meeting summary

Snow White and the Six Dwarves Run Climate Models in Italy

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ABSTRACT

As computing power has increased, it has become possible to run a state-of-the-art climate model on a workstation, and the use of climate models is spreading rapidly. However, the dispersion of climate modeling know-how has not kept pace with the dispersion of climate modeling capabilities. To connect new modelers with modeling know-how, a two-week climate modeling workshop was held. Participants designed and ran climate experiments under the guidance of a group of modeling experts. This paper describes the process that was followed in these climate experiments and gives an example of one experiment.

1. Overview

In the past, the typical researcher using an atmospheric general circulation model (GCM) was part of the team that developed it and had access to the team's collective knowledge of the GCM's strengths and weaknesses. GCMs are now used by a much wider scientific community at a greater variety of institutions and by researchers from many fields besides atmospheric sciences, but the drawback of this rapid spread of modeling is that the collective knowledge of the teams that built the GCMs is not widely available to those running them.

At a recent NATO Advanced Study Institute (ASI), participants formulated, designed, executed, and evaluated climate modeling projects, all in 10 days at an isolated hotel in Italy. Combining lectures and practical experience, the ASI, which took place 25 May–5 June 1998, brought together some leaders in the field of climate modeling and some aspiring climate modelers. The projects used a state-of-the-art GCM, the community climate model (CCM3) of the National Center for Atmospheric Research (NCAR).

The two-week ASI was held at Il Ciocco, an isolated resort hotel on a hillside in Tuscany. Participants agreed that the isolation benefited the ASI by fostering camaraderie, aided by four-course dinners, a swimming pool, a disco, and other diversions. The camara-

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derie and the amenities helped sustain participants through a grueling daily work schedule that included 4 h of lectures, many hours working on the projects, and some time editing chapters of a book based on the lectures presented at the ASI. Even after a long day in Florence on the intervening weekend, some hard workers could not resist checking on their model runs.

In order to run the CCM3 at Il Ciocco, Sun Ultra computers were rented and installed at the hotel. Expecting eight computers (one for each project), our local computer expert Alberto, who installed them, gave them the names of Snow White (Biancaneve) and the seven dwarves in Italian. Alas, Pisolo (Sleepy) never arrived; perhaps he overslept. The computers each had 128 MB of memory and a 1-GB hard drive; six had a single processor, but Brontolo (Grumpy) had two processors, and another had a 2-GB hard drive. The resolution used was trapezoidal T31 × 15, with 18 levels in the vertical, and at that resolution a year of model time could be run in about 18 h, barring any difficulties (of which there were an abundance; see below). J. Rosinski from NCAR brought a tape with all the needed datasets, the CCM3 code, and the analysis software (Ferret and Yorick). Rosinski installed everything on the seven computers and remained on hand to guide the project teams in modifying the CCM3 code as needed.

2. Organization of the project teams

Designing the project was a long process that began well before the ASI. Participants submitted about 30 suggestions ahead of time, and after voting by CCM3 experts B. Boville, J. Rosinski, and D. Williamson, a list of 24 (each with a difficulty rating) was presented to the ASI students on the first day for voting. The students narrowed the list to these eight ideas.

1) What is the role of midlatitude SST anomalies in midlatitude atmospheric circulation?
2) What is the circulation in a warm-pole regime, as prevailed during the Cretaceous period?
3) What is the transient response to changes in snow cover?
4) What is the effect of varying the rotation rate of the earth?
5) How does the North Atlantic Oscillation (NAO) influence the European climate?
6) What happens to the atmosphere if the sun is suddenly turned off?
7) What happens if the earth is flat?
8) How do chlorofluorocarbon (CFC) molecules released in, say, New York City reach the stratosphere?

When Pisolo failed to arrive, the CFC team was disbanded and each team ended up with about eight students and 1–2 lecturers. Each team chose a captain; the roles of the captain were primarily 1) to facilitate group discussions and decisions, and 2) to report to the project coordinator (P. Mote) at captains' meetings, which were held roughly every other day. The lecturer(s) in each group served as scientific advisor.

3. The end-to-end approach

Few of the students had worked with GCMs before, and many came from other fields entirely but intended to use GCM output or run GCMs as part of their research. Despite their inexperience, however, they forged strong working teams in the crucible of isolation and hard work, and learned a great deal from each other.

At the outset, project teams were charged with the task of planning the whole experiment before beginning any model runs. Starting with the one-line project description (above), they formulated the question more carefully and, within the limitations of time and disk space, considered the length and number of model runs, chose some diagnostics to perform, and chose a few essential model variables to save. They conferred with the CCM3 experts about modifying CCM3 code. The teams carefully monitored the model runs, sometimes performing diagnostics on the fly, and made course corrections as needed. On the penultimate day of the ASI, each team presented its results orally, usually by several presenters per team (valuable experience, especially for the nonnative English speakers). This end-to-end approach forced students to use resources carefully and also showed them the value of careful planning at the beginning.

4. Overcoming difficulties

The participants quickly learned that no principle is more applicable to running a GCM than Murphy's law: if anything can go wrong, it will. Here are some of the difficulties encountered at the ASI.

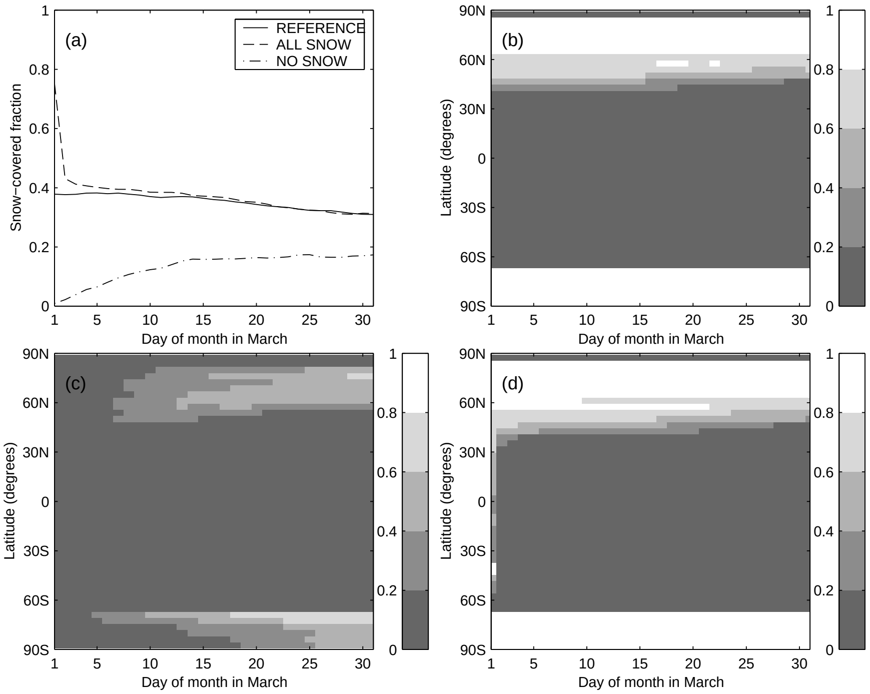

FIG. 1. Globally averaged (a) and zonally averaged (b–d) snow cover fraction in three climate model experiments: reference (b); "no snow" (c), in which snow is initially set to zero at every land grid point; and "all snow" (d), in which snow depth is initially set to at least 10 cm at every land grid point.

- Early in the first week of the ASI, lightning struck very near the hotel and the computers shut down; Mammolo (Bashful) had a damaged power supply that took nearly a week to replace.
- Ferret, it turns out, treats a variable named "T" as time, and has trouble dealing with the three-dimensional temperature field (also named "T") in the model output; solutions were nontrivial.
- In one of the two computer rooms, a switch on the wall next to the room lights turned out to control the power to Brontolo (Grumpy), a fact that we only discovered after a conscientious student turned out the lights. By a bizarre coincidence, the experiment running on that computer was the "turn off the sun" experiment—and, of course, the computer was a Sun.
- The sharpest limitation on the experiments was not the speed of the computers or the number of difficulties, but the disk space. For runs stretching to several years, only a few variables could be saved and only as monthly means, limiting potential analysis. Countless model runs crashed because of a full disk.
- When recompiling the model after changing a subroutine, one must remove the old object file of that subroutine. Otherwise the old one gets reused!
- Printing was a challenge. The transparencies we had brought did not work in the printer, and we had to find a store in rural Tuscany that would sell us some. When the color began to fade as everyone was preparing their reports at the end of the ASI, we had to find a store that sold color cartridges for that type of printer. Such emergency errands were made even more interesting by the white-knuckle driving on narrow, windy mountain roads and by the daily closure of shops for much of the afternoon.

Despite these and numerous other problems, each of the groups managed to perform a number of runs, analyze the output, and get results. Most of the groups paid some attention to statistical significance; some groups performed a number of ensemble runs in order to increase the significance of their results.

5. The snow experiment

To illustrate how the process worked, we describe the experiment posed as "What is the sensitivity of a short-term forecast to initial soil moisture or snow cover?" The group included two of the authors (DP, JY) and was led by one of us (DP) and advised by J.-F. Royer of France. The results presented below were those reached by the group during the ASI and have not been altered; however, owing to the difficulty of transporting data from Il Ciocco, the figures have been recreated from identically configured new model runs performed at the University of Washington by one of us (JY).

a. Planning

Within the constraints of time and disk space, the group decided to focus on snow cover and to simplify the experiment design by performing a control run and two perturbed runs: 1) removing all existing snow

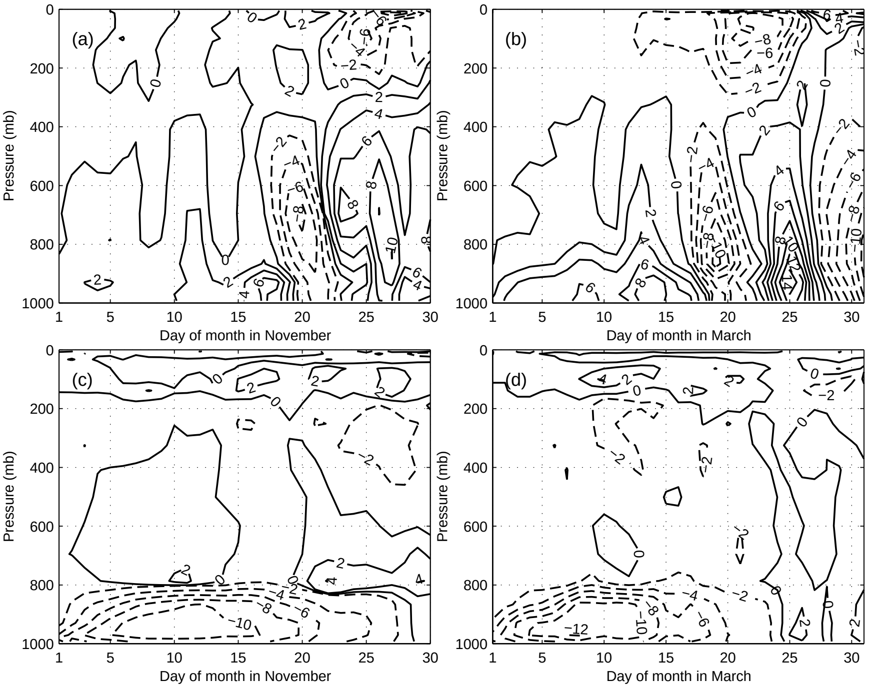

FIG. 2. Area-averaged temperature differences (in °C) from control. For Siberia (55°–70°N, 80°–130°E), the differences shown in (a) and (b) are between the “no snow” run and control. For the Sahara (15°–30°N, 3.8°W–30°E), the differences shown in (c) and (d) are between the “all snow” run and control.

cover, the “no snow” run and 2) adding snow where there was none, the “all snow” run. They chose to do all three runs as 30-day experiments for both November and March. They trimmed the list of output variables and added a few [like snowfall, relative humidity, and sea level pressure (SLP)] that are not automatically saved. Since the standard initial conditions for CCM3 were 1 September, the group planned to generate initial conditions for the November and March runs by running the model to the end of April and saving the output every month. As part of the planning process, the group considered three questions.

1) Would the snow cover in the perturbed runs converge toward that in the control run?
2) Would the synoptic situation be affected?
3) From these runs alone, can we conclude something statistically significant?

b. Modifying code

Snow cover can be modified in the subroutine that initializes time-dependent variables in the land surface component model of CCM3. For the all snow experiment, the group decided to put 10 cm of snow on every land grid point where snow depth was less than 10 cm. No other modifications were made, notably in the surface temperatures. The group made the changes correctly and even succeeded in performing all the runs without any computer problems.

c. Analyzing results

In response to question 1 above, they calculated separately the zonally and globally averaged fractional snow cover (Fig. 1). Snow that falls on warm or hot land melts quickly, and the snow cover in the all snow case (Fig. 1d) rapidly approaches that in the control run (Fig. 1b). It takes considerably longer for snow cover to be replenished in the no snow case (Fig. 1c). To answer question 2, the group calculated means over days 21–30. There were considerable differences in surface pressure (a coding error deprived the group of the SLP), but without ensemble runs, the group could not determine whether these differences were statistically significant.

They decided to focus on two specific areas, the Sahara and Siberia (Fig. 2), where the addition and removal (respectively) of snow would make a big difference in the surface energy budget. For Siberia (Figs. 2a, b) the differences between runs have deep tropospheric structure and seem to be due to weather “noise” rather than direct local response to the local change. For the Sahara (Figs. 2c, d), however, the addition of water (the snow of course melts quickly) causes a substantial and lasting cooling, especially for November (Fig. 2c). Evaporation and precipitation are an order of magnitude higher than in the control case, cloud cover is doubled, and net solar flux drops by 50 W m^{-2}.

6. Lessons learned

Within the constraints imposed by disk space and unforeseen difficulties, the climate modeling projects still were successful in introducing students to some important concepts in climate modeling. Among them were the following.

- Careful planning pays off. Thinking through the research question and how to answer it, anticipating the code changes and analyses that will be needed, and structuring the control and perturbed experiments in a sensible way.
- Be prepared for problems, and do not be discouraged.
- Ensemble runs, if possible, should be performed to ensure statistically significant results.
- When making code changes, it is important to check and recheck the output to be sure that the changes were done correctly.
- GCMs are valuable tools, even for learning the answers to silly questions.

If we were to hold another similar exercise, we would do several things differently:

- limit teams to about six members,
- enlist at least a part-time system administrator, and
- arrange for a small library of meteorology texts and some key articles.

Despite the hard work and frustrations, the participants generally felt very positive about the ASI and were sorry to see it end.

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