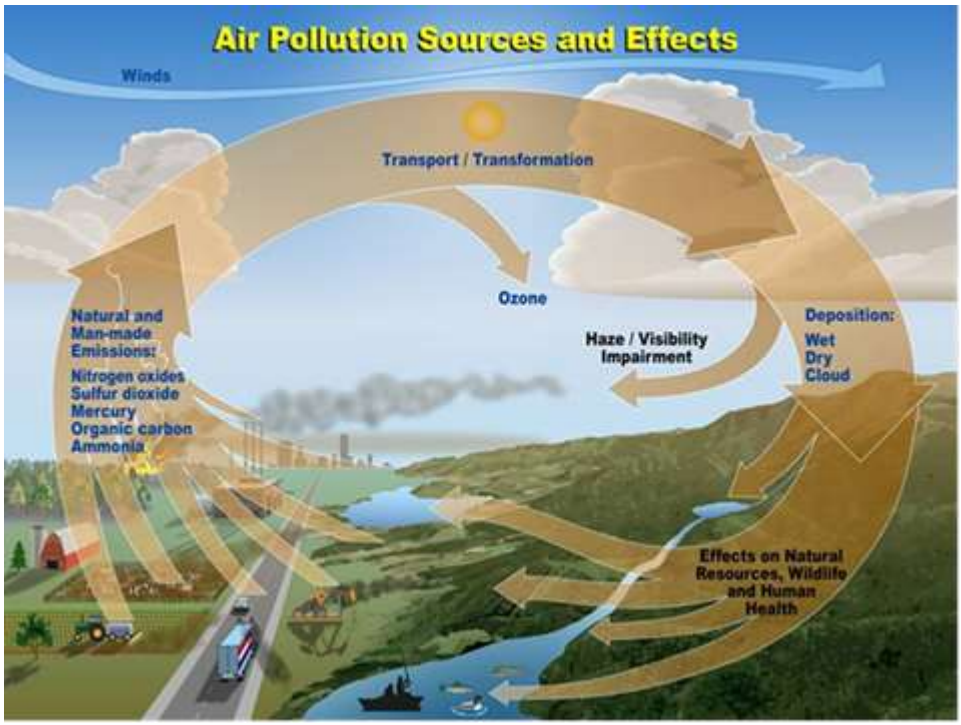
How Transboundary Pollution can affect Scottish Air Quality

The majority of the UK and Europe's air quality issues are derived from a variety of local emissions, point sources (e.g. factories), area sources (e.g. many smaller point sources) or mobile sources (e.g. road traffic). However, once pollutants have been emitted and are airborne they are subject to a variety of chemical and physical forces. Atmospheric chemical reactions between these primary pollutants and sunlight (UV radiation) and other substances in the atmosphere can cause the formation of secondary pollutants. For gaseous pollutants an example would be, UV light causing nitrogen oxides, released from vehicles, to react with hydrocarbons, from industrial activity, to produce secondary ozone. Fine particulate matter ($PM_{2.5}$ and smaller) is mainly formed by gas to particle conversions, such as the oxidisation of precursor gasses within the atmosphere. Both of which are harmful to humans and the natural environment. These pollutants, both primary and secondary, can also be "picked up" into parcels of air by the wind and transported to other areas. Depending on their chemical and physical properties the pollutants can remain airborne for significant periods of time. Figure 1 (http://cpcbenvis.nic.in/air_pollution_control.html) illustrates the sources, movement and effects of air pollution.

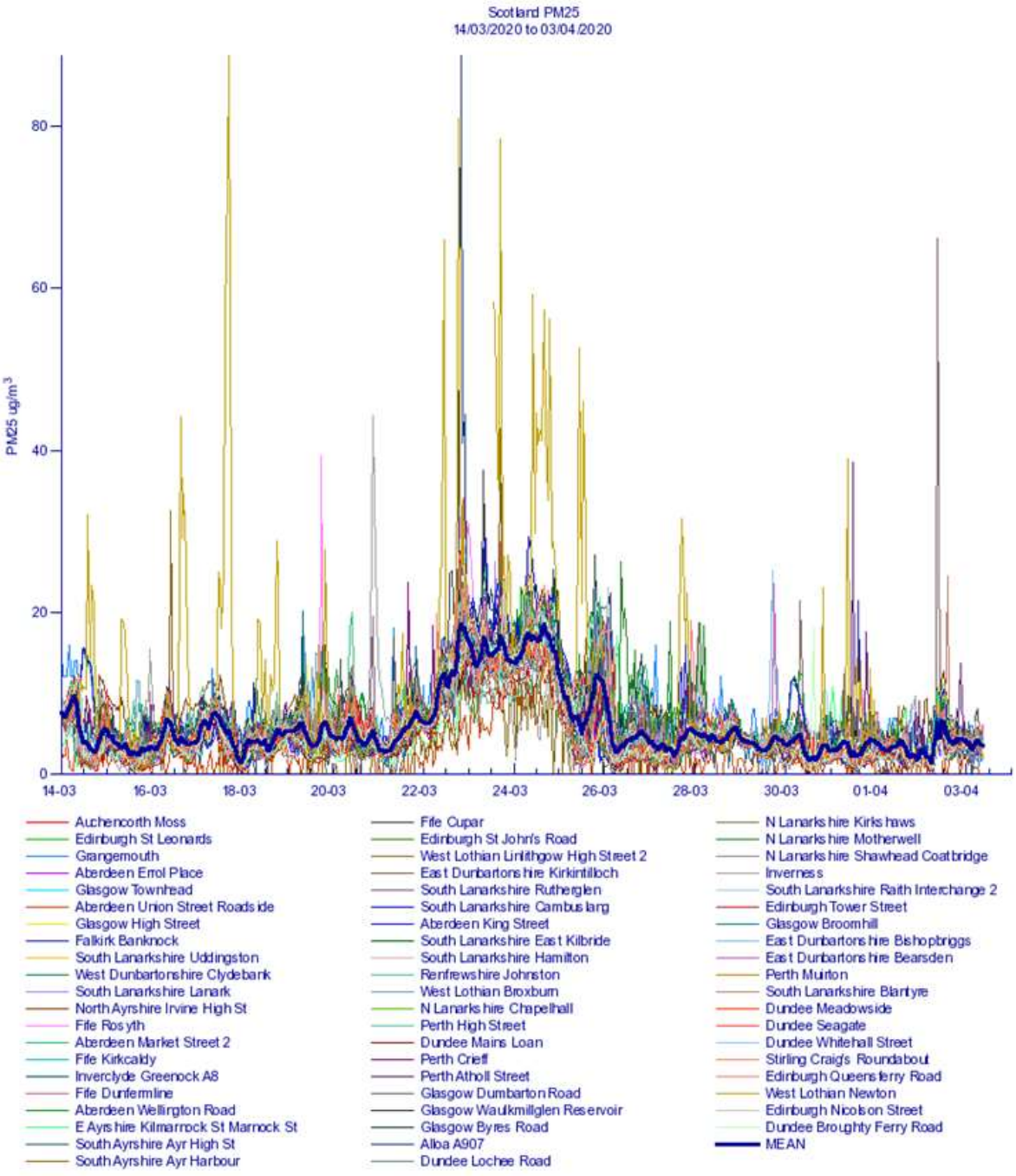
Figure 1:- Air pollution sources, transportation and deposition.



Depending on the strength and direction of the wind pollution can be distributed locally or transported to locations large distances away. This is known as transboundary pollution. Certain areas of continental Europe, such as the highly urbanised and industrialised areas of Paris (in France), Ghent (in Belgium) and the Ruhr valley (in Germany), especially in combination, emit many primary pollutants. If certain local weather conditions prevail, these pollutants can be transferred higher into the troposphere and picked up by weather fronts heading towards the UK. When these polluted air parcels reach the UK, they increase the background concentrations and combine with locally sourced pollution to create regional pollution episodes.

Recent evidence of this happening was seen between the 22nd and 26th of March this year where Scotland and other part of the UK experienced elevated concentrations of Particulate Matter ($PM_{2.5}$). Figure 2 below shows provisional $PM_{2.5}$ data for all stations in the majority of Scottish urban areas. The thick blue line shows the mean of all sites. Over the period in question there is a small but significant rise above normal levels. With the current restrictions in movement in place due to Covid-19 and no known increase of $PM_{2.5}$ source that would affect the entire country, this increase was highly unlikely due to local sources. However, when you look at the air mass trajectories above Scotland at the time the increase in concentrations makes more sense and an explanation can be found.

Figure 2:- $PM_{2.5}$ measurements for urban areas within Scotland in the second half of March.



Each coloured line on Figure 3 represents a different air parcel arriving at different locations within the UK. The lines produced using the HYSPLIT model accurately predicts how these parcels of air moved over the 96 hours before mid-day on Tuesday the 24th of March this year. As can be seen, air parcels left Greenland and travelled through the Arctic and Baltic regions before passing over most of the industrial and urbanised areas of northern Europe. On this journey the air parcels would have picked up the pre-cursor emissions needed to form transboundary pollutants such as $PM_{2.5}$. This air mass then travelled across the UK where it will have continued have continued to pick up pre-cursor emissions with further transboundary pollutant formation before arriving in Scotland causing the measured elevated $PM_{2.5}$ levels.

Figure 3:- Trajectory plot for air parcels arriving in Scotland on Tuesday the 24th of March 2020.