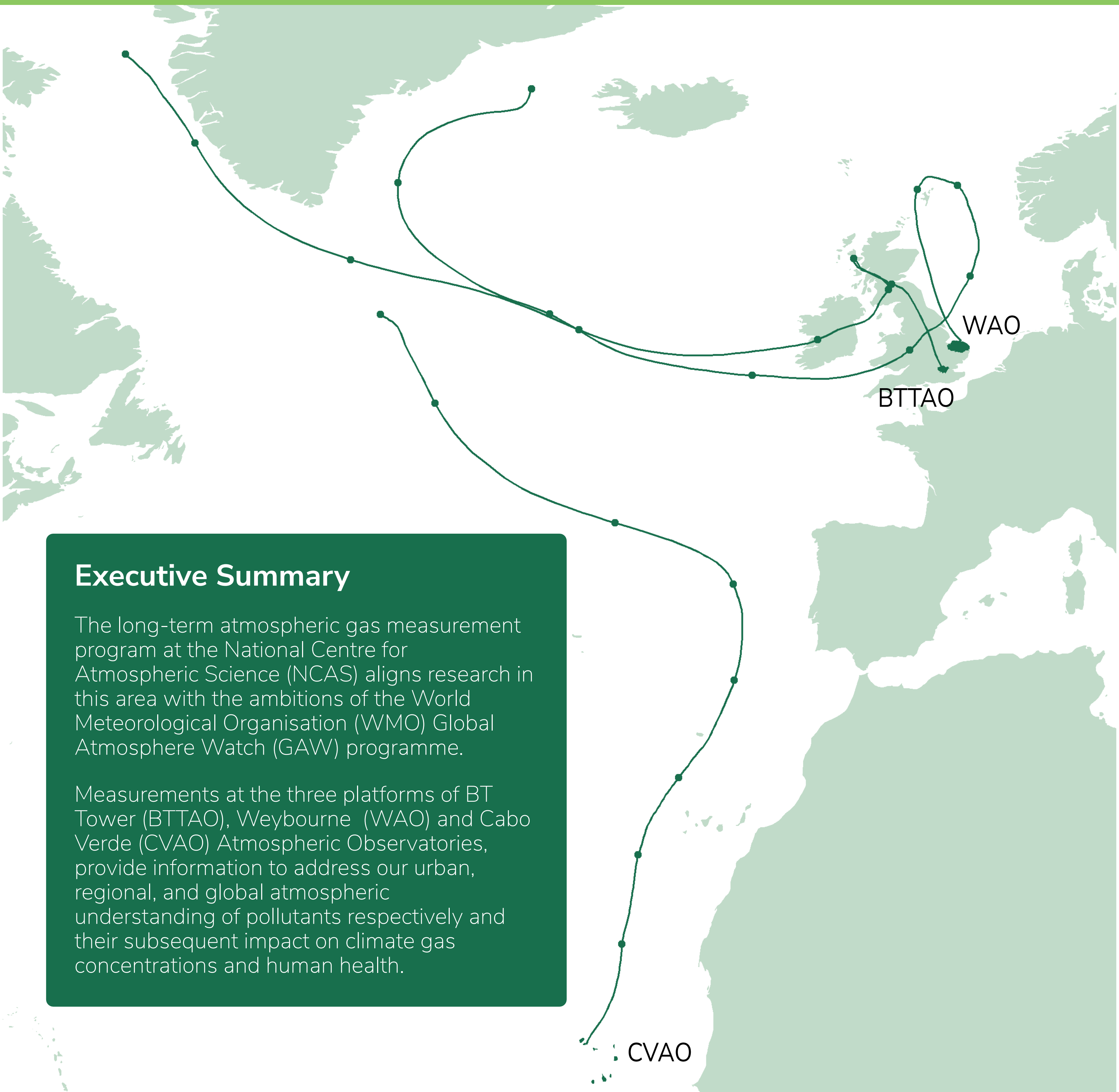
AMOF
ATMOSPHERIC MEASUREMENTS

Long-Term Measurements Bulletin

Introduction to the trace and greenhouse gas measurements made by NCAS



Executive Summary

The long-term atmospheric gas measurement program at the National Centre for Atmospheric Science (NCAS) aligns research in this area with the ambitions of the World Meteorological Organisation (WMO) Global Atmosphere Watch (GAW) programme.

Measurements at the three platforms of BT Tower (BTTAO), Weybourne (WAO) and Cabo Verde (CVAO) Atmospheric Observatories, provide information to address our urban, regional, and global atmospheric understanding of pollutants respectively and their subsequent impact on climate gas concentrations and human health.

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Introduction

In this first bulletin we introduce the sites that NCAS manage and what they can offer the national and international scientific community. The data is publicly available from the CEDA archive as it is funded through the Natural Environmental Research Centre's (NERC) national capability and in parallel, select data also contributes to key global networks (e.g. ACTRIS, ICOS) and frameworks such as WMO-GAW.

In addition to providing near-continuous measurements, the platforms also regularly support additional projects and campaigns through infrastructure, data and associated scientific expertise.

The sites are managed through the NCAS Atmospheric Measurement and Observation Facility (AMOF): For more information on how to apply for access to the facilities and to the data please visit the AMOF website (amof.ac.uk/.)

Measurements made at each of the three platforms are referenced and traceable to Global Atmosphere Watch (WMO-GAW) international calibration scales through the use of highly accurate primary standards in conjunction with routine working standards. NCAS AMOF can also provide UK community support for this.

NCAS is committed to sustainability and we work hard at ensuring best practice in this area. Solar panels have recently been installed at the CVAO to provide a third of the site power and where possible shipping effort and trips are combined with others to reduce the environmental impact in these areas. Plans are in place to also install solar panels at the WAO to provide 30-40 % of the site's power and these funds, which were awarded from the University of East Anglia (UEA), will also pay for a solar car charging point.

Instruments are replaced or upgraded sustainably, prioritising repair, reducing power consumption, and considering the environmental impact of the measurements.

Traceable calibration cylinders at the COZI-Lab, York (amof.ac.uk/laboratory) to support the long term measurements

Solar Field at the CVAO

BT Tower Atmospheric Observatory

Overview

The BT Tower Atmospheric Observatory is situated in central London and provides a measurement platform at ~190 m above ground level, allowing a rare opportunity to make direct emissions measurements in the middle of a large city,

NCAS focuses on measurements of trace gases which impact air quality. Nitrogen dioxide (NO_2) and Ozone (O_3) are gases subject to strict health impact guidelines, so understanding their local sources can provide important information for air quality abatement strategies.

NCAS works in partnership with the Centre for Ecology and Hydrology making a complimentary suite of measurements.

BTTAO in the UK's capital London makes measurements in an under sampled region of the atmosphere

Key Facts

Site type: Urban, local, emission monitoring

Objective: To understand what drives NO_x and O_3 concentrations in urban environments

Location: Central London, UK,
51° 31' 17.4'' N, 0° 8' 20.0'' W
190 m above ground level

Uniqueness: Tall tower in city centre

Measurements: NO, NO_2, NO_x fluxes, O_3,

Additional measurements: CO_2, CH_4, N_2O, Meteorological measurements

Measurements Began: 2012

Nitrogen dioxide, ozone and emission fluxes

NCAS has made continuous urban measurements of NO, NO_2, O_3 concentrations since 2012. Two intensive periods of measurement of NO and NO_2 emissions were conducted in 2013, 2017 and continuous measurements began in 2020. These emission measurements are made using the eddy covariance technique, requiring high time resolution measurements of both the gases and meteorological parameters. Due to the height of the tower, this method measures emissions within ~2 km of the tower and when coupled with CO_2 measurements, can provide information on the sources of NO_x within this footprint. This is particularly important information, as the local emissions are the aspect of the cities air quality that policy makers have direct control over, as they are decoupled from the regional background or meteorological effects.

These data allow us to monitor the impact of natural change (e.g., habitual change during COVID pandemic) and of policy interventions

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(ULEZ) in London. Comparisons can be made to emission inventories and thus enable improvements in our understanding of source emissions.

Figure 1 shows the measured concentrations of NO_x and O_3 since 2012, with annotations of key policy changes and other significant impacts The annual diurnal cycle of fluxes is highlighted for 2017 and 2021. Between these years NO_x emissions have decreased by a factor of ~5 and more recent data suggests these emissions have stayed low, despite an increase in activity following the lifting of restrictions related to the pandemic. This is a positive outcome for NO_x concentrations but Greater London still struggles to meet NO_2 air quality guidelines, and due to the non-linear chemistry between NO_x and O_3 may have other impacts that we need to understand and continue to monitor. Long term measurements such as these are key in our understanding of emissions on air pollution in highly populated areas. They are also important to understanding the contribution to the wider environment e.g, across country boundaries and on the global climate.

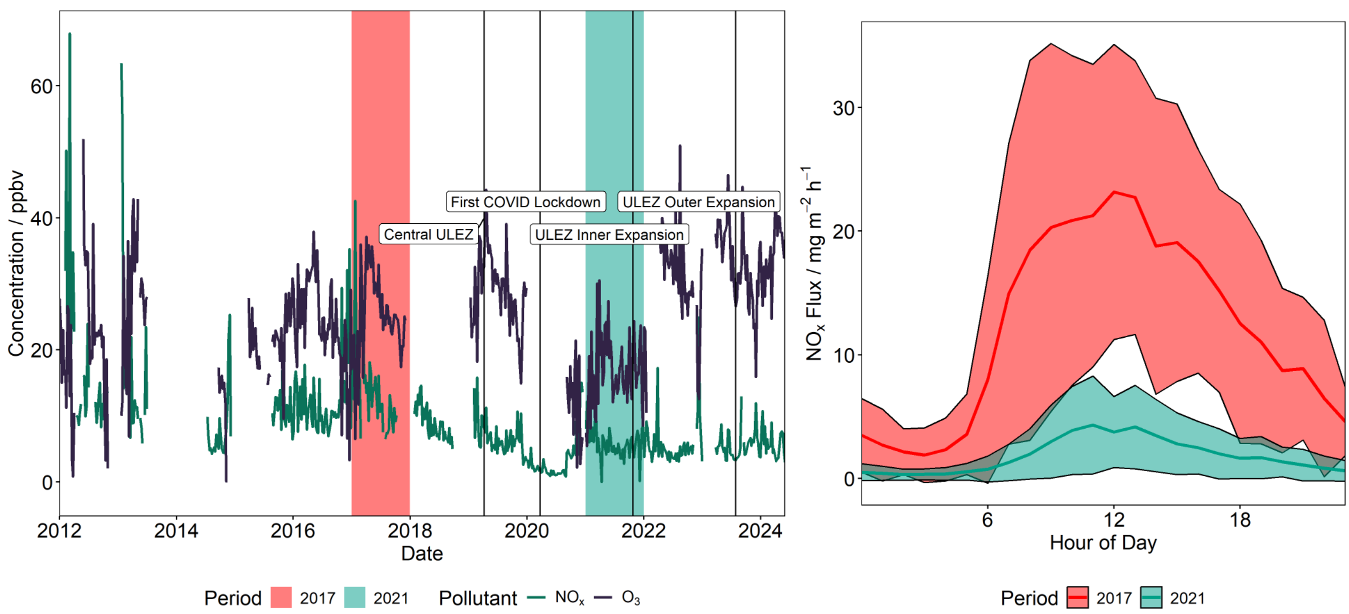

Figure 1: (Left) NO_x and O_3 concentrations measured at BTTAO since 2012, highlighted ribbons correspond to the measured fluxes in the right hand plot. (Right) Diurnal profiles of NO_x fluxes during selected periods in 2017 and 2021, showing the dramatic difference between the study periods.

References

Drysdale et al. 2022

doi.org/10.5194/acp-22-9413-2022

Cliff et al. 2023

doi.org/10.5194/acp-23-2315-2023

BTTAO Contacts

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Weybourne Atmospheric Observatory

Overview

Weybourne Atmospheric Observatory (WAO) receives air from several sectors including polluted air from the UK (e.g. London) continental transport from Europe over the English Channel, and clean air from the Arctic. The site is a regional GAW observatory and forms an essential part of the UK's commitment to the Integrated Carbon Observation System (ICOS), a pan-European network for the measurements and harmonisation of greenhouse gases. Furthermore, the greenhouse gas measurements form part of the UK Greenhouse Gas Emissions Measurement and Modelling Advancement (GEMMA) programme, which will assess the UK's progress towards achieving net zero.

WAO has a strong measurement focus on long-lived greenhouse gases and associated tracer measurements.

Key Facts

Site Type: Regional site, remote from local pollution

Objective: To measure background atmospheric constituents, transboundary pollution

Location: Weybourne, Norfolk
(52.95 ° N, 1.12 ° E, 10 m a.g.l., 29 m a.s.l.)

Uniqueness: polluted air from UK and Europe, background air from the Arctic

Measurements: CO_2, CH_4, N_2O, H_2, O_2/N_2, Black Carbon

Additional Measurements: Triple oxygen isotopes, O_3, NO_x, SO_2, Paticulate Matter, radon, Toxic Organic Micropollutants (TOMPs)

Measurements Began: 1993

Networks: ICOS, DEFRA, Environment Agency, and contributes to GAW

Greenhouse gases

Greenhouse gas measurements, which started in 2008 with CO_2, allow us to monitor regional emissions from East Anglia and gain a better understanding of their emission processes and where the emissions originate (i.e., UK or Europe). To do this we utilise atmospheric tracers, such as radon or isotopic measurements to learn about the history of the air mass being sampled. A long running tracer at Weybourne is the O_2/N_2 ratio. Due to the varied relationships between CO_2 and O_2, measuring atmospheric O_2, concurrently to CO_2, provides a wealth of additional information on carbon cycles not accessible when just measuring CO_2 alone. For example, O_2 measurements can help us better understand how much CO_2 is coming from fossils and how much is coming from the atmosphere's interactions with the biosphere

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NATURAL ENVIRONMENT RESEARCH COUNCIL

(e.g., photosynthesis vs. respiration). The data can also be used to investigate air-sea exchange of CO_2 and O_2.

Figure 2 shows the long running time series of CO_2 and O_2/N_2 ratio at Weybourne and highlights the continuing decline in O_2 as a result of the burning of fossil fuels. O_2 is decreasing more rapidly than CO_2 is increasing because there is a buffering effect on the increasing CO_2 by an increasing land carbon sink and ocean carbon sink whereas the O_2 decrease is affected by the increasing land and only a small O_2 degassing.

Further to O_2, in situ stable isotope measurements are being used to help us separate natural and anthropogenic emissions.

We have recently added state-of-the-art measurements of CO_2 isotopologues to assess their potential application to help us better understand how much CO_2 is taken up by plants. This year, measurements of methane (CH_4) isotopologues and ethane will be added to help us distinguish fossil sources of CH_4 from natural emissions.

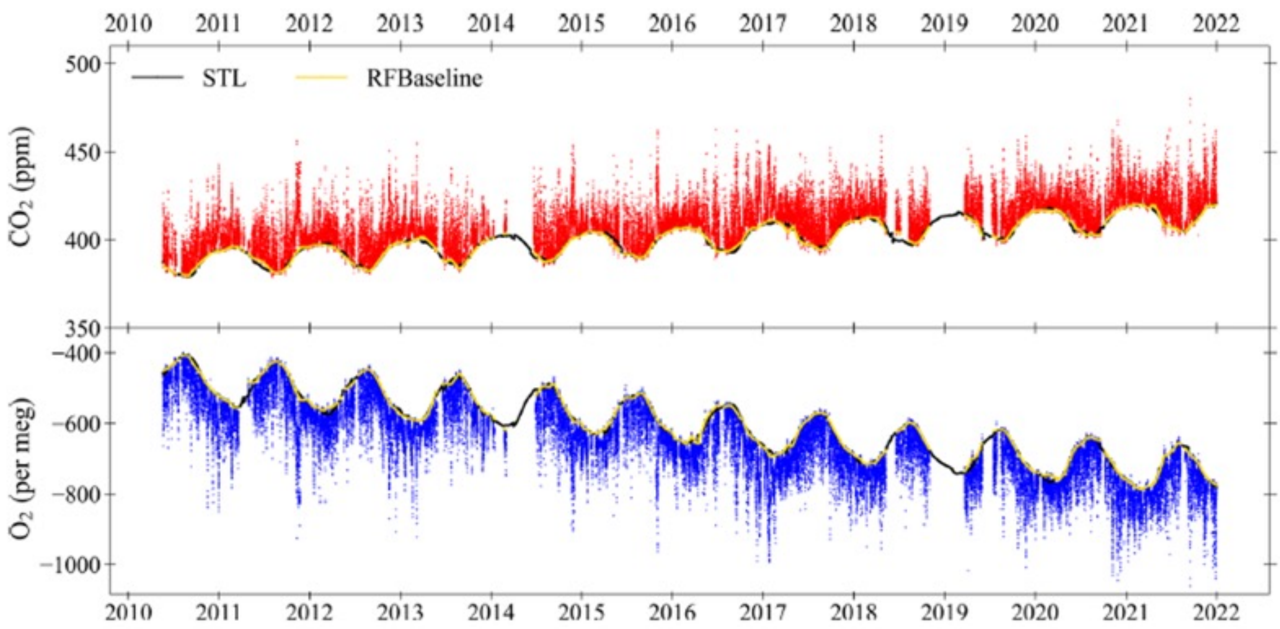

Figure 2. Hourly averaged CO2 (top panel) and O2 (bottom panel) at WAO between May 2010 and December 2021. Figure adapted from Adcock et al (2023).

References

Adcock et al., 2023

doi.org/10.5194/essd-15-5183-2023

Rodenbeck et al., 2023

doi.org/10.5194/egusphere-2023-767

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Cabo Verde Atmospheric Observatory

Overview

The Cabo Verde Atmospheric Observatory (CVAO) is one of 31 'global' GAW sites providing unique information of the global background of trace and greenhouse gases. In the majority of measurements (>95%) the measured air has not seen land for a number of days, and concentrations of anthropogenically influenced gases are at background levels. There is however evidence of the varying regions that the air has originated from, which includes North America, Europe, Africa and the South Atlantic. Understanding the path of air allows some characterisation of the emission changes that impact on the global climate. Data contributes to ECMWF reanalyses and other GAW activities.

CVAO is ideally located to study the well processed marine boundary layer of predominantly the North Atlantic.

Key Facts

Site Type: Global, remote, well processed air/ background

Objective: To monitor sub-tropical marine boundary layer background air

Location: Calhau, Sao Vicente, Cabo Verde, (16.85 ° N, -24.87 ° E, 10 m a.s.l.)

Uniqueness: One of only 31 'global' GAW stations in the world and the only one in sub-tropical Atlantic

Measurements: O_3, CO, VOCs, NO_x, SO_2, CO_2, CH_4, Halocarbons, Photolysis rates, Aerosol, Meteorological parameters

Additional Measurements: Physical and Chemical Aerosol

Measurements Began: 2006

Networks: ACTRIS and contributes to GAW

Ozone trends

Using 10-day back trajectories the FLEXPART Lagrangian particle dispersion model (v10.4, doi.org/10.5194/gmd-12-4955-2019) allows characterisation of the air masses received at the site and thus interpretation of trends of key species such as ozone (O_3), an important secondarily produced greenhouse gas; and carbon monoxide (CO), a tracer of anthropogenic and biomass burning emissions.

NCAS have responsibility for multiple other trace gas measurements at this location to aid in the interpretation of these and other key climate gases such as methane. These include volatile organic compounds (VOCs), nitrogen oxides, (NO_x) sulphur dioxide (SO_2) and short-lived halocarbons (VSLS), for which there are multi-year records of these of up to 16 years. Long

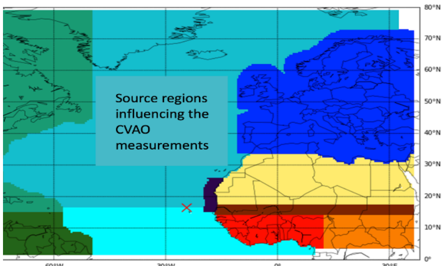

Figure 3:(above) Source regions used for the trajectory analysis

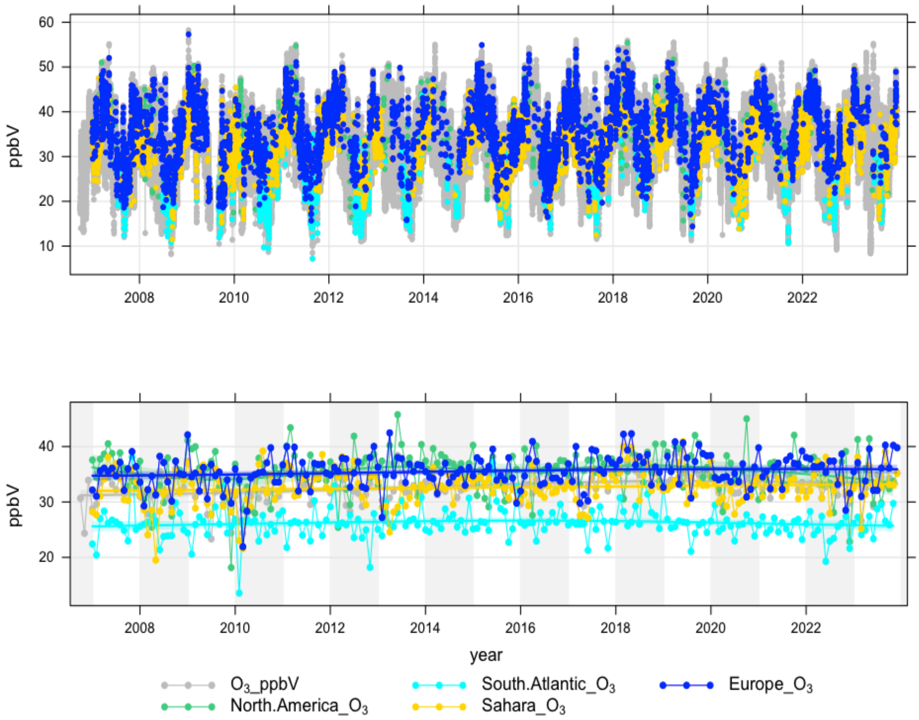

Figure 4 (right): Ozone concentrations for the South Atlantic, European, North America and Saharan regions

term measurements of trace gases such as these are globally sparse and yet allow advanced interpretation of the trends with respect to changing global emission sources and atmospheric sinks.

Figure 3 shows how the regions are characterised for back-trajectory analysis and Figure 4 shows the O_3 concentrations using filters of > 10 % for some of the defined regions. The air from the South Atlantic is clearly lower, this is in part due to there being much lower concentrations of the precursors of O_3 in the southern hemisphere but also because the CVAO receives air from this direction during September when the concentrations of the hydroxyl radical, OH, is high and so precursors such as VOCs which react with OH are removed more efficiently or 'cleaned up' from the atmosphere.

Over the last 17 years O_3 at the CVAO has shown a small annual increase of 0.16 +/- 0.08 ppbV. Using measurements at this site in addition to global models such as GEOS CHEM it is hoped to provide a detailed understanding of atmospheric gas trends and of possible future scenarios by considering changes in precursors in different regions, evaluating atmospheric sinks, and decoupling air mass contributions and seasonal differences.

These and associated measurements can inform on whether any emission changes or policy interventions have impacted on the background concentrations of this important climate gas in the North Atlantic region.

References:

Rowlinson et al., 2023

doi.org/10.5194/egusphere-2023-2557

Andersen et al., 2022

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Data availability

The CEDA catalogue lists the available data from the NCAS observatories:-

catalogue.ceda.ac.uk

Use the search term 'NCAS Atmospheric Observatory' and select 'platforms' as a filter.

To access the CEDA archive you will need a login which allows you to download the available datasets ('See Related Datasets').

Participation in global networks means that selected data from these sites can also be found at the World Data Centres for Greenhouse Gases and for Reactive Gases (WDCGG: gaw.kishou.go.jp/ and WDCRG: gaw-wdcrg.org/ respectively) and through the Integrated Carbon Observation System (ICOS): icos-cp.eu/data-services.

If using any of this data or have any questions please get in touch with the relevant site contacts.

Other NCAS-related long term effort

NCAS staff are also involved in other long-term data projects including making continuous in situ measurements at UK 'urban supersites' (Manchester, Birmingham and London), radar measurements at Chilbolton, the management of long term temperature records (CRUTEM) and of halocarbons by UEA, and long term climate data.

For more information on the breadth of facilities that NCAS offers please contact:- Dr Barbara Brooks at barbara.brooks@ncas.ac.uk.

Acknowledgements and partners

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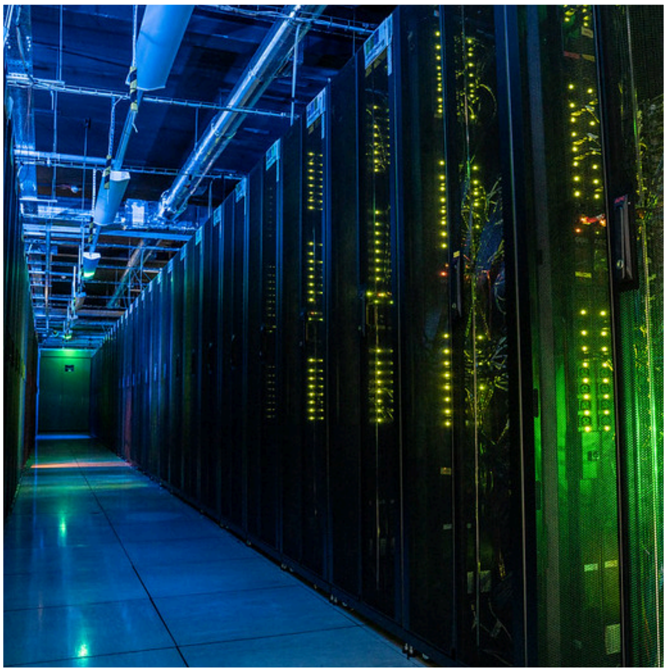

JASMIN data analysis facility at the Centre for Environmental Data Analysis (CEDA)

The Chilbolton Atmospheric Observatory Weather Radar