley E, Durre I, Dai A, Parker D, Vose R. 2012. HadISD: a quality controlled global synoptic report database for selected variables at long-term stations from 1973-2010. Climate of the Past, **8**: 1763-1833.

Eggborough Power Ltd. 2014. Welcome to Eggborough Power. http://www.eggboroughpower.co.uk/ (last accessed May 2014).

Hao J, Wang L, Shen M, Li L, Hu J. 2007. Air quality impacts of power plant emissions in Beijing. Environmental Pollution, **147**: 401-408.

Hayn M, Beirle S, Hamprecht FA, Platt U, Menze BH,Wagner T. 2009.Analysing spatio-temporal patterns of the global NO_2-distribution retrieved from GOME satellite observations using a generalised additive model. Atmospheric Chemistry and Physics, **9**: 6459–6477.

Mauzerall D, Sultan B, Kim N, Bradford D. 2005. NO_x emissions from large point sources: variability in ozone production, resulting health damages and economic costs. Atmospheric Environment, **39**: 2851-2866.

NAEI. 2014. Emission maps for the UK and DAs. http://naei.defra.gov.uk/data/map-uk-das (last accessed June 2015).

Pope RJ, Savage NH, Chipperfield MP, Arnold SR, Osborn TJ. 2014. The influence of synoptic weather regimes on UK air quality: analysis of satellite column NO_2. Atmos. Sci. Lett., **15**: 211–217.

SSE. 2014. Ferrybridge C. http://sse.com/whatwedo/ourprojectsandassets/thermal/ferrybridge/ (last accessed May 2014).

Selby Council. 2015. Air quality – monitoring and pollution control. http://www.selby.gov.uk/air-quality-monitoring-and-pollution-control (accessed April 2015).

Webb A, Hunter G. 1998. Power station contributions to local concentrations of NO_2 at ground level. Environmental Pollution, 102: 283-288.

Wheeler D. 2013. Regional weather and climates of the British Isles – Part 4: North East England and Yorkshire. Weather, **1**: 68-74.

WHO. 2014. Ambient (outdoor) air quality and health. http://www.who.int/mediacentre/factsheets/fs313/en/ (last accessed April 2015).

Zhou Y, Brunner D, Hueglin C, Henne S, Staehelin J. 2012. Changes in OMI tropospheric NO_2 columns over Europe from 2004 to 2009 and the influence of meteorological variability. Atmospheric Environment, **46**: 482–495.

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