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# Summary of Results of January Climate Simulations with the GISS Coarse-Mesh Model [*]

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## Introduction

The GISS coarse-mesh (8° x 10°) 7-layer global climate model (Hansen et al., 1980) has been used to carry out a series of linked perpetual January climate simulations, which have been described in detail elsewhere (Spar, 1981; Spar et al., 1981 a, b; Cohen, 1981 a, b; Wu, 1981). The purpose of this note is to summarize briefly the principal results and conclusions of that experiment, without the encumbering details and illustrations that are presented in the referenced reports.

The experiment began with two "water planet" simulations (001 and 000) on a globe with no continents, zonally symmetric sea-surface temperatures (SST's) derived from climalological mean January SST's, and polar ice caps. In run 001 the initial meteorological conditions were zonally symmetric values corresponding to an earlier model-generated January climatology, including winds at all levels, but with constant surface pressure. In run 000 the initial state was a horizontally

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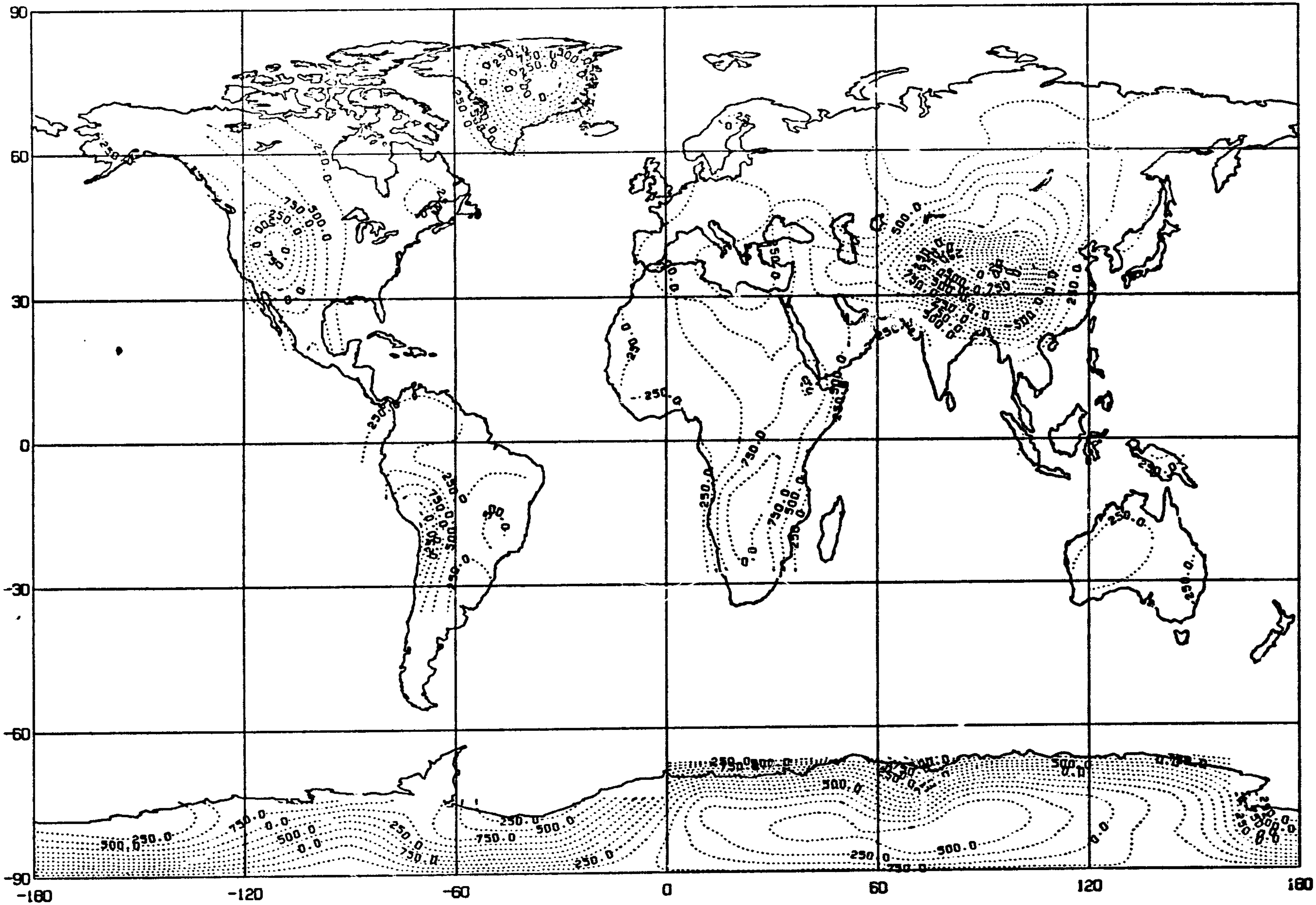
uniform (zero gradient) state of rest at all levels. A comparison of the climatologies generated by runs 001 and 000 provides information on the degree to which the model-generated climate depends on the initial conditions.

For the third simulation (002), which was initialized with the same horizontally uniform state of rest as the "water planet spin up" run (000), flat (sea level), dry continents were placed on the earth. Comparison of the model climatologies for the "flat continents" (002) and "water planet" (000) runs gives an indication of the thermal influence of the continents on the global January climate.

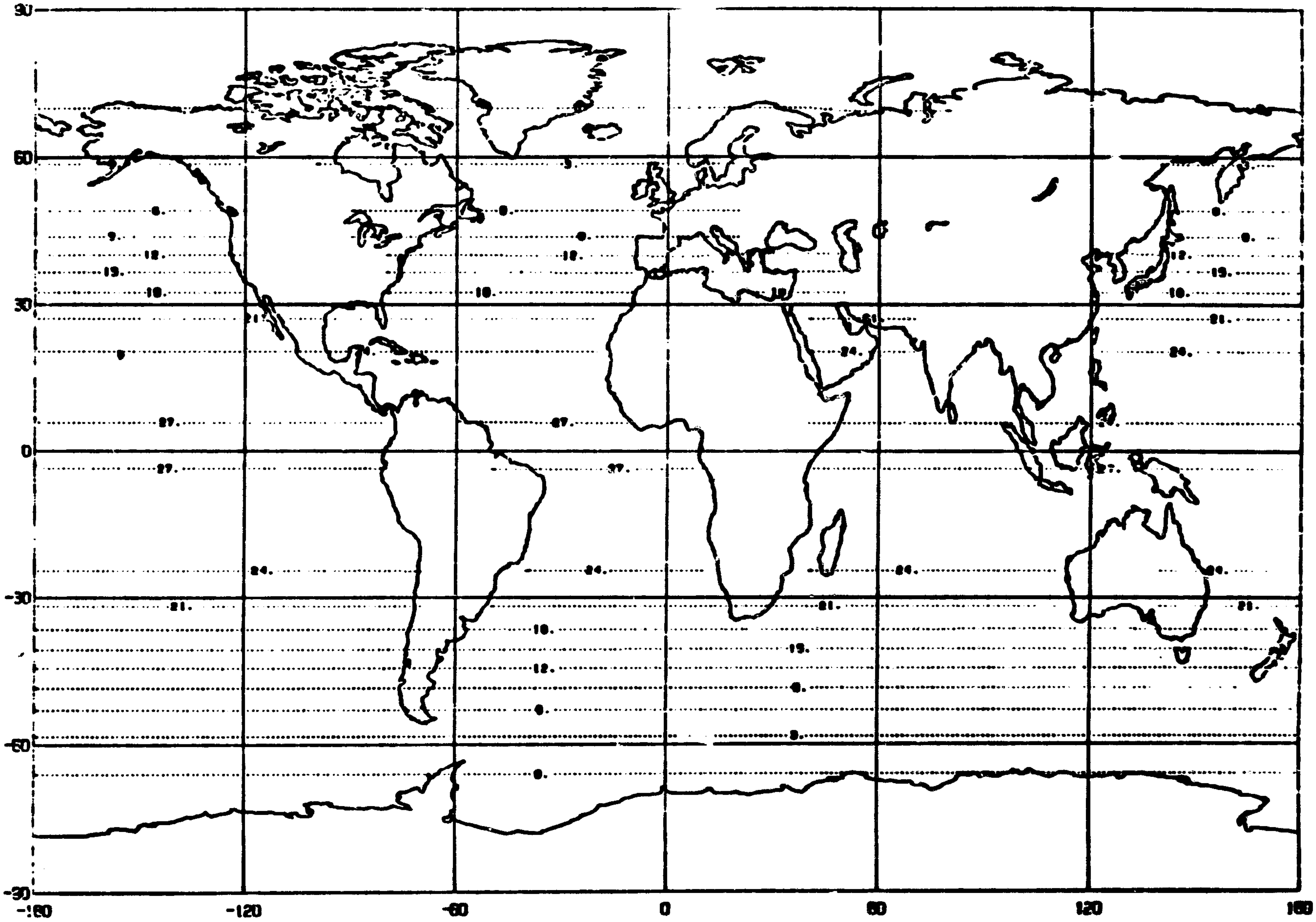
In the next computation (run 003) the surface boundary conditions were further altered by elevating the continental surfaces to correspond to the smoothed model (8° x 10°) terrain height above sea level (fig.1). For this "mountain" run the model was initialized with a dry isothermal atmosphere. The differences between the mean conditions generated by runs 002 and 003 are due largely to the effects of terrain height, for the influence of the change in initial conditions is found to be very small after the first 5 months, and these are discarded in the computation of the January model climatology.

Run 004 differs from 003 only in the inclusion of "surface physics" on the continents, specifically ground water hydrology and spatially variable surface albedo. Finally, in run 005 the zonally symmetric SST field (fig.2) was replaced by a realistic climatological SST field for January (fig.3), with realistic sea-ice boundary, but the model, including initial conditions, is otherwise identical to that used in 004. (The SST difference between runs 004 and 005 is shown in fig. 4.)



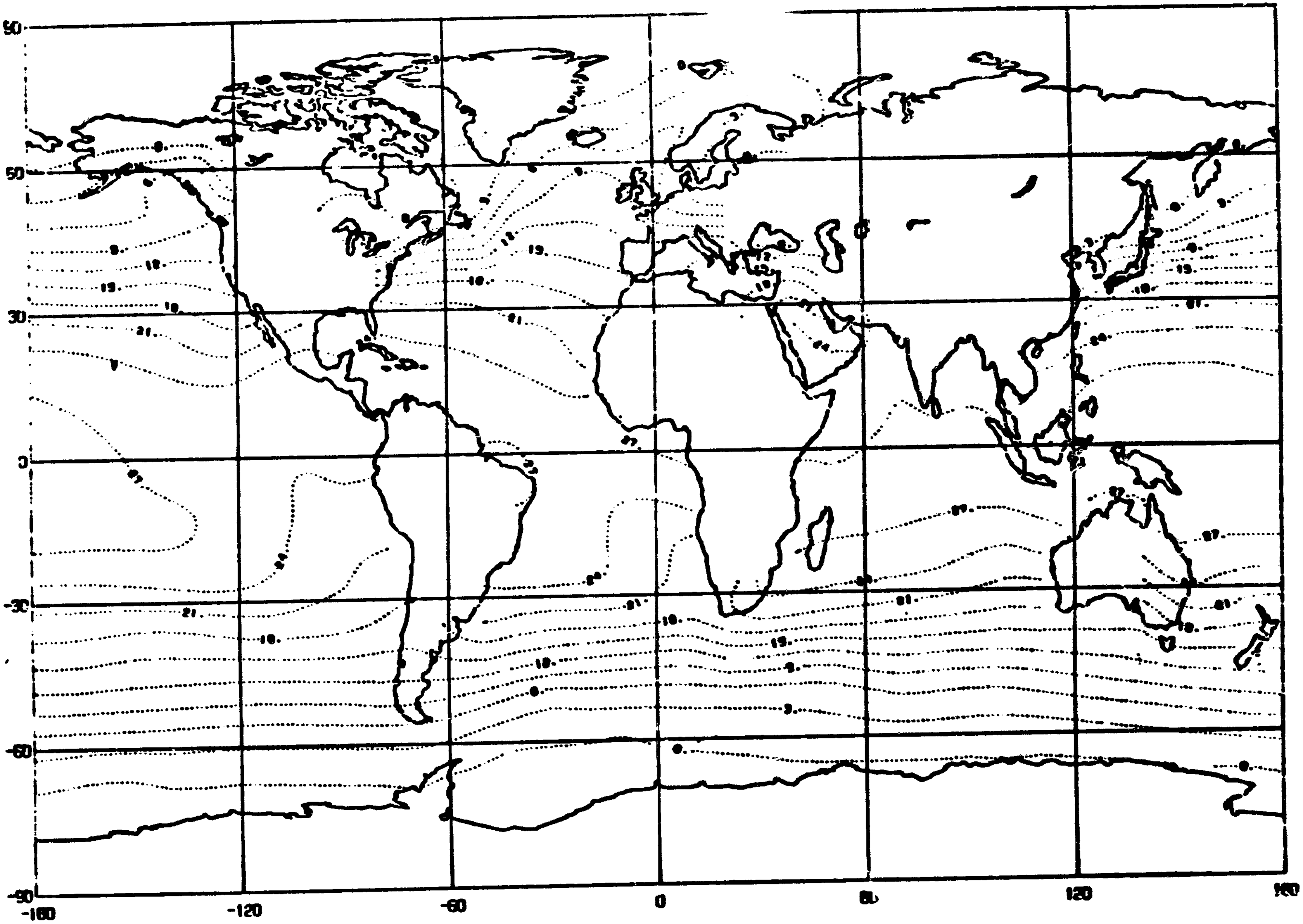
TOPOGRAPHY OF THE MODEL IN GEOPOTENTIAL METERS

Fig. 1



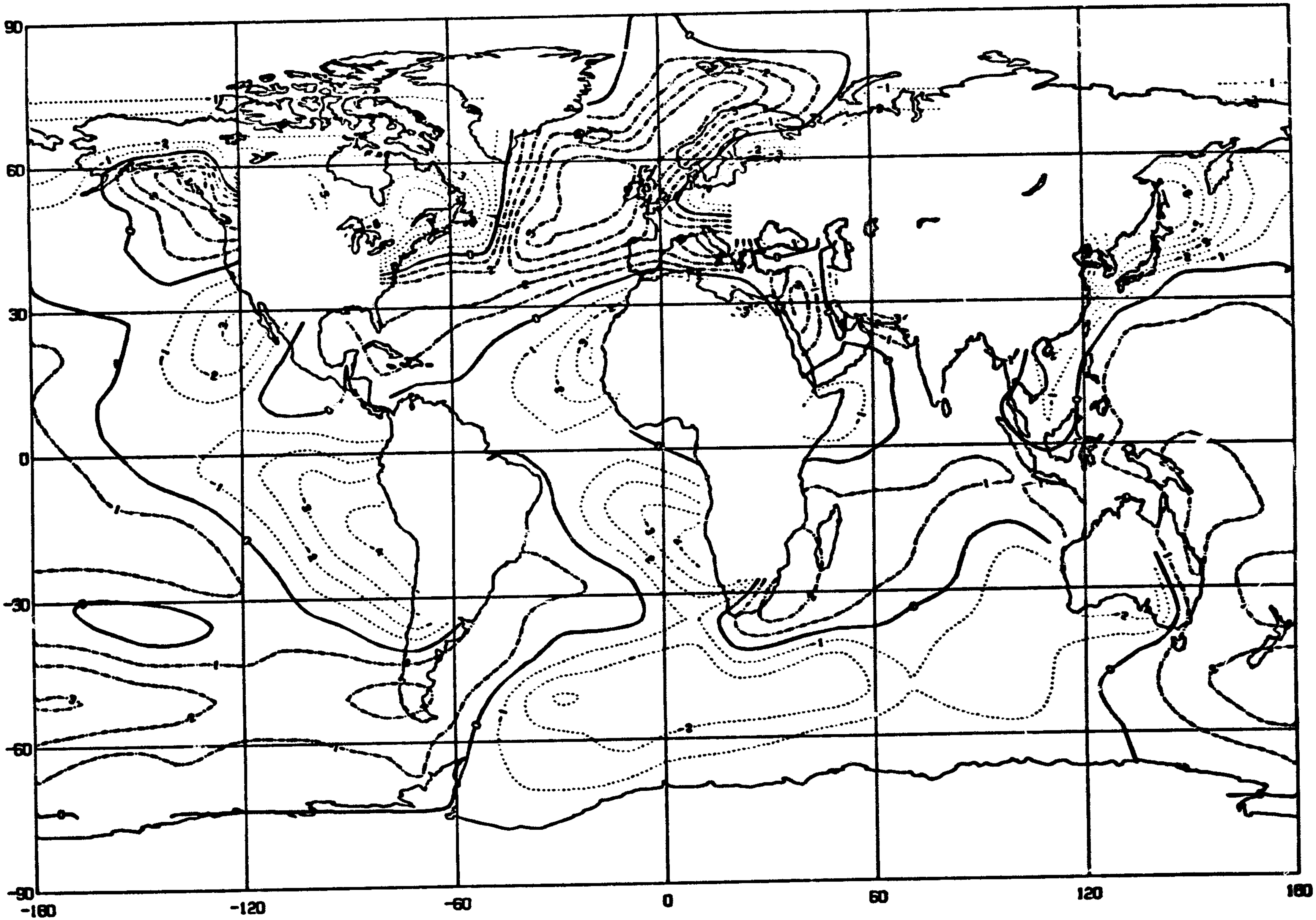
SEA SURFACE TEMPERATURE FOR RUNS 0 THROUGH 4 (DEGREES CELSIUS)

Fig. 2



SEA SURFACE TEMPERATURE FOR RUN #5 (DEGREES CELSIUS)

Fig. 3



SEA SURFACE TEMPERATURE (DEGREES CELSIUS) RUN 5 MINUS RUN 4

Fig. 4

In runs 001 and 000, 15 successive Januaries were computed, but only the last 13 of these were averaged to produce the ensemble mean, or model January climatology. For runs 002, 003, 004, and 005, 25 Januaries were computed, but only the last 20 months of each run were used to compute each ensemble average.

The results were analyzed in terms of the differences between pairs of mean horizontal distributions, as displayed on global maps and meridional profiles, as well as vertical distributions, as shown in mean meridional cross-sections. Standard statistical tests were used to establish the significance of the differences between pairs of ensemble means in terms of the variances of the individual Januaries. Spherical harmonic analysis was also used for the comparison of global maps.

## Summary and conclusions

1. The large-scale climates generated by extended runs of the coarse-mesh GISS climate model are relatively independent of the initial atmospheric conditions, if the first few months of each simulation are discarded.

2. As expected, continents act as regional heat sources in the tropics and in the summer hemisphere, and as heat sinks in the extratropical latitudes of the winter hemisphere, as indicated by the temperatures both at the surface and in the lower troposphere.

3. The perpetual January simulations with a specified SST field do produce excessive snow accumulation over the continents of the Northern Hemisphere. However, the southward penetration of the snow line is limited to about 30°N, and the model does not generate a catastrophic runaway glaciation of the hemisphere.

4. Mass exchanges between the cold (warm) continents and the warm (cold) adjacent oceans produce significant surface pressure changes over the oceans as well as over the land. Hydrostatic effects are also found aloft, with isobaric surfaces elevated over warm continents and lowered over cold continents. However, the synoptic effects of the flat continents on the mid-tropospheric (e.g. 500 mb) flow patterns are slight, with only small amplitude perturbations seen in the predominantly zonal circulation.

5. The heated continents of the summer hemisphere cause a second axis of the mean Hadley circulation cell to appear south of the Equator in the January flat continents simulation. The heaviest precipitation in this computation also is found south of the Equator over South America, as well as both north and south of the Equator over Africa. At the same time, the model continents have a desiccating effect on the zonal bands of heavy precipitation which appear over the Atlantic and Pacific Oceans just north of the Equator in both the water planet model simulation and in nature. On the other hand, the dry conditions over the Sahara Desert and Somalia are realistically simulated by the flat continents model.

6. While the flat, dry continents do reduce the total global evaporating surface, they also cause an augmentation of evaporation over the adjacent ocean regions, accompanied by the formation of extensive areas of low (stratus) clouds there but little or no increase in precipitation.

7. The observed meridional distribution of mean zonal precipitation in January, especially near the Equator, is better simulated by the water planet model (with specified zonally symmetric SST) than by the models with continents.

8. The presence of elevated terrain (including mountains) in the

model produces both beneficial and detrimental effects when comparison is made with the observed January climatology. Generally lowered surface temperatures over the elevated continents, and resultant increases in sea-level pressures (due to the method of reducing pressures to sea level) cause the continental highs to intensify and to move closer to their observed positions in the Northern Hemisphere, but in some cases these "corrections" are excessive. The elevated terrain accounts for a realistically higher mean sea-level pressure over the winter hemisphere north of the tropics, and more cellular structures both at sea level and at 500 mb. However, the 500 mb flow patterns generated with the mountain model are not in better agreement with observed climatology than are those of the flat continents model. At sea level, on the other hand, the Aleutian and Icelandic lows are simulated more realistically by the model with elevated terrain on the continents than by the flat continents model.

9. Elevated terrain produces the largest increases in the computed January precipitation rate over eastern China, South America, Africa and Australia, but almost no effects over North America or Europe in the coarse-mesh model. In South America, the Andes Mountains increase precipitation (in the model) by blocking the penetration inland of dry subsiding air from the subtropical high west of Chile, while in China it is the northward retreat of the Siberian high over cold elevated terrain that allows an increase of precipitation to occur.

10. The mean meridional cross-sections of tropospheric temperatures and zonal winds are only slightly altered by the terrain elevation, although significantly larger effects of the mountains are found in the stratosphere. However, the vertical motions in the January Hadley circulation system are strengthened (probably excessively) in the Southern Hemisphere when terrain height is included.

11. The model with flat continents produces a mean meridional sea-level pressure distribution that differs only slightly from that of the water planet. Elevated terrain, on the other hand, lowers the pressure in the equatorial low (unrealistically), and raises the pressures in high northern latitudes to more realistic values. However, no version of the model generates as deep a sub-Antarctic low as is found in nature, nor quite the correct latitudes of the sub-tropical high pressure belts, the latter being too far from the Equator in all model computations.

12. Evaporation of continental moisture coools the continents in both the summer hemisphere and the tropics, allows the northern hemisphere snow line to penetrate farther south, causing further cooling due to albedo effects, and raises the sea-level pressures over the continents of the Southern Hemisphere, thus weakening the thermal lows there, while lowering the pressures in the subtropical high pressure cells over the southern oceans.

13. Evaporation of continental moisture significantly increases the computed precipitation not only over the continents, notably Australia, but also (by providing additional continental moisture sources upstream) over certain ocean regions as well, notably around 4°N in the eastern Pacific. Compared with soil moisture and evaporation, the effects of spatial variations of the specified surface albedo on the model-generated climate are negligible.

14. Cooling due to evaporation of continental soil moisture extends up to about the 700 mb level. However, above this altitude, the release of latent heat of condensation by augmented cumulus convection produces a warming effect.

15. Changing the sea-ice boundary and SST field from zonally symmetric to realistically climatological has a generally beneficial effect on the simulated climate, bringing the model climatological surface air temperatures closer to the observed, especially, over the Northern Hemisphere. The winter monsoon circulation in the Indian Ocean is also better simulated when zonal gradients of SST are incorporated in the model. Desiccating effects of cold coastal SSt's on the precipitation are found near the west coast of South America and on the Somali peninsula, while augmented precipitation appears over the warmer SST's north of Scandinavia and in the south Indian and western Pacific Oceans.

16. The effects of surface boundary conditions are often remote, generally complex and highly interactive. For example, terrain altitude, SST variations, and continental soil moisture may modify circulations, change downstream advection, shift snow cover, increase albedo, and otherwise produce major climate alterations both locally and far from the source.

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