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Subject: Full proposal for a new COST Action:
TOPROF: Towards Operational ground based PROFiling with ceilometers, Doppler lidars and microwave radiometers for improving weather forecasts

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[*] Will be completed by the COST Office

DRAFT
MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action
designated as

COST Action

TOPROF: Towards Operational ground based PROFiling with ceilometers, Doppler lidars and microwave radiometers for improving weather forecasts

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 document COST 299/06 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Signatories are fully aware of.

2. The main objective of the Action is [*]

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at [*] Euro [*] million in [*] prices.

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 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 V of the document referred to in Point 1 above.

[*] Will be completed by the COST Office

A. ABSTRACT & KEYWORDS

A.1 ABSTRACT

The new generation of high-resolution (1km) weather forecast models now operational over Europe promises to revolutionise predictions of severe weather and poor air quality. To realise this promise, a dense observing network is required, focusing especially on the lowest few km of the atmosphere, so that forecast models have the most realistic state of the atmosphere for initialisation, continuous assimilation and verification. This action will focus on developing three instruments available throughout Europe: i) Several hundreds of ceilometers providing backscatter profiles of aerosol and cloud properties with 30m vertical resolution every minute, ii) more than 20 Doppler lidars, a new technology, providing vertical and horizontal winds in the lower atmosphere with a resolution of 30m every 5 minutes, and iii) About 30 microwave profilers giving profiles of temperature and humidity in the lowest few km every 10 minutes. These instruments are relatively inexpensive and have proven suitable for unmanned network operations. Current and recent COST and FP7 projects have considered the profiling ability of advanced lidars and radars, but none has specifically addressed these three instruments. In collaboration with Numerical Weather Prediction centres, the action will lead towards operational networking of these existing but so far under-exploited, instruments

A.2 Keywords

High resolution weather forecasts. Warnings. Hazardous weather. Flash floods. Pollution. Clouds and aerosols. Air quality. New observation networks. Ceilometers. Lidars. Doppler lidars. Microwave radiometers. Data quality. Data formats. Calibration. Maintenance. Retrieval algorithms. EUMETNET. EUCOS. ACTRIS. EG-Climet.

B. BACKGROUND

B.1 General background

A new generation of high-resolution (1km) forecasting models is now operational over Europe run by National Meteorological and Hydrological Services (NMHSs). Such models promise to provide increasingly accurate high-resolution forecasts of impending hazardous weather, ranging from flash floods to episodes of poor air quality. If this promise is to be fulfilled then a new generation of high- density observations through the lowest few km of the atmosphere, including the boundary layer, is required in real-time. Firstly these observations can be used to check that the parameterisation schemes inherent in such models lead to a realistic representation of the atmosphere. Furthermore, the observations can be used in near real time for data assimilation. This means that models used for both nowcasting (1-3 h) and for weather forecasting can be initialized and driven with the best possible representation of the current state of the atmosphere.

The WMO statement of guidance on observations (https://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html) for global Numerical Weather Prediction (NWP) concludes that the four critical atmospheric variables that are not adequately measured by current or planned systems are (in order of priority):

- wind profiles at all levels
- temperature and humidity profiles of adequate vertical resolution in cloudy areas
- precipitation
- snow mass

With respect to clouds the statement says: “Surface stations measure cloud cover and cloud bases with a temporal resolution and accuracy that is acceptable but a horizontal resolution that is marginal in some areas and missing over most of the Earth. … Active optical (lidar) and microwave (radar) instruments are required to give more information on the 3D distribution of clouds water and ice amounts and cloud-drop size. Some research instruments have been launched and more are planned”.

For 3-dimensional aerosol distribution it is stated: “Assimilation of aerosols is generally immature in global NWP but is likely to increase in importance. … Lidar measurements will be required to provide vertically resolved information; research demonstrations are under way”. And for 3-dimensional winds: “There is currently no present or planned capability. Research is required on indirect observations via sequences of geostationary infrared imagery, or through Doppler enabled microwave sensors”.

Finally, as the WMO report remarks, the instruments ‘would benefit from more timely availability and more wide distribution of some observations, … that are made but not currently disseminated globally’.
Two recent documents (“Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks” http://www.nap.edu/catalog.php?record_id=12540 and “When Weather Matters: Science and Service to Meet Critical Societal Needs” www.nap.edu/catalog.php?record_id=12888) by the United States National Research Council, stated that the structure and variability of the lower troposphere is currently not well known because vertical profiles of water vapour, temperature, and winds are not systematically observed. This lack of observations results in the planetary boundary layer being the single most important under-sampled part of the atmosphere.

Additionally, the latest IPCC report has identified the representation of clouds and aerosol and their interactions as one of the major areas of uncertainty, which leads to the current spread in predictions of future global warming. Satellites have difficulty probing the lowest atmosphere close to the Earth’s surface because it is frequently cloudy, passive satellite weighting functions have poor vertical resolution and the Earth’s surface often dominates the signal. Accordingly, such data are best provided by ground based profiling instruments such as lidar and microwave sensors.

The action will nurture the development of three instruments: ceilometers, Doppler lidar and microwave radiometers, that have the potential to be networked and the wind, temperature, humidity, cloud and aerosol data made available in real time to National Weather Services. Current and recent COST and FP7 projects have considered the profiling ability of advanced lidars and radars, but none has specifically addressed ceilometers, Doppler lidars and microwave radiometers, which are relatively inexpensive and have been proven to be suited for unmanned network operations.

Currently, several hundred laser ceilometers are in operation over Europe. Each instrument emits a pulse of laser light and then detects the backscattered signal. Originally, as the name suggests, such instruments were designed for detecting the cloud base or "ceiling", but current more sensitive ceilometer models provide high-resolution profiles of backscatter, from which vertically resolved aerosol and cloud properties can be characterised. Following the Icelandic volcano eruption in April 2010, many new ceilometers were purchased by NMHSs; the density is now about one every 100km in several countries in Europe. Such instruments are inexpensive (20-70 KEuro), can operate continuously, unmanned and need minimal maintenance. This is in stark contrast to more advanced lidars and cloud radars, which are 10 to 50 times more expensive. The new high resolution forecast models are now starting to represent aerosols, with a major goal to provide accurate warnings of poor air quality. Aerosols are advected by the wind and removed by processes such as precipitation. Precise knowledge of aerosol emissions and their geographical and vertical distributions are key elements to improve air quality predictions. Currently there are very few vertically resolved observations to evaluate the performance of the model in predicting aerosol loading. The new profiling ceilometers will fill this information gap. The forecast models also need accurate cloud representation if they are to improve predictions of heavy rainfall.

Modern commercially available Doppler lidars exploit new technology developed over the past decade. For a modest cost (about 150KEuro) they use the Doppler shift in the backscattered signals from aerosols to derive the vertical motions in the lower atmosphere when pointing vertically, and accurate horizontal winds with high vertical resolution when pointing away from zenith. They have very high vertical and temporal resolution and so reveal important boundary layer processes which are not currently captured by radar wind profilers. Over 20 of these lidars are currently installed, and the number is increasing rapidly. They are rugged, reliable, and can run unattended for long periods.

Microwave radiometers (MWR) are now robust instruments operating unattended and providing real time accurate atmospheric observations under nearly all weather conditions. The calibrated MWR receivers measure the down-welling emission from the atmosphere, from which tropospheric temperature and humidity profiles and the total cloud liquid water integrated along the viewing direction can be extracted. This information is complementary to the wind and cloud/aerosol profiles given by ceilometers and Doppler lidars. Some 30 MWRs are currently installed in Europe, and the number is increasing. Systems providing temperature, humidity and cloud information are available for less than 100 KEuro.

European companies are leading the world in the manufacture of modern ceilometers, Doppler lidars and microwave radiometers. This action will further develop and consolidate their economic position.

B.2 Current state of knowledge

The new generation of high-resolution models requires observations of winds, temperature, humidity, clouds and aerosols in the lower few km of the atmosphere. A brief review of the presently available sources of such data is presented followed by a discussion of how the new instruments will be exploited to improve weather forecasting in Europe.

A new technique, FSO (Forecast Sensitivity to Observations), Cardinali (2009), involves examining the adjoint matrix of the forecast model to estimate the precise impact of each observation on reducing the error in the forecast when compared to the subsequent analysis. Previously, such information could only be obtained by running costly data denial experiments. Now the impact of each observing system can be easily isolated.

A relatively small number of balloon-borne radiosonde ascents are made twice a day over Europe and provide profiles of winds, temperature and humidity, but coverage is sparse. Synoptic stations provide a rather denser network of the same variables but only at the surface. Over Europe a network of radar wind profilers provides continuous vertical profiles of the wind. Studies had concluded that the overall impact of the profilers on the forecast was neutral, but recently the FSO technique has demonstrated that individual profilers do have a positive impact. Those showing this benefit are the ones which are properly maintained with care being taken to ensure good data quality and are located at a strategic site. Winds can also be derived from the ground-based precipitation radar network, but these are restricted to areas where rain is actually falling. Winds extracted from cloud motion vectors obtained from sequential geostationary satellite images have a positive impact on the forecast when assimilated into the operational models. However, there can be errors of several km in assigning the correct height to the winds. The 'AMDAR' (http://www.eumetnet.eu/e-amdar) winds from instrumented commercial aircraft provide along path profiles of wind, temperature and humidity at airports over Europe. Infrared passive satellite soundings of temperature and humidity are very useful for the middle and upper troposphere, but there are difficulties in the lower few km of the atmosphere because of clouds, the poor vertical resolution of the weighting functions and the emissions from the surface.

The situation for profiling clouds and aerosols is even more complex than for winds, temperature and humidity. Passive satellites in the visible and infrared sense the cloud tops but give little information on cloud depth. The reflection of sunlight from aerosol in cloud free regions can, with some assumptions, be interpreted as an aerosol optical depth. Aerosol optical depth can also be derived from direct measurements with sun photometers at the ground; these observations are routinely available from 'AERONET' stations (http://aeronet.gsfc.nasa.gov) across Europe. These passive measurements provide optical depth but no information on the height distribution of the aerosols, and are limited to daytime and mostly cloud-free conditions. The active cloud radar and cloud lidar instruments on board CloudSat and Calipso satellites do measure backscatter profiles but only from a very narrow (<1km) swath with revisit times of several days; such data are invaluable for investigating process sudies, but are not sufficiently dense to impact the forecasts. The same limitations apply to the narrow swath lidar pointing 35degs off-nadir that will fly on the ADM satellite to be launched by ESA in 2015. It will supply line of sight winds but again with rather poor global sampling.

In today's harsh economic climate there is little prospect of large sums of money being available for spending on completely new observing systems. Therefore, this action will concentrate on exploiting existing instruments and facilitating the formation of networks to provide data in near real time. In particular the many hundreds of ceilometers currently installed over Europe are under-utilised. It will also coordinate the development of the new Doppler lidars, which are being installed across Europe and the existing microwave radiometers which currently operate independently. For a comparatively small expenditure this will make additional data available in near real time to the NMHSs to aid the prediction of hazardous weather and pollution episodes.

B.3 Reasons for the Action

At present, the data from ceilometers, Doppler wind lidars and microwave radiometers in Europe are scarcely used by forecasters. Many disparate groups are working in different countries, for example, each country has its own network of ceilometers usually run by the local NMHS, but the ceilometers do not report in real time and are not networked. Standardisation of the observations is also hindered because there are many different manufacturers of ceilometers and several models of Doppler lidars and microwave radiometers. The know-how with respect to operating procedures, maintenance, and calibration is dispersed amongst many different universities and weather services across Europe.

From an economic point of view, the action will benefit European companies manufacturing the three classes of instruments by further developing the capability of the instruments so the companies can improve their global competitiveness.

The major goal of this action is of a scientific/technical nature. It is to coordinate activities for the development of exploitation of these three new sources of observations across Europe so that reliable calibrated observations are produced and made available in near real time to NMHSs for use in weather forecasting and to the climate modelling community.

The benefits to society can be summarized as:
i) Flooding, hail and wind storms cause widespread damage to property in Europe. More accurate and specific forecasts of severe weather enable mitigating action to be taken to reduce such losses.
ii) Pollution episodes affecting the health of European citizens can be better predicted, so that appropriate action could be taken to reduce emissions, when such events are forecast.
iii) Better understanding, predicting and monitoring of the evolution of volcanic ash clouds so that interruption to air traffic can be minimised.
iv) Cost effective approach to improving weather forecasts by exploiting existing observation networks.

B.4 Complementarity with other research programmes

The FP7 'ACTRIS' action (Aerosol, Cloud and Trace Gases Infrastructure) is concerned with high performance lidars but specifically does not address ceilometers and microwave radiometers. The COST action ES0702, 'EG-CLIMET – Integrated Ground Based Observations of Essential Variables for Climate and Operational Meteorology' finishes at the end of 2012. It was concerned with many instruments and remote sensing techniques such as lidar, radar, and radiometers, and identified ceilometer, Doppler lidars and microwave radiometers as under-exploited sources of observations.

The FP7 MACC (Monitoring Atmospheric Composition and Climate) project operates and improves data-analysis and modelling systems for a range of atmospheric constituents including aerosols that are important for climate, air quality and surface solar radiation. Key scientists carrying out the implementation of MACC are involved in this proposal; the observations obtained with this action will be of use for evaluating the MACC model.

GRUAN: The GCOS Reference Upper Air Network (GRUAN) is an international reference observing network, designed to meet climate requirements and to fill a major void in the current global observing system. Upper air observations within the GRUAN network will provide long-term high-quality climate records. Many of the GRUAN stations have high quality cloud radar and cloud lidars for climate requirements, but the density of GRUAN sites is too low for use in data assimilation. The research carried out with this action will be useful to GRUAN for improved characterization of their instrumentation.

HyMeX (HYdrological cycle in the Mediterranean EXperiment) is a large-scale international field experiment devoted to a better understanding and quantification of the hydrological cycle in the Mediterranean, with emphasis on high-impact weather events. HyMeX encompasses a wide range of activities, from numerical modelling to observation and analysis, including several field campaigns. For the Special Observing Periods and Long Observing Period (10 years), the HyMeX programme strongly relies on data provided by existing observation networks (e.g. weather radars, synop). Though data from other sources (ceilometers, water vapor lidars, microwave radiometers) are desirable, no specific budget or activity is dedicated to the organization, harmonization, and coordination of establishing networks. This action should satisfy such requirements for future large field campaigns.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The aim of the action is to co-ordinate the operation of the many ceilometers, Doppler lidars and microwave radiometers installed across Europe, so that they can be networked and provide quality controlled and calibrated observations of winds, temperature, humidity, clouds and aerosols in the lowest few km of the atmosphere to NMHSs in near real time. The new generation of weather forecast models with resolutions of about 1km will benefit from such observations which should lead to improved forecasts of hazardous weather ranging from severe convective storms to pollution episodes.

C.2 Objectives

2.1 To implement a harmonized ceilometer network reporting quality-controlled calibrated attenuated backscatter profiles of aerosols and clouds in near real time across Europe.

2.2 To evaluate the backscatter profiles predicted by the prognostic aerosol schemes within the next generation of European forecast models for forecasting air quality as exemplified by the EU-FP7 MACC model at ECMWF.

2.3 To set up a system to monitor the spatial distribution, height and density of aerosol plumes (e.g. volcanic ash, mineral dust, biomass burning, or industrial accidents) over Europe, which are key information for air traffic safety, and to monitor the depth through which surface emitted species are mixed or trapped over Europe, a key factor for pollutant concentration predictions.

2.4 To establish the operational procedures for the new Doppler lidars by defining suitable scan strategies which combine zenith viewing operation to sense vertical wind structure and turbulence with azimuth scanning operation to provide accurate and representative high resolution profiles of horizontal winds.

2.5 To investigate the ability of the Doppler lidars to identify the various boundary layer states, such as, stable, unstable, coupled and decoupled, so that boundary layer classification and parameterization schemes implicit in NWP models can be evaluated.

2.6 To establish the operational procedures for the microwave radiometers by defining protocols for calibration procedures, scanning strategies, and maintenance.

2.7 To foster the utilization of disparate microwave radiometer observations by implementing a harmonized microwave radiometer data processing chain to provide quality-controlled calibrated multiple frequency radiances (for direct data assimilation into forecast models) and accurate profiles of temperature and humidity as well as cloud liquid water path in a near real time monitoring network.

2.8 To investigate optimized means of using downwelling radiance observed with the microwave radiometer network to derive profiles of temperature with highest accuracy in the boundary layer, lower resolution humidity profiles and the integrated water vapour and cloud liquid water path in the observed column.

2.9 To collaborate with researchers running NWP models in NMHSs to ensure that the quality controlled data from the remote sensing networks of ceilometers, Doppler lidars and microwave radiometers meets their requirements.

2.10 To discuss with climate modellers their precise requirements for long term data sets acquired by these ground based networks and their use in evaluating the parameterisation schemes in climate models run in forecast mode. If the climate models are based on sound physical principles rather than empirically tuned parameterization schemes, then there will be greater confidence in their ability to predict climate change.

C.3 How networking within the Action will yield the objectives?

Currently the ceilometers, Doppler lidars and microwave radiometers that are deployed across Europe are often operated in isolation. Instruments in a particular country may be the responsibility of a very small team or even a single person. To engender confidence in data exchange between different NMHSs, across Europe, data quality, calibration and retrieval algorithms must be agreed and be standardized. At the moment this coordination is lacking. This action will enable scientists working in isolation to attend meetings on a regular basis where they will interact with and learn from others working on the same or similar instruments. The data are required by the high resolution NWP models, but only a few of the larger countries within Europe have the resources to develop such models.

The proposal has the support of 15 of Europe's NMHSs, and the five major companies in Europe manufacturing ceilometers, Doppler lidars and microwave radiometers. Every six months there will be combined meetings lasting two or three days of the Management Committee and the Working Groups in the action; this will be the forum where the manufacturers, the NMHSs and scientists from research institutes can meet and exchange information, so that each group will be aware of the limitations and requirements of the other groups and modellers and instrumentalists can discuss their requirements together. The meetings will be particularly beneficial to representatives from smaller NMHSs who currently work in isolation. Representatives from EUCOS (see C5) will also attend these meetings; EUCOS is the European body responsible for developing the European observing system. The meetings will consist of a series of presentations at plenary sessions, and then intensive discussions within the specialised working groups. All presentations and documents from working groups will be posted on the 'TOPROF' web site.

A series of special working groups meetings, separate from the MC meetings, will be organised to focus on specific aspects of each instrument; these will be attended by manufacturers and researchers from individual institutes and NMHSs and will be held at sites where the instruments are deployed, so that 'hands-on' discussions of practical problems such as calibration and maintenance, and subtleties of coding up specific algorithms can be explored and improvements made.

Three training courses, one for each class of instruments, will be organised by this action so that young scientists and the users at the many separate NMHSs across Europe can efficiently learn of the latest advances made in the capability of the new instruments and how the measurements can be applied to aid weather forecasting.

By these methods the action will bring together experts in ceilometer, Doppler Lidar, and microwave radiometer profiling from industry, the research community and the operational NMHS community. This networking will ensure rapid transfer of expert methods and algorithms to operational networks for the benefit of larger user communities

C.4 Potential impact of the Action

High resolution numerical weather prediction has the potential to provide accurate warning of hazardous weather leading to flash floods and air pollution events. The major impact of the work of this action will be to provide high quality real time observations of the state of the lower atmosphere. The air motions in the boundary layer control the build-up, evolution, persistence and dispersal of noxious substances released at or close to the surface. These new high resolution observations can be used to improve the initial state of the model and so improve the timing, location and severity of hazardous events, and will enable specific mitigation actions to be efficiently targeted.

Until recently it has been difficult to quantify the impact of specific instruments in improving the weather forecasts when they are assimilated into the model. A new technique, FSO or 'Forecast Sensitivity to Observations' examines the adjoint matrix of the forecast model and is able to quantify the contribution of individual observations to reducing the error in the forecast. The results have been quite revealing. Whereas previously it was believed that the impact of the wind profilers was broadly neutral, the FSO technique shows that well maintained wind profilers have a positive impact in reducing forecast errors.   This finding reinforces the importance of ensuring good data quality and accurate calibration of instruments.

The specific scientific impacts will consist of:

i) Better observations of the levels of pollution over Europe and how such pollution evolves.

ii) A coordinated system for the observation of any future volcanic ash episodes.

iii) The evaluation of pollution transport models, which can also be used for predicting the transport of other hazardous materials.

iv) Evaluation of the performance of present models for predicting the levels of pollution, clouds, humidity, temperature and winds over Europe.

v) Identification of the shortcomings of such models and suggestions as to how such models could be improved.

vi) The direct real-time assimilation of the high resolution observations into forecasting models so they are more accurately initialised.

The specific economic impact will be the improved capability of European industry manufacturing these three types of instruments and the enhanced ability of European industry to compete in global markets.

C.5 Target groups/end users

The users of the information will be the NMHSs running the high resolution forecast models. Assimilation of the new data should improve forecasts of hazardous weather and provide more timely forecasts. Use of the data off-line to evaluate the skill of forecasts will provide information on biases and shortcomings in the parameterisation schemes used in the models to represent the small scale processes that can never be resolved. This would benefit models used to predict future global climate change which employ essentially the same parameterization schemes as are used in NWP. Member of all the major NWP centres in Europe are involved in this action.

EUMETNET provides a framework to enable the weather services to work together, share ideas, best practice, and to share the costs of major infrastructure investments. The EUMETNET Composite Observing System (EUCOS) is responsible for developing an observing system for Europe serving the needs of regional numerical weather prediction and, for example, is involved in coordinating wind profilers, weather radars, surface and ship observations. EUCOS have taken note of the potential of these new active ground based profiling instruments and as a result the wind profiler coordination project 'E-WINPROF' will be extended and renamed 'E-PROFILE', whereby its remit will be extended to include 'automatic lidar/ceilometer networks' together with radars. Representatives from EUCOS will be fully involved in this action.

It is important to note the complementary roles of EUCOS and TOPROF in implementing new observing systems. EUCOS is involved in in high-level coordination and setting up the hardware for data transfer, and does not have the resources to develop the required common calibration, maintenance, formats, and retrieval algorithms needed for the ceilometers and microwave radiometers to provide data of a quality needed by the national weather services. This development will be provided by this COST action. Indeed EUCOS is already (autumn 2012) setting up a contract with NMHSs to implement data transfer for ceilometers, with the expectation that TOPROF will provide the science support as detailed above. The 'Science Advisory Team' for EUCOS meets every April. For the past three years there has been a presentation informing them of progress in ground based profiling. In the new action this collaboration will be much closer with EUCOS involvement in the twice-yearly MC/WG TOPROF meetings.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The focus of the work is to ensure that networks of ceilometers, Doppler lidars and microwave radiometers provide high quality data which can be used for evaluating forecasting models and ultimately for incorporating in to such models so that the performance of the model in representing winds, temperature, humidity, winds, clouds and aerosols can be evaluated, and ultimately the data assimilated into the model so that it better represents the current state of the atmosphere and hence better initialisation of the model and improved forecasts.

More specifically the foci are:
- Harmonisation of the data quality of ceilometers and derived products.
- Define metrics for Doppler lidar observations and derived products.
- Harmonisation of the data quality of microwave radiometers and derived products.
- Evaluation of the model performance in representing the variables provided by the new instrument networks by comparing observations with the model state (so called O-B statistics).
- Ultimately, the provision of data which can be assimilated by the model to improve forecasts of hazardous weather.

D.2 Scientific work plan - methods and means

Below the work needed to establish the instruments networks is described and the methods for comparing the data from the networks with values held in the NWP models are discussed.

D 2.1 Ceilometers.
Quite a variety of ceilometers are deployed over Europe and it is important that the backscatter profiles are derived in a manner that is well documented. The aim would be to provide accurate attenuated backscatter profiles that can be compared with those predicted by the NWP forward model for the wavelength appropriate to the particular ceilometer. Instrument performance topics to be addressed include:
- Performance and sensitivity of the ceilometers during the day and night (for aerosol and cloud targets in particular).
- Short-term and long-term stabilities and drifts.
- Checking the operation of any automatic gain control system in the ceilometers.

- Characterisation and correction for beam overlap effects at low altitudes.
- Absolute calibration of the ceilometer backscatter based on different methods (molecular return, integrated backscatter on optically thick clouds, integrated extinction vs aerosol optical depth, effects of multiple scattering, …)
- Calibration of depolarization ratio for ceilometers that provide cross-polar profiles.
- Performance in rain.
- Added value in terms of model evaluation depending on wavelength (UV to Near-IR), single vs dual polarization, and availability of Raman scattering information.

D 2.2 Doppler lidars

Most lidars operate in the range 1.5 to 2um so molecular returns can be neglected. Multiple scattering effects are small because of the narrow beams. Instrument performance topics to be addressed include:

- Performance and sensitivity of the lidars during the day and night.
- Performance and sensitivity for accurate Doppler measurements.
- Performance and sensitivity of the cross-polar channel (when available).
- Beam overlap. Stability and correction procedures.
- Calibration via range integrated backscatter in water clouds which extinguish the signal .
- Definition of the optimum scan strategy by studying the trade of between long vertical dwells for vertical motions and off-zenith pointing for horizontal winds.
- Representativity of the horizontal winds during turbulent convective days.
- Cross comparison of winds derived with different Doppler lidars.
- Accuracy of inferred winds when compared to other independent methods.

D 2.3 Microwave radiometers.

A properly calibrated microwave radiometer measures brightness temperature with an absolute accuracy of ~0.3-0.5 K. Typical root-mean-square accuracy of the derived temperature is 0.5 - 2.0 K (decreasing from surface up to 5 km), 0.2 - 1.5 g/m3 for specific humidity, ~1.0 kg/m2 for integrated water vapour, and ~0.02 kg/m2 for cloud liquid water path. Initial tests have demonstrated that these quantities and/or the raw brightness temperatures can be assimilated into NWP models with a positive impact, but that this performances is often limited by poor calibration, improper maintenance, and loose quality control. Topics to be addressed include:

- Pursue the development of a sustainable network of European microwave radiometers.
- Establish protocols for providing accurate and quality-controlled microwave radiometer observations in near real time.
- Coordination of the data processing chain, including harmonized calibration control, measurement modes and observation procedures, data formats and the retrieval of atmospheric parameters.
- Definition of a trusted forward model for ground based radiometers based on the heritage of existing forward models currently used at NMHSs for satellite microwave radiometers. This will enable a direct assimilation of ground based microwave radiometer radiances into NWP models.

D 2.4 NWP models.

Regional Numerical Weather Prediction models are now run every hour with a resolution of 1km and about 70 vertical levels. In each grid box there are variables expressing the temperature, pressure, winds and mean humidity. Clouds are represented by two or three variables: the fraction of the box filled with cloud, and the ice and liquid water content of the cloud. Generally speaking, the cloud particle size and implicit concentration is prescribed in terms of the cloud water content and the temperature, although 'double moment' schemes where size is a prognostic variable may be implemented within the next few years. There is an implicit assumption of the vertical overlap of the clouds in partially filled boxes. Recently NWP models have begun to represent aerosols explicitly, with emission sources, advection by winds and convective motions, and removal processes by clouds and precipitation. For example the ECMWF 'MACC' model has various different species of aerosol such as black carbon, sulphates, with different size distributions to represent fine and coarse modes. Many of the small-scale processes such as glaciation and turbulence still have to be parameterised. Most models parameterize the air motions within the boundary layer (BL) dependent upon some form of boundary layer classification scheme, for example into stable, unstable, convection driven by surface heating or cloud cooling diagnosed from larger scale variables. As discussed in part B, there is a particular need for observations of winds, temperatures and humidity profiles (especially in the lowest few km of the atmosphere and in cloudy areas), together with 3D observations of clouds and aerosols. Moreover, there is an increased need for "Rapid Update Cycles" and "On Demand" simulations of specific weather situations and/or severe events for nowcasting and forecasting. For these cases, ground-based remote sensing systems (automatic systems with high temporal resolution) are of major interest. The main topics related to NWP model assimilation and verification are described below.

D 2.5 Evaluation of aerosol in NWP models.

As noted in Section B this is in its infancy. The approach is to compare the observed backscattered profiles with those predicted by the model at the appropriate wavelengths (e.g. 355nm, 532nm, 1064nm, 1.5um). Some evaluation has used the spaceborne lidar on board the Calipso satellite, but the sampling is very sparse and the sensitivity is low. Other evaluations have used the FP-5 EARLINET data base which is of very high quality, but again has low spatial representativity. In this action topics to be addressed will include:

- Comparison of the observed aerosol backscatter profile with the value computed from the model (O-B statistics). Initial comparisons are encouraging.
- Investigation of the observed spatial scale of aerosols compare with model value.
- Comparison of the observed shape of the vertical profiles with those in the models.
- Investigate the effect of humidity on the observed and modelled aerosol backscatter profiles.
- Investigate the ability of the depolarization ratio profiles to distinguish between different aerosol types.

D 2.6 Evaluation of clouds in NWP models with ceilometers and lidars.

The FP-5 Cloudnet project used data from advanced cloud radars and lidars at four locations in Europe to evaluate various NWP models by comparing mean profiles of fractional cloud cover, ice and liquid water content with mean values held in the models. The next step was to check if the models had the correct pdf of these variables, and then finally the skill score of getting the right cloud in the right place at the right time. This work will continue in the FP 7 ACTRIS project. The aim of the ceilometers would ultimately be for data assimilation so the first step would be:

- Establishment of 'O-B' statistics from the ceilometers network.
- Characterisation of the spatial structures of clouds within the model and the observations.

D 2.7 Evaluation of winds in NWP models with Doppler lidars.

- Investigation of the use of Doppler lidar to evaluate the BL classification schemes in NWP models.
- Investigations of the use of Doppler lidar for evaluating horizontal winds in NWP models.
- Evaluation of the impact of assimilating wind lidar profiles.
- Establishment of O-B statistics for observed and modelled horizontal winds.

D 2.8 Evaluation of temperature, humidity profiles and liquid water path from Microwave Radiometers

Temperature and humidity profiles retrieved from microwave radiometers have been extensively evaluated against simultaneous and nearly collocated radiosonde profiles for several sites around the world and demonstrated a positive impact. Recently, O-B statistics for 13 microwave radiometers, operating within the HyMeX West Mediterranean target area, have been computed for a one month period. Further investigation will focus on the improvements brought by ancillary data as additional constraints, such as satellite observations or NWP model analysis.

- Evaluate O-B statistics for temperature and humidity profiles for various sites in Europe.
- Evaluation of the impact of assimilating radiometric temperature and humidity profiles.
- Establish O-B statistics of liquid water path derived from microwave radiometers.
- Gather O-B statistics for directly sensed radiances, once the trusted forward model based on the heritage of satellite sensors is available.

E. ORGANISATION

E.1 Coordination and organisation

Co-ordination will be achieved by having Management Committee meetings combined with meetings of the working groups so that the full meeting lasts two or three days and takes place every six months.
Each year there will also be:
a) Four or five Special Working Group Meetings where a group of up to half-a-dozen participants from industry, research institutes and NMHSs can discuss in detail particular aspects of the instruments and data processing (see the long list in section D for each instrument) so that procedures can be harmonised, with industry making any modifications needed for the instruments, and the NMHSs arranging via EUCOS to set up the appropriate hardware needed for data protocol transfers or near real time exchange of information.
b) Four or five STSMs (Short term scientific missions) whereby a single scientist spends about one week in another institute so that more specific problems can be tackled, such as: instrumental calibration, comparison of the performance of different models of various instruments and their reliability, retrieval algorithm developments and evaluation.

The specific deliverables of the action will be:

i) Standardised techniques for calibrating, maintaining and operating ceilometers, Doppler lidars, microwave radiometers so that the products derived from them are quality controlled and accompanied by quantified errors.

ii) Standardised formats and data protocols, so that observations can be exchanged in near real time between the various NMHSs across Europe.

iii) Standardised retrieval algorithms for ceilometers, Doppler lidars and MWRs so that key atmospheric properties (clouds, humidity, temperature, aerosol, and winds) can be derived together with their errors.

iv) Forward models and metrics for model evaluation.

At each of the six-monthly MC/WG meetings the progress towards these deliverables will be reviewed, more specifically by:

i) Reports from NMHSs and research laboratories on progress on the deliverables.

ii) Reports from the working groups on progress.

iii) The written reports from recent Special Working Group Meetings

iv) The written reports from recent STSMs.

This will be followed by discussion of the MC on:

a) Future special working group meetings

b) Future short-term scientific missions

c) Progress in planning and execution of the three training schools for the three types of instrument.

The MC will then discuss the proposals and those that are approved will take place and the results presented at the subsequent MC meeting. It is at these MC meetings that the modellers from the National Weather Services together with those from EUCOS will be present to comment on the appropriateness of the data being supplied by the instruments.

WEB-SITE

An institute has been identified who will set-up and run the web-site in a timely and efficient fashion. They have considerable expertise in this work for COST actions. The full written reports from the special working groups meetings and STSMs will be promptly posted on a password protected section of the web site, as will be the minutes and documents presented at the six-monthly combined MC-WG meetings.

MONITORING

In addition to the standard procedure whereby a Rapporteur is appointed who attends the MC meetings and presents an assessment of the progress of the action each year to the Annual Progress Meetings (APC), two additional external scientists with a high reputation will be appointed to monitor the progress. They will have access to the web site and the reports and documents produced by the working groups, the special expert meetings, and the short term scientific missions. Their guidance, advice and judgement will be crucial to the success of the action.

Within one month after each combined MC/WG meeting (held every six months) a written report on the progress towards the deliverables and milestones will be sent to the rapporteur and two external assessors for their comment, criticism, feedback and advice.

The chair of the action will produce a written progress report each year and present it at the ESSEM Annual Progress Conference (APC). In this forum the achievements of the action are scrutinised in detail.

MILESTONES (refers to working groups - see E2; for timetable see section F)

Year 1

1. Establishment of Working Group leaders.

2. Definition of Year 1 SWGs and STSMs

3. Delivery of report on the current performance of the ceilometers, Doppler lidars, microwave radiometers, and their status in NWP (state of the art).

4. Organisation of meetings with manufacturers of the three instruments types to discuss potential modifications.

5. End of year one, review of STSMs, SWGs and progress of deliverables.

Year 2

6. Definition of Year 2 SWGs and STSMs

7. Delivery of final specifications on the calibration and operation procedures for each of the three instrument types.

8. Review of quality control and retrieval algorithms of the three instrument types

9. Initial specification of the data format for near real time exchange of data (BUFR) and long term storage for scientific purposes (NetCDF).

10. End of year two, review STSMs, SWGs and progress of deliverables.

Year 3

11. Definition of Year 3 SWGs and STSMs

12. Delivery of report of comparing instrument observations with values computed with NWP forward model.

13. Establishment of (O-B) statistics for the three classes of instruments.

14. Delivery of final specification of the data format for near real time exchange and long- term storage.

15. Organization of a two-day workshop on the basic principles of each instrument

16. End of year three, review of STSMs, SWGs and progress of deliverables

Year 4

17. Definition of Year 4 SWGs and STSMs

18. Delivery of final specification of the retrieval algorithms for the three instruments.

19. Organization of Training schools for operations and data handling for each of the three instruments.

20. Final meeting with NWP users on real time data handling and performance of the three instruments and their use for evaluation and assimilation into NWP models.

21. End of year four. Final science meeting.

E.2 Working Groups

There will be four working groups. These will meet every six months at the combined management committee/working group meetings. They will also benefit from four of five targeted STSMs each year, and four of five special working group meeting each year where experts will meet to tackle some particular topic as described in E1. A detailed list of the topics to be tackled by the working groups are to be found in section D2, and the milestones are listed at the end of E1.

The first three working groups deal with the three instruments: ceilometers, Doppler lidars and microwave radiometers. The organisation of these working groups is similar, so because of space limitations, below we describe a common organisation plan for each of the instruments. The fourth Working Group deals with the use the new data in NWP so the organisation for that group is dealt with separately.

E2.1 Ceilometers; E2.2 Doppler Lidars; E2.3 Microwave radiometers (with details of activities in D2.1, D2.1 and D2.3, respectively): These three groups will address the development of a sustainable network for each instrument and have a similar organisation:
Establish group leader (M1)
Report on the current performance (M3)
Meet with manufacturers to discuss performance and enhancements (M4)
Organise side-by-side comparisons of instruments.
Review STMSs and SWGs for year one and plan for year two. (M5)
Delivery of recommendations for calibration procedures (M7)
Recommend quality control and retrieval algorithms (M8)
Recommend initial data formats in collaboration with NMHSs (M9)
Meet with manufacturers to discuss implications.

Review STSMs and SWGs for year two and plan for year three (M10).
Deliver final specifications for data format. (M14)
Final specification of retrieval algorithms, calibrations, data quality and maintenance procedures.
Meet with manufacturers to discuss implications.
Organise workshop on the basic principles of each instrument - ESRs encouraged to attend.(M15)
Review STSMs and SWGs for year three and plan for the final year four (M16).
Delivery of specifications for operations and retrieval algorithms.(M18)
Run training school for each of the instruments (M19).
Report at final meeting (M21).

E 2.4 Use of the new data in NWP.

Examples of the topics to be addressed are given in D 2.5 for evaluation of the representation of aerosols in NWP, D 2.6 for clouds, D 2.7 for winds and the boundary layer, and D 2.8 for temperature and humidity profiles and liquid water path. The organisation will be as follows.

Establish group leader (M1)
Deliver report on the current use of the instruments in NWP (M3)
Discuss with NWP users their precise data requirements and the need for errors.
Review STMSs and SWGs for year one and plan for year two. (M5)
Recommend techniques for comparing observations (O) with model data (B)
Discuss precise form of data formats with NMHSs (joint with other WGs). (M9).
Review STSMs and SWGs for year two and plan for year three (M10).
Establish O-B statistics for the three classes of instruments (M13)
Review STSMs and SWGs for year three and plan for the final year four (M16).
Meeting with NWP users on use of data for evaluation and assimilation (M20)
Report at final meeting. (M21).

E.3 Liaison and interaction with other research programmes

EUCOS: as described in C5 members of EUCOS will attend the twice-yearly combined MC/WG meetings. This link is crucial: EUCOS, an organisation of the European NMHSs, is responsible for the development of an observing system for Europe. It is through this link that the activities and work of the Action will lead to the setting up of an operational European network for the delivery of the data from the ceilometers, Doppler lidars and Microwave radiometers in near real time to National Weather Services.

ACTRIS: Members of the Action are actively involved in the FP7 ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network). ACTRIS is a European Project aiming at integrating European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds, and short-lived gas-phase species. ACTRIS will have the essential role to support building of new knowledge as well as policy issues on climate change, air quality, and long-range transport of pollutants.

EUCLIPSE: The action will maintain contact with this FP7 project on 'European Union Cloud Intercomparison, Process Study and Evaluation' to make sure that the methods and datasets developed under the action are also well suited for evaluation of Global Climate Models and climate sensitivity studies over Europe. The datasets of temperature, humidity, wind, aerosol and cloud profiles that will result from this action will be of high importance for future Global Climate Model inter-comparison exercises.

HYMEX: The Euro-Mediterranean programme HyMeX encompasses a wide range of activities, from numerical modelling to observation and analysis, including short- and long-term field campaigns (SOP and LOP). Many scientists involved with ceilometer, lidar, and microwave radiometer remote sensing have contributed to the preparation of the HyMeX "Science Plan" and "Implementation Plan" documents. For the SOP and LOP, the HyMeX programme relies on data provided by existing and establishing observation networks. Natural interaction between HyMeX and TOPROF will happen within the HyMeX Observation Task Teams (TTO) and Modelling Task Teams (TTM), in particular the following ones:

TTO1 - Sounding of the atmosphere
TTO1e - Water Vapour and Temperature Lidars and Microwave Radiometers
TTO1g - Microphysics and aerosols
TTM4 - Data assimilation
TTM4a - Atmospheric data assimilation
TTM1 - High-resolution modelling platforms for intense events
TTM1c - Improvement of parametrizations for high-resolution models using dedicated SOP/EOP observations

ITARS: ITARS (Initial Training for Atmospheric Remote Sensing; www.itars.net) is an FP7 Marie Curie Initial Training Network for PhD students and Post Doctoral Researchers. ITARS brings together a group of universities, research organisations and high-tech companies from different disciplines (meteorology, geosciences, physics, electrical engineering, mathematics) with the aim to foster training and further development in the area of remote sensing of the atmosphere. The organisers of ITARS are involved in this proposal.

HD(CP)2: The research initiative High Definition Clouds and Precipitation for Climate Prediction HD(CP)2 funded by the German Federal Ministry of Education and Research deals with an improved representation of clouds in global models – one of the most pro-found and pressing issues in all of climate science. Specifically, three major points are (i) to develop the capacity to simulate climate processes using a next generation earth-system model at grid resolutions of hundreds of meters, over large areas such as northwest Europe; (ii) to integrate data from observational sites around northwest Europe for the evaluation of these simulations; (iii) to develop techniques for using the results from these simulations to develop state-of-the-art parameterizations for use in conventional climate models. The observational component of HD(CP)2 will greatly benefit from the instrument networks in TOPROF, specifically concerning data harmonization and the retrieval of the thermodynamic state of the atmosphere for model evaluation.

FUTUREVOLC: Members of the Action are actively involved in this recently started FP7 collaborative project. FUTUREVOLC is setting up an European volcanological supersite in Iceland for long-term monitoring experiment in geologically active regions of Europe prone to natural hazards. TOPROF and FUTUREVOLC activities may greatly benefit from each other, particularly in the large scale monitoring of ash dispersion in case of a volcanic eruption in Iceland affecting continental Europe.

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

GENDER BALANCE:
The University school of the lead institute in this proposal is one of the few in its country to have been awarded an 'Athena SWAN silver award' in 2012 for its good practise in support of women in the sciences; the award is being renewed in 2013. The award has resulted in a number of initiatives to support women:
- Early career workshops on career development, to talk about career development as well as highlighting flexible working arrangements.
- Active management of women's career progression: in the last 2 years the number of successful promotions of women has increased significantly. All promotions to Professor were for women (four in total) and four women were promoted without change of their job title.

All staff are asked to consider their career progression in their 'staff development review' – this is particularly important to Early Stage Researchers, 35% of whom are women. The school actively supports women by highlighting flexible working arrangements and its maternity leave policy.
Further details of the Athena SWAN awards can be found at http://www.athenaswan.org.uk/
These policies will be encouraged within the COST action, and will be the subject of discussion at each of the six monthly WC meetings.

TOPROF strives at attracting and encouraging female researchers towards a scientific career. This will be especially beneficial by linking to the Marie Curie Action ITARS. In fact, the success of ITARS, and vice versa the success of TOPROF is closely interrelated. Most awardees as well as the leading scientists working within ITARS (with 5 women out of 9 lead scientists, 4 female out of 11 PhD awardees) will be closely coupled to the activities of this proposal. In addition to the individual programmes at the participating institutions, TOPROF will arrange internal forums with senior female scientists during its meetings in order to network and foster an exchange of experiences.

COST rules allow for financial support to attend meetings for national MC representatives and a small number of invited experts. Currently six of the sixteen countries represented on our list of participants have women as candidates who have identified themselves for MC membership and for chairing the Working Groups.

EARLY STAGE RESEARCHERS

Recent experience with COST actions is that funding Early Stage Researchers to participate in meetings is more difficult, as they do not have the seniority to be nominated as national MC members nor as 'experts'. The solution to this dilemma will be:

a) Rotation of the six-monthly MC/WG meetings to different locations where they are hosted by different institutes active within the Action; this enables a larger number of younger researchers to attend with no need for financial support

b) Four of five special working group meetings will be organised each year targeting a particular problem; these are attended by about half a dozen scientists and half will be ESRs.

c) Four or five STSMs will be organised each year, whereby a young scientist can work in another institute for a week. Such activities are very successful in developing the careers of ESRs. Managers in National Weather Services feel they cannot spare senior staff for a week or more to undertake an STSM, so these activities are particularly appropriate for Earth Stage Researchers because in their case managers are more willing to agree to an absence of a week. The ESRs are also more likely to have hands-on experience of the detailed operation of the instruments and associated problems. The ESRs also usually reflect a better gender balance than more senior experienced researchers.

d) Corresponding to the three main instruments (Doppler lidar, ceilometer, microwave radiometer) this Action will organize three 2-day workshops on the basic principles and measurement potential of each instrument. Each workshop will be held together with a parallel MC meeting in order to guarantee the organization through the leading scientists of the action. These workshops will be announced throughout the European teaching and education institutions for remote sensing and will enable up to 10-15 ESRs to be educated in the scientific basics. The first half-day of each workshop day will be open to a broader public of high school students, through announcing a general introduction to the remote sensing method in local schools (outreach).

e) The organization of dedicated summer/winter schools for training in ground-based remote sensing of clouds and aerosols organized by the associated research initiatives (see E3) will be closely communicated with TOPROF. E.g., a training school for lidar remote sensing will be held by ITARS in the beginning of October 2013. TOPROF intends to support ESRs financially to be able to participate in these training schools. Vice versa, TOPROF networks will benefit from ESR participation in such training schools – talented PhD students and young Post Doctoral Researchers in remote sensing of the atmosphere will be able to quickly participate in this action.

f) A strong link with the E-PROFILE community dealing with operational survey of wind profilers and the setup of an European ceilometer network will be mandatory. This activity will substantially increase efficiency as well as participation of young scientists (the E-PROFILE responsible member as well as several other ones being young scientists) .

F. TIMETABLE

The milestones in section E1 define the timetable.

Year 1

1. Establishment of Working Group leaders.

2. Definition of Year 1 SWGs and STSMs

3. Delivery of report of the current performance of the ceilometers, Doppler lidars, microwave radiometers, and their status in NWP (state of the art).

4. Organisation of meetings with manufacturers of the three instruments types to discuss potential modifications.

5. End of year one, review of STSMs, SWGs and progress of deliverables.

Year 2

6. Definition of Year 2 SWGs and STSMs

7. Delivery of final specifications on the calibration and operation procedures for each of the three instrument types.

8. Review of quality control and retrieval algorithms of the three instrument types

9. Initial specification of the data format for near real time exchange of data (BUFR) and long term storage for scientific purposes (NetCDF).

10. End of year two, review STSMs, SWGs and progress of deliverables.

Year 3

11. Definition of Year 3 SWGs and STSMs

12. Delivery of report of comparing instrument observations with values computed with NWP forward model.

13. Establishment of (O-B) statistics for the three classes of instruments.

14. Delivery of final specification of the data format for near real time exchange and long- term storage.

15. Organization of a two-day workshop on the basic principles of each instrument

16. End of year three, review of STSMs, SWGs and progress of deliverables

Year 4

17. Definition of Year 4 SWGs and STSMs

18. Delivery of final specification of the retrieval algorithms for the three instruments.

19. Organization of Training schools for operations and data handling for each of the three instruments.

20. Final meeting with NWP users on real time data handling and performance of the three instruments and their use for evaluation and assimilation into NWP models.

21. End of year four. Final science meeting.

G. ECONOMIC DIMENSION

The following 16 COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Ireland, Italy, Netherlands, Norway, Portugal, Romania, Spain, Switzerland, United Kingdom. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 15 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

Experts from the following sixteen countries have indicated they will participate in the Action:
Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Ireland, Italy, Netherlands, Norway, Portugal, Romania, Spain, Switzerland, UK.

The list of experts who have indicated their wish to participate in the Action contains representatives from fifteen National Meteorological and Hydrological Services and ECMWF:

Austria, Belgium, Bulgaria, ECMWF, Finland, France, Germany, Hungary, Ireland, Netherlands, Norway, Portugal, Romania, Spain, Switzerland, UK.
When consideration is given to the value of the instruments which are involved in the action, the time spent by the experts responsible for the instruments and those working within NMHSs, the economic dimension of the activities to be carried out under the action has been estimated at 15 Million Euro for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

In Europe the NMHSs are responsible for running weather forecasts and climate models. Representatives from these organisations will participate in the Action and will be present at the two MC meetings to be held each year. We will also invite selected climate modellers from outside NSMHs who are not members of the Action to attend some of our combined MC/WG meetings.

Specific target audiences for the dissemination of the Action plan results will be:

- EUCOS project and other EUMETNET observation projects within NMHSs.
- Scientific groups developing remote sensing instrumentation for research application, boht in Europe, North America and Asia
- Instrument manufacturers
- Scientific groups developing numerical weather prediction models.
- Scientific groups developing data assimilation techniques.
- Scientific groups studying clouds and aerosols.
- WMO planning groups for GOS and GCOS.
- WMO groups associated with instrument development, standardisation and network deisng (CIMO).

H.2 What?

Important papers summarising the findings of the working groups will be posted on the publicly accessible part of the Action web site. These would include papers methods describe how to operate, calibrate the various instruments. Written reports defining the data format for exchange of information. Reports describing the details and performance of the retrieval algorithms.

H.3 How?

The major players from the NMHSs will be involved within the Action.

Results from the action will be presented at major international scientific conferences, such as the ISTP (International Symposium on Tropospheric Profiling), ERAD (European Conference on Radar in Meteorology and Hydrology), ILRC (International Lidar Research Conference), ISARS (International Symposium on the Advances in boundary layer Remote Sensing), Microrad (International Microwave specialist conference), all to be held during the time span of this action.

Each year the progress of the action will be reported to the EUCOS Science Advisory Team. Papers will be presented at the appropriate WMO CIMO workshops.

Part II - Additional Information (This part will not be element of the MoU)

Part II-A . LIST OF EXPERTS

Total number of participants 71

Gender balance: female 24 of 71 (33.80%)

COST Participants

AT - Austria

Mr Martin PIRINGER Zentralanstalt fur Meteorologie und Geodynamik [Potential MC Member] [WG Member] Expertise: ESSEM	

BE - Belgium

Dr Quentin LAFFINEUR Royal Meteorological Institute of Belgium Observations R&D [Proposal Participant] Expertise: ESSEM	

BG - Bulgaria

Prof Ekaterina BATCHVAROVA National Institute of Meteorology and Hydrology Meteorology [Potential MC Member] [WG Member] Expertise: ESSEM	

CH - Switzerland

Prof Niklaus KAMPFER Institute of Applied Physics Physics [Proposal Participant] [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Dominique RUFFIEUX MeteoSwiss Station Meteorologique, Payerne [Proposal Participant] [Potential MC Member] [WG Member] Expertise: ESSEM

DE - Germany

Dr Harald FLENTJE Deutscher Wetter Dienst Hohenpeissenberg [Proposal Participant] [WG Member] Expertise: ESSEM	Dr Ina MATIS Deutscher Wetter Dienst Hohenpeissenberg [Proposal Participant] [WG Member] Expertise: ESSEM
Dr Werner THOMAS Deutscher Wetter Dienst	

Hohenpeissenberg Observatory [Proposal Participant] [Potential MC Member] [WG Member] Expertise: ESSEM	Prof Rowland POTTHAST Deutscher Wetter Dienst Research and Development [Potential MC Member] [WG Member] Expertise: ESSEM
Dr Volker LEHMANN Deutscher Wetter Dienst Richard Assman Observatory [Proposal Participant] [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Bernhard POSPICHAL Institute of Meteorology, University of Leipzig [WG Member] Expertise: ESSEM
Dr Andreas BEHRENDT Institute of Physics and Meteorology, University of Hohenheim [WG Member] Expertise: ESSEM	Dr Thomas SCHWITALLA Institute of Physics and Meteorology, University of Hohenheim [WG Member] Expertise: ESSEM
Dr Steffen FREY Jenoptic Sensor systems business unit [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Holge WILLE Jenoptic Sensor systems business unit [WG Member] Expertise: ESSEM
Dr Patric SEIFERT Leibniz Institute for Tropospheric Reserach [WG Member] Expertise: ESSEM	Dr Matthias WIEGNER Meteorological institute, Ludwig Maximilians-Universitat Meteorological institute [Potential MC Member] [WG Member] Expertise: ESSEM
Dr Harald CZEKALA Radiometer Physics GmbH [WG Member] Expertise: ESSEM	Prof Jan CERMAK Ruhr Universitat Bochum, Faculty of Geosciences Faculty of Geosciences [WG Member] Expertise: ESSEM
Dr Sebastian KAUCZOK Selex Systems Integraton GmbH [WG Member] Expertise: ESSEM	Prof Susanne CREWELL University of Cologne Institute of Geophysics and Meteorology [Potential MC Member] [WG Member] Expertise: ESSEM
Dr Ulrich LOENHERT University of Cologne Institute of Geophysics and Meteorology [Proposal Participant] [Potential MC Member] [WG Member] Expertise: ESSEM	

ES - Spain

Ms Maria LOPEZ State Meteorological Agency of Spain (AEMET) [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Mercedes MARURI MACHADO University of Bilbao Escuela de Ingenieros de Bilbao [WG Member]

	Expertise: ESSEM
Dr Jesus FERNANDEZ-GALVEZ University of Granada Centro Andaluz de Medioambiente (CEAMA) [Potential MC Member] [WG Member] Expertise: ESSEM	

FI - Finland

Mr Erik GREGOW Finnish Meteorological Institute Remote Sensing [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Anne HURSIKKO Finnish Meteorological Institute Remote sensing [WG Member] Expertise: ESSEM
Dr Ewan O'CONNOR Finnish Meteorological Institute Remote Sensing [WG Member] Expertise: ESSEM	Dr Raisa LEHTINEN Vaisala [WG Member] Expertise: ESSEM
Mr Reijo ROININEN Vaisala Product Manager [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Christoph MüNKEL Vaisala Research [WG Member] Expertise: ESSEM

FR - France

Dr Martial HAEFFELIN Institut Pierre Simon Laplace, CNRS SIRTA [Proposal Participant] [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Ludovic THUBOIS Leosphere [WG Member] Expertise: ESSEM
Dr Laurent SAUVAGE Leosphere Leosphere [WG Member] Expertise: ESSEM	Mr Thomas BOURCY MeteoFrance [WG Member] Expertise: ESSEM
Dr Olivier BOUSQUET MeteoFrance [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Alain DABAS MeteoFrance [Potential MC Member] [WG Member] Expertise: ESSEM

HU - Hungary

Mr Peter NEMETH Hungarian Meteorological Service [Potential MC Member] [WG Member] Expertise: ESSEM	

IE - Ireland

Dr Saji VARGESE Irish Met Service Valentia Observatory [WG Member] Expertise: ESSEM	Prof Colin O'DOWD National University of Ireland, Galway Physics [Potential MC Member] [WG Member] Expertise: ESSEM
Dr Giovanni MARTUCCI National University of Ireland, Galway School of Physics [Proposal Participant] [WG Member] Expertise: ESSEM	

IT - Italy

Dr Gelsomina PAPPALARDO Istituto di Metodologie per l'Analisi Ambientale, CNR [WG Member] Expertise: ESSEM	Dr Vinia MATTIOLI University of Perugia DIEI [WG Member] Expertise: ESSEM
Prof Rossella FERRETTI CETEMPS, Univ of l'Aquila CETEMPS [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Emanuela PICHELLI CETEMPS, University of L'Aquila [WG Member] Expertise: ESSEM
Dr Luca DI LIBERTI CNR Institute of Atmospheric Sciences and Climate Atmospheric Sciences [WG Member] Expertise: ESSEM	Mr Gian Paolo GOBBI CNR Institute of Atmospheric Sciences and Climate Atmosphericc Sciences [Potential MC Member] [WG Member] Expertise: ESSEM
Dr Federico ANGELINI ENEA UTAPRAD-DM [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Domenico CIMINI IMAA-CNR IMAA [Proposal Participant] [Potential MC Member] [WG Member] Expertise: ESSEM
Dr Luca DI LIBERTO isac [WG Member] Expertise: ESSEM	Dr Stefania ARGENTINI ISAC-CNR ISAC [WG Member] Expertise: ESSEM
Dr Fabio MADONNA Istituto di Metodologie per l'Analisi Ambientale, CNR [WG Member] Expertise: ESSEM	Dr Giandomenico PACE Italian National Agency of the New Technologies Energy and Sustainable Economic Development [WG Member] Expertise: ESSEM
Prof Frank MARZANO Sapienza University of Rome DIET/CETEMPS	

[Potential MC Member] [WG Member] Expertise: ESSEM	

NL - Netherlands

Dr David DONOVAN KNMI [Potential MC Member] [WG Member] Expertise: ESSEM	

NO - Norway

Mr Harald SCHYBERG Norwegian Meteorological Institute [Potential MC Member] [WG Member] Expertise: ESSEM	

PT - Portugal

Mr Victor PRIOR Instituto Portuges do Mare e do Atmsophera Observatorio Meteorologica do Funchal [Potential MC Member] [WG Member] Expertise: ESSEM	

RO - Romania

Dr Florinella GEORGESCU Nation Meteorological Administration [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Doina NICOLAE National Institute of R&D for Optoelectronics [Potential MC Member] [WG Member] Expertise: ESSEM
Prof Sabina STEFAN University of Bucharest Faculty of Physics [WG Member] Expertise: ESSEM	

UK - United Kingdom

Dr Angela BENEDETTI ECMWF [WG Member] Expertise: ESSEM	Dr Phillipe LOPEZ ECMWF [WG Member] Expertise: ESSEM
Dr Vincent-Henri PEUCH ECMWF Research [WG Member] Expertise: ESSEM	Dr Guy PEARSON halo-photonics halo-photonics [WG Member] Expertise: ESSEM
Ms Susan BALLARD Met Office	

Met Office at Reading [Potential MC Member] [WG Member] Expertise: ESSEM	Dr Christina CHARLTON-PEREZ Met Office Met Office, Reading [WG Member] Expertise: ESSEM
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None

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None

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Part II-B. HISTORY OF THE PROPOSAL

This proposal is a resubmission of an earlier proposal to develop the three currently under-exploited new instruments (ceilometers, Microwave radiometers and Doppler lidars) so they can be efficiently networked to provide data in real–time which can be fully exploited by NMHSs and improve weather forecasts. The panel was of the opinion that the proposal provided excellent scientific justification for the work and involved key stakeholders, but that the proposal needed clearer deliverables, milestones, and plans for involvement of Early Stage Researchers and for gender balance. In this resubmission we explain more fully how this shall be achieved.

The resubmission has support from 15 NMHSs, rather than 11 previously. the new NMHSs are those of

Austria, Ireland, Portugal and Romania.

The participants to the proposal include representatives from six companies manufacturing the relevant remote sensing instruments: Jenoptic, Selex Systems Integration, RPG Radiometer Physics GmbH, Leosphere, Halo Photonics, and Vaisala.

This proposal has developed from COST ES0702 action entitled 'European Ground-based observations of essential variables for CLImate and operational METeorology' (EG-CLIMET) which in its MOU had as the main objective:

- The specification, development and demonstration of cost-effective ground-based integrated profiling systems suitable for future networks providing essential atmospheric observations for both climate and weather.

The secondary objectives were:

1. Complete development of individual remote-sensing systems of both observatory type reference observations and cheaper basic operational systems. Generate recommendations and specification for the compatibility, reliability and accuracy of these systems.
2. Develop test and report on classification and integration methods to derive better quality profiles of cloud, temperature, humidity and wind, expanding the range of atmospheric conditions considered to dare.
3. Develop methods to improve the understanding of the atmosphere at high resolution and improve its representativeness in Numerical Weather Prediction models.
4. Develop operational infrastructure necessary to communicate to the users measurements and products of integrated profiling systems taking into account network security issues.
5. Evaluate the effectiveness of different possible network designs for improving forecasting of significant weather and for studying the atmospheric processes important for climate studies
6. Develop data assimilation techniques suitable for exploiting high temporal resolution data from remote sensing systems. Coordinate the analysis of case studies to target known problems with modelling and forecasting of severe weather.

These objectives are very general and the EG-CLIMET MOU identified a large number of potential instruments to be evaluated for sensing cloud, temperature, humidity and wind. Work in the action has narrowed down the many potential instruments to just three and concluded that:

- There are five or six well instrumented 'reference sites' around Europe where expensive cloud radars and advanced lidars are deployed to make high quality observations of clouds temperature, humidity and winds.
- These sites are appropriate for evaluating NWP and climate models, but for improving predictions of severe weather with the new generation of high resolution forecast models the requirement is for a denser network of more economical instruments.
- In view of the financial constraints, any dense network must be comprised of many inexpensive instruments, which can operate unmanned and provide high quality data with minimum maintenance.
- The primary candidate instruments are the existing ceilometers, which have been used for measuring cloud base, but can in fact now provide accurately calibrated backscatter profiles from clouds and aerosols, and, if networked, provide these data in real time.
- The other two candidates are a) existing microwave radiometers providing low resolution temperature and

humidity profiles as well as cloud liquid water, but need coordination and harmonization within a network structure, and b) Doppler lidars that provide vertical and horizontal winds in the lowest few km of the atmosphere and which exploit a new technology especially suitable for a future European network.
The aim of TOPROF is to focus on these three under-exploited instrument systems, ceilometers, Doppler lidars and microwave radiometers, which are available throughout Europe.
Below is a brief review of some recent work on ceilometers, Doppler lidars and microwave radiometers, with an emphasis on contributions by those involved in the preparation of the proposal. A few of the most relevant recent publications are identified and can be found in Part II D.
Ceilometers:

The CloudNet project (Illingworth et al, 2007) demonstrated that ceilometers are reliable instruments that can be used to quantify the properties of liquid clouds for long-term comparisons of observations of clouds with their representation in forecast models. A simple technique for calibrating ceilometers using the returns from water clouds, which extinguish the lidar signal, is described by O'Connor et al. (2004). Morille et al. (2007) propose a portable method to retrieve and classify atmospheric layers (i.e. cloud and aerosol layers, the boundary layer) using single wavelength backscatter lidar or ceilometer. Barret et al (2009) used ceilometer and radar observations to evaluate forecasts of clouds within the boundary layer. Monitoring of the atmospheric boundary layer diurnal evolution using ceilometers and low power automatic lidars is a topic of active research (e.g. Haeffelin et al. 2012; Emeis et al. 2008; Münkel et al. 2007). Following the Iceland volcanic eruption of April 2010, several groups started investigating the possibility of monitoring long-range aerosol transport using networks of ceilometers (e.g. Flentje et al. 2010). Hence it has been demonstrated that the rather simple and widely available ceilometers are fitted to monitor several key atmospheric parameters, provided that their measurements are calibrated, analyzed and interpreted in a careful and consistent manner.

Doppler Lidar:

Recent work has demonstrated that Doppler lidars have the ability to continuously monitor the wind vector throughout the boundary layer, to estimate levels of turbulence and provide additional information on the cloud and aerosol particles. Hogan et al. (2009) showed how velocity variance and skewness from a Doppler lidar can be used to classify different boundary layers. Barlow et al. (2011) discuss the use of a Doppler lidar to study boundary layer dynamics over London. Dacre et al. (2010) report on the use of Doppler lidar to study the ash plume of the Icelandic volcano. The use of the Doppler lidar to estimate turbulent dissipation energy rates is to be found in O'Connor et al (2010). Westbrook et al (2008) describe how the properties of ice crystals falling from supercooled clouds can be inferred from Doppler lidar observations. Wesbrook and Illingworth (2009) use Doppler lidar to infer the size spectrum of ice crystals in clouds; this is an important parameter in forecast models.

Microwave Radiometers.

In the last decade, the operational performance of microwave radiometers for estimating cloud liquid path, temperature and humidity profiles have been demonstrated (Güldner and Spänkuch 2001, Löhnert and

Crewell, 2003; Crewell and Löhnert 2003; 2007; Cimini et al. 2006). Gaussiat et al (2007) showed how accurate liquid water path could be retrieved from low cost microwave radiometers using additional information from lidars. More recently the benefits of microwave radiometer measurements during dynamic weather conditions (Knupp et al., 2009) and in support of weather nowcasting and forecasting (Löhnert et al. 2007; 2008; Cimini et al., 2011) have been demonstrated. In the last couple of years, the focus has been moving towards the quality of microwave radiometer measurements and the retrieval uncertainties (Güldner et al., 2009; Löhnert and Maier, 2012) in the light of suitability for operational network application and also on the coordination of networks for the assimilation of microwave radiometer data into NWP models (Hardesty and Hoff Eds., 2012; Cimini et al. 2012).

General remarks on NWP.

The proposed observations are expected to have a positive impact on improving NWP models, especially concerning the so-far used crude parameterisation schemes for the boundary layer. Severe weather is often triggered by conditions within the boundary layer, so that a more precise representation would be very beneficial.
In the past, NWP clouds schemes have been improve based on ground-based remote sensing observations. A review of the work performed under the FP7 Cloudnet project can be found in Illingworth et al (2007). In this project the vertical profile of clouds observed at four sites in Europe with cloud radar, ceilometers and microwave radiometers was compared with the performance of seven operational forecast models within Europe. The project identified various shortcomings in the model representation of clouds, for example, mid-level clouds were under-represented in the model, and the models had difficulty in producing the correct probability distribution of fractional cloud cover within the grid box.

Lately, a new technique, the FSO (Forecast Sensitivity to Observations) by Cardinali (2009) has become available. This method estimates the precise impact of each observation assimilated into the NWP model through analysing the reduction forecast error. The technique has the potential to be very important in quantifying the impact of any new observations, which are assimilated into the NWP model and will be very valuable for estimating the impact of the proposed novel observations networks presented in this proposal.

Part II-C. PRELIMINARY WORK PROGRAMME

This is described in detail in section D and E

Part II-D. RECENT PUBLICATIONS

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Part II-E. FURTHER REMARKS