Interdisciplinary Tropospheric Research: from the Laboratory to Global Change (INTROP)

An ESF scientific programme

Climate change and air quality are key challenges for all of humankind. In fact, it has become clear over the last decade that the development of our societies cannot be uniquely wealth orientated but that sustainable development requires an 'environmentally friendly' approach. However, such an approach is possible only if scientifically sound knowledge is made available to our societies. A co-ordinated scientific programme on atmospheric chemistry is thought to be one of the best ways of dealing with issues of strategic importance in European science policy. Understanding the multiphase chemical transformations of trace species in the troposphere requires a multidisciplinary approach which must involve groups of researchers with highly complementary skills. None of the European countries has at its disposal the full range of scientific excellence, experimental expertise or research infrastructure to tackle the problems alone. Therefore, building a framework that is able to meet new challenges in the field of atmospheric chemistry and physics requires collaboration between the best research teams that can be found throughout Europe. By making available resources to foster collaborations between laboratories and for regular meetings and training, this programme aims to enhance the development of interdisciplinary tropospheric research in Europe.

The European Science Foundation acts as a catalyst for the development of science by bringing together leading scientists and funding agencies to debate, plan and implement pan-European initiatives.

Scientific background

Humans and the biosphere respire and reside in the Earth's atmosphere which has, for a long time, been considered as an unalterable reservoir for life. Nowadays, this simple approach is no longer supported as it became clear that human activities have altered the composition of the Earth's atmosphere.

As chemical processes and cycles in the atmosphere are critical components of the life support system of the planet, a major goal is to develop our knowledge in such a way that the fate of pollutants can be fully understood. Atmospheric sciences are indeed focusing on the description of how a molecule introduced into the atmosphere is altered by the oxidising medium of the atmosphere and, in turn, how this alteration affects the atmospheric composition and atmospheric properties.

The challenge of sustainable development is to adapt our domestic and industrial activities to a changing environment, and to control its evolution under natural and anthropogenic influences. Our capacity to adapt and to develop 'environmentally friendly' approaches depends fundamentally on our capacity to describe, understand and model environmental processes. Global change encompasses complex phenomena over different space- and time-scales in the physical, chemical and biological components of the Earth System.

Global change issues cannot be solved within the restricted frame of traditional disciplines but require a multidisciplinary approach that gathers together specialists from many fields. At the same time, the environmental sciences have experienced many changes, including new knowledge and understanding, new methods and skills (for example those associated with modelling complex non-linear systems), and the increasing exploitation of a wealth of Earth observation systems.

It became obvious in the last decades that economic development without respect for social and ecological constraints is doomed to remain unsustainable. In fact, environmentally friendly approaches are required in all fields of human activity. However, these approaches are possible only if scientific knowledge is steadily enlarged.

Today the understanding of atmospheric chemistry is of crucial value to a range of economic and policy issues. It has become clear that atmospheric chemistry is intimately linked to climate and global environmental changes. The science behind 'atmospheric chemistry' is interconnected and plays a pivotal role in understanding other key atmospheric problems such as air pollution on different scales; for example urban, regional and global, degradation in visibility and health effects.

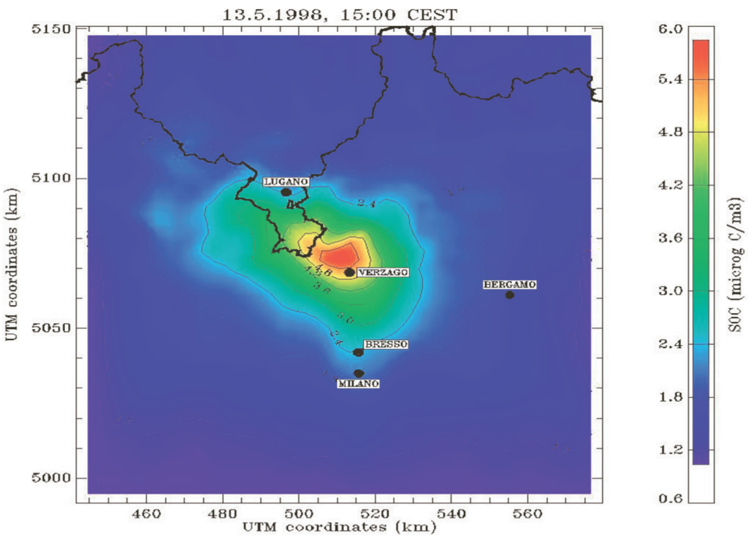
Human activities with global or regional impact are expected to change global climate (such as the increase of the Earth's surface temperature[1]) and water resources (for example the desertification of the Mediterranean area). Regional impacts are not well understood because they are strongly influenced by the presence of aerosols of both anthropogenic and natural origins. In fact, our understanding of the chemistry and physics of aerosols

[1] Houghton, J.T. and Intergovernmental Panel on Climate Change. Working Group I., Climate change 2001: the scientific basis: contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change. 2001, Cambridge; New York: Cambridge University Press. x, 881

does not currently allow any assessment of future trends. As recognised by the WMO report on global change, the uncertainties carried by aerosols is so large that it could regionally compensate for or strengthen greenhouse gas effects.

In terms of radiative forcing, climate change and air quality predictions, there are still large uncertainties in our quantitative understanding of the relative importance of natural and anthropogenic emissions, the formation and transformation of gas phase species and aerosols, cloud formation and the interaction between aerosols and clouds, resultant radiative properties, climate forcing and effects on the hydrological cycle. For instance, the current IPCC estimates of uncertainties associated with radiative forcing by gases is typically less than 30% of the absolute forcing, whereas in terms of aerosol direct radiative forcing, the uncertainty is typically greater than 100% and in some cases more than 200%. In terms of the indirect radiative forcing by aerosols, no quantification is given and the uncertainty is considered three to four times that associated with radiatively active gases. Moreover, regional scale forcings can be significantly greater than the global average, as can their associated uncertainties.

Furthermore, human health is at risk because of aerosols in two ways: persistent semivolatile organic compounds attach to aerosol particles (and partition also to the hydrosphere, soil and vegetation), accumulate in the food chains and cause adverse chronic effects in organisms including humans. Fine and ultrafine particulate matter at the present emission levels causes acute and chronic adverse health effects in vulnerable parts of the European population. In fact, EU legislation on chemicals, the POP conventions and EU environmental policy (air quality daughter directive), require an improved understanding of aerosol science to be effective. The improved understanding can only result from a multidisciplinary approach involving groups of researchers with highly complementary skills. A combined approach involving laboratory experiments, field measurements and modeling is required and none of the European countries is capable of performing this range of activities alone. Therefore, building a programme that is able to meet new challenges in the field of interdisciplinary research is the most promising, synergic and cost-effective approach.



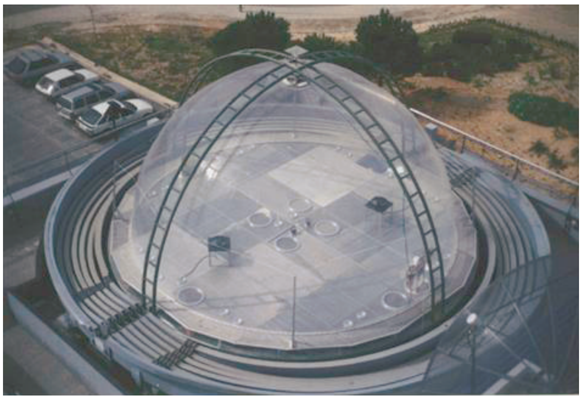
Secondary organic carbon in the highly industrialised area of Milan, Northern Italy in May 1998, as modelled with CAM-x. © U. Baltensperger, PSI - Villigen

Accordingly, the ESF INTROP programme will contribute to:

- ***Strengthening collaborative research***

In the past, many excellent scientists in European laboratories have devoted their research to fundamental studies of chemical kinetics and related disciplines, driven by different motivations and relating to many independent applications. Focusing their research on issues of atmospheric chemistry is a societal challenge. In order to foster such focused high quality research, it is necessary to stimulate collaboration between these laboratories by exchange of experiences as well as optimisation of experimental techniques and theoretical approaches on the widest possible basis. A Europe-wide scientific programme is the most suitable structure to pursue such an approach.

One of the two identical EUPHORE reactors in Valencia, Spain. Each of them consists of a hemisphere with a diameter of 9.2m and a volume of 200 m^3. © CEAM Valencia



● ***Enhancing multidisciplinarity in the field***

The atmosphere is filled with clouds and aerosol particles which constantly interact with trace compounds in the gas phase. Therefore it is necessary to study this heterogeneous system as a whole, using an integrated approach. INTROP will integrate experimental, theoretical and modelling competence from several disciplines; for instance, from chemistry, physics, engineering, and meteorology, since interdisciplinary collaboration is the only feasible way to gain a full understanding of the atmosphere system as a whole.

● ***Promoting mutual awareness***

The best policy for promoting awareness for the environmental issues addressed by our scientific community is to make sure that all potential contributors are confronted with current networking initiatives. This will stimulate and intensify collaboration between the best, creating an added value by increasing the quality of the research, whereby new networking initiatives will be encouraged in a timely response to the up-coming research needs of European countries.

The ESF INTROP programme offers a unique opportunity to structure the European science community in this highly interdisciplinary area. A survey by the members of the steering committee has revealed that over 50 research teams from the member states of the European Community, from several candidate countries, and from Israel are able and willing to contribute to the proposed activities. This exceeds the critical mass which is required to provide accurate kinetic information and other fundamental parameters on elementary processes occurring in the air, at the surface of droplets and particles, and in cloud water. It is expected that needs for such data, which will arise from other networking activities dealing with global change issues, with health effects of small aerosol particles and other environmental challenges, for example under the EC 6th Framework Programme, must be satisfied at short notice. The proposed programme provides a means of quick and flexible response to these research needs, thereby improving the overall 'environmentally friendly' approach of Europe's research community to the challenges of the future.

Interdisciplinary collaboration in this spirit is a key feature of our programme. In fact most research teams that we expect to contribute to this scientific programme are (or will be) funded by national and/or European organisations, in response to environmental issues identified by these funding agencies. Such projects are typically dominated by field studies or modelling activities which involve only relatively small groups of scientists dealing with laboratory or theory-based research. This has the disadvantage that these small groups must work in isolation from their partners in other projects, thus lacking mutual awareness. As a consequence, competitiveness at the European level is seriously affected as none of the European countries has the national capabilities to cover the full range of required process studies. We have therefore initiated a framework which fosters international collaboration between scientists involved in all areas of interdisciplinary tropospheric research, thereby promoting transnational links, the exchange of knowledge and of students, and the training of young scientists at the European level. The added value of this approach is a considerable enhancement of the common research capacities. With these goals in mind the scientific programme will take clear and definite advantage of all the tools provided by the ESF mode of operation to promote international collaboration: short term visits of research scientists, workshops, student exchanges, summer schools, etc., all focusing on common scientific objectives.

Scientific objectives

Despite a large number of process studies over the past decades that have improved our understanding of ozone chemistry, many processes fundamental to atmospheric chemistry are still poorly understood or need to be described in greater detail. This is necessary to furnish a scientifically sound basis for creating better assessment tools in terms of chemical and physico-chemical process modules which can be included in numerical models of our atmospheric environment. A timely example is the chemical, physico-chemical, morphological, optical and toxicological characterisation of aerosol particles (PM_{10}, $PM_{2.5}$). This information is needed to assess their impact on air quality (for example visibility reduction), on climate and on human health. Another example is the development of structure-activity relationships for various classes of new volatile or semi-volatile chemicals, which are needed to assess their tropospheric lifetimes, the number, structures, and properties of their degradation products, their impact on ecosystems and their potential to contribute to new particle formation.

Accordingly, many important questions concerning the degradation of simple organics and of numerous volatile chemicals still remain to be answered:

- ***Can we predict the atmospheric fate of novel complex pollutants?***

An 'environmentally friendly' approach requires that the fate of novel chemical compounds in the atmosphere be assessed *before* they are released into the environment. However, the scientific basis for such assessments is not always as sound as one would wish, especially when the fate of very complex compounds such as aromatic hydrocarbons and multifunctional oxygenates, etc. comes into play.

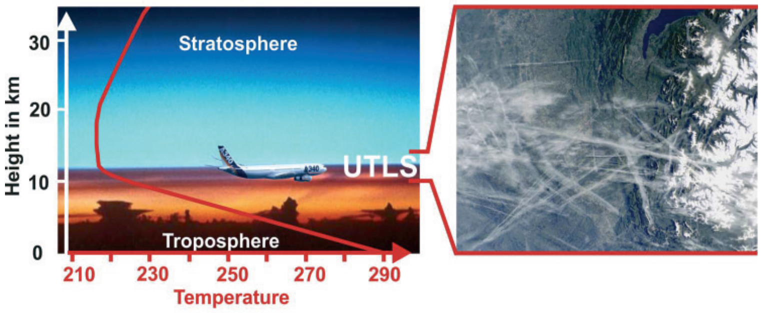
- ***Do we understand the impact of aerosols on global change?***

The atmosphere is not purely homogeneous, but contains condensed matter in the form of liquid and solid particles. Epidemiological studies have revealed that aerosol particles with diameters less than 10µm and 2.5µm (PM_{10}; $PM_{2.5}$) or smaller represent an important health hazard. In addition, heterogeneous chemistry on aerosol particles and its impact on air quality as well as particle composition are far from being well understood, and large uncertainties are associated with the climate forcings exerted by different types of atmospheric aerosols.

- ***Can we understand and predict atmospheric composition change using models?***

Because of the complexity of the Earth System, the unique tool for studying

Part of the aerosol instrumentation within the temperature controlled indoor 27-m^3 chamber at the Paul Scherrer Institute. © U. Baltensperger, PSI - Villigen



Left: typical temperature profile of the troposphere and stratosphere at mid-latitudes. The underlying image of the troposphere which shows deep convective clouds in the troposphere was taken from Space Shuttle. *Right:* Satellite image of persistent contrails above the Rhone valley, superimposed on natural cirrus clouds.

long-range – long-term atmospheric composition change is numerical simulation. Inclusion of the complete set of known chemical reactions and multiphase interactions in chemistry transport models (CTMs) is prohibited by computing time limitations, and mechanism reduction is unavoidable. However, scientifically sound reduction procedures need as a basis the ‘complete’ mechanism and associated rate parameters which are not yet available.

Our goal is to establish a network of European scientists in order to study these and other important issues with a coordinated and interdisciplinary approach. Bringing together the best available experimental and theoretical groups will widen our knowledge base. This should lead to a better understanding of the impact of atmospheric chemistry on climate change (for example, through increasing tropospheric ozone levels), and vice versa, of the effect of climate change on atmospheric chemistry.

Activities

To achieve its scientific goals over its five-year duration, the ESF INTROP programme will promote the following activities:

- ***Exchange of knowledge and sharpening of common awareness***

Annual conferences

There will be calls for *annual conferences*, to be organised at predetermined dates by the programme steering committee. Their purpose is to foster common awareness, to exchange information and know-how on a wide as possible basis, and to organise work plans and collaborations for the next working period.

Ad hoc workshops

The annual conferences will be supplemented by topic-based *ad hoc workshops,* which are likely to attract smaller numbers of scientists.

- ***Training of young scientists***

Grants

Grants will be made available for researchers (PhD or post-doctoral level) to visit other European institutes. These grants will be allocated on the basis of dedicated yearly calls to be issued by the programme steering committee.

Summer schools and study centres

These events will contribute to the training of young researchers on specific topics matching the scientific objectives of the programme. This is a cost-effective way of training researchers and exchanging information on very specific areas of research over a short period of time (1-2 weeks). Two summer schools or study centres are expected to be organised over the five years’ duration of the programme.

Again this will foster the exchange of know-how and disseminate specific knowledge at the cutting edge of science which would otherwise be available only in institutions which are scattered all over Europe.

- ***Diffuse and disseminate information to a wider public***

Website

The programme will maintain its own website. This will serve the following purposes:

- keep potential contributors to the programme informed about matters arising, such as workshops, working group meetings, exchange of co-workers between laboratories, etc.;

- inform the wider public (for example university students and educated amateurs) about the problems associated with a changing atmosphere under the impact of climate change, and about the goals of the scientific programme with respect to these challenges;
- present new (first level) data from experimental studies which have not yet passed the process of quality control. This process will occur via a web-based discussion or peer-reviewing process, and will eventually lead to review data sets. These can then be recommended for use by the wider scientific community. A good example of a web-based reviewing system is given by the recently launched web-based journal Atmospheric Chemistry and Physics Discussion (www.atmos-chem-phys.org) ;
- disseminate quality controlled data from the programme. This will eventually establish a database of kinetic parameter, degradation schemes, chemical, physical and optical properties of aerosols, and other relevant parameters, enabling the international scientific community interested in interdisciplinary tropospheric research and other potential users to keep abreast of the progress made by the scientific programme.

● *Shaping the future of atmospheric chemistry research in Europe*

The structure of the scientific programme is open and flexible, driven exclusively by discussions with collaborating scientists. This ensures that the structure of the scientific programme can be quickly adapted to any new challenges in the area of atmospheric chemistry research which may evolve over the five years' duration of the project.

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For the latest information on this programme consult the *INTROP* home page: www.esf.org/introp

Cover picture:
Polar stratospheric clouds at Kiruna, Sweden. © CNRS Photothèque, Patrick Aimedieu

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