Department of the Environment and Heritage

Air Quality Forecasting

for Australia’s Major Cities

2nd Progress Report

Prepared by Project Management Committee
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The Director
Air Quality Section
Environment Protection Group
Environment Australia
The Administrative Building
King Edward Terrace, Parks ACT 2600

Attention Ms Chris Schweizer

Dear Ms Schweizer,

Re: Air Quality Forecasting for Australia's Major Cities — Second Progress Report

We are pleased to present the second progress report for the Australian Air Quality Forecasting System. The report is a compilation of progress reports for each of the four collaborating organisations for the project and managed by CSIRO Atmospheric Research. The project team comprises:

Environment Protection Authority (Victoria)
Environment Protection Authority of NSW
Bureau of Meteorology Research Centre
CSIRO Energy Technology and
CSIRO Atmospheric Research

Introduction

A description of the Project, its Management Structure and the Work Schedule are described in the Appendix immediately following this Main Report.

Progress

This Report essentially indicates progress up to Phase 2, though some work in meeting objectives for Phase 3 is reported by EPA Victoria. This should be expected in a project where internal priorities change and allow some components to run faster than others.

Progress has been good. The following sections summarise this. Appended are copies of several publications / presentations that members of the Team have prepared.

The following highlights are especially interesting:

- The latest version of the Victorian emissions inventory from EPA is now being used in the modelling system. It includes all point sources in the region.
- Biogenic VOC emissions and sea salt aerosol emissions are computed online in response to meteorological conditions. Other components are to follow.
- The Chemical Transport Model is now working in spherical coordinates, in preparation to being fully integrated with the enhanced LAPS meteorological model.
- Trialing of the prototype system in parallel with the pilot system is presently underway.
- The preliminary version of the web site is operating and will become available to participants in the next Phase.
- The enhanced LAPS meteorological model is currently being tested in the Victorian domain and verification procedures have been devised.
- A presentation to EPA NSW on progress with the Forecasting System and on measurement of biogenic VOC emissions from grasses and trees is included as an attachment.

Project Developments

A closed web site for the AAQFS is now running, as discussed in the CSIRO Report. It should be an important source of information on the development of the project, and will hold forecast fields as they are developed and will show a variety of kinds of presentations. We will be seeking feedback about the development and the best ways to present information.

Issues of Note

Dr Phillip Morgan, Manager, Air Quality Unit of Department of Environmental Protection, Western Australia, has agreed to be the Project Reviewer. His role is to provide an external perspective to the Committee.

For and on behalf of
AAQFS Management Committee

(Dr) **Peter Manins** PSM, FTSE, CCM, QEP

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Emissions Inventory

Phase 2 – Detailed Victorian Inventory

The bulk of the Victorian Inventory is complete. There are still some outstanding data issues, which are described in more detail below. Computer files have been provided to CSIRO including a description of the data format.

Major industrial point sources have been added to the inventory database. The biogenic inventory has been completed and entered into the database. The motor vehicle inventory for Victoria is also complete.

The area based emissions inventory is complete except for a delay in establishing a protocol to receive the prescribed burning and wild fires data. EPA Victoria has obtained historical data but this is not useful for the system. Further discussions are continuing with the Department of Natural Resources and Environment and the Country Fire Authority. It is hoped that the data will be obtained on a daily basis from these organisations in an electronic format that will link directly into the system to avoid manual input of data.

The Victorian-wide inventory is the largest and most detailed inventory compiled in Australia to date. The data format allows the inventory to show the regional differences in emissions. This is important for emission sources like domestic wood combustion where rural areas will have greater activity that the urban regions.

Phase 3 –Run Time System Development and Sydney Inventory

The development of the run time system is progressing. System documentation has been written including program descriptions and a data dictionary. The model has been broken into six modules:

- Point source
- Area source
- Biogenic source
- Motor vehicle
- Wildfire and prescribed burning
- Speciation.

Note that in the 1st progress report, it was stated that EPA Victoria would develop the wind blown dust module. LAPS will supply all data for calculating wind blown dust. CSIRO AR will now develop this module due to their much greater knowledge of LAPS.

The point source module has been completed. The base point source data files have been run through the module and the output data have been quality assured. EPA Victoria is awaiting access to the NEC supercomputer to test the point source module and to begin integrating the module with the on-line forecasting system.

The motor vehicle module development is halfway complete. The base data files have been created and the processor development is continuing.

The area based module is 60% complete. The spatial and temporal processors are finished. The temperature correction processor, which adjusts certain emissions in response to temperature, is complete.

A paper proposing the means of integrating the emissions estimated from the motor vehicle module and the power-based module has been forwarded to CSIRO ET. Further discussions to finalise the method are needed.

The Sydney inventory data collection is continuing. Area based, motor vehicle and biogenic data have been received from the NSWEPA. The Sydney point source inventory will be provided once the contract between CSIRO and NSWEPA is signed. Growth factors that will allow the 1993 Sydney inventory to be projected for 1999 are expected soon. Discussions into the issues around the gridded population data are underway. Processing of the Sydney inventory into a format that is compatible with the inventory modules will start at the end of September.

Meteorological Data

1-hourly ambient data (first level validation) are being provided to the Bureau of Meteorology on a daily basis from all stations within the Port Phillip Control Region. The data are being used to validate LAPS modelling.

Air Quality Data

EPA Victoria is also providing CSIRO with first level validated 1-hourly ambient data on a daily basis from all stations within the Melbourne Basin. The data are being used for preliminary validation of air quality forecasts.

Vertical Profiling for Melbourne

The site location of the Acoustic sounder has not been finalised. The new proposed site is at the Werribee Treatment Plant owned by Melbourne Water. EPA is currently waiting on approval from Melbourne Water to locate the Acoustic sounder to the Werribee site. The device is expected to be running in about two month's time. Once these issues have been rectified, the data can be provided to CSIRO and BoM

CSIRO Atmospheric Research

2nd Progress Report

CSIRO Atmospheric Research

2nd Progress Report

Martin Cope[1,2], and Sunhee Lee[1]

[1]CSIRO Atmospheric Research, [2]CSIRO Energy Technology,

Development of the Australian Air Quality Forecasting System- Air quality modelling component.

1 Introduction

In this progress report, we summarise the work completed during Phase Two of the reporting cycle of the AAQFS project. Key tasks of this phase included the replacement of the 1990 Melbourne emissions inventory with a state-of-knowledge Melbourne / Victoria inventory, the development and testing of algorithms for source groups with strong meteorological dependencies, and the initial trialing of the prototype air quality forecasting system for Melbourne / Victoria. These tasks are discussed in Section 2. In addition, we have continued the development of the AAQFS web site, we have undertaken a presentation on the AAQFS to personnel at EPA-NSW, and we have prepared an AAQFS status paper for presentation at the International Congress of Biometeorology and International Conference on Urban Climatology – ICUC-UBC (Macquarie University, NSW- November 1999). The web site development work is discussed further in Section 3.1 and copies of the EPA-NSW PowerPoint presentation and the ICUC-UBC paper have been appended to the main report.

2 Key Tasks

2.1 Emissions inventory upgrade

The Victorian Environment Protection Authority (EPA-VIC) has provided a preliminary version of the 1996 Melbourne / Victorian emissions inventory (EPA-VIC 1998) for motor vehicle, population-based and industrial source groups. This inventory replaces the 1990 inventory (Carnovale et al. 1991), which has been used in the pilot system since testing first commenced in May 1998. The inventory was gridded onto a spherical coordinate system in the horizontal (i.e. principal axes are positioned along lines of constant latitude and longitude) with a grid spacing of 0.05 degrees ($\approx$ 5 km). The inventory comprised 140 $\times$ 190 cells (latitude $\times$ longitude) and covered a region that extends from –41° S to –34.05° latitude and 141° E to 150.45° E longitude (Victoria-wide coverage). Twenty-one species were specified, including NO_x, CO, SO_2, volatile organic compounds (VOCs), and two lumped particulate groups (PM2.5 and PM10). The VOC species consist of eight functional groups, lumped according to the requirements of the Carbon Bond IV photochemical reaction mechanism (Gery et al. 1989). The inventory also includes three air toxic species (1,3-butadiene, benzene and formaldehyde) and ammonia. Emissions may be considered to be representative of average weekday summer conditions.

Integration of the new inventory into the AAQFS framework required the development of software to read and convert the inventory data sets to the default CTM (Chemical Transport Model) format. It was also necessary to lump the CBIV VOC species into a single, reactivity-weighted VOC as required by the GRS mechanism. Furthermore, as discussed in Section 2.4, use of the new inventory entailed that the CTM horizontal coordinate system be reformulated from equi-distance to spherical. This step also had to be propagated through the entire CTM pre- and post-processing system.

Note that the prototype AAQFS testing is currently being undertaken for a subset of the Victorian inventory (Figure 1). Operation of the AAQFS for the entire Victorian domain will commence at a later stage following further speed-based optimisations of the CTM software.

2.2 Meteorologically dependent emissions

Progress has been made in the development and testing of modules for the prediction of emissions from source groups with a strong meteorological dependency. AAQFS source groups, which fall into this category, include:

1. Biogenic VOC emissions (i.e. isoprene emissions from eucalyptus trees),
2. Emissions of NO_x from soils.
3. Wind blown dust.
4. Sea salt aerosols.

During this reporting period, online testing was undertaken using modules for source categories (1) and (4). A brief description of these algorithms is now given.

2.2.1 Biogenic emissions of VOC

The EPA-VIC is in the process of developing a comprehensive, real-time biogenic emissions algorithm, which is based on the BEIS series of models (Birth 1995). While this work is in progress, preliminary online testing has been undertaken using a simpler model, which was developed for airshed modelling studies in NSW and Western Australia (Carnovale et al. 1996; Cope and Ischtwan 1995). According to this model, biogenic emissions of isoprene and monoterpenes (as α-pinene) may be estimated as follows:

$$E(VOC)^i_{LS} = [f_{dg} \bullet q_{dg} + (1 - f_{dg}) \bullet q_{ndg}] \bullet bm^i_{LS} \bullet V_f \bullet C_L \bullet C_T \qquad (1)$$

where $E(VOC)^i_{LS}$ is biogenic VOC mass emission flux (g m^{-2} s^{-1}) for landscape category *i*.

Here, q_{dg} is the mass emission rate of the dominant genera per gram of foliage (g g^{-1} s^{-1}) at a standard temperature of 30°C and a photosynthetically active radiation (PAR) flux of 1000 µmol m^{-2} s^{-1}, and q_{ndg} is the mass emission rate of the non-dominant genera per gram of foliage (g g^{-1} s^{-1}) at a temperature of 30°C and a radiation flux of 1000 µmol m^{-2} s^{-1} and bm^i_{LS} is the leaf biomass for the defined landscape category (g m^{-2}). Furthermore, f_{dg} is the biomass fraction of the landscape category assigned to the dominant genera, V_f is the fractional spatial coverage of the vegetation landscape within a grid cell, and C_L, C_T are functions to correct the standard emission fluxes to other temperatures and radiation fluxes.

Further details regarding the form of (1) can be found in the previously cited references. In the prototype AAQFS, biogenic VOC emissions are estimated on an hourly basis for every land-based grid point using equation (1), together with a gridded database of landuse category and the LAPS forecasts of leaf-level temperature and radiation. An example of the calculated biogenic VOC emission rates is shown in Figure 2 for the Victoria domain, where the 2-D spatial distribution (for hour 12), and a 1-D time series of lumped isoprene and monoterpene emission rate for 6 September 1999 are plotted. Note that the emission rates are relatively small because of the low (12-15°C) ambient temperatures that were present at the time.

2.3 Emission of sea salt aerosol

The flux of sea-salt aerosol is estimated according to the methodology described in Gong et al. (1997) and references therein. If it is assumed that bubble-bursting is the primary aerosol production method, then a size-segregated emission flux may be parameterised as follows (O Ɗowd et al., 1997):

$$dF_0/dr = 1.373 U_{10}^{3.41} r^{-3} (1 + 0.057 r^{1.05}) x 10^{1.19 e^{-B^2}} \qquad (2)$$

where dF_0/dr is the particle density function (particles m^{-2} s^{-1} μm^{-1}), r is the particle radius (μm), U_{10} is the wind speed at 10 m above sea level and $B = (0.380 - \log(r)) / 0.650$. The cumulative mass emission flux is obtained by integrating (2) over the desired size range (here $0.01 - 10$ μm). In the prototype AAQFS, the flux of sea salt aerosol is determined on an hour-by-hour, cell-by-cell basis (for grid cells located over the ocean) using the LAPS 10 m windspeed forecast.

2.4 CTM enhancements

In order to effectively run the chemical transport model using the updated emissions inventory, it was necessary to convert the horizontal coordinate system of the CIT photochemical airshed model from equi-distance to spherical.

This has been done using the methodology described in Toon et al. (1988) in which geometric scaling factors (map factors) are introduced into the governing equations. This can be seen through consideration of the governing equation for the equi-distance version of the CIT photochemical airshed model (here simplified to one species and flat terrain)

$$\frac{\partial C}{\partial t} + \frac{\partial uC}{\partial x} + \frac{\partial vC}{\partial y} + \frac{\partial wC}{\partial z} = \frac{\partial}{\partial x} K_{xy} \frac{\partial C}{\partial x} + \frac{\partial}{\partial y} K_{xy} \frac{\partial C}{\partial y} + \frac{\partial}{\partial z} K_z \frac{\partial C}{\partial z} + (P - L). \qquad (3)$$

Here C is the species concentration, u is the x-component wind speed, v is the y-component wind speed and w is the vertical component of the wind speed, K_{xy} is the horizontal eddy diffusivity, K_z is the vertical eddy diffusivity, P is the rate of change due to chemical production and L is the chemical loss rate.

We now introduce the horizontal map factors $M_1 = \cos(q)$, $M_2 = 1$ and $M_3 = R_{earth}$, where q is the grid point latitude and R_{earth} is the Earth's mean radius. Using the scaled distance increments $dX = M_3 dx$ and $dY = M_3 y$, the scaled velocity components $U = u/M_1$, $V = v/M_2$, the scaled horizontal diffusivity $K_x = K_{xy}/M_1^2$ and $K_y = K_{xy}/M_2^2$ and the scaled concentration (when expressed as a mass density) $C^* = C \times M_1 M_2$, the governing equation can be expressed in horizontal spherical form

$$\frac{\partial C^*}{\partial t} + \frac{\partial UC^*}{\partial X} + \frac{\partial VC^*}{\partial Y} + \frac{\partial wC^*}{\partial z} = \frac{\partial}{\partial X} K_x \frac{\partial C^*}{\partial X} + \frac{\partial}{\partial Y} K_y \frac{\partial C^*}{\partial Y} + \frac{\partial}{\partial z} K_z \frac{\partial C^*}{\partial z} + (P - L) M_1 M_2 \tag{4}$$

where dX is longitude increment and dY is latitude increment. Note that expressing the CTM in this form is highly advantageous because it removes the need to map the LAPS meteorological forecast fields (which are already in a spherical coordinate system) to an alternative horizontal coordinate system. This has a number of benefits, including the implicit retention of the mass conservation properties inherent in the LAPS flow fields.

2.5 Prototype testing

The prototype forecasting system is now undergoing testing in Victoria. The prototype system uses the 1996 Melbourne/Victoria emissions inventory, and the online algorithms for the determination of biogenic and sea salt emission fluxes. All components of the system now operate with the same horizontal coordinate system. Although meteorological and emission estimates are now available for all of Victoria, air quality forecasts are currently only available for a subset of this domain, for reasons of computational efficiency. A typical output from the system is shown in Figure 3 where the forecast concentrations of PM10 have been plotted for a number of hours on 6 September 1999. Note how the Melbourne plume is predicted to impact over a significant proportion of the Victorian domain.

Although the prototype system is now able to run on a daily basis for Victoria, it is still intended, in the short term, to continue to forecast air quality using the pilot AAQFS. The simultaneous operation of both systems for a period of one to two months will enable the forecasts of the prototype system to be checked for consistency. Such checks are essential for ensuring that the prototype system has been correctly configured.

3 Other tasks

3.1 Web Site development

As mentioned in the introduction, work has continued on the construction of an AAQFS web site. The program of web site development has two major goals

1. Provision of a forum for conveniently passing information between members of the project team during the development phase of the AAQFS.

2. Provision of a forum for showcasing the AAQFS technology to the wider public during the demonstration phase of the project. The site will also be used to provide forecast data to the EPAs on a daily basis for use in combination with their existing forecasting schemes.

In the case of (1) access to the AAQFS web site will be restricted to personnel at CSIRO, BoM, EPA-VIC and EPA-NSW. The web site will be maintained by CSIRO during this stage.

In the case of (2) the site will be substantially enhanced using resources from both CSIRO and BoM. Note that the latter organisation will eventually take over management of the site. However, dissemination of air quality forecasts for each state will still be controlled by the EPAs.

A schematic diagram of the web site layout as developed for stage (1) is shown in Figure 4 and the introductory screen is in Figure 5. It can be seen that the site contains information regarding the project goals, team members, and system layout. The web site also contains air quality forecasts for Melbourne and Sydney. These forecasts, which are updated on a daily basis, consist of 2-D ground-level concentration isopleths of NO_x and O_3 (Figure 6). It is planned to expand the site to include PM_{10} and a range of meteorological fields in the near future.

The forecast for 'yesterday' is also provided, together with plots of observed and forecast 1-hour air quality time series for monitoring sites in Sydney and Melbourne (Figure 7). Observed and forecast near-surface and upper level wind and temperature forecasts will also become available in the near future.

The resource section of the web site will contain journal and conference papers written by members of the project team together with extracts from the progress reports prepared for Environment Australia. All reports will be available for download in pdf format. The resources section will also contain links to groups in other Australian states and other countries who are also developing or operating air quality forecasting systems.

The final component of the web site is a logbook of work in progress, and of milestones achieved. The purpose of the logbook is to provide an up-to-date indication of progress.

3.2 PowerPoint Presentation

See appendix in main report

3.3 ICUC-UBC '99 Paper

See appendix in main report

4 References

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Gery M. W., Whitten g.Z., Killus J.P. and Dodge M.C., 1989. A photochemical kinetics mechanism for urban and regional scale computer modelling. *J. Geophys. Res.*, **94**, 12925-12956.

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O'Dowd C.D., Smith M.H., Consterdine I.E. and Lowe J.A., 1997. Marine aerosol, sea-salt and the marine sulphur cycle: A short review. *Atmos. Environ,*. **31**, 73-79.

Toon O.B., Turco R.P., Westphal D., Malone R. and Lui M.S., 1988. A multidimensional model for aerosols: description of computational analogs. *J. Atmos. Sci.* **45,** 2123-2143.

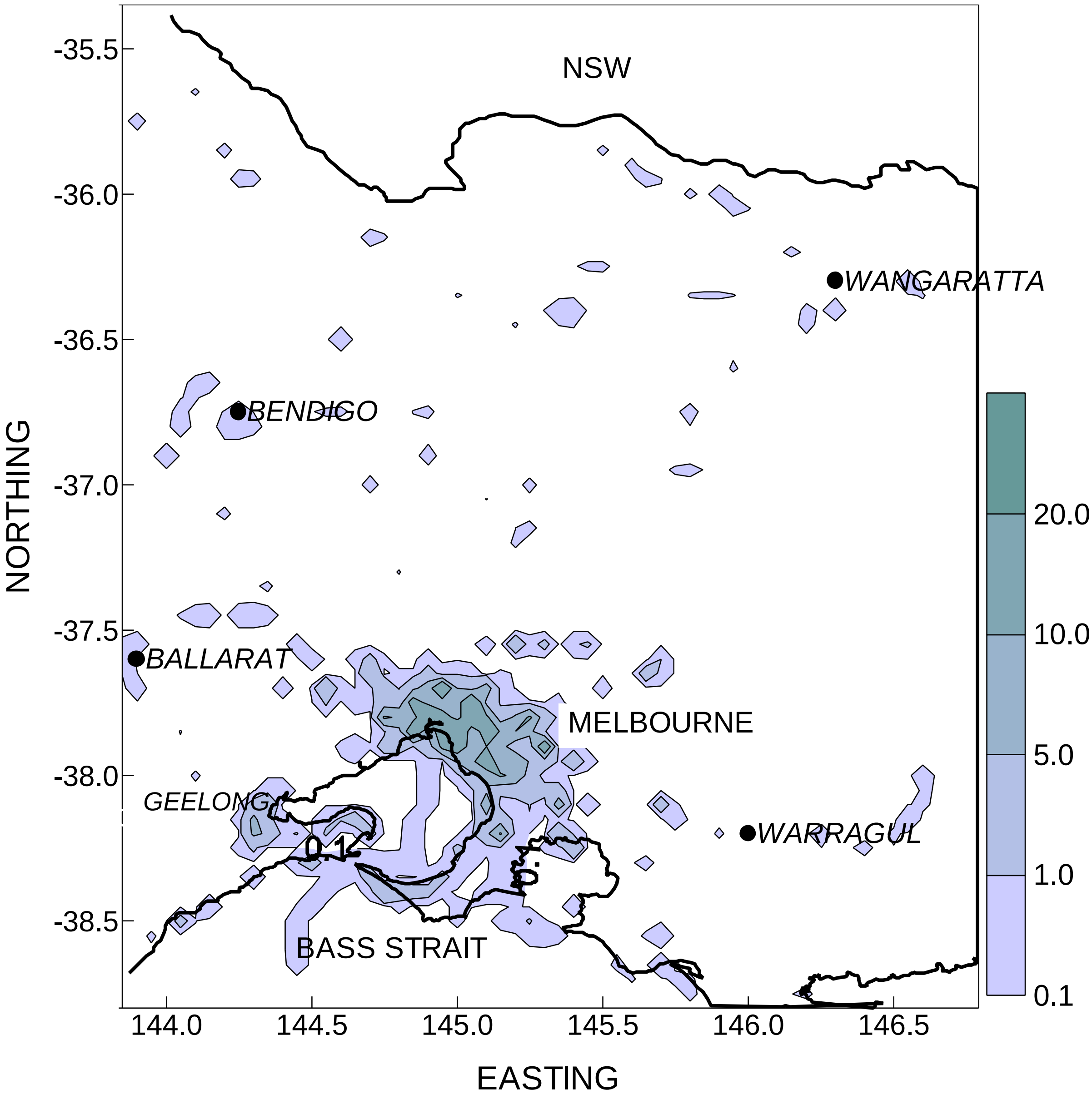


Figure 1: Modelling domain used by the AAQFS for testing the preliminary Victoria-wide emissions inventory. Also shown is the spatial distribution of PM10 emissions (g s^{-1} per 0.05° x 0.05° cell) for hour 9 from mobile sources (note the shipping lanes), industry and population-based area sources.

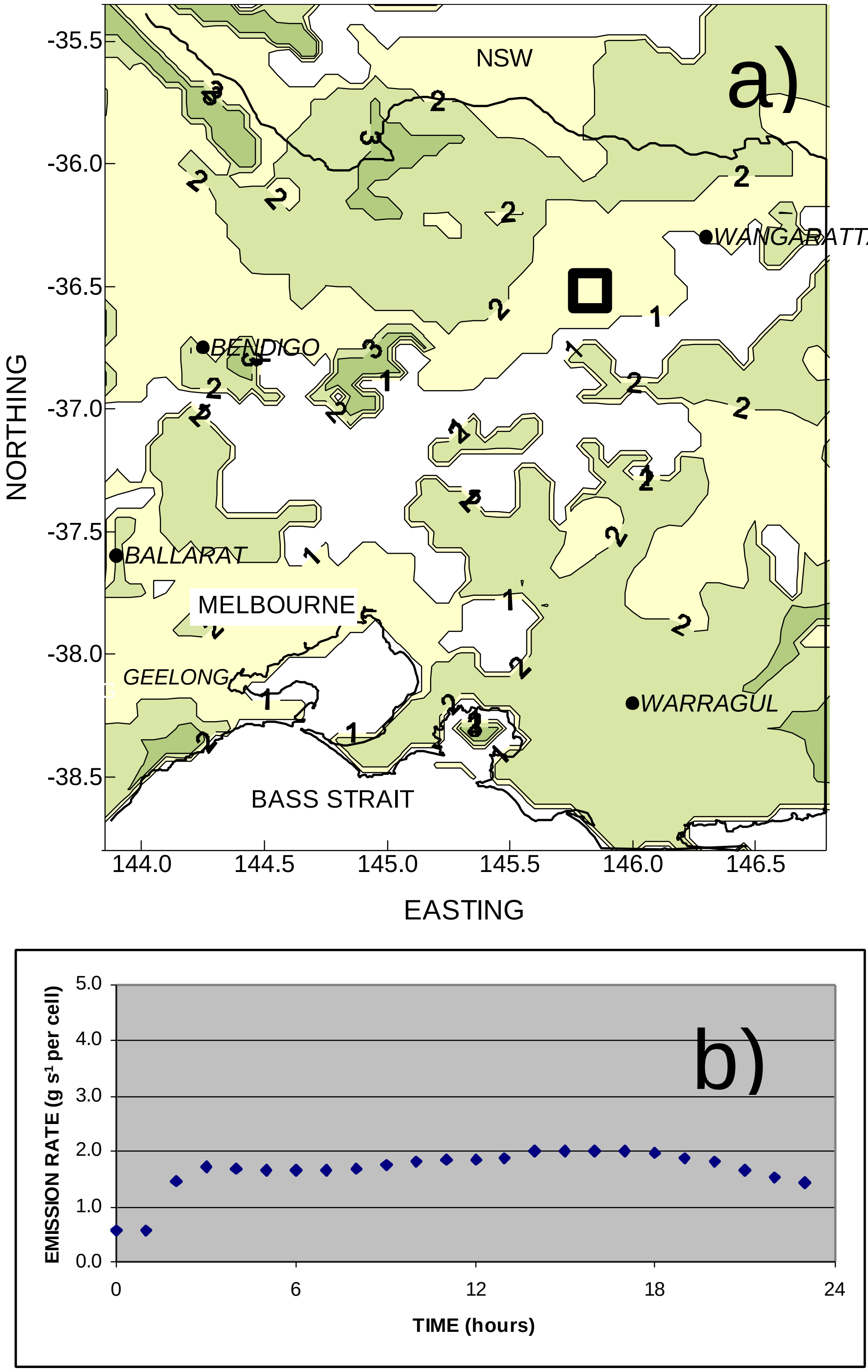


Figure 2: Spatial (a) and temporal (b) distribution of biogenic VOC (isoprene + monoterpenes) emission rates (g s^{-1} per 0.05° x 0.05° cell). Emission rates were calculated using the meteorological forecast for 6 September 1999. The time series plot corresponds to the emissions from a cell in the boxed area shown in (a).

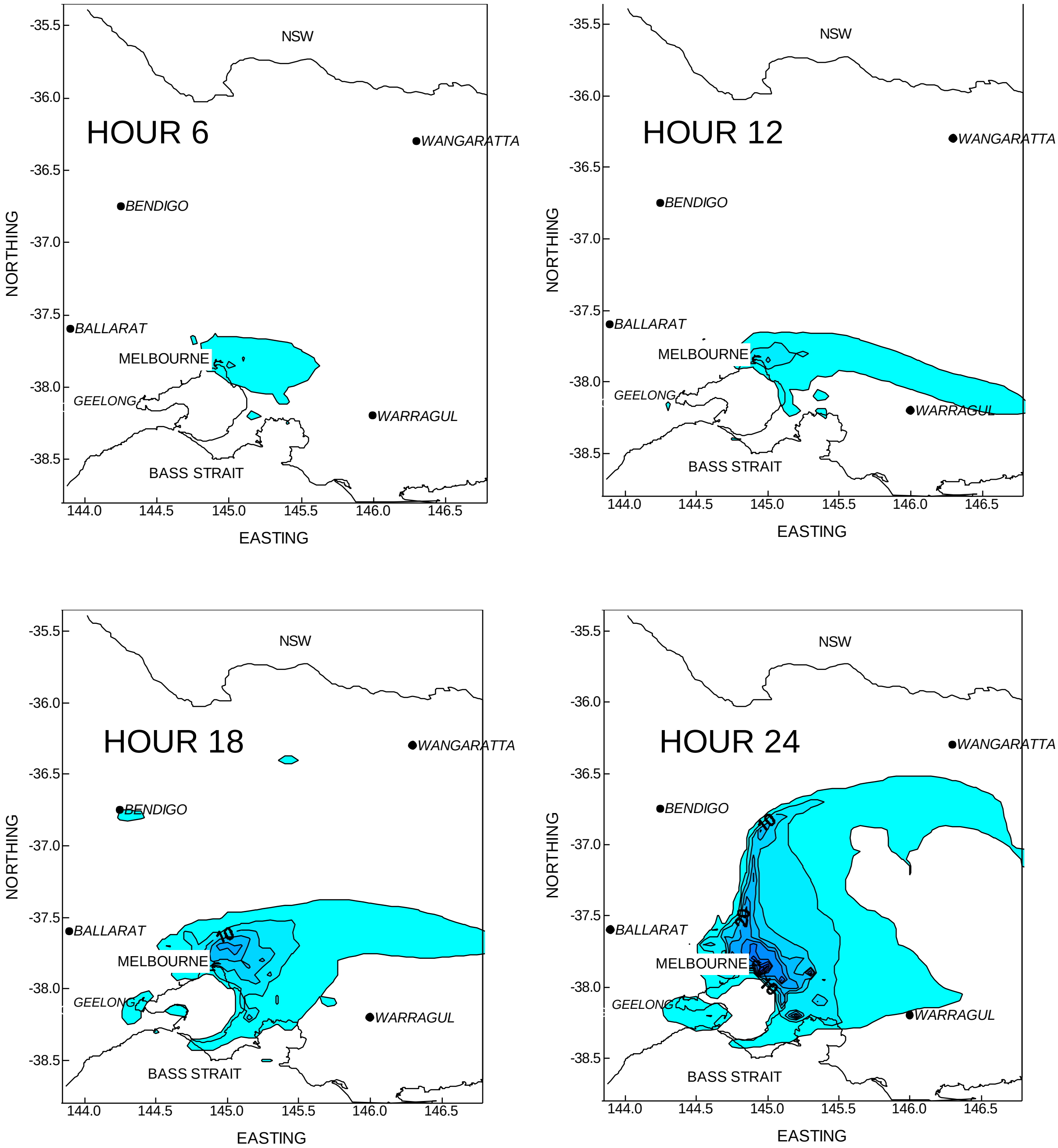


Figure 3: One-hour concentrations of PM10 (mg m^{-3}) as forecast for selected hours on 6 September 1999. The forecast was generated using the prototype forecasting system described in the text.

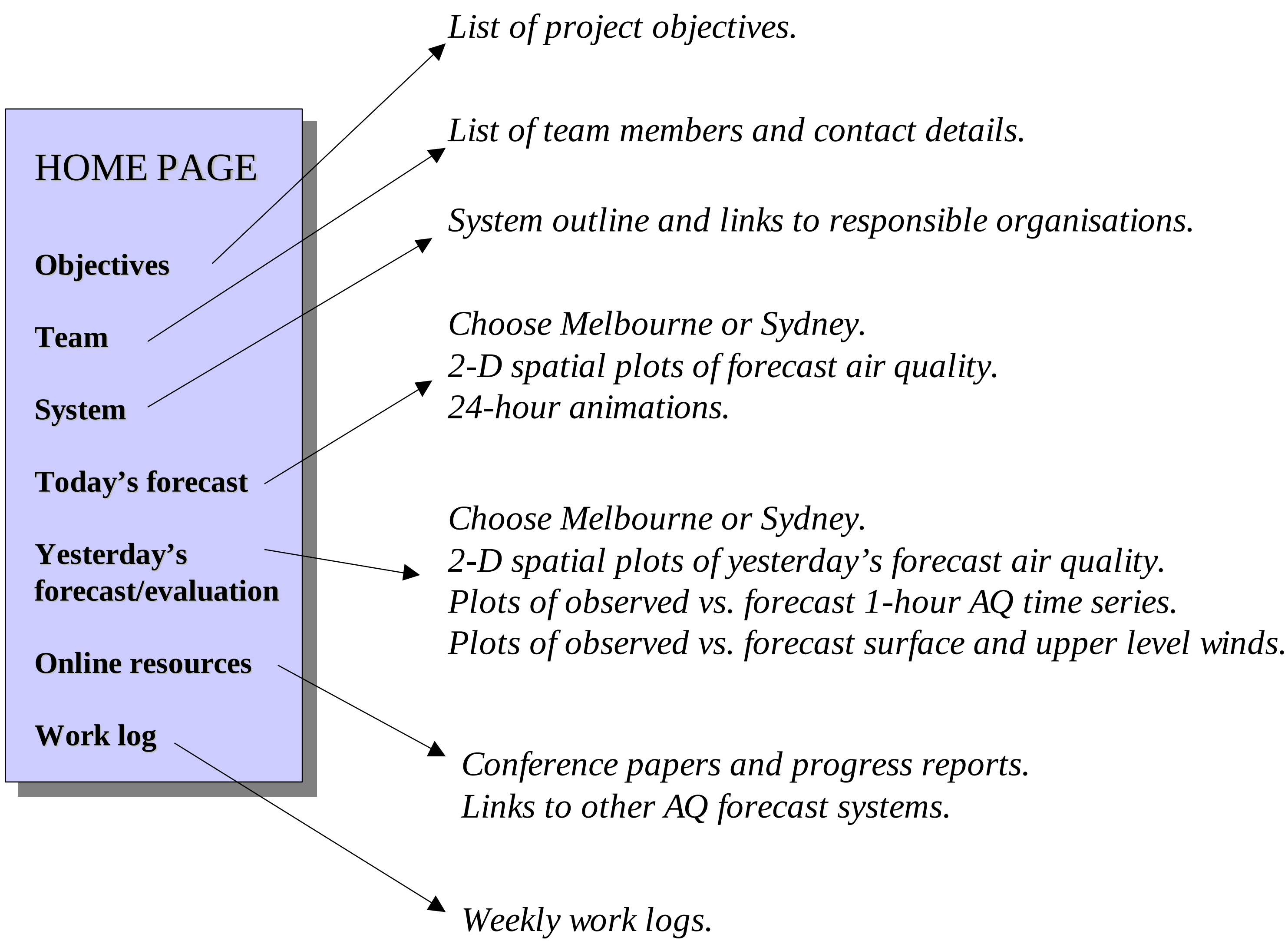


Figure 4: Schematic of AAQFS web site as configured for the project development stage.

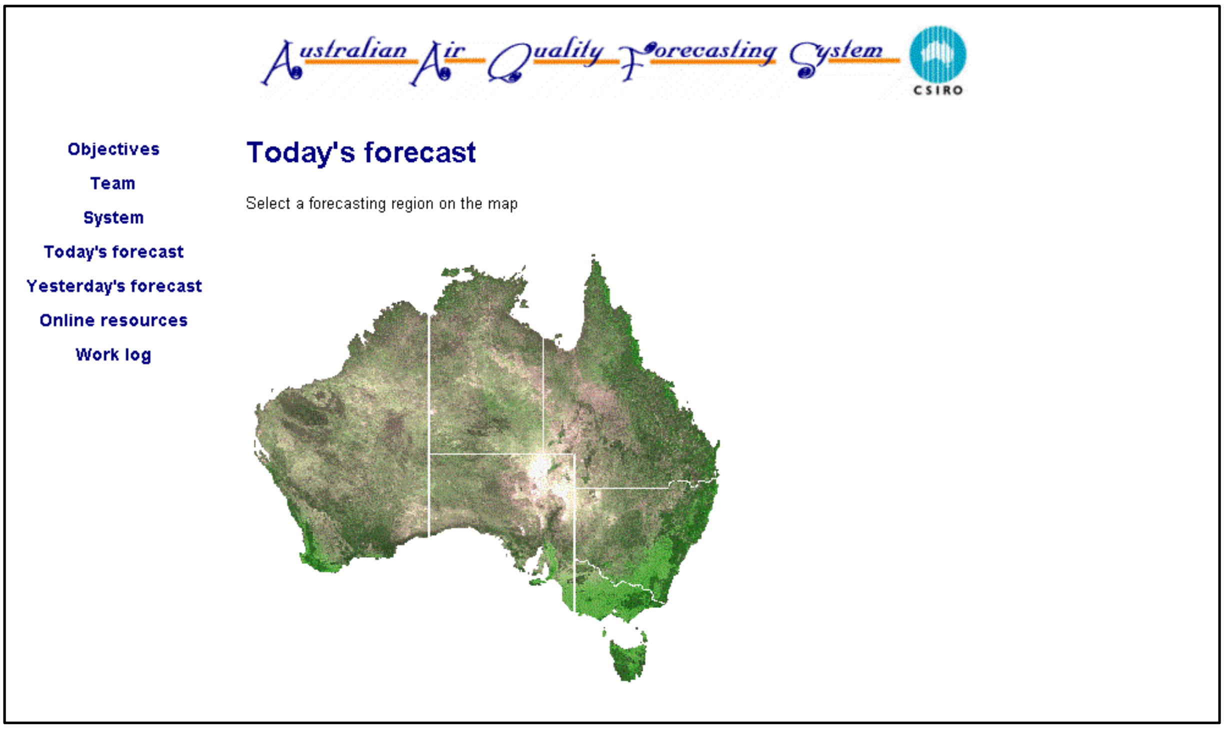


Figure 5: An example of the home page and forecast-selection page on the AAQFS web site.

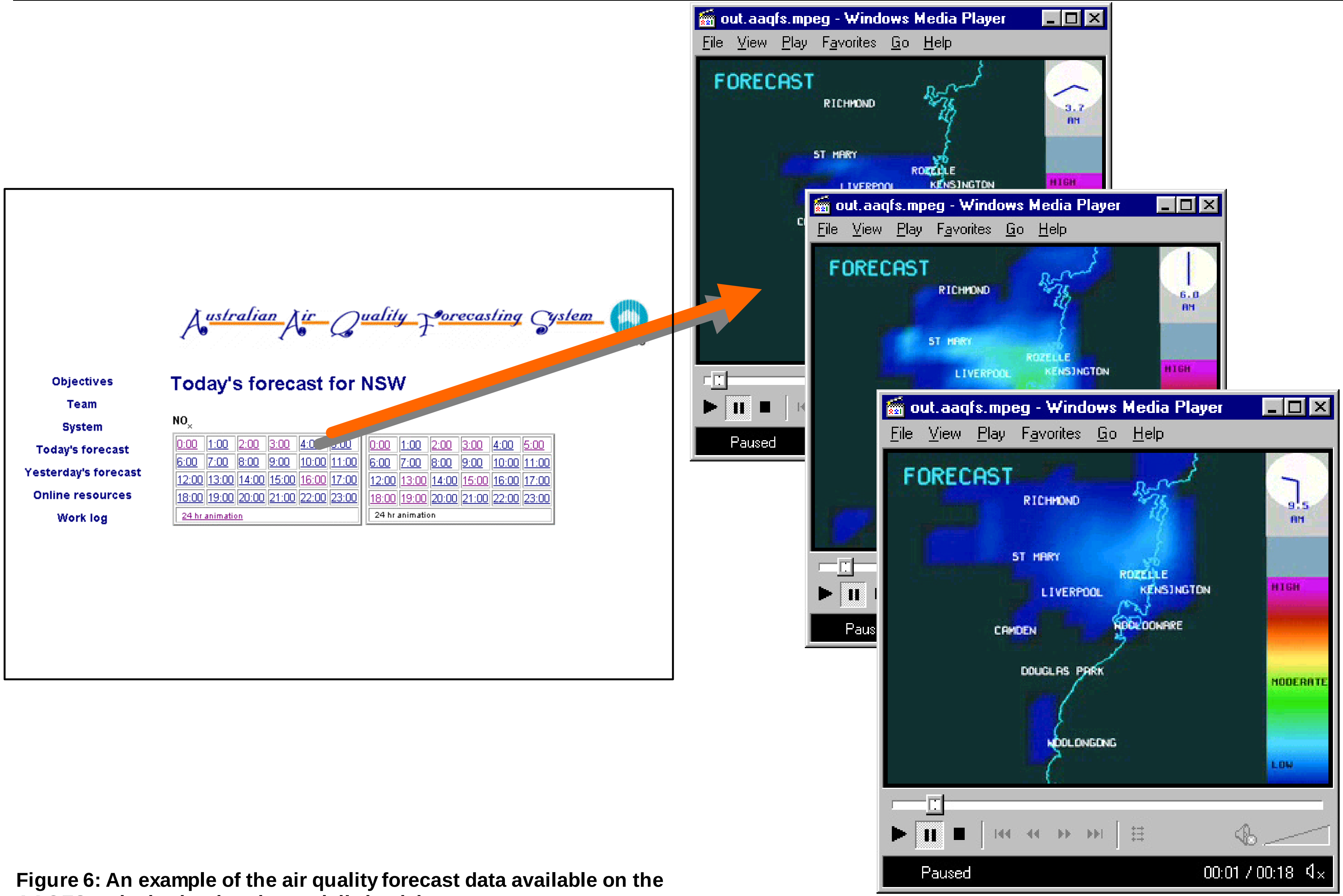


Figure 6: An example of the air quality forecast data available on the AAQFS web site (updated on a daily basis).

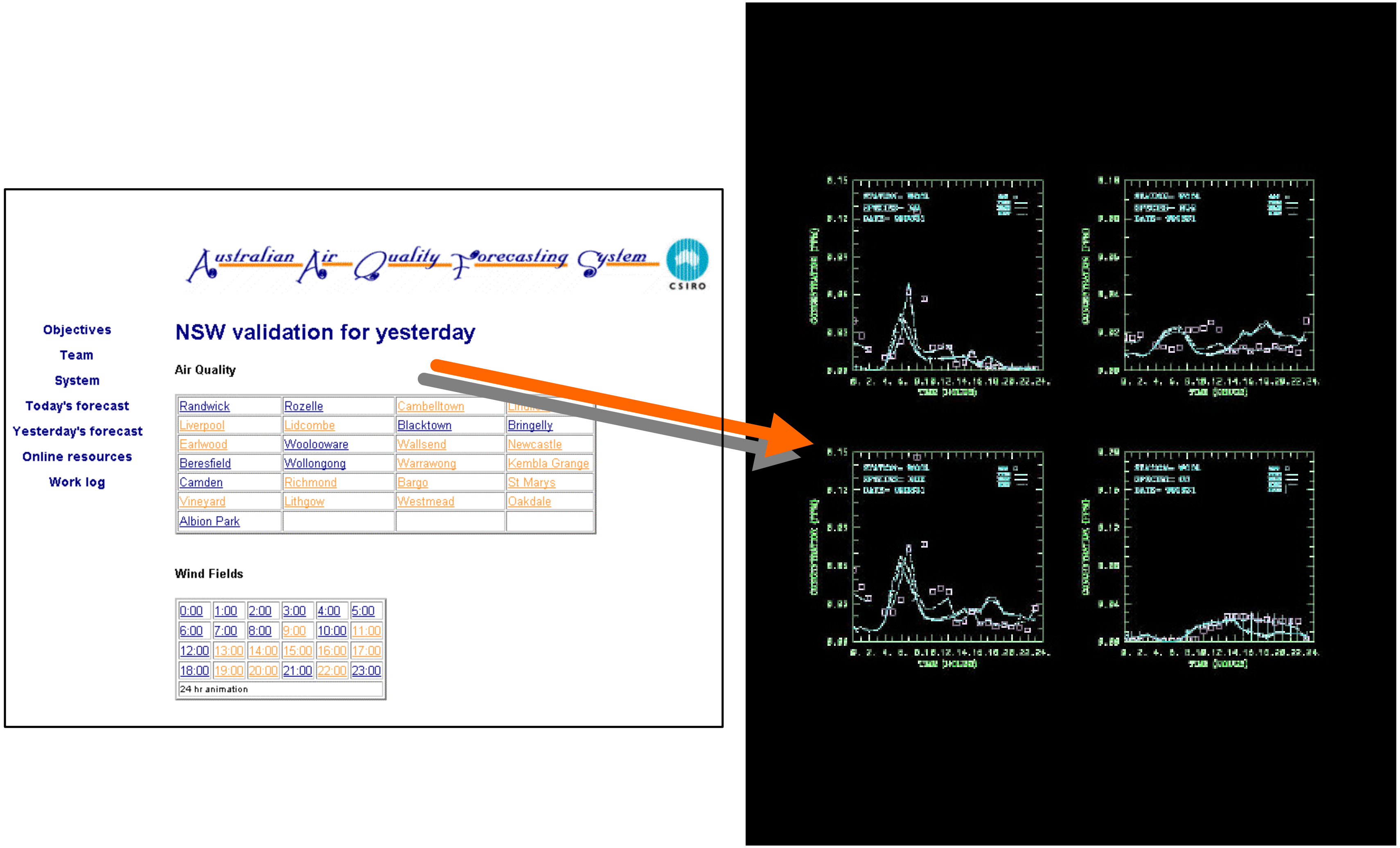


Figure 7: An example of the air quality validation data available on the AAQFS web site (updated on a daily basis).

Bureau of Meteorology Research Centre

2nd Progress Report

Bureau of Meteorology Research Centre

2nd Progress Report

G. D. Hess, G. A. Mills and J. McBride

Introduction

The Bureau of Meteorology (BoM) runs a limited-area numerical weather prediction system (NWPS) twice a day at a horizontal resolution of 0.05° (approximately 5 km) for domains covering Victoria and New South Wales. The output from these model runs (the winds, temperatures, humidities, etc.) is used as input for the chemical transport model (CTM), which determines how pollutants move, disperse and chemically evolve. In this report we discuss the progress in the NWPS in two areas: efforts to improve the resolution of the NWPS model (LAPS05) and work to develop an objective model verification system.

Status.

The LAPS05 model in the original Pilot System at the beginning of the project had the following configuration: there was a simple turbulent mixing scheme; the surface fluxes were determined by a parameterised scheme; there was no vegetation; the soil properties were assumed to be uniform; soil hydrology consisted of a simple scheme for water balance in a "bucket" (precipitation increased the water in the bucket; evaporation decreased it; if the level of the water became too high, there was runoff); there was a skin temperature, two variable soil temperatures, and a fixed climatological soil temperature; a single roughness length characterised the processes of momentum, heat and moisture exchange; smoothed topography was employed (interpolated from a 0.10° grid); monthly sea surface temperatures were used interpolated from a 1° grid; the model was initialised by interpolating the analysed fields at 0.75° resolution to the 0.05° grid; boundary conditions were interpolated from 0.75° resolution; the computational grid was 0.05° in the horizontal and there were 19 vertical levels.

A number of improvements to the LAPS05 model have already been implemented to the original Pilot System. The current version of LAPS05 has a non-local turbulent mixing scheme for convective conditions; there is direct calculation of the surface fluxes; the average effects of vegetation have been added; soil texture and hydraulic properties are uniform temporally and spatially; diffusion of moisture in the soil is treated by a highly nonlinear technique; there is a skin temperature and four layers for soil temperature and moisture; there are separate roughness lengths for momentum, heat and moisture; weekly sea surface temperatures are used interpolated from a 1° grid; the model is initialised by interpolating the analysed fields at 0.375° resolution; boundary conditions are interpolated from 0.375° resolution; the computational grid is 0.05° in the horizontal and has 29 vertical levels.

In the new, high-resolution version of LAPS05, that is at present undergoing testing, a number of further model changes have been implemented. These include the implementation of variable vegetative effects (32 vegetation/land use categories at 0.05° resolution); horizontal variation in the soil (8 soil textures/ hydraulic categories at 0.05° resolution); daily sea service temperatures at 0.25° resolution; and high-resolution topography (based on 0.008° data).

Figure 1 shows a comparison of the data fields for the Victorian region for vegetative fraction, vegetation roughness length and the effective roughness length (which combines the effects of vegetation and topography) for the current version of LAPS05 and the new, high-resolution version of LAPS05. The increased detail of the new fields is apparent.

Figures 2 and 3 show some preliminary results for a simulation initiated at 2300 UTC on 8 December 1998. This date was chosen because 10 December 1998 was a day of high ozone in Melbourne.

The effects of the higher-resolution topography and surface and soil properties clearly influence the skin temperature (compare Figure 2b with Figure 2c, for example), but have less impact on the screen temperature at 2 m height (Figure 2b), although some differences between the results for the current model configuration and the new high-resolution version also occur for the screen temperature. However, the impact on the contours for screen dewpoint temperature (Figure 2c) (i. e. the effect of the near surface moisture) is marked.

The impact on the near-surface wind field (Figure 3a) is subtle. The general wind pattern remains the same, but subtle changes to the wind direction and speed occur, reflecting the changes in topography and surface roughness, particularly. In the remaining two panels (Figures 3b and 3c) the pattern of distribution of the surface fluxes of sensible and latent heat is more detailed in the new model and the range of values is increased because of the modifications.

We now turn our attention to model verification. The measure of model performance that is currently used for the BoM larger-scale operational models is the skill score for the mean sea level pressure pattern. However, by the time the resolution of the model reaches 0.05° this accepted measure of verification is no longer useful and new methods of model verification must be developed.

A preliminary scheme of model verification for the surface fields has been created. This scheme concentrates on the near-surface wind field and the screen temperature and dewpoint temperature.

A graphical representation of model verification is shown in Figure 4 for the near-surface wind field. The forecast winds are compared with observations from the BoM METAR/SYNOP network, which is augmented by measurements from the EPA. The agreement between the predictions and observations is generally good for this case (the latest day available at the time of this writing).

In addition to this graphical methodology, a statistical approach can also be pursued. Tables 1 and 2 show the latest daily summary for the Victorian and New South Wales domains, respectively. These indicate the number of observations, bias, deviation (absolute value of the bias), root mean square (RMS) error, the average measured value, the average predicted value, the standard deviation of the measured values, the standard deviation of the predicted values, the correlation between the measured and predicted values at zero lag, the range of the measured values and the range of the predicted values.

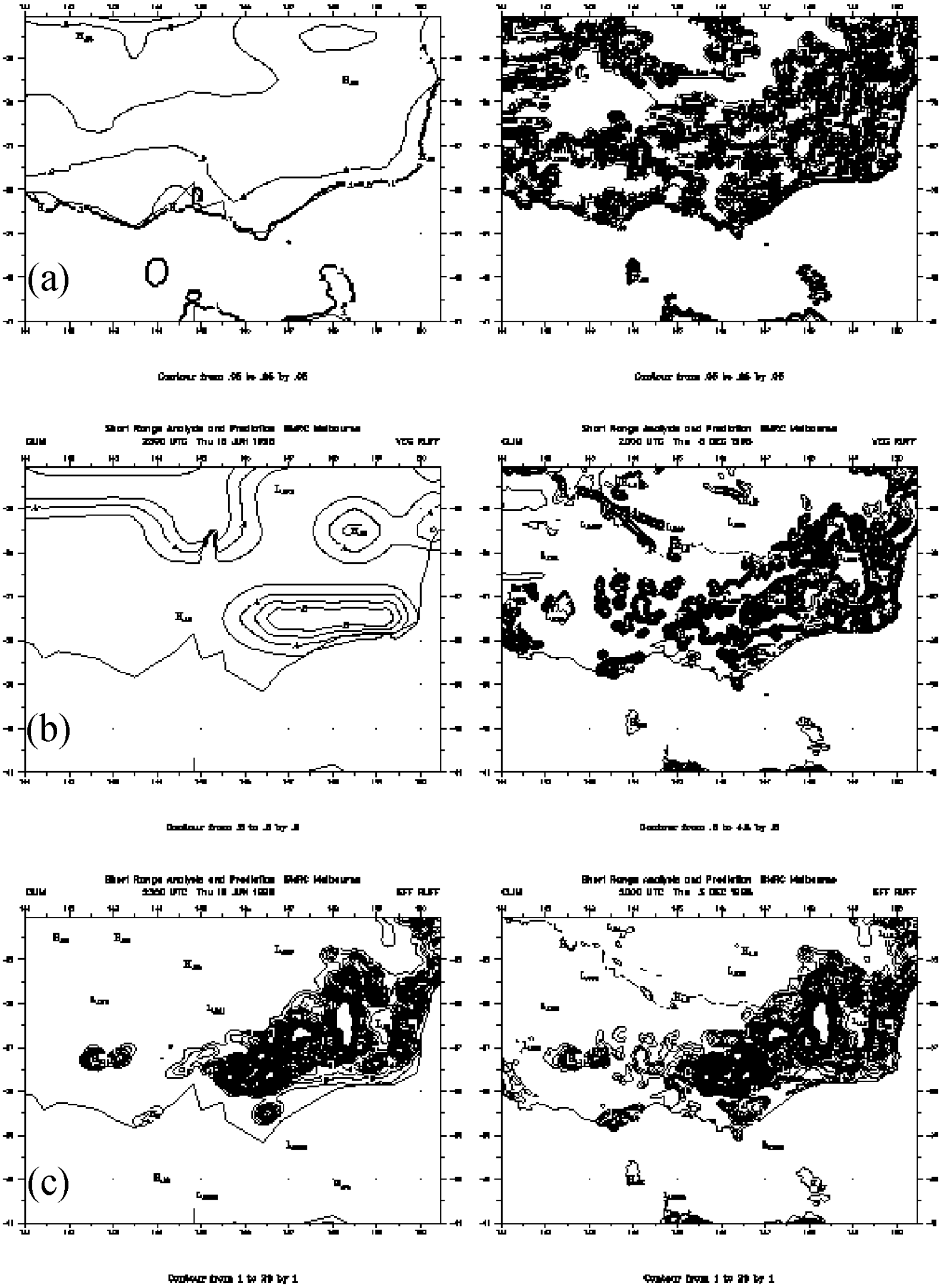


Figure 1. Comparison of data fields for the current version (left column) and the new, high-resolution version (right column) of LAPS05: (a) vegetative fraction; (b) vegetation roughness length; (c) effective roughness length.

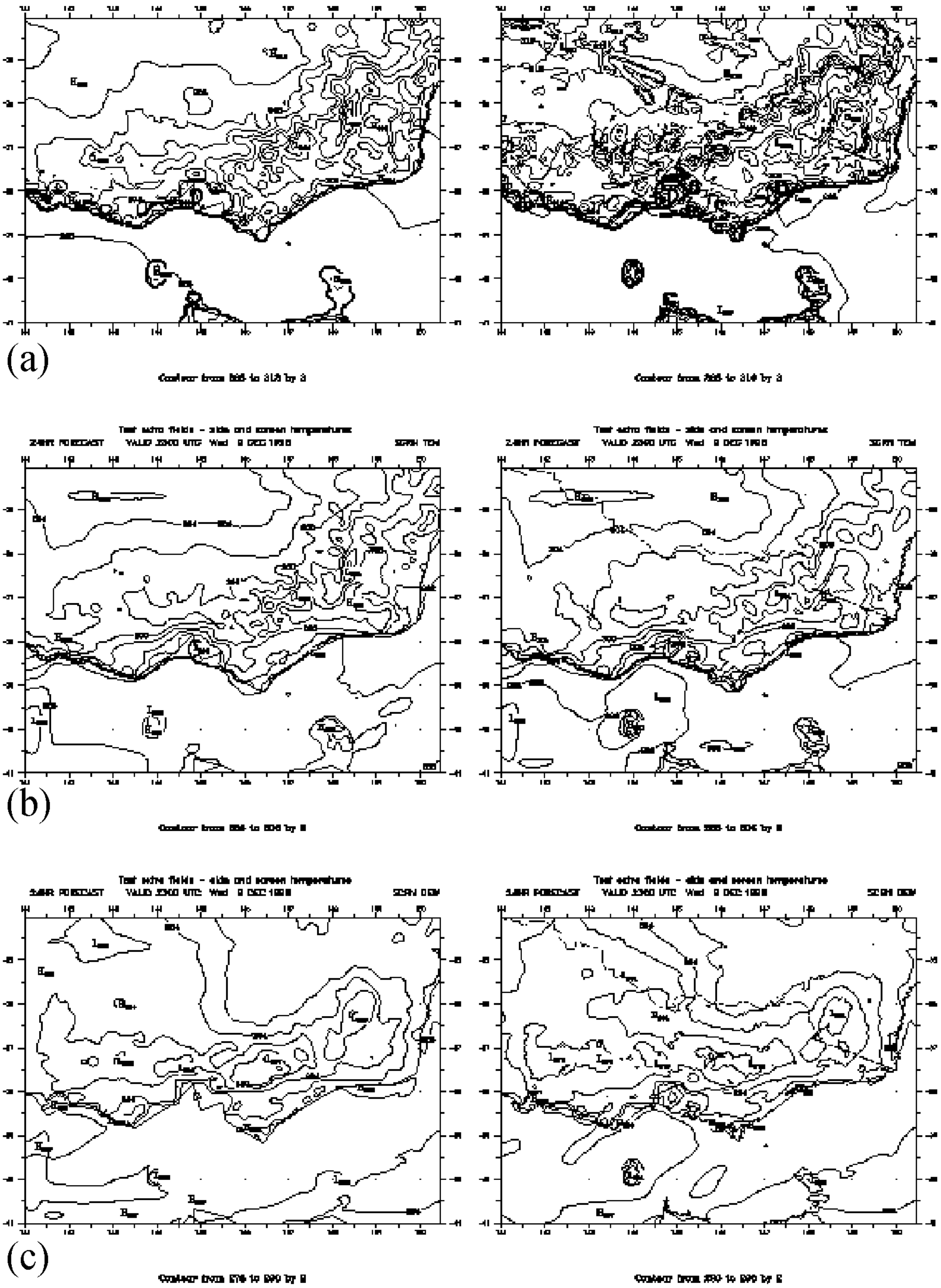


Figure 2. Comparison of 24-hour forecasts for the current version (left column) and the new, high-resolution version (right column) of LAPS05: (a) skin-temperature; (b) screen temperature; (c) screen dewpoint temperature. The forecasts were initiated at 2300 UTC 8 December 1998.

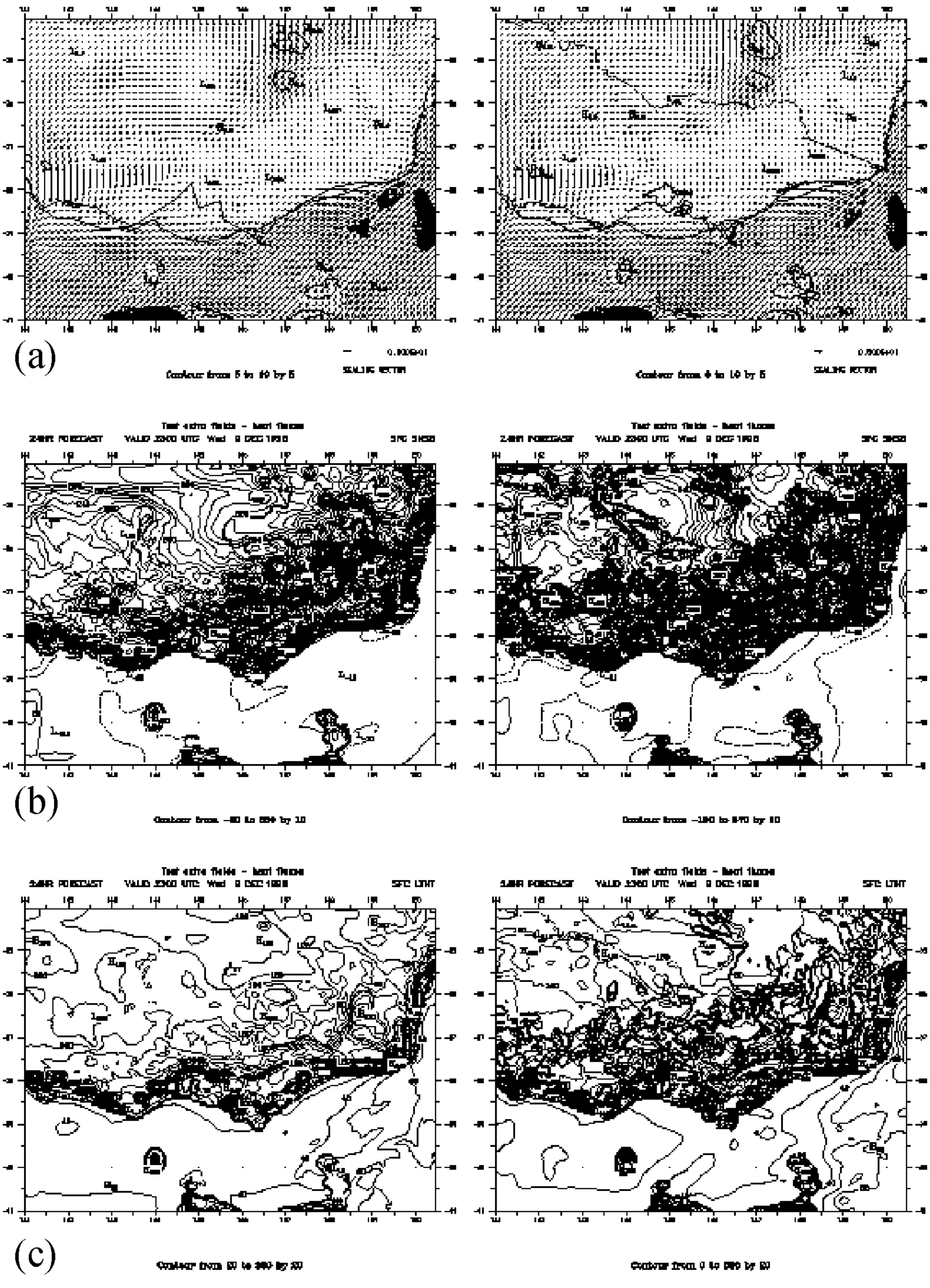


Figure 3. Comparison of 24-hour forecasts for the current version (left column) and the new, high-resolution version of LAPS05: (a) wind field at 10-m height; (b) sensible heat flux; (c) latent heat flux. The forecasts were initiated at 2300 UTC 8 December 1998.

The scheme will produce both daily and monthly statistics of model performance. Once monthly data sets are available, time series and statistics for individual stations and individual hours of the day can be computed. Preparations for a benchmark test of LAPS05 for Sydney for the period 15-30 Sepember 1998 have already begun, using the current model version.

Work will commence soon on incorporating verification measures above the surface. Particularly important are the winds and the temperature structure (including the determination of the height of the boundary layer). As a first step, daily AMDAR data (winds and temperatures from commercial aircraft) are being collected. Examples of the AMDAR vertical profiles of virtual potential temperature are shown in Figure 5. Wind and temperature data from rawinsondes, pilot balloons, acoustic sounders and RASS vertical profilers will increase the coverage.

These preliminary model verification schemes will be merged with a general BoM model verification package now under development. This package will produce model verification for all of the LAPS model configurations.

Table 1. Victorian domain verification statistics for a 24 hour forecast initialised at 1100 UTC 20 August 1999. The statistics include all stations for all hours of the day.

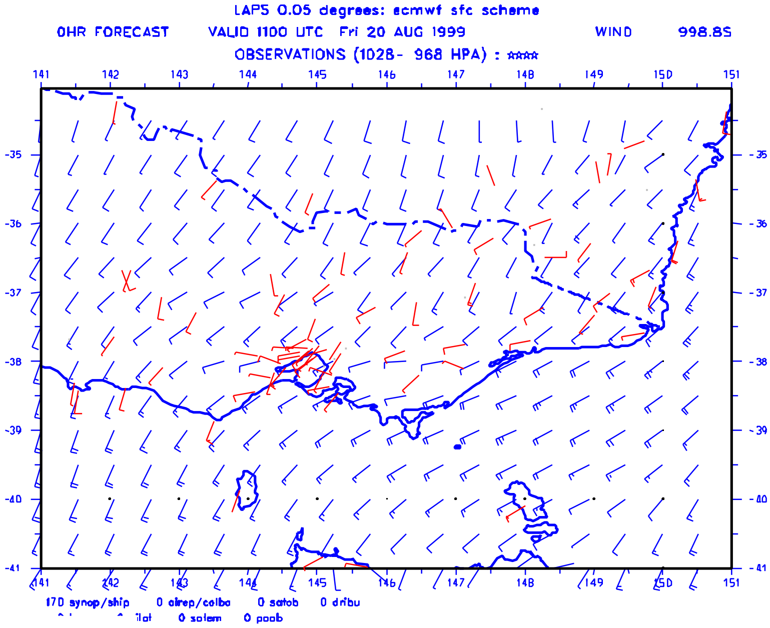
Var.	No.	Bias	Dev.	RMS Error	Ave. .Meas.	Ave. Pred.	SD Meas.	SD Pred.
W Speed	1663	-1.109	1.738	2.257	3.504	2.395	1.945	1.641
W Dir	1663	-16.667	76.703	132.106	-59.682	-76.349	111.928	103.851
U	1663	-0.418	1.579	2.099	1.732	1.314	2.441	1.580
V	1663	-0.399	1.449	1.907	1.557	1.159	2.164	1.694
T	1663	1.003	2.054	2.670	7.175	8.178	4.599	4.655
Dew Point	1663	-1.355	2.281	2.961	2.879	1.525	3.586	2.665

Var.	Cor0	Range Meas.		Range Pred.	
W Speed	0.410	0.515	12.870	0.033	12.888
W Dir	0.264	-170.000	180.000	-179.877	179.980
U	0.548	-7.207	12.870	-3.935	9.518
V	0.556	-5.070	11.153	-2.869	11.454
T	0.857	-8.200	16.000	-5.819	16.235
Dew Point	0.682	-21.800	8.5000	-7.224	9.154

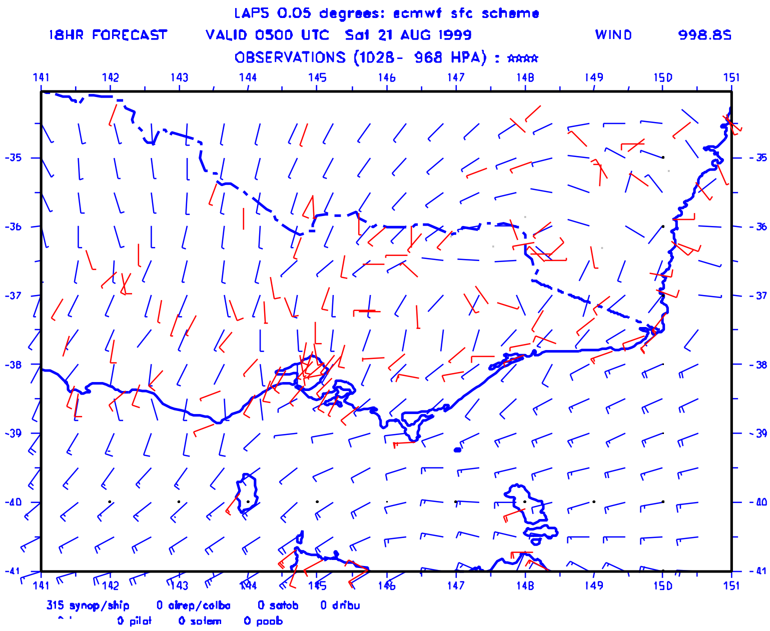
Table 2. New South Wales domain verification statistics for a 24 hour forecast initialised at 1100 UTC 20 August 1999. The statistics include all stations for all hours of the day.

Var.	No.	Bias	Dev.	RMS Error	Ave. .Meas.	Ave. Pred.	SD Meas.	SD Pred.
W Speed	1542	-1.115	1.681	2.186	3.352	2.237	1.842	1.500
W Dir	1542	-35.333	87.230	141.586	-0.233	-35.566	130.727	123.155
U	1542	0.102	1.495	1.959	0.264	0.366	2.444	1.606
V	1542	-0.491	1.597	2.146	1.815	1.325	2.301	1.669
T	1542	0.280	1.949	2.593	9.131	9.411	5.746	5.390
Dew Point	1542	-2.533	3.533	4.264	3.554	1.021	4.517	3.714

Var.	Cor0	Range Meas.		Range Pred.	
W Speed	0.381	0.515	12.355	0.026	12.888
W Dir	0.418	-170.000	180.000	-179.822	179.504
U	0.602	-7.207	9.675	-3.477	8.203
V	0.484	-5.070	11.153	-1.962	11.454
T	0.895	-8.200	23.600	-6.644	20.596
Dew Point	0.669	-21.800	13.200	-12.332	12.671



(a)



(b)

Figure 4. Comparison of LAPS05 winds (in blue) with observations (in red) for (a) the initial time, 1100 UTC 20 August 1999; (b) 18-hour forecast, 0500 UTC 21 August 1999. Full wind barbs indicate 10 knots; half barbs indicate 5 knots; no barb nominally indicates 2 knots (1 knot is approximately 0.5 m/s).

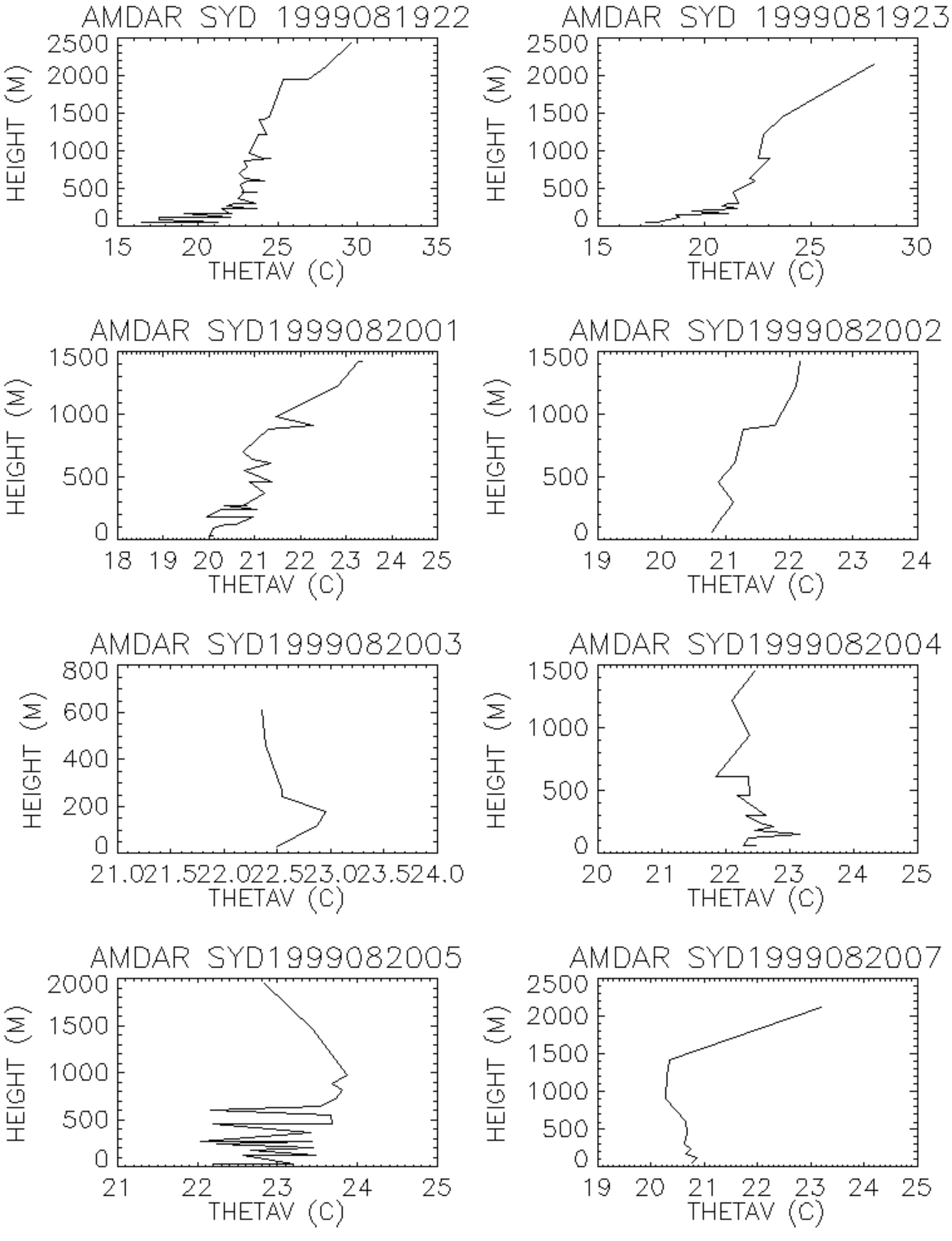


Figure 5. AMDAR measurements (from commercial aircraft) showing virtual potential temperature vertical profiles over Sydney for 19–20 August 1999. The date-time (YYYYMMDDHH) is given above the figure. The time (the last two digits) is in hours UTC.

Conclusions

Development of the LAPS05 model is making good progress. High-resolution topography, daily sea surface temperature, 32 vegetation / land use categories, and 8 soil textures / hydraulic properties have been introduced and the necessary code has been written and implemented to upgrade the model physics. The new, high-resolution version of LAPS05 is currently being tested in the Victorian domain. The preliminary results are very encouraging, and the modifications are now being introduced to the New South Wales domain. Because of the large number of modifications introduced , extensive testing is necessary.

A preliminary model verification system for near-surface variables is now in place for both the Victorian and the New South Wales domains. Work will soon commence to incorporate verification measures above the surface. Development has already begun on a general verification package that will be applicable for all of the LAPS model configurations. The preliminary model verification system will be merged with the general system.

Appendix

Description of the Project

The primary objective of the *Air Quality Forecasting System for Australia's Major Cities Project* is to set up, validate, and trial for a four month demonstration period, a real time software system capable of providing accurate air quality forecasts to the public for the purpose of "*preventing, combating, or rectifying*" the level of air pollution, particularly on forecast high pollution days.

After the Australian Air Quality Forecasting System (AAQFS) is demonstrated in Sydney and Melbourne, the Commonwealth shall have the exclusive right to use the System in Australia for Air Quality Forecasting and will have a non-exclusive right to use the System overseas for the same purpose.

The System will be completed and demonstrated to the public in Sydney in time to provide air quality forecasts for the 2000 Olympic Games. The demonstrations in Sydney and Melbourne need not necessarily be run simultaneously.

The AAQFS comprises the following components:

(i) The "access system", which manipulates

- emissions data based on traffic and industry activity for a particular region from pollution inventories,
- meteorological data from the Limited Area Prediction System (LAPS), being a system developed by the Bureau of Meteorology,
- other materials necessary for the development of the System,

(ii) The "customised airshed system", being the consolidated airshed model that will be customised for a particular region or city,

(iii) A "visual graphics modelling system", which offers a visual graphics representation of the forecasts suitable for the world wide web.

Management Structure and Responsibilities

The AAQFS is being developed with funding from the *Air Pollution in Major Cities Program*, and was approved by the Minister for the Environment as one of the *Clear the Air* projects on 15 May 1998. The Project is legally organised as a contract between the Commonwealth and CSIRO Atmospheric Research, with subcontracts to other participants. However, the actual conduct of the Project is by a collaborative arrangement as follows:

> Bureau of Meteorology Research Centre (BMRC) is responsible for the preparation of the LAPS model for the Project and for the consolidation of various air pollution emissions and chemical transport components to make up the full System. BMRC is providing the resources of the Bureau to access verification data, trialing the System in its various forms and is working with the EPAs to set up information streams to the EPAs from the System. BMRC also is working with CSIRO and the EPAs to develop the visualisation systems.
>
> Environment Protection Authority (Victoria) is providing expertise in developing a real-time emissions inventory system in collaboration with CSIRO, is working with EPA NSW

to prepare the Sydney emissions inventory for the Project, and is providing an extended emissions inventory for Victoria. EPA (Victoria) is also providing data for validation purposes from the Melbourne monitoring network.

Environment Protection Authority of NSW is providing data for validation purposes from the Sydney monitoring network, is working with EPA (Victoria) in preparing the Sydney emissions inventory for the System, and is facilitating the introduction of the System into Sydney.

CSIRO Energy Technology is underpinning CSIRO Atmospheric Research in the Project by contributing to extensions of the air pollution modelling components, is developing an advanced version of their chemical reaction scheme for high speed smog forecasts, and is developing and providing advanced algorithms for the real-time calculation of vehicle emissions that depend on power requirements, and which in turn depend on hilly terrain — a characteristic of many cities, particularly Sydney.

CSIRO Atmospheric Research is assisting and advising EPA (Victoria) in the development of the real-time emissions inventory, is developing, extending and customising the air pollution modelling component, is working with BMRC to incorporate the air pollution components into the LAPS model, and is participating with the EPAs and BMRC in the development of graphical outputs.

The Project is managed by Dr Peter Manins of CSIRO Atmospheric Research. He chairs the Steering Committee that meets every two months or more often as necessary. The Steering Committee is made up of representatives of the collaborators.

Schedule

As specified in the contract between the Commonwealth and CSIRO, the Project is in seven phases, with reporting required within 30 days of completion of the phase. The phases are described in the table below.

Phase	**Tasks**	**Date commenced**	**Date completed**
Phase 1	Trial a working test system in Melbourne, determine areas of concern and devise requirements for extension, verification measures, criteria	May 1999	Jun 1999
Phase 2	Recast latest emissions inventory for Melbourne (Mar 99) into form for the System. First pass at extending inventory to respond to weather, events. Trial full prototype system in Melbourne, test performance	Jun 1999	Jul 1999
Phase 3	Extend real-time emissions inventory methodologies to Sydney, incorporating the new power-based vehicle emissions application. Install full prototype System in Sydney and verify against measures and data.	May 1999	Dec 1999

Phase 4	Iterate on performance measures for forecasts for Sydney and Melbourne, finalise extensions to meteorology component, incorporate advanced GRS smog model, commence development of display systems and other products in consultation with users	Jul 1999	Apr 2000
Phase 5	Demonstration to EPAs of prototype System in Melbourne and Sydney over summer period. Fix problems and refine display products in consultation with users in Sydney and Melbourne	Jan 2000	Jun 2000
Phase 6	Demonstrate full System in Sydney and Melbourne with products to EPA NSW and EPA VIC for dissemination to media	Jun 2000	Sep 2000
Phase 7	Package outputs for EPAs in light of demonstrations. Document performance, validate against System performance measures and recommend extensions	Oct 2000	May 2001