

For more information about air quality,
you can find detailed scientific research at the
PRIMEQUAL programme website:
www.primequal.fr

Atmospheric pollution knows no boundaries, and our regions may be impacted by pollutant emissions from often distant locations. The PRIMEQUAL programme involved scientific research in order to better understand the mechanisms that underpin long-range pollution. The summaries and reports produced from these research projects can be downloaded from the www.primequal.fr website ("Projects" => "Completed projects").

List of research projects funded under the call for research proposals on long-range pollution, presented in 2014 at the Lille conference:

- 1 "Vulnerability of ecosystems to atmospheric nitrogen. Towards a model of critical N loads incorporating the protection of plant biodiversity in France (Valerian)", led by Anne Probst, Laboratoire Ecologie Fonctionnelle et Environnement (ECOLAB)
- 2 "20 years of atmospheric data measurements in France (SESAME)", led by Stéphane Sauvage, Ecole des Mines de Douai
- 3 "Use of sphagnum moss bogs to quantify deposits of long-range atmospheric contaminants and to measure their environmental impact", led by Nadine Bernard, Laboratoire Chrono-Environnement (LCE), Université de Franche-Comté
- 4 "Evaluation of long-range air pollution combat strategies within the context of climate change (SALUT'AIR)", led by Bertrand Bessagnet, National Institute for Industrial Environment and Risks (INERIS) and Sophie Szopa, Laboratoire des Sciences du Climat et de l'Environnement/IPSL
- 5 "Impact of long-range pollution on particles and their gas-phase precursors in Paris and Ile de France (FRANCIPOL)", led by Valérie Gros, Laboratoire des Sciences du Climat et de l'Environnement (LSCE, CNRS-CEA-UVSQ)
- 6 "Long-range transportation and air quality in the Mediterranean basin (TRAQA)", led by Jean-Luc Attié, Laboratoire d'Aérodynamique (LA)
- 7 "Measurement of atmospheric deposition and verification of its representation in regional models (DEMO)", led by Gilles Bergametti, LISA, Université Paris 12
- 8 "Analysis and forecasting of the impact of fires on air quality in the Mediterranean and in Europe (APIFLAME)", led by Solène Turquet, Laboratoire de Météorologie dynamique/Institut Pierre Simon Laplace (LMD/IPSL)
- 9 "Characterisation of organic nitrate sources and wells, with a view to improved description of long-range transportation of reactive nitrogen via chemistry-transport models", led by Bénédicte Picquet-Varrault, Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA), Université Paris 12
- 10 "Source and reactivity of gaseous organic carbon in continental contaminant plumes (CARBO-SOR)", led by Agnès Borbon, LISA, Université Paris 12
- 11 "Development of a chemical tool for studying long-range pollution. CTM application to the study of continental contaminant plumes and competition between pollution of differing scales on air quality", led by Isabelle Coll, LISA, Université Paris 12
- 12 "Miniature Standalone Atmospheric Composition Observation Station for the MERA network (SMOAA)", led by Paolo Laj, Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE)

PRIMEQUAL is an inter-body research programme that focuses on improving air quality. The programme is coordinated by the Ministry of Ecology, Sustainable Development and Energy (MEDDE) and by the Environment and Energy Management Agency (ADEME). It aims to provide decision-makers and environment managers with the scientific foundations and tools they need to monitor and improve indoor and outdoor air quality, and therefore to reduce the risks to health and the environment. It is a unique programme in the sense that it draws together various scientific disciplines concerned by air pollution and its impacts, including physical sciences (metrology, chemistry, air flows, meteorology, etc.), life sciences (biology, toxicology, epidemiology, ecology, etc.), mathematics (modelling, statistics, etc.) and social sciences (economics, sociology, environmental psychology, etc.).

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LONG-RANGE ATMOSPHERIC POLLUTION:

ASSESSMENTS, RISKS, MANAGEMENT AND DECISION-MAKING

Summary of the results of research projects
conducted under the PRIMEQUAL programme



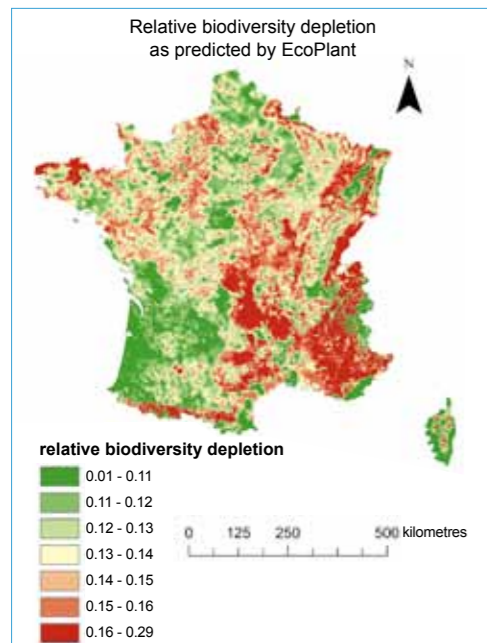
LONG-RANGE POLLUTION: Impacts on ecosystems and health, and an economic challenge

Identifying the impact on populations and ecosystems, and determining the effectiveness of public policies on air quality are key national and international challenges, enshrined in the 1979 Geneva Convention on Long-range Transboundary Air Pollution.

Risk of biodiversity depletion → 1

One of the first innovative projects designed to gain a better understanding of the effects of long-range pollution of ecosystems involved the development of a combined biogeochemical-ecological critical nitrogen load model for French forest ecosystems.

A series of maps showing changes in ecological diversity in France was then produced, based on the results of this model. Those areas with the lowest biodiversity, and that are therefore sensitive to atmospheric nitrogen deposition,



include Brittany, some areas of the Massif Central, the Mediterranean coastline and the Vosges. In terms of relative biodiversity depletion, those regions most likely to be affected are south-eastern France and, to a greater or lesser extent, certain mountain areas. More generally speaking, based on the applied nitrogen deposition assumptions, total biodiversity is likely to be depleted by up to 10% by 2100.

Biodiversity trend map based on the results of combined modelling

Improving monitoring through observation → 2

The last 10 years and more have seen an explosion in atmospheric pollution mitigation policies. Yet how do we know whether these policies are effective? In order to answer this question, a unique database has been created, containing atmospheric data measurements observed in France over the last 20 years or so, and a statistical analysis has been conducted. The drastic reduction in sulphur dioxide pollutant emissions has led to a significant fall in the acidity of atmospheric deposits, although these deposits are still responsible for soil acidification in certain regions (Landes forest, southern Massif Central). Despite this marked reduction in emissions, however, nitrogen compounds remain a major atmospheric pollution problem. This further demonstrates the need to step up efforts to reduce these emissions, and to pursue monitoring strategies.

Critical nitrogen load

Critical nitrogen load is an estimate of the maximum amount of nitrogen depositions that an ecosystem can sustain without an apparent negative effect on a sensitive component of the environment.

In practice: combined modelling for forest ecosystems → 2

Researchers have developed a biogeochemical modelling tool, combined with a plant module, to gain a better understanding of the effects of long-range pollution on ecosystems. The purpose of this combined modelling system is to estimate the impact of atmospheric nitrogen deposition on the biogeochemical function of soil, and therefore its consequences in terms of biodiversity. The researchers used the ForSAFE biological model because of its ability to simulate the complex and varied biogeochemical processes that occur within forest ecosystems. This was associated with the EcoPlant statistical ecological model, following initial enrichment work using the results of new flora and soil surveys in the Mediterranean region. The results show that the ecological diversity trend predicted by EcoPlant is heavily dependent on environmental acidification and/or eutrophication (both of these variables are modelled by ForSAFE), despite the multitude of environmental variables affecting ecological response among plants.

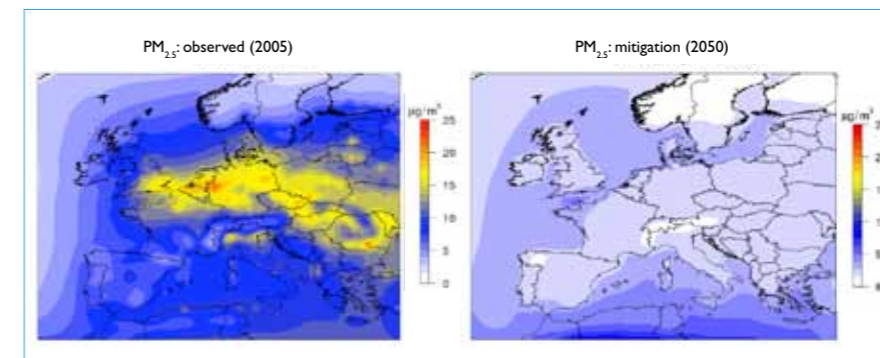
Sphagnum moss bogs: natural pollution archives → 3

Another, more isolated and less widespread ecosystem than forests was also studied – in this case, sphagnum moss bogs. These wetlands are generally found in highland areas, and provide an accurate record of past pollution levels, as well as the effect of pollutants on microbial communities.

Measurements taken in central and eastern France show that metal pollutant deposits (copper, lead, etc.) have been on the decline for the last 20 years or so. The data collected have also been used to create an atmospheric contaminant deposition model, which may subsequently be used to produce long-range pollution maps at national level. Finally, this work provides new avenues for post-implementation assessment of the effect of public atmospheric pollution reduction policies on the quality of isolated ecosystems such as sphagnum moss bogs.

Tackling climate change: positive impact on air quality → 4

All too often, local authorities still view climate change policies as a pure cost. In reality, the benefits of these policies outweigh their cost. This is demonstrated by the exhaustive air quality and regional climate modelling system used in a cost benefit analysis. This system was used to produce two forward-looking scenarios for Europe, identical in terms of air quality management policies, with one scenario disregarding any climate change measures, and the other scenario seeking to limit global warming to 2°C by the end of the century.



Fine particle pollution today and in 2050, according to the scenario including climate change reduction (mitigation) policies and current air quality regulations.

The results show that the climate change mitigation scenario also has a major positive impact in terms of air quality, reflected in both the reduction of air quality management costs and the indirect reduction of pollutant emissions. Furthermore, the health benefits of climate change mitigation policies compensate almost entirely for the associated implementation costs. It would therefore appear that tackling climate change has a substantial positive impact on air quality.

Sphagnum moss

Sphagnum moss is a rootless plant that captures and stores metal contaminants from the atmosphere. It also houses a wide variety of micro-organism species, some of which have skeletons that persist after death and accumulate in the bog. Sphagnum moss bogs therefore act as natural archives.

€62 billion

This is the amount of money that could be saved on health spending through the implementation of climate change mitigation strategies. These strategies also help to reduce air quality management costs by limiting the need for expensive exhaust purification technologies.

REGIONAL OBSERVATION of pollutant transport

Measurement surveys are now the only effective way of directly understanding the true complexity of atmospheric conditions. Technological progress has meant that huge volumes of field data can now be collected and processed, and combined with advanced statistical analyses, to identify the various components of atmospheric pollution, their origin, and their impact on sensitive environments. These measurements can also be used to verify the robustness of atmospheric pollution simulation models.

Atmospheric pollution in urban environments → 5

A team of researchers in Ile-de-France focused on characterising the **gas-phase precursors** of PM_{2.5} fine particles. An innovative, real-time measurement survey was conducted in an urban background station in Paris over a period of one year. The data obtained were supplemented by additional measurements taken at a rural site.

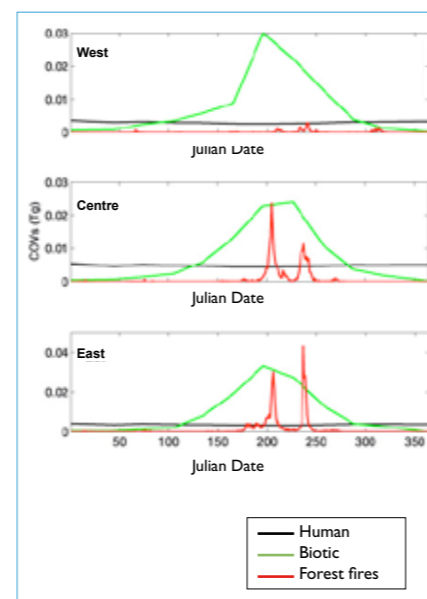
As a result of this measurement survey, the researchers were able to identify the fine particle precursors in an urban background site in Paris that were of local origin, regional origin, or from a wider scale. The results indicated a significant local and regional contribution to sulphur dioxide. They also revealed that the majority of gas-phase and particulate nitrates were of local origin, mainly resulting from vehicle nitrogen oxide emissions. Using these results, the researchers were also able to establish a link between ammonia concentrations and regional agricultural activities. Conversely, comparisons between these results and other existing field surveys revealed a significant concentration of soot of regional origin, linked to a range of factors including the use of wood-fired heating systems, as well as a high concentration of wide-scale biogenic oxygenated VOCs in background fine particle content in Paris. Improvements were also made to the representation of all organic and inorganic particle precursors in the CHIMERE chemistry-transport model, in order to conduct appropriate sensitivity tests for multi-scale emissions scenarios.

Dust in the Mediterranean sky → 6 and 7

The Mediterranean basin is particularly suited to the observation of atmospheric pollution, since it is located at the intersection of several continents and is surrounded by mountains. A measurement survey was conducted in the north-western region of this basin in summer 2012, in order to document gas and particulate pollution using a vast array of different instruments 6. A range of different situations were observed, including a pollution episode in the Gulf of Genoa, a moderate Mistral wind episode, and an extreme case of Saharan dust pollution. The data gathered verified the reliability of the chemistry-transport models used to reproduce the spatio-temporal variability of the observed atmospheric pollutants. The measurements revealed vast dispersion of pollutants across the Mediterranean basin, indicating that, for these specific pollution cases, air quality improvement measures are needed across the entire territory. These measures will need to be taken at local level, by relevant local authorities, and at regional or even European level across Spain, France and Italy.

Gas-phase precursors

In chemistry, a gas-phase precursor is a compound involved in a chemical reaction that produces one or more other compounds. Secondary particles are therefore produced through the transformation of other chemical pollutants, both organic (Voluntary Organic Compounds – VOCs) and inorganic (nitric acid – HNO₃, ammonia – NH₃, and sulphur dioxide – SO₂).



Breakdown of VOC emissions by source in the Euro-Mediterranean region during 2007.

A study was also conducted on Saharan dust deposits in the western Mediterranean and southern France 7, using an automatic, standalone atmospheric data collection system (CARAGA). The results show that these deposits decrease in intensity with distance from the African coastline, and that the values are lower than those observed in the late 1980s, based on sampling surveys conducted in Corsica. The measurements obtained are also aligned, to a satisfactory extent, with digital simulations for the selected sites in the majority of cases. The datasets collected for this research will prove particularly useful in validating these chemistry-transport models.



CARAGA

One-off atmospheric pollution events: wildland fires → 8

One-off events can have a negative impact on air quality. One example of this type of event are wildland fires, which frequently occur in Southern Europe and Eastern Europe during the summer period. Although these fires are known to emit large quantities of gases and aerosols into the atmosphere, little is known about the location, duration, atmospheric composition or transport of the contaminant plumes produced by these fires. A research team set about studying all of these processes, using an innovative modelling system based on satellite data. The team also developed a modelling system for emissions from forest fires. The results showed that the inclusion of wildland fire data can improve pollution threshold exceedance simulations, particularly in terms of PM₁₀ fine particles. This, in turn, can help to enhance information provision to populations living in the regions affected by these phenomena, as well as supporting more accurate analysis of the proportion of pollution threshold exceedance events that may be attributed to natural sources.

In practice: CARAGA → 7

The PRIMEQUAL programme led to the development of a standalone measurement system, known as CARAGA. It is an automatic atmospheric data collection unit with an extended battery life (around six months), capable of withstanding harsh conditions such as snowfall. CARAGA was deployed at six stations and collected a unique dataset to study the spatial and temporal variability of the occurrence and intensity of mass Saharan dust deposits between 2011 and 2013.

In practice: a modelling system for forest fire emissions → 8

Researchers developed a modelling system to calculate emissions from forest fires detected via satellite in real-time. This system was created to meet information and air quality management needs. The emissions data are calculated extremely quickly and can easily be incorporated into forecasting systems. The modelling system was incorporated into the national Prev'Air air quality forecasting system, on an experimental basis, for summer 2013. The emissions registers calculated for the period 2003-2012 are available via the ECCAD international public database (Emissions of atmospheric Compounds & Compilation of Ancillary Data). Users can also request access to the fire emissions calculation module from the project sponsor.

45%

The proportion of PM₁₀ fine particle threshold exceedance events attributable to wildland fires in Greece in summer 2007.

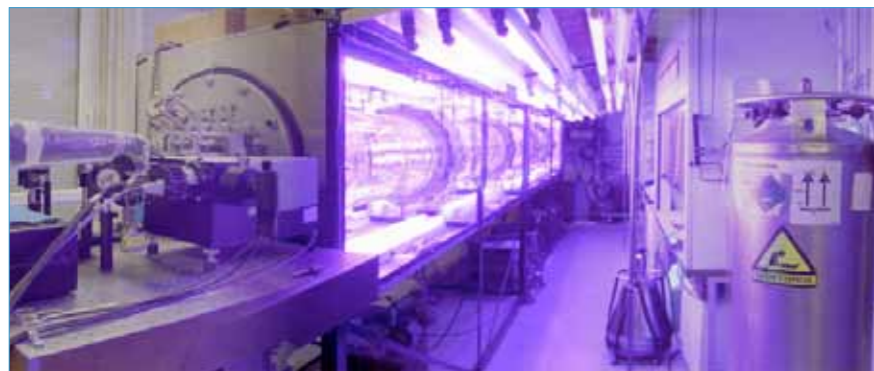
LONG-RANGE POLLUTION:

Understanding the mechanisms and responding at local level

The mechanisms by which pollutants are transported over long distances, and the impacts of these pollutants on air quality in cities and in rural areas, are complex and not fully understood at present. What processes govern changes to pollutants during transportation? How can we model this phenomenon? What data do we need to collect and how?

Secondary pollution and organic nitrates → 9

Secondary pollution may occur far from the area in which its precursors were emitted. Nitrogen oxides are among the most common types of precursor. These may be trapped within relatively stable "reservoir compounds", which prevent degradation of the nitrogen oxides during transport prior to their release at vast distances from their original emission sources. One particular study looked at the **role of organic nitrates in the long-range transport and release of nitrogen oxides**, adopting a cross-disciplinary approach combining laboratory experiments, theoretical calculations and digital simulations. The results of this study **provided detailed information about the speeds and mechanisms behind the chemical reactions that form organic nitrate sources and wells – the principal reservoir compounds for nitrogen oxides**. These high-quality results will subsequently be used to develop simplified reaction mechanisms and to improve air quality forecasting and simulation models.



Laboratory-based atmosphere simulation chamber

Secondary pollution

Secondary pollution is the result of degradation of pollutants emitted directly by pollution sources (primary pollutants), producing secondary oxidised compounds such as ozone or secondary organic particles. These may have adverse health effects. These phenomena involve complex interactions between solar radiation (known as photochemical pollution), Volatile Organic Compounds (VOCs) and nitrogen oxides (NO_x).

The role of Volatile Organic Compounds → 10

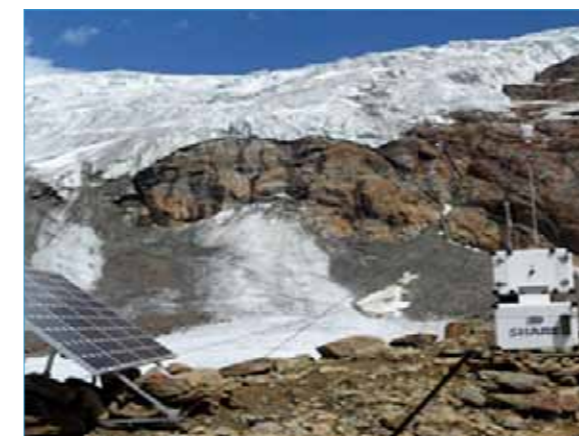
Another factor in secondary pollution, Volatile Organic Compounds (VOCs), were also studied. Although the emission sources of this pollutant (both human and biogenic) are now clearly identified, the same cannot be said of the scale, temporal variability and chemical composition of these emissions. There are also large gaps in current knowledge about the process by which VOCs (primary pollutants) are transformed into secondary pollutants such as ozone and secondary organic aerosols. **As a result of work in this area, it is now easier to quantify the primary and secondary sources that influence the presence of VOCs in Europe**. Researchers have been able to confirm the persistent presence of significant levels of VOCs far from their original emission zones, **as well as the important role that they play in terms of long-range pollution**.

A long-range pollution model → 11

The **CHIMERE** digital pollution modelling tool has been improved and now provides a better representation of pollutant transportation mechanisms and trends in Europe. The aim is to improve the monitoring of wide-scale pollutant emissions. This research has already led to improvements in knowledge and understanding. For example, **imported organic compounds trigger local ozone production on a scale comparable with such production from local emissions**. During continental stagnation episodes, the amount of ozone produced from imported organic compounds can even reach twice the level of production from local emissions. **The modelling tool has also confirmed the key role that biogenic emissions play in secondary organic aerosol trends**. Long-range pollution modelling tools such as this are important in the development of effective air quality management policies.

Data on mountain areas → 12

Mountain areas are notoriously difficult to access, therefore hindering the collection of atmospheric composition data for these areas. They are often located far from urban centres, yet are susceptible to the same problems in terms of long-range pollution. A **prototype standalone measurement station**, known as **SMOAA-BOX**, has been developed to overcome this problem. This station is easily transportable and is equipped with innovative



SMOAA-BOX

technologies. It may be deployed on international peaks and in remote regions over the coming years, offering new possibilities in terms of long-distance pollution analysis.

The CHIMERE modelling tool

CHIMERE is a chemistry-transport modelling tool developed jointly by the Institut Pierre-Simon Laplace (IPSL) and the National Institute for Industrial Environment and Risks (INERIS). It is designed to calculate the concentration fields of gases and aerosols in regions of varying sizes, from individual cities to entire continents. There are other, similar models in France such as Polyphemus and MOCAGE.

In practice: SMOAA-BOX

The SMOAA-BOX is able to transmit atmospheric composition data from any mountain area. The data transmitted include particle concentration (by number and by mass), soot concentration, carbon dioxide (CO₂) and ozone (O₃) concentration, as well as temperature, pressure, air density, and wind direction and strength.

4,000 metres

This is the maximum altitude at which the SMOAA-BOX has been deployed (in Pakistan). This confirms that it is able to withstand extreme conditions.