Annex D

Draft Report* from the Ad Hoc Group of Experts on the Long-range Transport and Dispersion Model Verification Database

For submission to the WMO EC Panel of Experts,
CAS Working Group on Environmental Pollution and Atmospheric Chemistry

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***Disclaimer** - This draft is a preliminary version of a report being prepared for the CAS Working Group. The final report when submitted and if accepted, may or may not include changes to this version. Although this version is preliminary, it was thought that the information about the potential availability of a wide range of field experiments for the validation of long-term transport and dispersion models was sufficiently important to circulate at an early stage to WMO, WHO, and associated organizations to solicit comments and identify sources of funding. For more information please contact:

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1. Background

The recent meeting of the World Meteorological Organization (WMO) Commission for Atmospheric Sciences (CAS - XII) emphasized the importance of the coordinating role of WMO in emergency response activities and the increasing number of models to address the long-range transport of pollutants The Commission decided there was a need to create a database of all known field experiments and the corresponding meteorological data in a common format that could then be used for model verification and development. The USA and Australia agreed to assemble a small expert group to consider the tasks required to address this issue and report their results to the CAS Working Group on Environmental Pollution and Atmospheric Chemistry.

2. Introduction

The long-range transport of pollutants in the atmosphere has received considerable attention in recent years, corresponding with a comparable number of models to address these issues. In particular there has been consistent emphasis on nuclear reactor accidents since Chernobyl by the International Atomic Energy Agency (IAEA) and the World Meteorological Organization (WMO) through the organization of WMO Regional Specialized Meteorological Centres (RSMCs). There are now 8 of these centres (Toulouse, Bracknell, Montreal, Washington, Melbourne, Tokyo, Beijing, and Moscow), each with their own modelling capabilities The European Tracer Experiment (ETEX) symposium evaluated 47 different models The recent ratification of the Comprehensive Test Ban Treaty (CTBT) will require the use of atmospheric dispersion models to attribute measured air concentrations to a particular source location. There is the potential for the development of a whole new class of models to deal just with this issue. The introduction of more fuel efficient jet aircraft engines (running at higher temperatures) has made modern commercial aircraft very sensitive to volcanic ash from eruptions. Centres for the modelling of volcanic ash dispersion are currently being organized through the International Civil Aviation Organization (ICAO).

Most, if not all, atmospheric transport models (ATM) are linked to one or more operational meteorological forecast models, or a particular meteorological archive, which is then used by the ATM. The data predicted by the meteorological models are routinely evaluated and compared against common performance standards. Although similar verification standards exist for the ATMs, there is a sense in the dispersion modelling community that there is very little data available to perform these evaluations. Perhaps because these data are not as easily obtained and are usually limited to single events or controlled (and expensive) field experiments that are not available on a routine basis. However there are many isolated experiments, some of which are controlled tracer releases and others from the sampling of tracers of opportunity. The problem with many of these data sets is that some are now decades old, reports are difficult to locate, if available the data are in various formats, and not all experiments archived the corresponding meteorological data.

The recent completion of meteorological re-analysis projects at several international meteorological centers provides an opportunity to link high quality modern meteorological data with each of these dispersion experiment data sets. The concept would be to create a set of CD ROMS, containing experimental data, relevant reports, meteorological data, and statistical analysis and display software, all in a common non-proprietary form. This new common database would permit the modelling community to conduct sensitivity and verification studies with considerable less preparation and effort than is now required. In addition, each modelling center or research group could produce results for each experiment that then could be compared with results from all other groups through participation in a model verification symposium.

The objectives of this report are to suggest some common standards for the data archive, review which experimental data should be included, develop a list of common model performance measures that could be incorporated in the database, and estimate the costs to complete this effort, suggest potential contractors or research laboratories that might do the work, and perhaps identify potential sources of funding.

3. Data Standards

There are three primary data sources of interest:

1) information about the pollutant release;
2) meteorological data used to calculate the pollutant transport and dispersion; and
3) measured pollutant values that can be compared with model results.

Each of these should be in a common format so that any experiment simulation can be quickly setup and results produced. Depending upon the type of experiment, information or measurements provided, there should be certain minimum requirements for an experiment s inclusion into the database.

3.1 Meteorological

It is important that the meteorological data used for all dispersion experiments is not only in a common format, but from a common source. The most easily obtained common source of gridded fields would be from one of the existing meteorological re-analysis projects. A re-analysis involves the recovery of land surface, ship, rawinsonde, pibal, aircraft, satellite and other data, quality controlling and assimilating these data with a data assimilation system which is kept unchanged over the re-analysis period, eliminating jumps associated with changes in the data assimilation system and then running the meteorological forecast model to produce the time series of gridded meteorological fields.

If a dispersion experiment had archived special observations, these could be included in the master database. Only a limited subset of the re-analysis data, sufficient for the required computations, should be included with each dispersion experiment. This is in part to limit the data volume, and in part to insure that it would be possible to reach agreements with the meteorological centers to provide the data without restrictions. If researchers require access to the complete data set, it would still be available from the original center. One may presume that these gridded meteorological fields are only one version of 'truth' and subsequently may be modified or pre-processed to support various research or modelling studies. However, it should be the best that can be done with the thoroughness of the re-analysis procedures and within the budgetary constraints of the database project.

Once it is established which experiments are to be included then an accurate estimate of data volume can be obtained. However for planning purposes let us assume that the NCEP (NOAA)/NCAR re-analysis data will be used. The fields are available on a Gaussian grid (2.5 degree) on 28 sigma levels. If all the state variables (5) are archived at all model levels, and packed in Grib format (assume 2 bytes per data point), at 4 output fields per day, the space requirements are on the order of 12 Mb per day - or only 50 days per CD. Because some of the dispersion experiments span several months, it is clear that a sub-grid corresponding to the experimental domain is required to reduce data volume. The largest reasonable domain would be a quarter hemisphere (90° latitude, 90° longitude), which reduces meteorological data requirements to about 1 MB per day. If experimental domains are further restricted to 1500 km domain, then data volumes shrink to 10 Kb per day. In any event, the re-analysis data will have to be processed, i.e. unpacked, the experimental domain extracted, and re-packed. Some remaining questions that can be resolved during the preparation of the final proposal are should the extracted meteorological data be in Grib, NetCDf, or perhaps some other format?

Some experiments (e.g. ETEX, CAPTEX, and perhaps a few others) may require a resolution much finer than 2.5 deg to properly capture the mesoscale effects noted by researchers working with these data. Typically one would expect those resolutions to be on the order of 1 deg and hence the costs associated with the additional factor of 6 data volume would need to be addressed in the final proposal details.

3.1.1 NCEP/NCAR re-analysis project (1958 - 1997)

The NCEP/NCAR Re-analysis Project is a joint project between the National Centers for Environmental Prediction (NCEP, formerly "NMC") and the National Center for Atmospheric Research (NCAR). The goal of this joint effort was to produce new atmospheric analyses using historical data and analyses of the current atmospheric state (Climate Data Assimilation System, CDAS). Although the output is not under a copyright, there are nominal fees to copy the data to tape from the archives at NCAR (Boulder CO, USA) and CDC (Boulder CO, USA). The data assimilation and the model used are identical to the global system implemented operationally at NCEP on 11 January 1995, except that the horizontal resolution is T62 (about 210 km). The database has been enhanced with many sources of observations not available in real time for operations, provided by different countries and organizations. Reference: Kalnay et al., Bull AMS, 1996, 77, 437-471 and see http.//wesley.wwb.noaa.gov/reanlysis.html

3.1.2 ECMWF re-analysis project

The ECMWF Re-analysis (ERA) Archive contains global analyses and short range forecasts of all relevant weather parameters, beginning with 1979, the year of the First GARP Global Experiment (FGGE). ECMWF Data Services can provide information about which years are currently available. The full model resolution for ERA is Spectral T106 , Gaussian N80 (approximately equivalent to latitude/longitude 1.125 degrees), with 31 hybrid model levels in the vertical. Additionally, the upper air data are available on 17 pressure levels. All data are written in the international standard GRIB format. ECMWF does have copyright restrictions and significant data access costs Further it is not clear if suitable arrangements can be negotiated to provide a subset of their data without distribution restrictions. Reference: http://www.ecmwf.int/data/era.html

3.1.3 Other meteorological data.

The Data Assimilation Office (DAO) at NASA's Goddard Space Flight Center (Maryland, USA) is currently producing a multi-year gridded global atmospheric data set for use in climate research, including tropospheric chemistry applications. The data, which are being made available to the scientific community, are well-suited for climate research since they are produced by a fixed assimilation system designed to minimize the spin-up in the hydrological cycle This assimilation produces 2 x 2.5 latitude longitude by 20 level gridded data at 6 and 3 hour intervals. Data include upper air heights, winds, temperature, and moisture as well as numerous derived quantities such as radiative heating, precipitation, ground wetness, etc. Reference· Schubert et al. 1993, Bull. Amer.Meteor.Soc., 74, 2331-2342. See http://hera.gsfc.nasa.gov/experiments/assim54A.html

3.2 Source emissions

Each experiment should include at a minimum, the location (decimal degrees) and height of the release, the amount pollutant released (kg) as a function of time (UTC). Some accidental events (such as volcanic eruptions) may have very little documented information about the release except the initial time and location. however these events may still provide valuable model performance statistics, with regard to pollutant transport directions, if not quantitative estimates of the concentrations. Other source details, if applicable, should include the nature and species of the tracer or pollutant, whether it is passive, soluble, its half-life, and if available, information on atmospheric ambient background levels. If emission amounts are known as a function of time, this information can be provided in a simple ASCII file, with each record corresponding to a known emission period, with information about the starting time, ending time, height, and amount. All fields should be space delimited, so that they can easily be used in other programs or spreadsheet applications.

3.3 Sampling Information

Pollutant sampling can be an instantaneous snapshot, such as a satellite photo, or represent temporal averages, at a fixed location, or a spatial average, such as a sample collected on an aircraft. Distinct sample collection, regardless of platform, shares some of the same data characteristics (height, location, time, duration, etc.), while satellite photos, are a rather unique product for model verification, and may be associated with some subjectivity in their interpretation due the different kind of information that may be extracted from the data. There are bound to be problems in this area.

Although consistency is very important, it remains to be seen whether it is 100 per cent achievable. Standards need to be established as to when zeroes are to be regarded as significant and included in the archive. Some experiments may report as much as 80-90 per cent of the observations as zero if they are away from the center of the plume. Missing information must be distinguished from zero readings.

3.3.1 Fixed or mobile platform samples

To maintain a certain consistency in data format between sampling platforms, although at a cost of redundancy, each sample should be identified on a unique record which contains date, time, location, height, concentration data. In this way both fixed ground-level sampling locations and samples collected on aircraft can be merged into a single database structure.

3.3.2 Satellite photos

There are several problems associated with using satellite photos: retrieval from archives, multiple channels, large data volume per photograph, and quantitative interpretation of the pollutant cloud dimensions. All the images should be converted to a standard geographic projection that can easily be matched to model output. In general these data would only be used for verification of volcanic eruptions and smoke from large scale fires. There are still many uncertainties associated with the use of these data. For instance, how the model outputs be quantified and compared with the images, how the models define the edge of the image, and should the satellite images be processed and only vectors defining the plume be saved to the archive? It is not clear that sufficient consensus exists to create a uniform database from these images. Although it is tempting to dismiss the satellite archive as too complicated to deal with in the initial phases of such a project, the sheer number of different events that could be simulated and the uniqueness and relevance of the data to the aviation industry, suggest that perhaps a corresponding verification development using the satellite archives should be considered. New satellite coming on-line will provide more quantitative aerosol measurements and could provide sufficient complementary information to properly utilize the older archives.

3.3.3 Non-conventional

For some reported experiments only derived data may be available such as plume widths as a function of distance, rather than air concentrations. Other data may include deposition, which may have been derived from many different measurement methods and over different accumulation periods at each location. These experiments will have to be evaluated on a case-to-case basis to determine their suitability for inclusion in the larger archive.

4. Potential Experimental Databases

Only experiments in which the transport distances from source to the majority of the samplers are in excess of 200 km should be considered for inclusion into the database. This is the range at which there is a transition from the Planetary Boundary Layers control of dispersion to the larger-scale 2-D synoptic influence on dispersion. Although many long-range transport models are being successfully extended to meso-scales, and therefore it may be worth thinking of a similar meso-scale verification database in the future, it would no doubt need substantial extra work due to the greater number of experiments at those scales. A similar database for very short-range experiments is being constructed by H. Olesen at RISO for short ranges (such as Kincaid, Copenhagen, Lillestrom and Indianapolis). As this proposal moves forward to the design stage, the two schemes should be mutually referenced and certainly would benefit from each other development in terms of data standards, statistical methods, and literature reviews.

It is necessary to establish guidelines for which type of data should be included in such an archive. In general there are three types of experiments:

1) controlled experiments in which the pollutant release rate is known,
2) accidental ones in which it is unknown (and never will be), such as volcanic eruptions, and
3) pure transport experiments, such as balloon releases.

The controlled group would include such events as the Chernobyl accident, in which the source term was reconstructed after the fact. Controlled experiments provide quantitative concentration or deposition data, however in general one will find that each experiment has different limitations, usually related to how many samples could be analyzed. Experiments with detailed spatial and temporal resolution are usually limited to a few cases. Experiments that cover many events usually have either low spatial or temporal sampling resolution. Each experiment may serve a different model verification or development purpose. Accidental uncontrolled releases, such as volcanic eruptions, may have little or no quantitative sampling data, but yet may be rich in temporal history of satellite photographic images of plume positions.

An abstract of potential experiments, familiar to the working group members, follows below, each with known references and availability of data. There are probably a considerable number of other experiments, less familiar to this group, that should also be reviewed. The initial stages of the database design should include a comprehensive literature search, the results of which should be included in the database regardless of whether the individual experiments have been included

4.1 Controlled Field Experiments

4.1.1 USA, Idaho, Kr-85, 1974

Three months of Kr-85 releases from Idaho and continuous 12 h sampling at 13 locations in a line about 1500 km downwind. Limitations: many samples near background and background variability comparable to signal. Advantage: continuous time series does show a few distinct plumes and unique in that transport was across the Rocky Mountains. Data available: only in publication. Reference: Atm. Environ., 1982, 16: 2763-2776.

4.1.2 USA, Oklahoma, PFT, 1980

A single release perfluorocarbon (PFT) tracer over a 3 hour duration with samples of 3 hour duration collected at about 40 sites 600 km downwind from the release. An additional Heavy Methane (HM: $^{12}CD_4$ and $^{13}CD_4$) tracer released simultaneously with the PFC was measured at 3 locations up to 2000 km downwind. Limitations: single event with release in pre-defined conditions. Advantage: Detailed temporal and spatial history as plume passes 600 km sampling arc under rather unique conditions of nocturnal jet and secondary tracer maximum. Data available: only in publication. Reference PFC. Tech. Report EPA-600 copy at:

ftp://www.arl.noaa.gov/pub/tracer/captex.

Reference HM: M.M. Fowler and S. Barr, 1983, Atm. Environ., 17:1677-1685.

4.1.3 USA, CAPTEX, PFT, September - October 1983

Cross Appalachian Tracer Experiment consisted of six 3 h PFT releases, all independent of each other, four from Dayton, Ohio and two from Sudbury, Ont, Canada with samples collected about 80 sites, 300 to 800 km from the source, generally at 6 h averages for 48 hours with each release. Advantages: extensive multiple aircraft samples available for many of the releases at various downwind distances. Data available: ftp://www.arl.noaa.gov/pub/tracer/captex. Reference: NOAA Tech Memo ERL ARL-142.

4.1.4 Ukraine, Chernobyl Accident, April 1986

A 10 day release with extensive air concentration and deposition measurements. Limitations: still some controversy regarding the reconstructed emissions and there is limited information on daily wet deposition of Cs-137. Advantage: the only data with extensive measurements of air concentrations and radioactive wet and dry accumulated deposition with much more data available now than at the time most initial studies were published. Data available: Cs-137 and I-131 air concentrations, and Cs-137 daily and accumulated deposition from the REM data bank at JRC Ispra at http //java ei.jrc.it/. Reference: Klug et al., Evaluation of long-range atmospheric models using environmental radioactivity data from the Chernobyl accident. EUR 14148 EN. Elsevier. 1992.ISBN 1-85166-766-0.

4.1.5 USA, ANATEX, PFT, January - March, 1987

The Across North America Tracer Experiment consisted of 66 PFT releases (33 each from two different locations) every two and one half days. Air samples were collected over 24 h periods at about 60 sites covering most of the eastern US and southeastern Canada. Aircraft sampling limited to within a few hundred kilometers from the sources. Limitation: temporal and spatial resolution is poor. Advantage: many distinct tracer plumes move through the sampling network under a variety of different meteorological conditions. Data available: ftp://www.arl.noaa.gov/pub/tracer/anatex. Reference: NOAA Tech Memos ERL ARL-165, 167, 175, and 177

4.1.6 USA, Southwest - Mohave, PFT, 1992

Continuous releases for two one month periods, summer winter, daily sampling at a variety of locations in complex terrain over several hundred kilometer domain. Data available: ftp://eafs.sage.dri.edu/currproj/mohave
References: contact Mark Green (green@snsc.dri.edu)

4.1.7 *Europe, ETEX, PFT, 1994*

Two releases of PFT with 3 h sampling at 167 locations to 2000 km from the source over a 3 day period. Limitation: only a limited number of measurements are available for the second release that occurred during a frontal passage.
Advantages: tracer measurements from aircraft are available, although they have not yet been extensively evaluated. Data available. from http.//www.ei.jrc.it/etex/. References: EUR publications in progress, submitted to special issue of Atm. Environ.

4 1 8 *USA, Mid-Atlantic coast, ACURATE, Kr-85, 1982-1983*

The ACURATE experiment consisted of measuring the Krypton-85 air concentrations from emissions of the Savannah River Plant, SC, Twice-daily (12h) average air concentrations were collected for 19 months (March 1982 - September 1983) at 5 locations along the east coast of the U S from 300 to 1000 km from the plant. Limitation: only 5 locations with frequently only one or two sites showing above background signal for any event. Advantage: the only experiment that covers all four seasons with 750 of 3858 samples showing above background signal. Data available· ftp://www.arl.noaa.gov/pub/tracer. Reference: NOAA Tech Memo. ERL ARL-130

4.1.9 Australia, Mt. Isa SO2 plume, 1979-1981

Measurements by Division of Coal and Energy Technology, CSIRO. Data available: john.carras@syd.dcet.csiro.au. References: Carras and Williams, 1981, Atm. Environ., 15.2205-2217 and 1988, Atm. Environ., 22·1061-1069.

4.1.10 England, North Sea experiment

Transport of SF6 from a South Yorkshire power station over the North Sea. References: A. S Kallend and J. Crabtree, 'The fate of atmospheric emissions along plume trajectories over the North Sea; Final Report'. Leatherhead: Central Electricity Research Laboratories TPRD/L 2340/R82, 1983 and J. Crabtree in the 13th NATO/CCMS Conference (1982), and J. Crabtree in Air Pollution Modelling and its Applications III, Plenum Press, p. 129-138.

4.1.11 England, Windscale Accident, 1957

References. J. Crabtree, 'The travel and diffusion of the radioactive material emitted during the Windscale accident', Q. J Roy. Met. Soc. '85(362), 1959; A.C. Chamberlain, 'Deposition of iodine-131 in Northern England in October 1957',Q. J. Roy. Met. Soc., 85(350), 1959; J. Gray et al., 'Discharges to the environment from the Sellafield site 1951-1992', J. Rad. Prot., 15(2), 1995.

4.1.12 *Europe, TRACT-TRANSALP experiments, 1989-1992*

TRACT relates to mesoscale transport of pollutants to distances of 100's of kilometers TRANSALP consisted of three campaigns in the middle of the Alps. Only in the third (1991) of the TRANSALP experiments, tracer (PFC) was released from the northern edge of Lake Lucerne and measured over distances larger than 100 km to Lake Maggiore in Italy. In the other two campaigns (1989, 1990) the range of distances was considerably lower (40 km). Aircraft measurements were also performed Data available: Data bank of the experiment is available at JRC Ispra by request from Dr. G Graziani (giovanni.graziani@jrc.it) Reference: Special Issue on Transport of Air Pollutants over Complex Terrain (TRACT), Atm. Environ , Vol 32, April 1988, pp 1141-1352.

4.1.13 Europe, the Oeresund Experiment, 15 May - 14 June, 1984

Nine tracer experiments were performed during the campaign. In each of them, the tracer (SF6) was released close to the upwind coastline and sampled in the Oeresund, at the downwind coastline and further inland. Data availability: data-bank of the experiment is available at Risoe. Dr S.E. Gryning, sven-erik.gryning@risoe.dk. Reference: The Oeresund Experiment Data bank, ISBN 87-550-1592-1

4.1.14 Antarctic, June and October 1984

Four releases (January, June, and October) from aircraft of heavy methane and 3 day sampling at 8 ground-level locations up to 60 days after the release. Some limited aircraft sampling during the period. Advantage: transport and dispersion in a unique environment in both winter and summer Limitation: not all samples were analyzed, to reduce experimental cost. Data: supplemental data tables on microfiche from AGU. Reference: E.J. Mroz et al., 1989, J Geophys. Res., 94(D6)8577-8583.

4.2 Uncontrolled Releases (generally only satellite data available)

There are perhaps more questions than answers with regard to these events. Bushfires and volcanic eruptions certainly need to be treated differently. Emission heights need to be estimated from the satellite archives. It is important to distinguish between cloud and ash. Different events will have different lifetimes, the time during which a clear distinction can be made of the plume from the background. Picture resolution will depend on whether the event occurs during the day where the higher resolution VIS images are available or at night when infrared is available IR images may have to be processed to obtain brightness temperatures and thus approximate release height. The frequency at which the images are to be archived (to reduce storage requirements) should be determined from the temporal evolution of the plume.

4.2.1 USA, Mt St. Helens eruption, 1979

Extensive satellite and ground observations were made during the event. References: Satellite images of the Mount St. Helens cloud can be found at Holasek and Self (1995) GOES weather satellite observations and measurements of the May 18, 1980, Mt St. Helens eruption, Journal of Geophysical Research 100: 8469-8487, http //www.geo.mtu.edu/eos/ppages/self html(*); also J. Crabtree and M. Kitchen, Atm Environ., Vol. 18, No. 6, 1984.

4.2.2 Philippines, Mt. Pinatubo eruption, 1991

References Holasek RE. S Self, and AW Woods (1996) Satellite observations and interpretation of the 1991 Mount Pinatubo eruption plumes. J Geophys. Res. 101, 27635-27655.

4.2.3 Kuwait, Oil Fire smoke plume, 1991

Reference: J.T. McQueen and R.R Draxler, 1994, Atm Environ., 28:2159-2174; K.A. Browning et al , Nature, May 1991, 351, 363-367.

4.2.4 Recent Events

Some of the more recent events have not yet been well documented in the literature, but certainly images could be retrieved from satellite archives These could include events such as the Papua New Guinea Rabual eruption (1994), the New Zealand Ruapehu eruption (1996), bushfire smoke from Kalimantan, Sumatra, Irian Jaya, Papua New Guinea (1997), and the China Dust Cloud (April, 1998).

4.3 Other potential experimental data

Balloon flight data provide an opportunity to test only the transport component of a model, rather than both transport and dispersion However, in addition to balloon position, the altitude must be known as well, which is usually tabulated with the controlled balloon experiments for various research projects such as the ACE 1 experiment near Tasmania in 1994 (J. Geophys Res , 1988, 103:16,297-16,758), the Smith/Kavanagh balloon trajectories over Australia in 1993 (Mills et al , 1994, Aust. Met Mag . 43:29-39), the February 1995 Fossett trans-Pacific manned flight (Weather and Forecasting, 1996, 11:111-114), a European balloon race (K.Baumann and A. Stohl, 1997, J. Appl Meteorol , 36 711-720), and some tetroon releases in the central US (W A. Hoecker, 1977, J. Appl Meteorol., 16 374-383) Recent manned balloon flights by Fossett over the North and South Atlantic and the recently completed ACE-2 experiment can also be added to the list when data become available Other balloon experiments of opportunity do not always have detailed height data available such as the 190,000 small helium balloons that were released in May 1986 all over the USA, of which 8,000 were found and their final position reported (R.A. Stocker, et al., 1990, J. Appl. Meteorol. 29:53-62).

5. Data Processing Requirements

In general the space requirements of the sampling data will be small compared with the meteorological data fields that will accompany each experiment. There will be some effort required to digitize any data not already in that form and reformat those that are already in digital format. Space estimates for meteorological data (shown below) are quite modest for the low resolution fields (2.5 deg) and still reasonable for the high resolution data (1 deg), in that at least all the major tracer experiments should fit on one 640 Mb CD.

Experiment	Domain Lat x Lon	Period Days	Low-Res Mb	Hi-Res Mb
Idaho	30 x 40	90	15	60
Oklahoma	20 x 30	5	1	5
CAPTEX	15 x 25	20	1	5
ACURATE	15 x 15	570	15	75
Chernobyl	40 x 60	30	10	40
ANATEX	30 x 60	90	20	80
Mohave	10 x 20	80	2	10
ETEX	30 x 40	5	1	5
Total			65	275

The effect of the addition of satellite data to the archive is uncertain, but the addition of one or more CDS would not diminish is practical applications. The greatest cost of the satellite data would be the processing required to standardize the images.

6. Statistical Analysis and Display Software

The statistical package could be included in two versions, one that may be based on a common proprietary software that might already be available to many researchers (e.g. IDL, SAS, NCAR graphics, etc.) and which would include some graphical routines as well and a non-proprietary version which will allow modelers to analyze and display their results in a common format to facilitate inter-model comparisons. These could be pre-compiled programs for Windows PCS or C or Fortran source code that could be compiled on Unix workstations. Recent developments in statistical model comparisons, in particular the ETEX data, demonstrated how model evaluations could be taken beyond the time and station paired methods to temporal and spatial pattern matching approaches.

7. Work Plan Guidelines

At this point it is uncertain where and how the work to develop the database should be accomplished It is possible to estimate the costs required to complete the database. Perhaps an existing government, research laboratory, or contractor, could be enlisted. Scientific oversight is required. In general the tasks are summarized below with a gross estimate of the man-months effort for each component, some of which could be completed concurrently.

7.1 Creation of the final work plan by the project team

This would include the results of a comprehensive literature search for suitable experiments, the final technical specifications, and element should be harmonized with budget Effort: 3 months.

7.2 Development of a standard electronic format

This will encompass all the different experimental data with specific application programs for each experimental data set to create a common format product. If digital copies of the data are not available it will be necessary transcribe published results to electronic form. Effort: 6 months.

7.3 Meteorological data

Meteorological data that corresponds to the spatial domain and period of the experiment should be obtained from one of the re-analysis projects and extracted, and re-packed into a common format for all experiments. Effort: 6 months

7.4 Satellite data

The satellite data will provide images primarily for qualitative verification at this stage. With the launch of POLDER, TOMS, OCTS, MODIS, and MISR instrumentation, quantitative verification of aerosol transport and dispersion may soon be possible. However there should be at least 3 images per event and it would include both VIS for higher resolution (when possible) and IR for temperatures Resolution should be sufficient to extract plume position information but with a conscious effort to conserve storage volume. Effort: 9 months.

7.5 Guidelines

Provide guidelines for model developers to also output their results in a standardized format. Rewrite existing statistical analysis and display software to access both Experimental and model data and provide software either as an executable that can be run on a common platform (i.e. Windows PC) or provide code (C or Fortran) that could be compiled and run at each of the modelling centers. Effort: 6 months.

7.6 Copies of CD

Arrange for multiple copies of the CD and distribution to a wide audience, perhaps in conjunction with an article in a major international journal. WMO would sponsor a model verification symposium inviting participation through the journal article. Effort: 6 months

8. Funding Sources

This report, with the recommendations of the CAS Working Group on Environmental Pollution and Atmospheric Chemistry, should be distributed by WMO to the IAEA, ICAO, and other national and international agencies interested in long-range pollutant transport. As part of the issue regarding finding sources of funding it is necessary to identify who will actually do the work. This may simplify the funding uncertainty For instance, financing could be sought in the next Cost-Shared-Actions programme of EC DG XII (Environment and Climate) that starts next year. Perhaps if one major funding source were identified, others would be more willing to contribute toward to the project's completion.

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