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Protecting the North Atlantic Atmosphere: A Report on the Outcome of an International Meeting on the Twentieth Anniversary of the Second Aerosol Characterisation Experiment (ACE2)

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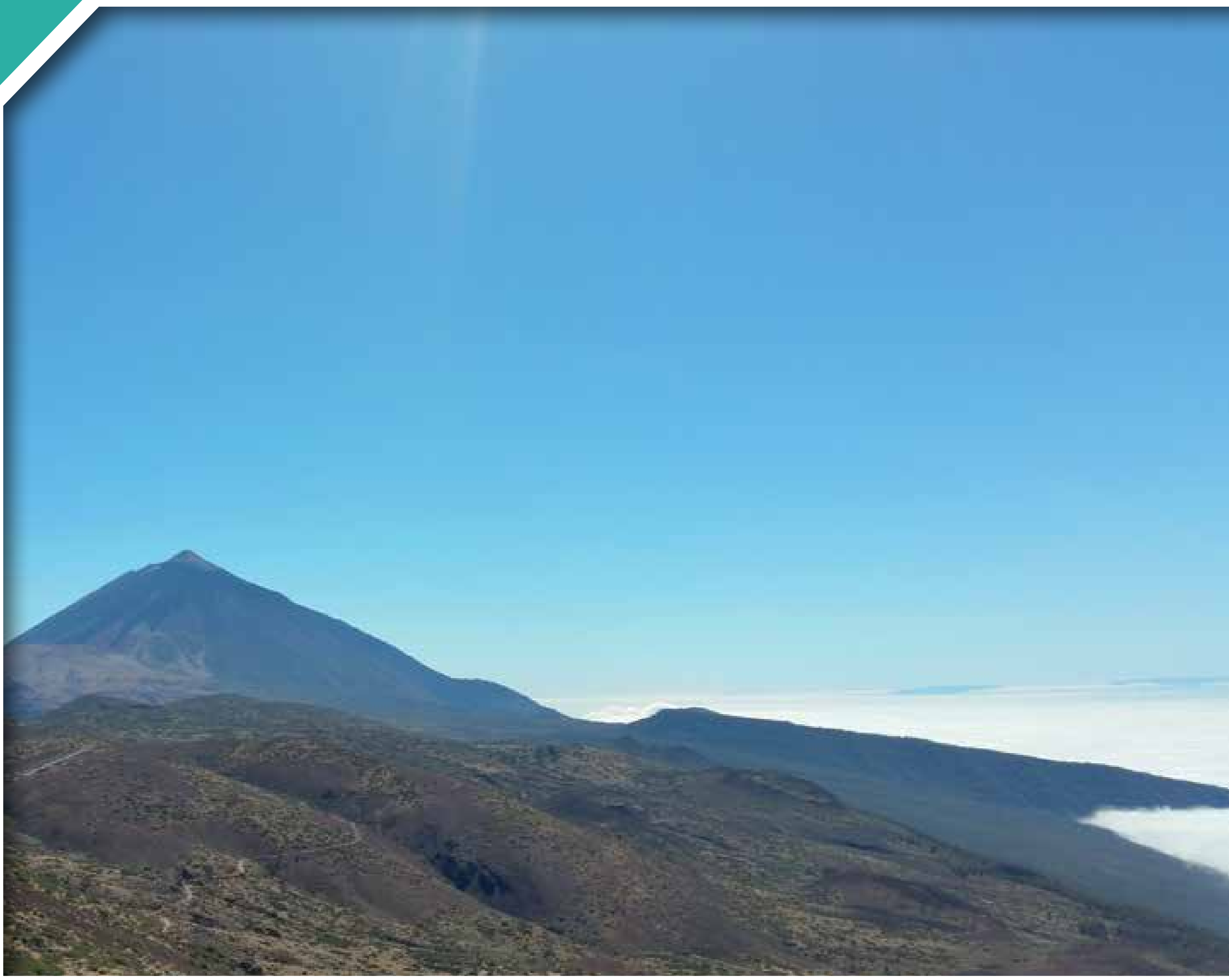

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Protecting the North Atlantic Atmosphere

A Report on the Outcome of an International Meeting on the Twentieth Anniversary of the Second Aerosol Characterisation Experiment (ACE2)

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Prepared for the Environmental Protection Agency

by

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The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

The North Atlantic Ocean is flanked by four major continental regions, two of which, Western Europe and North America, are among the most economically advanced regions in the world. It is also bounded by large desert areas of North Africa and developing areas in that region and in Central America and northern South America. It is impacted by emissions from these regions, including those from the major conurbations and industrial regions, as well as by emissions from intercontinental and regional transport systems.

These emissions are increasingly changing the atmosphere over the North Atlantic; this includes changes to the atmospheric radiation balance with a resultant increased uptake of energy in the ocean systems and the cryosphere. Desert dust deposition is a major feature of a large part of the region. Environmental changes are also occurring because of transport and deposition of long- and short-lived pollutants that alter the oceanic biosphere, some of which lead to a build-up of persistent pollutants, such as heavy metals, in ecosystems and food chains.

The Atlantic also has unique vulnerabilities related to the stability of key features, including the ocean meridional overturning circulation, the Greenland ice shelf and the rapidly changing Arctic region. The extent and rate of changes that are occurring will probably have impacts on regional weather and climate systems and potentially irreversible impacts on the surrounding continental areas and islands.

In July 2017, a scientific meeting took place in Santa Cruz de Tenerife, Spain. The aim was to review the legacy of the 1997 ACE2 (the second Aerosol Characterisation Experiment) and to consider the state of observatory-based atmospheric research in the North Atlantic region and how it relates to current science and policy questions and issues.

ACE2 was focused on the climate impacts of air pollutants and desert dust in the subtropical North Atlantic region. Its scientific contributions to our understanding of aerosol forcing of climate were recognised as being significant, as were subsequent developments in spin-off research activities, the establishment of research groups, and the improvement and development of research infrastructure.

In relation to observation systems, the North Atlantic currently hosts some of the most advanced atmospheric observation sites in the world, including Izaña, Tenerife, Spain, and Mace Head, Ireland. Strategically important sites have been established from Cape Verde to Svalbard and at sites in the Western Atlantic, notably on Barbados. These have largely developed independently and gaps exist both in the range of observations carried out and their geographic distribution, which is sparse in contrast to the density of observation sites in continental Europe and North America.

Observations from these sites provide considerable insights into the drivers of regional and global change. Links exist between various observatories through specific global networks. However, there is an absence of an integrating structure to provide a coherent picture of regional atmospheric change over the North Atlantic and its impacts. Steps to address this were identified in four areas: (1) scientific analysis; (2) observational capacity; (3) outreach; and (4) policy and institutional supports.

Scientific analysis

Scientifically, a key aim is to develop and publish an agreed climatology of the composition of the North Atlantic atmosphere. Options to advance this goal include a combination of existing systems, such as the Copernicus Atmosphere Monitoring Service (CAMS), which includes data from space-based observations and analysis for similar initiatives. Linking model products with the regional observational records would be an essential element to validate and capture the representativeness of the various analyses. This would provide a shared basis for analysis of atmospheric change and its impacts, the objective being to provide the bases for regular assessment of the status of the North Atlantic atmosphere, the driver of atmospheric changes and their consequences.

Observational capacity

The regional super-sites at Izaña and Mace Head provide an excellent foundation for development. Other sites are less well developed or focus on narrower issues. An assessment of the degree to which these stations can address areas of scientific and policy interest and where additional stations are needed to fill in gaps is required. The above climatological analysis can assist in this process. However, it can be progressed now based on existing information and in cooperation with remote sensing and Earth systems modelling communities. The aim is to inform the phased development of required regional observational capacity. A first step is to establish an ad hoc group to consider and report on the atmospheric observational requirements of the North Atlantic region based on agreed scientific criteria and policy issues.

Outreach (arts and science)

Communication of atmospheric protection issues emerged as an unexpected element of the meeting. European and North American programmes exist to develop the links between arts and science in order to enhance communication. There are key challenges in communication of atmospheric change, which is largely intangible. However, current and new technologies are opening up the potential to visualise the invisible. There is a need to further develop concepts for communication of atmospheric issues using established and new and emerging technologies. Engagement with existing programmes in this area is warranted.

Policy and institutional supports

A range of policy instruments and processes are designed to advance specific atmospheric protection issues. These have similar but differing processes for assessment, development and review. Options to provide a more fully integrated approach to inform comprehensive policy responses on atmospheric protection that avoid barriers and conflicts should be explored. Proposals to establish such a structure have been published, e.g. the Convention on Long-Range Transboundary Air Pollution (CLRTAP) Scientific Assessment Report 2016.[1] A broad-spectrum assessment of the nature, and the causes and consequences, of atmospheric change over the North Atlantic region can advance thinking on such a process. Organisational ownership and institutional support are required to advance such a strategic initiative. This report can provide a mechanism to engage with key actors, including policymakers, research funding and performing organisations, and operational bodies – all having a shared interest in protecting the North Atlantic atmosphere.

1 http://www.unece.org/fileadmin/DAM/env/lrtap/ExecutiveBody/35th_session/CLRTAP_Scientific_Assessment_Report_-_Final_20-5-2016.pdf

1 Introduction

Paul Crutzen, in his Noble Prize acceptance speech,[2] spoke about the circumstances that caused depletion of the upper atmosphere ozone layer and the consequent increase in dangerous ultraviolet (UV) radiation reaching the Earth's surface and said: "Noting that nobody had given any thought to the atmospheric consequences of the release of chlorine or bromine before 1974, I can only conclude that mankind has been extremely lucky." Strategic and effective investments in research and integrated systematic observation systems are required if humanity is to stay lucky.

Humans have impacted the "health" of the atmosphere in many ways. The consequences of a changing composition are well documented and are based solidly on a wide range of scientific studies and systematic observations. As a result, a series of international cooperative policy processes have been established to protect the atmosphere, including the 1979 UNECE (United Nations Economic Commission for Europe) Convention on Long-Range Transboundary Air Pollution (CLRTAP), the 1985 Vienna Convention for the Protection of the Ozone Layer and the 1992 UN Framework Convention on Climate Change (UNFCCC). They exemplify the benefits that can accrue from international cooperation that promotes the generation and dissemination of knowledge that serves as the basis for the development of sound environmental protection policy.

However, we have a poor understanding of many aspects of the key cycles and processes that affect atmospheric composition. Consequently, we cannot fully assess how the changing atmosphere impacts human health, the environment and climate. This is particularly true in regions outside the major population centres. There are major gaps in observations over large regions, including for the greater North Atlantic region, which is the focus of this report. The North Atlantic is impacted by a vast array of natural and anthropogenic materials emitted from the Americas, Europe and Africa. Although much research has been carried out in this region to characterise these impacts, to date, there has not been a substantial effort to coordinate research efforts. Indeed, there is no systematic process to identify existing programmes or to characterise the types and frequency of measurements that are being made.

The various policy responses, while welcome, have also resulted in structural gaps. For example, the major environmental conventions that aim to protect the atmosphere have each established largely singular scientific, technical analysis provision processes. These can lead to fragmented scientific investment in atmospheric research. Opportunities for synergistic activities are seldom realised. Policy processes can create barriers that can be difficult to overcome and resultant policy conflicts can be difficult to resolve.

ACE2 (the second Aerosol Characterisation Experiment) was designed to address a knowledge gap at the scientific interface between climate change and air pollution. It focused on increasing understanding of the influences of aerosols on climate. Aerosols are generally referred to as particulate matter (PM) by air quality specialists. Aerosol climate interactions are scientifically complex but their impacts are considered to "mask", at least temporarily, the effects of greenhouse gas (GHG) warming. In July 2017, the 20th anniversary of ACE2, a meeting ("ACE20") was held to explore its legacy, subsequent developments and wider regional and policy contexts. Its key activities are outlined here along with recommendations on how to address the issues identified.

2 https://www.nobelprize.org/nobel_prizes/chemistry/laureates/1995/crutzen-lecture.pdf

2 Background

In the late 1980s and early 1990s, leading scientists promoted the concept that certain feedbacks could counteract global warming. This was popularised in a series of books by James Lovelock[3] as the "Gaia hypothesis". Scientifically, this included ocean responses, which were postulated to result in the formation of increased amounts of aerosols that would directly reflect sunlight and change cloud cover and cloud properties. It was proposed by Charlson *et al.* (1987) that these processes could potentially have a cooling influence that counters some of the warming produced by GHGs. Their hypothesis served to highlight two major issues: (1) the large scientific uncertainty in aerosol and aerosol-cloud radiative forcing of climate; and (2) the importance of ocean–atmosphere interactions in the global climate system. Oceans are estimated to absorb over 90% of the additional energy being trapped by enhanced GHG levels. The oceans are also the major sinks for carbon dioxide, which has consequences for their chemistry. The ocean is also a major source of biogenic and sea salt aerosols.

Two major international projects under the International Global Air Chemistry (IGAC) project were designed to increase understanding of these issues: the first Aerosol Characterisation Experiment One (ACE1) and ACE2. ACE1 took place in the Southern Hemisphere off Cape Grim in Tasmania, Australia. It focused on processes and systems taking place in an ocean environment that was relatively free of continental influences. In 1997, ACE2 took place in the eastern sub-tropical North Atlantic region around Tenerife and between Europe and north-west Africa. It focused on assessing the impacts of anthropogenic aerosols (air pollution) from Europe and desert dust from North Africa on the energy balance of the sub-tropical North Atlantic region. Individually and in combination, they provided considerable insights into aerosol and aerosol-cloud processes. Over the subsequent 20 years, there has been significant progress in understanding aerosol and climate issues and significant advances in technologies and systems for observing atmospheric change.

From 4 to 6 July 2017, a group of international experts (Appendix 1) from Europe and North America gathered in Santa Cruz de Tenerife, Spain, for a meeting that had two key objectives. The first was to consider the legacy of ACE2. The second was to review and assess the breadth and depth of observatory-based research in the greater North Atlantic region and to consider options to strengthen future observatory-based research in that area. A key aim was to review gaps that need to be addressed through better integration of observation-based research with emerging weather, climate and environmental modelling/observational systems of Europe and North America. It also considered examples of emerging frameworks for integration. These include:

- the European Copernicus Atmosphere Monitoring Service (CAMS), aimed at emerging research-based observational infrastructures in Europe;
- the In-service Aircraft for a Global Observing System project (IAGOS), aimed at atmospheric composition measurements from commercial aircraft;
- the Aerosols, Clouds, and Trace gases Research Infrastructure Network (ACTRIS), aimed at integrating European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds and short-lived gas-phase species;
- the Integrated Carbon Observation System (ICOS), aimed at the measurement of GHGs in Europe to support the Global Atmosphere Watch (GAW) network of the World Meteorological Organization (WMO); and
- the Svalbard Integrated Arctic Earth Observation System (SIOS), aimed at addressing regional Earth system science questions in the North Atlantic–Arctic region.

3 James Lovelock initiated measurements of the atmospheric build-up of Chlorofluorocarbons on the west coast of Ireland, which were later implicated in stratospheric ozone depletion. These measurements continue at Mace Head and globally via the Advanced Global Atmospheric Gases Experiment (AGAGE) network.

3 The Importance of the North Atlantic Region

Why is the North Atlantic region important? It is the second largest ocean basin in the world, following the Pacific. It comprises two linked basins based on topography and ocean currents: the North Atlantic and the South Atlantic. Here, we focus on the North Atlantic (see Figure 5.1). It is where the cold arctic waters mix with warm southern Gulf Stream waters and sink to drive the "global ocean conveyor", a circulation pattern that plays an important role in regulating atmospheric carbon dioxide concentrations and the Earth's climate. The region is geographically and politically complex. The surrounding continental areas of Europe, North America and their associated islands are among the most developed areas in the world. Other areas in North Africa and Latin America are among the least developed. Key regions, such as the Caribbean, are vulnerable to changes and shifts in weather and climate systems. The stability of the vast Greenland ice sheet is a major regional and global concern because of its potential impacts on ocean currents and contribution to sea level rise. The North Atlantic is connected to the Arctic Ocean and the rapidly changing Arctic region. These areas are interconnected with the global ocean circulation in complex ways that affect climate.

The North Atlantic atmosphere is inundated by air pollution, particularly from eastern North America, Europe and areas of West Africa. In the eastern and southern regions it is affected greatly by Saharan dust, which can travel as far as Texas and the central USA and across Central America to the Pacific. The southern tropical North Atlantic is the spawning ground for tropical cyclones and hurricanes. These generally track westwards and impact the Caribbean, Central America and eastern North America. The region includes some of the busiest global transport routes and is consequently influenced by emissions from aviation and maritime transport.

Historically, environmental concerns resulted in considerable regional investment in actions to respond to issues such as acidification and eutrophication in Europe and North America. The UNECE CLRTAP aimed to address these and related issues. Associated networks were designed to monitor key pollutants, such as sulfur and nitrogen species, and their impacts (see Figure 5.2). The increasing recognition of the long-range nature of pollutant emissions resulted in the formation of the UNECE Task Force on Hemispheric Transport of Air Pollution (HTAP),[4] which operates under the guidance of the US Environmental Protection Agency (EPA) and the European Commission. The analysis provided by the HTAP Task Force indicates an increasing trend in ozone concentrations at a number of remote sites across the Northern Hemisphere, including the North Atlantic region, suggesting an increase in the hemispheric baseline ozone concentration of a factor of two during the latter half of the 20th century. It is considered likely that much of this change is due to increases in anthropogenic emissions of precursors. This has increased baseline ozone concentrations to the point where they exceed current thresholds for protection of vegetation in many locations and occasionally exceed thresholds for the protection of human health in some locations.

The HTAP Task Force also identified intercontinental transport of PM crossing oceans and identified the potential of advanced satellite observation and ground-based systems to provide quantitative information on intercontinental transport of PM, including estimates of the amount of pollution transported, the altitude of transport and, in some cases, aerosol properties. It links these to emission source functions and the meteorological conditions responsible for them, and provides important information on aerosol properties and their effects on air quality, sensitive ecosystems and regions (e.g. the Arctic) as well as on their influence on weather and climate systems.

Dust and pollution aerosol are considered to have roles in cyclone production and development, but these processes have been little studied and are poorly understood. There is emerging evidence of connections between processes such as aerosol pollution, rainfall in North Africa, desert dust and

4 http://www.htap.org/publications/2010_report/2010_Final_Report/EBMeeting2010.pdf

tropical cyclones. Extra-tropical storms develop in the western part of the North Atlantic in the westerlies underlain by the contrasting waters of the Arctic's Labrador/Greenland currents and the Gulf Stream of tropical origin. The Gulf Stream is responsible for the temperate climate of high-latitude Europe (Oslo and Stockholm at 60°N, which compares to Yellowknife in the Canadian Northwest Territories) and part of the meridional overturning circulation.

Currently, there are a substantial number of active research observatories in the North Atlantic region. Some of these are as shown as red stars in Figure 5.1. Four of the six observatories shown are global stations in the UN WMO GAW network. Those shown are primarily funded nationally and by the EU. There is a dearth of long-term stations in the western Atlantic. Of note is the station on Barbados, which is operated by the University of Miami primarily with funding from the US National Science Foundation. There are also long-term atmospheric chemistry programmes in Miami and on Puerto Rico under the University of Puerto Rico. The larger star identifies Izaña as a comprehensive observatory and host of ACE2 and this event.

From a carbon cycle point of view, the role of the North Atlantic as a sink for carbon is poorly understood and will benefit from better coupled atmosphere–ocean models that are constrained by adequate observation systems. The dynamics and influences of the various oceanic contributions, including inorganic and organic compounds and various biogenetic substances, are only now beginning to be understood.

The observed global distribution of aerosol optical depth highlights the complexity of the North Atlantic atmosphere (Figure 3.1). Focusing on the area in the red oval, it is clear that the North Atlantic is impacted in the south by strong outbreaks of African dust and central African biomass-burning emissions that are carried westwards in the trade winds as far west as the Amazon basin in South America and Texas and the Midwestern USA. In the north, it is contaminated by air pollution from eastern North America and Europe. Recent studies from Izaña show that North American sources influence air masses over the North Atlantic.

Ocean atmosphere exchanges are central to the regional atmospheric dynamics and processes. Exchanges of heat and water in various forms are

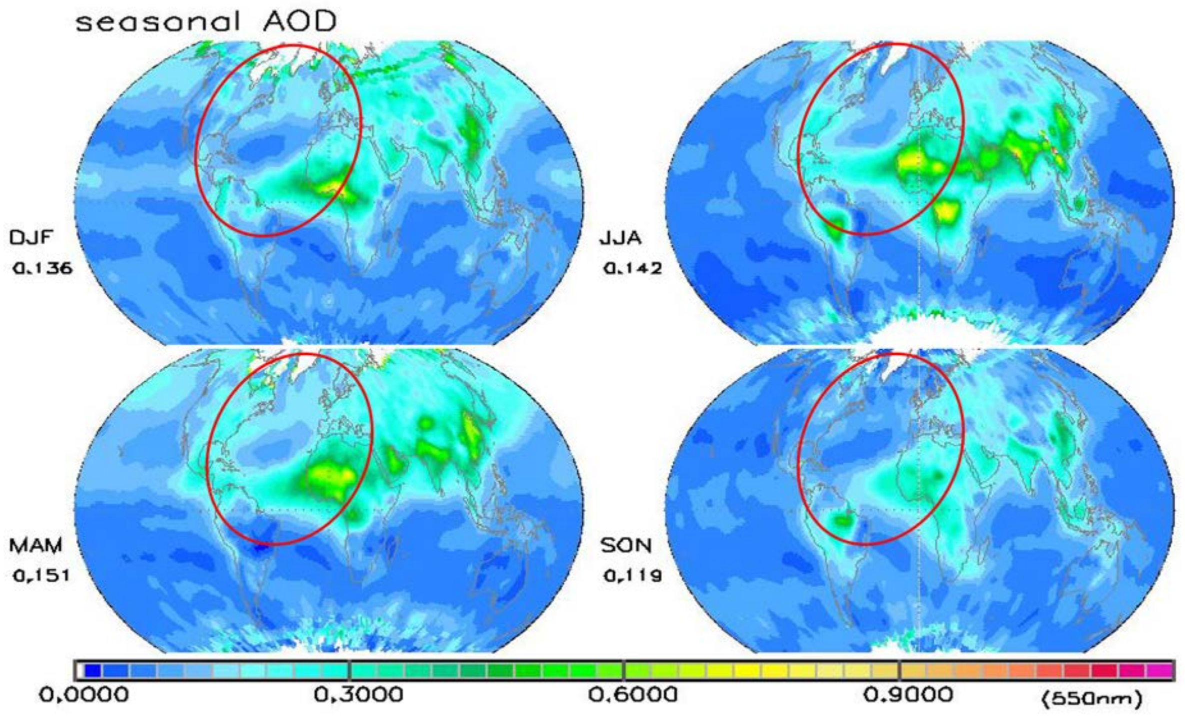

Figure 3.1. Long-term global-average atmospheric aerosol optical depth for the 1990s by season. The red oval marks the greater North Atlantic region. Complied by combining data from satellites with surface-based aerosol sun-photometer data. Satellite observations were validated using ground-based aerosol optical depth observations. Plots courtesy of S. Kinne, MPI, Hamburg, Germany.

fundamental to weather and climate systems. The winds over the North Atlantic drive air–sea interactions, which generate sea spray and biogenic sulfur aerosols and modulate the exchange of carbon dioxide, thus making it an important component of the global carbon cycle.

In conclusion, enhanced understanding of these systems and process and their evolution is central to issues of global climate and environmental change. Scientifically, an Earth systems science approach based on integrated observations and linked development of models is required at a scale that can capture the essential details needed to support decision-making at local to global levels. The North Atlantic region uniquely combines the complexity, capacity and urgency to address these issues. It is ideally situated to provide a focus on the development of integrated scientific analysis of ongoing and projected regional and global changes and inform effective collective management of these.

4 Messages at ACE20

The abstracts for the ACE20 meeting are provided in Appendix 2. The meeting format was designed to summarise the past and present observational research accomplishments and to stimulate member interactions and discussion of the future needs and gaps in the region. It was organised by Frank McGovern, currently EPA Ireland, who led the implementation of ACE2 with Joe Prospero and Frank Raes.

Emilio Cuevas, head of the Izaña Observatory, emphasised the long history of observations at Izaña, dating as far back as 1645 when members of the British Royal Society made measurements of atmospheric pressure, and 1799, when Alexander von Humboldt visited. In 1832, Charles Darwin was quarantined in Tenerife harbour as a result of cholera on the HMS *Beagle* in the harbour. Darwin subsequently noted a major Saharan dust storm event in the regions from observations from the Cape Verde Islands: “On the 16th of January (1833), when the Beagle was 10 miles off the N.W. end of St. Jago, some very fine dust was found adhering to the underside of the horizontal wind-vane at the mast-head; it appeared to have been filtered by the gauze from the air, as the ship lay inclined to the wind….”

Formally, Izaña Observatory was inaugurated in 1916 and celebrated its 100th anniversary two years ago. In 1954, Christian Junge, one of the founders of atmospheric chemistry and the WMO GAW programme, spent 3 months in Izaña observing Saharan dust. It played a key role in the 1958 International Geophysical Year. In 1989–1998, Izaña was a key observatory in the Atmospheric/Ocean Chemistry Experiment (AEROCE), connecting observations made at various sites around the North Atlantic, led by Prof. Joe Prospero of the University of Miami, Florida, USA. The longest record of observations at Izaña is of sunshine duration since 1915. The first atmospheric composition measurements began in 1981 when German–Spanish cooperation led to GHG measurements at Izaña, which have continued ever since. Today, Izaña is a key foundation stone in global, European and North Atlantic observation-based research networks. It also is a calibration centre for (1) the National Aeronautics and Space Administration (NASA) Aerosol Robotic Network (AERONET) and WMO GAW aerosol optical depth network observations, (2) the NASA and WMO GAW Total Carbon Column Observing Network (TCCON) total column carbon dioxide and methane network, and (3) the GAW global total column ozone network. All these networks are essential for calibrating satellite observations and understanding aerosol, carbon and ozone atmospheric cycles. See Appendix 3 for images of this observatory taken during the site visit during this workshop.

Frank Raes, European leader of ACE2, provided a retrospective on the achievements of ACE2. The intensive observational research campaign involved multiple aircraft and enhanced ground-based observations in the region for 6 weeks in 1997. It was successful in several ways.

First, it built a European aerosol research community that has gone on cooperating with ACTRIS. This network is close to becoming a European Strategy Forum on Research Infrastructures (ESFRI) infrastructure that integrates European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds and short-lived gas-phase species. ACTRIS will have the essential role of supporting the building of new knowledge and addressing policy issues on *climate change, air quality and long-range transport of pollutants*.

Second, it characterised atmospheric aerosols, and aerosol–cloud interactions off the Iberian peninsula–Northwest Africa–Izaña atmosphere, in unprecedented detail; stimulated the advancement of technologies for better aerosol characterisation; highlighted the need to perform better aerosol studies in the source regions; and resulted in the publication of 139 papers with an H factor of 44 and 200 citations per year since the 1997 field programme.

Frank Raes emphasised the importance of conveying scientific knowledge to the general population. He suggested that the arts could be used to communicate scientific results to the public in a meaningful way to develop broad support for science and to enhance the support of science-based policy. To illustrate this, Frank Raes provided a theatrical lecture on the evolution of the Earth and the role of humans in bringing about the Anthropocene. He has presented this entertaining account of the threat of human inaction to our planet over 50 times to students and the public, who have received his message with enthusiasm and appreciation.

Joe Prospero outlined African dust transport research, its history and its future. His studies of African dust began 50 years ago and he has long stressed the importance of Saharan dust transport and deposition to the North Atlantic. He emphasised that he saw this meeting as a means to "organise a coherent effort to address North Atlantic observational research". Even today, after decades of effort, dust gets short shrift in funded atmospheric and oceanic research projects and programmes. This is now changing with the implementation of the WMO Sand and Dust Warning Advisory and Assessment System (SDS-WAS; https://www.wmo.int/pages/prog/arep/wwrp/new/Sand_and_Dust_Storm.html and https://sds-was.aemet.es/), the inclusion of dust aerosols in the CAMS (https://www.ecmwf.int/en/about/what-we-do/copernicus/copernicus-atmosphere-monitoring-service) and the inclusion of dust in global climate models that contribute to the Intergovernmental Panel on Climate Change (IPCC) assessments.

Nevertheless, there is a large gap in our observational capacity over the Atlantic. While there are dense networks over North America and Europe, there are very few in North Africa or over the Atlantic. Most efforts consist of independent programmes that are linked only through ad hoc connections. Figure 4.1 shows model-estimated deposition of Saharan dust globally. It serves to emphasise the potential impacts of dust and biomass burning on the North Atlantic Ocean and on background air quality in North, Central and South America. As previously noted, this region is the breeding ground for tropical cycles, some of which migrate to the mid-latitudes as highly destructive storms (e.g. hurricane "Sandy", which impacted on the north-east of the USA and eastern Canada). Mixed with this dust is pollution from major African urban complexes in West Africa and biomass burning in Central Africa. Despite the presence of these huge sources, there are only three research observatories in the North Atlantic (Figure 3.1) that routinely study these emissions as they move westward, namely Izaña, Cape Verde and Barbados.

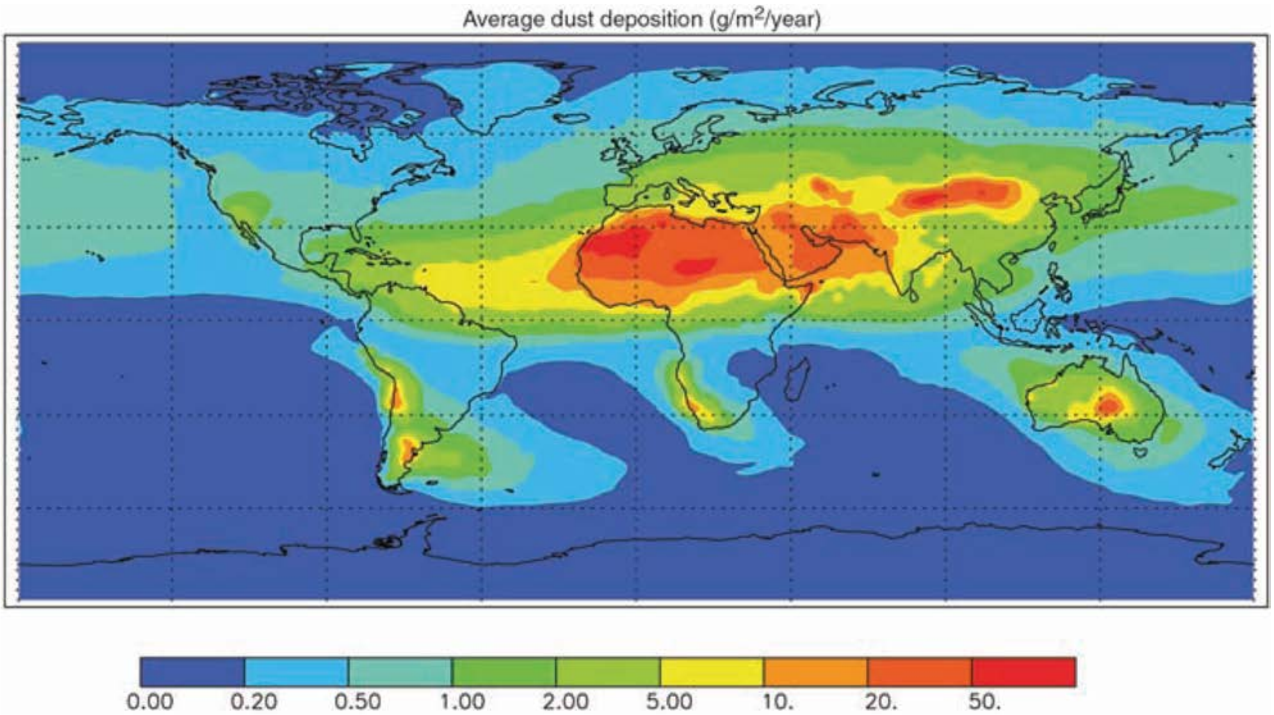

Figure 4.1. Composite of three published modelling studies that match satellite optical depth, *in situ* concentration and deposition observations. Source: Jickells *et al.*, 2005. Reproduced with permission from AAAS.

In the future, a new node of the WMO SDS-WAS at the Caribbean Institute for Meteorology and Hydrology will help coordinate and report research, forecasts and observations of sand and dust and African biomass burning in the Caribbean, north-east South America and the Southern USA. This will include a Caribbean ad hoc Aerosol Health Network, since Saharan dust impacts air quality levels ($PM_{2.5}$ and PM_{10}, e.g. levels of Particulate Matter in size ranges below 2.5 and 10 microns) in the region sometimes at levels above those recommended as safe by the World Health Organization and national environmental protection groups. Every summer, African dust penetrates into central USA by way of the Gulf Coast and is subsequently carried by westerly winds across the east coast of the USA and into the central North Atlantic.

Numerical modelling and combining models with satellite observations will play an increasingly important role in this region, such as is done by CAMS. This service is the product of over 10 years of extensive cooperative European research (Global and regional Earth-system Monitoring using Satellite and in situ data – GEMS; Monitoring Atmospheric Composition and Climate – MACC; MACCII) to include aerosols (currently black carbon, organic matter (OM), dust, sulfate), reactive gases (e.g. O_3 and CO) and GHG (CO_2, CH_4) in one of the most skilful weather forecast models in the world. CAMS is developed and operated by the European Centre for Medium-range Weather Forecasts (ECMWF) under a delegation agreement with the European Commission. The ECMWF itself operates under an international convention. This is done by incorporating the atmospheric sources, transport, photochemical reactions and removal processes of each constituent into the model and running forecasts initiated by the assimilation of satellite observations. Non-satellite observations (surface based and aircraft) are used for validation and improvement of the parameterisation of processes.

Mark Parrington of the CAMS team at ECMWF summarised its progress and emphasised the need to strengthen the North Atlantic observational research network and links to CAMS. Notably, he offered a recent global reanalysis of atmospheric composition and deposition from 2003 to the present by CAMS as a resource for atmosphere/ocean researchers in the region as well as a product of CAMS that will benefit from evaluation and improvement by North Atlantic research observatories. Joe Prospero noted that CAMS was a well-kept secret. This emphasises the need to improve dissemination of the products of this global climate and atmosphere service to the international science community and to the public. A coordinated North Atlantic research observatory would help to do this.

Kjetil Tørseth, Research Director of the Norwegian Institute for Air Research (NILU), represented two major European initiatives that are very relevant to the North Atlantic observational research effort. These are the European Monitoring and Evaluation Programme (EMEP) network that has been operating under the UNECE CLRTAP since 1979 and the SIOS, which is a European infrastructure.

The UNECE CLRTAP activities, supported by EMEP's regionally representative monitoring sites and air chemistry source receptor transport modelling, has played a large role in bringing about a reduction in SO_2 emissions from Europe and western Russia from 28 million tonnes in 1980 to about 10 million tonnes in 2017. A number of EMEP stations are in locations relevant to North Atlantic observations, such as the Irish station at Valentia, which cooperates with the other Irish Global GAW station in Mace Head (Figure 5.1). The EMEP network and the WMO GAW global network are coordinated formally through a long-established Task Force on Measurements and Modelling. Both networks are supportive of the European ACTRIS research infrastructure and are beneficiaries of this effort.

Leonard Barrie reviewed recent studies published in *Nature* and elsewhere showing that sulfur dioxide emission controls in Europe realised through actions taken under the LRTAP convention have had a substantial impact on North Atlantic sea surface temperature anomalies, tropical cyclone (hurricane) frequency and, in general, on the climate of the greater North Atlantic region, including North Africa. Furthermore, there is an observed correlation between anomalies in North Atlantic sea surface temperature (possibly driven by pollution and volcanic aerosol), North African rain, African dust and tropical cyclone frequency. Thus, climate change within the region has extra-regional impacts and vice versa.

Kjetil Tørseth noted that the SIOS includes a long-term WMO GAW and EMEP research observatory at

Zeppelin Mountain, where aerosols, reactive gases, GHGs, persistent organic pollutants and aerosol–cloud interactions are studied by a consortium of researchers coordinated by Norway and NILU. This is the starred site in the far North Atlantic (Figure 3.1).

The Mace Head Observatory near Galway, Ireland, has been a GAW and NASA–AGAGE (Advanced Global Atmospheric Gases Experiment) network observatory for a long time. It hosts a strong research programme focused on the North Atlantic marine atmosphere and involves a consortium of researchers. Jurgita Ovadnevaite reported on the programme studying aerosol cloud and climate interactions. Major advances have been made in improving the source function for sea salt aerosols that are used in IPCC Climate Models as well as the nature and origin of the organic components of sea salt particles coming off the North Atlantic. Mark Lunt reported on chlorofluorocarbon (CFC) measurements at Mace Head, which are critical in confirming progress in emission reductions under the 1985 Vienna Convention on Stratospheric Ozone and its subsequent Montreal Protocol and other protocols. Methyl chloroform observations have been very useful in understanding trends in atmospheric hydroxyl radical concentrations, which, in turn, are the main cause of methane removal from the atmosphere.

The long history and current state of the Valentia Observatory in the southwestern-most corner of Ireland was presented by Saji Varghese, Research Director of the Irish Meteorological Service (Met Éireann). Valentia and Mace Head are complementary stations in a dynamic dual-observatory system for weather, climate and environment, bringing together the meteorological service, the environment department and the National University of Ireland, Galway (NUIG) atmospheric researchers. Beginning in 1860 with meteorological and climatological observations, Valentia began geophysical observations in the 1950s and air and water pollution observations in the 1970s. It is an EMEP station under the UNECE CLRTAP convention and is part of the WMO GAW ozone total column and balloon–sonde network. A new remote EMEP observatory near Valentia was installed in response to an external review of Mace Head and Valentia operations commissioned by the government of Ireland in 2006. Cooperation with Mace Head and NUIG is active. Through these two stations, there is great opportunity for observation-based research in Ireland.

Katie Read presented 10 years of research observations at the São Vicente, Cape Verde, global GAW station, operated by the National Centre for Atmospheric Measurements, University of York, with UK and other funding. The measurements in the marine boundary layer include O_3, CO, non-methane volatile organic compounds (NMVOCs), NO, and NO_2, along with meteorological variables as well as GHGs, aerosols, halocarbons, halogen oxides and total gaseous mercury. Recently, they have discovered that nitrate aerosol is a dominant source of nitrogen oxides (NO_x) in the remote marine boundary layer and that there are unexpectedly high mercury levels coming from Africa.

Paulo Fialho reported on the baseline Pico Mountain Observatory (PIC). Situated at Pico Island, in the Azores archipelago, at about 2225 m above sea level, is operated by IVAR (Instituto de Investigação em Vulcanologia e Avaliação de Riscos) of the University of Azores, Portugal, with the cooperation of the Michigan Technological University, Institute of Arctic and Alpine Research, and the University of Colorado, Boulder. With the political, and some financial, support of the regional Government of Azores, PIC has been able to operate essentially with research projects submitted to the USA research funding agencies. PIC was founded in 2001 jointly with the late Professor Richard Honrath as an experimental observatory (PICO-NARE) to measure transatlantic transport of pollution from North America, Europe, Africa and the equatorial Atlantic. Despite its years of successful operation – almost 17 – the future of PIC remains uncertain. Principal investigators are seeking more sound long-term support to integrate PIC as a station in the WMO GAW programme network and also as part of ACTRIS. Hopefully, the Portuguese Science Programmes will support the involvement of the Portuguese atmospheric community, allowing the Institute for Marine and Atmospheric Research (IMAR) and the Portuguese universities to be involved in solid cooperation with international partners, which should allow the establishment of a sound foundation for international cooperative research that fills a major gap in the eastern North Atlantic.

Frank McGovern, a principal organiser of ACE2 and chief climate scientist at the Irish EPA, discussed the policy context of North Atlantic atmospheric observations from a national and European perspective. He cited IPCC forcing analysis (Figures

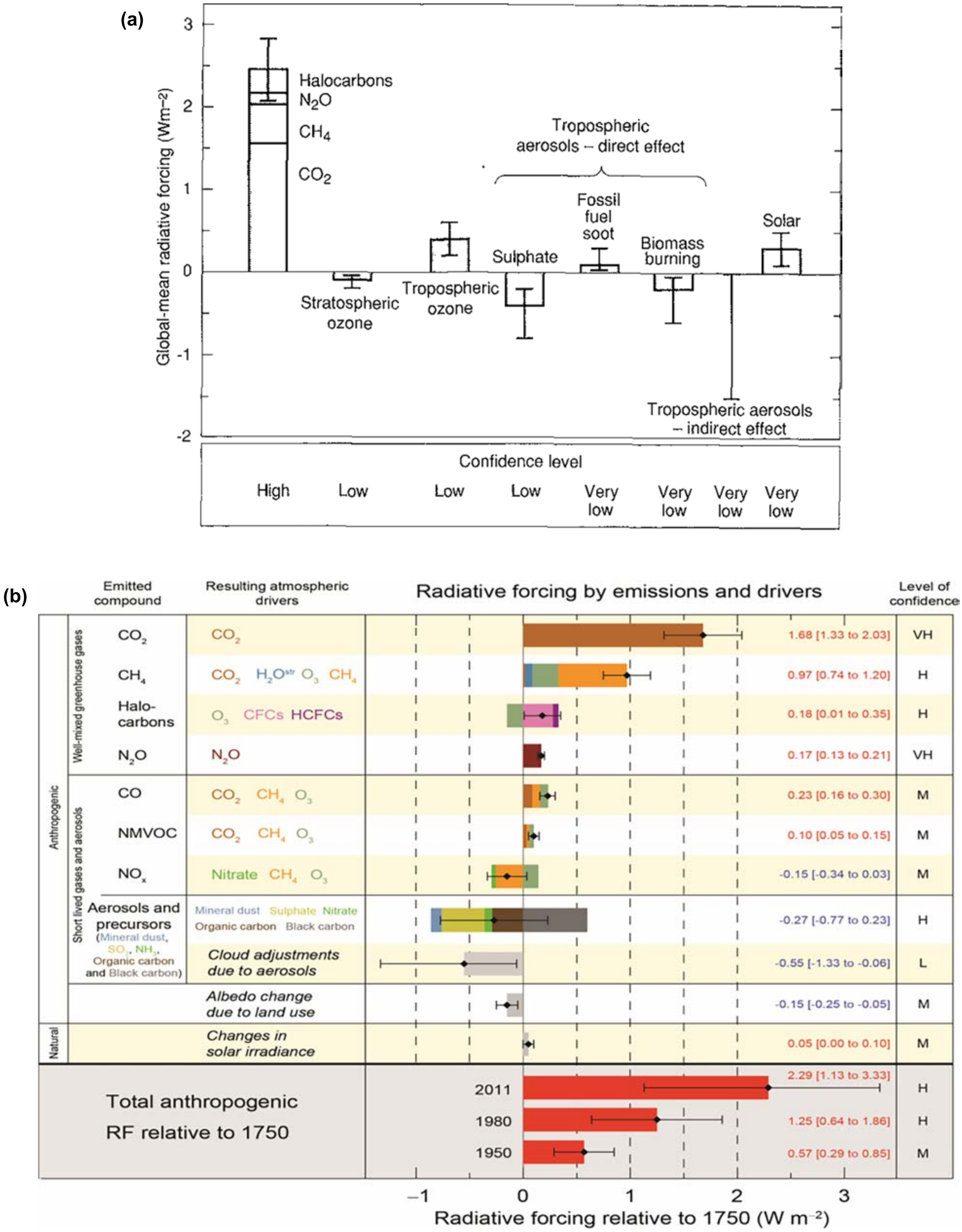

Figure 4.2. (a) Estimates of the globally and annually averaged anthropogenic radiative forcing (in Wm^{-2}) due to changes in concentrations of GHGs and aerosols from pre-industrial times to the present (1992) and to natural changes in solar output. Reproduced from IPCC (1995) Second Assessment Report. (b) Progress in determining the contribution of aerosols and other short-lived climate forces between the Second IPCC Assessment Report in 1995 and the Fifth IPCC Assessment Report in 2013. Reproduced from IPCC (2013) Fifth Assessment Report.

4.2a and 2b) to highlight how much progress has been made on understanding aerosol forcing of climate since 1997 and that ACE2 had a role in this, but that further progress and integration is needed. He emphasised that understanding the role of this vast and varied marine region is key to environmental and climate protection related to numerous threats including (1) severe weather, (2) air pollution, (3) stratospheric ozone depletion, (4) the spread of persistent organic pollutants and mercury, and, last but not least, (5) climate change. In the greater North Atlantic region, there is a need to move from the fragmented efforts of the past to a more focused programme of research, combining observations, modelling, process studies and communications with users and the general public. He challenged the group to consider ways to pull this together through cooperative programmes that draw together policymakers, scientists, service deliverers, communicators and the public.

Frank Dentener of the Joint Research Centre, Italy, gave an interactive remote presentation on improving our understanding of hemispheric transport of air pollution. He leads major international projects to combine atmospheric chemistry models with observations and is co-chair, with Vincent-Henri Peuch (Director of CAMS), of the WMO GAW Scientific Advisory Group on Applications. He pointed out that the following four conclusions from a recent GAW measurement–modelling fusion workshop for total atmospheric deposition in February–March 2017 (GAW No. 234; www.wmo.int/pages/prog/arep/gaw/documents/FINAL_GAW_234_23_May.pdf) were relevant to the North Atlantic discussions in this workshop:

1. There is a need to extend the GAW measurement network into regions that are presently poorly covered (e.g. intensive measurements at super-sites).
2. Organic nitrogen, NH_3, NO_x, iron (over the ocean) and dust are deemed the highest priority globally for measurement in new and/or existing networks.
3. Publicly available, integrated, high-quality global data sets are critical to the success of the measurement–modelling fusion approach to improved deposition.
4. Satellite measurements and their products are evolving rapidly and should be included in future measurement–model fusion activities.

5 How to Advance Understanding of Climate and Environmental Issues in the North Atlantic Region

The presentations were followed by discussions of how policymakers, scientists and service providers can approach the future study of the North Atlantic region and its role in (1) severe weather, (2) air pollution, (3) stratospheric ozone depletion, (4) the spread of persistent organic pollutants and mercury, and, last but not least, (5) climate change.

Can the ACE2 provide inspiration for building a community to better understand and predict the multifaceted role that the North Atlantic region plays in climate and environmental issues regionally and globally? It was successful in launching a European aerosol research community, which has now evolved into the emerging ACTRIS. It stimulated the advancement of technologies for better observation of aerosols and clouds. This means that Europe is effectively creating the first research-based observing network equipped with advanced instrumentation for aerosols, clouds and short-lived gas-phase species.

Is there an effective policy tool for bringing a North Atlantic research effort together? The UNECE CLRTAP of 1979 was founded to address the regional to hemispheric problem of long-range transboundary transport of air pollution. The Antarctic Treaty is used to coordinate international activities in this vast complex component of the Earth system. What mechanism can be used to improve cooperation to build a better understanding of the coupled atmosphere–ocean–land system in the greater North Atlantic?

The group agreed that there is a scarcity of long-term surface-based atmospheric observatories in the North Atlantic and on the coasts of the bordering land masses. Figure 5.1 clearly shows the lack of coverage in the Caribbean and the southern and western North Atlantic and the identified gaps that need to be filled. The USA, Canada, Greenland and Iceland do not have stations equivalent in stature to that at Izaña or Mace Head.

The group was very aware of how difficult it has been to sustain funding for the *existing* research-based observatories and that it will be even more difficult to add others to fill gaps. What is lacking from a policy perspective is a balance in funding between research infrastructures and research projects on a national as well as on an international scale. Europe is attempting, with partial success, to address this through the European Strategy Forum on Research Infrastructures (ESFRI), such as IAGOS, ICOS, SIOS and the emerging ACTRIS. Central and North America lag far behind in having such initiatives. One strong possibility for filling gaps in this observatory system is to redirect funds from potentially surplus surface-based observatories in Europe and eastern North America to the periphery of those regions.

Figure 5.2 shows the network of precipitation chemistry stations in the world from a recent assessment sponsored by WMO GAW and highlights the disproportionate density between the vast North Atlantic region and the surrounding continents for wet deposition of non-sea salt sulfate. This is typical for all atmospheric chemistry variables (e.g. aerosols and reactive gases). The policy challenge is how to channel resources from somewhat surplus observations in the high-density part to increase the density in other poorly sampled regions of the Earth system.

More support and cooperation from other agencies, especially national weather and hydrological services, space agencies and environmental departments, is essential to sustain a healthy surface-based research observatory network. While the general principle that diverse investment portfolios are more stable than single investments is widely acknowledged in finance, a similar principle for observatories is not widely acknowledged; namely that a diverse multi-stakeholder support portfolio for observatories leads to more stable long-term operations. In other words, the solution to the generic problems of weak funding of surface-based observatories is the addition of sponsors from those institutions that are currently funded to address related issues.

One possible policy solution is for governments to mandate space agencies to support routine

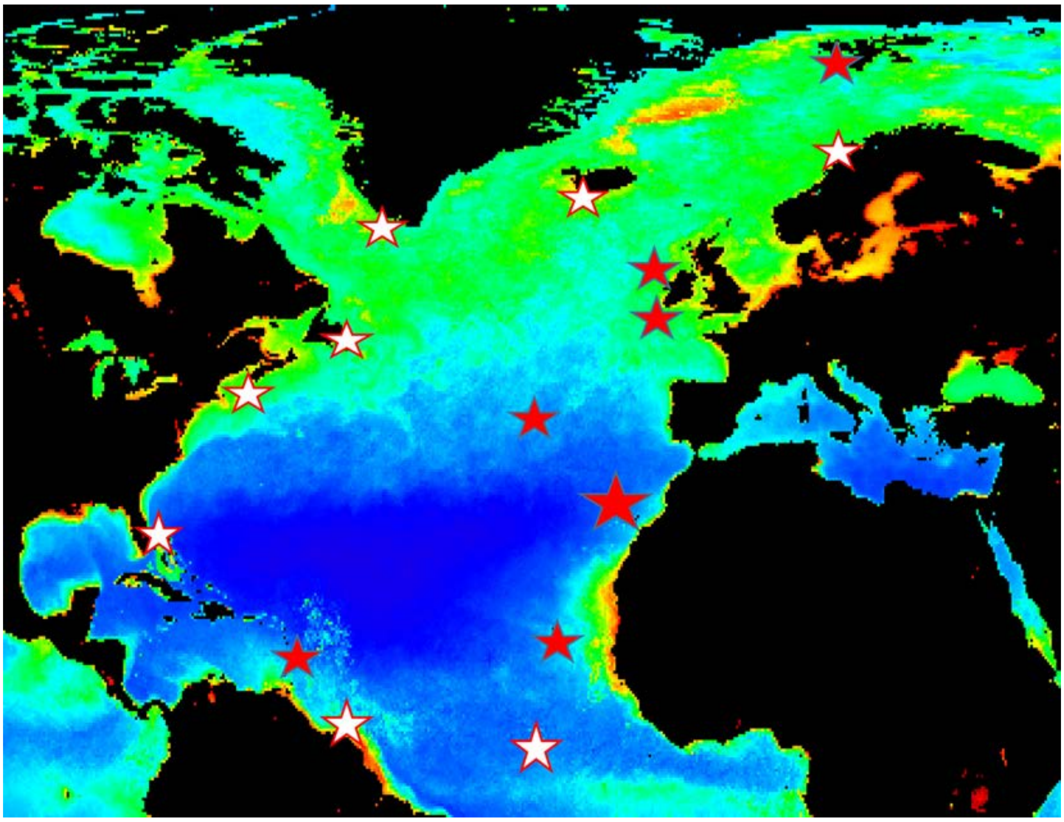

Figure 5.1. A map of some of the key North Atlantic atmospheric surface-based research observatories (red-filled stars) and potential observatories (white-filled stars). The larger red-filled star is observatory Izaña on Tenerife, which was the observatory central to ACE2 and ACE20. The background is satellite-derived productivity–chlorophyll mass from ocean colour satellites in 2007.

non-satellite ground-truthing of their satellites. A small fraction of satellite development and operations funding would go a long way to sustaining necessary ground-based validation and evaluations. NASA has been especially active in this regard. For instance, it has used agency funds to effectively develop AERONET, which is a network of ground-based sun photometers, which measure atmospheric aerosol properties and the Micro-Pulse Lidar Network (MPLNET) global networks for aerosols as well as for other variables such as GHGs. These ensure the accuracy and usefulness of satellite observations. In contrast, the European Space Agency (ESA) is not mandated to support long-term ground-truthing operations provided by surface-based networks and therefore it does not do so. Because the funding pendulum swings strongly to the publicly visible satellite platform, the less sensational surface-based observatories needed for validation and evaluation are significantly underfunded.

In general, there is a need for an integrated approach to climate and environmental observational studies involving aerosols and trace gases. Specifically, such an approach would prove useful in the logistically difficult and geographically complex North Atlantic region. Such an approach involves integrating observations of all types (satellites, surface-based *in situ* and remote sensing and aircraft) and assimilating these by atmospheric models that include all relevant processes.

Improvements in observations and in our understanding of processes will be ensured through funding research that is closely connected with the integrated observation and modelling systems. Since the early 1990s, this concept has been widely applied with great success for standard meteorological variables, namely wind, temperature, pressure, water vapour, clouds and precipitation. This has led to improved weather forecast skill scores and global three-dimensional (3D) reanalyses of the atmosphere, which are useful in climate modelling and research supporting the IPCC assessment processes. Only more recently has this been applied to aerosols and trace gases important to weather, climate and

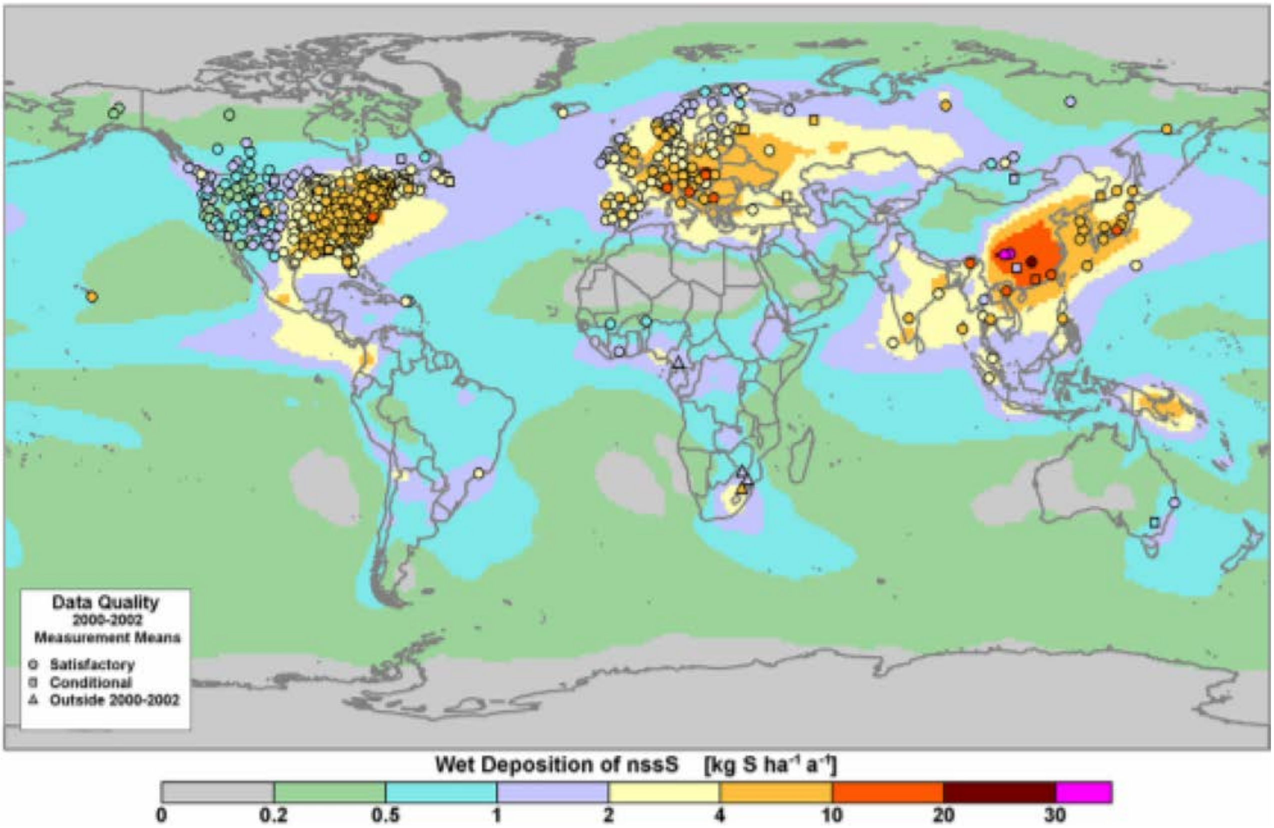

Figure 5.2. Observed and modelled wet deposition of non-sea salt sulfate as sulfur in 2000–2002 (WMO-sponsored assessment by Vet *et al*., 2014) is an example. Note the disproportionate density between the vast North Atlantic region and the surrounding continents for wet deposition of non-sea salt sulfate. The same is true for deposition of other constituents, aerosols, reactive gases and GHGs.

the environment. The possibilities were first pointed out in the 2004 WMO/ESA assessment report on integrated global atmospheric chemistry observations, through Integrated Global Atmospheric Chemistry Observations (IGACO) (GAW report No. 159 www.wmo.int/gaw; ESA SP1282). It is a concept that the Group on Earth Observations (GEO) and WMO community, including GAW, are implementing with global partners.

The integrated observing/modelling system for atmospheric composition concept is applicable to the greater North Atlantic region now that there is a long-term CAMS, which supplies the proper modelling tool needed for integration of observations. Indeed, as reported in this workshop, CAMS has a 15-year global reanalysis available for atmospheric aerosols and reactive gases that can be evaluated and applied to this region. One outcome of this event was that the time is ripe for greater operational and research cooperation with CAMS, centred on the ECMWF. The centre has been one of the leading weather forecast research and operations models in the world for more than 20 years.

The CAMS group is connected to a European observations community through various research infrastructures and through many users. It has added aerosols, reactive gases and GHGs to the weather model to provide forecast and reanalysis services and products. The CAMS group has confirmed willingness to cooperate and apply the global reanalysis of aerosol and reactive gas composition to the region.

The range of policies that now address atmospheric protection illustrate that science can inform policy and that atmospheric science and observation systems have an essential role to play in providing the necessary understanding to enable effective policy responses. The major policies and conventions also mandate scientific analyses and observations. Consequently, a range of structures such as the Global Climate Observing System (GCOS) and EMEP and analysis processes now exist which reflect the history of policy development. This may not be the most effective manner to advance atmospheric protection. Gaps and unintended consequences may occur, as happened between the UNFCCC and Montreal Protocol on ownership of the process for the phase-down hydrofluorocarbons (HFCs) and powerful GHGs used as substitutes for ozone-depleting substances. This was recently resolved, but such issues should be avoided in future. It is timely to consider how to develop an integrated approach to ensure coherence while retaining the integrity and capacity to achieve the key objectives and goals. A first step in this process would be a more integrated approach to the science. The North Atlantic region, with its shared geopolitical interest in its protection and the scientific capacity of these areas is ideal for development of such an approach.

6 A Strategy for Integrated Analysis of the Greater North Atlantic Region

The key to moving forward towards a strong, internationally supported North Atlantic surface-based research observatory system is to recognise that it is an *essential* component in a larger entity: an integrated North Atlantic atmospheric chemistry observing and modelling system for climate and environment. The challenge is *how to achieve a consensus among governments, policymakers and stakeholders that such action is needed and requires funding*. This report provides a first step in an engagement process with the aim of addressing the key challenges and gaps that have been identified. The essential activities include:

1. engagement with policymakers, funding agencies, operational bodies and scientists interested in the greater North Atlantic region;
2. identifying the essential roles that surface-based research observatories play relative to satellites, aircraft and ships in an integrated North Atlantic air chemistry observing system;
3. exploring ways that surface-based *in situ* and remote sensing, aircraft and satellite observations can be better integrated in the region;
4. producing scientific publications that assess the influences of natural and anthropogenic sources in the North Atlantic and their role in societal issues, related weather, climate and environment;
5. identifying critical gaps in long-term surface-based research observatories and their support, and outline why they urgently need to be filled.

To ensure success there is a need to gain the support of key regional actors, including operational and research funding agencies in the USA, Canada, European countries and the European Union and ideally from North Africa, Latin America and the Caribbean as well. There is also a need to engage international organisations such as WMO, UNECE, the United Nations Environment Programme (UNEP) for environmental services, GEO, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) and the International Maritime Organization (IMO).

7 Elements for Development

It is clear that integration, in many senses of the word, is necessary. There are options and approaches to achieve such integration at a number of levels. Here we identify actions for science, observation systems, outreach and policy.

The North Atlantic provides a key research area for understanding and observing planetary change. It is flanked by two of the most economically advanced regions in the world, Europe and North America, and is impacted by emissions from the major industrial regions located therein. The Atlantic Ocean is also bounded by large desert regions in North Africa and developing continental areas in Central America and northern South America. The Atlantic Ocean has unique vulnerabilities arising from the stability of key features, including the meridional overturning circulation of the ocean, the Greenland ice shelf and the rapidly changing Arctic region. These are increasingly impacted by changes in atmospheric radiative forcing and the resultant uptake of energy in the ocean systems and cryosphere. Other environmental changes are occurring because of transport and deposition of long- and short-lived pollutants, which can alter the oceanic biosphere and lead to the build-up of persistent pollutants such as heavy metals in ecosystems and food chains. Desert dust deposition is also a major feature of a large part of the region. The extent and rate of changes that are occurring in this region will probably have major and irreversible impacts on the surrounding continental areas and islands.

The North Atlantic region also hosts some of the most advanced observation sites and systems in the world, including leading ground-based facilities and satellite observation systems. As outlined during ACE20, many of these have developed independently. Links exist, for example, through global networks. However, an integrating focus is lacking that would enable a coherent analysis of atmospheric change and associated impacts. The North Atlantic region itself can provide this focus for a comprehensive integrated analysis and assessment of atmospheric change, its drivers and its regional and global consequences. Currently no specific organisation or body has been identified as having responsibility for advancing such a strategic initiative. As a consequence, potential steps in advancing such a process are identified here.

Recommendation: science. Based on discussions during the meeting, the steering group considered that a number of scientific papers should be produced, ideally in a coordinated manner. One aim would be to develop an agreed climatology of the North Atlantic aerosol/atmospheric composition using CAMS and similar analyses. This would provide a shared basis for consideration of how the array of sites in the region validate and capture the various elements identified in these analyses. Linking modelling products with the observational records from the sites in the region would be essential. This would also contribute to a strategy to address observation gaps. The production of complementary papers, which, for example, address specific elements such as dust transport or utilise other models, would therefore be encouraged. The ultimate objective would be to provide regular integrated assessments of the status of the North Atlantic atmosphere and analysis of the various continental and ocean influences and dynamics.

Next steps: options to advance this including funding to be identified. Interested groups are considered to include the Joint Programming Initiative “Connecting Climate Knowledge for Europe” (JPI Climate), Directorate-General for Research and Innovation, Copernicus, ESA, NASA, US National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA) and the US Department of Energy.

7.1 Review of Sites and their Observational Windows

The North Atlantic region is recognised as having some of the most advanced observation sites in the world. These are situated, to some extent, in strategic locations, such as Izaña and Mace Head. Other sites are less well developed or focus on narrower issues. Thus, we require an assessment of the current capacity and disposition of sites and their contributions to areas of scientific and policy interest. The aim would be to assess where additional development of current stations or new sites is needed to address gaps. A very initial assessment was made at this workshop through a survey completed by the ACE20 participants, who were asked to identify areas for development (see Figure 5.1). Further development of this is required to address issues, including the potential and capacity of the sites with regard to their objectives, current and future development plans, infrastructure requirements and capacities, including scientific and technical capacity necessary for the proposed measurements. A strategy for the phased development of sites in the region may be developed based on agreed criteria and protocols. Alternatively, an approach based on capacity may be developed. Overall, a process to develop criteria and protocols to assist and advance the strategic development of observation sites is needed. This should be done in tandem with remote sensing communities, both surface based and space based, and Earth systems modelling communities.

Recommendation: observations. Establish an ad hoc group to consider the range and scope of observational platforms (including surface-based research observatories) that would address the atmospheric observational requirements of the North Atlantic region and take into account the gaps in surface-based observatories identified in Figure 5.1 from this workshop. Engage with and more fully include space agencies and associated bodies working in this area in this process. This would aim to produce a strategic science-based analysis of development needed in the region.

Next steps: agree the terms of reference and membership of the expert group, including existing organisations and schedule a meeting to consider the issues identified.

7.2 Outreach to Broader Community (Arts and Science)

The wider options for communication of atmospheric protection issues emerged as an unexpected element of the discussion at ACE20. European and North American programmes exist to develop the links between arts and science in order to enhance communication. There are key challenges in communication of atmospheric change, which is largely intangible. However, current and new technologies are opening up the potential to visualise the invisible.

Recommendation: develop concepts for communication of atmospheric issues using established and new and emerging technologies.

Next steps: establish informal exchanges on options for doing this with public and private broadcast and communication groups with the aim of holding a workshop or similar with key groups and authorities.

7.3 Informing Policy Development and Integration

ACE20 heard discussion of the range of policy instruments and processes that are designed to advance areas of atmospheric protection. These have similar but differing processes for assessment, development and review. There is a need to explore options to more fully integrate these to inform comprehensive policy responses to atmospheric protection that avoid barriers and conflicts. Proposals have been made to establish a policy structure that frames atmospheric protection issues, e.g. the 2016 CLRTAP scientific assessment report.[5] A broad spectrum assessment of the causes and consequences of atmospheric change over the North Atlantic region may provide a useful input to advancing thinking on such a process. It would also enable a substantive dialogue between regional actors at various levels.

Recommendation: aim to use an integrated scientific assessment process for the greater North Atlantic region to provide a basis for discussions by key actors, including policymakers, in the region on how to address shared interests and develop the required responses.

Next steps: develop an initial paper/opinion document on this issue and aim to hold a further exploratory meeting to identify and build on linked initiatives.

5 http://www.unece.org/fileadmin/DAM/env/lrtap/ExecutiveBody/35th_session/CLRTAP_Scientific_Assessment_Report_-_Final_20-5-2016.pdf

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Abbreviations

ACE2	Second Aerosol Characterisation Experiment
ACTRIS	Aerosols, Clouds, and Trace gases Research Infrastructure Network
AEMET	Agencia Estatal de Meteorología
AEROCE	Atmospheric/Ocean Chemistry Experiment
AERONET	Aerosol Robotic Network
AGAGE	Advanced Global Atmospheric Gases Experiment
ALE	Atmospheric Lifetime Experiment
CAMS	Copernicus Atmosphere Monitoring Service
CFC	Chlorofluorocarbon
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
CVAO	Cape Verde Atmospheric Observatory
ECMWF	European Centre for Medium-range Weather Forecasts
EMEP	European Monitoring and Evaluation Programme
EPA	Environmental Protection Agency
ESA	European Space Agency
ESFRI	European Strategy Forum on Research Infrastructures
GAGE	Global Atmospheric Gases Experiment
GAW	Global Atmosphere Watch
GEO	Group on Earth Observations
GHG	Greenhouse gas
HFC	Hydrofluorocarbon
HTAP	Hemispheric Transport of Air Pollution
IAGOS	In-service Aircraft for a Global Observing System project
IARC	Izaña Atmospheric Research Centre
IASOA	International Arctic Systems for Observing the Atmosphere
ICOS	Integrated Carbon Observation System
IFS	Integrated Forecasting System
IPCC	Intergovernmental Panel on Climate Change
MACC	Monitoring Atmospheric Composition and Climate
MPLNET	Micro-Pulse Lidar Network
NASA	National Aeronautics and Space Administration
NILU	Norwegian Institute for Air Research
NMVOC	Non-methane volatile organic compound
NO_x	Nitrogen oxides
NPF	New particle formation
NUIG	National University of Ireland, Galway
OM	Organic matter
PFR	Precision Filter Radiometer
PIC/PICO-NARE	Pico Mountain Observatory
PM	Particulate matter
PMO	Pico Mountain Observatory
RI	Research Infrastructure
SAON	Sustaining Arctic Observing Networks
SDS-WAS	Sand and Dust Warning Advisory and Assessment System
SIOS	Svalbard Integrated Arctic Earth Observation System
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultraviolet
VOC	Volatile organic compound
WMO	World Meteorological Organization

Appendix 1 List of Attendees

ACE20 PARTICIPANT LIST	
NAME	**ORGANISATION**
Katie A. Read	National Centre for Atmospheric Science, University of York
Mark Lunt	University of Bristol
Jurgita Ovadnevaite	National University of Ireland Galway
Saji Varghese	Met Éireann
Paulo Fialho	Instituto de Investigação em Vulcanologia e Avaliação de Riscos
Mark Parrington	European Centre for Medium-range Weather Forecasts
Leonard Barrie	McGill University, Montreal
Frank Dentener	JRC, Ispra, Italy
Frank Raes	JRC, Ispra, Italy
Frank McGovern	Environmental Protection Agency
Claire Camilleri	Environmental Protection Agency
Joe Prospero	University of Miami
Kjetil Tørseth	Norwegian Institute for Air Research
Emilio Cuevas-Agulló	AEMET
Sergio Rodríguez	University of La Laguna
María Isabel García-Álvarez	University of La Laguna
Natalia Prats	AEMET
Saviz Sehat	Atmospheric Science and Meteorological Research Center, Iran
Javier López –Solano	AEMET
Elisa Sosa-Trujillo	AEMET

Appendix 2 ACE20 Abstracts

Hundred-year Anniversary Celebration of the Izaña Observatory

Dr Emilio Cuevas-Agulló, AEMET

The most noteworthy scientific campaigns and experiments that took place before the 20th century, and which already showed the great interest of the international scientific community for the summits of the island of Tenerife to carry out atmospheric studies, are introduced. The relevant scientific milestones that took place at the Izaña Observatory from its official opening on 1 January 1916 to the present day are summarised, highlighting the importance they have had in the current development of different lines of atmospheric research. The Izaña Observatory, with its recent enrolment in the WMO club of centennial stations, contributes to understanding the natural variability of climate and climate change seen from a unique high mountain station located in the subtropical North Atlantic region and is of great atmospheric interest. Finally, the most noteworthy activities carried out in 2016 and 2017 to celebrate the centenary of the observatory of Izaña are shown.

The Legacy of ACE2: What We Did and What We Learned?

Dr Frank Raes, ACE2 Project leader for JRC (Joint Research Centre), Ispra, Italy

ACE2 was a major initiative aimed at advancing understanding of aerosol interactions with climate. It was ambitious and creative. Its main focus was on the impacts of pollutants and dusts from Europe and North Africa on direct and indirect radiative forcing in the sub-tropical North Atlantic region. An overview of ACE2 and its key outcomes are provided.

A 50-Year History of African Aerosol Studies in the Atlantic: Izaña, ACE2 and AEROCE

Prof. Joe Prospero, Professor Emeritus, Department of Atmospheric Sciences, Rosenstiel School of Marine and Atmospheric Science, University of Miami

Systematic studies of the transatlantic transport of African dust began on Barbados in 1965 with the work of Parkin and Delany. In 1966, the University of Miami took over the Barbados station. Over 50 years, we have generated the world's longest record of long-range aerosol-dust transport. Concurrent measurements at Miami, Bermuda and Izaña observatories (and recently at Cayenne) demonstrate the widespread impact of dust over a huge region. Dust concentrations have varied greatly over this period in response to changes in North Africa, notably the drought that began in the 1970s and which continues to this day, possibly exacerbated by land use. Dust transport to the Caribbean, the southern USA and South America impacts multiple facets of climate, including interactions with solar radiation and with clouds. Deposition affects the biogeochemistry of the ocean and ecosystem productivity in soils. African dust could also adversely affect human health in the region because of high $PM_{2.5}$ and PM_{10} concentrations.

Many aspects of this phenomenon remain poorly understood, including the impact of climate variability on the frequency and intensity of dust transport, the evolution of the size-resolved composition of dust as it traverses the Atlantic Ocean in a journey of 5 to 7 days and the impact of transported dust on air quality in the Caribbean Basin. Of particular interest are the roles of atmospheric “ageing” on the physical and chemical properties of dust and the bioavailability of trace nutrients in dust, the subsequent impacts on ocean productivity and marine biogenic emissions, and the effect of co-transported biomass burning emissions on air quality, budgets of trace nutrients and climate.

Over the past decade, there have been a number of field programmes that have focused on specific aspects of the African dust story. While these have greatly expanded our understanding of this phenomenon, it is difficult to integrate these results into a coherent picture. The time is ripe to address these issues with coordinated studies so that we can compare the physicochemical characteristics of African aerosols near the source and later in its journey at receptor sites along the coast of Africa and subsequently in the Caribbean Basin and South America. This integrated approach will yield a "Lagrangian" view of aerosol transport and ageing. These measurements are critical for improved model predictions of the impact of dust on climate processes. Most importantly, it is necessary to continue to characterise the transport of dust and other aerosols over this region as climate changes. Africa is the world's largest dust source, accounting for 50–70% of global emissions. Yet, in the recent IPCC assessment, models could not agree as to the future climate in those regions of Africa that are known to be the most active dust sources in the present day. So, it is not possible to anticipate future emissions and transport. Moreover, the population in these sensitive source regions is growing rapidly, which could further exacerbate dust emissions, complicating our modelling of future trends.

Beyond ACE2: The Need for Coordinated Atmospheric Chemistry Studies over the North Atlantic

Prof. Joe Prospero, Professor Emeritus, Department of Atmospheric Sciences, Rosenstiel School of Marine and Atmospheric Science, University of Miami

To be supplied during the conference.

An Overview of the Contributions of the Izaña *in situ* Aerosol Research Programme to the Scientific Knowledge

Dr Sergio Rodríguez, Lead of the Aerosol Research Program, Izaña Atmospheric Research Centre, AEMET, Tenerife

In this presentation, an overview of the studies on atmospheric aerosols performed at Izaña Observatory is presented. These studies have covered different topics across different decades, including the first description of the meteorological scenarios of Saharan dust export to the North Atlantic (Font, 1950), among the first worldwide studies on aerosol chemistry (Savoie, 1984), large-scale experiments on aerosol transport and, during the last decade, research on new particle formation, optical properties, long-term variability of North African dust, trends and new sources, ice nuclei, solubility and ocean fertilisation, radioactive isotopes, speciation of organic aerosols and transatlantic transport of aerosols from North America. Since 2006, Izaña has been providing aerosol observations within the frame of the WMO GAW programme. The long-term aerosol chemistry programme of Izaña has 30 years' observations, which is among the largest in the world. This data set is being used to assess how aerosol composition has changed in connection to air quality policies and atmospheric transport.

Potential Role of Pollution and Dust Aerosols in the Changing Climate of the Greater North Atlantic Region

Prof. Leonard Barrie, Professor Emeritus, Stockholm University and Adjunct Professor, McGill University, Montreal

Atmospheric aerosols in the greater North Atlantic region are subject to anthropogenic and climate influences, and they in turn potentially impact weather, climate and the environment. What aerosol types affect the energy budget of the greater North Atlantic region? How have changes in aerosols over the last 120 years enhanced or masked climate change due to GHG forcing? Is there evidence of the influence of aerosols on storms and extra tropical cyclones? What are some possible climate feedback mechanisms in the region related to aerosols? These are questions that are explored in this presentation.

EMEP Monitoring Strategy Beyond 2019, GAW IP and Open Access to Data

Kjetil Tørseth, Research Director Atmospheric and Climate Research Department (ATMOS), Norwegian Institute for Air Research (NILU), EMEP

European-scale harmonised monitoring of atmospheric composition was initiated in the early 1970s, following the concerns about acid rain in Scandinavia. These efforts have expanded to include a broad range of measures and to address air pollution impacts on ecosystems, health and climate. Major revisions of the monitoring requirements to address these subjects were made in 2003 (2004–2009) and 2009 (2010–2019), and currently a revision is ongoing to guide requirements for the period 2020–2029. A close collaboration exists between EMEP and WMO-GAW. GAW recently published a revised implementation plan, and this presentation focused on the monitoring efforts undertaken in the Atlantic region and the data available resulting from these efforts (http://ebas.nilu.no).

Organic Aerosol Pollution – An Emerging Concern in North-east Atlantic Aerosol–cloud–climate Interactions

Dr Jurgita Ovadnevaite, School of Physics and C-CAPS, National University of Ireland Galway

Since the 1980s, measures mitigating the impact of transboundary air pollution have been implemented successfully, as evidenced in the 1980–2014 record of atmospheric sulfur pollution over the north-east Atlantic, a key region for monitoring background northern-hemisphere pollution levels. The record revealed a 72–79% reduction in annual average airborne sulfur pollution (SO_4 and SO_2, respectively) over the 35-year period. The north-east Atlantic, as observed from the Mace Head research station on the Irish coast, can often be considered clean for 64% of the time, during which sulfate dominates PM_1 levels, contributing 42% of the mass, and, for the remainder of the time, under polluted conditions, a carbonaceous (OM and black carbon) aerosol prevails, contributing 60% to 90% of the PM_1 mass and exhibiting a trend whereby its contribution increases with increasing pollution levels. The frequency of occurrence of major pollution events over the north-east Atlantic was also studied by deploying satellite remote-sensing platforms: CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization), MODIS (Moderate Resolution Imaging Spectroradiometer) and SEVIRI-MSG (Spinning Enhanced Visible and Infrared Imager – Meteosat Second Generation Spacecraft) 9 and revealed four types of extreme pollution events, namely European outflow, volcanic ash, US/Canadian wild fire emissions, long-range transport and Saharan dust over a 6-year period. In total, 17 extreme pollution events were registered, which translated into approximately three extreme pollution cases per year (0.8% of the time), and was in a good agreement with the aforementioned statistical analysis of the ground-based measurements. Aerosol chemical composition for both extremely polluted and polluted events was dominated by the carbonaceous compounds, and these compounds are known to be diverse in source and nature; inauspiciously, however, they are not measured in regulatory air quality networks. In response to that, an unprecedented real-time pilot air quality network (funded by EPA Ireland, AEROSOURCE), comprising of three atmospheric monitoring system (AMS) instruments running concurrently, has recently been launched in Ireland. It is the first such approach worldwide to deliver real-time chemical speciation, and, in particular, OM mass. It also enables the determination and assessment of hemispheric transboundary air pollution contribution due to unique network measurement locations – coastal and urban background settings. Such sophisticated networks in addition to satellite-based remote sensing will significantly advance aerosol observations. However, in order to relate aerosols to cloud-climate issues, its effects on cloud microphysics have to be studied. Cloud microphysical properties under the influence of different air masses and hence different aerosol types and concentrations were investigated at Mace Head. The number of cases was spread over a period of more than 6 years, allowing a statistically sound interpretation of the processes and effects of aerosol–cloud interactions. The study indicated that cloud properties were dependent on the origin and cleanliness of the cloud with expressed seasonal variation. Long-term statistical analysis confirmed the findings of higher cloud droplet number concentrations and lower effective radius with greater pollution resulting in higher cloud optical thickness and albedo in more polluted conditions. Therefore, a synergetic deployment of multiple ground-based and satellite-borne sensors improved our understanding of cloud characteristics and thus aerosol–cloud-weather–climate interactions.

Thirty Years of AGAGE GHG Measurements from Mace Head, Ireland, and Ragged Point, Barbados, As Part of the ALE/GAGE/AGA

Dr Mark Lunt, University of Bristol

Over the last 30 years, measurements of trace gases have been made at both Mace Head, Ireland, and Ragged Point, Barbados, as part of the Atmospheric Lifetime Experiment (ALE)/Global Atmospheric Gases Experiment (GAGE)/AGAGE network. Since 2004, improvements in instrumentation have meant over 30 gases in the ppm to ppq range have been measured at high frequency, charting the changing trends of the atmospheric concentrations of many GHGs. This talk will focus on the main results and features shown by these data, including the decrease in CFCs and the consequent rise in their hydrochlorofluorocarbon (HCFC) and HFC replacements. Moreover, we will discuss how these data have been used to infer both global and regional emissions of these GHGs. Furthermore, as the policy focus increasingly moves towards monitoring national-scale emissions, we will explore what progress has been made recently and the role that North Atlantic stations can play in this.

Ten Years in the Life of the Cape Verde Atmospheric Observatory

Dr Katie A. Read, National Centre for Atmospheric Measurements, University of York, UK

The Global Atmospheric Watch Cape Verde Atmospheric Observatory (16.848°N, 24.871°W), a sub-tropical marine boundary layer atmospheric monitoring station situated on the island of São Vicente, has recently celebrated its 10th anniversary. Almost continuous measurements of the trace gases O_3, CO, NMVOCs, NO, and NO_2, along with meteorological parameters, have been obtained. Other data from the CVAO (Cape Verde Atmospheric Observatory), for example of GHGs, aerosol, halocarbons, halogen oxides and total gaseous mercury (Global Mercury Observation System), are also available over various timescales. The CVAO has produced 38 peer-reviewed publications, which have been mostly focused on the measurement and modelling of atmospheric gases and aerosol. During this presentation, I will present the key scientific highlights relating to the trace gases. Very recent published work includes our discovery of nitrate aerosol as a dominant source of NO_x in the remote marine boundary layer and analysis of our 4-year total gaseous mercury record, which suggests influence from an unregulated source of mercury from West Africa. Continuing areas of scientific interest include, but are not limited to, the impact of hydraulic fracturing on the chemical composition of gases such as methane and ethane in this region, the significance of shipping on background NO_x levels and the subsequent effect on ozone production/removal, the role of halogenated compounds in the sub-tropical troposphere, air–sea flux of atmospheric trace gases and the monitoring of emissions from Africa (e.g. from dust, fossil fuels, biomass burning origins).

Evolution of the Aerosols-related Programmes at the Izaña Atmospheric Research Centre (IARC)

Dr Emilio Cuevas-Agulló, AEMET

In this presentation, developments made in the various atmospheric aerosols observation and investigation programmes since ACE-2 was held in 1997 are shown. The incorporation of Izaña into the GAW-Precision Filter Radiometer (PFR), AERONET and MPLNet networks has been a great complement to *in situ* aerosol observation programmes. The Izaña Observatory, as a calibration centre of GAW-PFR and AERONET-Europe photometers, provides quality assurance services to the column aerosols scientific community. In the technological part, Izaña has developed new observational capabilities, such as the new Triple CE318-T Cimel instrument and developments in the Robotic Lunar Observatory (ROLO) model for nocturnal aerosols observations, and new techniques/methodologies for aerosols observation focused on mineral dust watch, as the new zenith-looking narrow-band radiometer-based system (ZEN). In the framework of the WMO Commission for Instruments and Methods of Observation (WMO-CIMO) Testbed for Aerosols and Remote Sensing Instruments, the Izaña Observatory tests and validates new aerosol products from other observation networks (Brewer, Pandonia), and also carries out capacity-building activities. Finally, Izaña Atmospheric Research Centre (IARC)'s active participation in the creation and ongoing operation of the WMO SDS-WAS Regional Centre for Northern Africa, Middle East and Europe, managed by AEMET and the Barcelona Supercomputing Centre (BSC), has led to participation in dust modelling validation activities (within EU MACC and Copernicus/CAMS). Research has also been carried out on dust sources and atmospheric processes that modulate the Saharan dust transport, as well as on the impact of mineral dust on the Sahel.

Global Contribution and Future Aspirations of the CVAO

Dr Katie A. Read, National Centre for Atmospheric Measurements, University of York, UK

In 2009, the CVAO was awarded GAW (http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html) “Global” status, and it is one of only 32 stations with this accolade. To maintain this title, the observatory has to demonstrate a long-term commitment to the GAW programme, measure a number of climatically significant gases and aerosol, and make the data publicly available in a timely manner through the GAW world data centres (World Data Centre for Greenhouse Gases – WDCGG, World Data Centre for Reactive Gases – WDCRG, etc.).

Although not a European site, the CVAO also contributes volatile organic compound (VOC) and NO_x data to the European ACTRIS programme, a programme closely aligned with GAW. Working in this way allows support and development of common protocols and procedures to improve the provision of data to the user (http://actris2.nilu.no/). Measurements of background NO_x, for example, are very challenging and few in number due to the limitations of atmospheric instrumentation. Our measurements are therefore highly reliant on and appreciated by these global networks (http://library.wmo.int/pmb_ged/wmo-td_1560_en.pdf). This is also true of the VOC measurements that are made at the CVAO, with the significance clearly evident in a new VOC bulletin, which highlights our measurements (https://library.wmo.int/opac/doc_num.php?explnum_id=3554). There are only a handful of observatories making these measurements, and in particular those of the oxygenated hydrocarbons, which makes our measurements very valuable to the atmospheric community and to global atmospheric modellers.

The Geostrategic Pico Mountain Observatory: A Central Role in International North Atlantic Research Programmes

Dr Paulo Fialho, Instituto de Investigação em Vulcanologia e Avaliação de Riscos

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Pico Mountain Observatory (PMO) is an established research facility integral to a vibrant international effort aimed at monitoring climate and pollution within the North Atlantic region. PMO is situated at 2225 m above mean sea level on the caldera summit of Pico Island and experiences air masses transported over long distances from North America, the Arctic, Africa, Europe and the equatorial Atlantic. This strategic location and high elevation makes PMO truly unique with respect to other observatories in the North Atlantic basin. The measurements at PMO are a vital component of the international research that is carried out within an Atlantic chain of atmospheric observatories extending from Ascension Island, Cape Verde, the Azores, the Canaries and Ireland to Iceland, Summit, Greenland and Spitzbergen in Svalbard. PMO typically experiences air masses from the upper marine boundary level or the lower free troposphere.

In the presentation, we will present some of the work done at PMO and address the observatory’s future. We stress the vital importance of the continued operation of PMO as a contributing station within the international North Atlantic research network. Specifically, we have identified opportunities to operate PMO as a high-profile Portuguese station within the WMO GAW programme and as part of ACTRIS.

An Overview of Observations Programme and Infrastructure at the Valentia Geophysical and Meteorological Observatory in Ireland

Dr Saji Varghese, Met Éireann

Valentia Observatory, located in Cahersiveen, Co. Kerry, Ireland, is a regional GAW station with an observational history dating back to 1860. While the primary focus of the observatory was meteorological observations in the initial years, geophysical measurements were introduced from the 1950s at various stages. Air/water pollution monitoring commenced in 1970. Currently, four of six groups of GAW variables are measured: ozone (column, surface-*in situ* and profile), spectral UV, aerosol chemistry EMEP style (major ions) and bulk precipitation chemistry (major ions). Aerosol optical depth is measured using the Precision Filter Radiometer, being part of the PFR–GAW network. It is also responsible for the Irish solar radiation network. Plans are in place to introduce the Atmospheric Chemical Speciation Sampler (ACSM) and GHG measuring instruments at the newly developed environmental monitoring facility at the Valentia Island as well as ground-based remote-sensing instruments (wind profiler and radiometer) at Cahersiveen by the end of this year (2017). Other meteorological and geophysical monitoring programmes at the observatory include phenology, geomagnetism, seismology, lightning detection, surface meteorological observations, upper-air observations and radiation detection. Details of the different measurement programmes and future plans will be discussed at the talk.

Mace Head Atmospheric Research Station: Aerosol Sources and Climate Implications

Dr Jurgita Ovadnevaite, School of Physics and C-CAPS, National University of Ireland Galway

Marine aerosol is an important part of the natural aerosol and often dominates the total aerosol burden in remote locations. However, the exact chemical and physical properties of marine aerosol are still not well quantified, especially in terms of the organic aerosol component and its effects on cloud formation. Atmospheric aerosols have been sampled and characterised at the Mace Head north-east Atlantic atmospheric research station since 1958, with many interesting phenomena being discovered. Here, we review the latest results of experimental studies focusing on marine aerosol over the north-east Atlantic, which extends from a new sea spray source function encapsulating important influences of wave height, wind history, friction velocity and viscosity to effects of chemical sea spray composition on particle water uptake properties and secondary aerosol composition effects on cloud formation. We show a clear dependence of OM fraction enrichment in sea spray on phytoplankton biomass and an apparent dichotomous OM behaviour in terms of water uptake. Specifically, sea-spray aerosol enriched in OM possesses a low hydroscopic growth factor, while simultaneously having very efficient condensation nuclei activation. Likewise, the formation of secondary marine particles is related to the biological activity, e.g. an occurrence of new particle formation (NPF) events over the North Atlantic is linearly correlated to chlorophyll-a. Moreover, observational and theoretical evidence illustrates that, in ambient air, surface tension lowering, due to organic surfactants, can prevail over the Raoult effect, leading to substantial increases in cloud droplet concentrations that result from these NPF events. Granted that activation of aerosols into cloud droplets is a fundamental process requiring adequate encapsulation in weather and climate models, our new results dictate that incorporation of size and aerosol composition along with phase separation effects into activation thermodynamics leads to a significant improvement in the understanding of marine aerosol–cloud–climate interactions.

Norwegian Monitoring at Zeppelin Svalbard and an Introduction to SIOS, IASOA and SAON

Kjetil Tørseth, Research Director Atmospheric and Climate Research Department (ATMOS), Norwegian Institute for Air Research (NILU), EMEP

This talk briefly introduced some initiatives aiming to strengthen Arctic observations of atmospheric composition. These initiatives range from research infrastructures (SIOS) to more overarching networking and branding efforts (International Arctic Systems for Observing the Atmosphere – IASOA, Sustaining

Arctic Observing Networks – SAON). A major concern addressed is the challenge to find long-term financial support for running costs associated with atmospheric measurements.

Canada and US East Coast

Prof. Leonard Barrie, Professor Emeritus, Stockholm University, and Adjunct Professor, McGill University, Montreal, and Prof. Joe Prospero, Professor Emeritus, Department of Atmospheric Sciences, Rosenstiel School of Marine and Atmospheric Science, University of Miami

ACTRIS – From Project to Established Research Infrastructure in ESFRI

Kjetil Tørseth, Research Director Atmospheric and Climate Research Department (ATMOS), Norwegian Institute for Air Research (NILU), EMEP

This presentation introduced ACTRIS and the status of preparing for ACTRIS to become an established ESFRI research infrastructure. The ongoing ACTRIS Project Preparatory Project (ACTRIS-PPP) deals with the detailed planning of its operations, funding and other governance issues. It is assumed that ACTRIS-RI may be formally established in 2020/2021.

Policy Context and Overview of Issues and Challenges: Global Policy to Protect Our Atmosphere

Dr Frank McGovern, Chief Climate Scientist, Environmental Protection Agency

The atmosphere is a uniquely shared and vulnerable resource. Its changing make-up, structure and dynamics can have profound impacts for the whole planet. In recent times, these changes provide a remarkable testimony to human development and activities and may have major consequences for the future of humanity. Atmospheric science and observation systems have an essential role to play in providing the necessary understanding to enable the development of coherent and effective polices and measures to protect the atmosphere and ensure its stability. Paul Crutzen pointed out in his Nobel Prize acceptance speech that we have been lucky in that we have not already compromised life in large areas of the Earth. Using the atmosphere as an unmanaged dumping ground is no longer tenable. The risks are too great for human health, ecosystems and the stability of the Earth's climate systems. This understanding has developed slowly from the first actions to address the immediate and local health impacts of air pollution in 1950s London to the entry into force of the Paris Agreement on climate change in 2016. In between, we have had major steps, including the UNECE CLRTAP, the Vienna Convention and its Montreal Protocol and the UNFCCC. These have their own structures and supporting research and monitoring activities as well as a downstream implementation process from regional to county and local levels. Each has its unique aims and goals, assessment cycles and processes, some of which overlap and which can have unintended consequences for each other. They are all linked through the medium of the atmosphere, and it is timely to consider how these various systems can be better integrated to ensure coherence, while retaining their integrity and capacity to act in achieving the key objectives and goals. A review of these issues is presented.

Improving Understanding of Hemispheric Transport of Air Pollution (HTAP)

Frank Dentener, European Commission, JRC (Joint Research Centre), Italy

Forecasting and Monitoring Long-range Transport of Pollution over the North Atlantic in the Copernicus Atmosphere Monitoring Service

Dr Mark Parrington, ECMWF (European Centre for Medium-range Weather Forecasts)

The North Atlantic is a key region of interest for atmospheric composition and long-range transport of pollution from wildfires and industrial sources in North America, and wildfires and dust from northern and western Africa. Understanding the physical and chemical processing of air masses during their transport across the Atlantic is vital to quantifying the impact of these emissions on surface air quality and deposition far from the source region, e.g. Europe and Central/South America. CAMS, implemented by ECMWF on behalf of the European Commission, provides a unique perspective on global atmospheric pollution, utilising near-real time satellite observations of aerosols and trace gases, and wildfire locations and emissions. Five-day forecasts of global aerosol, trace gas and GHG distributions, operationally produced twice a day at 0 UTC and 12 UTC with the ECMWF Integrated Forecasting System (IFS) at a spatial resolution of approximately 40 km (9 km for GHGs), are initialised from analyses that assimilate the latest satellite observations in the IFS and most accurately represent the latest chemical state of the atmosphere. Regional air quality forecasts for Europe within CAMS utilise a suite of state-of-the-art air quality models to calculate multi-model ensemble products, with lateral boundary conditions provided by the global system. In addition to the real-time operational products, CAMS produces reanalyses to provide consistent, multi-year (2003 to present) datasets of regional air quality and global atmospheric composition. A critical component of CAMS is the validation of the analyses and forecasts against near-real time ground-based and airborne *in situ* measurements, and this is especially true in relatively data-sparse regions such as the North Atlantic. This presentation will give an overview of the CAMS system and real-time products and their validation against *in situ* observations, and the use of CAMS forecasts for case studies of long-range transport of smoke pollution across the North Atlantic.

ICOS: An Overview

The ICOS Research Infrastructure (RI) is a major initiative to develop an advanced integrated observation systems for GHGs. The ICOS RI promotes fundamental understanding of the carbon cycle, GHG budgets and perturbations and their underlying processes. To facilitate this, ICOS aims to provide data from a high-precision, long-term network of stations, which measure GHG fluxes from ecosystems and oceans and GHG concentrations in the atmosphere. ICOS may provide key inputs for consideration of the achievement of the balance of GHG emissions and removals that is envisaged in the UNFCCC Paris Agreement. The ICOS structures and operations will be outlined.

Appendix 3 Pictures at Izaña Observatory Taken During ACE20

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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Protecting the North Atlantic Atmosphere

Authors: Leonard A. Barrie and Frank McGovern

Pressures

The North Atlantic region has unique vulnerabilities, including to the stability of key ocean cycles and to changes in major regional ice sheets. These are being impacted by emissions to the atmosphere from surrounding regions including from Europe, North Africa and North America. These influence air quality, weather and climate systems, and ocean and terrestrial ecosystems.

Policy

A complex suite of regional and global policy responses has emerged that address a range of atmospheric protection issues. However, these are progressed in different policy frameworks that may not be optimally aligned and can give rise to analysis and response gaps.

Solutions

The North Atlantic region is uniquely positioned to provide a focus to develop an integrated analysis of the causes and consequences of atmospheric change that addresses key scientific issues in an integrated manner and enables improved cross-policy support and actions.

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