THE AUSTRALIAN AIR QUALITY FORECASTING SYSTEM

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The recent advances in supercomputing have opened up a number of new areas of potential applications for meteorological forecasting. One such area is numerical air quality forecasting. It is now possible to combine a high-resolution meteorological model with a high-resolution air quality model to forecast the concentrations of various pollutant species at a spatial resolution comparable to the size of suburbs. However, increasing the detail of the air quality forecast from the scale of the urban airshed down to the scale of suburbs brings with it a whole new set of scientific problems and challenges.

The Australian Air Quality Forecasting System (AAQFS) is a joint project between the Bureau of Meteorology (BoM), CSIRO Atmospheric Research (CAR), CSIRO Energy Technology (CET), the Environment Protection Authority of Victoria (EPA-VIC) and the New South Wales Environment Protection Authority (NSW EPA) to develop a high-resolution air quality forecasting system. The initial development of AAQFS was funded by the Air Pollution in Major Cities Program (sponsored by Environment Australia). Currently 24-36 hour forecasts are produced in both Melbourne and Sydney. The System was trialled in a Demonstration Period from August 2000 – July 2001 (which included the 2000 Olympics and Para-Olympics in Sydney and the 2000-2001 summer oxidant season).

The project has a number of specific goals: to provide the ability to generate 24-36 hour air quality forecasts twice per day (available 9 am and 3:30 pm); provide forecasts for a range of air pollutants including oxides of nitrogen (NO_x), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), benzene (C_6H_6), formaldehyde (CH_2O) and particulate matter (PM10 and PM2.5); provide forecasts at a resolution sufficient to consider suburban variations in air quality; and to provide the ability to generate simultaneous forecasts for a 'business-as-usual' emissions scenario and a 'green emissions' forecast. The latter scenario may correspond to minimal motor vehicle-usage and will be used to indicate the reduction in population exposure that could result from a concerted public response to a forecast of poor air quality for the next day.

The AAQFS consists of five major components: a numerical weather prediction (NWP) system, an emissions inventory module (EIM), a chemical transport module (CTM) for air quality modelling, an evaluation module, and a data archiving and display module (data package).

The BoM's operational Limited Area Prediction System (LAPS) system has been adapted for the AAQFS NWP component. Comprehensive numerics and physics packages are included and recent work has paid special attention to the resolution and treatment of surface processes. The model has 29 vertical levels and a horizontal resolution of 0.05° (covering the state of Victoria and most of New South Wales). This model is nested in LAPS at 0.375° resolution, which in turn is nested in the BoM global model, GASP.

EPA-VIC and CSIRO, with support from NSW EPA, have developed the emissions inventory. The inventory uses size-fractionated and speciated particle emissions, 0.01° gridded area sources over the densely populated regions and meteorologically dependant emissions that are generated based on LAPS predictions. Recent innovations include updating the emissions model for wood-burning heaters; implementing and testing a wind-blown dust model; developing and testing a power-based vehicle emissions model developed to generate road-specific vehicle emission fluxes for the purpose of near-road impact modelling; and the introduction of the beginnings of a bushfire modelling component.

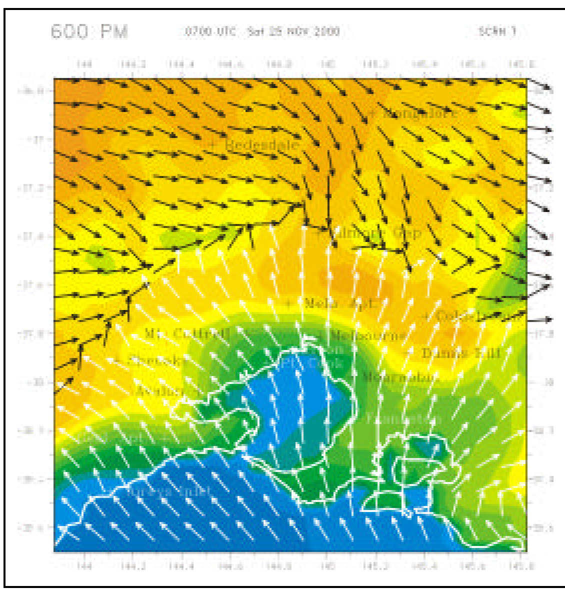
The CTM has been custom built for the project using state-of-the-art methodologies. A notable inclusion to the CTM is the Generic Reaction Set (GRS) photochemical mechanism, a highly condensed (7 species and 7 reactions) photochemical transformation mechanism featuring minimal computational overhead. Testing is going on to update this model to include 12 species and 14 reactions. Particle transformation is modelled by a sectionally based particle scheme. The transport fields are updated every 60 minutes. The CTM has 17 vertical levels and simulations use a 0.05° outer grid, with nested 0.01° inner grids for major urban areas.

Both the meteorological and air quality forecasts are the subject of on-going and case-specific validation. This is done through comparison of LAPS meteorological fields with METAR/SYNOP (near-surface) and AMDAR (vertical profiles from commercial aircraft) data and meteorological observations from the EPA monitoring networks. Air quality forecasts are compared to 1-hour EPA observations for NO_x (both as NO and NO_2) and O_3. This has been expanded to include SO_2, PM10, PM2.5, CO and, where available, non-methanic hydrocarbons. Critical to the validation process has been the availability of EPA data sets by the end of each forecast period, enabling the on-going validation to be substantially automated.

Data archiving is in NetCDF data packets, which are accessible via GUI-driven Q&A software. Sufficient information is available in a data packet to enable the CTM to be run offline at a later time. The EPAs have access to the daily forecasts via the AAQFS Web Site and manage the dissemination of the forecast data.

A public-access website, making all of the AAQFS reports available, is currently under construction; for further details, contact: d.hess@bom.gov.au.

The interaction of synoptic-scale and mesoscale flows is particularly important in forecasting air quality in Melbourne and Sydney. Figures 1 and 2 show two examples. Figure 1 shows a sea breeze, which formed in the late morning/early afternoon due to the land-sea temperature contrast, and was opposed by the westerly-northwesterly synoptic flow. The model was able to simulate this observed interaction (Fig. 1). Figure 2 shows predicted NO_2 concentrations advected by the Melbourne Eddy that forms in the lee of the mountains to the northeast of Melbourne when stable stratification forces the air to flow around the topography, rather than over it. Observations confirmed the model simulation of this clockwise circulation.



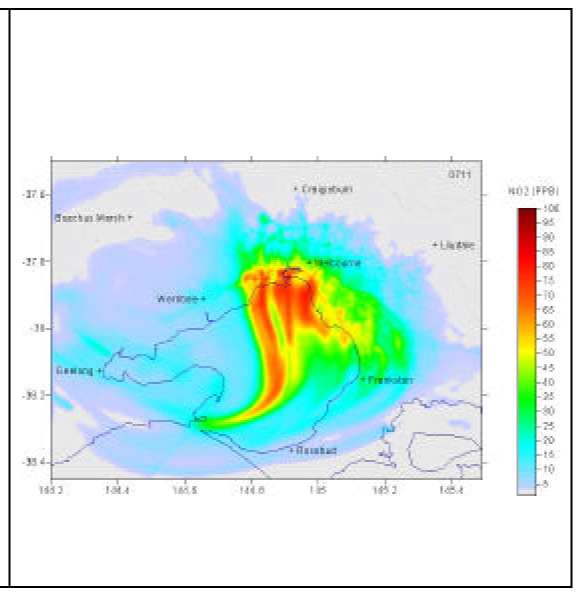


Fig. 1. Forecast of the sea breeze (white vectors) at 1800 EDT on 25 November 2000 in Melbourne showing the opposing synoptic flow. The background colour indicates screen temperature; blue is cool, yellow-green is warm, orange is hot.

Fig. 2. Forecast NO_2 concentrations at 1100 EDT 07 March 2001. Note that the NO_2 plume has been rotated clockwise by the Melbourne Eddy centred to the east of Geelong.