

**SEE-Chem Meeting**  
**Tuesday 6<sup>th</sup> December 2016**

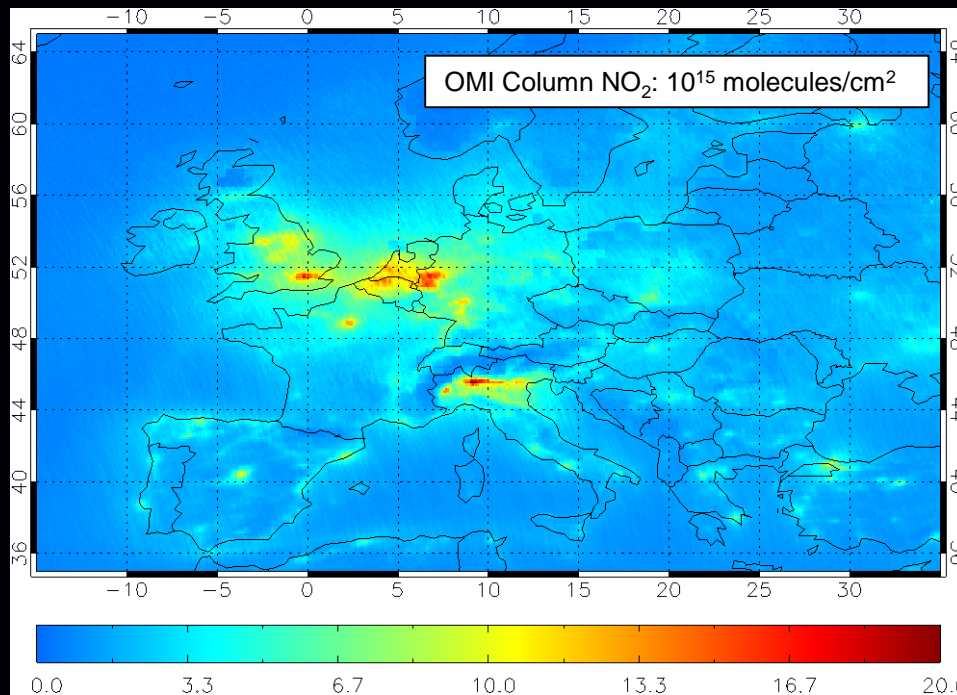


**School of Earth and Environment**



**School of Chemistry**

# Observing Air Quality from Space



## Presentation Outline:

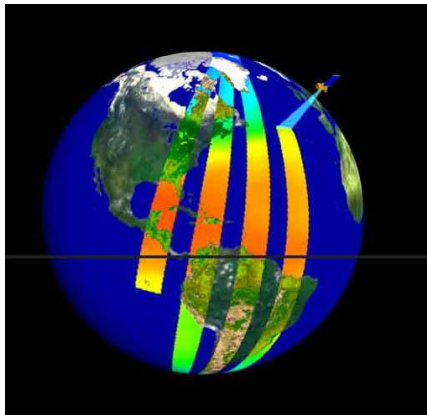
- Measurements
- Global air quality
- Regional air quality
- Satellite data and models

# Satellite Measurements:

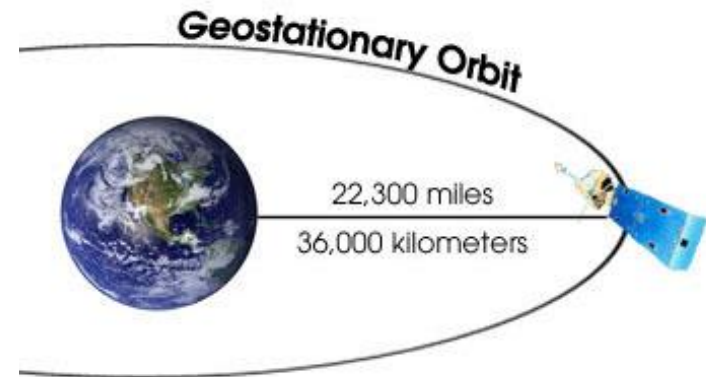


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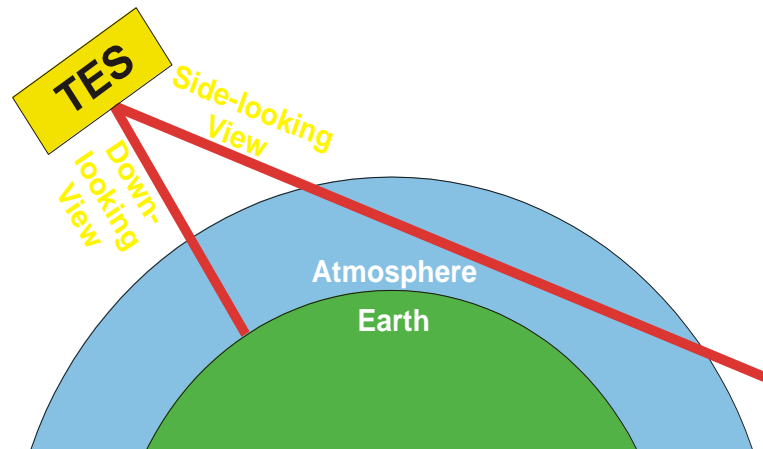
## Polar Orbits:



## Geostationary Orbits:



## Nadir Viewing:



## Limb Viewing:



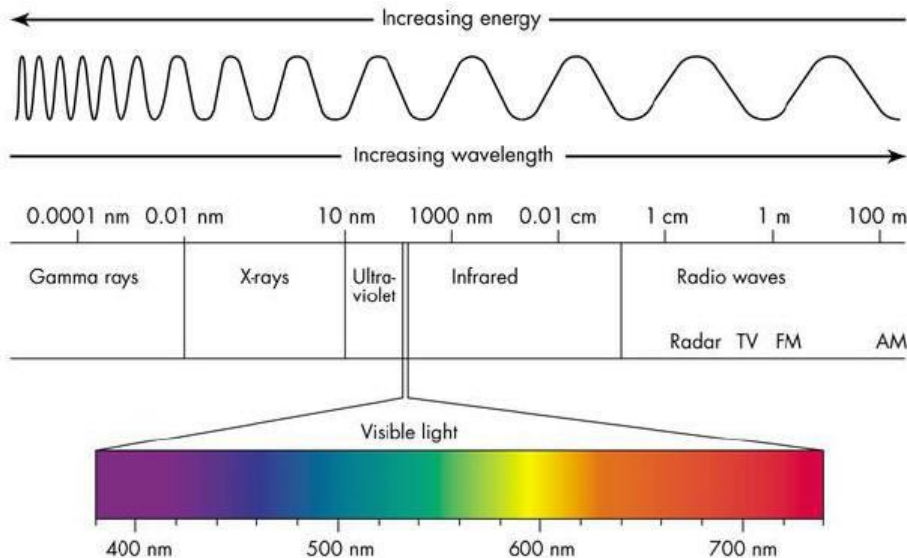
# Satellite Measurements:

## UV/vis/NIR:

- Sensitivity down to surface
- Limited number of species
- Daytime only
- Limited vertical resolution

## IR:

- Large number of species
- Day and night measurements
- Better vertical resolution in nadir
- Weighted to mid-troposphere



## Air Quality Products:

- Tropospheric NO<sub>2</sub>
- Sub-column (0-6km) O<sub>3</sub>
- Total Column HCHO and AOD
- PBL SO<sub>2</sub>
- Vertical O<sub>3</sub> and CO profiles
- UTLS PAN, Ethane, CO and O<sub>3</sub>

## Sources:

<http://www.temis.nl/index.php>

<http://reverb.echo.nasa.gov>



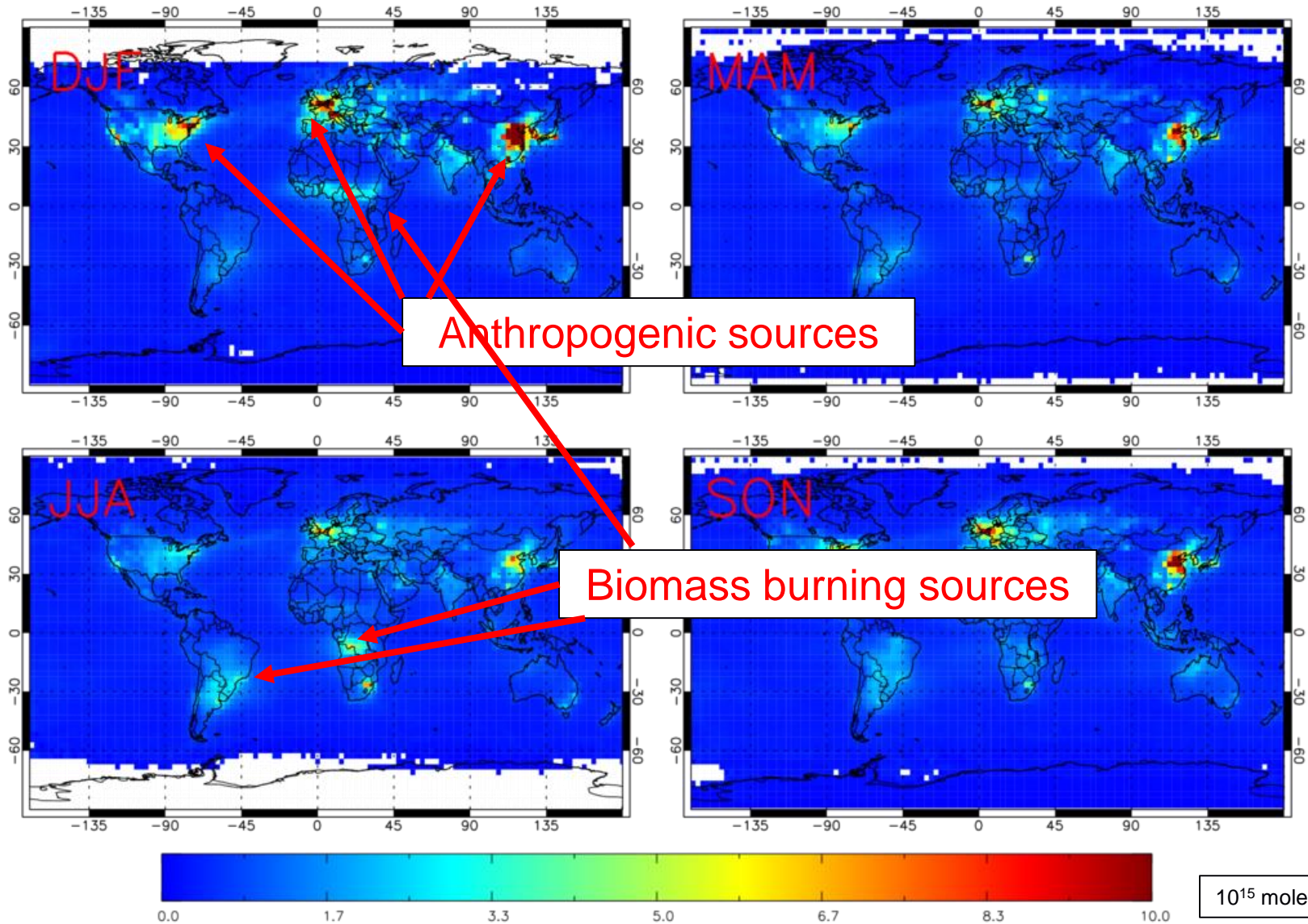
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# Global Air Quality

# Ozone Monitoring Instrument (OMI): Tropospheric Column NO<sub>2</sub>



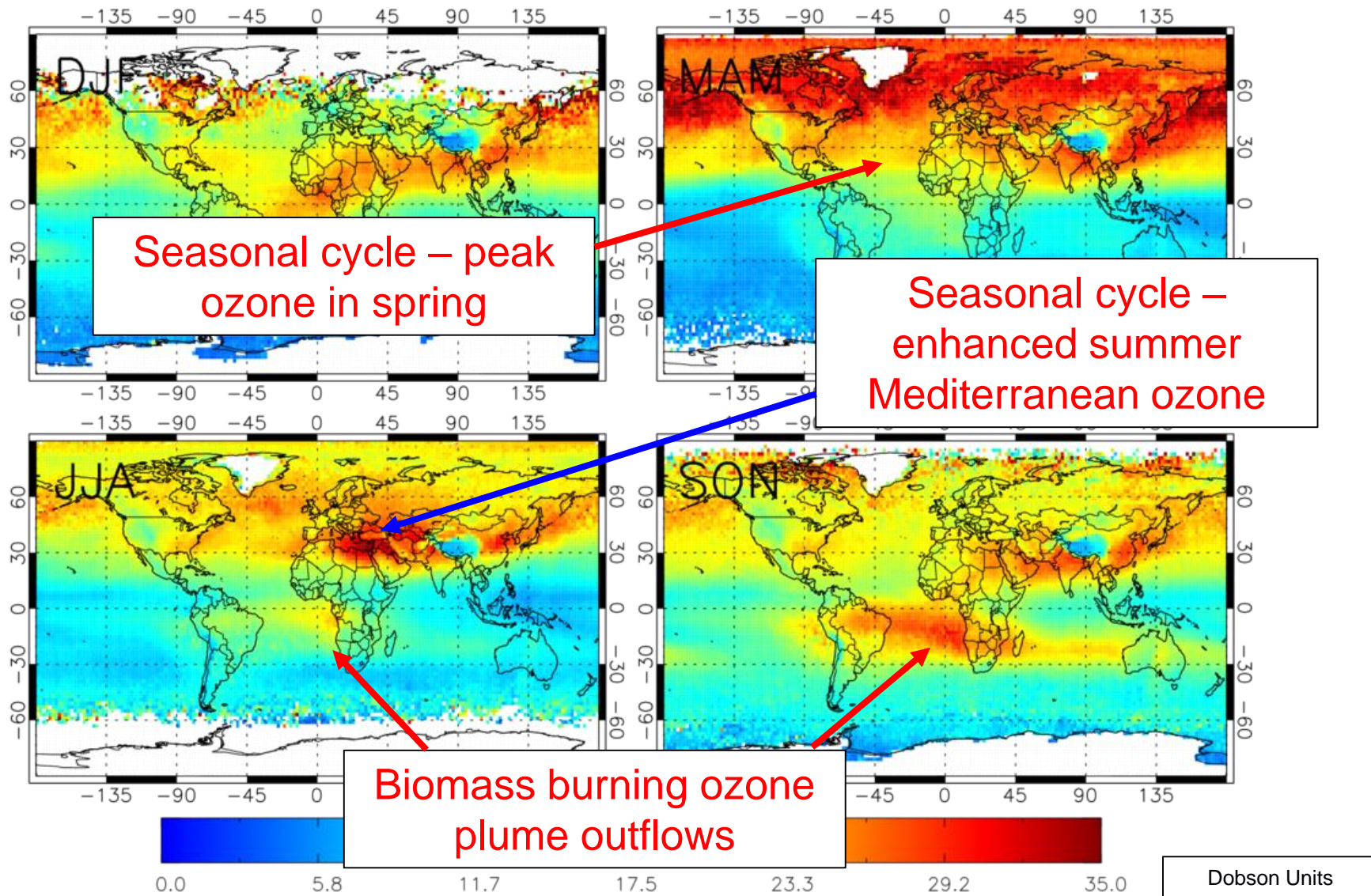
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# Global Ozone Monitoring Experiment-2 (GOME-2): 0-6km Subcolumn O<sub>3</sub>



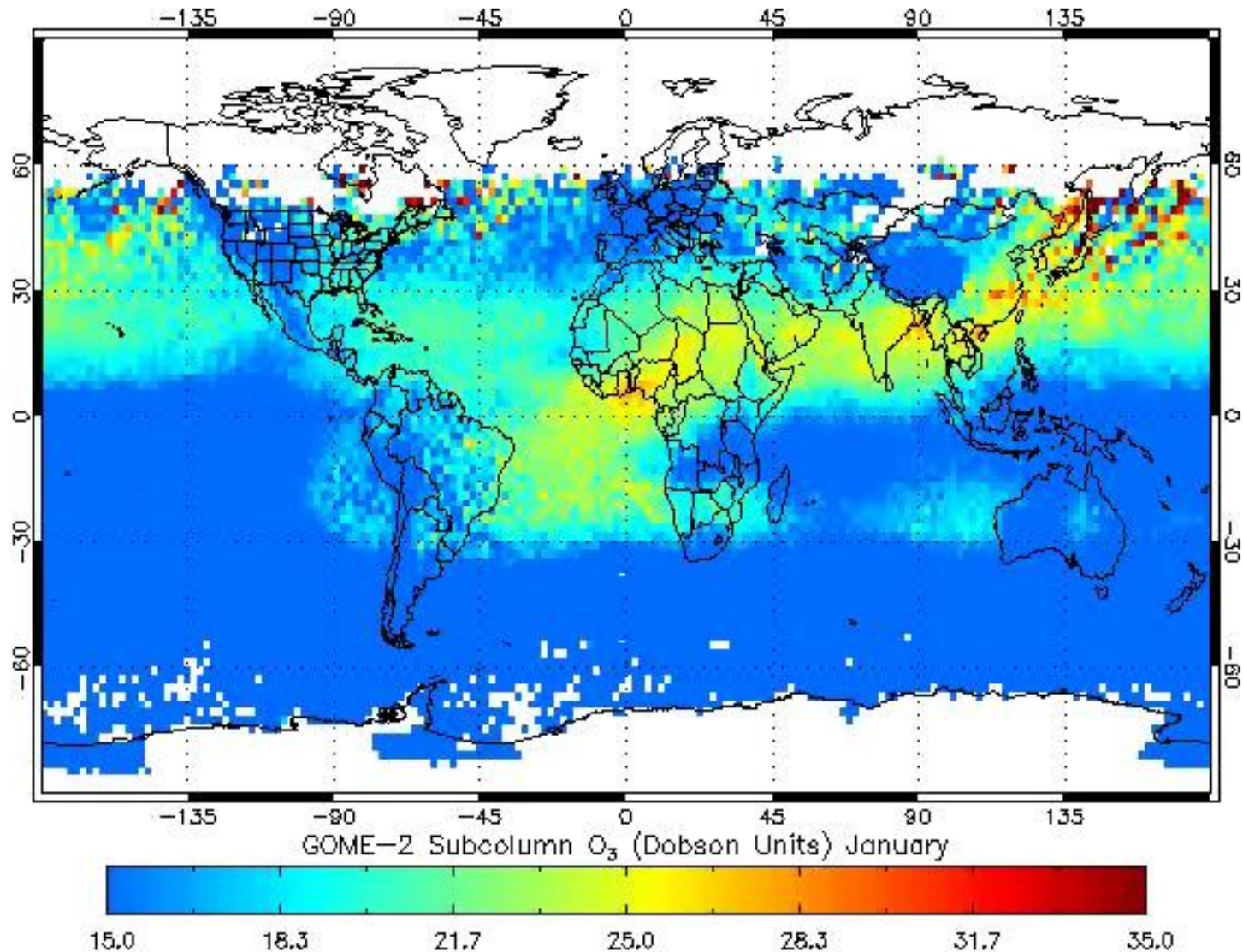
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# Global Ozone Monitoring Experiment-2 (GOME-2): 0-6km Subcolumn O<sub>3</sub>



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# MIPAS: Peroxyacetyl Nitrate at 150 hPa

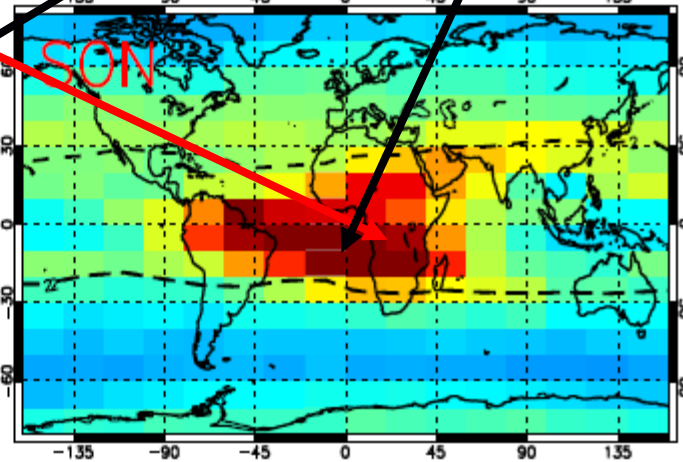
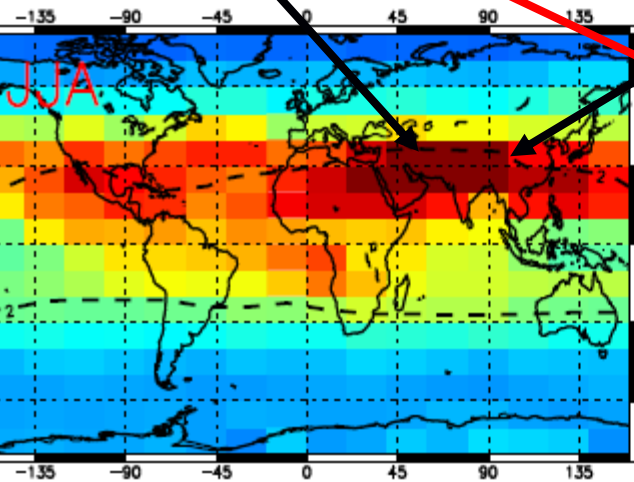
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Summer-time Asian monsoon

MAM

Long range transport of  $\text{NO}_x \dots \text{O}_3$  formation in clean regions

Biomass burning signals



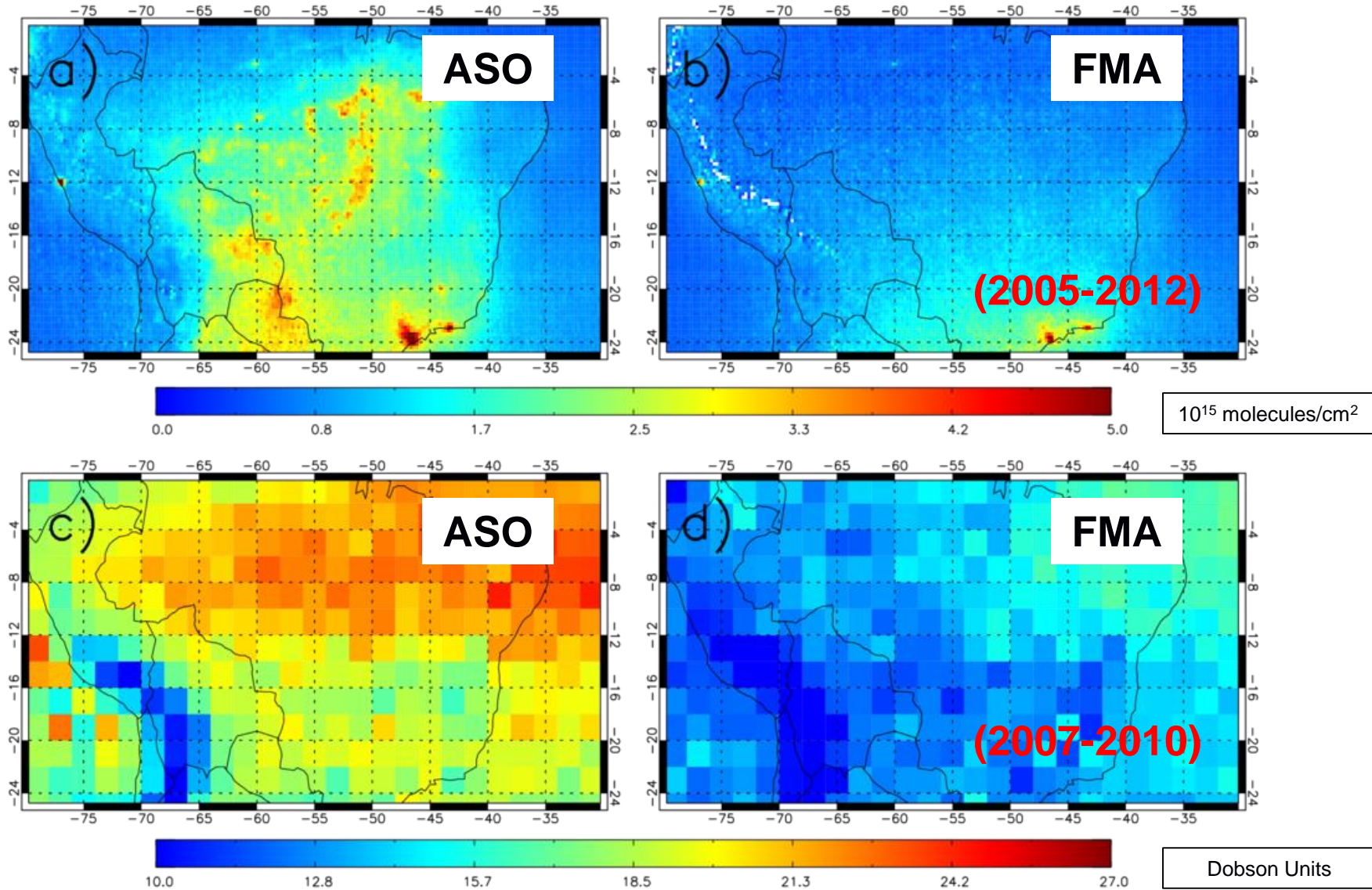


# **Regional Air Quality**

# South America Fires: Tropospheric $\text{NO}_2$ & Sub-column $\text{O}_3$



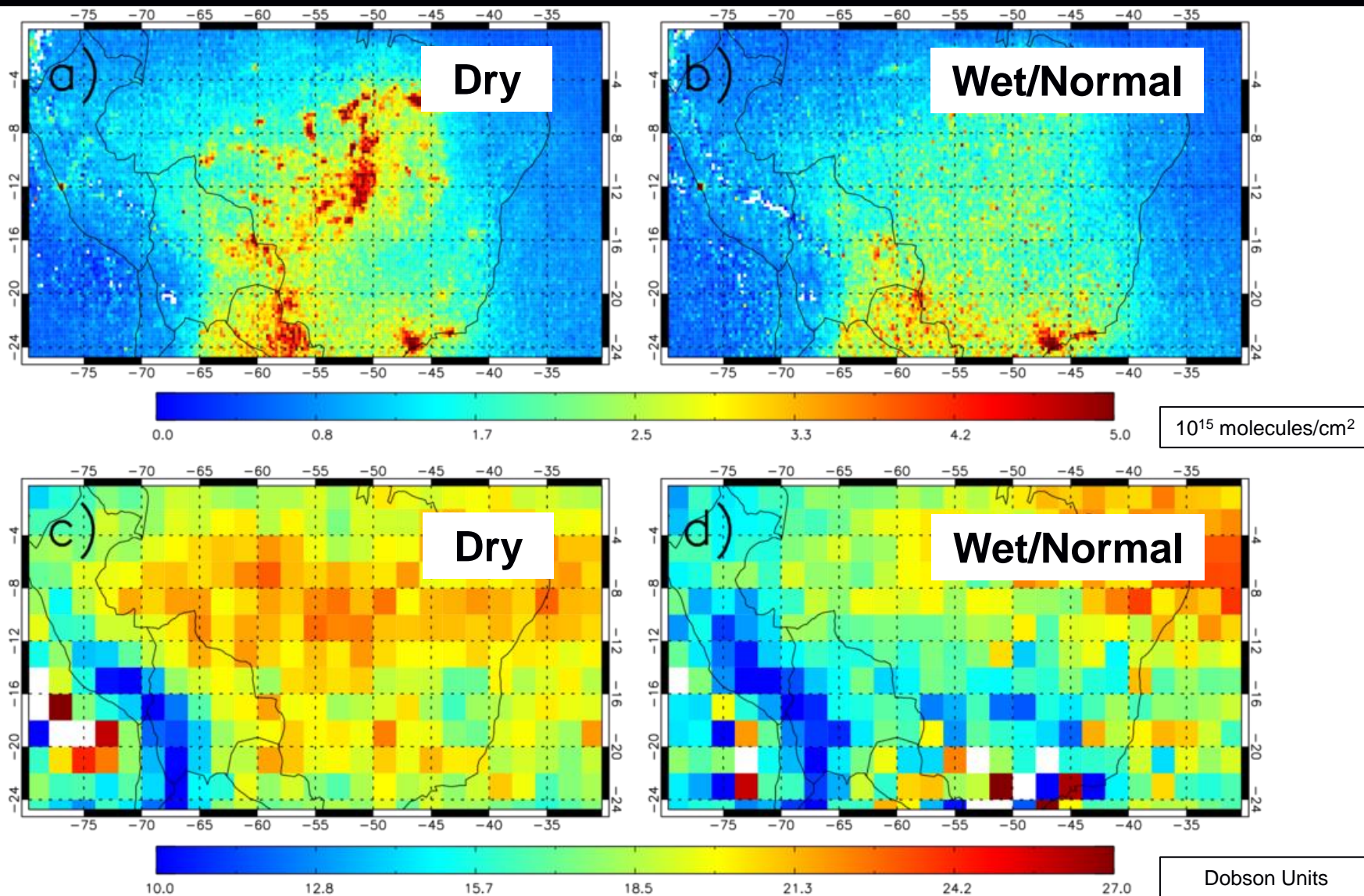
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# South America Fires: Extreme/Normal Biomass Burning Seasons



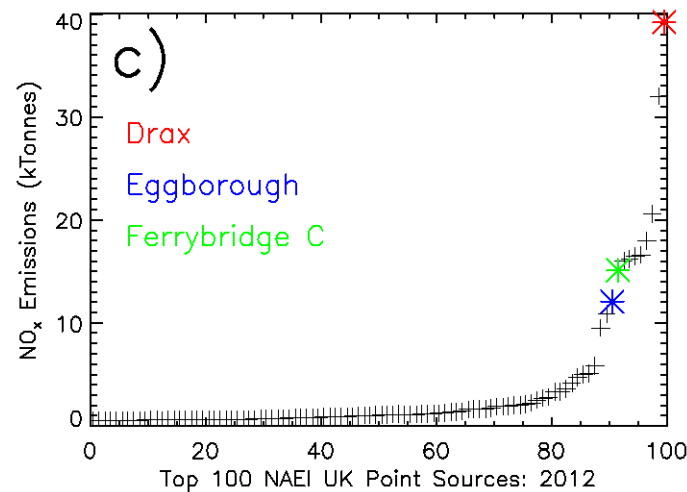
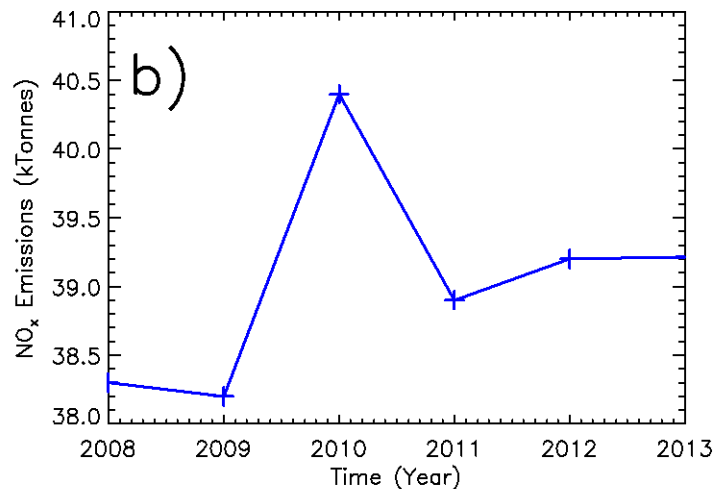
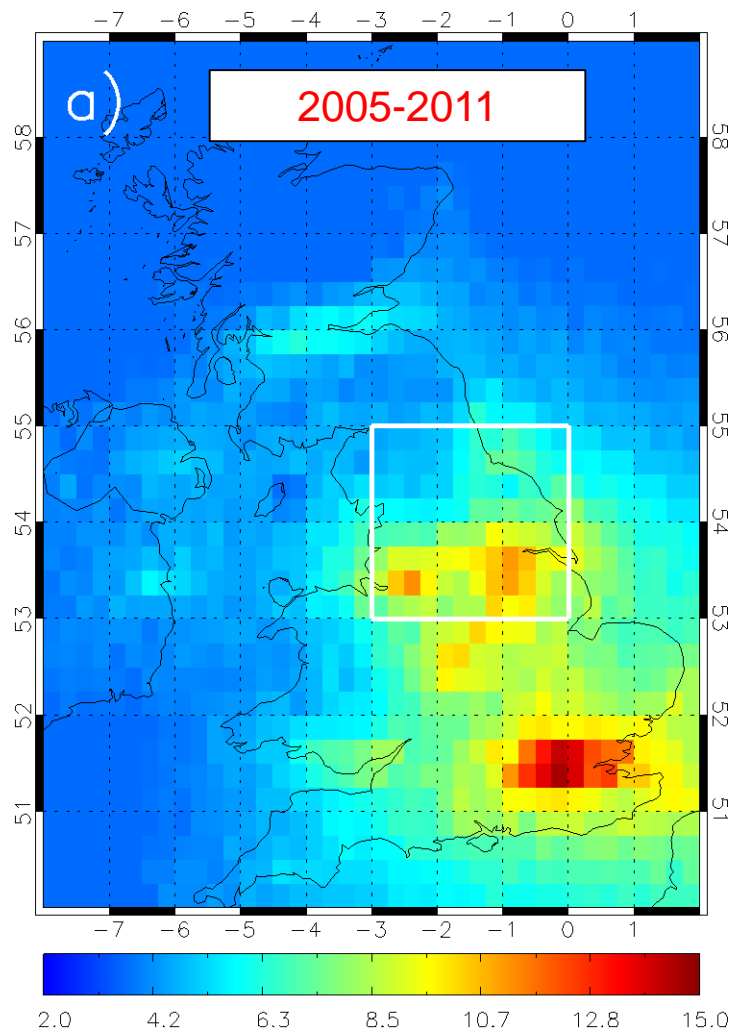
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# Yorkshire Power Stations: OMI NO<sub>2</sub>



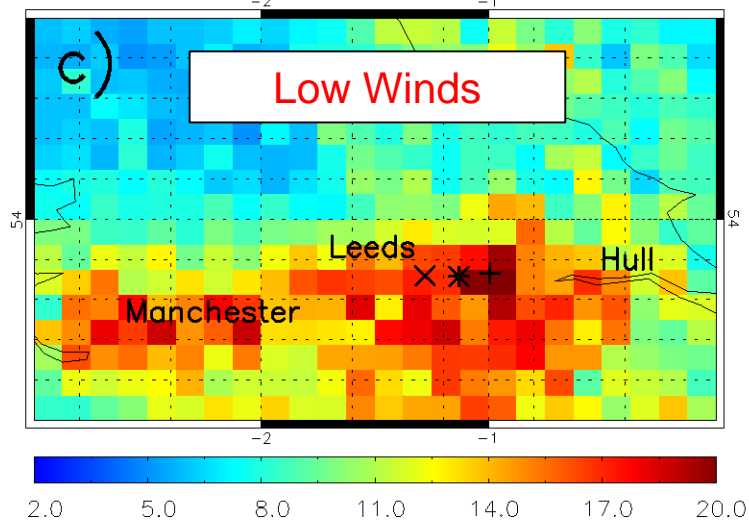
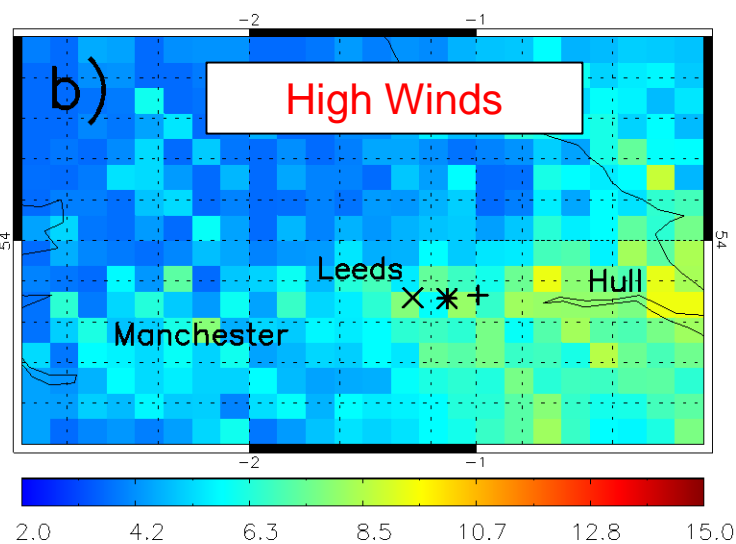
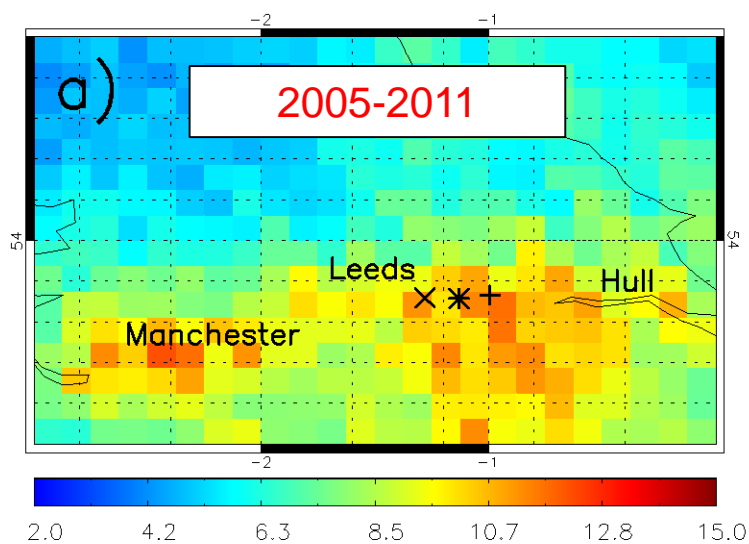
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# Yorkshire Power Stations:



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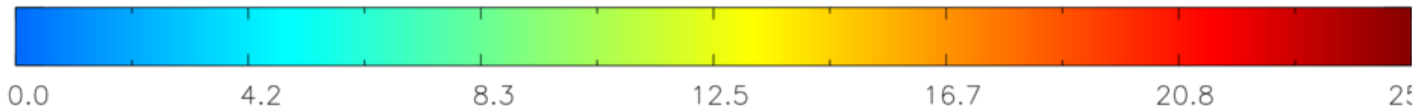
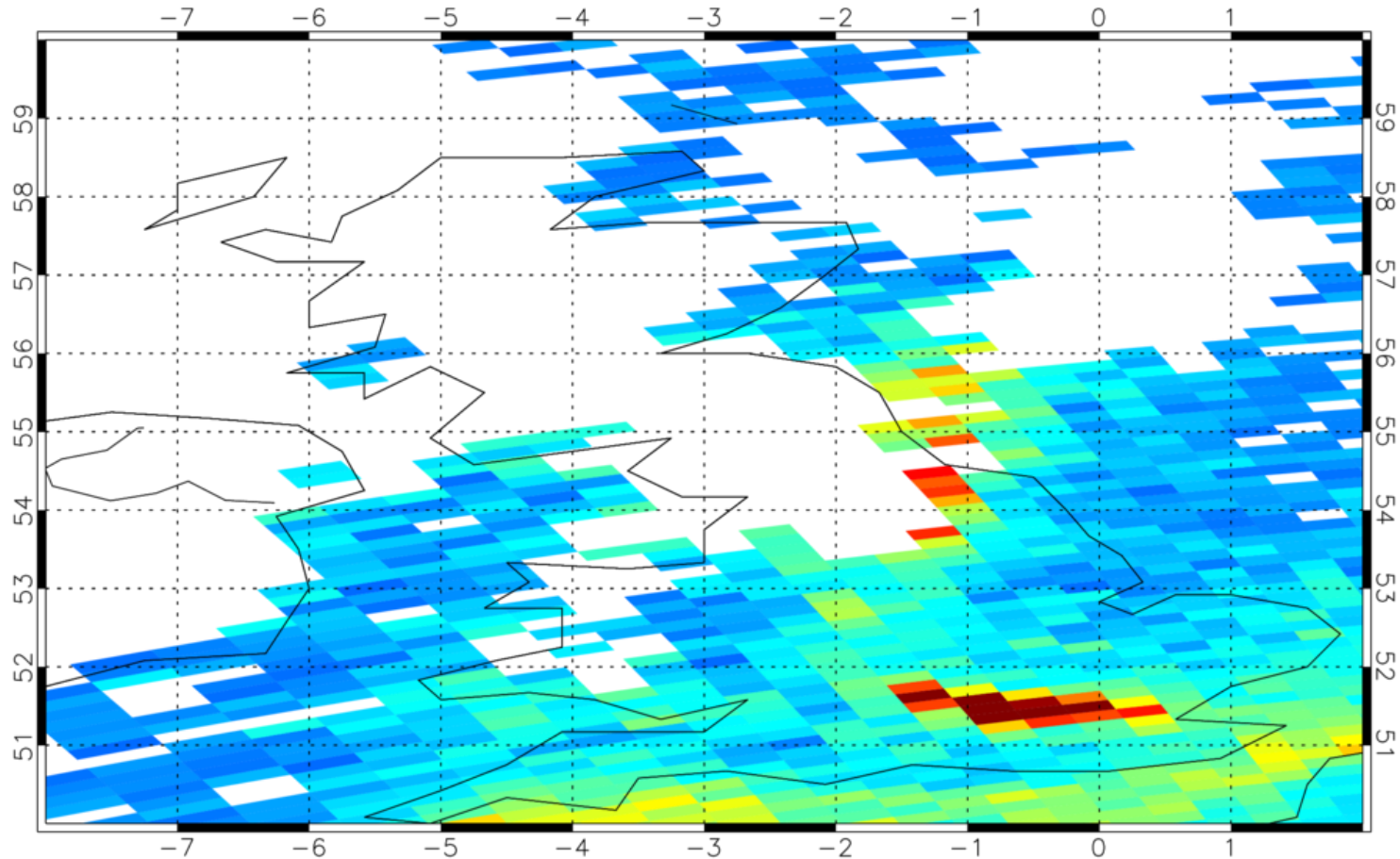


- + Drax
- \* Eggborough
- X Ferrybridge



# OMI Pixel Overlapping (22/06/2006):

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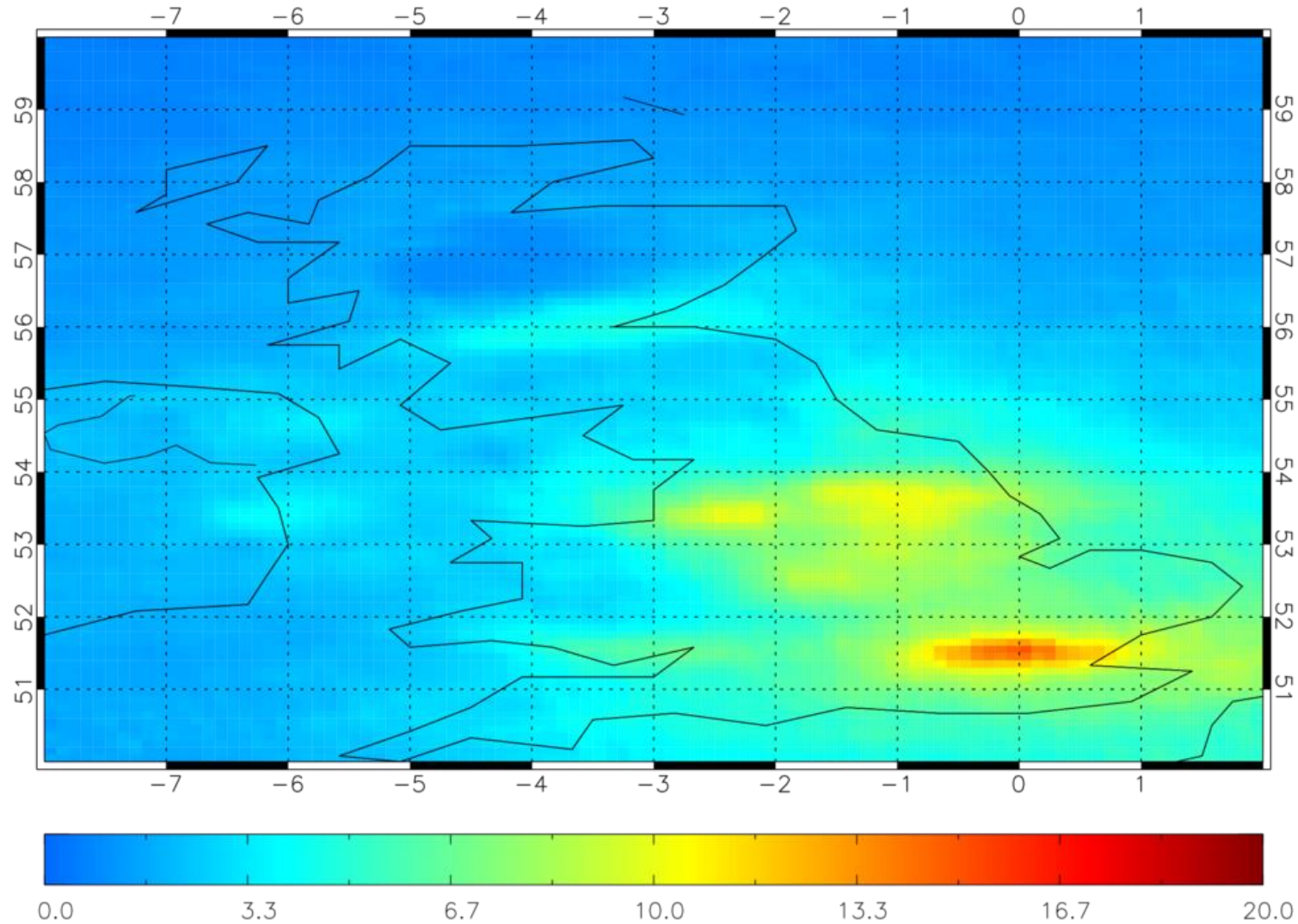


$10^{15}$  molecules/cm<sup>2</sup>

# OMI Pixel Overlapping (2006):



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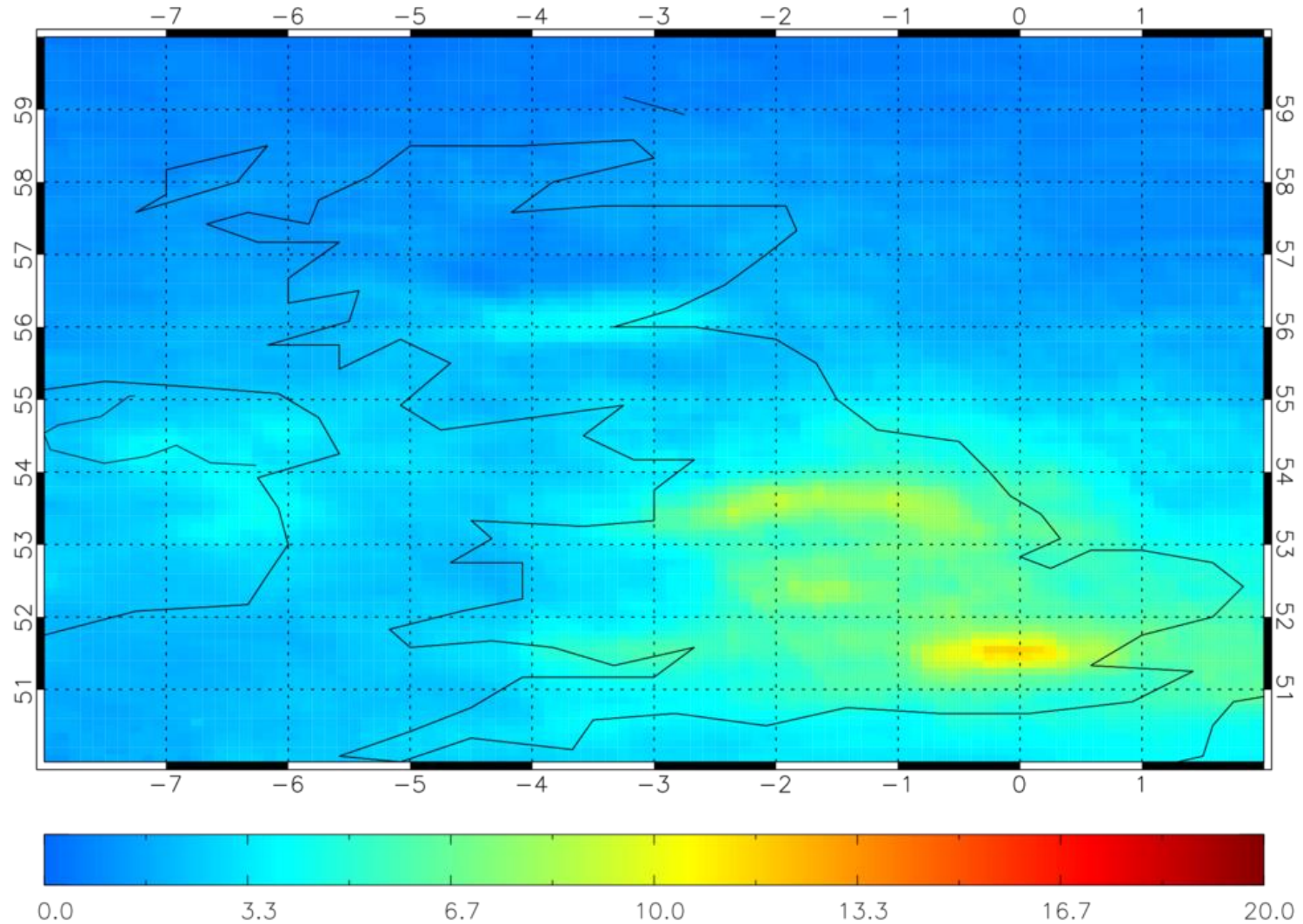
$10^{15}$  molecules/cm<sup>2</sup>





# OMI Pixel Overlapping (2015):

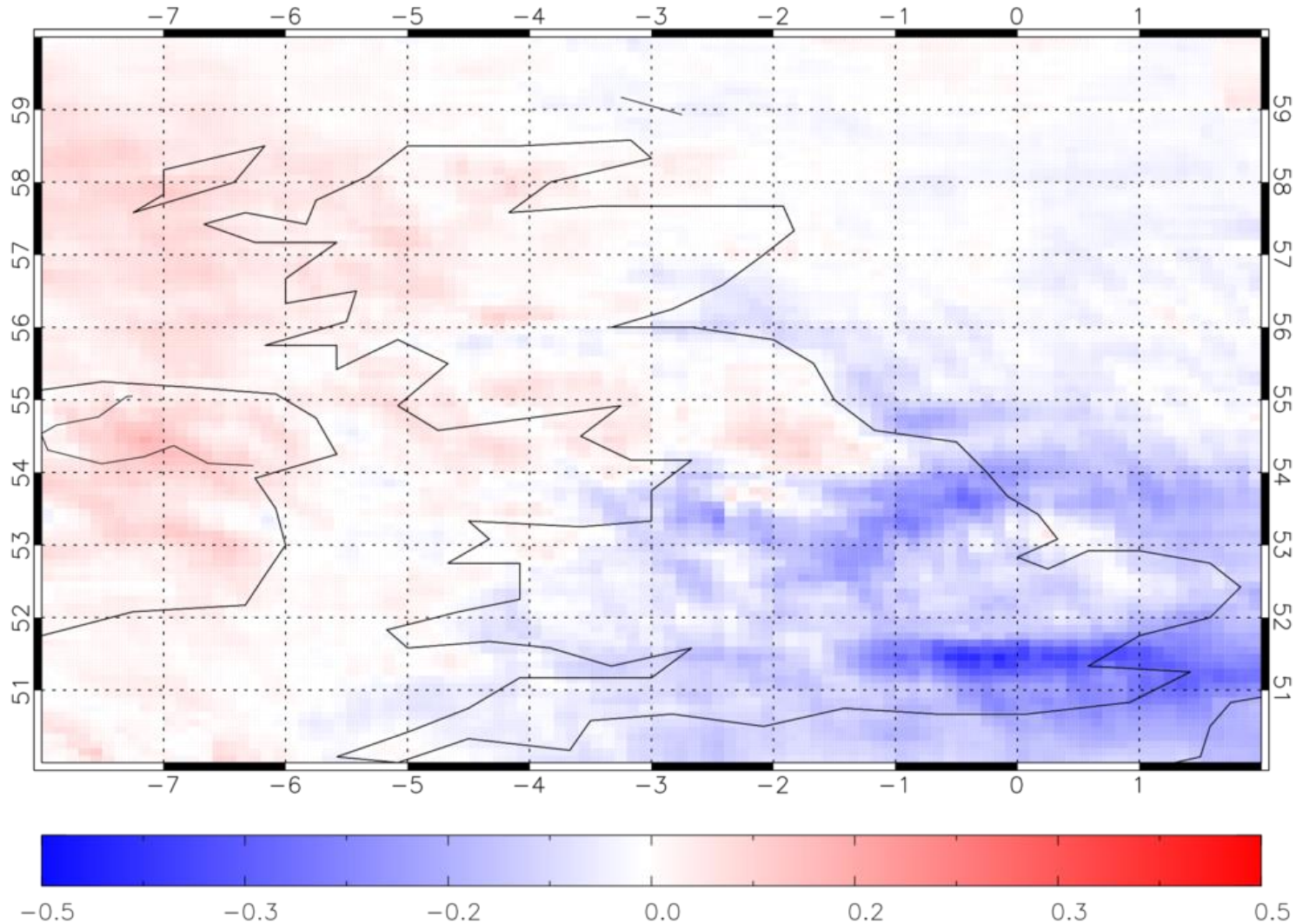
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$10^{15}$  molecules/cm<sup>2</sup>



# OMI Pixel Overlapping (Trend 2006-2015): UNIVERSITY OF LEEDS

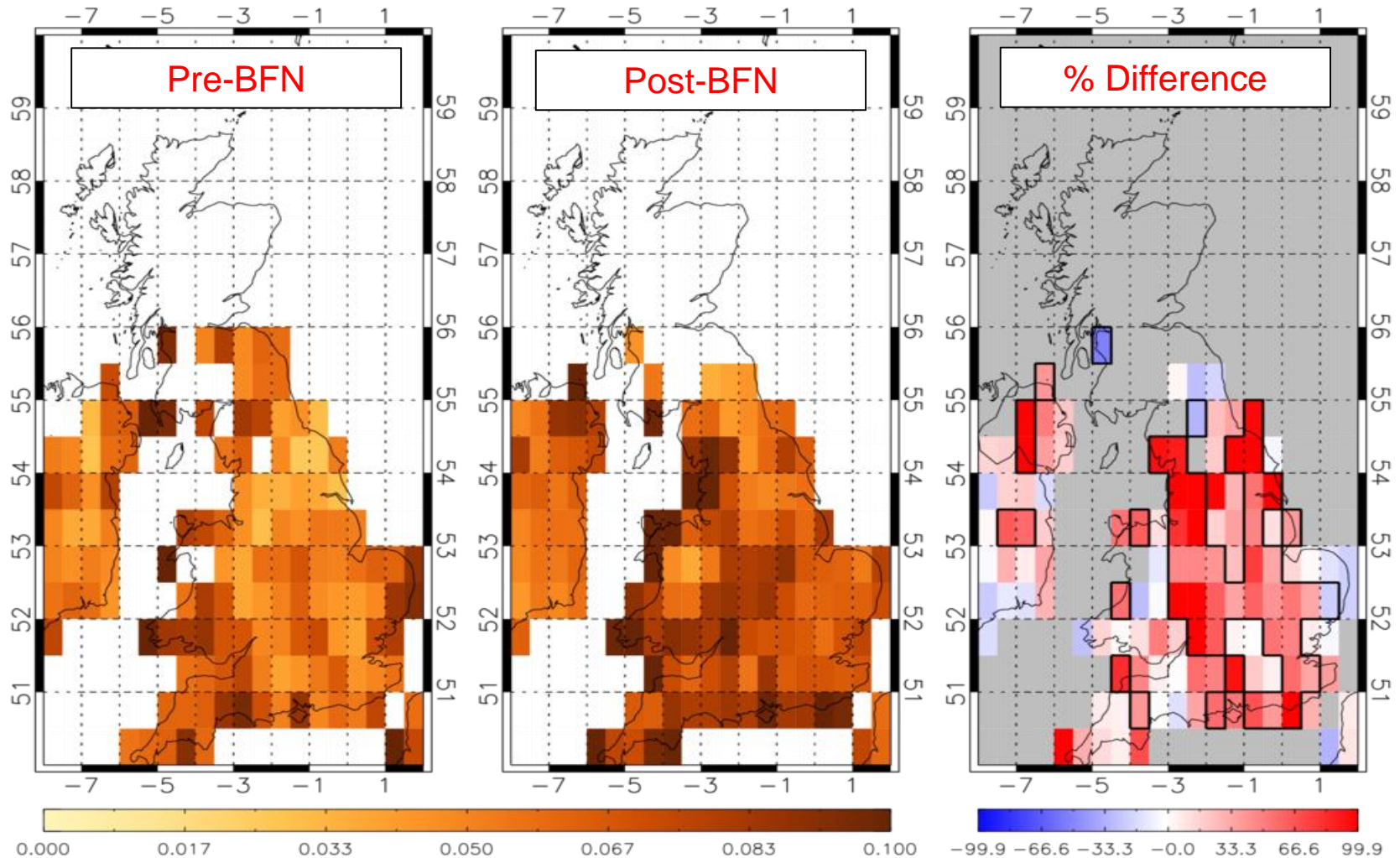


$10^{15}$  molecules/cm<sup>2</sup>/year

# MODIS Aerosol Optical Depth: Bonfire Night 2002-2015



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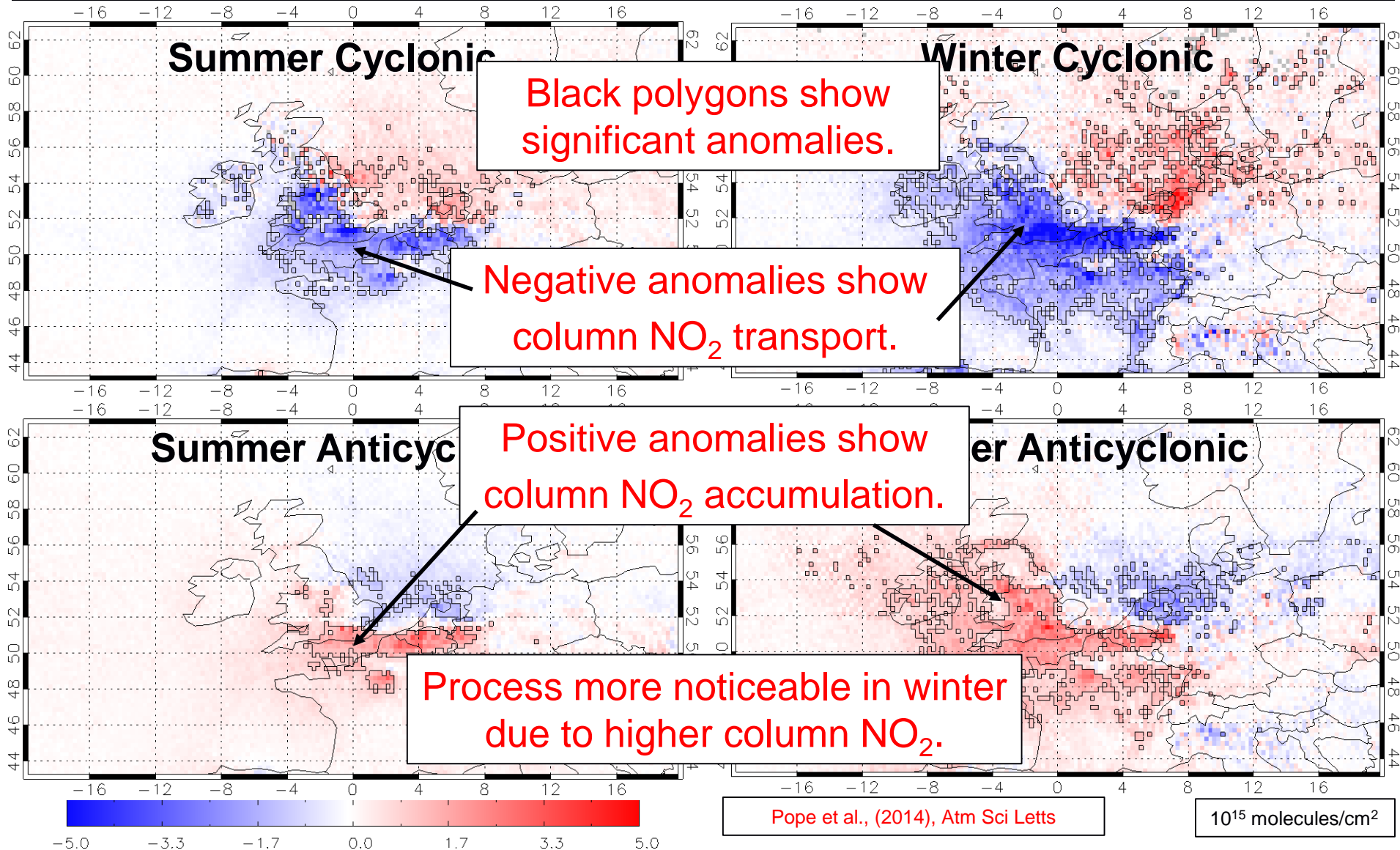
Pope et al., (2016), Weather

Pre-BFN = 3<sup>rd</sup>-5<sup>th</sup> Nov and Post-BFN = 6<sup>th</sup>-8<sup>th</sup> Nov

# OMI NO<sub>2</sub> Synoptic Composite Anomalies:



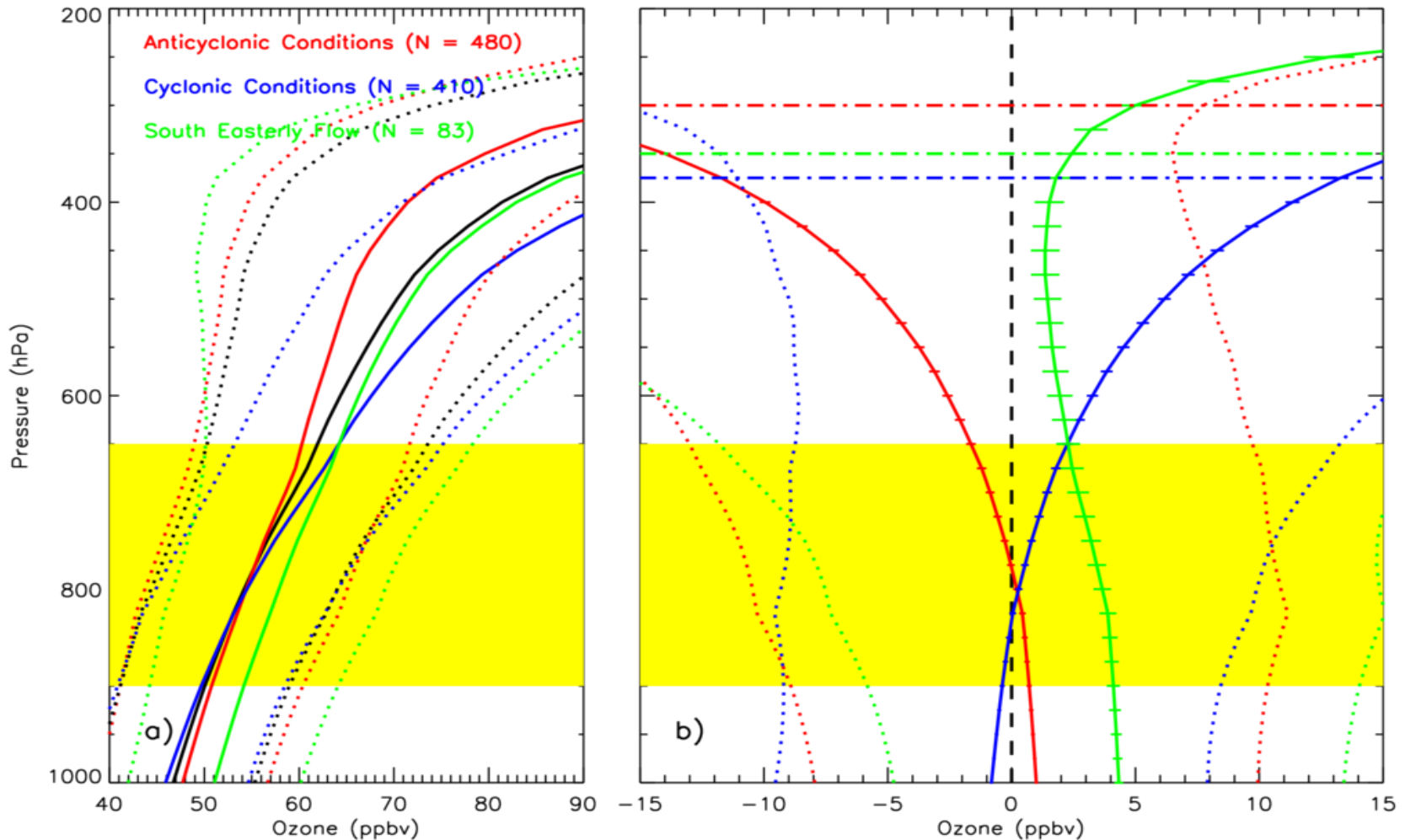
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# Tropospheric Emissions Spectrometer (TES): O<sub>3</sub> Synoptic Composite:



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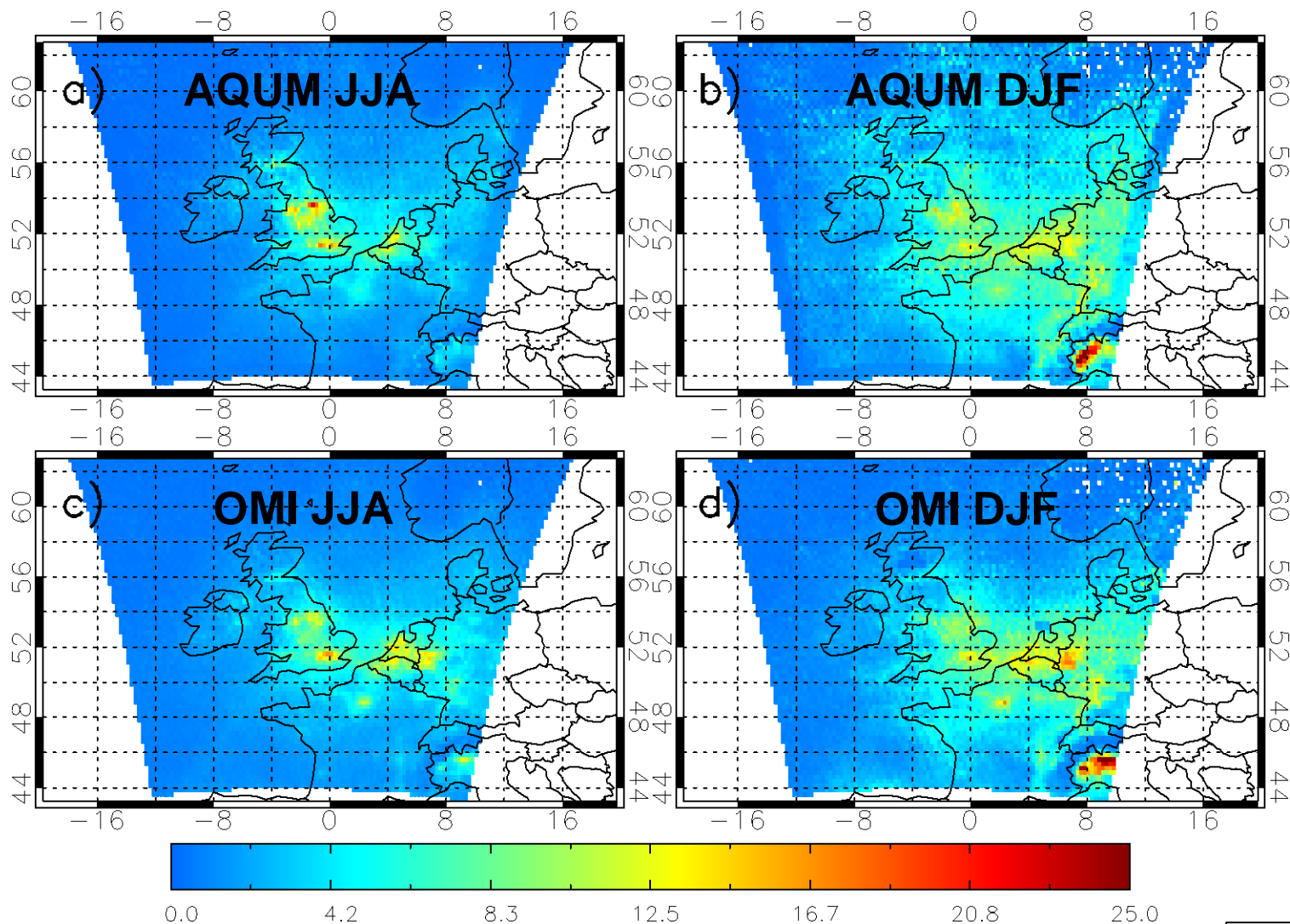


# Satellite and Models

# AQUM & OMI Trop Col NO<sub>2</sub>: 2006



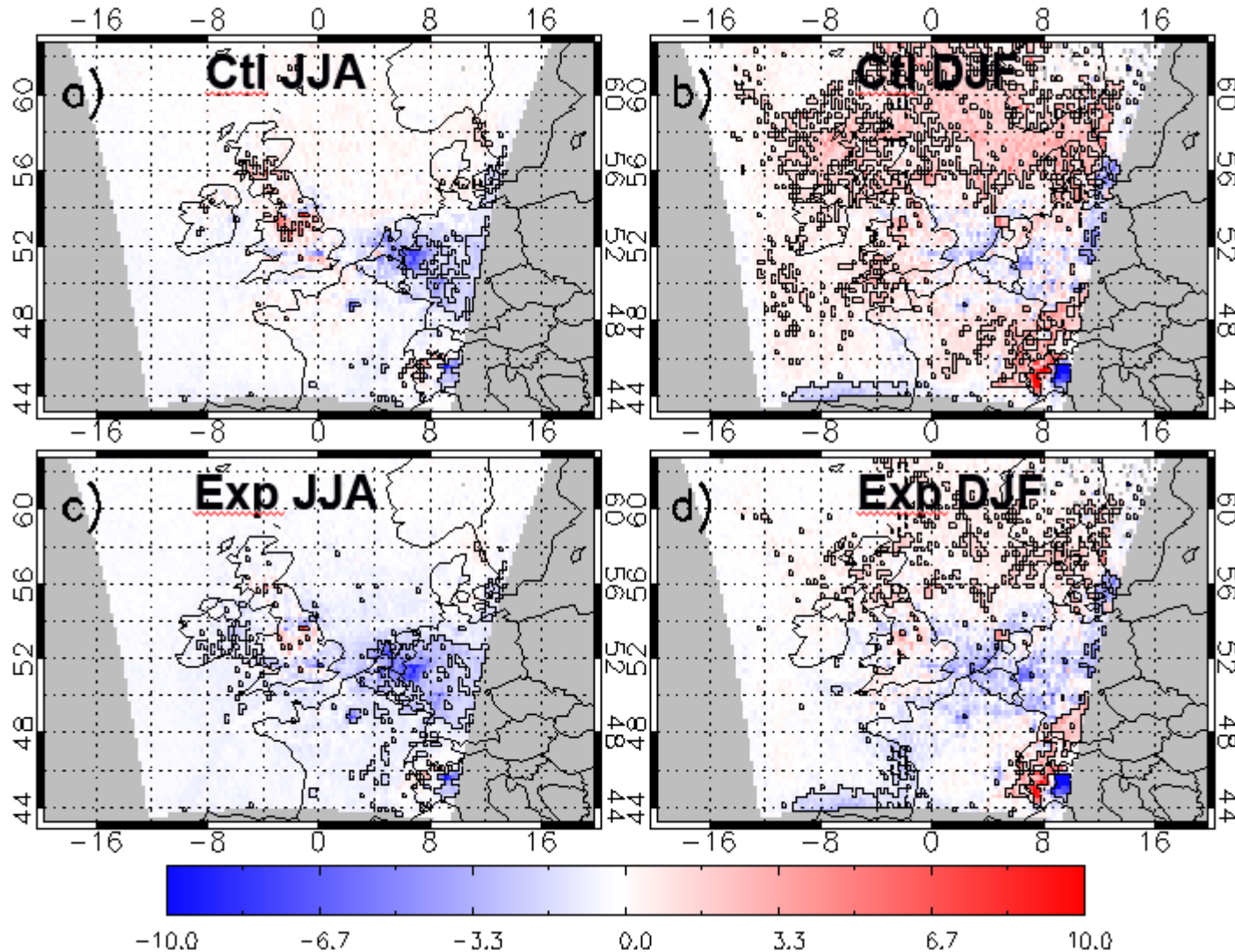
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# AQUM – OMI NO<sub>2</sub> (Updated N<sub>2</sub>O<sub>5</sub> Chemistry): 2006



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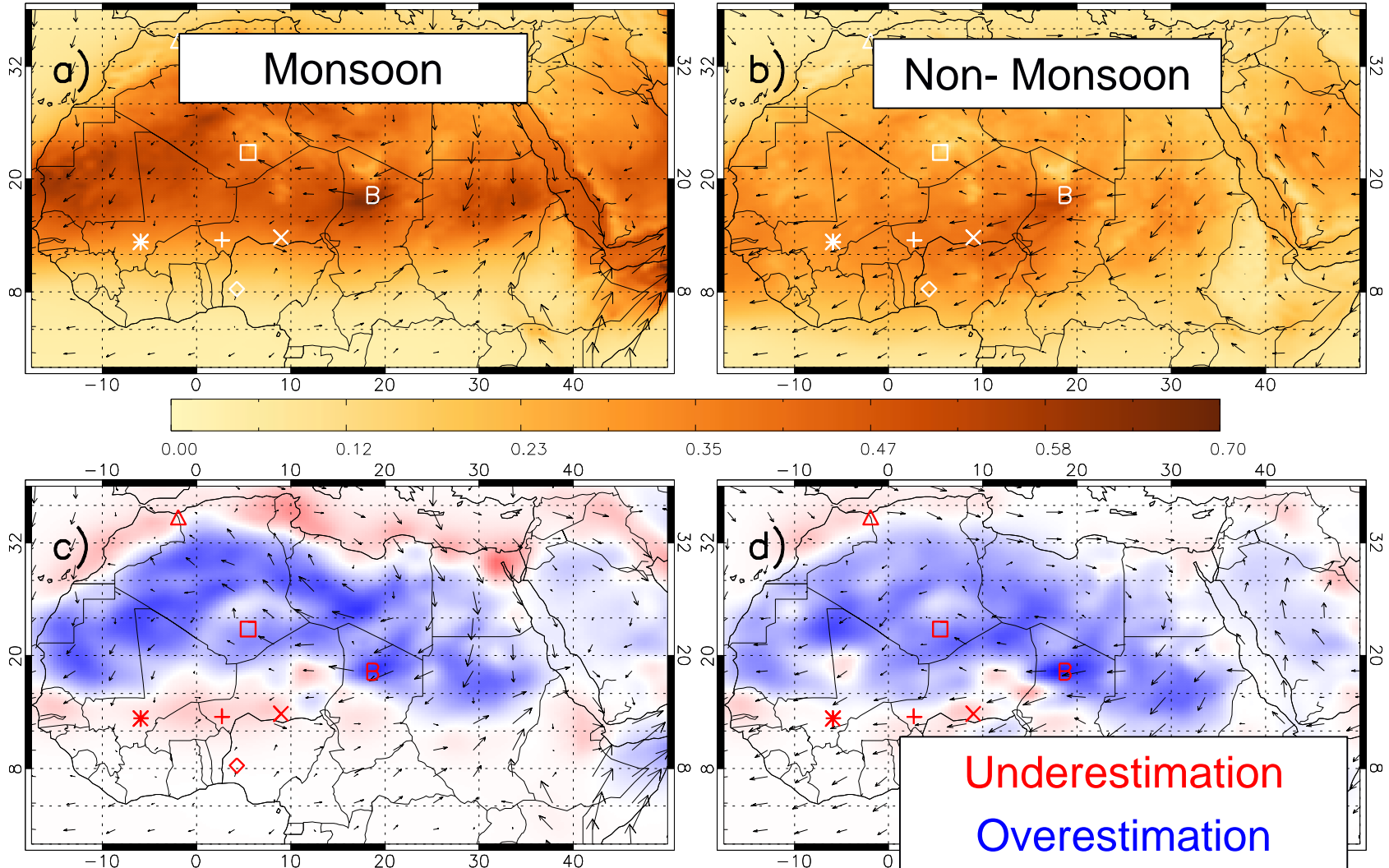




# Unified Model and Data Assimilation of MODIS AOD (550 nm)



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Pope et al., (2016), GRL

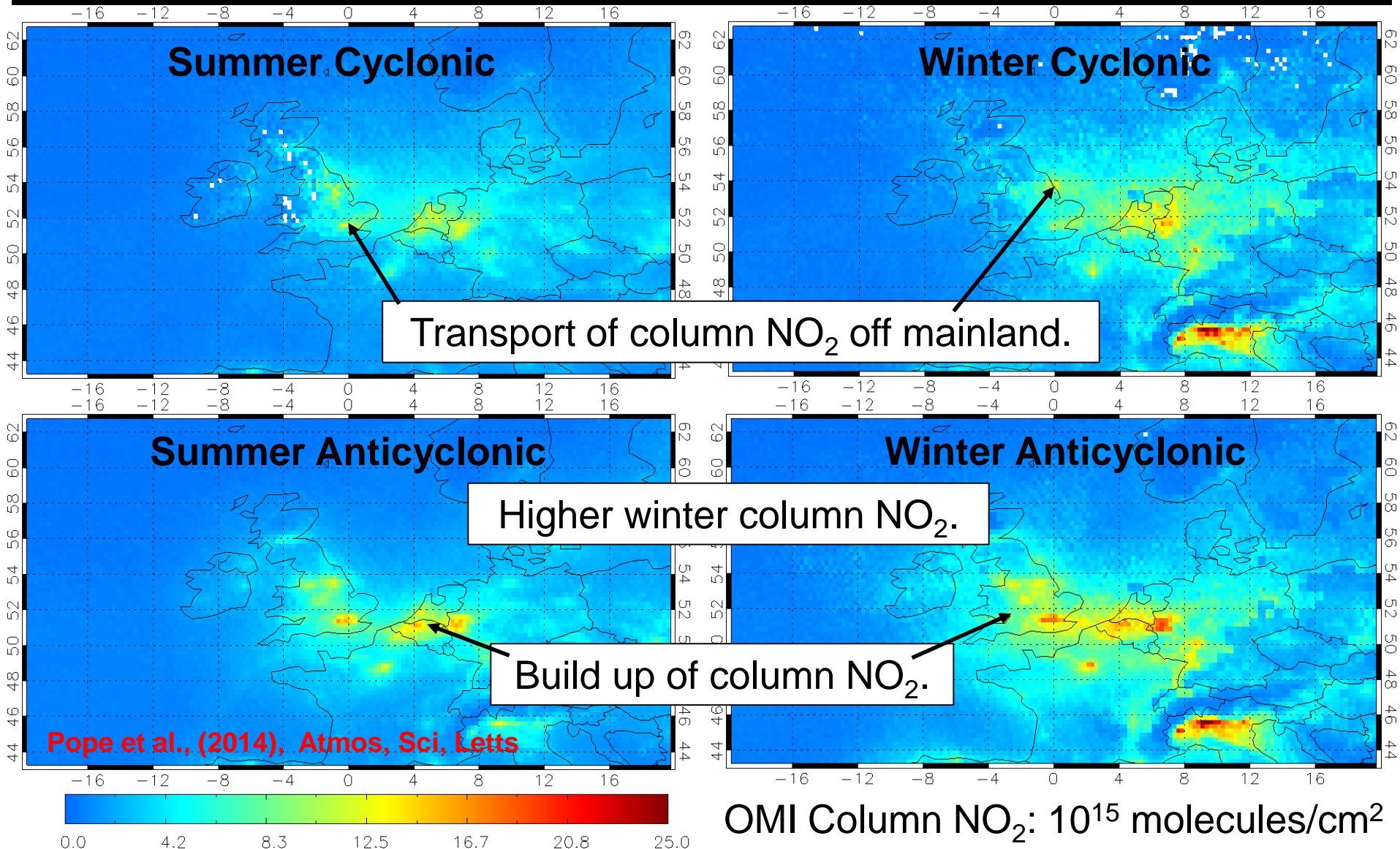


- Satellites can be used to investigate multiple air pollutants on both the regional and global scale. This despite the large uncertainties and errors associated with individual retrievals.
- Satellite data can see robust relationships between air pollutants and synoptic weather conditions.
- Satellites are a powerful tool to evaluate model skill through direct comparisons and data assimilation.
- Higher resolution instruments (e.g. TROPOMI) and geostationary satellites (e.g. TEMPO) will soon become operational.
- Improvements in processing algorithms to retrieval surface/boundary layer information.

# OMI NO<sub>2</sub> Synoptic Composites:



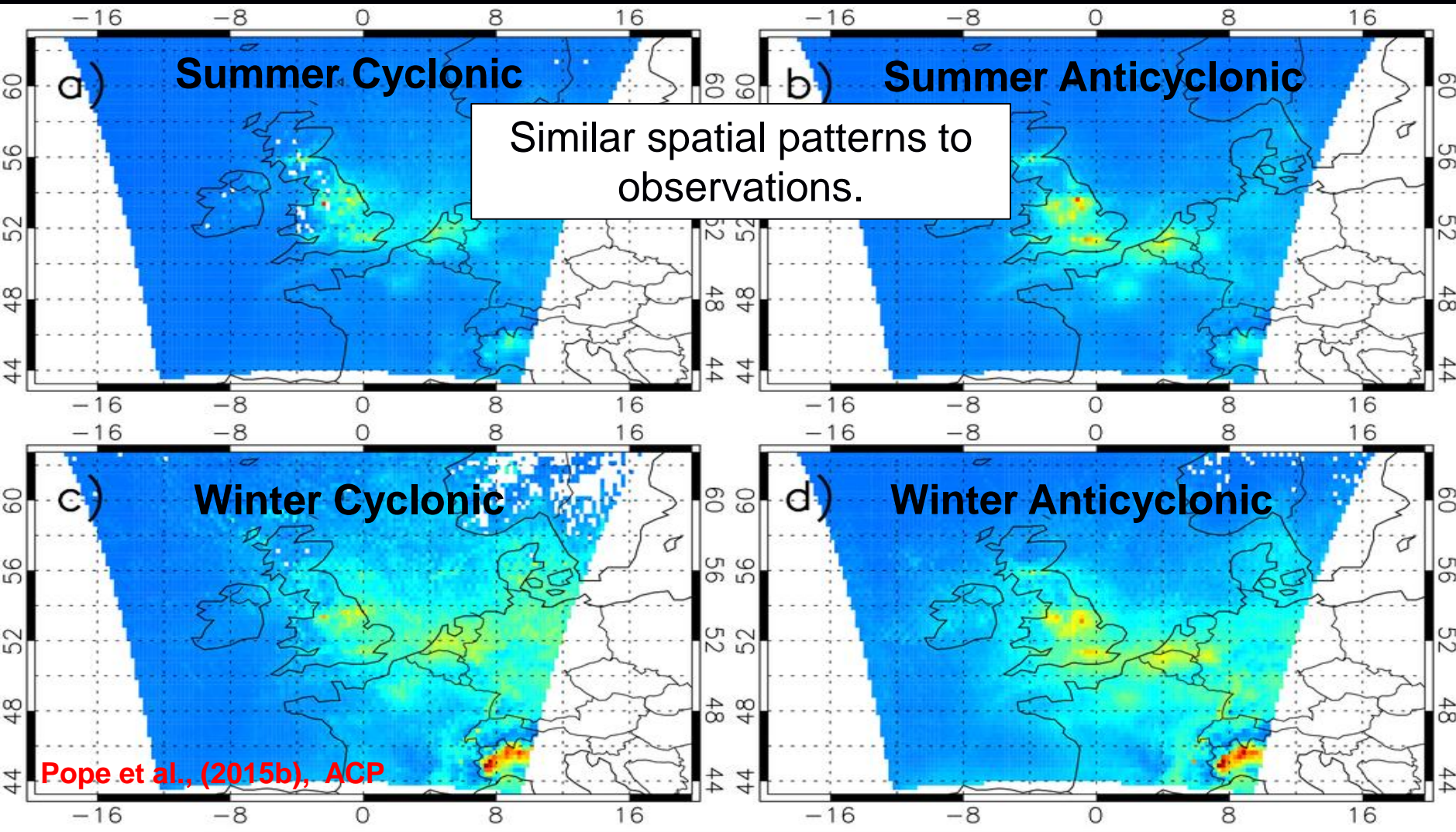
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# AQUM NO<sub>2</sub> Synoptic Composites:



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Pope et al., (2015b), ACP

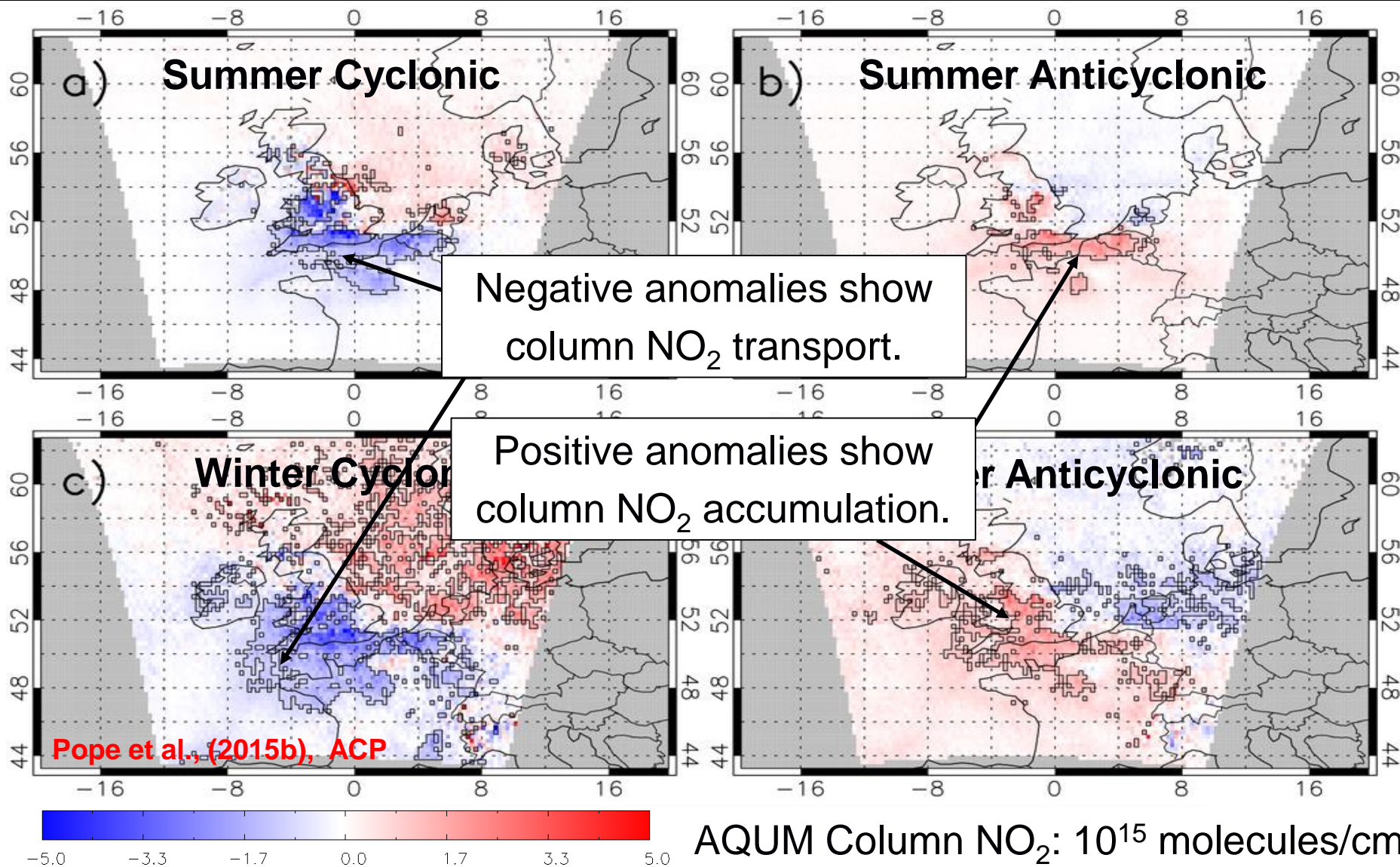
AQUM Column NO<sub>2</sub>: 10<sup>15</sup> molecules/cm<sup>2</sup>

0.0 4.2 8.3 12.5 16.7 20.8 25.0

# AQUM NO<sub>2</sub> Synoptic Composite Anomalies:



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# AQUM NO<sub>2</sub> Synoptic Composite Anomalies:



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- AQUM can capture enhanced [NO<sub>2</sub>] under anticyclonic conditions.
- Important for forecasting hazardous pollution episodes.
- Experimented with idealised tracers with multiple e-folding lifetimes in the model NO<sub>x</sub> emissions to diagnose the AQUM NO<sub>2</sub> life time.

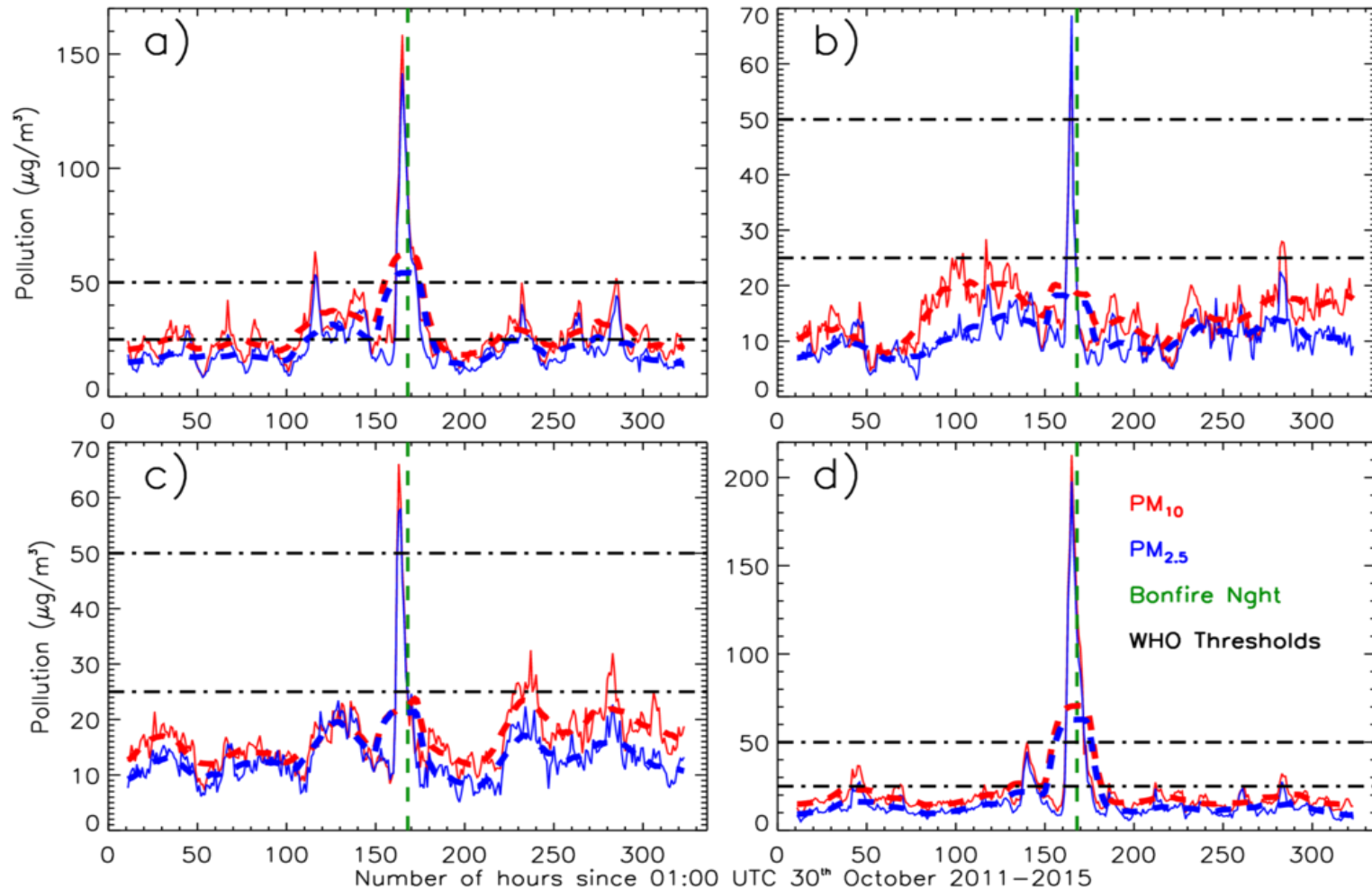
<b>Pope et al., (2015b), ACP</b>	<b>Summer Cyclonic</b>	<b>Summer Anticyclonic</b>	<b>Winter Cyclonic</b>	<b>Winter Anticyclonic</b>
<b>Lifetime (Hours)</b>	<b>4.5</b>	<b>6.0</b>	<b>7.0</b>	<b>11.0</b>

- Urban populations are more exposed to pollutants (NO<sub>2</sub>) under anticyclonic conditions and in winter.

# Fireworks: AURN PM<sub>2.5</sub> & 10



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**Figure 1:** Particulate matter (PM<sub>2.5</sub> (blue) & 10 (red)) between 30<sup>th</sup> October and 12<sup>th</sup> November, 2011- 2015. Solid (dashed) lines represent hourly (24 hour running average) time steps. Green and black dashed lines show the time step of bonfire night and the World Health Organisation (WHO) 24 hour mean safe exposure limit (PM<sub>2.5</sub> = 25  $\mu\text{g}/\text{m}^3$  and PM<sub>10</sub> = 50  $\mu\text{g}/\text{m}^3$ ).

Pope (in prep), Weather