Memorandum of Understanding

For the implementation of a European Concerted Research Action designated as
COST Action 728

ENHANCING MESO-SCALE METEOROLOGICAL MODELLING CAPABILITIES FOR AIR POLLUTION AND DISPERSION APPLICATIONS

The signatories to this Memorandum of Understanding declaring their common intention to participate in the concerted Action referred to above and described in the Technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of the document COST 400/01 "Rules and Procedures for Implementing COST Actions", the contents of which the Signatories are fully aware of.

2. The main objective of the Action *is to develop advanced conceptual and computational frameworks to enhance significantly European capabilities in mesoscale meteorological modelling for air pollution and dispersion applications.*

3. The overall cost of the activities carried out under the Action has been estimated on the basis of information available during the planning of the Action as EUR 4,000,000 at 2004 prices, over the period 2004 to 2009 inclusive.

4. The Memorandum of Understanding will take effect on being signed by at least five Signatories.

5. The Memorandum of Understanding will remain in force for a period of five years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter 6 of the document referred to in Point 1 above.

TECHNICAL ANNEX

ACTION 728

ENHANCING MESO-SCALE METEOROLOGICAL MODELLING CAPABILITIES FOR AIR POLLUTION AND DISPERSION APPLICATIONS

A. BACKGROUND

A.1 An overview of the current status of European mesoscale modelling capability

A.1.1 Meteorological modelling

Over the past few years there has been a growing need to simulate meteorological fields for complex situations at finer spatial resolutions. This has been partly stimulated by scientific and technological advances (for example, in dynamics, computational methods and facilities) and partly by policy pressures requiring more detailed assessment of air pollution on urban to regional scales. As a consequence, complex dynamical models, have been increasingly used in Europe and the USA for meteorological and air pollution applications (for example, Seaman 2000). Models developed for short- or long-range applications, however, are not always appropriate in flow conditions involving intermediate meso-scale features and processes (of order 1-200 km, i.e., meso-β and meso–γ according to the nomenclature of Orlanski, 1975), because appropriate approximations and parametrizations need to be different for models of different scales. In addition, at these mesoscales the simulated phenomena are driven by both local scale influences (e.g. orography, urban area) as well as synoptic scale processes (e.g. cyclones). Complex mesoscale atmospheric flow conditions of interest include, for example, land-sea or lake-breeze interactions and their combination with upslope winds and flow over complex terrain (e.g., the regional recirculations in the Western Mediterranean Basin in summer, or the effects of road traffic through the Alps). All of these involve urban/rural transitions, including recirculations and feedbacks. These locally forced features interact with synoptic scale processes, such as fronts and convection. Consequently, these are a challenge for both weather predictions and for simulating regional pollution transport. Even more, the interaction of meteorology (e.g. cloud formation) and pollution transport (cloud nuclei, precipitation) is very important in the regional scales, where clouds can no longer be treated as sub-grid-scale features and falling rain drops are explicitly simulated. These aspects require a close coupling between weather forecasting and air quality.

Current meso-scale models have serious problems describing the flow and turbulence fields accurately enough to be used in pollution transport studies (e.g. wind directions within 10°). Difficulties also arise from the treatment of heterogeneous surface characteristics and water process (low clouds and fog). Other situations which present huge challenges include dispersion in very stable, or low wind speed conditions, and/or the production of secondary pollutants, such as ozone and particles during mesoscale transport. All these aspects imply the correct simulation of the diurnal cycle of the atmospheric boundary layer (ABL), especially under strongly stable or unstable conditions. Therefore, flow and turbulence models are the core elements of the assessment process and can influence substantially the results of subsequent modules (chemistry and/or assessment).

In order to describe meteorological phenomena on a smaller scale, there is a trend in developing non-hydrostatic (NH) mesoscale models. NH-meso-scale models have been developed in most European countries for flow simulations and for dispersion studies. Public/research domain versions are available from European and US National Weather Services (NWS) and other agencies (e.g. ALADIN/AROME, UM, COSMO LM, COAMPS, MM5 and RAMS). Models such as MM5 are more commonly employed as meteorological pre-processors/drivers for photochemical models (e.g. CMAQ as part of the USEPA Models 3 System) and have demonstrated their usefulness for air pollution assessment down to spatial resolutions of 1km and temporal resolutions of 1 hour. Other research models which have been similarly employed include MEMO, MESO-NH, METRAS and VADIS. There is, therefore, the need to assess the benefits of coupling more recent or improved models (e.g. UM, WRF, LM, ALADIN/AROME) to

Chemistry-Transport Models (CTM) for potentially more accurate diagnostic and prognostic applications.

The future requirements for more accurate description and forecasting of complex meteorological conditions and air pollution levels at high temporal and spatial resolutions demands improved parametrization of processes such as boundary layer fluxes, deep convection and clouds. Thus, there is a need to assess a new conceptual step that would embrace in a theoretically appropriate manner key relevant meso-scale processes and features. Both Numerical Weather Prediction (NWP) and research models have to face similar difficulties such as adequately parametrizing processes on the mesoscale and assimilating initial data in a suitable way to accommodate the higher heterogeneity of small-scale features.

A.1.2 Air pollution and dispersion applications

One of the key aims of European environmental policy is to improve air quality in Europe. The framework Directive on air quality assessment and management, addresses air quality near to major sources and in cities. Other instruments, such as the National Ceiling Directive, the Large Combustion Plant Directive and the Gothenburg Protocol address long-range trans-boundary issues as well as local ones. The key requirement is the use of models to attribute measured concentrations to the sources from which the pollution may have been emitted or to assess environmental impacts of pollutants or pollution reduction strategies. For short-range local problems (< 0-10 km), simple Gaussian-type models have generally been used and for long-range transboundary problems (>200-2000 km), trajectory models have generally been used to address, for example, dispersion of accidental releases of radioactive compounds. Eulerian models, on the other hand, were often applied to simulations of acid deposition and photochemical oxidant production.

Meteorological models (MetM) able to resolve mesoscale processes (1-200 km) are considered to be the main tools in future air pollution assessments because they allow for sufficiently high spatial and temporal resolution and can trace back the linkages between sources and impacts of long travel distances and times. Additionally they can accommodate a wide range of specific local conditions. However, they are by their nature more complex than existing assessment tools and have not been subject to the degree of testing applied to short-range dispersion models. Meso-scale models for pollution prediction (either Chemical-Transport models, CTMs, that need meteorological input from a MetM or meteorological models with on-line chemistry - MetCTMs) have not been extensively evaluated in a harmonised way.

Most CTMs have embedded meteorological pre-processors/drivers or are coupled to one. There are, however, a host of various approaches to provide the input meteorological parameters and the situation is further complicated for the high-resolution end of the mesoscale (1 to 5 km) as effects like urban heat island or urban canopy sub-layer are often ignored in NWP models. Moreover, non-adequate surface interaction parameterisations, involving iterations with numerical derivatives, could lead to erroneous fields. Calm/stagnant situations with winds below 1 m/s, which lead to episodes, present a key challenge for air pollution modelling. Alternative treatments in CTMs and MetCTMs, need to be investigated, for example, a probability density function or some statistically robust characteristics instead of the meteorology field might provide improved outputs than a deterministic scheme.

One can identify a separate pseudo-type of models: MetM-for-CTM. One example is MM5. They are rarely used directly for NWP but rather for down-scaling real NWP-data specifically for the needs of a particular CTM. The reason for this intermediate class is the insufficient resolution and shortage of outputs of standard NWPs, especially concerning the description of the boundary layer. In fact, any high-resolution CTM run requires pre-processed meteorological fields by using the type of MetM-for-CTM model fed from some true NWP model. Thus, a timely and innovative field of activity for this COST Action would be to assess the interface between MetMs and CTMs and the MetM-for-CTM models, and to establish common basis for their use.

Though meso-scale models developed outside Europe, such as MM5, or its successor, WRF Model, or similar models, such as RAMS (Regional Atmospheric Modelling System) or TAPM (The Air Pollution Model), address some of the complex situations listed above, these meso-scale models may need adjustment in European pollution calculations based on the model's relative strengths and weaknesses under various conditions. Corresponding tests have only rarely been performed in a harmonised way for the European MeTMs (one example is MESOCOM) and MetCTMs (e.g. FVM, GRAMM, MESO-NH, MEMO, METRAS, SUBMESO and VADIS). Further work to develop evaluation methodologies to test model performance is, therefore, essential.

The meso-meteorological capabilities of MetMs are generally not specifically optimised for pollution applications. For example, MetMs conventionally contain options for treating processes which users must select for themselves, e.g., which ABL parameterisation to use, or the MetM may contain implicit assumptions which need to be adjusted for application in Europe. Several MetMs, such as WRF and RAMS, have a capability to run in a Large-Eddy Simulation (LES) mode to simulate atmospheric boundary layer processes. Hence it will be important to offer advice to less-experienced users on how a model should be run. A common framework for employing MetM-CTMs for European air pollution and dispersion applications would assist all users. Another tangible benefit of this Action will result form making MetMs, CTMs and MetM-CTMs accessible to a wider community of potential users.

As demonstrated above, activities and investigation requirements are multiple but dispersed. Thus, a COST Action seems to be the best approach to advance, integrate, streamline and harmonise these national efforts and hence benefit the wide community of scientists and users. This Action is also timely because of the wide range of associated collaborative, international activities under way within the European research community (see A.1.3 and section F). The new Action will build upon these activities with a particular focus of enhancing European mesoscale modelling capability.

A.1.3 Relevant COST ACTIONS and European projects

There are several previous and current COST Actions that are relevant to this proposal. COST-615 led to an inventory of air pollution monitoring datasets and models. The Action, however, focused mainly on small scales (up to a few streets). COST 710 focused on pre-processing of meteorological data for air pollution modeling purposes. For example, the activities involved the treatment of surface energy balance, mixing height determination, vertical profiles, and flows around complex terrains. COST-715, which is near completion, considered meteorological processes relevant to urban air pollution and, like COST-710, did not focus on improving any mesoscale modelling capability. Action 715 has, however, employed models, such as, HIRLAM and MM5 to better understand the meteorology prevalent during pollution episodic conditions. The methodologies and datasets resulting from COST-720 (Integrated ground-based remote sensing stations for atmospheric profiling) will be useful for model evaluation as it has identified the data needs of mesoscale NWP models. This new Action 728 will also complement COST-722 which is aiming to develop short range forecasting methods for fog, visibility and low clouds.

There is also extensive data and information resulting from European-supported projects and initiatives which, in fact, were instrumental in alerting to the importance of mesoscale circulations. These include SATURN (Urban Air Pollution subproject of EUREKA/EUROTRAC2) which also produced a model database. Similarly, the activities of the European Environment Agency (EEA) have led to extensive monitoring and model inventories which will provide the basis of the activities of the new Action (see section C). FUMAPEX (FP5 project) is employing NWP models such as HIRLAM and MM5 as part of integrated air quality management systems. This experience will be particularly useful in relation to air pollution and dispersion application. A recently approved FP6 STREP project, AIR4EU, will investigate uncertainties in air quality assessment methodologies including those employing mesoscale models. The Cluster for European Air Quality Research (CLEAR), consisting of ten FP5 projects, will provide a useful framework for interaction and dissemination.

A.1.4 Overall scope of the new ACTION

The proposed Action will address key issues concerning the development of the science (see the scientific programme below), but not the development of new models *per se*, nor the improvement of meteorological aspects on their own. Furthermore, the Action will not involve the direct comparison of one model with another. The Action will encourage the advance of the science in terms of parametrization schemes, integration methodologies/strategies, air pollution and other dispersion applications as well as developing model evaluation methods. In terms of air pollution applications it is recognised that chemical mechanisms and emissions pre-processing are vital components. However, in order to maintain the overall focus of the Action, these issues will only be addressed in relation to the meteorological influences on atmospheric chemistry and emissions. It is also appreciated that the climate modelling community is increasingly employing MetMs and is involved in further developments in this area. This new Action will benefit from interaction and coordination with climate researchers, but will not directly include climate modelling improvements.

B. OBJECTIVES AND BENEFITS

B.1 Objectives

The main objective of the Action is to develop advanced conceptual and computational frameworks to enhance significantly European capabilities in mesoscale meteorological modelling for air pollution and dispersion applications. This will be achieved through the following specific objectives:

1. To extend existing model databases with detailed documentation of physical parametrizations, models, applications and evaluation procedures.
2. To conduct a comprehensive compilation and review of existing methodologies, tools and datasets for mesoscale meteorological model validation approaches and studies.
3. To classify mesoscale modelling applications in air quality and dispersion with respect to important physical processes and to identify priorities for general and specific applications in this field.
4. To establish areas of parametrization which are poorly treated in relation to requirements for air pollution and dispersion applications.
5. To conduct an overview of existing module structures and identify the advantages and disadvantages of different strategies for integrating MetM and CTMs.
6. To formulate requirements for mesoscale MetMs as input to air pollution models and for model interfaces capable of coupling MetM results to CTMs.
7. To identify and make recommendations on the data requirements for developing, running (including data assimilation) and validating meso-scale models for various air quality and dispersion applications.
8. To examine the ability and the limitations of MetM-CTMs to adequately predict air pollution episodes such as during stagnant and low wind conditions and for a range of orographic situations.
9. To identify improvements in MetM-CTMs for air pollution and emergency forecasting purposes.
10. To examine and document operational procedures and protocols for employing MetM-CTMs for assessing real-world air pollution and dispersion problems including model configuration and initial/boundary conditions.
11. To derive and recommend validation procedures for mesoscale meteorological models for pollution transport and development of protocols for model quality assurance based on scientific and fundamental principles.
12. To identify the main requirements for an integrated mesoscale modelling capability/strategy for Europe.
13. To increase accessibility of mesoscale models and related information using a web portal and other dissemination strategies.
14. To produce guidance and recommendations for using mesoscale models for air pollution and other dispersion applications for the benefit of users.

B.2 Benefits

Currently, the weather forecasting and air quality communities are overlapping but somewhat disparate. This is a natural result of separate aims; the weather forecasting community has, of necessity, considered large scales and errors dominated by initial conditions, while the air quality community considered very small scales and errors dominated by local geography. The interests of these two communities are beginning to merge as NWPs becomes feasible at smaller scales and air quality forecasting begins to use the objective methodology of NWP models. This Action will help to bring together these communities and focus future developments on common interests. It will also help to broaden the application of existing research, especially expensive field trials through links with other relevant COST actions and projects as stated in A.1.3. There will be benefit for the regional climate community as well, for example, through highlighting strengths and deficiencies of some approaches and introducing new tools, and will draw on their work where interests overlap. There will also be a range of specific benefits resulting from this new Action in addition to key deliverables mentioned in section C:

(i) The COST Action will provide an independent, authoritative forum for the discussion and evaluation of mesoscale meteorological models for air pollution transport.

(ii) Recommendations from the Action will encourage model evaluation studies of comparable quality across Europe.

(iii) This Action will facilitate discussion of a joint European strategy for an integrated mesoscale modelling capability. The Action will also help to build such a strategy and lay the base for new generation of integrated 'weather-environment' forecast and assessment mesoscale models.

(iv) Strategies will be developed for improving meteorological pre-processors and constructing model interfaces capable of coupling NWP model results and measurement data to air pollution models. This will lead to an improved European capability to forecast and assess air pollution episodes.

(v) The Action will provide criteria for non-experts to evaluate the reliability of pollution assessment studies that use meteorological model results. This will be particularly important for decision and policy makers as they will have access to guidance and information for employing advanced tools within the broad requirements of national and international air quality management legislation.

(vi) Guidance for employing mesoscale models for meteorological and air pollution applications will be provided and will assist users at various levels including universities, research organizations, national weather services, environment agencies, city authorities, enterprises and environmental consultants.

C. SCIENTIFIC PROGRAMME

The process of model prediction normally has the following general stages:

1) Model dynamics/physical parametrizations.
2) Numerical implementation and model integration.
3) Model configuration (resolution/domain/time stepping/nesting).
4) Initial/boundary data (includes sea surface and soil temperature, soil moisture, snow cover).
5) Ancillary data (e.g. orography, land-use).

NWP developers are mainly concerned with stage 4 once 1 and 2 are well treated for the atmosphere as a whole. Air quality researchers on the other hand have been more interested in 1 and 5 in order to address the problems of down scaling. Consideration of stage 3, however, is also important and can lead to large errors. From the view point of air pollution modelling, the problem of lateral and upper boundary conditions in MetMs (providing input to CTMs) also deserves more attention as in many cases the concentration fields are mainly determined by fluxes through these boundaries.

This Action will address all the main components through the activities of four working groups (WG):

WG1	Meteorological parametrization/applications
WG2	Integrated systems of MetM and CTM: strategy, interfaces and module unification
WG3	Mesoscale models for air pollution and dispersion applications
WG4	Development of evaluation tools and methodologies

This Action would involve a range of partners focussing on specific issues related to mesoscale modelling for air pollution and dispersion applications. At this stage, no restriction would be placed on the type of meso-scale MetM or CTM considered. Thus, for example, to recognise weather service interests, both prognostic (real-time pollution forecasts) and diagnostic models (air quality assessments) would be included.

C.1 WG1 Meteorological parametrization/applications

All mesoscale models have to simplify the effects of a variety of atmospheric processes through parametrization. Typically, parametrization schemes have to simulate the effects of:

- Surface fluxes (and, as a result, some sub-surface processes such as heat, moisture and momentum transport);
- Aggregation of these fluxes;
- Atmospheric radiation;
- Cloud processes including cloud and precipitation microphysics;
- Sub-grid flows such as turbulence within and outside the boundary layer, shallow and deep convection and gravity waves.

Many individual schemes have been developed to treat these processes, usually with reference to detailed experimental results from the field and/or using highly detailed reference models (such as Large Eddy Simulation), but compromises must always be made between cost and accuracy. In many real mesoscale flows, furthermore, the interaction between these processes may be of considerable importance, so it is often not sufficient to test individual components.

Different modelling philosophies exist. Some models use a single set of parametrizations, perhaps with small variations of parameters allowed, which may have been carefully tuned to work well together in the applications envisaged. In contrast, other models provide a wide variety of alternatives, with the advantage that different selections may work well in different circumstances, and the disadvantage that a great deal of work is required to establish which options work well together, and none have been especially designed to work in combination.

Similarly, some approaches are simpler than others, in the sense that they require fewer prognostic equations to describe the atmosphere, though added complexity, and with it, added degrees of freedom and additional parameters, does not guarantee added accuracy. Furthermore, physical parametrizations have to be coupled to numerical solutions of atmospheric dynamics; both the nature of the coupling and the dynamics can have a significant impact on performance.

The overall aim of WG1 will be to provide a framework within which the state of the art of physical parametrization in mesoscale models can be advanced, with particular application to air pollution and dispersion applications. The integration of modules will be considered within WG2 and the performance of models as a whole will be covered in WG4; WG1 will cover purely the individual physical parametrizations and their interactions. To achieve this aim the following activities are planned within WG1:

a) Extension of the model database established during the planning phase to include detailed documentation of physical parametrizations used within each model. This documentation will, where possible, include discussion of design criteria, applicability (e.g. to model horizontal or vertical resolution, specific flow regimes) and expected limitations.

b) Documentation of methods and reference data that have been used to construct or validate individual model components. Where possible, data, or references thereto, will be made available to European model developers for comparison.
c) Documentation and, more importantly, classification of known applications of mesoscale modelling applications in air quality and dispersion with respect to important physical processes.
d) Identification of priorities for general and specific applications in air quality and dispersion. For example, treatments of deep convection are probably not of general importance to the nocturnal, urban, boundary layer but may be in very specific situations.
e) By reference to existing results, establish the strengths and weaknesses of current approaches and common successes or failures (if any). This work will feed into WG4, and the model validation datasets established within WG4 (from, e.g. FUMAPEX, COST715, CITY-DELTA, ESCOMPTE, MESOCOM) and elsewhere (e.g. the EUMetNet Short Range Numerical Weather Prediction programme, SRNWP) will also be reviewed to highlight which model parametrizations are thought to be most critical in each case.
f) Establish areas of parametrization which are universally poorly treated in comparison with requirements for air pollution and dispersion applications.

The internet, reports and papers(see section F) will be the primary tools for delivering outcomes from these activities, and it is anticipated that sites will remain live well beyond the lifetime of the Action as new documentation, results and datasets are added.

Inputs to the Activity
Inputs to the activities will be information on individual physical parametrization schemes from model developers, data- and/or metadata-sets describing reference physical or numerical results, and results from sensitivity or tuning experiments. Results from WG2 will also be used to link, where possible, performance of parametrization schemes to outputs required by transport models.

Deliverables
Key deliverables of WG1 will be:
1) Overview of physical parametrization schemes used within mesoscale models and their availability in specific models.
2) Establishment of a database of parametrization test data and results or references thereto and mechanisms for developers to use and add to this database.
3) Establishment of agreed ranges of applicability, strengths and weaknesses of existing parametrization schemes based on documented and reviewed experience.
4) Establishment of areas requiring further research and development common to all models to improve application to air quality and dispersion modelling, and proposals for future R&D.

C.2 WG2 Integrated systems of MetM and CTM: strategy, interfaces and module unification
Historically, air pollution forecasting and numerical weather predictions (NWP) were developed separately. This was plausible in the previous decades when the resolution of NWP models was too poor for meso-scale air pollution forecasting. Due to modern NWP models approaching meso- and city-scale resolution and using land-use databases with finer resolution, this situation is changing. As a result the conventional concepts of meso- and urban-scale air pollution forecasting need revision along the lines of integration of MetM and CTM. For example, a new Environment Canada conception suggests to switch from the weather forecast to the environment forecast. Some European projects (e.g. FUMAPEX) already work in this direction and will feed into this Action. Within FUMAPEX, for example, Urban Air Quality Information and Forecasting Systems (UAQIFS) will include integration of NWP models to urban air pollution and population exposure models (Baklanov et al., 2002).

The eventual integration strategy will not be focused around any particular model – instead it would possibly be to consider an open integrated system with fixed architecture (module interface structure) and with a possibility of incorporating different MetMs/NWP models and CTMs. Such a strategy would only be realised through jointly agreed specifications of module structure for easy-to-use interfacing and integration. An example of such an integrated approach is that of the PRISM specification for integrated Earth System Models: http://prism.enes.org/.

As pointed out earlier urban/rural transition processes (e.g. recirculations and feedbacks) are important as are interaction of these locally forced features with synoptic scale processes (e.g. fronts and convection). Furthermore, at regional scales the interaction of meteorology (e.g. cloud formation) and pollution transport (e.g. cloud nuclei, precipitation) becomes significant. In this case off-line coupling does not allow the study of feedbacks of atmospheric pollutants on meteorological processes and the access to meteorological fields are limited by the model outputs and a large amount of data exchange. Online coupling, on the other hand, would allow the implementation of 'integrated' physical and chemical parametrization schemes. Additionally, NWP models are not primarily developed for air pollution modelling and their results need to be designed as input to meso-scale air quality models or they have to be integrated into joint modelling systems for air quality forecasting and assessments. For this reason both off-line and on-line coupling of MetMs and CTMs will be considered in WG2. Thus, a timely and innovative field of activity will be to assess the interfaces between MeTMs and CTMs and the MetM-for-CTM models, and to establish the basis for their harmonization and benchmarking.

WG2 will also review practical aspects of running meso-scale models, e.g., gaining access to meteorological and environmental/geographical datasets, running models, accessibility of model codes and data sets. It will consider methods for the aggregation of episodic results, model down-scaling as well as nesting. The activity will also address the formulation of requirements of mesoscale meteorological models suitable as input to air pollution models.

Examination of data assimilation techniques will also form part of WG2 activities as it has been shown that powerful assimilation techniques may be just as critical for achieving accurate forecasts as the comprehensiveness of the model, at least on the short-range (1-2 days). In this respect, the Action will inspect the requirements for assimilation techniques with a view to development of future monitoring networks. Meteorological networks are under a transition phase with many manual stations changing to less numerous automatic stations. The use of remote sensing data is increasing and will be assessed (e.g. through GMES). Pollutant monitoring networks are still very coarse and their resolution cannot generally cope with high-frequency meteorological processes.

Both CTM and NWP meso-scale models require and are dependent on specific input data that may also influence the final outputs: land-use and topographical data, parameters coupled with land-use (e.g., albedo) and emission data. The Action will assess existing datasets and methods in order to propose recommendations for the basic characteristics of datasets required for these models with respect to factors such as spatial and temporal resolution and classes split.

The overall aim of WG2, therefore, will be to identify the requirements for the unification of MetM and CTM modules and to propose recommendations for a European strategy for integrated mesoscale modelling capability. In order to achieve this aim the following activities are planned:

a) Overview of existing integrated (off-line and on-line) systems in Europe and outside Europe.
b) Identification of the advantages and disadvantages of strategies for integrating of MetMs and CTMs.
c) Development of guidance and strategy for on-line coupling of MetMs and CTMs and for their off-line interfacing.
d) Overview of existing module structures of MetMs and CTMs, along with recommendations and requirements for module unification.
e) Formulation of requirements of mesoscale MetMs suitable as input to air pollution models and improved meteorological pre-processors and model interfaces, including deposition processes, capable of connecting mesoscale MetM results to CTM models.
f) Recommended methods for the model down-scaling and nesting, as well as assimilation techniques.

g) Identifying requirements (including observation data needs) for an integrated mesoscale modelling capability/strategy for Europe.

Inputs to the Activity:

Inputs to the activity will include data and information on CTM and Met models, used and developed in different countries, their experience of model integration, as well as existing module interface structures. As to data requirements, it would include meteorological data, chemical pollutant data as well as emission inventories for selected pollutants (such as NOx, VOCs and PM10).

Deliverables:

1. Overview of existing integrated (off-line and on-line) mesoscale systems.
2. Overview of existing module structures of MetMs and CTMs, recommendations and requirements for module unification.
3. Requirements of meso-scale MetMs suitable as input to CTMs, assessment of meteorological pre-processors and model interfaces between MetMs and CTMs.
4. Recommended methods for the model down-scaling and nesting, as well as assimilation techniques.
5. Requirements for an integrated mesoscale modelling capability/strategy for Europe, including data needs.

C.3 WG3 Mesoscale models for air pollution and dispersion applications

There are various air pollution situations that require the use of complex mesoscale models to adequately describe the processes and dynamics as well as incorporate chemistry and emissions in an adequate manner. For example, many cities in Europe are influenced by the surrounding complex orography which determines to a large extent the flows of air masses and hence the movement of pollution. In cases of cities located in the vicinity of rivers, estuaries and coastal regions wind reversals with diurnal cycles can be expected, even in climatic regions where neutral atmospheric conditions dominate. In all of these cases, wind reversals, and thus oscillations of any polluted air masses, can also be expected under some or most meteorological conditions. Wind reversals caused by orography-driven processes are also associated with the formation of return flows and stratified layers aloft, and these can play a much more important role in the regional transport of photo-oxidants than hitherto considered. The recirculations can become "large natural photo-chemical reactors" where most of the NO_x emissions and other precursors are transformed into oxidants, acidic compounds, aerosols and O_3, which exceed EC directives for several months during the year. Under these conditions, feedback processes dominate, and a further important aspect relating to tropospheric chemistry is that air mass aging can go on for days within these recirculations while new emissions are continuously being added to it.

The regional and long-range transport (LRT) of air pollution in stratified layers over flat terrain, mountain regions, and particularly over the land-sea transition, is a much more frequent phenomenon than is usually acknowledged. The various processes involved in layer formation, the transport of these layers to hundreds of km with little or no vertical diffusion, and the possible chemical transformations within each layer, are still very difficult to include in existing dispersion and photochemical models. Similar comments could be made for modelling trajectories in recirculatory flows; that is, after deep convective or convective-orographic injection, and stratification aloft by compensatory subsidence, the aged pollutants can be incorporated into the surface flows several days later.

Levels of pollutants, such as, O_3 and PM10 are significantly influences by mesoscale flows and processes. A large fraction of O_3, in particular, may result from fumigation pollutants emitted a few hundred km upwind on the previous day (s) and, maybe, from different places. Similarly, the transport of fine particles from LRT can often lead to exceedances of air quality standards (e.g. Malcolm et al 2000). It is, therefore, important to include the appropriate driving processes in meso-scale models for the correct interpretation and/or forecast of O_3 concentrations, both of which are now required by the European Directives (Beck et al., 1999).

Other aspects that are important include conditions of stratification with little or no vertical diffusion and with low wind speeds. Layering of air masses have been shown to transport material such as Saharan dust and pollutants over Europe (e.g. Alonso et al., 2000).

Meteorological processes can, hence, influence tropospheric chemistry (e.g. ozone and air quality changes) and its interactions with the biosphere, in several ways including:

- The nitrogen cycle within regions of Europe,
- Particulate matter via the formation of secondary organic aerosols,
- Climate/chemistry interaction via additional photochemical heating of the lower troposphere at the local scale (e.g. change in the frequency of summer storms in a region) and feedback mechanisms involving particulate matter,
- Climate/chemistry interaction at the larger scale, via deep orographic venting (upper troposphere-lower stratosphere) of the polluted boundary layer along the upper branch of the ITCZ.

Thus, the aim of this WG is to develop strategies to improve existing mesoscale meteorological models and their dispersion modules, for these and other atmospheric applications. This activity will look at mesoscale (1-200 km) features, processes, situations that should be successfully modelled by CTMs together with meteorological mesoscale NWPs in order to address the needs and requirements of air pollution stake-holders, such as, scientists, emergency monitoring bodies and environmental authorities.

The main activities of the WG will include:

a) Collation and review of the capabilities of current individual or class of models to simulate given situations or processes.
b) Review of selected MetM-CTM systems according to applications in terms of various factors including input/operational conditions/resolution/data availability.
c) Identification, through sensitivity analysis, of the meteorological parameters and physics schemes that are important for air pollution (including deposition) and other dispersion applications.
d) Examination of the ability and the limitations of MetM-CTMs to adequately predict air pollution episodes such as during stagnant and low wind conditions for a range of orographic situations and heterogeneous situations.
e) Identification of improvements in MetM-CTM for air pollution and emergency forecasting purposes.
f) Assessment of meteorological parameters that have a critical influence on chemical mechanisms (e.g for O_3 and PM) and emissions (e.g for biogenic VOCs).
g) Examination and documentation of operational procedures and protocols for employing MetM-CTMs for assessing real-world air pollution and dispersion problems including model configuration and initial/boundary conditions.

This activity will draw upon projects such as FUMAPEX, AIR4EU and CITY DELTA as well as past and current programmes in including SATURN, MESOCOM and ESCOMPTE. It is expected that consensus will be reached on the areas that require improvements as well as strategies for implementing these improvements. Interaction will be established with other relevant research communities, including NWP modellers. Examples where interaction will be developed with other groups/networks are given in Section F.

Inputs to the Activity

Member partners will input the data and information on CTM and Met models used and developed by different research groups. Dataset will include meteorological data, chemical pollutant data as well as emission inventories for selected pollutants (such as NOx, VOCs and PM10). It is expected that there will be input from end users in relation to their requirements for air quality assessment and management applications.

Deliverables

1) Review of the capabilities of selected MetM and CTMs for air pollution and dispersion applications.
2) Documentation of the capabilities of MetM-CTM for describing and predicting air pollution episodes.
3) Identification of improvements of MetM-CTM systems for prognostic and diagnostic applications.
4) Documentation of procedures and protocols for using MetM-CTMs for real air pollution and dispersion applications.

C.4 WG4 Development of evaluation tools and methodologies

Despite the wide application of mesoscale meteorological models for air pollution transport and dispersion, no procedures or protocols have been established at the European level that assure minimum requirements for the use or performance of mesoscale meteorological models (MetMs). Scientific principles that assure model consistency and robustness do exist, but are not organised or adopted globally according to a well-defined protocol. Currently, model testing is mainly performed on the basis of few analytical solutions for simple ideal cases and by application of the model to different real case studies. The latter rely on the use of local (in space and time) measurements for both case configuration and model verification. Often this reduces the simulation to a "trial and error" process aiming at reproducing, at best, the observations available without considering the representativeness and error included in the latter, nor the global consistency of model results. There is the need, therefore, for protocols that encompass various aspects of model testing with increasing complexity and that could ensure model robustness and applicability of the mesoscale meteorological model to air pollution transport and dispersion studies. An initiative of this nature would be very relevant and beneficial for model development, amelioration and verification. Such an evaluation guideline for mesoscale meteorological models is currently developed by the German Engineering Association VDI on the basis of a validation procedure proposed by Schlünzen (1997). Other initiatives of this kind include the activities of SATURN (urban air pollution subproject of EUREKA/EUROTRAC2) which focussed more on local and urban scales (Borrego et al 2003). The outcome could be much more significant if the model evaluation protocols would be harmonized on a European level.

The overall aim of WG4 is the development of tools and methodologies that can be applied to validate and evaluate mesoscale meteorological models for pollution transport and dispersion applications. Different methods shall be developed for single case studies in a forecast type of model application as well as for calculating statistical quantities (e.g. exceeding threshold values as defined in EU Air Quality directives and the daughter directives).

To achieve this aim, the following activities are planned within WG4:

a) Worldwide collection and review of existing methodologies and tools for mesoscale meteorological model validation with emphasis on concepts that are based on fundamental physics principles rather than on single case application.
b) Extending the previous database on mesoscale meteorological models information on validation procedures. This can be based on the information available from EUROTRAC2-SATURN (http://www.mi.uni-hamburg.de/technische_meteorologie/Meso/saturn/overview.html).
c) Identification of the advantages and limits of the different evaluation methodologies and tools.
d) Critical review of available, well documented, three-dimensional data sets of known quality for model validation on the regional scale. This includes air pollution episode datasets as resulting from or used in earlier projects (e.g. FUMAPEX, COST715, CITY-DELTA, TFS).
e) Selection of case studies from the available data sets that can be used for evaluation on the regional scale.
f) Characterisation of the impact of model errors (including initial and boundary value uncertainties) on meteorological data relevant for concentration calculations.
g) Derivation of validation procedures for mesoscale meteorological models for pollution transport and development of protocols for model quality assurance based on scientific and fundamental principles.

The evaluation of models is necessary but not sufficient to ensure reliable model results. Mesoscale models are too complex to be applied without deep knowledge of and experience in such applications. There is currently no consensus on the extent or the depth of training that would be required for a non-expert to competently use mesoscale models. This Action will provide guidance on both aspects as well as recommend procedures for non-experts to evaluate the reliability of model results used e.g. in environmental impact assessment studies. The following further activities, therefore, are planned to achieve this objective:

h) Collection and review of existing methods and tools for mesoscale meteorological model user training.
i) Development of a catalogue of necessary model user skills.
j) Development of a conceptual framework for user training.
k) Development of guidance for model result evaluation that considers both model evaluation and user training.

For the documentation of the tools/methodologies as well as of the data sets, the evaluation protocols and the guidance will be available on the Action website. Additional publications will be in COST reports, conference and peer reviewed publications.

Inputs to the Activity:
Partners will provide the data and information on models, datasets and evaluation methods for model evaluation. In addition, software usable for user training or model evaluation will be an important input.

***Deliverables*:**
Key deliverables of WG4 will be:

1) Overview on tools and methods for model evaluation, datasets for model evaluation (meta-data) and tools and methods for user training.
2) Recommendation for mesoscale model evaluation guidelines for model developers.
3) Documented framework for user training.
4) Guidance for model result evaluation aimed at end users and non-experts.

D. ORGANISATION AND TIMETABLE

The overall duration of the Action is 5 years. A period of 5 years is required as much of the activities in this field is scattered and of diverse nature and is being performed at various National Weather Services (NWS), research centres and universities in Europe with limited collaboration. In order to address this a sufficient period is required to establish procedures for cooperation and to implement the activities for each of main WGs. Hence, a dedicated preparatory phase will be implemented during the first year and will help to identify and prioritise the various activities and needs. Much of the compilation work will be conducted using open literature, internet, e-mail and questionnaires. This will be followed by four focussed WGs. The overall time plan for the main phases will be as follows:

Phase 1	Planning, operational arrangements, establishment of WGs and inventory (Year 1);
Phase 2	Main scientific work to be conducted by each WG (Years 2, 3, 4);
Phase 3	WGs to conclude work with emphasis on reports and final publications (Year 5).

During the first year, the Management Committee (MC) will supervise the establishment of WGs based on a survey of models, processes and activities to be considered within the Action. The participants would specify their contribution and goals through the Expression of Commitment scheme developed by the Technical Committee for Meteorology. It is envisaged that four WGs would be established broadly developing the research areas described in section C.

By the beginning of the second year a Workshop will be held at which preliminary results and plans will be discussed and the activities and membership of WGs will be finalised. At this stage, the detailed work programme for the Action will be established by the participants. The opinions of the wider community will be sought through the initial Workshop for setting up the detailed work programme. Over the main period of work (3 years), interactions between the WGs will be firmly established so that they work in synergy rather than independently, and eventually coming together in the final phase (last year) during which the research will be completed, integrated, peer reviewed and published. During the final phase joint recommendations of the WGs will be published as a final report for wide dissemination.

The MC and WGs will meet twice a year, usually in conjunction with each other. Each WG will be coordinated by a chairperson who will report back to the MC. Coordinators will also be allocated for each sub area of the WGs. If required, external experts can be invited to some of the MC-meetings to seek advice and/or enlarge the application basis of the Action. The MC will supervise the overall progress of work, coordinates WG-activities, and will ensure wide dissemination of results. For that very purpose, one partner will set up a website and update it in a timely and continuous manner.

The three phases of the Action with the main milestones of the envisaged WGs activities are described below. Figure 1 shows the overall time schedule for the proposed Action.

Phase 1: Inventory (year 1, 12 months)

- MC: Establish initial WGs and membership and define initial work. Identification of users, and planning and organisation of 1st workshop
- WG1/2/3/4 All WGs will jointly prepare inventory of existing relevant models with detailed description as well as detailed work plans
- WG1 List critical meteorological processes and start reviewing their parametrization basis
- WG2 Review key components of models' infrastructure
- WG3: Inventory of needs and limitations from the modellers and users
- WG4: Inventory of validation approaches
- WG1/2/3/4 Report to the MC

Phase 2: Development, Assessment, Applications and Evaluation (years 2-4, 36 months)

- 1st workshop with proceedings and conclusions of the work for the Action.
- Establish final WGs and preparation of detailed plan of work based on outcomes of phase 1.
- WGs: Regular WG-meetings for planning, implementing, reviewing and synthesising the work.
- Report to the MC every 6 months on the progress of work
- MC: Short Term Scientific Missions as appropriate.
  Preparation of 2nd Workshop
  Monitoring of WG activities and advances in the field outside the Action

At the end of Phase 2 the following key achievements are expected (other deliverables are listed in section C):

- A catalogue and database of types of MetMs and CTMs with recommendations as to the input data, parameterisation schemes, initialisation data, assimilation requirements and observational data.
- Consensus on ranges of applicability, strengths and weaknesses of existing parametrization schemes based on documented and reviewed experience.
- Identification of areas requiring further research and development common to all models to improve application to air quality and dispersion modelling, and proposals for future R&D.
- Requirements of meso-scale MetMs suitable as input to CTMs, assessment of meteorological pre-processors and model interfaces between MetMs and CTMs.
- Recommended methods for the model down-scaling and nesting, as well as assimilation techniques.
- Requirements for an integrated mesoscale modelling capability/strategy for Europe.
- Critical examination of the capabilities and the limitations of MetM-CTMs to adequately predict air pollution episodes during, for example, stagnant and low wind conditions and for a range of orographic situations.

- Identification of improvements in MetM-CTM for air pollution and emergency forecasting purposes.
- Assessment of the meteorological parameters that have a critical influence on chemical mechanisms (e.g for O_3 and PM) and emissions (e.g for VOCs).
- Documentation of the operational procedures and protocols for employing MetM-CTMs for assessing real-world air pollution and dispersion problems including model configuration and initial/boundary conditions.
- Recommendation for mesoscale model evaluation guidelines for model developers.
- Documented concepts for model user training and guidance for evaluating model results for end users and non-experts.

<u>Phase 3: Synthesis and Dissemination of Action results</u> (year 5, 12 months, overlapping with Phase 2)

- WGs: Finalisation of the expected outputs
- WGs: Contributions to the final report
- MC: Organisation of the Final Workshop
- MC: Completion of the final report
- MC: Dissemination of results through publications and participation to International conferences

Figure 1. Overall timetable of the Action

	Year 1				Year 2				Year 3				Year 4				Year 5				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Phases 1	■	■	■	■																	
Phase 2					■	■	■	■	■	■	■	■	■	■	■	■					
Phase 3																	■	■	■	■	
MC-meetings	X		X		X		X		X		X			X		X		X		X	
WG-meetings			X		X		X		X		X			X		X		X		X	
Workshops							W							W				W			
WG reports					R		R			R	R			R		R	R		R		
Reports to TC				X				X				X				X				X	
Final report																					X
WWW-info pages	←		——		——		——		——		——		——		——		——		——		→
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	

E. ECONOMIC DIMENSION OF THE PROJECT

It is expected that many COST countries will be interested by this Action as mesoscale modelling is a new strategic development at most research and operational centres and because assessment of air pollution is mandatory in all EU-countries. According to the involvement and expressed interests for the development of this MoU, one could probably expect 20 participant countries. Even assuming that the commitment to this Action was shared with other research activities it would not be unreasonable to estimate that national contributions as a minimum over five years would amount to EUR 200,000 per country leading to an estimate of EUR 4,000,000 as the cost of the research programme.

This Action will lead to substantial savings in the time required to set up, test and run mesoscale models. Assuming conservatively that in the shortterm (over 2 years) 50 detailed studies of pollution levels in and around cities are required under EU Directives, the saving per study using information on mesoscale models made available by this Action could amount to EUR 100,000 per study, leading to a total saving of EUR 5,000,000.

F. DISSEMINATION

The results of the Action will be disseminated through a range of methods. These will include a dedicated web site, COST reports, conference presentations and peer reviewed publications. Particular attention will be paid to informing policy makers and to transmit results to modellers. This will apply to both, those using these methods and those who might have an application for these methods. For example, the European Environment Agency and the European Commission through the CAFÉ programme (Clean Air for Europe, COM(2001)245) would be obvious beneficiaries. This COST Action has been subject to extensive consultation by circulating earlier drafts amongst interested scientists for their comments.

The final workshop of this Action will also be used for disseminating the results especially among potential users and for promoting COST-activities in Europe and worldwide. Special efforts will be made to invite external keynote speakers and to publicise the Workshop outside the Action. In particular direct links will be established with existing European networks and bodies, such as, EUMetNET, EEA, EURASAP, WMO, the Cluster of European Air Quality Research (CLEAR) and ACCENT (FP6 Network of Excellence).

It is timely that this Action is introduced now, because of the wide range of associated collaborative, international activities under way within the European research community. Associated activities include (see also section A.1.3):

(1) Efforts by national weather services to improve boundary layer parametrizations, including urban boundary layers.

(2) The EUMetNET initiative on forecasting ground-level ozone using meteorological models within its Working Group for Environment.

(3) The EU DG/Environment programme CAFÉ, Clean Air for Europe (COM(2001)245), is looking at the implications of international policy, such as the National Emissions Ceiling Directive and the Gothenburg Protocol on ambient air quality. The City-Delta project organised by JRC/IES is concentrating on urban background concentrations in eight cities. The results are expected to represent the collective response from a number of models. All the models used are three dimensional mesoscale models.

(4) The ENV-e-City project which aims to improve access to, and harmonisation of, environmental data. Meteorology for air pollution assessments is a pilot application area.

(5) The objectives of the FP5 FUMAPEX project (Integrated systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure) are to improve meteorological forecasts for urban pollution, coupling weather prediction models to urban air pollution and exposure models in cities subject to various European climates. It aims to improve urban air quality information forecasting systems.

(6) Recently approved FP6 STREP AIR4EU will investigate uncertainties associated with air pollution assessment methods including mesoscale models.

(7) There is already a worldwide user community based on the USEPA Models3 comprehensive community air pollution transport model.

(8) The WMO GAW Urban Research Meteorology and Environment Project (GURME) aims to provide links between urban pollution predictions for cities as diverse as Moscow and Beijing.

(9) Decision makers formulating emergency plans in the event of an accidental radioactive release, are evaluating trajectory forecasts in the ENSEMBLE project.

(10) WMO activities such as GEWEX (Global Energy and Water Cycle Experiment, and its component BALTEX), THORPEX (THe Observing System Research and Predictability Experiment) and WGNE (Working Group on Numerical Experimentation) of the World Climate Research Programme (WCRP).

(11) Development and validation activities of the Unified EMEP model at the Meteorological Synthesising Centre-West.

All these activities will provide potential cooperative groups for discussing problems, mutual planning of activities and the broader dissemination of results.

Work of this Action will be coordinated with activities of several EUMetNET-programmes, such as EUCOS (the EUMetNET Composite Observing System to optimise profile and surface level measurements of temperature, wind, humidity and precipitation observations in Europe), WINDPROF (the EUMetNET project to maintain and develop wind profiling radars) and COST-720 on integrated ground-based remote sensing stations for atmospheric profiling.

The final workshop of this Action will also be used for disseminating the results especially among potential users and for promoting COST-activities in Europe and worldwide. Special efforts will be made to invite external keynote speakers and to publicise the Workshop outside the Action.

Wherever possible the Action will host workshops jointly with other international meetings. These will include:

- Urban Air Quality Conferences
- European Meteorological Society annual meeting
- Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
- NATO/ITM Conference on Air pollution Modelling and its Applications

PART II: ADDITIONAL INFORMATION

The idea for an activity on mesoscale modelling of air pollution within COST originated from some participants of COST Action 715 on urban air pollution. Assessing or forecasting air pollution in city is partly determined by the larger-scale meteorological conditions, so that it was thought to investigate how these boundary conditions can be best estimated and used. On the other hand, independently, a group of scientists from the SATURN-community was interested in developing at the European level validation procedures for models. The Technical Committee for Meteorology recommended that the two initiatives be integrated as they would mutually benefit each other.

Since model development with test runs cannot be directly funded through a COST Action, it was thought that integrating the interests of the meteorological community working on mesoscale processes and modelling would be beneficial for both communities in order to develop conceptual approach to developing, running and applying mesoscale models for air pollution and other applications.

The MoU of this COST Action has evolved during about 18 months through extensive consultation by circulating earlier drafts amongst scientists from the above-mentioned communities. However, in order to enlarge the potentially interested community and to focus on current state of the art modelling issues, the Technical Committee for Meteorology asked that an Expert Group (EG) be convened, involving many key organisations or activities in Europe. After working by correspondence, this EG met in Paris (Dec. 18-19, 2003) to finalise the MoU of this proposal.

The following scientists have participated in the drafting of the Technical Annex of the MoU as part of the Expert Group:

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COST728 Annex - Model Names and Acronyms

Acronym	Full Name
ACCENT	Atmospheric Composition Change: a European NeTwork
AIR4EU	Air Quality Assessment – Local to Continental Scales (FP6 project)
ALADIN	Aire Limitée Adaptation Dynamique développement InterNational
AROME	Applications of Research Operation at MEsoscales
BALTEX	The Baltic Sea Experiment
CITY-DELTA	A model intercomparison exercise to predict urban air-quality in 2010
CLEAR	Cluster of European Air Quality Research
CMAQ	Community Multi-scale Air Quality model
COAMPS	US Navy Coupled Ocean/Atmosphere Mesoscale Prediction System
COSMO LM	Consortium for Small Scale Modelling) Lokal-Modell
CTM	Chemical Transport Model
EMEP	European Monitoring and Evaluation Programme
ENSEMBLE	Ensemble Atmospheric Transport Modelling
Env-e-City	Towards an Environmentally Viable Electronic City
ESCOMPTE	ESCOMPTE is the French acronym for a field

	experiment to constrain the models of pollution emission transport
EUCOS	EUMetNET Composite Observing System
EUMetNet	Network of European Meteorological Services
EURASAP	European Association for the Science of Air Pollution
FUMAPEX	Integrated systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure (FP5 project)
FVM	Finite Volume Model
GEWEX	Global Energy and Water Cycle Experiment
GRAMM	Graz Mesoscale Model
GURME	GAW Urban Research Meteorology and Environment Project
HIRLAM	High Resolution Limited-Area Model
MEMO-NH	Mesoscale Model – Non Hydrostatic
MESOCOM	Mesoscale Model Inter-comparison
MetM	Meteorological Model
METRAS	Non-hydrostatic Mesoscale Model???
MM5	Fifth-Generation NCAR / Penn State Mesoscale Model
RAMS	Regional Atmospheric Modelling System
SATURN	Studying Atmospheric Pollution in Urban Areas – EUROTRAC2 Subproject
SRNWP	EUMETNET Short Range Numerical Weather Prediction programme
SUBMESO	Urban Boundary Layer Model
TFS	German Tropospheric Research Programme
THORPEX	THe Observing System Research and Predictability Experiment
UAQIFS	Urban Air Quality Information and Forecasting Systems
UM	UK MetOffice Unified Model
VADIS	3D Street Canyon Model
WCRP	World Climate Research Programme
WGNE	WMO Working Group on Numerical Experimentation
WINDPROF	EUMetNET project to maintain and develop wind profiling radars
WRF	Weather Research and Forecast model