

7.1 THE AUSTRALIAN BUREAU OF METEOROLOGY'S NEXT GENERATION FORECASTING SYSTEM

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1. INTRODUCTION

This paper outlines the philosophy, history and current and future developments of forecaster workstations in the Commonwealth Bureau of Meteorology (CBM), the national meteorological service for Australia. The initial system requirements were far ranging with the first version released in the mid 1990's aiming at an integration of the underlying system infrastructure. The next major release of the system builds on this common infrastructure enabling applications to share data and interface elements. This release also aims to incorporate a much stronger forecast process element in the design of the applications and the user interface.

2. AUSTRALIAN INTEGRATED FORECAST SYSTEM (AIFS)

The Australian Integrated Forecast System (AIFS, Kelly and Gigliotti, 1997) is installed in 9 major sites across Australia, 15 smaller sites, and 2 overseas locations.

The primary function of AIFS is to support the operations of the state based Regional Forecast Centres (RFCs). Each RFC is a relatively large office, with up to 150 staff. The RFCs have weather forecasting, warning and monitoring responsibilities out to 7 days, responsibility for a large land area (in the case of Western Australia, approximately one third of the Australian continent, while Victoria, the second smallest state, is about the same area as the United Kingdom), as well as marine forecast responsibility for ocean areas. Some sites have international responsibilities in the case of the Darwin Regional Specialised Meteorological Centre (RSMC) and the National Meteorological and Oceanographic Centre (NMOC). RFC operations include aviation, public and severe weather functions, as well as climate and hydrology. Engineering and computing support groups are co-located with each RFC.

The NMOC serves as the central real-time operational hub for Australia's national weather service. NMOC maintains a nationwide weather watch, provides centralised guidance products to the Regional Forecasting Centres and issues a range of analysis and prediction products.

NMOC has the international functions of a World Meteorological Centre (WMC) and Regional Specialised Meteorological Centre (RSMC) of the World Meteorological Organisation (WMO) World Weather Watch (WWW); a Regional Area Forecast Centre (RAFC) of the International Civil Aviation Organisation (ICAO) World Area Forecast (WAF) System; and a National Data Processing Centre of the WMO Integrated Global Ocean Services System.

3. AIFS DEVELOPMENT AND DEPLOYMENT

The AIFS was developed between 1994 and 1996, with deployment and ongoing development between 1996 and 1999. Decisions on a development strategy for AIFS were undertaken in 1993/4. A number of overseas options were considered as the basis for AIFS, but the wide range of functions and operations required meant that any "off the shelf" solution would only satisfy a small percentage of the operational requirements. With two notable exceptions, AIFS was developed as an internal project.

The two exceptions to this include the database schema and Application Programming Interface (API) - Navy Environmental Operational Nowcasting System (NEONS, Tsui and Jurkevics, 1993) from the US Navy, and the Man computer Interactive Data Access System (McIDAS, Suomi et al., 1983), which is used for visualisation and processing of satellite imagery, NWP data.

Other AIFS modules include:

- a communications system, which is nationally integrated, including decoding, onforwarding, monitoring, restarting, and archiving of data;
- a common database across RFCs and the NMOC based upon Oracle, NEONS and the Abstract Data Distribution Environment (ADDE, Taylor et al., 1995; Murray et al., 2001), which enables seamless access to all data including NWP models at full resolution;
- an Automatic Product Generation system which routinely creates a wide range of bulletin products such as rainfall, river, aviation, and public weather bulletins;
- an online product store (intranet) which allows browsing of all output products and bulletins Australia wide, Digital facsimile (DIFACS) charts, including climate, World Area Forecast System (WAFS), aviation significant weather (SIGWX) charts, warning products (highlighted when current), and includes removal of old forecasts and warnings from the store;

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- hydrological integration, with catchment modelling, routine assessments and GIS display of rainfall;
- a forecast preparation system which allows graphics to be included in routine forecasts and warnings, as well as a macro programming capability;
- a suite of visualisation programs based on the Interactive Development Language (IDL);
- McIDAS for Satellite and NWP visualisation, processing and data serving;
- a Forecast Guidance System;
- verification and alerting facilities; and
- a text to speech system for automatically loading products onto telephone answering services.

Over the last 7 years of operational AIFS use, a number of valuable improvements have been made to the system by operational users and on site computing support staff. The local enhancements include:

- web based system monitoring tools;
- a backup forecast preparation system for use during system outages; and
- an IDL based visualisation tool for NWP models.

One of the key features of AIFS has been to facilitate integration activities, especially with the NMOC and the Observations and Engineering Branch (OEB). This integration work has involved:

- moving to shared decoders between NMOC and RFCs (a feat only recently completed);
- implementing a national station dictionary, where one site's updates are passed on to others, and NMOC changes are passed on to RFCs;
- using the Engineering Sites Database as one of the main authorities for seeding and updating the national station dictionary, where changes are automatically notified (with filtering) to each RFC's computing staff; and
- an integrated approach to product management, with links between AIFS, a national product register (the Services Information Management System, SIMS) and the CBM's external web server (www.bom.gov.au).

The implementation of the AIFS across all forecasting offices in Australia has resulted in a more unified computing infrastructure across the CBM, and has allowed for some powerful leverage activities. The communications system used in the NMOC as part of the GTS for message switching (both to Australian and overseas sites) has been adapted and extended for use in AIFS. The same database configuration (Oracle/NEONS/ADDE) is used in the national office and in all state offices. All sites have instant access to full resolution data available in the national office. An ADDE interface to the archival system (ECMWF's Meteorological Archival and Retrieval System, MARS) has been developed so that all sites will have rapid access to all historical data as well. The CBM's

operational centres, training centre, and research centre (BMRC) amongst others now share a very similar computing infrastructure. There are now many opportunities to leverage off this common infrastructure.

a. Streamlining and Enhancing Forecast Operations

Following the national rollout of the AIFS, a number of review and forward planning activities were initiated, to document what issues should be addressed, and to plan the future evolution of the operational systems. Each AIFS site prepared a "Post Implementation Review" (PIR) and an organisational initiative was commissioned known as the "Forecast Streamlining and Enhancement Project" (FSEP). This project is a shared responsibility between computing, services, research and training, with the services branch taking a lead role in the requirements and priority setting for the FSEP projects.

Key factors identified by the PIRs and FSEP have indicated that the next generation system should include:

- a more integrated environment via improved sharing of information, including forecast policy and geographic data;
- support for a more streamlined forecast process and
- a much greater range of consistent output products, tailored to client needs.

These objectives are guiding the development of the next generation system, known as AIFS 2, to provide enhanced support for operational forecasting activities. This will:

- provide better services, in a rigorous manner;
- achieve a better person-machine mix; and
- alleviate some of the mundane and repetitive operational tasks.

4. AIFS 2 DEVELOPMENT CHOICES

The predecessor to AIFS was known as AROS (Automated Regional Operations System), and was based on Tandem mini-computers. The AROS was developed, installed and maintained by the one section within the CBM, meaning less than a dozen people. This included training, documentation, and networking activities. With AIFS, it was recognised that the system complexity was such that it was beyond a single section, and a virtual team was formed involving a large number of people from other sections and branches in the CBM, including communications, networking, training centre and hydrology. For AIFS 2, the level of system complexity will jump again, and consequently there is a need not only to draw on the expertise of CBM staff, but also to leverage off work already underway around the world.

Another key factor in planning a development approach is the need for flexibility. This comes about

in a number of ways. One aspect is that it is difficult for the services requirements to be clearly specified far enough in advance for the development work to proceed in a predictable manner. The requirements are known to change fairly rapidly as the system is developed. So in order for the system to meet the changing requirements, it must be very flexible, and extensible.

Taking these factors into account, the development choices for AIFS 2 are guided by:

- a survey of current activities around the world, to leverage off work already underway;
- alignment with CBM plans and world wide trends in service and technology; and
- the specification of services requirements, and need for flexibility and extensibility.

5. BUILD, BUY OR COLLABORATE?

A related consideration is whether to build a system or to buy one off the shelf, and whether a middle ground of collaborative development is preferable.

Buying an off the shelf system has a lot of appeal, and the CBM has done this with a number of systems already. Systems such as NEONS, McIDAS, MARS and Horace have been deployed to varying degrees in the CBM. These systems all perform well for their designed purpose, but they do not necessarily provide the flexibility to extend system functionality easily. For example NEONS and MARS do not support data stored in conventional database tables, for easy access by users on Personal Computers (PCs). Alternative means of providing the additional functionality must be developed. As flexibility has been identified as a key goal for the next generation system, this limitation is a major drawback.

Building the entire system in house is an option, however with a relatively small development team, it was decided that this option would be too slow and might also fail to deliver the full functionality desired.

The third option of collaboration would potentially be a middle ground between the above two options. If the collaboration was around a common toolset, then it might provide the leverage required to speed up the development effort, but at the same time still provide for a flexible development path.

So overall, the buy option is usually too inflexible (and sometimes too expensive), the build option is too slow, while collaboration around a common toolset could be just the right mix.

6. ALIGNMENT WITH CBM IT STRATEGIC DIRECTION

The CBM's Corporate Information Technology Plan (CITP) outlines objectives including reducing the cost of ownership, alignment with trends in scientific

community, government IT, and the IT community in general. The 1989/94 CITP was instrumental in bringing about the common infrastructure (UNIX/Open Systems in NMOC and RFCs).

a. Reduced Cost of Ownership

The cost of ownership can be reduced by developing cross platform applications, which can be moved quickly to the most cost effective hardware platform available at the time.

Using the Java programming language (Arnold, 2000) means applications can run on cheap Intel desktops (Windows or Linux operating systems) if desired, but also have the flexibility to be deployed on the UNIX server too. The porting costs are minimal, amounting to debugging some platform specific issues on occasion.

b. Emerging Trends in the IT Community

Within the IT community, the trend towards Open Source Software (OSS e.g. Linux, Open Office) has been gathering strength over recent years. Major commercial entities, such as Australia's telecommunications giant Telstra, are seeking to reduce software costs by adopting open source solutions in whole or in part (Sainsbury and Mills, 2003).

According to Graeme Philipson (1999), "we are witnessing a significant change in the centre of gravity in the IT industry". Philipson was referring to the increasing importance of "free software" which has been developed by a virtual programming team across the world competing to write the best or most efficient algorithm. In many cases the virtual programming team has produced higher quality software than a team of "wage-slaves" working to a tight deadline to make the next release date.

c. Government Trends

The Australian Government, through the National Office of the Information Economy (NOIE) is raising awareness of OSS by running seminars on the topic for government agencies. At a recent seminar, Mr John Rimmer (2003), CEO NOIE stated that "agencies are free to implement OSS where it provides a fit-for-purpose, value-for-money solution to their needs. In fact not just free to, but obliged to under Commonwealth purchasing guidelines." He also noted that "The Government will encourage trials of open source software within the framework of fit-for-purpose and value-for-money."

d. Scientific Community Trends

A 1999 survey of the papers presented in the "Aviation, Internet and Visualisation Applications" section of the IIPS Conference showed that approximately one third of the 34 papers related to systems using the Java language in whole or in part, or where there were plans to migrate to Java. Java was identified as the emerging language of choice for

new development work in the fluid earth sciences, especially where a need to share data and applications over a wide geographical area exists.

Unidata (UCAR) announced in 1998 adoption of a cross platform environment as a key component of their strategy to reduce costs and increase quality (Rew et al, 2000).

Forecast Systems Lab (FSL, McCaslin et al., 1999) adopted a domain specific Open Source visualization tool (Vis5D) for their D3D component (abandoning a general purpose visualization tool, AVS).

e. Strategic Direction

The cost of IT ownership can be reduced through using a cross platform development tool such as Java. A survey of scientific community trends showed Java is in widespread use, and a survey of IT industry and government trends reveals that open source software should be considered. In the CBM, our own experience is that general purpose tools such as IDL and GIS do not provide the domain specific functionality required. This experience parallels that of FSL in abandoning AVS because of the "overhead in multidisciplinary systems". In summary an ideal tool would be a domain specific, open source, Java based component level library to base our next generation system on.

f. Where to Start

An open source, component library for Java has been developed specifically for the fluid earth sciences, over the last 12 years, by some 20 major contributors from 6 organisations. This system is known as VisAD (Visualisation for Algorithm Development; Hibbard, 2003; Hibbard et al. 1999), and the development work has been lead by the University of Wisconsin.

VisAD is a good functional match to CBM requirements, and has a well defined collaborative framework. In addition, this system has grown up in close proximity to the developers of McIDAS, so VisAD is very compatible with existing CBM datasets, and is immediately able to access all operational CBM datasets, such as satellite and Numerical Weather Prediction (NWP) data.

7. AIFS 2 MODULES IN RESPONSE TO FSEP/SERVICES DIRECTIONS

AIFS 2 work is proceeding under the guidance of an FSEP steering committee and a co-ordination group. The FSEP approach has been to develop an integrated system, but to commission particular projects addressing immediate needs. Thus AIFS 2 has started as a number of specific applications, but care has been taken to make use of a unified data model, and common interfaces, so that the applications may be integrated as desired.

The work leverages off international experts for components such as the integrated data model, and navigation and projection system (use of VisAD). Other common components and libraries across specific applications are a layer manager (for turning on/off data layers on the graphical display), and tools for interactive panning, zooming and manipulation. At least 10 practises necessary to achieve effective integration have been identified, which are described below.

a. Methodology : An XP Approach

An eXtreme Programming (XP, Beck and Fowler, 2000) methodology has proven to be a useful approach with the AIFS 2 applications development. In part this comes about because of the lack of detailed up front requirements, and also the inability of users to comment on any development work until it is functional. Thus the XP approach of release early, release often has proven valuable. This gives users and management early feedback on progress, and involves the users as early as possible in the process, and the frequent release cycle gives users immediate feedback on their suggestions.

A project metaphor is used to provide a short clarifying concept of the project in everyone's mind. A pending task list is kept updated online, and it is prioritised, along with estimates of how long each (fine grained) task will take. Email discussion lists, and archives are used for feedback, and video conferences are used to resolve priorities when necessary.

b. Methodology: Integration

Here are the top 10 integration practises being used by the AIFS 2 projects. They are some of the things required (necessary but not sufficient conditions) to achieve integration:

1. information re-use (eg forecast decisions re-used in many modules, via integrated way of representing met data, the VisAD data model);
2. common look and feel (agreed GUI standards and walkthroughs);
3. consistent control over display (tools for panning/zooming, manipulating etc);
4. consistent visual data management (layer manager);
5. customisation, user-definition (Common configuration management system);
6. help system;
7. mapping, projection management and navigation system (eg VisAD);
8. integrated way of displaying met data (eg VisAD graphics libraries); and
9. common coding standards
10. maintained through code walkthroughs.

A number of integration services are at an early stage of development, such as:

11. an event service;
12. a spatial data management system; and
13. a forecast database interface.

8. FSEP Data Base (FDB)

The FDB is similar in concept to NOAA's National Digital Forecast Database (NDFD, <http://www.nws.noaa.gov/ndfd>). The important feature of the FDB is that the forecaster uses an interactive graphical manipulation tool to adjust some forecast value (eg wind speed and direction), and this digital value is stored in the FDB, and is known as the forecast policy. Forecasts are then produced automatically from the digital forecast policy. The FDB is currently based on forecast location points, as opposed to the grid bases approach used in the NDFD.

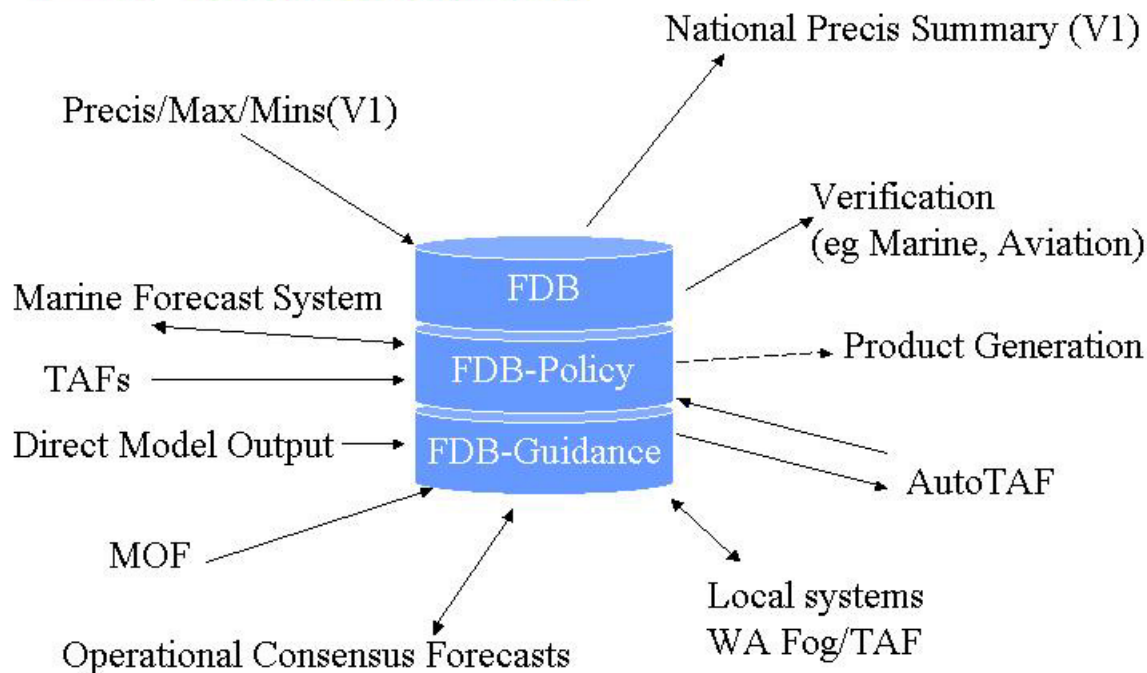
The FDB stores:

- forecast guidance data, such as Model Output Forecasts (MOF) and Direct Model Output (DMO) from a wide variety of models, Operational Consensus Forecasts (OCF, an optimal combination of multiple guidance sources), and automatically generated guidance for TAFs;
- forecast policy data, such as forecast decisions about temperatures, wind, humidity, and cloud cover; and
- general forecasts such as précis, maximum and minimum temperatures nationally, which are used to produce a national précis summary.

Other important functions of the FDB are:

- to feed the verification process, for marine wind forecasts, and TAF verification; and
- to provide support for automatic product generation, described below.

FSEP Data Base (FDB)



Commonwealth Bureau of Meteorology

Figure 1. FSEP Data Base (FDB) showing existing forecast guidance storage (e.g. DMO, MOF, OCF), forecast policy storage (e.g. marine wind forecasts, TAFs, Précis), and output products (AutoTAF, Verification, marine forecast products, and the developing product generation system)

9. THE PRODUCT GENERATOR

The Product Generator under development is the FSEP Mechanism for producing forecasts, warnings, observation bulletins and advices.

The scope of the production generator includes product design, generation of graphical and text content, assembling of products, content review and editing, interaction with policy editors (such as AMFS or TIFS), monitoring product generation, product dissemination and backup functionality.

10. AIFS 2 VISUALISATION MODULES

a. 2D Radar

For some time the CBM has been using two programs for the viewing of radar data. These programs are PC-Rapic and 3D-Rapic. PC Rapic displays 2D radar data only, it provides animation, mosaicing and data retrieval capabilities. It is an assembly and Pascal based program intended to be run under DOS. Its compatibility with modern operating systems was marginal. 3D-Rapic is a UNIX OpenGL visualisation package for viewing volumetric and doppler radar data.

The 2D Radar Module was developed to:

- allow replacement of the aging PC-Rapic system;
- provide a more modern and integrated user interface; and
- provide a reusable radar layer, for use in this and other applications.

2D Radar is presently at Version 0.8 and is close to being feature complete. It comprises 28,000 lines of

code unique to this application and has been worked on for approximately 10 person months.

Infrastructure which has come out of radar module includes:

- the Animation Manager (presently reused in FDV); and
- the progress displaying splash screen (presently reused in TIFS and FDV).

b. On Screen Analysis

NMOC currently use the United Kingdom Met Office's (UKMO) Horace On Screen Analysis (OSA) program to produce Mean Sea Level Pressure (MSLP) analyses over the Australian region, and to create graphical output products for distribution to forecast offices.

The AIFS 2 OSA program is being developed to provide an analysis program which has a user interface consistent with other AIFS 2 applications and to allow the analysis feature to be integrated into any AIFS 2 application.

Infrastructure which has come out of OSA includes the 2x zoom tool.

c. FSEP Data Viewer

The FDV is the general purpose data viewer for AIFS 2. It currently displays NWP guidance and satellite imagery, and is being extended for oceanographic data display.

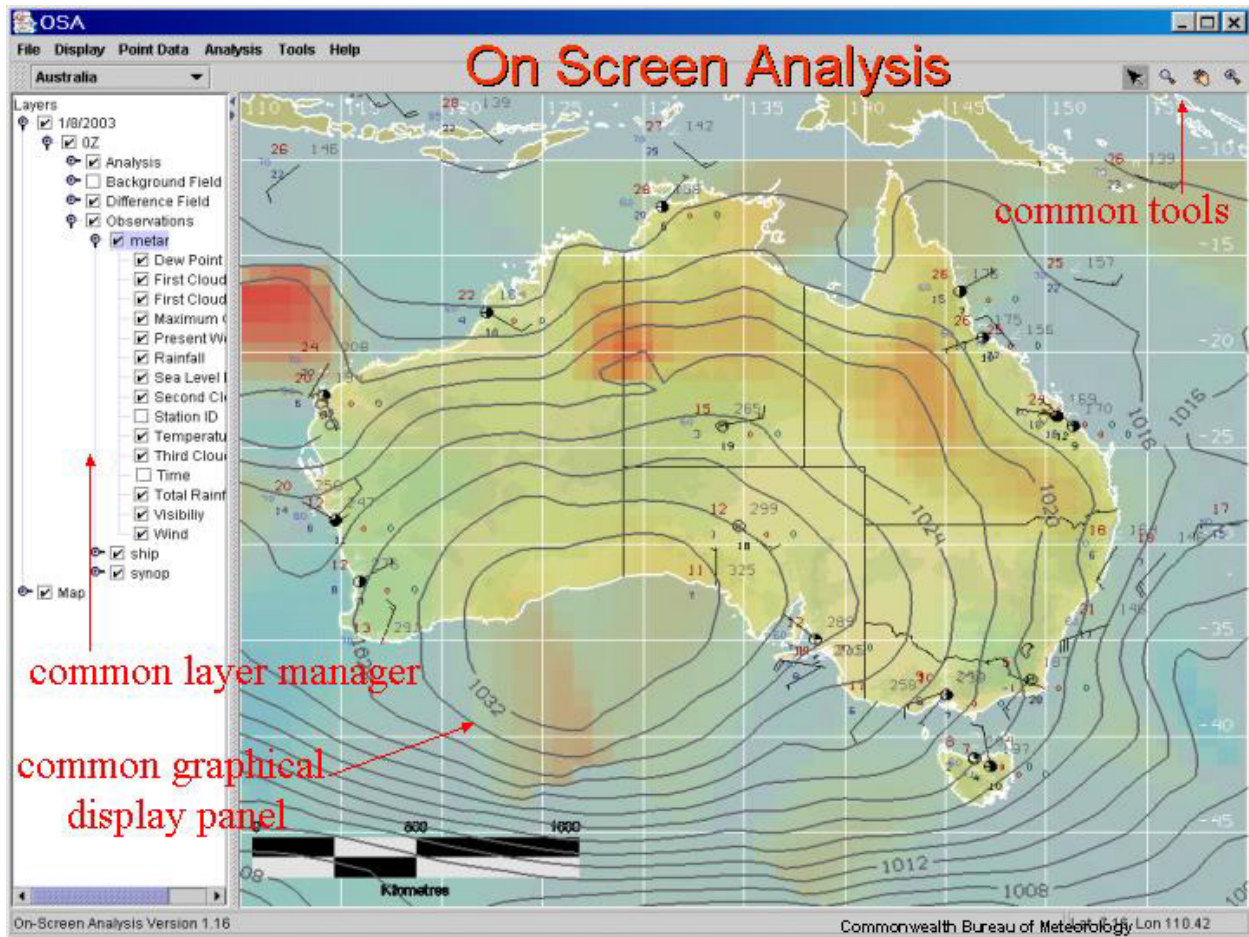


Figure 2. The On Screen Analysis (OSA) program showing surface observation plots, and an MSLP analysis. AN NWP pressure field has been used as the first guess field, followed by a 3 pass Barnes analysis. The coloured background image highlights in red areas where the new analysis differs from the model first guess.

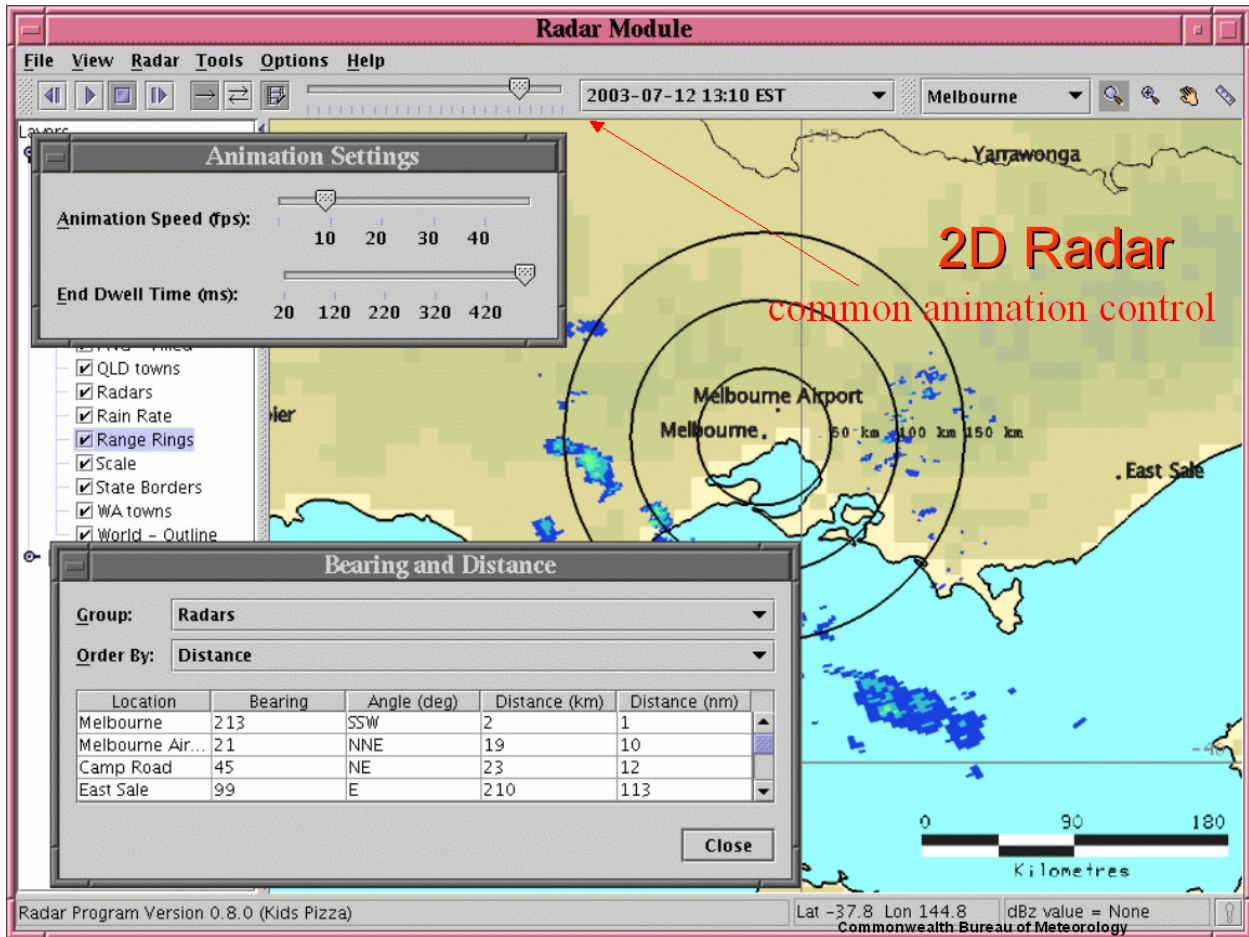


Figure 3. The 2D Radar program, displaying reflectivity from the Melbourne Airport radar. Note the animation tool in the top toolbar, showing the multiple time steps available, represented as “tics”

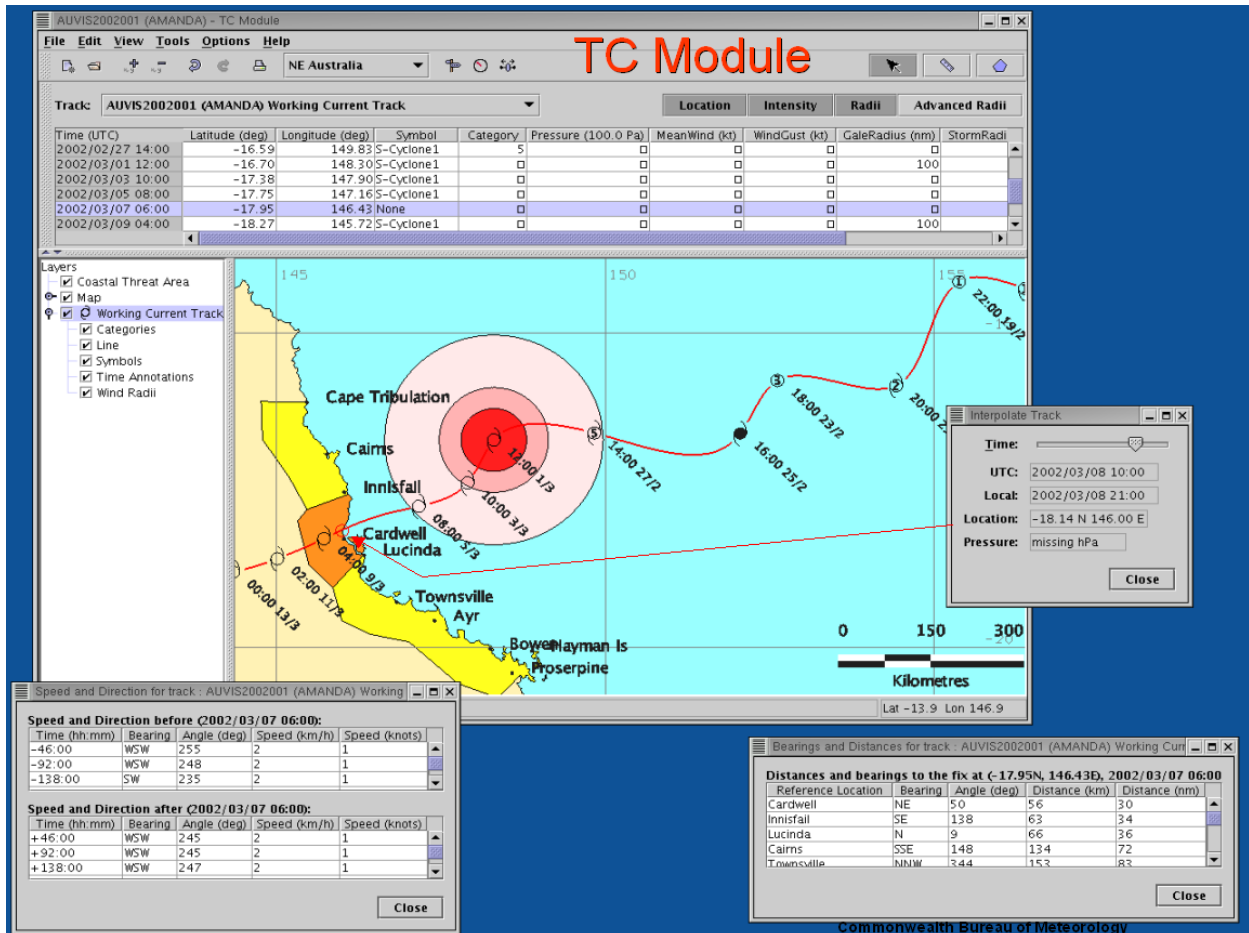


Figure 4. The TC Module, showing a Tropical Cyclone track, and forecast location, radius of gales, storm and hurricane force winds (as coloured circles in the graphical display panel). Also shown are a tabular displays of:

- the TC track (top table), with location and pressure information;
- speed and distance information (bottom left table);
- distance and bearing of the cyclone from the nearest towns (bottom right table); and
- an “interpolate track” control which displays the TC position and details for the time on the slider control.

Note that coastal zones are coloured according the level of the TC threat.

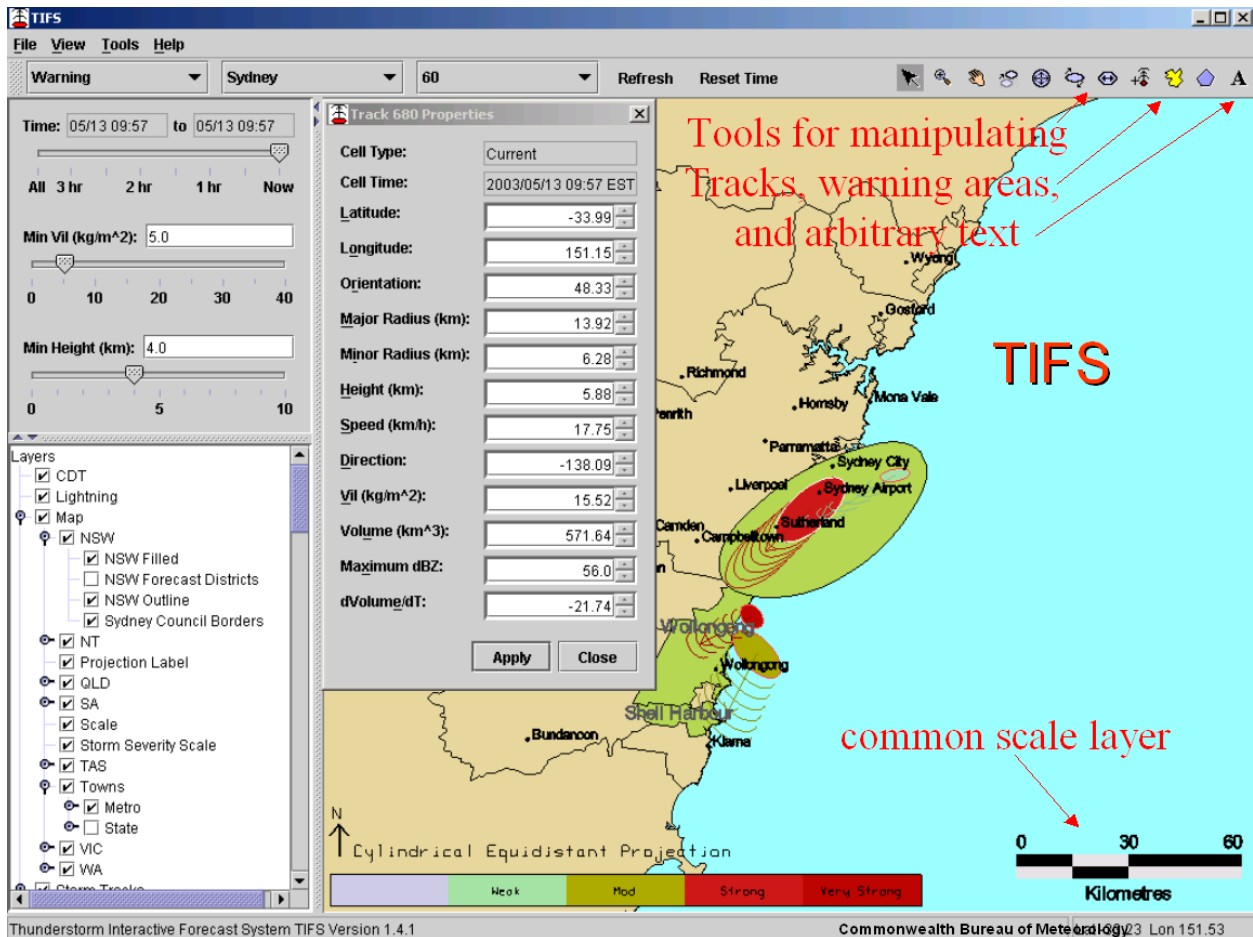


Figure 5. The Thunderstorm Interactive Forecast System (TIFS), showing thunderstorm positions as filled in ellipses, and the forecast track as an arrow and half ellipses. Forecast thunderstorm tracks may be manipulated, and text warnings and graphical products are created automatically. Thunderstorm cell properties may be edited by clicking on a cell and adjusting the values in the dialog shown in the figure. Cells are coloured based on a parameter value, such as intensity (dBZ).

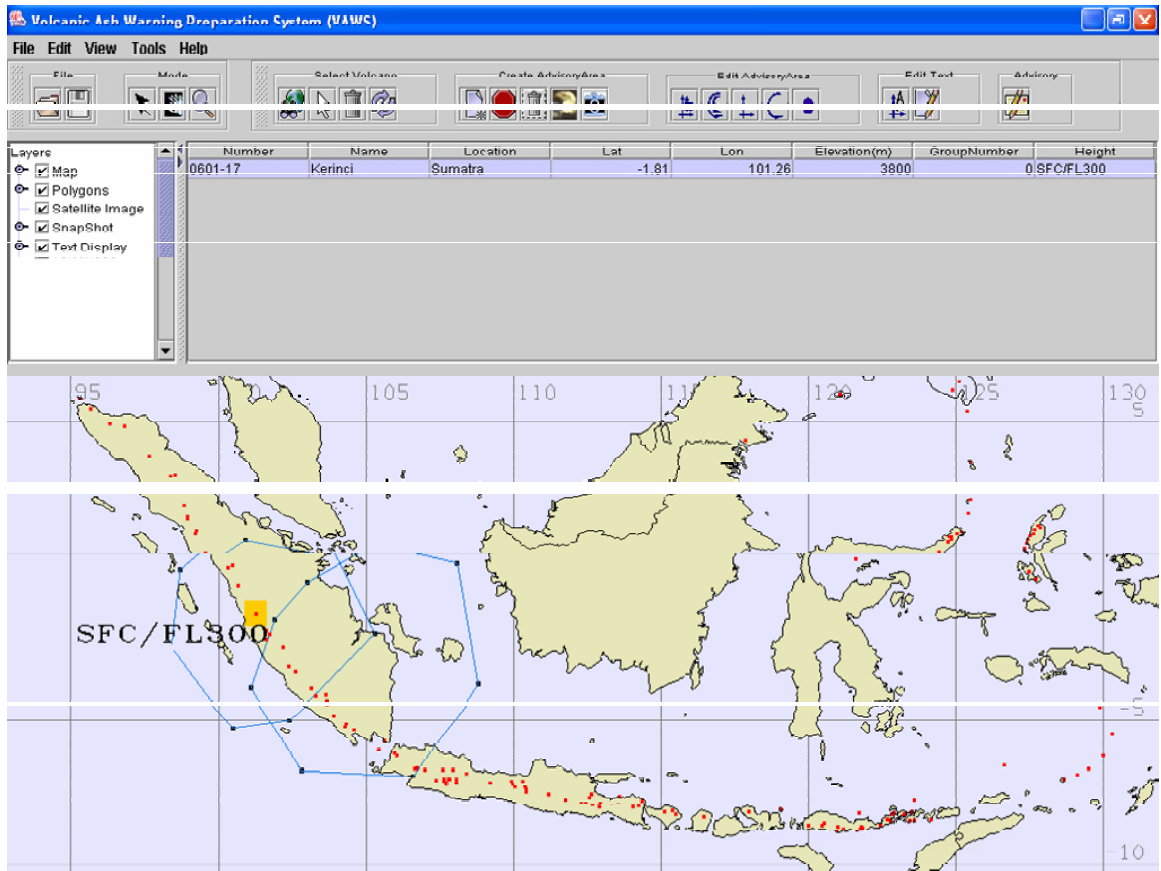


Figure 6. The Volcanic Ash Warning System (VAWS), showing an analysed area of Volcanic ash cloud, and a forecast area. As for TIFS, text and graphical forecast products can be created automatically.

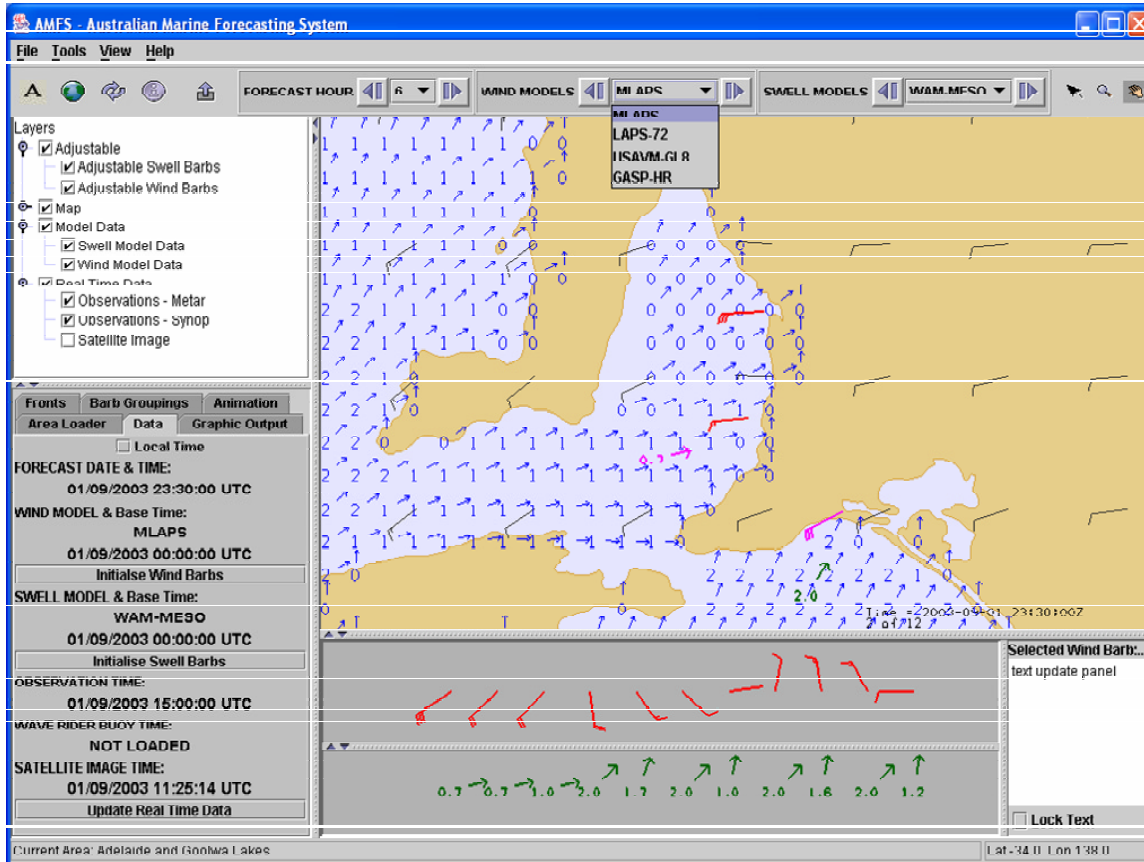


Figure7. The Australian Marine Forecast System (AMFS), showing background NWP wind (black wind barbs) and swell (blue arrows representing swell direction, and blue numbers representing the swell height in metres). Adjustable wind barbs (in red or pink, pink indicating the barb has been selected by a mouse click) and swell arrows (green or pink) are used to set forecast wind and swell policy. Text and graphical output products are then created automatically.

10. AIFS 2 POLICY EDITORS

Policy editor is the general name given to interactive graphical applications which enable users to manipulate the digital data they are displaying. In the case of forecast guidance data, after adjustment by the forecaster, this digital data becomes official forecast policy. For example this might be forecast wind speed and direction for nominated coastal waters locations and/or zones.

a. TC Module

The Tropical Cyclone (TC) Module was developed to provide:

- A replacement for an existing application known as ATCW (Australian Tropical Cyclone Workstation);
- a platform for integrating other data types including satellite, radar and NWP data;
- a platform for integrating verification;
- generation of graphical warnings and forecasts;
- generation of text products;

- integration with despatch system for text and graphical products.

TC Module has been operational in Queensland and the Northern Territory since the 2001/02 season and in Western Australia since the 2002/03 season.

TC Module is presently at Version 2.5 and, as time permits, is undergoing updating to contribute to forecast streamlining and enhancement now that a good baseline program exists. It comprises 59,000 lines of code unique to this application and has been worked on for approximately 24 person months.

Infrastructure which has come out of TC module includes:

- map layers (presently reused in all AIFS2 software);
- dynamically updating Map Scale (presently reused in Radar, TIFS and OSA);
- user configurable town locations and names (presently reused in Radar and TIFS);
- the LayerManager (presently reused in all AIFS2 software);

- the ToolManager (presently reused in Radar, TIFS, AMFS, OSA and FDV);
- viewports (presently reused in Radar, TIFS and OSA);
- the TextProductGenerator (presently reused in TIFS).

b. TIFS

TIFS is the Thunderstorm Interactive Forecast System. TIFS was originally developed as a research system (Bally et al., 2001) for the rapid analysis and forecasting of Severe Thunderstorm events, partly for use during the Sydney Olympics.

TIFS is operational in NSW and scheduled for operations in Victoria and Queensland for the 2003/04 severe storm season. TIFS comprises 49,000 lines of code, and was developed over approximately 16 person months.

Infrastructure which has come out of TIFS includes the text product formatter (used in the TC Module).

c. VOLCANIC ASH WARNING PREPARATION SYSTEM (VAWS)

The CBM operates the Darwin Volcanic Ash Advisory Centre that provides advice on volcanic ash for the aviation industry as part of the ICAO International Airways Volcano Watch (ICAO, 2001). The advice issued is based on an initial report or detection of a volcanic eruption or ash cloud, an analysis of satellite data to identify and track the ash cloud, and a forecast of the movement of the ash derived from upper level winds and an atmospheric dispersion model.

Uncertainties in the satellite analysis (Tupper et al, 2003) and output from the ash dispersion model make it essential for the forecaster to directly interact with interim products to generate the output products. This process is manually intensive and delays the issue of warning products that must be issued promptly so that aircraft can take appropriate avoidance measures.

The VAWS has been developed to:

- Streamline preparation of the VAA text product;
- Generate a corresponding graphical product;
- Enable more integrated use of satellite data and dispersion model output; and
- Provide a stable framework that simplifies operational implementation of improved analysis and prediction components.

The VAWS user interface is illustrated in Fig. 6. This shows the layer manager, a volcano table and the map window that displays coastlines and all volcanoes in the region. Using the mouse the forecaster can easily select the volcano of interest and delineate the analysed and forecast threat areas, from which the VAA text and graphical products are generated. Operational trials of the system are currently underway.

d. AMFS

AMFS is the Australian Marine Forecast System, as shown in Fig. 7. AMFS is used to create wind speed and direction forecasts, as well as swell direction and height. These digital forecast values are then used to generate graphical and text output products. For an example graphical product, see <http://www.bom.gov.au/products/IDT65280.shtml>. For more details on AMFS refer to Kelly et al, 2003.

11. Research

The Bureau of Meteorology Research Centre (BMRC) is leading analysis activities of information content, information flows and forecast process. BMRC is also actively contributing to FSEP and AIFS 2 development via a wide range of activities such as the development of prototype and demonstration systems (such as TIFS), ongoing development of the Operational Consensus Forecasts (Woodcock and Engel, 2003) as well as radar data serving, thunderstorm analysis and tracking algorithm integration, and rainfall diagnosis. Since the computing infrastructure of the research branch and the operational systems have converged, the level of collaboration between the branches has been rising rapidly. For example the VAWS is a collaborative development between the research and operations groups, leveraging off tools developed for operational AIFS 2 use. There is also collaborative work underway on providing intelligent alerts to forecasters. This system will filter out unnecessary alerts, and compare current forecast products with guidance and real time observations.

12. Training

The Bureau of Meteorology Training Centre (BMTC) was heavily involved in AIFS 1, and is a willing partner and contributor in FSEP and AIFS 2. Training is an important agent for cultural change, and is best if integrated into underlying systems and processes, and where it is included for the start of the process. Specialist trainer involvement in both AIFS 1 and 2 has had strong management and user support. Training has incorporated the following types:

- System based, “*which button do I click?*”;
- Meteorological background, In-service courses, self paced online courses/material and general reading;
- Product / diagnostic specific; and
- Case studies based on competencies

Train the trainer programs have been particularly successful, as they have been an efficient use of central resources, while developing ongoing training expertise in each forecast office.

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