by William Lahoz

CITIZEN'S OBSERVATORY

Where does our air quality come from?

A personal and user-friendly excursion into what determines air quality and what you can do to inform yourself about it

You are interested in the quality of the air where you live – the 'air quality', often identified as 'AQ'. Good air quality is desirable, you wish for no harmful substances in the air composition – you want to live in a healthy environment. For example, you would be interested in knowing the amount of ozone in the air, as it could affect your lungs; you might be interested in the amount of pollen in the air – the pollen count – as it could affect your allergies. So you ask what affects the air composition where you are located – what affects your air quality?

Thinking about this issue, and having some knowledge of what determines air composition, you consider that two elements contribute to the air quality where you are located: chemical interactions involving substances in the air above and around you; and emissions of substances from the surface where you live – for example, from industry. You recognize this and feel safe because you live in a remote part of the world where the air above and around you is clean, and therefore you think there are likely to be few substances to be involved in chemical interactions; and you know that where you live there is little or no industry to emit substances that could be harmful. But you are a scientist, and this is not enough, so you make a measurement of the air composition where you live with an instrument you borrow from your friend from the measuring station up the road. And you are surprised to find a number of potentially harmful substances are detected in significant amounts in the air, including ozone and aerosols such as particulate matter. What went wrong? How could this happen?

Long-range transport

What went wrong is that you forgot that air moves from one place to another, and that this air can carry potentially harmful substances from far away to where you are located. And even if local conditions provide good air quality, conditions far away may not. The local conditions where you live could not prevent this air with potentially harmful substances from reaching you. The process that you overlooked is called long-range transport (Figure 1), and it is the third element that contributes to the air quality where you are located.

You now know that three elements contribute to the air quality where you are located: chemical interactions; emissions; and long-range transport. These are described in studies by, for example, HTAP (2007)[1] and D J Jacob (2000).[2] But again, you are a scientist and would like to know more details about the air quality where you are located. In particular, you would like to know the concentration of potentially harmful substances, and how this concentration evolves in space and time. The air quality may be good today, but will it be good tomorrow? The air quality may be good today where you are, but it may not be good at a location near you, and long-range transport could bring this bad air quality to you tomorrow.

Observational gaps

To understand how you can determine the concentration of substances contributing to air quality, you recognize you must take account of a key characteristic of observational information, namely that it has gaps in space and time (Figure 2). You also recognize that these gaps depend on the nature of the observation – for example, if the observation is made remotely from a satellite in space, or if the observation is made in situ on the ground. Do these observational gaps matter for air quality? They do in at least two ways: first, you may wish to know the air composition at gaps in the observational information; and second, you may wish to derive extra information from the observations that requires this information be provided on a uniform grid. In both cases you need to fill in the gaps in the observational information. How could you do this? You could assume the observations are constant; you could interpolate linearly between the observations; or you could do something more sophisticated. In all cases you are using a model of how the observational information behaves to fill in the observational gaps. You realize you need a model to fill in these gaps.

Choosing a model

The choice of model complexity is up to you, but this choice could depend on what you need to know, and how you want to know this. The model could be very simple, or very complex; for example, it could include chemical reactions, emissions and transport processes. Also, the model information, which is available at places other than where you are located, needs to be evaluated – one would commonly do this by comparison with observations. So you also need observations not just where you are, but at other locations, to evaluate the model. Finally, you realize that to make sense of a comparison between the model and observations and, in fact, to make use of the information from the observations and the model, you need to know the uncertainty associated with this information. This uncertainty will tell you how much trust you should place in the observations and/or the model. And this will help you make informed decisions in response to the air quality information at your disposal. For example, if you have an allergy and the pollen count is high, you should consider staying indoors.

Data assimilation

But the model information need not be considered on its own to fill in the observational gaps. For example, you could combine it with observational information in an objective manner, including its uncertainties, to fill in these gaps. And this is already done – this is "data assimilation", a subject on which there is considerable literature, in particular with respect to weather forecasting.[3,4] This approach is also used for air quality forecasting. [5,8]

The data assimilation procedure produces a data set called an "analysis". An attractive feature of the analysis is that it "adds value" to the observational and model information. To the former, it adds value by filling in the observational gaps; to the latter, it adds value by constraining it with observational information. This added value is reflected objectively in that, provided the observational and model information are well characterized, including their errors, the information content of the analysis is higher than that of the observational and the model information separately.[4] So the information provided by the analysis is likely to be more useful than the observational or model information separately.

The analysis produced by data assimilation can be used as the initial conditions of, for example, the state of the atmosphere, for a weather forecast using a model. Similarly, it can be used for an air quality forecast. The more accurate these initial conditions, the more accurate the forecast is likely to be. So it is important to use the observational and model information in the best way possible, and a lot of effort is spent by the meteorological agencies to determine the best possible initial conditions of the state of the atmosphere.[3]

The observations that provide information on where air comes from, and which you could use to provide an air quality forecast, and also to evaluate the model that provides information on where air comes from, have to be placed at suitable locations. This is important when both local (chemical interactions and emissions) and remote (long-range transport) factors affect the air composition, and thus the air quality, at your location. Identifying these locations is useful, but may be difficult to do objectively. How do you determine the best locations? You could use both the information from the model and from the observations. And this is already done using data assimilation ideas by the

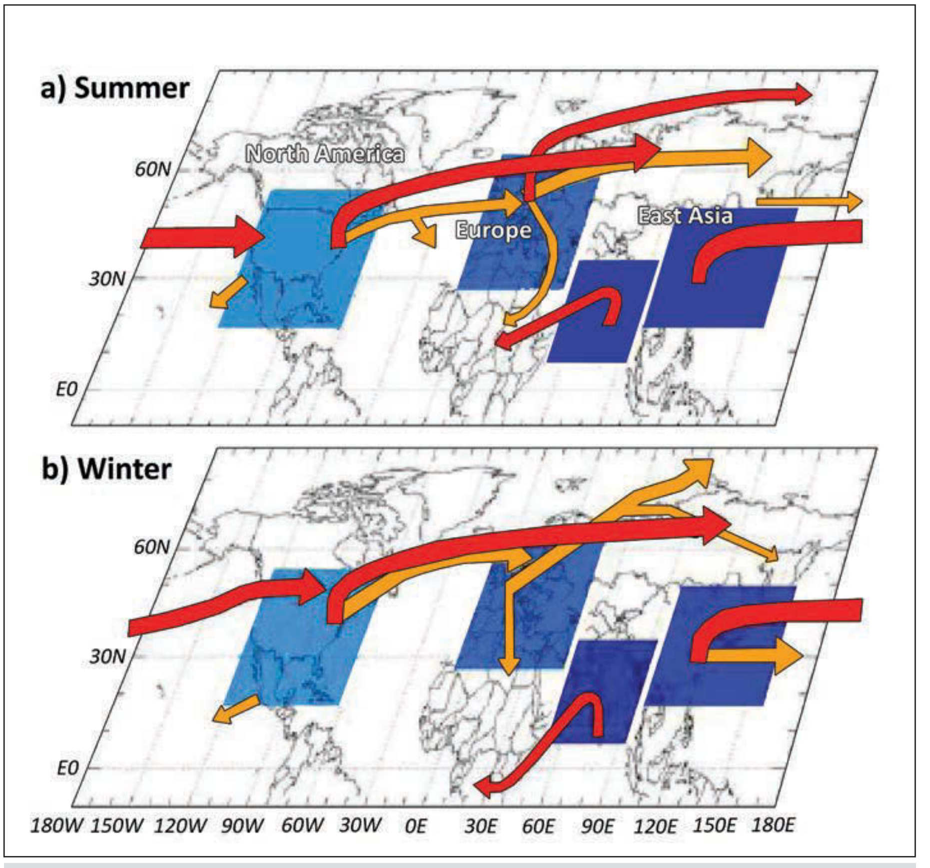

Figure 1: Plot representing intercontinental transport pathways in the Northern Hemisphere. Arrows approximate the magnitude of these pathways for summer (June/July/August, panel a, top) and winter (December/January/February, panel b, bottom). Orange arrows indicate transport near the surface (altitudes less than 3km); red arrows indicate transport higher in the atmosphere (altitudes greater than 3km). The boxes indicate regions used in model studies to study this transport. Plot based on material from HTAP (2007)

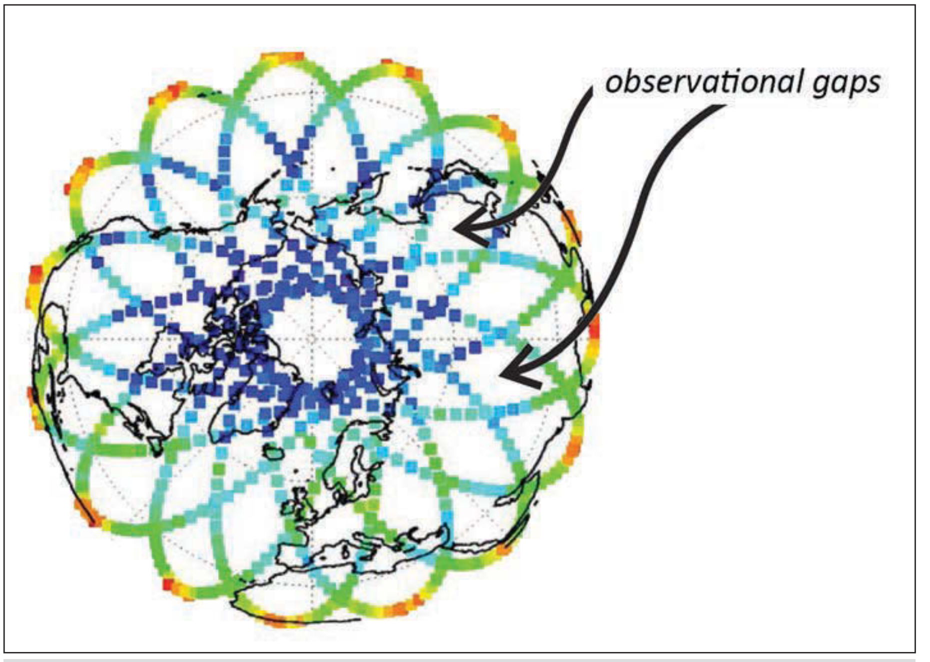

Figure 2: Plot representing ozone data at 10hPa (approximately 30km in altitude) showing the observational geometry of measurements from a limb-viewing satellite. Blue denotes relatively low ozone values; red denotes relatively high ozone values. The measurements are typical of Northern Hemisphere winter, showing relatively low ozone values in the Arctic region. Note the gaps between the satellite orbits. Plot based on material in Lahoz et al. (2010)

meteorological agencies and the space agencies to assess where to locate future observations, and to design an observational network. This network could be used, for example, to monitor air quality and assess if regulations (for example, from the European Commission) are being complied with. The approach is called an observation system simulation experiment (OSSE).[6,7]

Work by NILU

You now know that observational and model information combined and/or on their own, is useful to: provide air quality information locally; take account of local and remote factors affecting air quality; provide the initial conditions for an air quality forecast; and help design an observational network to monitor air quality. NILU Norwegian Institute for Air Research scientists are working on all these aspects of the research into improving our knowledge of atmospheric composition and how this affects air quality.

Once you recognize that the level of information you are interested in is often required at a very local level – for example, where you live, or the street where you walk – you also recognize the possibility of you being the observation platform, you being a citizen's observatory. For this you would need to be able to receive and transmit information on the air composition where you are located. And there is a ubiquitous observational platform that has this potential use: the mobile phone. The potential of this platform has been recognized by the European Commission, notably by funding a number of EU-wide projects, including the CITI-SENSE project, which is coordinated by NILU (http://citi-sense.nilu.no). This project was described at the European Commission Green Week held in Brussels in June 2013 (http://greenweek2013.eu/).

In recognizing which factors affect air composition, and thus air quality, and that we can obtain information on air quality from observations and models, and their combination, we have come full circle: from recognition that air quality affects you, and that both local and remote factors contribute to air quality, to the recognition that you can be the observational platform that both provides information about air quality and receives information about air quality. This empowers you, the citizen's observatory. ∎

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William Lahoz is a senior scientist at NILU Norwegian Institute for Air Research