Visualizing Weather Data

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Extended Abstract

Numerical weather models are producing enormous amounts of data. A typical model output data set may consist of one billion points in a five-dimensional rectangle, composed of a 100 by 100 horizontal grid, by 30 vertical levels, by 100 time steps, by 30 different parameters. Such a data set can fill thousands of two-dimensional plots, and challenges the capacity of current systems for its management, analysis and visualization.

The University of Wisconsin-Madison Space Science and Engineering Center (SSEC) developed the Man-computer Interactive Data Access System (McIDAS) as a tool for accessing weather data as animations of two-dimensional images and graphics (Smith, 1975). This system was a revolutionary change from the traditional paper facsimile plots, because it gave the user control over the geographic extents and contents of its images and graphics, and because it provided animation. However, numerical models and modern remote sensing instruments are generating data sets whose size, dimensionality and complexity exceed the capacities of current interactive weather systems. Thus we began an effort about six years ago to develop a four-dimensional capability for McIDAS. This system generates animated displays of multivariate three-dimensional images from weather data.

Our system manages weather data as two and three-dimensional uniform grids, as trajectory paths through space and time, and as images. Grids can be grouped together for multiple parameters and multiple time steps, allowing us to manage a five-dimensional rectangle of model output data as a whole. Our system includes a wide variety of user commands for housekeeping and analysis operations on our data structures. Gridded data can be resampled in space and in time, combined by arithmetic operations, transformed to a moving frame of reference and manually editted. Gridded data provides an indicator for missing data values, and this can be exploited to visualize only a region of a grid by marking other areas as missing. Trajectories can be generated from gridded U, V and W wind components.

The four-dimensional McIDAS system can be used to generate animation sequences of three-dimensional images which combine many physical paremeters, using a variety of graphical techniques (Hibbard, 1986a; Hibbard, 1986b). All of our images are rendered in a rectangular box, including a flat or topographical map on the bottom, with optional physical and political boundaries. Our graphical primitives include:

** opaque and transparent trajectories, rendered as thin cylinders

** opaque and transparent contour surfaces

** grid mesh contour surfaces

** contour isopleth lines lying either on the topographical map or on a horizontal surface defined by some other gridded variable such as pressure or potential temperature

** volume rendered densities, with the opacity of each three-dimensional point proportional to some gridded variable

** opaque and transparent texture mapped images, lying on some plane in space

** visible satellite images texture mapped onto a cloud top surface defined by the corresponding satellite infrared derived heights

We often combine our animation sequences with a rocking motion of about 1 or 2 degrees, as a way of making the three-dimensional geometry of the depicted weather phenomena more apparent (Hibbard, Santek and Dengel, 1988). We also sometimes stop the time action and rotate the images through large angles.

We have applied our software to produce visualizations of data from many different numerical weather models (Pauley, Hibbard and Santek, 1988; Meyer and Seablom, 1988; Uccellini, 1988; Santek, Leslie, Goodman, Diak and Callan, 1987). We have also applied our software to a wide variety of remote sensed data from satellites, radars, lidars, observing networks and sounding instruments. These visualizations are used for teaching at the University of Wisconsin and other institutions, for conference presentations of case studies, and by modellers and instrument developers wishing to understand their data.

Our experience producing visualizations of weather data has shown that a more interactive system is very important (Hibbard, 1988). We are currenlty developing a new system based on the Stellar GS-1000 graphics supercomputer. Most of our images contain between 5000 and 20000 shaded triangles, and roughly the same number of line vectors. Our animations generally run at 7.5 frames per second. The GS-1000 should be able to produce similar animations in real-time, giving the user interactive control over the display for rotation, zooming, changing the combination of selected parameters, retrieving values at a cursor, changing the levels of contour surfaces, and varying the images in many other ways.

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