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The Influence of Ground Moisture Conditions on Summertime Climate As Modeled in a GCM

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The influence of boundary conditions on seasonal climate, and their use as a forecasting tool is a subject of continuing interest. In order to affect climate over a time scale of a few months, altered values of the boundary condition must last at least that long. One aspect of the climate system that may have such a time scale is the ground moisture.

To test the influence of the ground moisture on the summertime climate we used the GISS general circulation model, "model 2" (Hansen et al., 1982). The version used had 8 x 10° horizontal resolution and 9 layers in the vertical. This version produces a good simulation of the current climate, as shown in Fig. 1 for lower atmosphere temperatures over the U.S. Furthermore, the version used allowed the ocean temperatures to change, and the year-to-year variability was also similar to observed values (Fig. 2). The model has two layers in the ground, and a water field capacity dependent upon local vegetation. The water field capacities of the two layers are shown in Fig. 3; given the average rate of precipitation of a few mm/day, it can be seen that the second layer has a time scale for moisture replenishment on the order of 100 days. This would seem sufficient to influence climate over a three-month period.

The control run was integrated for 10 years. On June 1 for three of those years the ground moisture in the U.S. and Northern Mexico in both the first and second layers was reduced to 1/4 of its value in the control run. The actual year-to-year variations in ground moisture were of this order of magnitude in some grid boxes in the model, and in the real world as well (Haffer, personal communication). What is extreme in the experiment is that the reduction in moisture was introduced throughout the U.S.

With the reduced ground moisture on June 1, the runs were integrated through August, and compared with the control runs. Shown in Figs. 4-9 are the temperature and precipitation changes for the three months, averaged for the three years. Also shown are the model standard deviations for the months involved, determined for the 10-year run; these define the noise level of the model. As the results are averaged for three different runs, a 2σ standard deviation is highly significant.

As can be seen in Fig. 4, reducing the ground moisture on June 1 resulted in a significantly warmer June throughout the U.S. The warmer temperatures were also noticed in July (Fig. 5), although some erosion of the pattern was visible along the west coast, with flow off the ocean. By August (Fig. 6) this erosion is even more noticeable, although several interior points are still significantly warm. The warmer temperatures result from a change in the method of removing heat from the surface: with a drier ground, the latent heat flux decreased by some 30% (40 W/m^2) while the sensible heat flux, which requires warmer surface temperatures, increased by a similar amount.

In Fig. 7 the precipitation change in June is shown, along with the standard deviation. Precipitation decreased over most grid points, although the magnitudes were not much greater than the usual variation. Grid points near the ocean seemed to be less affected. The same result applied in July (Fig. 8) with an additional region of wetness spreading up from the south. By August, most of the dry pattern has disappeared.

These results seem to indicate that a knowledge of the ground moisture at the beginning of summer might allow for improved summer temperature forecasts; in the model, dryness on June 1 could have been used to predict warmer temperatures over the U.S. Some predictive value is also seen in the precipitation, at least for the first half of the summer. However, there are several caveats that must be recognized. The initial dryness extended over the entire U.S. - this is unlikely, and more isolated variations will likely have a more muted impact. Also, many aspects of the ground hydrological cycle, which must be parameterized in any GCM, are currently uncertain, and there is no guarantee that the magnitude of the effect will not be model dependent. Nevertheless, the time scale for replenishment of ground moisture seems to be appropriate for it to influence regional climates over a few month period; further studies of this effect are in progress.

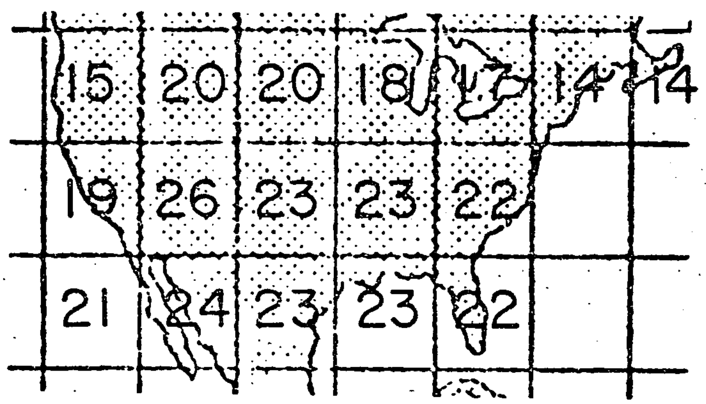

Fig. 1a. Observed July surface-850 mb temperature (°C).

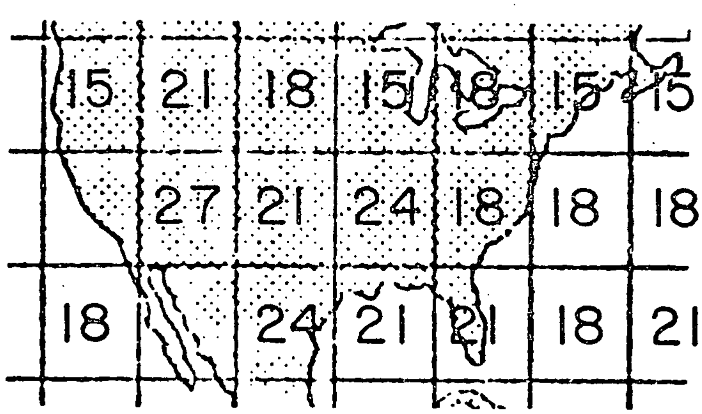

Fig. 1b. Model July 1000-850 mb temperature (°C).

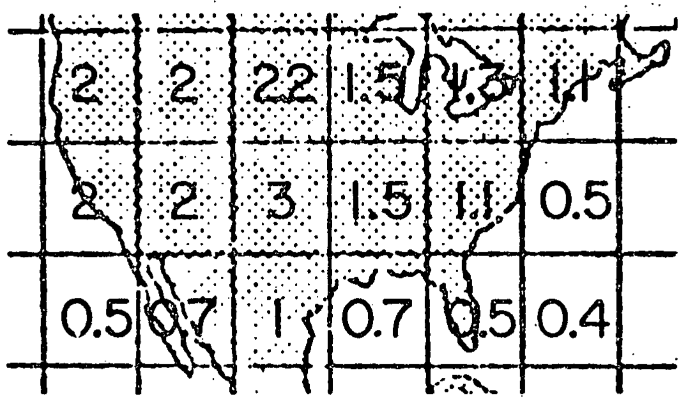

Fig. 2a. Observed July 850 mb temperature standard deviation (°C).

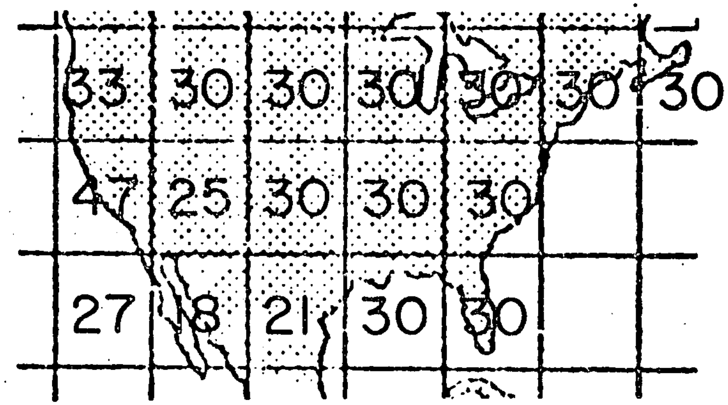

Fig. 3a. Water field capacity of first model ground layer (mm).

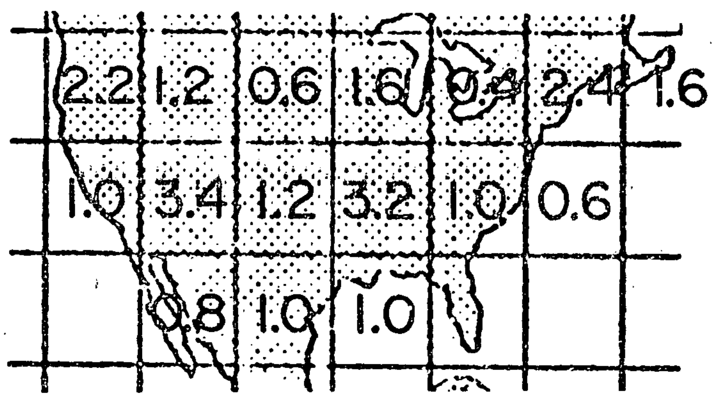

Fig. 2b. Model July 1000-850 mb temperature standard deviation (°C).

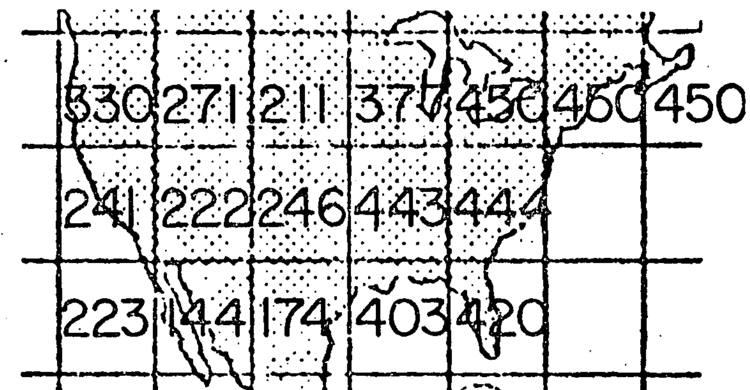

Fig. 3b. Water field capacity of second model ground layer (mm).

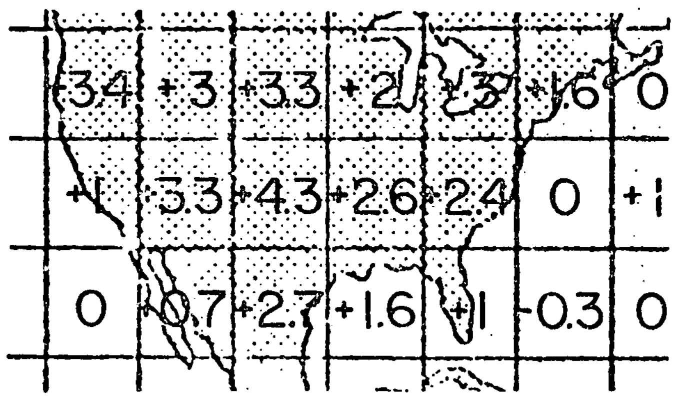

Fig. 4a. Average surface temperature difference (°C) for 3 Junes, drier ground experiment minus control.

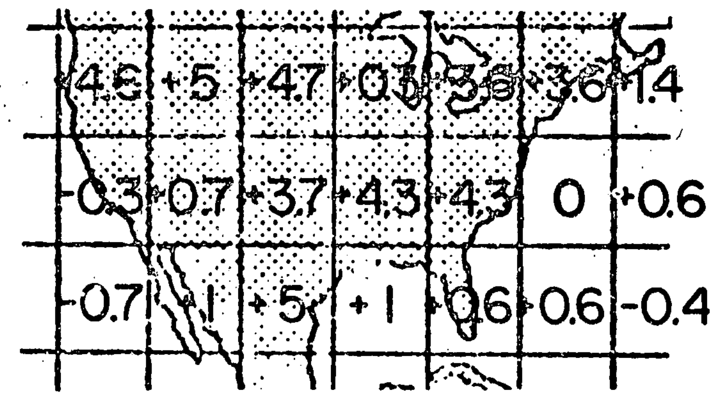

Fig. 5a. Same as 4a for July.

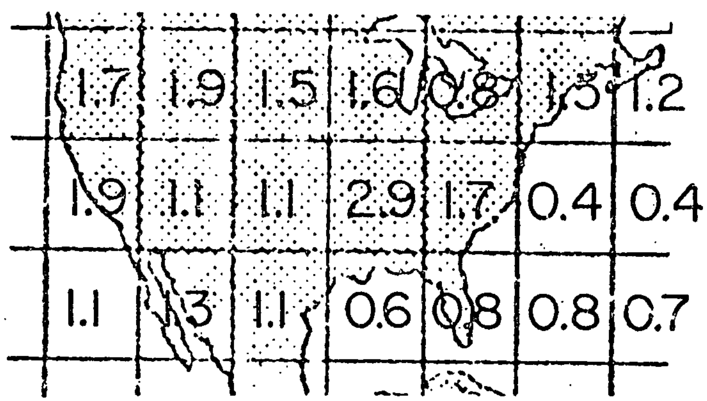

Fig. 4b. Model June surface temperature standard deviation (°C).

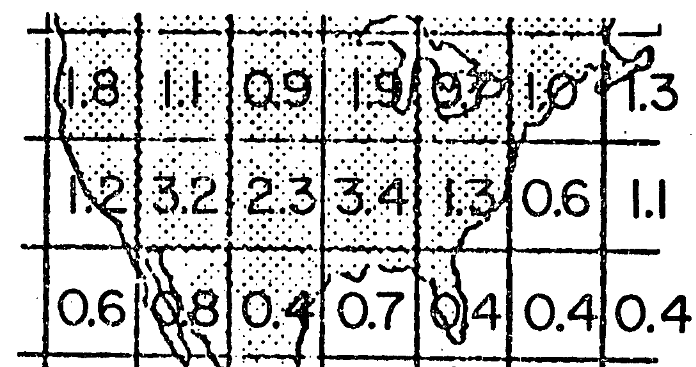

Fig. 5b. Same as 4b for July.

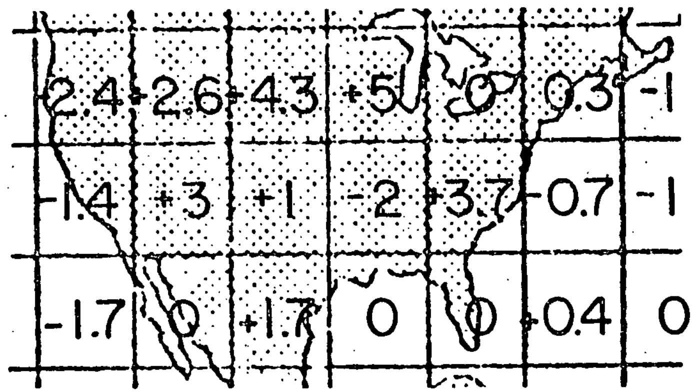

Fig. 6a. Same as 4a for August.

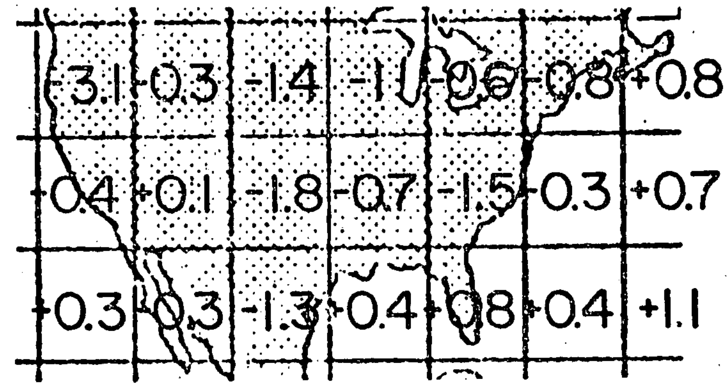

Fig. 7a. Average precipitation difference (mm/day) for 3 Junes, drier ground experiment minus control.

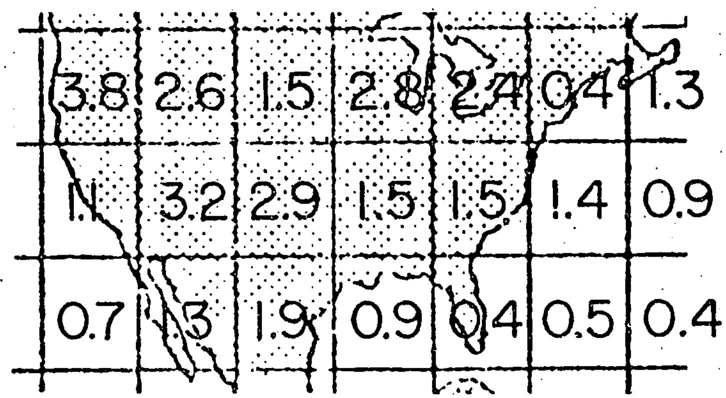

Fig. 6b. Same as 4b for August.

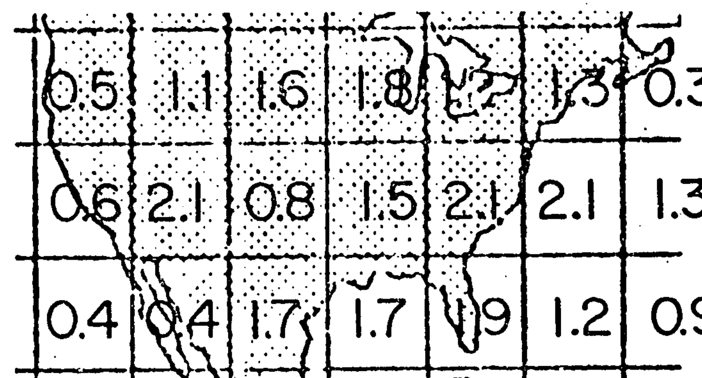

Fig. 7b. Model June precipitation standard deviation (mm/day).

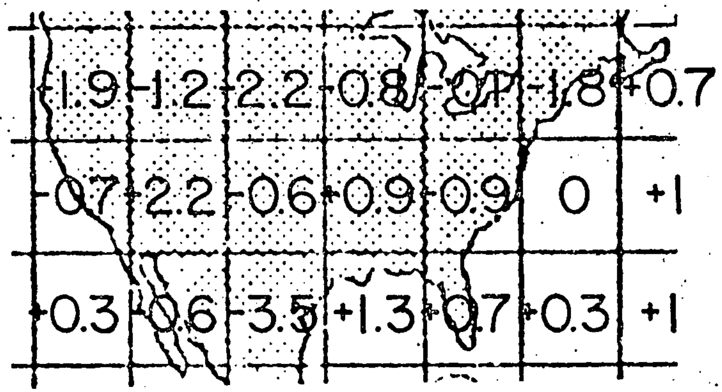

Fig. 8a. Same as 7a for July.

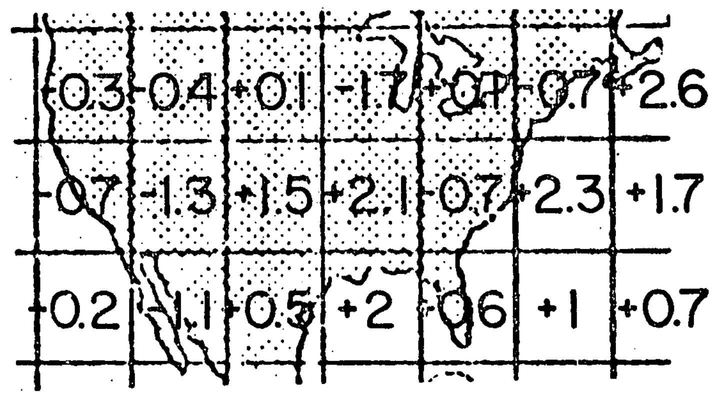

Fig. 9a. Same as 7a for August.

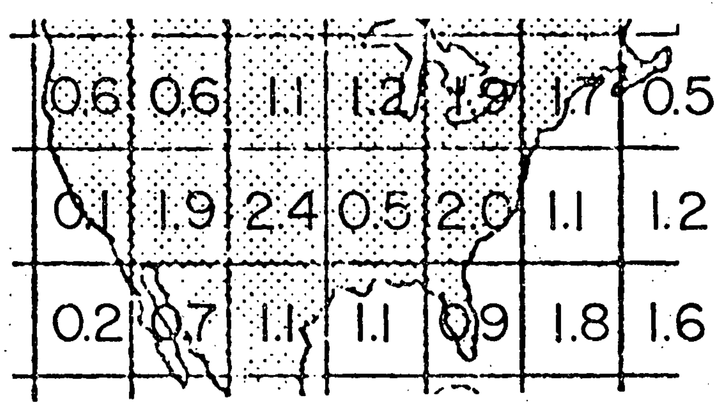

Fig. 8b. Same as 7b for July.

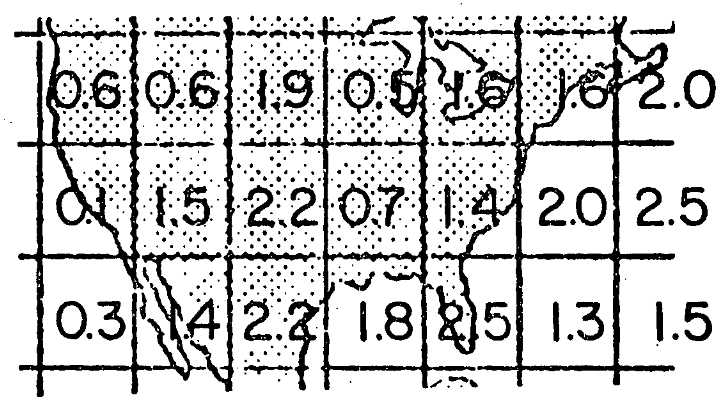

Fig. 9b. Same as 7b for August.