METEOROLOGICAL DATA ANALYSIS AND EVALUATION OF A VISUALIZATION SYSTEM

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Abstract

Multi-variate data analysis and scientific data visualization techniques available on a supercomputer environment were used for producing animations of meteorological parameters. Through experimenting, animations of single meteorological parameter and combinations of meteorological parameters were used to investigate evolutions of winter cyclones.

A visualization system used for producing graphics and animations was evaluated for its subsystem functional efficiencies.

1. INTRODUCTION

Traditionally, meteorological data have been analyzed with layers of two-dimensional charts on pressure surfaces or heights. Data animations, for example by Klemp and Rotunno (1984), were done mostly by showing a single-surface or multi-layer view. A three-dimensional structure is hard to grasp with this type of data representation.

Recently, some research efforts have been made by Hibbard (1986), Grotjahn and Chervin (1984) to use three-dimensional animation to study mesoscale and large scale weather phenomena. In this type of research, several meteorological parameters are displayed, and each parameter is depicted by a different color or symbol. By viewing the animation of these parameters a meteorologist infers the interactions among them. The type and number of meteorological parameters are not definite. However, parameters often used are: wind vectors, streamlines, temperature, and water substances such as water vapor, cloud water and rain content. Occasionally, vorticity and divergence are also incorporated into data display.

The first step toward understanding parameter interactions is to view parameters simultaneously. However, choices of parameters and what is to be investigated often are not clearly defined a priori by a viewer. The reason may be that traditionally most meteorologists have been studying parameters individually. Therefore, even when more than one parameter is presented, it is being viewed as a separate entity without due regard to underlying physical laws that control the interactions.

This paper presents a case illustrating how to select and visualize parameters. Parameters identified as controlling factors of a cyclonic system evolution will be discussed. A supercomputer-based visualization system with its computational environment for data processing and animation production will be discussed.

2. COMPUTATIONAL ENVIRONMENT

Supercomputers were used for this research project for data preparation and image data generation. Through a local area network, data and software are accessible among personal computer, workstation, and supercomputer. The major operating system is UNIX, and it is used by workstations and supercomputers alike. The graphics image data were transmitted to workstations, and displaying/recording was done at the graphics workstation. Detailed descriptions of computers and software systems will be given in section 6.

3. DATA PREPARATION

A database consisting of 168 hourly forecast data was created at the European Centre for Medium-Range Weather Forecasts by a numerical weather prediction model run on a CRAY X-MP/48. The database contains geopotential, temperature, specific humidity, vertical velocity, vorticity, divergence, relative humidity, and u, v wind components. Each parameter has data for 91 x 47 horizontal grids and 14 height levels. The data were recorded on a magnetic tape in WMO GRIB format. Meteorological parameters u, v wind components, specific humidity, etc. were retrieved from this tape. Each parameter has its own dataset after retrieval.

4. DATA ANALYSIS AND VISUALIZATION

The data analysis and visualization involve following steps:

4.1. Parameter Selection

In this research, the selection of parameters was done rather unconventionally. As a demonstration case, kinetic energy, potential temperature and specific humidity were chosen; subsequently they served as a minimum set of meteorological parameters for studying cyclonic system. By selecting kinetic energy other than u, v wind components in scalar or vector form, one can perceive how the kinetic energy was transported, and how it would relate to cyclone formation. By selecting potential temperature rather than temperature itself, one can see how thermodynamic quantity -- entropy -- is related to the storm. By selecting specific humidity, one can visualize the outline and structure of a weather system.

4.2. Contouring/Viewing

To analyze a parameter, graphics with try-out, three-dimensional, and rendered iso-contours with a certain viewing perspective were created for an hourly grid data. These graphics were generated on the CRAY computer, but viewed on SUN and IRIS workstations. The contouring/viewing process was repeated until satisfactory contouring intervals and a perspective view were obtained.

4.3. Pseudo-Animation

Since the graphics workstations used for this research did not provide fast playback capability, the animation was previewed as follows: for each parameter, a low spatial and temporal animation sequence with numerous video frames was produced. This low resolution sequence with frames was previewed on a graphics workstation frame after frame. Thus the motion of contoured features could be viewed in a pseudo animation mode, while the motions of features were felt by displacement. If the motion proved satisfactory, one proceeded to the next step. Otherwise, it was back to the previous step for determining contour levels.

4.4. Video Production

In this step, the high resolution and fine temporal animation sequence was to be produced. The graphics object rendering was done on the CRAY computer. Video frames were transported to the workstations via network and recorded on a video tape.

5. DATA ANALYSIS RESULTS

Complete parameter animation results will be shown during the video presentation. Here, the important conclusions are listed as follows:

- Kinetic energy field shows structure of tropospheric jet structure. The jet depicted by kinetic energy iso-contours is much more effective than that depicted by other meteorological parameters such as momentum or wind vector. An example of such structure, located in the middle altitude, is shown in Figure 1 .

- Water vapor specific humidity field shows structures unknown to most meteorologists. A terrain-like summit indicates a cyclonic storm center, and peak/trough indicates a frontal zone in three-dimensions. An example of such storm structure, located near the earth surface, is shown in Figure 1 .

- Potential temperature field shows a near-circular structure associated with a cyclonic storm. An example of such structure is shown in Figure 2.

- Animation of kinetic energy shows that the jet structure changes shape constantly. The wedge-like configuration is generally associated with a cyclone.

- Animation of water vapor specific humidity shows that iso-surfaces are driven by winds, and the motion of surface is three-dimensional with evidence of vertical oscillation, possibly relating to gravity waves.

- Composting animation of kinetic energy and water vapor shows that two fields are related. The evidence of a middle atmospheric jet feeding energy to a low-level cyclone for its further development can be seen from the composite animation.

- Animation of potential temperature shows that the near-circular structure at one time became nearly stationary horizontally, and the motion was confined to a downward direction. This is evidence of an air subsidence during a later stage of cyclonic life cycle.

6. VISUALIZATION SYSTEM EVALUATION

Advantages of using a computer complex with computers of different computing powers for producing animation was assessed by Chen (1988). This research was conducted by using such a computer complex system. Some details of the computer complex, networking system, and computer graphics software system used are presented as follows:

6.1. Computer Complex

The computer complex includes a supercomputer and workstations. The supercomputer, a Cray X-MP/18, is available to a user who can log-on from a local workstation/terminal to execute jobs. The main operating system is UNICOS.

The workstations used include an IRIS and a Sun. The Sun workstation was used as a general purpose workstation/terminal. The IRIS graphics workstation with DiaQuest video controller connected to a Sony video recorder was used for video production. This computer complex provides adequate computational power for medium to low volume animation production. A frame image generation requires about 10 to 20 CRAY CPU minutes. Video frame recording rate is about 2 minutes for 1 frame.

6.2. Network

Because all of the computers are interconnected by a Local Area Network (LAN), a user can access any computer through the communication network. Telnet is used for remote logging on to other computers, and file transfer protocol (ftp) is used for transferring files. Different computers appear as different nodes. While residing at one node, application software programs can be run at remote nodes. The entire networked system is designed for multi-user and multi-tasking applications; therefore any user can configure his/her own system using different computers. The rate of data transfer depends on network traffic. LAN used is Ethernet. The data rate is approximately a few mega bits per sec. Sometimes, when transferring image files, sluggishness is felt.

6.3. Graphics Software Systems

The Cray OASIS graphics system includes three-dimensional modelling and rendering routines. It also has graphics composite and animation capability, but it cannot run a realtime animation. It is capable of generating a series of frames which can be recorded sequentially on a recording device. The OASIS software system was implemented at JPL CRAY X-MP/18, IRIS and SUN workstations. However, Cray X-MP/18 does rendering, IRIS and SUN do visualization, and IRIS does video image recording.

The rendering component of OASIS produces very high quality ray-traced image. It can be executed very efficiently with CRAY Y-MP and CRAY 2. For Cray X-MP/18, which has only a single processor and is relatively slow, an animation lasting about a minutes would take a few day to complete.

7. CONCLUSIONS

This research demonstrates to meteorologists that with the proper computation and production environment, one can use available animation techniques to study the evolution of cyclonic systems.

Similar cases analyzing other meteorological parameters can be accomplished, and they may shed more light on understanding the evolution of weather systems.

Though the present visualization system is efficient for producing animation frames, a faster and more interactive computer graphics system is desirable. The task of faster and interactive graphics may be augmented by a mini-supercomputer or a super-workstation.

8. REFERENCES

Chen, P. C., 1988: Computer graphics systems. Proceeding: Workshop of Graphics in Meteorology, December, 3-5. European Centre for Medium-Range Weather Forecasts, U. K.

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Figure 1
Volume-Rendered Kinetic Energy and Water Vapor Specific Humidity

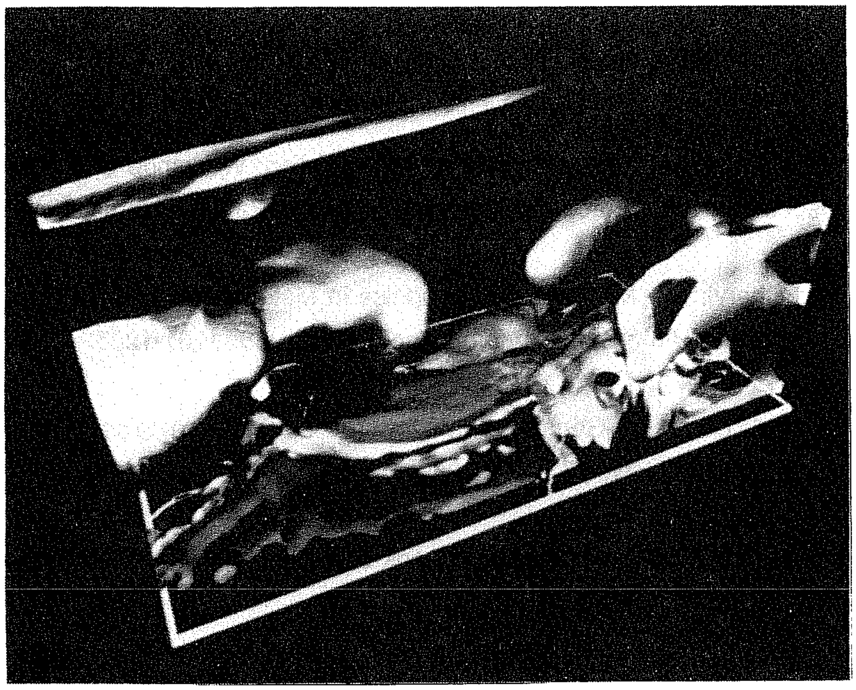

Figure 2
Volume-Rendered Potential-Temperature