The Royal Society Global Environmental Research Committee (GERC)

Executive recommendations of GERC on the topic "*Air Quality and Atmospheric Composition*"

GERC recommends that UK funding agencies should take note of four areas where progress may be made in deciding priorities for funding in the next few years. These four main areas area are:

1. Air quality mitigation science –Science to underpin development and implementation of air pollution mitigation strategies, and to assess their effectiveness.
2. Enhanced and integrated observing system – including an enhanced role of satellite observations coupled to improved data science and modelling.
3. Air quality and climate – recognise at both the science and policy development level the need for work to elucidate and mitigate antagonisms.
4. Integrated health outcomes – combining a range of measures to improve understanding of the role of air quality and other environmental exposures in determining human health.

The context for GERC reports

The Royal Society's Global Environment Research Committee (GERC) is charged with advising the Royal Society, and interacting with research councils, the environmental science community and other bodies. To do this, it is undertaking a rolling series of reviews of areas of science within its remit. The areas it has identified are (in alphabetical order): Air quality, Biodiversity, Carbon and other biogeochemical cycles, Climate, Natural resources (including land use) and food, Oceans and polar science, Water. In each area, GERC uses its own expertise, and that of a small number of invited experts to consider the questions:
1. What are the hot research topics in this area at present?
2. What is the status of UK science within this area?
3. What are the most pressing research needs in the next 5-10 years?
4. Are there specific areas where UK science should be focussed to meet these needs?
5. How should priority topics be incorporated into multidisciplinary (funded across research councils) issues that Future Earth and its UK committee should consider?

This paper is the one resulting from the discussion about Air Quality, held in November 2017. In addition to contributions from its regular and co-opted members, the committee was advised in person by Professor Ally Lewis (University of York), Professor Martin Williams (Kings College, London), Professor Claire Reeves (University of East Anglia), Dr. Paul Young (Lancaster University), and Dr. Heather Walton (Kings College, London). The resulting paper evidently represents only a snapshot of issues, and is not a comprehensive survey of the science area. It does not represent the view of the Royal Society, but aims to advise the Royal Society Council. Exclusion of a topic from this document does not negate its importance, and many areas that are already under intense research are not highlighted here. However, we hope that this document will put a spotlight on some trends that will inform future activity by the Royal Society, Research Councils (and in future UKRI), and UK Future Earth.

Membership of GERC (including co-opted members) at the time this topic was discussed (Nov. 2017) was: Prof Eric Wolff FRS (chair), Prof Peter Cox, Dr Maria Dornelas, Prof Joanna Haigh FRS, Dr Kate Hamer (NERC), Prof Gideon Henderson FRS, Professor David Hopkins, Dr John Ingram, Prof Corinne Le Quéré FRS, Prof Yadvinder Mahli FRS, Prof Paul Monks, Prof Peter Smith FRS, Prof Martin Solan, Prof Chris Thomas FRS. Dr Scott Hosking acted as Secretary.

Background and discussion

Poor air quality remains a pervasive menace across much of the globe. Air quality is often seen as solely the scourge of urban areas, but it must be recognised that it has impacts across wider temporal and spatial scales. Air quality is for example an important factor affecting including human health, eco-system productivity and national heritage, while pollutant chemistry has impacts on issues such as stratospheric chemistry and global and regional climate.

1) Mitigation of poor air quality

Science must be ready for the task of mitigating air pollution on all scales. There needs to be a new paradigm of "continuous improvement" for air quality, where integrated observations (see 2) provide a continuous feedback on the effectiveness of mitigation measures. This moves the science towards solutions rather than just attribution, giving it a role in informing development of novel technologies to reduce emissions, as well as assessing the impact of urban design (including for example urban trees) in reducing pollutant levels once they are in the air. At the level of the individual, we are moving gradually away from establishing effects towards considering and evaluating solutions that involve behaviour change and purchasing choices. It is clear that there is a requirement for more ***socio-economic*** research ***alongside*** the atmospheric science.

International studies are crucial in this respect because different parts of the world (including their cities) are at different stages of development and mitigation with respect to air quality. This means that historical lessons learnt in one place can be used to inform outcomes and solutions elsewhere.

There still remain some near-term issues the research community should engage with such as (1) Determining real-world road transport NOx emissions (2) Assessing the amounts and toxicities of non-exhaust emissions, and how they might change as new technologies (such as electric and driverless cars) come on-stream (3) Identifying exactly what are the harmful components of the particulate matter mix.

2) Observations

Observations and their integration with models form the crucial backbone of air quality science, and observations provide the essential baseline of the changing composition of the atmosphere. There is a need for continued support for a diversity of atmospheric observation as no one observational system can capture the spatial, temporal and speciated view of the atmosphere required for a combination of guardian and discovery functionality. Research-level observation networks can detect the chemical challenges of tomorrow, such as high molecular weight organics that may be precursors to particle formation. Small "low cost" sensors offer an unparalleled opportunity to instrument urban areas at high densities, but may be limited in analytical performance. New geostationary satellites will provide a much richer data source at all spatial scales than current platforms. These are not just for direct air quality measurements, but also proxies such as visual records of activity data (e.g. vehicle movements) to validate and improve emission inventories.

The true value of observations can only be achieved with appropriate data science techniques to support the analysis, including appropriate characterisation of uncertainties, optimal combination across multiple sensors and with integration with process-based models. Models are key to forecasting air pollution and health impact, assessing mitigation strategies, and determining links between air quality and climate change. The models need to be rigorously validated against observations, allowing future model development to target key uncertainties. A specific difficulty for modelling surface air quality is accurately modelling the dispersion of air pollutants.

3) Climate change and air quality

Air quality encompasses the here-and-now of pollutant emissions, atmospheric transformations and their direct effect on human and ecosystem health. Climate change deals with the drivers leading over long timescales to a warmer world and its consequences. These two science and policy issues are inexorably linked *via* common pollutants, such as ozone, methane and black carbon.

To date there has been little scientific assessment of the impact of climate policies on air quality and vice-versa. There are several pertinent questions: How high are NO_2 levels around CHP plants in cities? How much is wood burning contributing to ambient levels? How will improved air quality impact aerosol inventories that cause negative radiative forcing that may mask some greenhouse warming. There is a pressing need for holistic energy system modelling, incorporating both air quality and climate policy targets to minimise climate and air quality penalties.

Pollutant emissions also impact stratospheric composition. In recent years, it has been realized that, in addition to the long-lived ozone depleting substances (such as CFCs and halons), very short-lived substances (VSLSs), which have short atmospheric lifetimes, can contribute significantly to the stratospheric halogen loading and thus stratospheric ozone loss. There is a pressing need to identify sources, develop scenarios as well as a concerted effort to understand chemistry/climate impacts of these substances. Similarly, climate change will impact recovery of stratospheric ozone, and will affect emissions, dispersion and the chemistry of air pollutants.

4) Integrated health outcomes

The exposome can be defined as the measure of all the exposures of an individual in a lifetime and how those exposures relate to health. An individual's exposure begins before birth and includes insults from environmental and occupational sources. It is important to understand how exposures from our environment, diet and lifestyle interact with our own unique characteristics such as genetics, physiology, and epigenetics is required. The extent to which air quality drives the exposome remains an open issue. This requires an understanding of the toxicology of individual components in particles and gases, and of indoor as well as outdoor air quality, given that city dwellers in developed countries spend by far the majority of their time indoors.

Wider Considerations

The science of science of air quality and atmospheric composition sits in a disciplinary space that encompasses digital technology, big data, energy (e.g. emissions from combustion, biofuels crops), and food security (land-use change) as well as health and wellbeing. With respect to the grand challenges set by the industrial strategy, air quality and its mitigation lies at the heart of clean growth, while the mobility theme poses air quality considerations beyond those of exhaust emissions? Air quality could also be a prime target for studies under the Global Challenges Research Fund, where UK expertise and experience can inform research to provide healthy and sustainable lifestyles in developing (ODA) nations.

It is clear that in the broad area of atmospheric composition and climate, the opportunities from systems science (multi-compartment earth system) and multidisciplinary societal impact research (transdisciplinary research embracing industry, commerce and civil society) have not yet being achieved. There remains a need to balance the fundamentals of observing, learning and discovering with research that addresses the challenges that atmospheric composition poses to society.