UFAM Strategy 2008

Alan Blyth and Jim Hopkins

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1 Introduction

Most major advances in atmospheric sciences have come from technological innovations that have enabled us to make new measurements of the atmosphere. This document is designed to look ahead to the future needs of UFAM so that there are state-of-the-art instruments capable of addressing the major issues in atmospheric science, particularly including those within NCAS Weather, Composition and Climate. It is most emphatically not a shopping list. It highlights key gaps in our current capabilities with a goal of setting priorities within UFAM and NCAS for pursuing the different avenues for funding, collaboration and partnerships.

UFAM is responsible for specialised instruments on the aircraft, ground-based instruments and the Instrument Scientists that maintain and operate those instruments.

UFAM Mission statement:

The Universities Facility for Atmospheric Measurement (UFAM) deploys observing facilities, analyses the data and develops instruments that our research community needs to make the observations that address important questions in atmospheric science.

UFAM has four major observational priorities:

- Enabling innovative field campaigns
- Maintaining field sites and long-term measurements
- Developing new instruments
- Calibration of instruments

UFAM also works up the raw data, analyses the data, and submits to shared databases, such as BADC.

UFAM has been very successful in enabling major collaborative field campaigns in the atmospheric sciences. The list of current UFAM instruments is given in Appendix A. However, it is evident that there are several key instruments and new developments needed to address the major scientific questions.

2 Challenges in Atmospheric Science

The grand challenges in atmospheric science for which UFAM needs to be particularly prepared are described below. These are major questions highlighted in the Weather, Composition and Climate directorates.

Aerosol-cloud interactions, including glaciation and thermodynamic effects. How do anthropogenic aerosols modify cloud properties on a local and global scale? Mixed phase clouds are complex. It is important to understand the influence of aerosols on supercooled raindrops, ice nuclei, riming, secondary ice production, entrainment and mixing, dynamics and thermodynamics. Recent results suggest that the accumulated precipitation decreases with increasing aerosol in continental clouds, while it increases in tropical marine clouds up to droplet concentrations of about 400 cm^{-3}, then decreases. Other results suggest that this is about the optimum value for the vigour of the deep convective tropical storms, such as Hector.

Key new instruments needed: Cloud radar on 146; Mobile and fixed continuously operating ground-based radars and lidars; Techniques and inlets for measuring the composition of ice nuclei; coarse mode aerosol on 146; improved inlet system and methods of sampling from it; Improved CVI on 146; single particle mass spectrometers or similar to measure ice nuclei and water drop residuals.

The Aerosol Indirect Effect. Aerosols serve as cloud condensation and ice nuclei, thereby modifying the microphysics, the radiative properties, and the lifetime of clouds. The aerosol indirect effect is usually split into two effects: the first indirect effect, whereby an increase in aerosols causes an increase in droplet concentration and a decrease in droplet size for fixed liquid water content and the second indirect effect, whereby the reduction in cloud droplet size affects the precipitation efficiency, tending to increase the liquid water content, the cloud lifetime and the cloud thickness. Experiments need to be carried out to determine if aerosol/chemical transport model (such as UKCA) predictions can be used to predict CCN concentrations and thereby use predictions of effects on cloud characteristics to generalize globally and so develop an estimate of the indirect effect of aerosols on the global radiation balance. Aerosol composition, number and size all control activation of particles into cloud droplets. All of these have a significant influence on the potential cloud droplet number but a solid theory to predict cloud droplet activation in mixed organic-inorganic particles is not yet available and needs to be tested. This needs to be performed through careful laboratory measurements, including chamber studies, coupled to field studies that cover the main aerosol composition types.

Key new instruments needed: aerosol hygroscopicity/volatility measurements.

The initiation and development of convective clouds and the quantity of precipitation produced. Flooding caused by heavy rain is a major international problem. Rain associated with deep convection is an important ingredient in the majority of high-impact events such as flash floods. The new generation of high-resolution numerical-weather-prediction models have shown some success in representing convective storms, but forecasts of the location and timing of such storms and the quantity of precipitation are often still poor, particularly over complex terrain. Some progress has been made recently due to the Convective Storm Initiation Project (CSIP) in the UK and the Convective Orographically-induced Precipitation Study (COPS) in Germany. The major questions to focus on now are the quantity of precipitation and the initiation and development of storms over complex terrain.

Key new instruments needed: Mobile and fixed continuously operating ground-based radars and lidars; Water-vapour lidar; Water-vapour lidar and Doppler lidar on FAAM 146; Improved wind measurements on 146

The initiation of ice and precipitation in clouds. More than 50% of the earth's precipitation originates in the ice phase. Ice nucleation, therefore, is one of the most basic processes that lead to precipitation. The poorly understood processes of ice initiation and secondary ice multiplication in clouds result in large uncertainties in the ability to model precipitation production and to predict climate changes. Therefore, progress in modeling precipitation accurately requires a better understanding of ice formation processes. UFAM needs to be ready to participate in key upcoming projects in the US Ice Initiative in the Carribean and in New Mexico, as well as international ice cloud chamber experiments.

Key new instruments needed: Precipitation and Cloud radars on the 146; Doppler lidar on 146; Improved wind measurements on 146; Ground-based radars and lidars; Phase particle discriminator (PPD); Ice nucleus counter; improved sampling inlets for ice crystal residuals; and new technologies for ice crystal residual measurements such as single particle mass spectrometry.

Extra-tropical storms. Climate change is leading to a rise in sea level, and the probability is that some hazards, such as severe storms, droughts and floods, are increasing as a consequence of more energy in the atmosphere and oceans. There is a need to improve the quality of forecasting of storm track and intensity by numerical weather predictions. This will involve understanding the core physical processes.

Key new instruments needed: Mobile and fixed continuously operating ground based radars and lidars; Cloud radar and precip radar (X-band) on the 146; Doppler aerosol and wv lidar on 146.

Boundary layer meteorology. There are many key questions in boundary-layer meteorology. Can we calculate mixing across the BL top under non-convective conditions? How do urban areas affect their own meteorology? Can we model the transport of heat, momentum and constituents between the local scale and the general urban boundary layer? How do cities impact on regional weather and climate? Can we model accurately how damaging winds result from air flow over hills/buildings? How well do we understand the properties of stratocumulus clouds, especially the effect of aerosol on such clouds?

Key new instruments needed: Mobile and fixed continuously operating ground based radars and lidars; Water-vapour lidar; AWSs; Tethersondes; Doppler aerosol and wv lidar on 146; Improved wind measurements on 146.

Flow in complex terrain.

Production and destruction of pollutants. What are the long-range effects of atmospheric breakdown of primary emissions -both anthropogenic and biogenic? What is the fate of key reservoir species such as oxygenates, nitrates etc? What do our long term datasets tell us about sources? - Shipping as a European NOx source, LRT influencing tropical methane loss? Can we provide explanation for decadal trends in surface O3? Addressing these questions requires complex sets of instrumentation and we have only limited datasets. There remain major measurement gaps, associated with speciation within chemicals groups, hydroperoxides, peroxy radicals etc.

Key new instruments needed: water-vapour lidar; Doppler lidars; Oxides of Nitrogen (NOy); Nitrous acid (HONO); Higher molecular weight PANs; Spectral radiometer; Tethersondes.

Sources and sinks of aerosols. The deliverables here are key measurements that i) enable air quality forecasting and prediction tools that can map gas and particulate phase pollutants from their source to their sinks to be assessed and tested and ii) to obtain new or improved information on key processes in those models. In developing this framework we will be able to test model prediction of the rising influence of mega cities, such as Mexico City, Beijing and LA; address regional deposition budgets that affect acidification and eutrophication and so influence water systems; determine regional effects on climate and assess air quality-climate interactions. There are key processes here that are currently not understood such as the generation of secondary organic aerosols, the role of the ammonium nitrate/nitric acid/ammonia system is distributing nitrogen on regional scales; the mixing state of aerosols and how that influences cloud activation and transport (for example black, dust); aerosol nucleation. To achieve these science goals ground and airborne measurements should be coupled. Long term ground based measurements need to be utilised that measure fundamental gas and particle properties. Remote sensing techniques need to be coupled to in situ methods to link scales and couple dynamics to composition. Laboratory and chamber experiments are necessary to resolve key problems, notably secondary organic aerosols, where there is a major gap between model prediction and measured abundance and there is a lack of knowledge of the way the SOA impacts on the optical and cloud forming potential of the particles. Urgent needs here include the ability to measure involvatile gas phase organic species and to be able to measure the volatility of the particulate and gaseous organic compounds. This capability is needed in the laboratory and the field. Sulphur is a key component of polluted aerosol, yet the main precursors SO2 and H2SO4 are not measured well by the community at present on either the ground or in the air. Measurements of ultrafine particle size distributions are needed to test model descriptions of new particle formation. At the present time these are available during ground based intensives but model testing requires long term ground based measurement and also aircraft instrumentation.

Key new instruments needed: Mobile and fixed continuously operating ground based radars and lidars; Water-vapour lidar; Lidars at multiple wavelengths; Tethersondes; Black carbon; Aerosol volatility, analysis of less and in-volatile organic compound in the gas phase; Improved SO2 measurement on the FAAM aircraft; long term and airborne measurements of aerosol size distribution, especially ultrafine aerosols.

Transport of aerosols and chemicals. The mechanisms that govern transport of chemicals out of the boundary layer and surface layer need to be determined. For example, do conveyor belts really lift BL air directly to the lower stratosphere? How do rapid changes in surface type (mountains, hills, coasts, cities) affect the transport and mixing of chemicals? Once in the free troposphere, aerosols and chemicals are transported and mixed via mesoscale meteorological systems (including gravity waves). These processes need to be examined. A major issue is how to quantify the limitations of trajectory analysis for identifying air mass origins.

Key new instruments needed: Mobile and fixed continuously operating ground based radars and lidars; Water-vapour lidar; Water-vapour and ozone lidar on FAAM 146; SO_2 *on FAAM 146; Tethersondes.*

Aerosol Direct effect and optical properties of aerosols. Aerosol particles both scatter and absorb radiation and hence have a significant effect on the Earth's radiation balance. Key aerosol types are dust, biomass burning aerosols and urban pollution aerosols. Dust predominately scatters radiation but both biomass burning and fossil fuel combustion contain black carbon and hence can partially absorb incoming radiation. At the present time the ratio of scattering to absorption is difficult to predict in models, largely because the optical properties of the particles is poorly known as is the extent to which mixing state influences behaviour. For example mixing biomass burning aerosols with dust particles may decrease the absorbing efficiency of the biomass burning particles if the dust particles efficiently scatter radiation back to space. However if the biomass burning particles are combined onto the dust then their absorbing efficiency will increase as they are in a more optically active size range.

It is difficult to assess both the scattering and absorption of aerosol with the required accuracy and sensitivity required to perform closure studies that link aerosol physics and chemistry to optical properties and further to obtain an accurate budget of radiation throughout the atmospheric column. Measurements of optical properties are necessary from the laboratory on well characterised test systems. New technologies for accurate measurement of refractive index, and scattering and absorption coefficients need to be developed and utilised. Long term remote sensing and in situ measurements from ground and airborne platforms are required.

Key new instruments needed: Wet-dry nephelometer; Single particle laser ablation system new methodologies for measurements of optical properties (scattering, absorption, extinction coefficients, refractive index) that include humidity effects, measurements of mixing state, in particular black carbon; robust measurements of aerosol size distribution, remote sensing of aerosol properties from the ground and aircraft; improved inlets for coarse mode particles and improved chemical characterisation of dust.

Air quality. How can we obtain better source attribution in cities? - primary/secondary/long range transport - What are the main secondary sources in the UK vs Europe? Do biogenic components play a major role? Can we explain current trends in PM? High density measurements for micro/mesoscale model validation – how can we achieve this? Does night-time oxidation chemistry reduce the burden of pollutants such as VOCs? What links to aerosol phase and what impacts on pollutant transport? UK summertime biogenic emissions – how important?

Key new instruments needed: PM10/25; high spectral resolution lidar; Doppler lidar; On FAAM 146: Water-vapour lidar; Oxides of Nitrogen (NOy); Nitrous acid (HONO); Higher molecular weight PANs; Spectral radiometer; Carbon dioxide, Methane; SO2.

Background maritime. Marine aerosol composition: can we explain the relative inorganic and organic composition? What role as vector for recycling and new particle formation? Ozone and methane destruction in the background atmosphere: do we have a complete description of the key processes?

Key new instruments needed: In-situ concentrations of a range of halogenated species, e.g. in-situ ClO and BrO, halogen nitrates; size distributed measurements of ultrafine particles and also SO2/H2SO4 measurements.

3 Enabling Field campaigns

There are four aspects to the strategy of enabling innovative field campaigns designed to address the key issues in atmospheric science: new instruments; large item replacements; regular maintenance and personnel. UFAM Instrument Scientists is considered in Section 7.

3.1 Priority new instruments

UFAM will prioritise effort in order to be prepared for field campaigns designed to address the above challenges. Priority will therefore be placed on the following instruments. Details of the instruments are given in Appendix A. Partnerships will be sought for several of these instruments.

- Mobile ground-based radar. Priority is one system, but two are needed eventually to allow wind fields to be produced via dual-Doppler analysis. Chilbolton, Reading group.
- Doppler Lidars (Halo Photonics) for network of sensors. Emphasis will therefore be placed on involving Guy Pearson in UFAM. Salford, Cardington, Reading, and FAAM 146.
- Ground-based mobile water vapour lidar. In partnership with University of Manchester. Purchase of system from Leosphere and modification to make Raman wv.
- Cloud radar (94 GHz similar to Wyoming Cloud Radar) on FAAM 146. Joint with MO. Need 1 IS at Cranfield.
- Additional tethersondes, new balloon and mooring system.
- Water vapour, ozone and aerosol lidar on the FAAM 146. Current pending system a priority. Rod Jones, Cambridge.
- Instruments to measure greenhouse gases: carbon dioxide, methane, and sulphur dioxide. Weybourne and Cape Verde.
- Oxides of nitrogen (NO_y).
- Higher molecular weight Peroxyacytyl nitrate (PAN) instruments.
- Spectral Radiometer.
- Particle Phase Discriminator (PPD), designed and built at the University of Hertforshire, for use as the detector on the Ice Nucleus counter as well as with the CVI on the aircraft. The PPD will allow the real time determination of the sizes, shapes, and concentrations of particles down to about 1 μm in size, at particle data rates up to about 9,000 particle per second. The instrument will assist atmospheric physics researchers in determining the growth and abundance of particles under varying conditions.

- SO_2 with inlet for FAAM 146.
- Bulk aerosol absorption Aethelometer operating at 7 wavelengths (370, 470, 520, 590, 660, 880 and 950 nm).
- Single SMPS system for ultrafine PSD measurements.
- Volatility addition to HTDMA.
- Speciated peroxy radicals.
- Condensation Particle Counters for ultrafine particles on the FAAM 146.
- Ultra-high sensitivity aerosol spectrometer (UHSAS) for FAAM 146.
- Newly developed fine particle size distribution for 146: 3–300 nm at 1 Hz.
- AIMMS probe for improved turbulence measurements on FAAM 146.

3.2 Large-item replacements (>10k)

In order to maintain the current observational capability within UFAM several of the instruments may need to be replaced in the coming years. Table 1 shows a list of large instruments and components, along with anticipated time-scales and the associated replacement costs, which may need to be replaced in the near future.

Item	**Ave time**	**Cost**
Aircraft FAGE laser	8-10 years	180
GB FAGE laser	8-10 years	150
FAGE Pump set x 2 (GB and a/c)	5-10 years	10
Fast Oscilloscope (FAGE)	10 years	10
FAGE Gating system/delay gnrtrs	10 years	10
GB FAGE Container	10-15 years	50
GB Calibration system	10 years	20
Ozone lidar laser	10 years	50
Aircraft lidar laser	1 years	50
94 GHz radar tube	2-3 years	100
Optical counters	3 years	10-20
DMAs	3 years	10
Perkin Elmer Gas chromatograph	3-5 yrs	20
Agilent Gas chromatograph	3-5 yrs	20
PAN Gas Chromatograph	5-10 yrs	30
Aerolaser CO instrument	5-10 yrs	40
Laser for EnFlo Doppler Anemometry	5-10 yrs	20
3V-CPI	2 yrs	80

Table 1: Large items that require more than £10k to be replaced, their average lifetime and the approximate cost of replacement.

Average cost per year for large-item replacement: £x.

4 Field sites and laboratory facilities

UFAM has Instrument Scientists at one laboratory facility (EnFlo) and five field sites (Aberystwyth (Capel Dewi), Cape Verde, Cardington, Chilbolton and Weybourne) that are also long-term monitoring sites. UFAM is committed to supporting the activities at these sites for the foreseeable future.

4.1 Aberystwyth

The Natural Environment Research Council (NERC) Mesosphere-Stratosphere-Troposphere (MST) Radar is situated at Capel Dewi near Aberystwyth, Wales. The radar is the most powerful and versatile wind-profiling instrument in the UK. The Facility additionally operates and hosts a number of instruments whose observations complement those made by the MST radar including: boundary layer (below 2 km) wind-profiles, (column) integrated water vapour measurements, surface measurements of meteorological parameters (i.e. wind-speed and direction, temperature, pressure, humidity, solar radiation and rain rate), cloud base altitudes and sky images.

4.2 Cape Verde

The Cape Verde Atmospheric Observatory – Humberto Duarte Fonseca (CVAO) is a ground-based platform for the long-term continuous monitoring of the atmospheric composition of the tropical marine boundary layer and investigation into air-sea interactions. UFAM provides funding for the trace gas measurements of O3, CO, NOx, VOC, halocarbons; and for the meteorological measurements of wind, temperature, relative humidity, and total radiation. Greenhouse gas measurements of CH4, CO2, N2O, and SF6 are made in situ by the Max Planck Institut fr Biogeochemie, in Germany and measurements of the physical and chemical characteristics of aerosol are provided by the Leibniz Institut fr Troposphrenforschung, in Germany. The site is scientifically coordinated by a UFAM scientist but managed locally by staff from the Instituto de Naional de Meteorologia and Geofisica (INMG), in Cape Verde. Additional technical support is also provided from the above named partner institutes.

The CVAO has some capability to accommodate instrumentation from other international groups who have their own funding and specific scientific questions, and at present this includes two filter samplers, a ceilometer, a spectral radiometer and a MAX-DOAS. It has also proven to be perfectly positioned to host process study campaigns such as RHaMBLe (Reactive Halogens in the Marine Boundary Layer Experiment) in 2007 and SOS (Seasonal Oxidant Study) in 2009; experiments which are particularly focussed in researching the highly oxidative nature of this region of the atmosphere.

Initial analysis, interpretation and dissemination of the obtained data are attended to by the respective responsible institutions and for the trace gases this is the responsibility of a UFAM instrument scientist. All of the data obtained from the site is routinely submitted and stored at the British Atmospheric Data Centre (BADC), available instantly for those with a relevant scientific interest and within 1 year to the general public. The main external interest in the datasets arises from global chemistry and climate modellers who use the data to validate their models for a previously data sparse but highly climatically-significant region of the atmosphere. The site is an integral part of the long-term monitoring Global Atmospheric Watch (GAW) network.

4.3 Cardington

The Met Office field site at Cardington in Bedfordshire maintains a suite of surface-based and mast-mounted instrumentation. The main purpose of this instrumentation site, which is logged 24 hours a day, is to provide data for boundary-layer atmospheric processes research, and for the testing and validation of numerical model output and performance. Data are stored at BADC. There is an open fetch in most directions, with the exception of to the north, where the presence of two large airship hangars have a major influence on the air flow.

There have been several joint Met-Office/NCAS projects at Cardington and many more are planned. It is crucial to understand boundary-layer processes in order to improve Numerical Weather Prediction models. Cardington is an important long-term measurement site for the physical properties of the boundary layer – air flow, turbulence, temperature, humidity, scattering properties of aerosols, visibility, radiation, and soil moisture and temperature. Furthermore it is an important testbed site where many instruments can be calibrated and tested. There is one part-time UFAM Instrument Scientist currently at Cardington. Another full-time UFAM Instrument Scientist position will begin in April 2009.

4.4 Chilbolton

The Chilbolton Facility for Atmospheric and Radio Research (CFARR) in Hampshire offers a unique set of active and passive instruments for measuring clouds and precipitation. It is home to the world's largest steerable meteorological radar: the 3 GHz Chilbolton Advanced Meteorological Radar (CAMRa) radar, which has full Doppler and dual-polarisation capability. The 25-metre dish allows a high sensitivity and a narrow beam. The Advanced Clear-air Radar for Observing the Boundary layer And Troposphere (ACROBAT) radar mounted on the same dish is used for studying boundary-layer clear-air features. The observatory also operates a large number of other radars, lidars, and radiometers, many of which operate round the clock. Chilbolton is a **long-term measurement site**. Data from many of the instruments are used for the continuous evaluation of profiles of cloud properties such as cloud fraction, ice water and liquid water content which are mapped on to the hourly grids of operational forecast models for the Chilbolton grid box. This is part of the Cloudnet project. The hourly output of several European forecasts is also archived. cloud profiles in seven operational models as Chilbolton is also an Aeronet (AErosol RObotic NETwork) site for long-term monitoring of aerosols.

CFARR is owned by the Science and Technology Facilities Council (STFC) and operated by the Radio Communications Research Unit, a division of the Space Science and Technology Department at the STFC-Rutherford Appleton Laboratory. CFARR receives infrastructure funding from the NERC Services Review Group (SRG) There is a Service Level Agreement between NERC and STFC which includes a financial commitment from NCAS. Extra support for the repair and maintenance of two JIF-funded radars and several lidars comes from UFAM. A UFAM Instrument Scientist works with the Chilbolton radar data.

4.5 Weybourne

The Weybourne Atmospheric Observatory (WAO) is a well-established research site positioned at Weybourne on the North Norfolk coast. The site operates 24 hours a day, 7 days a week monitoring a variety of trace gases (including O3, NO, NO2, NOy, CO, SO2, CCN, PAN, H2, CO2 and oxygenated volatile organic compounds) along with meteorological parameters (wind direction, wind speed, relative humidity, temperature, pressure, irradiance and net Irradiance). A recent acquisition of a Metek, sodar/Rass and ground based sonic anemometer system allows for the measurement of the meteorological parameters in the air column above the station (Air speed, direction and temperature).

Instruments at the site are supported by NERC, UFAM and NCAS composition as part of a long-term measurement initiative that feeds data to the BADC national facility. The site also feeds data into the UK Ozone network and the European Hydrogen network as well as the CarboOcean and TOMPs projects.

The observatory has hosted three major measurement campaigns in recent times (Inspectro (EU), TORCH I and TORCH II (NERC)) and has also taken part in more opportunistic experiments based at WAO involving collaboration with the British Antarctic Survey (BAS), the National Physics Laboratory (NPL), the Met Office, Cardington and a variety of University research groups.

4.6 EnFlo

EnFlo, the Environmental Flow Research Centre, was established in 1993 as a focus for UK research activities based on laboratory scale simulation of atmospheric flow and pollutant dispersion. The wind tunnel has a 20 m long working section, 3.5x1.5 m in cross section, and is stratified by differential heating of the incoming air, together with heating and cooling of the tunnel walls. It is an ideal tunnel for performing research in boundary-layer meteorology. For example the wind field can be measured at many points in space and time in a scaled model of a city street as in DAPPLE (Dispersion of Air Pollution and Penetration into the Local Environment). The project involved combined fieldwork, wind tunnel and computational simulations in order to provide a better understanding of the physical processes affecting street and neighbourhood scale flows of air, traffic and people, and their corresponding interactions with the dispersion of pollutants. A UFAM Instrument Scientist helps to maintain EnFlo and perform the experiments.

4.7 New instruments required for long-term measurements and laboratory facility

1. Now
2. 1-3 yrs
   - CO_2 and methane
   - Refinement of present 24/7 CO_2 flux measurements at Chilbolton.
   - Further development of moisture and sensible heat fluxes at Chilbolton using the extensive range of scintillometers and sonic anemometers currently deployed.
   - GRIMM 1.109 aerosol spectrometer at Weybourne and two other sites for UKCA database assimilation.
3. 3-5 yrs
   - Key climate instruments:
     - Number size distributions by optical scattering,
     - Multiwavelength nephelometer and absorption photometers to derive single scattering albedo
     - CCN spectrometers – at 3 sites: Weybourne (European background pollution site); Cape Verde (tropical marine with some long range transport and dust/biomass burning influences); a mountain ridge site close to Mexico City (Mega city/lower sub tropical free troposphere; regional Mexico). This activity should be developed on a 3-5 year time horizon. Planning should begin now and if opportunities exist then the horizon shortened.
   - PTR and CO at Weybourne.

5 Instrument/technology development

UFAM scientists are involved in a considerable number of development projects. UFAM will seek more resources for development projects, in particular in response to the NERC Technology Theme Action Plans. Items in this section will be continually reviewed and updated.

5.1 On-going development projects

- Tethersonde. Stephen Mobbs and Matt Hobby.
- Lab on a chip. Alistair Lewis.
- Fast-ozone sensor. Jim McQuaid.
- New species detection by FAGE: Peroxy radicals, Nitric oxide, Nitrogen dioxide. Dwayne Heard.

- Characterise gas chromatograph systems for measuring monoterpenes. Jim Hopkins.
- Characterisation of the new 2DS cloud particle instrument. James Dorsey?
- Work with Aerodyne to combine the AMS with an SP2 laser so that the heater in the AMS is replaced by an incandescence laser. Essentially, the aim is to flash heat carbon containing particles, measure the mass of their coatings with the AMS and then incandescence the core soot and measure its mass also.

5.2 New developments

- Upgrade the ground-based Leosphere aerosol lidar to a Raman water vapour lidar.
- Modify the current ground-based ozone lidar to Raman water vapour.
- Aircraft OH reactivity instrument.
- Dvelopment of instruments for measuring scattering and absorption coefficients of aerosols as a function of humidity with improved accuracy and precision.
- Single particle laser ablation time of flight particle analyser. Currently there is no reliable method of determining non volatile dust composition on the 146 other than collection and post analysis of filters which can be problematic and time consuming. Suggest collaborative project with NOAA/NCAR to develop the next generation of this instrument for airborne use - this would e timely as I believe such a programme is already underway in the US? Hugh Coe to coordinate.
- Multiple wavelength lidar.
- Nitrous acid (HONO).
- Speciation of oxides of nitrogen (NOy)

  NO_y speciation is of key importance to the atmospheric composition community and as such there is significant activity underway in the university community to expand and improve observations of this important group of compounds. NCAS is directly involved in some of this activity through FAAM and NCAS composition. Currently UFAM is not directly involved, but is well aware of the interest in this field and will aim to be involved in the near future either through operation of these instruments, once they have been proven in the field, or through coordination of instrument intercomparison exercises and calibration. For example, the instrument which is used for the calibration of the PAN GC system aboard the FAAM aircraft could be used to test and calibrate many of these techniques.
- In-cloud temperature probe
- Aircraft water vapour instrument for both in and out of cloud.
- Doppler scanning radar on a/c. Needs development with international partners. The NCAR/NCAS memo of understanding will be very helpful to facilitate a joint development project. This is a long-term project. During the past several decades, a new generation of scanning phased array radars with no moving parts (rotating antennas) has been developed. It may be possible to utilise this technology for an airborne precipitation radar.
- Networks of sensors:

  The new 1.5 km resolution Met Office model needs a dense ground-based observational network to constrain the initial state of the model and thus improve the 0-12hr forecasts of hazardous weather. Real time data from a trial network (say) 30 km by 30 km of (a) in-situ low cost temperature, humidity and wind sensors and (b) active remote sensing of profiles of winds, and humidity using e.g./ compact lidars, and GPS receivers, would be assimilated into the operational forecast to quantify the impact and optimise the network design.

- Peroxy radicals: development of next generation CIMS to give HO2/RO2 ratios.
- As yet unknown method for determiing single peroxy radical species, e.g. CH3O2, C2H5O2. Perhaps using cavity enhanced methods. These have the potential to be small and compact. Several groups use these and are developing them for atmospheric measurements.

6 Calibration facilities/testbeds

There are numerous examples, within the UK atmospheric community, of multiple instruments being used to measure the same atmospheric parameters. One example is mixing ratios of volatile organic compounds being measured by gas chromatography and proton transfer reaction mass spectrometry (PTR-MS). The need for detailed intercomparison of the different techniques and methods in order to make comparisons between measurements in different environments is clear. There is also a need to calibrate instruments in special facilities, such as cloud and aerosol probes in the Latham Laboratories in Manchester and the HIRAC chamber and Leeds which offers the opportunity for calibrations under atmospheric conditions (can change T, humidity, pressure, O3, NOx etc.), and also provide opportunity for intercomparison. Intercomparison exercises are often planned before large field experiments, but time constraints often result in this important activity being overlooked. UFAM is ideally placed to coordinate intercomparison exercises. Its long-term funding of the Instrument Scientists allows for intercomparison exercises to occur between large field campaigns. Many of the current UFAM instrument scientists are directly involved in the measurements of such parameters. UFAM will be place more importance on this activity. Table 2 shows the planned calibration activity and the Instrument Scientists that will coordinate it.

A new Instrument Scientist is proposed for Manchester to help with calibration of the UFAM aerosol and cloud probes. The Instrument Scientist will also be expected to coordinate international effort in this area, particularly with NCAR. The special partnership with NCAR will be used to facilitate this joint activity. The Instrument Scientist will also work with FAAM and the Met Office in order to coordinate the best use and calibration of cloud and aerosol instruments.

6.1 New calibration facilities required

- Ozone calibrator
- PAN calibrator
- OVOC calibration
- Dust dispenser for Manchester Ice and Cloud Chamber
- Particle Phase Discriminator for use in Manchester Ice and Cloud Chamber
- A Combustion Aerosol STandard (CAST) soot generator for use in aerosol and cloud chambers.

7 Management of UFAM

7.1 Changes to existing programme

The existing programmes are: Cambridge (Lidar on FAAM 146 aircraft); UEA (Chemistry instruments at Weybourne); Leeds Chem (ground-based FAGE and FAGE on FAAM 146 aircraft); Leeds Env (Sodars,

Measurement	Techniques	Institute	Coordinator
Mixing ratios of volatile organic compounds	Gas chromatography with flame ionization detectors (DC-GC-FID)	York-UFAM	Jim Hopkins
	Proton transfer reaction mass spectrometry (PTR-MS) UEA, CEH		
	Comprehensive two-dimensional gas chromatography with flame ionization detectors (2D-GC-FID)	York	
	Proton transfer reaction time of flight mass spectrometry (PTR-TOF-MS)	Leicester, York	
Mixing ratios of peroxy acetyl nitrate (PAN)	Gas chromatography with electron capture detectors NOy instruments	York-UFAM, UEA UEA	Jim Hopkins
Mixing ratios of ozone	UV absorption	Many institutions	Ruth Purvis
Mixing ratios of carbon monoxide		York-UFAM, FAAM, WAO, CEH	Ruth Purvis
Mixing ratios of peroxy radicals	Laser induced fluorescence	York-UFAM	Lisa Whalley
	Peroxy radical chemical amplifier (PERCA)	Leicester	
	Cavity enhanced absorption spectrometer (CEAS)	Leicester	
Cloud droplet size distribution	FFSSP, CDP	Manchester	New IS
Ice crystal size distribution	SID II, CPI, 2D-S, etc	Manchester	New IS
Wind speed and direction and turbulence	Doppler lidars, sonics, tethersondes	Cardington	Cardington IS
Water vapour	Lidar, in-situ instruments on 146, tethersondes, GPS	Cardington	?
Ozone	Lidar, tethersondes, sondes	Cardington	?

Table 2: Summary of intercomparison exercises coordinated by current UFAM instrument scientists.

tethersonde); Manchester (lidar, wind profiler); Manchester (cloud physics and aerosol); Reading (radars and lidars at Chilbolton); Salford (Doppler lidars; radiometer); York (GCs); Cape Verde (Long term chemistry measurements)

There are currently no plans to change existing programmes. UFAM is the focus of attention at the NCAS Advisory Committee meeting in July 2009 and a detailed report will be prepared for that meeting.

Weybourne recently underwent a thorough review by an external committee. Significant enhancements of the programme occurred as a result of the review: a Weybourne Users Group was set up; long-term measurements, making use of Weybourne facilities was highlighted in the NCAS science plans; Bill Sturgess took over to lead the programme.

7.2 Structure of UFAM

UFAM has successfully achieved its objectives of providing observational facilities and expertise in atmospheric science. The structure is sufficiently flexible to allow UFAM to meet the challenges in atmospheric science (section 2) which may require a shift in focus (i.e. redeployment of funds or personnel to a particular area of atmospheric science) or, more likely, for expansion into new areas with new equipment.

UFAM Instrument Scientists are involved in many different activities and projects. The core of their work lies in maintenance of instruments and in the provision of observational data during field campaigns or long-term measurements at observatories. These activities are considered to be National Capability and can be thought of as continuous. The instrument scientists are also involved in many other activities including; working with other instruments (not directly funded through UFAM); developing new instruments; and writing proposals. This work should continue (and increase) in the future and form an important part of the instrument scientists' career development by helping to broaden the range of skills and experience gained. Where this additional work load begins to form a major portion of the instrument scientist's time, costs for such activities should be recouped from each project or activity. This can be considered as "fixed term" whereby a piece of work with a finite goal is performed.

Where significant fixed-term activity is covered by the UFAM Instrument Scientist, it may be necessary to employ post-docs or technicians to cover their core duties for which they would take an overseeing role. Once the fixed-term work has been completed, the instrument scientist could return to their former role, thus maintaining continuity in personnel and experience. The fixed-term portion of an instrument scientist's work will inevitably change over time and could be large in one year and not exist in another.

7.3 New programmes

7.3.1 Description of work

UFAM will develop three new areas.

- Cloud Physics Instrument Scientist at Manchester: An Instrument Scientist is needed to help with calibration of the UFAM aerosol and cloud probes, to coordinate international effort in this area, particularly with NCAR, and to work with FAAM and the Met Office in order to coordinate the best use and calibration of cloud and aerosol instruments. There are several new state-of-the-art cloud physics instruments: 2DS, CAPS,...

- A new position will be created at Cardington as part of the joint agreement with the Met Office. The position should be a mix of support to the scientists (similar to existing staff at MRU), and instrument research and development (similar to existing UFAM staff). The day to day tasks would involve instrument maintenance, calibration, quality control and archiving. They would also participate in field campaigns by maintaining and running instruments. This is an area where Cardington is currently challenged. It is essential that instruments are well maintained, calibrated and run properly during field campaigns to ensure good quality data. There are currently a multitude of projects that require instrument development, including development of equipment to go on tethered balloons (e.g.

radiometer, aerosol devices) and development of surface-based instruments. The person would also help coordinate instrument intercomparisons etc. It is proposed that they would be part of UFAM and participate in UFAM meetings and correspondence.

- Cranfield at FAAM: Two dedicated Instrument Scientists are required to operate the cloud radar on the FAAM 146 aircraft. UFAM will provide 1 position and the Met Office will provide the other.

7.3.2 Annual cost

The Cardington position is already in the budget. Funds will have to be found for the other two positions. The annual cost will be approximately £70k each for the cloud radar and aerosol and cloud calibration positions, giving a total of £140k per annum.

8 Education and Outreach

- UFAM will lead the annual Atmospheric Measurement summer school currently held in Arran.
- UFAM will work with university outreach organisations such as SciFun at the University of Edinburgh that perform demonstrations in schools.
- UFAM Instrument Scientists and PIs will continue to give talks in schools on instrumentation and atmospheric science.
- UFAM will promote at least 1 PhD project per year in order to train new instrument scientists. Candidate projects include:
  - Design and build the OVOC calibrator
  - Development of an aerosol cavity ringdown instrument for field use
  - Developing new approaches for analyzing high-resolution aerosol mass spectrometry data
  - Characterisation of aerosol and cloud inlets
  - Development and evaluation of in-cloud temperature probe
  - Secondary organic aerosol formation.

9 Strategy for Funding

Several avenues will be followed for funding UFAM.

- New instruments will continue to be requested in consortium and standard grants if they are key to a particular project.
- Development projects will respond to Calls from the NERC Technology Theme. In addition, UFAM will continue to assist in driving the technology theme agenda.
- Maintenance from NC funds
- Joint ventures with the Met Office
- ?

10 Appendix A: Current instruments in UFAM

University/IS	Instrument/Facility	Measurement
Cambridge Vitchko Tsanev	Airborne Lidar	Vertical profiles of O_3, H_2O and aerosol
	Airborne Tunable Diode Laser Absorption Spectrometer (TDLAS)	Methane and CO_2
East Anglia Brian Bandy	Atmos Chem Instruments used in mobile lab, on FAAM, and at Weybourne Atmos Observatory	NO/NO_2 with ANNOx, Teco 42C Quasi NOy, PAN, O_3, CO, CN, SO_2, Peroxide, Formaldehyde
Leeds Chem Lisa Whalley (GB) Trevor Ingham (a/c)	Ground-based and airborne Fluorescence Assay by Gas Expansion (FAGE)	OH, HO_2 and IO; OH lifetime (separate with GB laser); Supporting measurements of $j(O^1D)$ (2-π Filter Radiometer), O_3, H_2O vapour and NO
Leeds Env	3 mini-sodars	Vertical profile of BL winds; top of BL
	Tethersonde system	Vertical profile of tempr, dew pt, 3D winds, pres, aerosol size distribution
	Radiosonde station	Profile of tempr, dew pt, wind speed and dirn
Manchester (*in-situ*) James Dorsey (cloud physics) Paul Williams (aerosols)	Brewer Spectrophotometer	spectrally resolved UV in the range of 295-365 nm
	Scanning Mobility Particle Sizer	concentrations and size of aerosol particles
	Differential Mobility Particle Sizer	Aerosol Size Distribution 3-800nm
	GRIMM OPC's	Aerosol Size Distribution 0.13 - 20 um
	Condensation Particle Counter	Total Aerosol Number (3-1000 nm)
	2B Ozone Analyser	Ozone Concentration 0-500ppbv
	G-B and 146 Aerosol Mass Spectrometer	average mass distribution as a function of size for particular components
	G-B Hygroscopic Tandem DMA	size resolved aerosol hygroscopic properties
	G-B and 146 Droplet Analyser	cloud droplet diameter in (0.5 - 200 μm)
	G-B and 146 Cloud Particle Imager	images, size and concentration of particles (15-2500 μm)
	Low Turbulence Inlet (LTI)	Characterised aerosol inlet for sub and super-micron particles
	Ice Nucleus Counter	Total number of ice nuclei
	Condensation Particle Counters	Total Aerosol Number 3-1000nm or 10-1000nm (3010)
	TSI Aerosol Electrometer	Total net change on aerosol particles from 2-5000 nm
	Topaz Aerosol Generator	Broad Distribution Aerosol Generator
	TSI Electrospray Generator Generator	Nanometer Size Aerosol Generator
	Cessna aircraft instruments	BL winds, T and dew pt, aerosols, ozone
Manchester (remote) Emily Norton	1290 MHz Wind profiler	Three components of wind u, v and w. Precipitation and boundary layer evolution
	Ozone lidar	Vertical distribution of ozone and aerosols
	Radiosonde station	Profile of T, dew pt, ws, wd

University	Instrument/Facility	Measurement
Reading John Nicol	1275 MHz Doppler radar on Chilbolton dish	Clear-air features and small cumulus
	35 GHz radar	Microphysics and dynamics of clouds
	94 GHz radar	With 35 GHz: Profiles of liquid water content, and ice particle sizes
	Vaisala 905nm ceilometer	Identification of liquid clouds, aerosols, boundary layer depth
	355 nm Raman lidar	Humidity profiles, cloud and aerosol extinction
	HALO 1.5 μm Doppler lidar	Profiles of v wind, skwnss and diss rate, aerosol bksctr
	355 nm EZ polarisation lidar	Liquid/ice discrimination, cloud ar aerosol optical depth, particles shape. With cloud radars: ice water content and ice particle size.
	Sonic anemometer and CO2/H20 probe	Sensible, latent heat and CO2 fluxes
	Radiosonde system	Profile of T, dew pt, ws, wd
Salford Fay Davies	Doppler lidar	Radial velocities in BL
	Radiometer	Vertical profiles of humidity and temperature
	Sonics + AWS	T, RH, p, ws and wd
Surrey Paul Hayden	EnFlo wind tunnel and towing tank	Wind velocities, concentration of tracers
York Jim Hopkins	Gas Chromatographs	Atmosphere volatile organic compounds (VOCs)
	PAN instrument	Peroxyl-Acetyl-Nitrate
	Whole Air Sampling (WAS) system	air samples from the 146
	Aerolaser CO instrument	Measurement of CO
	NCAS Composition NO/NO_2 ANNOX	Measurement of NO, NO_2, NOX

11 Appendix B

Priority list of new instruments for: field campaigns (FC) Long-term measurement (LT); and/or Calibration facilities (Cal). Manufacturer (if known) and approximate cost are also listed.

Instrument	**Use**	**Type**	**Cost (£k)**
Moveable Doppler radars	FC	Doppler on Wheels or equiv.	600
3 Doppler lidars	FC	HALO Photonics	360
Raman (WV) Lidar	FC		900
Additional tethersondes, new balloon and mooring system	FC		30
Optical particle counters	FC	Grimm	30
Dust distributor	Cal		10
Carbon dioxide	LT		50
Methane	LT		50
Hydrogen	LT		50
Sulphur dioxide	FC		20
Oxides of Nitrogen (NOy)	FC		50
Higher molecular weight PANs	FC		50
Single particle laser ablation instrumentation	FC		100
Phase particle discriminator (PPD)	FC & Cal	University of Hertfordshire	20
SO_2 with inlet for FAAM 146	FC	CIMS?	150
Bulk aerosol absorption Aethelometer	FC		100
Single ultrafine SMPS system	FC		50
Volatilty addition to HTDMA	FC		20
Multiple cpcs for ultrafine pcls	FC		50
Ultra-high sensitivity aerosol spectrometer (UHSAS)	FC		70
Fine particle size distribution for 146	FC		100
AIMMS probe for 146	FC		25