Airborne Measurements During the Buncefield Incident

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Acknowledgments

- People
  - Steve Abel, Clare Lee – Met Office.
  - Steve Ball – Head of FAAM.
  - Aircrew and FAAM staff.
  - James Allan, Hugh Coe – Aerosol Mass Spectrometer Univ of Manchester.
  - Hazel Jones, Martin Gallagher – Cloud Particle Imager, Univ of Manchester.
  - EMARC and dispersion teams at Met Office
- Agencies
  - NERC Centre for Atmospheric Science - support to CPI and AMS instruments and staff
  - NERC and Met Office – jointly run the aircraft.

The Facility for Airborne Atmospheric Measurements

NERC Centres for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

FAAM Overview

- **The FAAM BAe146-301 is one of the most comprehensively instrumented atmospheric research aircraft in the world!**
- **Aircraft** owned and converted by BAES
- **Aircraft** operated by Directflight
- **FAAM** is a collaboration between the Natural Environment Research Council (NERC) and the Met Office.
- **FAAM** operates from the airfield at Cranfield University, Bedfordshire.

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Aircraft Characteristics

Crew	Two Pilots
Scientists	18 max
Length	31 m
Wingspan	26 m
Height	8.4m to top of tail 4.4m to top fuselage
Engines	4 Honeywell LF507-1H turbofans
Max Altitude	35,000 ft
Min Altitude	50 ft
Range	3,700 km
Cruise Altitude	27,000 ft
Typical Endurance	5½ Hours
Min Manoeuvring Speed	90 – 115 m s^{-1} depending on payload
Payload	4,000 kg instrumentation

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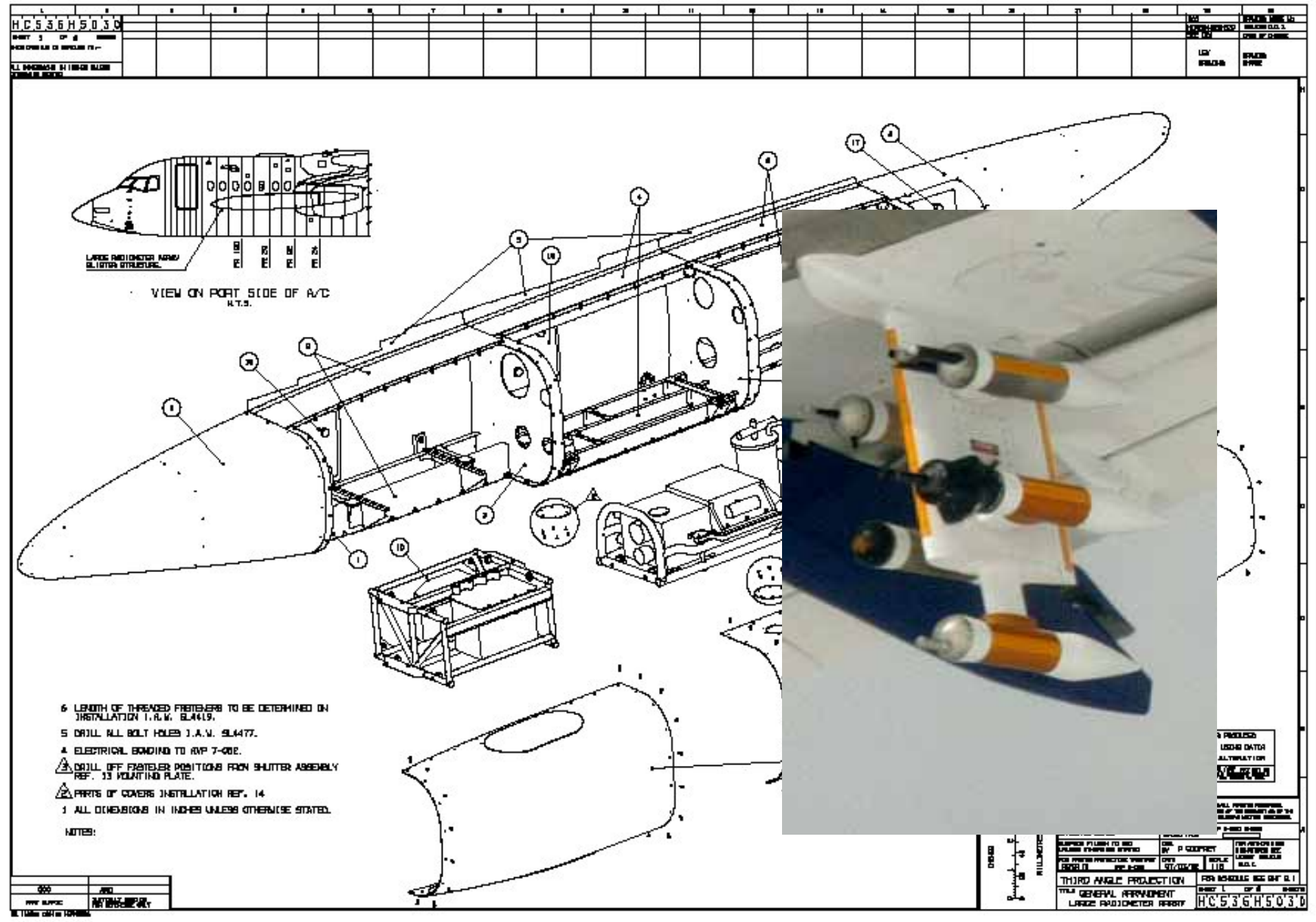
FAAM BAe146-301 ARA Instrumentation

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TELEX
ICS
LOCK FOR TAKE OFF & LANDING


TELEX
BIG EAT
WALKERS

Basic Meteorology Measurements

- Air temperature
- Position - latitude, longitude, pitch, roll, heading, altitude
- Static pressure
- Wind speed, turbulence and fluxes
- Dew point temperature
- Sea Surface Temperature
- Dropsondes, Temp,humidity,winds
- Video Cameras (4)
- Satcom communications

Radiometers

- SWS - short wave spectrometer - 303.4 - 1706.5 nm pixel resolution 3.2 nm up to 948.7 nm, 6.3 nm thereafter.
- ARIES - infrared interferometer - 3.3-16μm max OPD = 1.037cm (~ 0.5cm^{-1}) – 4800 channels
- MARSS, Deimos - passive microwave radiometers - 24, 50, 89, 157, 183GHz – same as AMSU.
- TAFTS - far infrared interferometer 80-1000cm^{-1} - Imperial College
- BBR - irradiance measurements, 0.3-3.0μm, 0.7-3.0μm and 4-50μm
- SHIM - Spectral Hemispheric Irradiance Measurement - 303.4 - 1706.5 nm pixel resolution 3.2 nm up to 948.7 nm, 6.3 nm thereafter

Cloud Microphysics

- Total water content
- Cloud liquid water content
- Cloud Ice Content

Cloud particle spectrum - FastFSSP (1-47μm), PMS 2D-C (25-800μm), PMS 2D-P (200-6400μm), Small Ice Detector (SID-1 and SID-2 - 1 to 25μm), SPEC Cloud Particle Imager (images of particles up to 2mm), Phase Doppler Particle Analyser ADA-100 (0.7 - 128μm), High Volume Precipitation Spectrometer HVPS (200 to 6400μm), Hallett Cloud Scope - water/ice images.

Aerosols and Particulates

- TSI 3 channel nephelometer,
- Particle Soot Absorption Photometer,
- Cloud Condensation Nuclei Counter (static diffusion chamber),
- Ice Nuclei Counter (continuous-flow diffusion chamber type),
- PMS PCASP (0.1 - 3μm),
- Condensation Particle Counter,
- Millipore filter system,
- Aerosol Mass Spectrometer,
- Counterflow Virtual Impactor (CVI) for size-selective cloud particle measurements.

Chemistry

- Ozone,
- NO,
- NOX,
- CO,
- SO2,
- CO2
- PAN,
- Formaldehyde,
- HOX,
- Hydrocarbons,
- CFCs etc. etc.
- Species can be sampled in Tevlar Flasks

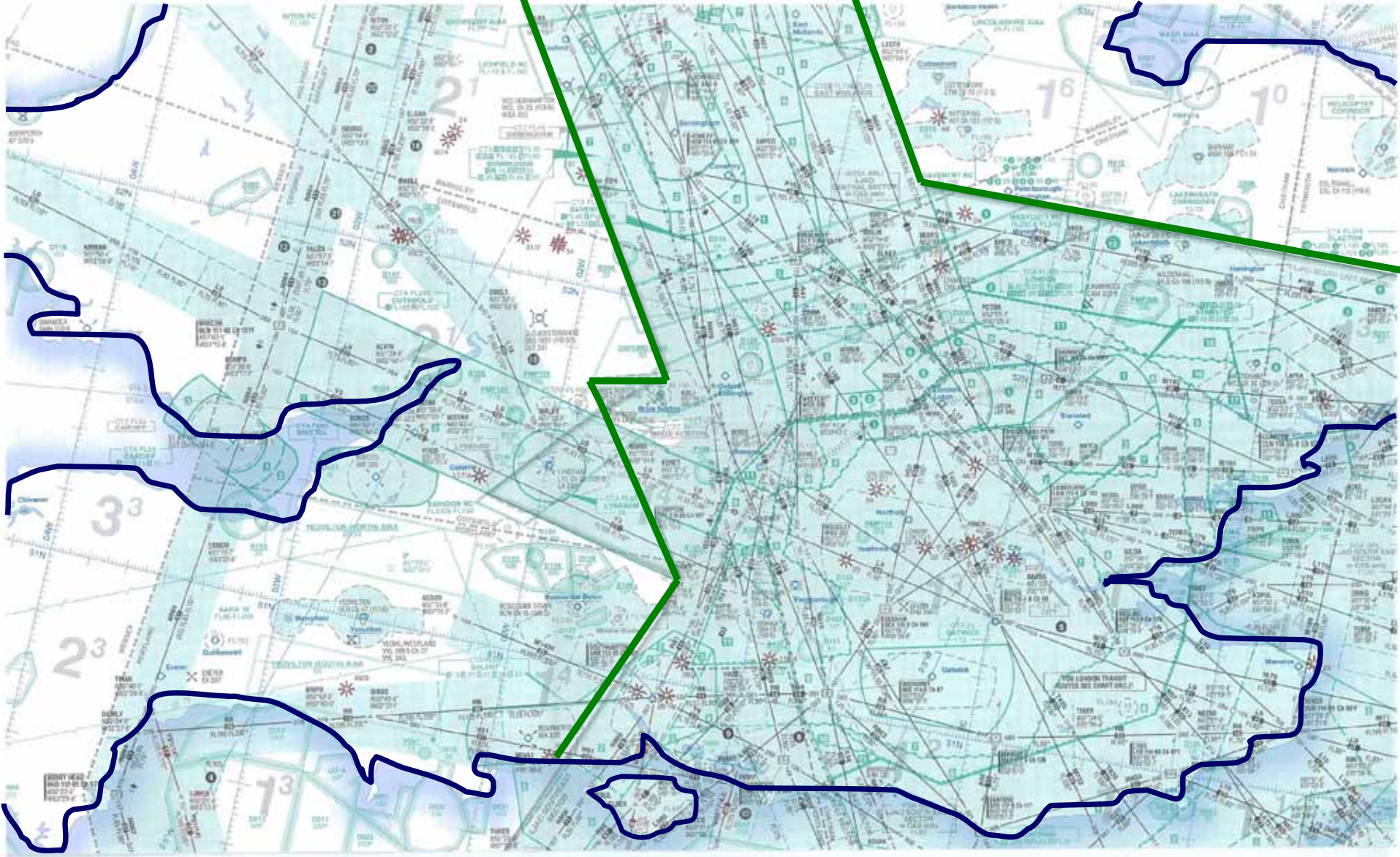
The FAAM BAe146-301 Aircraft Response

- Flew on Monday 12th and Tuesday 13th December. Monday flight around South Coast due to flight restrictions. Tuesday flight over source and 78km downwind.

- First civil contingency use of BAe146, fortuitous in that aircraft was in the UK, had team of scientists in place and most of the useful instrumentation installed.

FAAM BAe146-301 Samples Smoke Plume on Tuesday 13th December

NAME model prediction of plume valid at 1400



Most of South East England is controlled airspace.

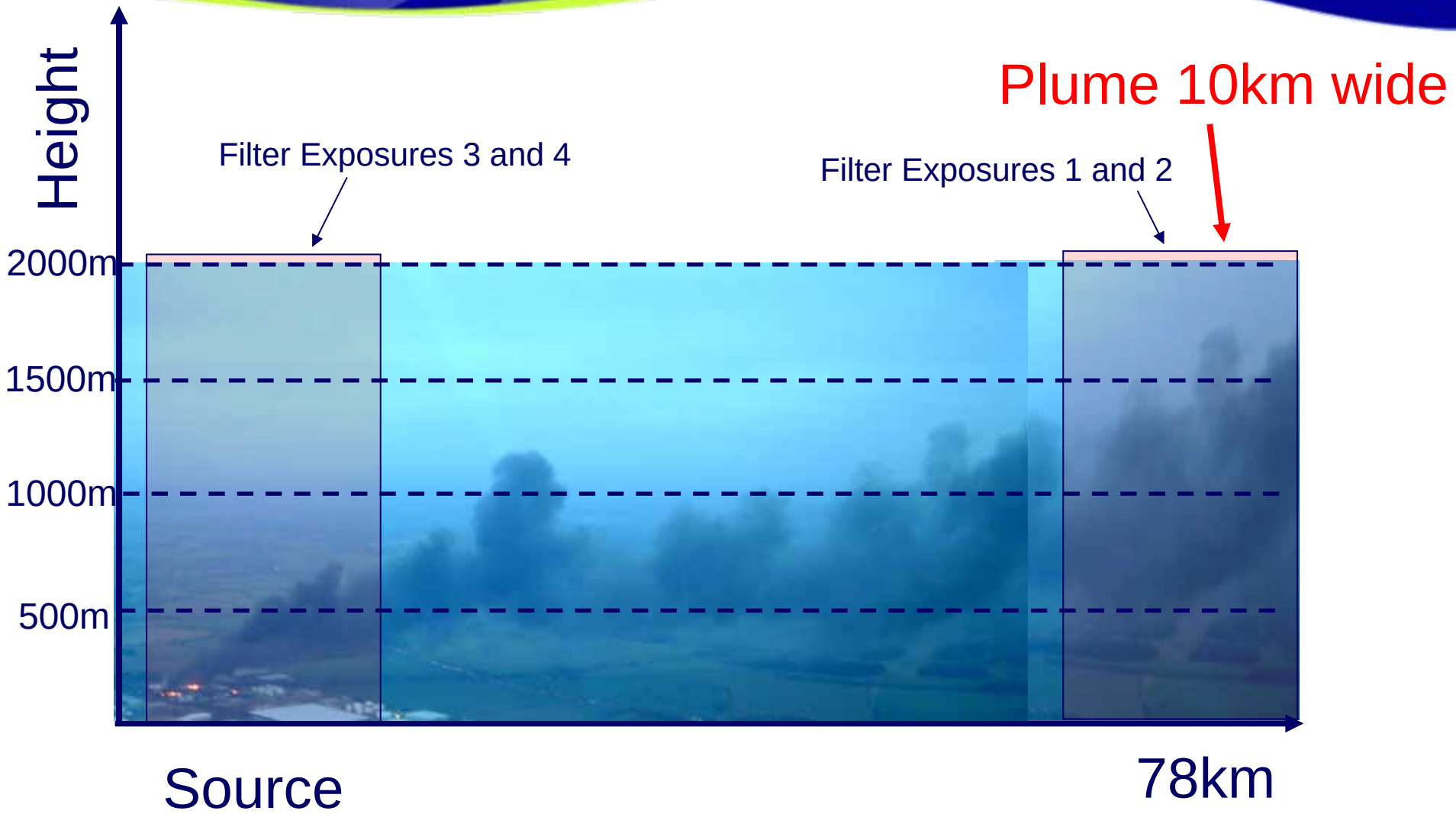
78km away from the source the smoke mixes with clouds

Still from forward facing video camera

Communications

- Direct satcom telephone communications with the aircraft allowed results of measurements in the air to be reported immediately to verify NAME model predictions and report on chemistry.
- We were able to report important results like: Aerosol Mass Spectrometer measured low levels of Polycylic Aromatic Hydrocarbons during entire sortie and low levels of particulate organics (~2μgm^{-3}).
- Also useful for advising aircrew of status of air traffic control clearance negotiations.

Structure of Smoke Plume.

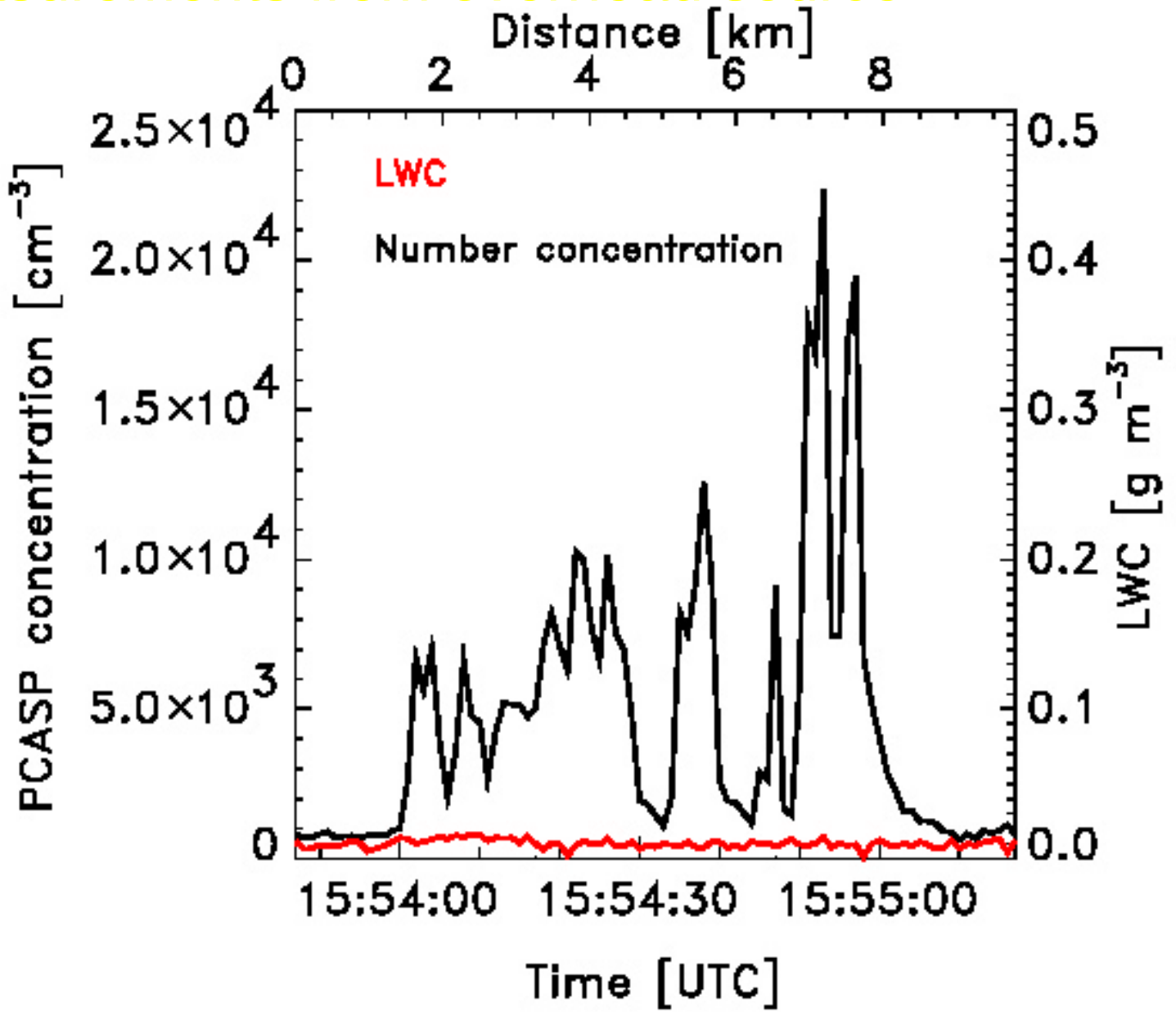


Passive Cavity Aerosol Spectrometer Probe

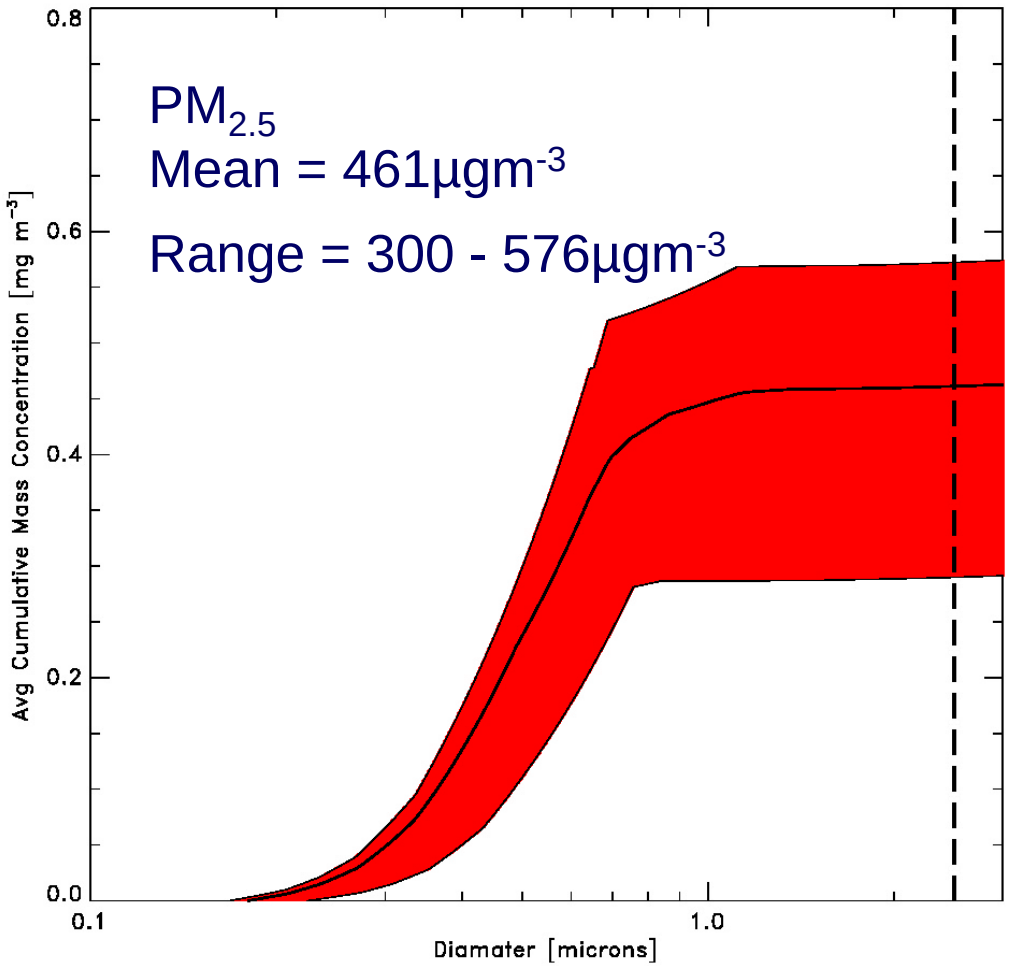
Wing mounted instrument that measures aerosol particles in the 0.1 to 3μm diameter range.

Calibrated with latex spheres so corrections need to be made to account for difference in refractive index of the black carbon.

Measurements from overhead source

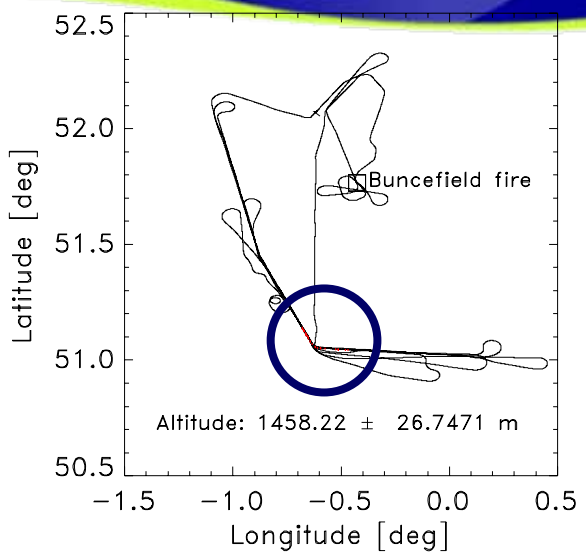


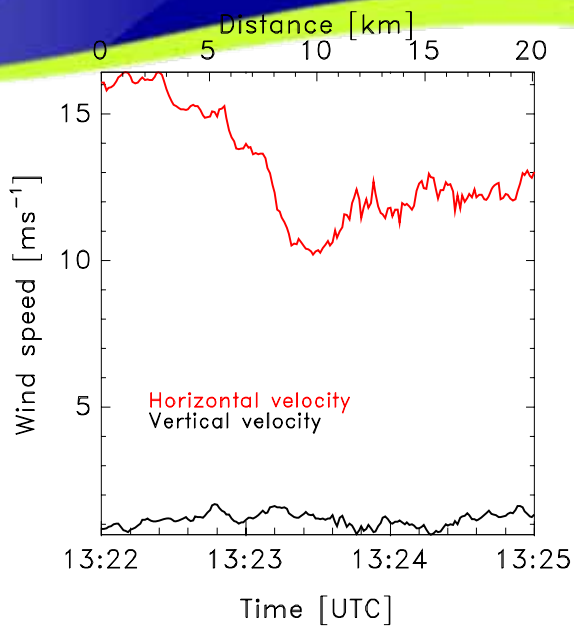
Measurement of Mass Concentration near source

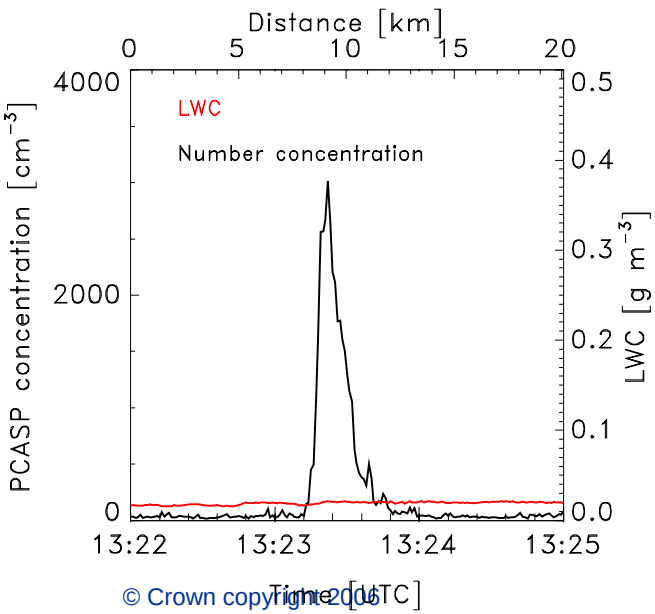


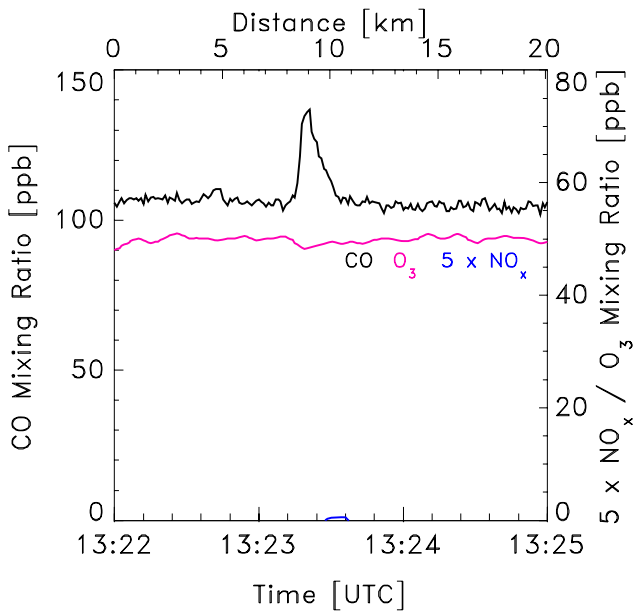
- Select 6 different sets of refractive indices and densities of black carbon from the literature
- Re-process PCASP data for each case
- Gives a range of mass concentrations which indicates uncertainty
- If assume $PM_{2.5}$ is 60% of PM_{10} then PM10 ~ 768µgm^{-3}

Measurements from 78km downwind



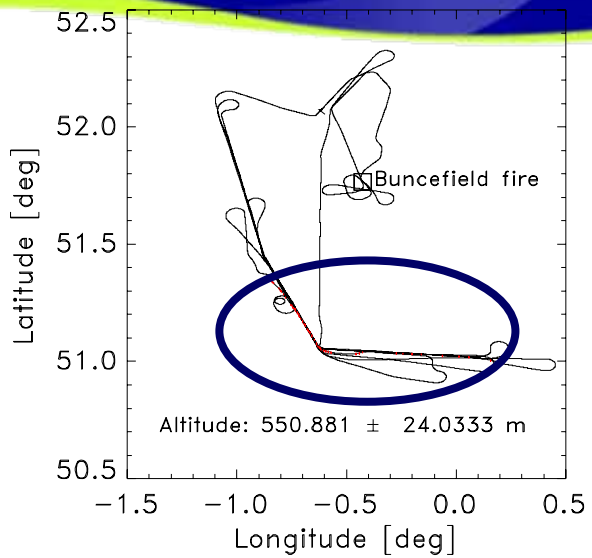


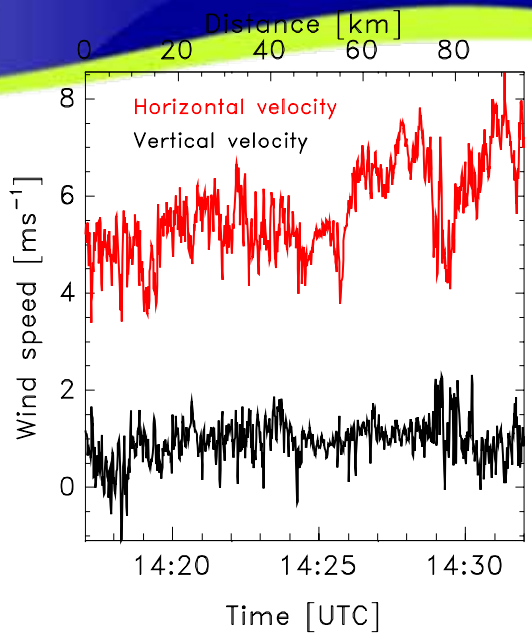


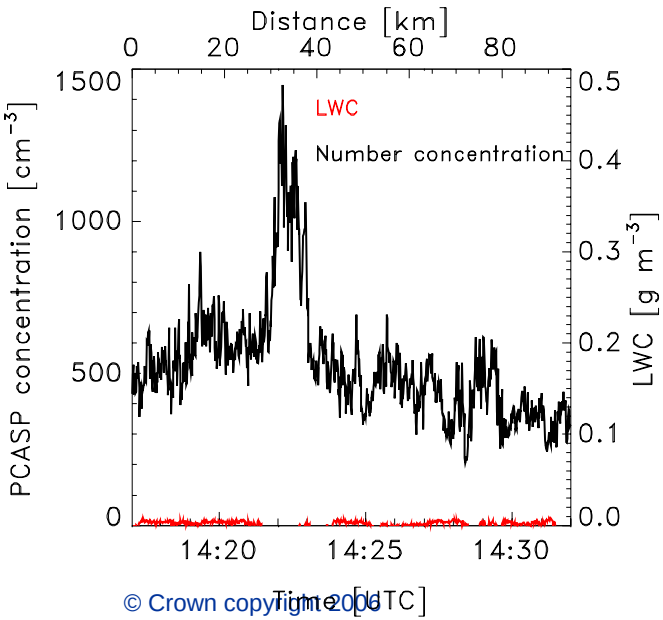


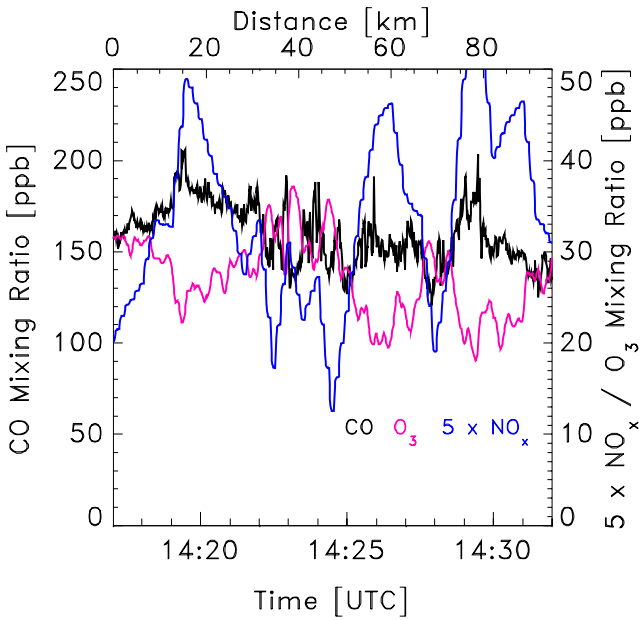
- Data from 1458m near top of plume
- CO increases from background of 108ppb to peak of ~137ppb.

Measurements from 78km downwind.









- Data from 550m near base of plume
- CO background levels are around 150 to 200ppb so plume barely detectable above background

Dioxins, Furans and PCBs from the FAAM BAe146

- Dioxins, Furans and PCBs analysed by Harwell Scientifics for filters exposed 78km down the plume
  - No PCBs detected
  - Polychlorinated dibenzodioxins and dibenzofurans – Committee on Toxicity Tolerable Daily Intake for children slightly exceeded, but this was at altitude and unless exposure was prolonged there would only be a slight impact on body burdens
- PAHs analysed for filters 78km downwind and overhead source

Filter Analysis – Harwell and HSL

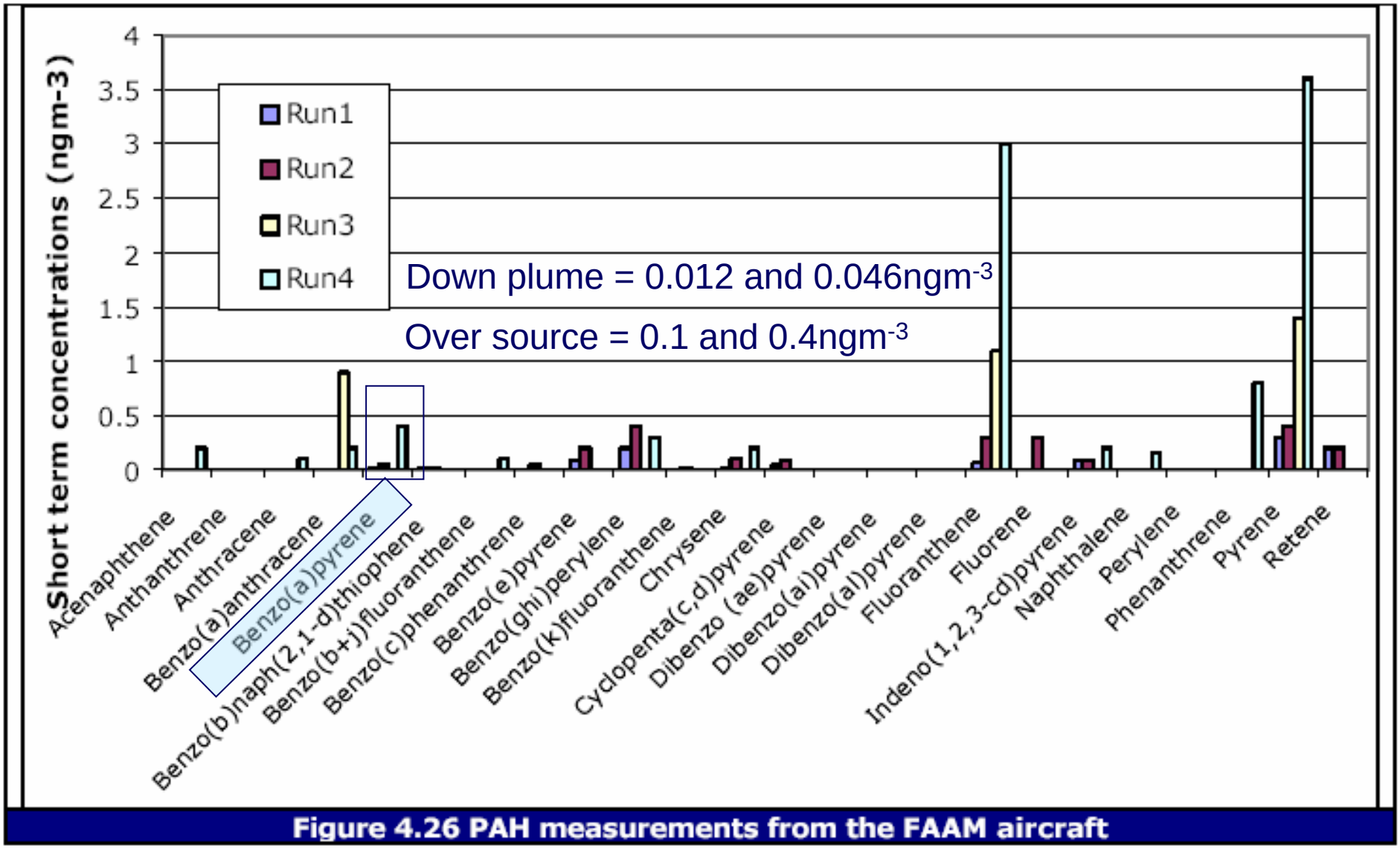
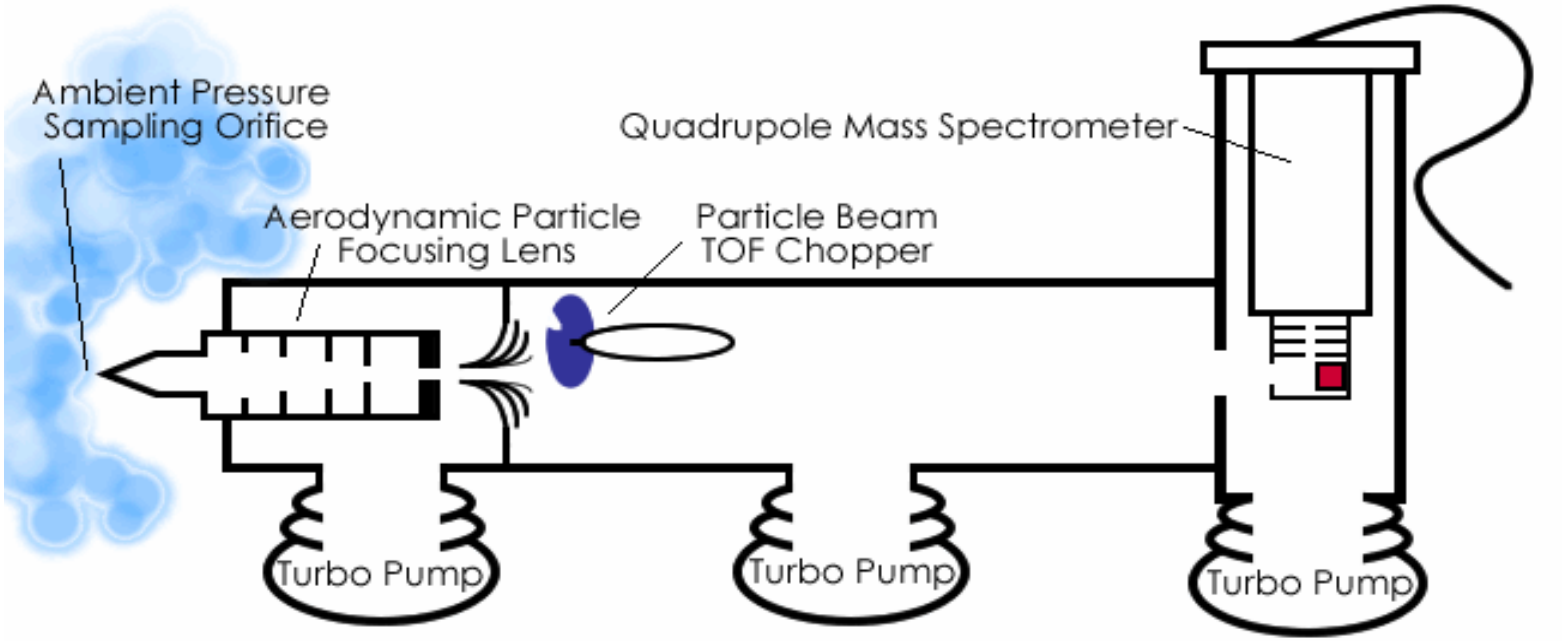


Figure 4.26 PAH measurements from the FAAM aircraft

The Aerodyne Aerosol Mass Spectrometer (AMS)

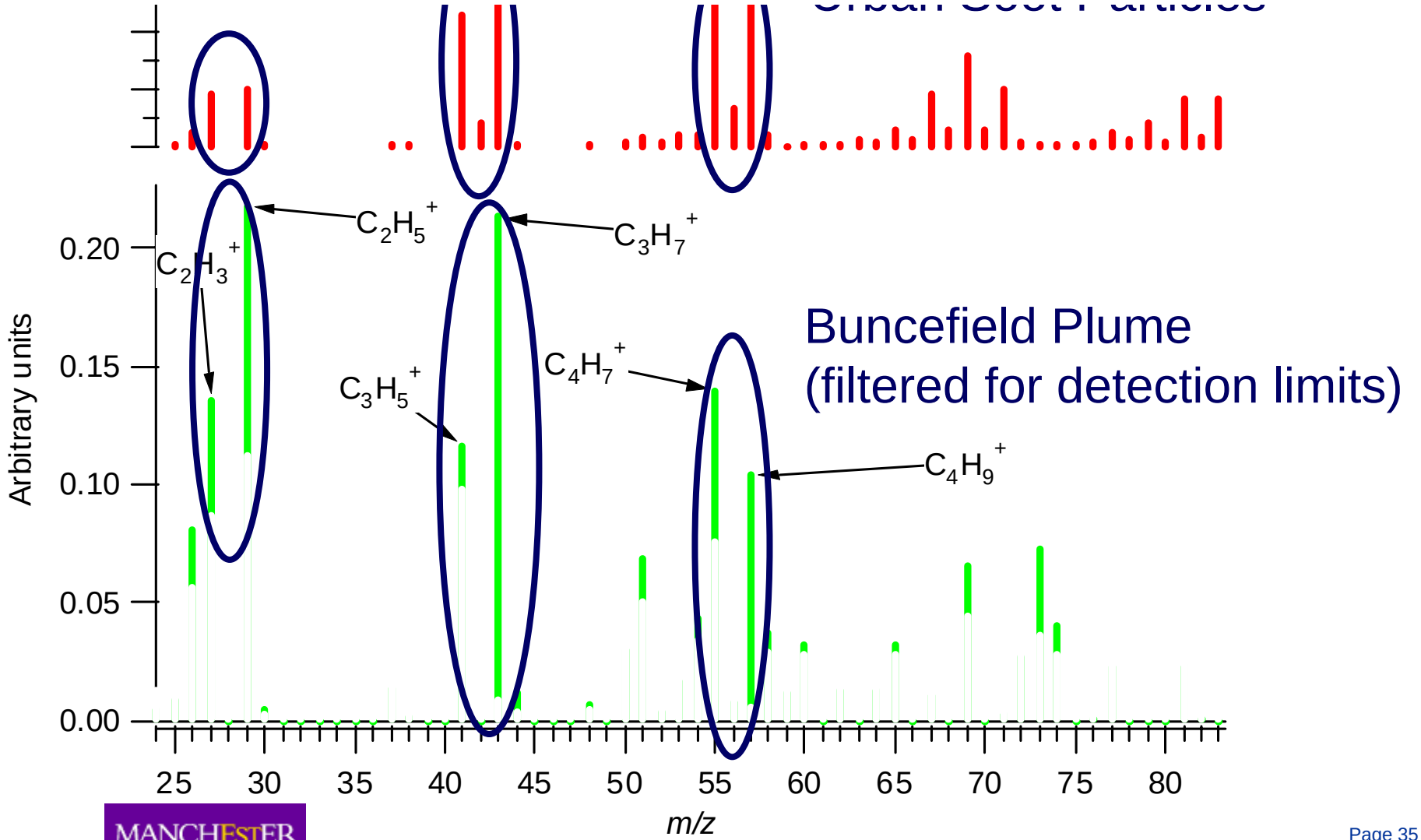


- Vaporises particles and analyses the resultant gases online using mass spectrometry.
- Designed for the study of particles less than 1 μm in diameter.
- Typically measures sulphate, ammonium, nitrate and organic matter.
- Cannot study refractory materials (e.g. elemental carbon, sea salt, dust).

AMS Results

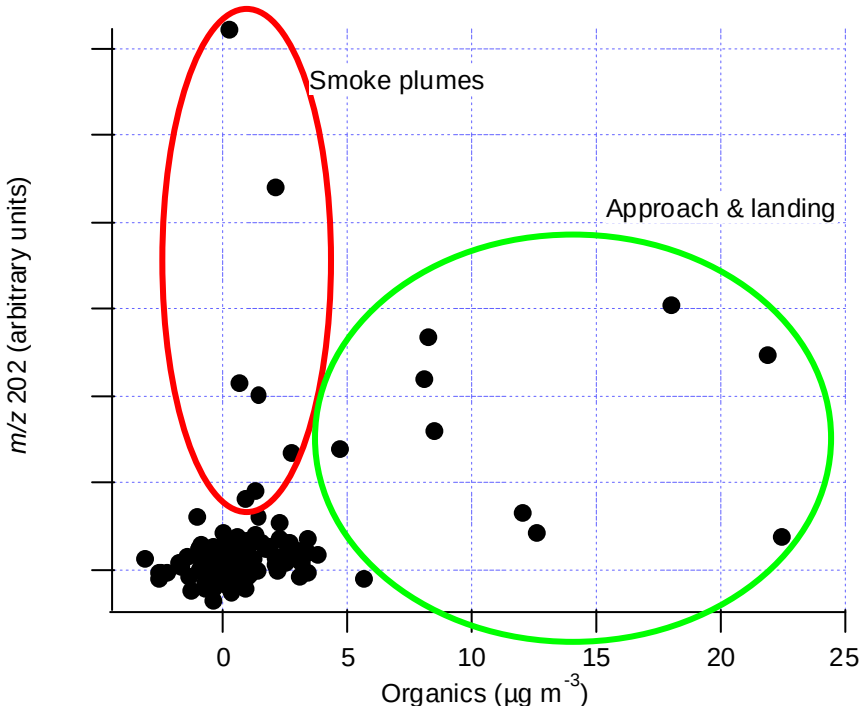
- The AMS measured approximately 3 µg m^{-3} submicron organic matter in the plumes, although much more mass probably existed within larger particles or in the form of elemental carbon (as shown by the PCASP and PSAP), neither of which are detectable with the AMS.

The peaks within the organic mass spectrum that possessed significant signal corresponded to hydrocarbon fragments and are considered typical of the organic matter present in soot.



Enhanced PAHs? Data still being analysed by Manchester University Staff.

- Polycyclic Aromatic Hydrocarbons (PAHs) are often produced in flames and are potentially very important to consider from a health perspective.
- Lab and field studies have shown that this can be measured using the AMS, the largest peak typically occuring m/z 202, which corresponds to C16H10+ (pyrene).
- The fractional contribution of m/z 202 to the total organic signal was around 19 times greater in the fire plumes when compared to the approach and landing phase of the mission.
- This implies that there were much higher concentrations of PAHs per µg m-3 of organic aerosol in the plume compared to 'normal' polluted air, although exact quantification is difficult in this case.



Filter Analysis – Harwell and HSL

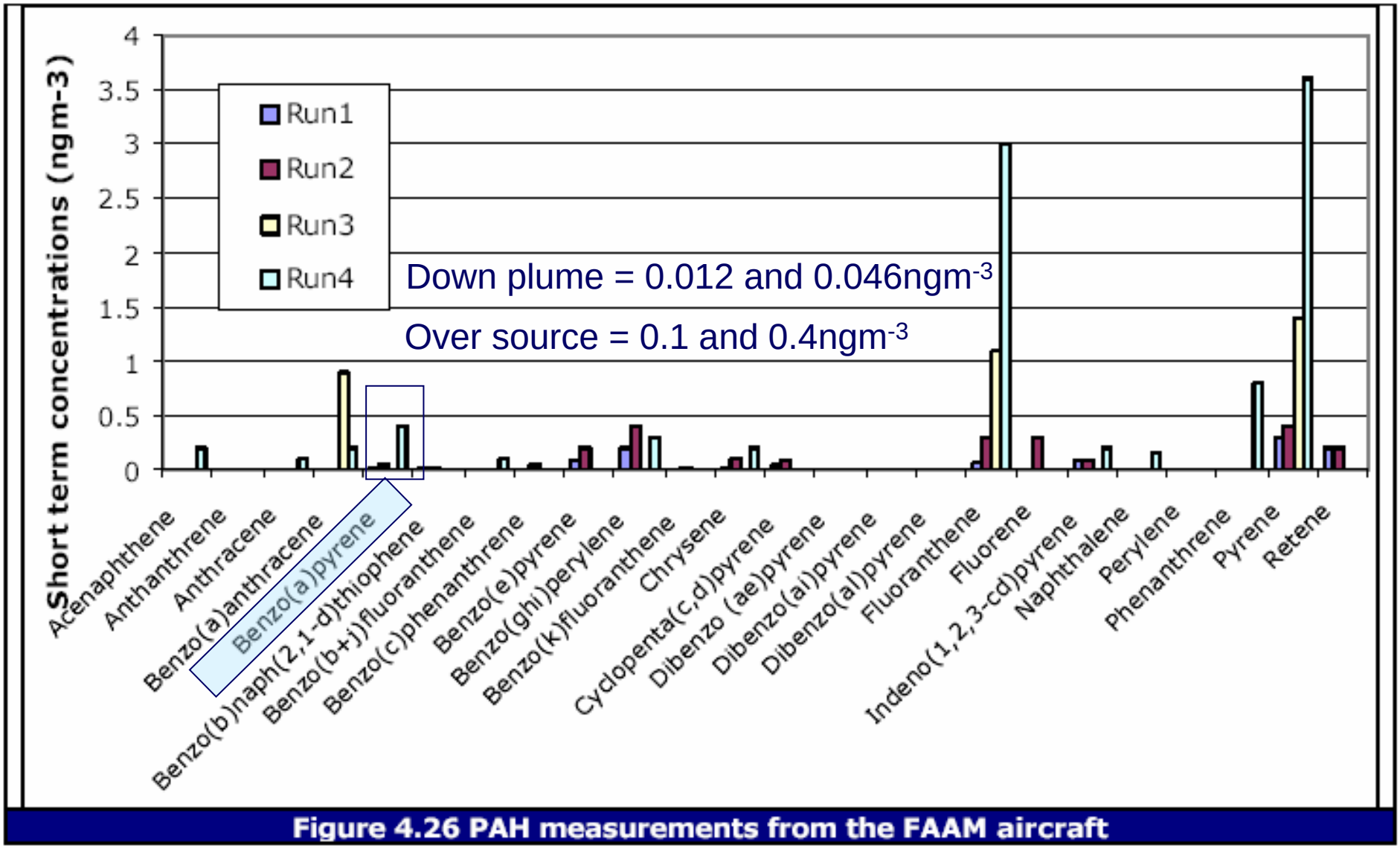
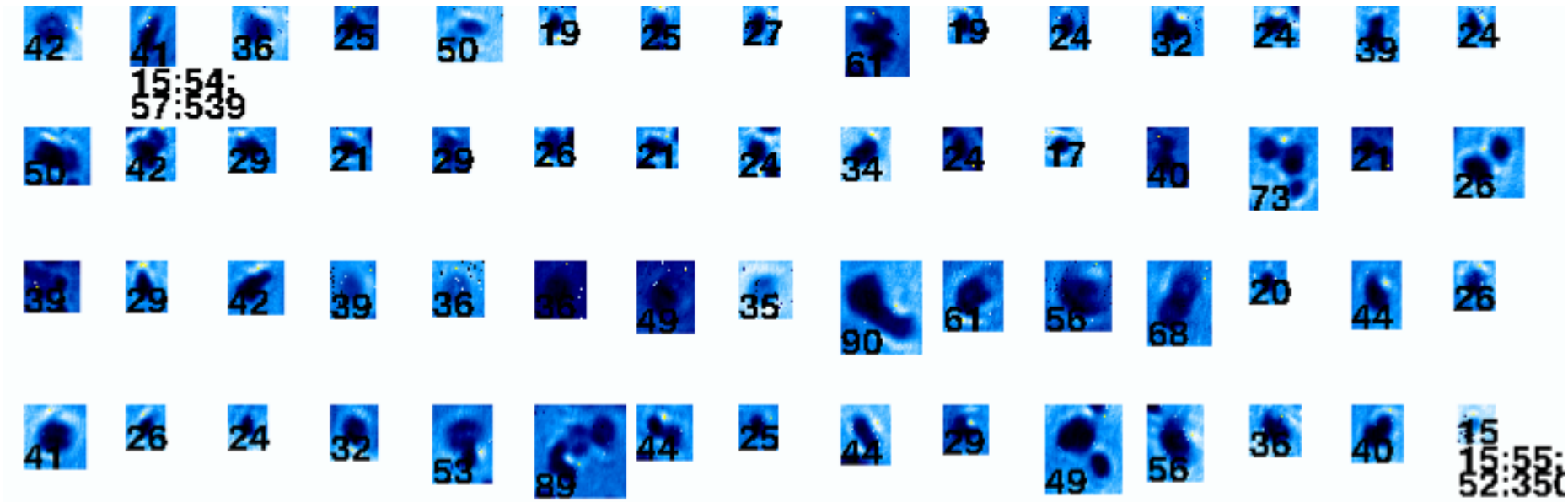
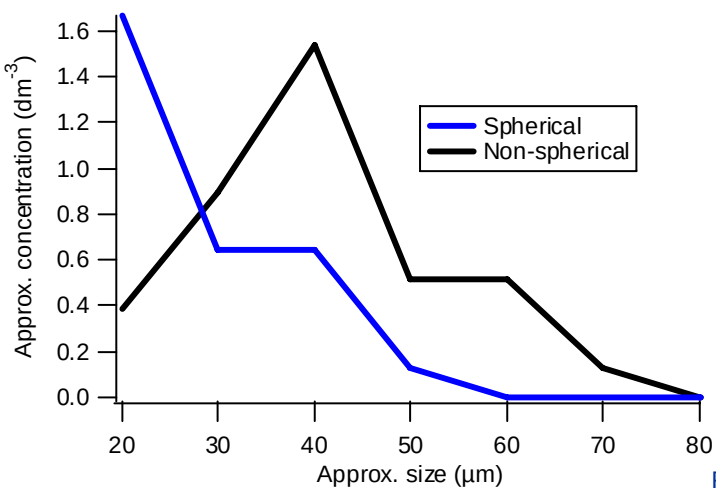


Figure 4.26 PAH measurements from the FAAM aircraft

CPI images



- While the CPI is designed for the study of large ice particles, some soot particles were imaged. The approximate sizes (in µm) are overlaid on the images.
- The larger of these particles were irregular in shape and probably aggregate in structure.



Summary of Filter Analysis

- Filter analysis confirms initial reports from the aircraft that pollutant levels were low.
- This is probably the result of high combustion temperatures and/or the highly refined fuel being burnt.
- Main constituent of smoke plume was “black carbon” (soot).

Conclusions

- The FAAM BAe146-301 was able to provide immediate information regarding the contents of the Buncefield smoke plume.
- Subsequent analysis of data has confirmed that plume was mainly “black carbon” and did not pose a significant risk to health.
- Aircraft data is now being used to analyse performance of the Met Office NAME model, hopefully leading to enhancements in the modelling of such events in the future.

Any questions?

For more details on the aircraft please visit:

http://www.faam.ac.uk