Visualising the Atmosphere in Motion

Ian Bell and Jeff Wilson
Bureau of Meteorology Training Centre
Melbourne
I.Bell@bom.gov.au, J.Wilson@bom.gov.au

Abstract

The atmosphere is an extremely complex fluid with nonlinear interactions over a wide range of scales. In order to help new and existing meteorologists better understand the atmosphere the Bureau of Meteorology Training Centre (BMTC) has developed a wide range of Computer Aided Learning (CAL) modules for visualising atmospheric processes and phenomena. These range from simple demonstration models for atmospheric processes to the animated display of satellite imagery and numerical prediction model output. This paper discusses the approaches used by BMTC. Examples of CAL modules illustrating these approaches will be demonstrated and are also available through ftp (ftp.met.ed.ac.uk).

Keywords

Computer aided learning, visualisation, meteorology, Toolbook

1. Introduction

There are a number of aspects that limit our ability to understand and forecast the future state of the atmosphere. The atmosphere is a highly complex fluid with interactions across a range of scales, there is never enough observational data to accurately describe its current state, we can't isolate individual processes or phenomena, we can't undertake repeatable experiments on it, our theoretical understanding is incomplete, and numerical weather prediction models, even on the fastest supercomputers, are limited. Finally, there is such a vast array of possible ways of viewing the atmosphere that most forecasters stick with tried and not-always-true displays which may not always be optimal.

The Bureau of Meteorology Training Centre has been using computer aided learning to increase forecasters' understanding of the atmosphere. This paper focuses on ways in which visualisation is being used to understand atmospheric processes and to allow forecasters to view the vast amounts of atmospheric data in more efficient and effective ways.

2. Visualisation

Data visualisation is about comprehension, not graphics. It can be thought of as a range of techniques that enable numerical data and its internal relationships to be displayed in a form most appropriate for processing by the human brain. Visualisation itself is not new to meteorology. What is new are the number and complexity of visualisation tools that can be used.

2.1 Visualising atmospheric processes - simple models

Due to the complexity of atmospheric processes it can be beneficial to look at simplified models in isolation. This enables the student to gain an understanding of the processes involved which can then be applied to the real atmosphere. Two examples of these simplified models will be shown. The first, “atmospheric kinematics” illustrates in a highly visual way the manner in which idealised flow patterns will alter the temperature field to produce cold fronts. This program (**kinem.tbk**) and others (unless otherwise specified) were produced using Multimedia Toolbook V 3.0a (Asymetrix).

The second is of a simple one dimensional numerical model (**1dmod30.tbk**). Students can interact with it to isolate the effects of changing just one component of the model (boundary conditions, mathematical scheme, wave shape, etc) and receive immediate feedback via a graphical display. This would be impossible in the highly complex numerical weather prediction models.

2.2 Visualising the atmosphere as a fluid

Surface or upper level analyses are essentially a two dimensional visualisation. Traditionally single-level, single-time analyses are shown on perhaps hundreds of sheets of paper hanging in a display area. Internal relationships in the data (isotach and / or isotherm analysis combined with the pressure, height or streamline analysis) are shown as permanently overlain fields. What these single level static visualisations fail to do is to depict the atmosphere as a 3-dimensional moving fluid.

Few meteorologists would examine satellite imagery without first looking at an animated sequence (eg, **solsticD.tbk**, **solsticJ.tbk**). Constant level analyses or forecast fields should be viewed in the same fashion. An animated sequence clearly shows the development and progression of features much more clearly than looking at individual charts. The computer gives the additional advantage of being able to build up the sequence in complexity and to include prognosed fields as part of the sequence. (**armsl.tbk**, **longwave.tbk**).

2.3 Visualising complex data

Visualisation is not just adding animation to still images, it also includes the ability to examine data in different ways. For example, viewing the structure associated with an extra-tropical cyclone via its temperature fields (**etctemp.tbk**), examining the movement and development of an extra-tropical low from an earth centred framework, or a system centred framework (**etcsapic.tbk**), or showing the use of satellite imagery and model data to describe the flow on isentropic surfaces (**isentropic.tbk**).

Two of the main elements that operational meteorologists produce forecasts for are cloud cover and the type and amount of precipitation. In the Bureau of Meteorology these elements are not available directly from the numerical model guidance and so have to be deduced by the forecasters. To forecast these elements they traditionally use relative humidity and vertical velocity diagnostics (at a limited number of levels, often one) to forecast broadscale cloud. They then modify this mental image according to expected variations between the model and the atmospheric behaviour. This subjective process, at times, leads to major forecast errors. To demonstrate an alternative approach based on visualisation, a simple algorithm based on three dimensional relative humidity is used to display prognosed satellite imagery from operational numerical model output. These images (**proggms.tbk**) displayed in combination with surface pressure and incremental model precipitation prognostic fields give a forecaster rapid access to the main features of that numerical prediction and remove the subjectivity of the manually visualised cloud.

Students (and some operational Meteorologists) are traditionally poor at modifying temperature soundings (used for predicting cloud and thunderstorms) as they normally only see upper wind and temperature data 12 or 24 hours apart. To overcome this output from a PC based teaching numerical model has been sampled at each model timestep (every 20 minutes - giving 109 traces for a 36 hour forecast) and the resulting traces have been animated (**skewT.tbk**). Results very clearly show the atmospheric stability variations in a manner previously unseen.

2.4 Visualising in new frameworks

The examples discussed to date have principally been animations and overlays. In the last 12 months the Australian Bureau of Meteorology has moved its computing infrastructure from a mainframe environment to an open systems UNIX environment with UNIX workstations throughout the organisation. This change has given the BMTC and operational meteorologists a chance to use high end visualisation software such as the University of Wisconsin Space Science Engineering Centre's VIS-5D package and the Bureau's in-house three dimensional radar display (**radar3D.tbk**).

Using VIS-5D it is possible to portray any 4 dimensional field as an iso-surface, horizontal or vertical cross-section, overlaying and animating fields at will (**vis5dex.tbk**).

The challenge with such products is how will they be useful for forecasting, with at least part of the answer being selection of the types of fields we put into these products. A second question that using these products raises is how well do we understand the atmosphere? Products such as VIS-5D come closest to allowing us to depict atmospheric processes and phenomena in the context of fluid movement. The next generation of visualisation tools (virtual reality) will enable us to visualise ourselves as part of the fluid. Will our thinking and understanding be up to the challenge?

3. International cooperation

Education and training cooperation in meteorology is coordinated through the World Meteorological Organisation, especially through the Working Group on Computer Aided Learning. CAL modules are freely shared and may be downloaded from the CALMET site at the University of Edinburgh (ftp to: **ftp.met.ed.ac.uk** or WWW url: **http://www.met.ed.ac.uk/calmet/**). Biennial Computer Aided Learning in Meteorology conferences are held (the next will be in Melbourne in July 1997), a CD-ROM "Images of Meteorology" has been produced to provide source images and CAL modules for educational use, a number of cooperative development projects are underway and data and software are freely exchanged.

4. Conclusion

The power of the modern tools is that they can be used to present the data in a myriad of ways. The challenge for the trainers is to get the forecasters to change their way of thinking about the atmosphere. If the forecasters continue to rely almost solely on traditional analyses and their associated thought processes the power and potential of the new tools will not be utilised.