FINAL REPORT

ASSIMILATION OF MGS DATA INTO A COUPLED GCM-MESOSCALE MODEL OF THE MARTIAN ATMOSPHERE

PREPARED BY:

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I. Introduction

The project sought to develop a coupled GCM-mesocale model and to assimilate Mars Global Surveyor (MGS) data into the coupled model. To achieve the project goals, four specific research activities were proposed. These activities are reiterated for completeness and the progress in each of the activities is noted in future sections of this report.

Activity One

MRAMS was to be fitted with an appropriate radiation package. A radiation parameterization provides to MRAMS the ability to simulate atmospheric phenomena over a diurnal cycle, and to reproduce thermally driven circulations. The completion date for this task was mid-August.

Activity Two

Model coupling required an interface between the GCM output and the MRAMS ISAN package. This activity focuses on reconfiguring ISAN to ingest Mars atmosphere data. The GCM will provide large-scale atmospheric initialization and boundary conditions, and MRAMS will use that information to simulate the circulations at a much finer scale.

Activity Three

Surface characteristics often have a strong influence on the numerical solutions from the GCM and MRAMS. At present, the surface characteristics—topography, surface roughness, albedo, soil heat capacity, etc.—are known only crudely. The arrival of Mars Global Surveyor data is changing this. The analysis and assimilation of the newly acquired MGS data into the models is, therefore, of great interest, and is the objective of this task. This task had no completion date as the effort is on going. Of particular importance and interest is the MOLA topography.

Activity Four

The Mars climate has been catalogued by the GCM based upon low resolution surface data sets, most notably topography. It was proposed that the climate simulations be reanalyzed with the MGS data with a focus on physical processes that can be further refined by the mesoscale model. This may include the investigation of changes in mountain wave drag in the GCM and explicit simulation of the drag effects by the mesoscale model.

Other numerical investigations of interest included: simulation of the boundary layer evolution over a diurnal cycle; investigation of dust devils; and modeling of flow over complex topography and the related aeolian activity; The modeling activity comprises the bulk of the proposal, and constitutes where most effort will be directed after mid-August.

Summary of Activities

ACTIVITY	DESCRIPTION	ACTIVITY PERIOD
Activity 1	MRAMS radiation code implementation	June 1 – August 15
Activity 2	GCM – MRAMS Coupling in ISAN	June 1 – August 15
Activity 3	MGS data ingestion	June 1 – May 31
Activity 4	Numerical Simulation	June 1 – May 31
Sub-activity A	GCM simulations with new topography	Within one month of data arrival
Sub-activity B	MRAMS simulation of "Big Crater"	Within one month of acquisition of crater data from Greeley MDAP group
Sub-activity C	Other simulations TBD: dust devils, mountain wave drag, other MDAP sites.	August 15 – May 31

II. Progress

All of the activities defined in the originally funded research proposal are completed or nearly completed. Progress on each of the activities is discussed in detail below.

A. Activity One: Radiation

The NASA Ames GCM radiation package was implemented into MRAMS by the end of August, just slightly behind the expected completion date. After comprehensive testing of the code, inconsistencies between the modeled and expected results necessitated further investigation of the implementation. By the end of September, several small but crucial code fixes were implemented and the radiation parameterization became operational. This task was carried out by Dr. Rafkin

B. Activity Two: ISAN

This task was assigned primarily to a graduate student, Mr. Timothy Michaels. The activity is now complete, but was finished well passed the expected completion date. As discussed in the progress for Activity Four, the delay in completion of this task limited the ability to conduct some of the scheduled simulations.

Figure 1 displays GCM fields and topography and these same fields and topography as ingested through the newly modified ISAN code. The meteorological fields for the GCM are at the lowest model level (~40m), and at the fourth MRAMS level (~43m) to aid in comparison. A new method for mapping these fields onto the higher resolution MRAMS grid was developed to accomplish this task.

The standard gridded data input from the NASA Ames General Circulation Model is on σ-pressure surfaces. These data are then horizontally interpolated to the MRAMS polar stereographic projection via a bilinear interpolation scheme. The topography for MRAMS is locally higher or lower than the GCM, because MRAMS is at higher resolution and utilizes a higher resolution topographical data set. Consequently, the vertical mapping of the GCM data to MRAMS is not trivial. The vertical interpolation to the MRAMS coordinate has been modified from the original terrestrial code as follows: Potential temperature and wind components in MRAMS are determined using the following transformation:

$$\chi_R(Z) = \chi_G(Z - \delta(Z))$$

where,

$$\delta = -(Z - h)\frac{(\Delta_{topo})}{H},$$

$$h = H + topo_R.$$

χ is the model variable undergoing transformation, Z is the height above the geoid, Δ_{topo} is the difference between MRAMS and GCM topography, $topo_R$ is the height of MRAMS topography above the geoid, and H is a distance above the topography of MRAMS where the MRAMS and GCM properties are identical. When $Z > h$, δ is set to 0. It can be seen that for $Z=topo_R$ (the surface in MRAMS) that $\delta=\Delta_{topo}$, and the surface value in MRAMS is set equal to the surface value in the GCM. When $Z=h$, then $\delta=0$, and the MRAMS value at Z above the geoid is equal to the GCM value at Z above the geoid. The net effect is a transformation where the atmospheric structure near the surface in the GCM is preserved in the translation to the MRAMS coordinate. The pressure on the MRAMS grid is obtained by a hydrostatic integration downward from $Z=h$. Before vertically interpolating the GCM fields to MRAMS, the GCM data are first bilinearly interpolated in the horizontal direction to the MRAMS coordinate.

C. Activity Three: MGS data

Gridded data derived from MGS is now easily ingested into MRAMS. The 1.0 x 1.0 degree topographic MOLA data has been implemented into MRAMS since July. Other gridded data such as albedo and thermal inertia can also be utilized if selected by the user.

D. Activity Four: Simulations

A wide variety of simulations have been conducted with the MRAMS code containing the new radiation scheme and MGS data. However, because of the delay in completing Activity Two, these simulations were idealized simulations. An idealized simulation means that only a single sounding was used to initialize the model.

Simulations to date include: two dimensional mountain (gravity) waves; three dimensional flows over big crater; and Large Eddy Simulations. Examples from each of these are shown in Figures 2 through 4. Experiments with the GCM-initialized model are currently underway.

III. Conclusion

The majority of the proposed tasks were fully completed. Activity Two was not fully completed due to the delay in completing the ISAN modifications. However, numerical experiments are currently underway with the new initialization package. Overall, the objectives of the project were accomplished. The research has paved the way for the complex simulations that are now currently underway. These simulations include examination of circulations at the MPF landing site, and slope flows and mountain waves associated with the mountainous Tharsis region.

The PI would like to thank NASA and Dr. Robert Haberle for their support of this research.

FIGURE CAPTIONS

1. Comparison of NASA Ames GCM fields with the MRAMS initialization fields obtained by processing the GCM fields through ISAN. GCM topography (1A) and MRAMS topography (1B) derived from MGS MOLA 1x1 degree data. Lowest level GCM air temperature (1C) and MRAMS level four air temperature (1D). Both temperature plots are at approximately 40m. GCM (1E) and MRAMS (1F) surface pressure. GCM (1G) and MRAMS (1H) Z=40m wind vectors and speed overlayed on shaded topography.

2. Horizontal (left column) and Vertical (right column) wind speed for three different mountain wave simulations. The stability and wind profile were modified to generate different values of scorer parameter. In the top simulation, vertically propagating waves are clearly evident. In the bottom simulation, vertically propagating waves are damped. The middle simulation represents an intermediate case.

3. Surface friction velocities (shaded in m/s) and near surface wind vectors for a big crater simulation with radiation turned on. The stress patterns produced by the crater are superimposed on those produced by convective boundary layer circulations.

4. Statistical properties obtained by a Large Eddy Simulation (a) and horizontal crossections from the LES displaying dust devil-like circulations (b). In (b), the upper row displays vorticity (shaded in per second times 100) and wind vectors for two different times. The lower row displays vertical velocity (shaded in m/s) for the same time as the panel directly above and the a crossection of vertical velocity indicating the coherence and tilt of the circulation with height.

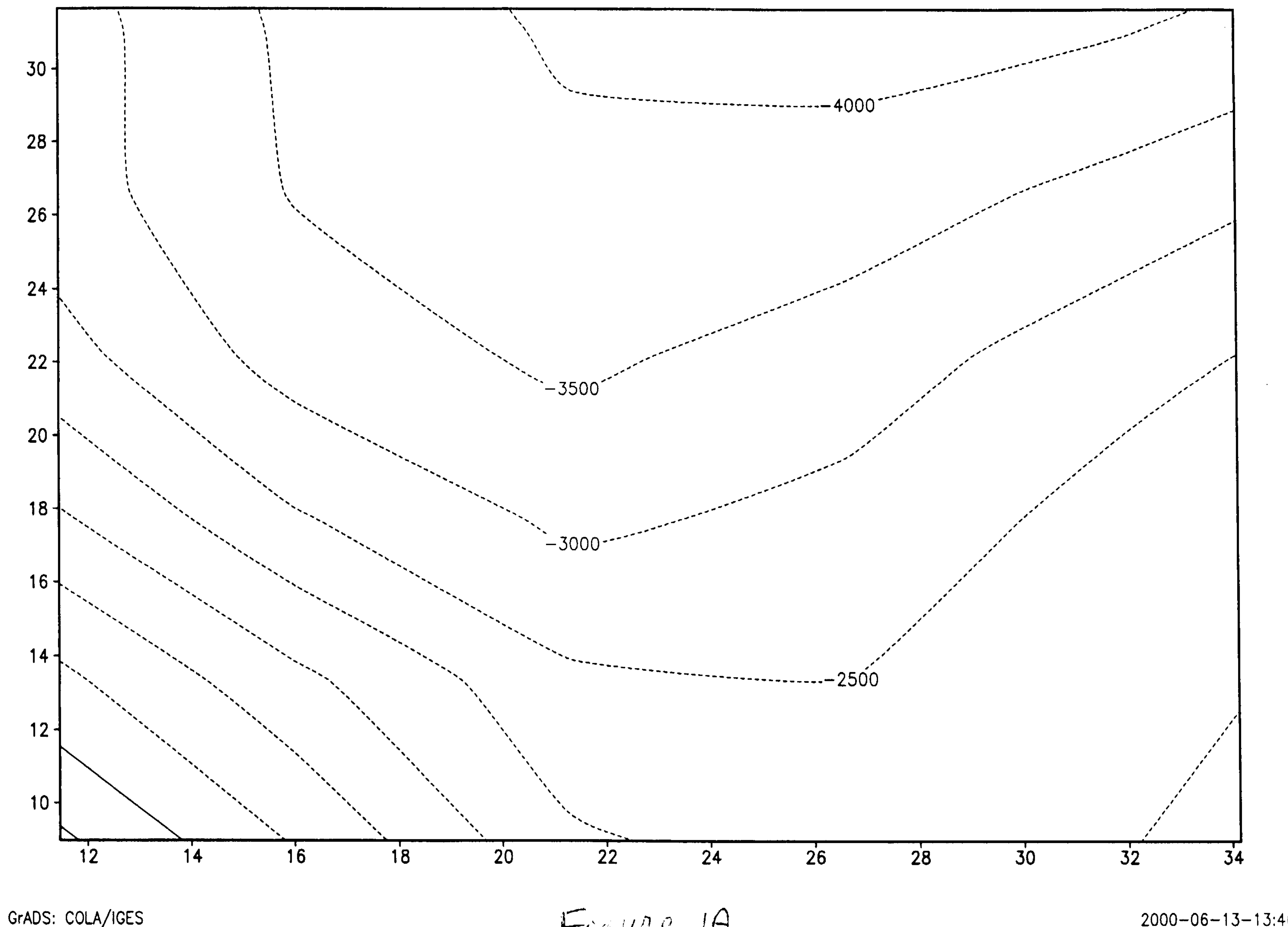
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Figure 1A

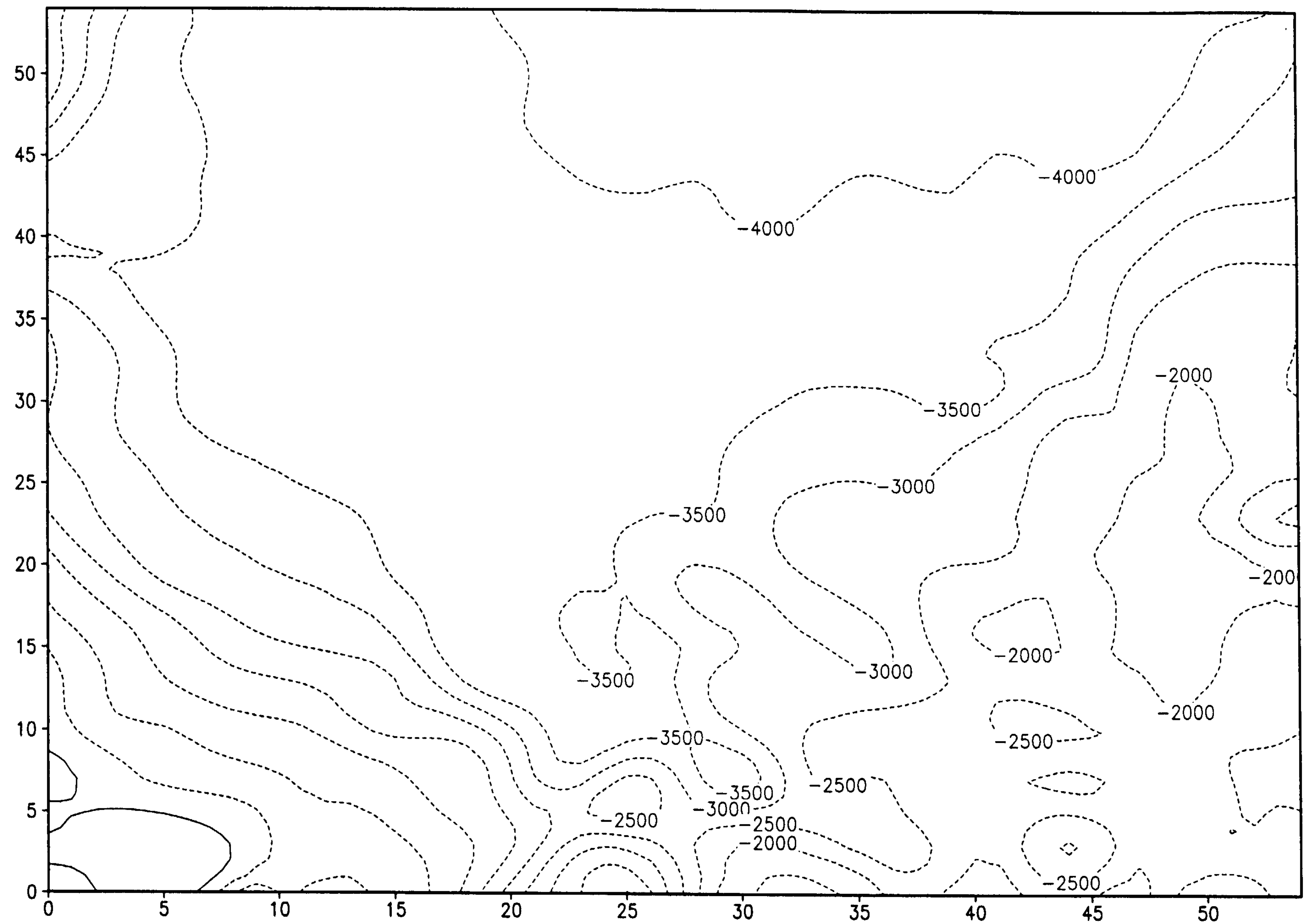

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Figure 1B

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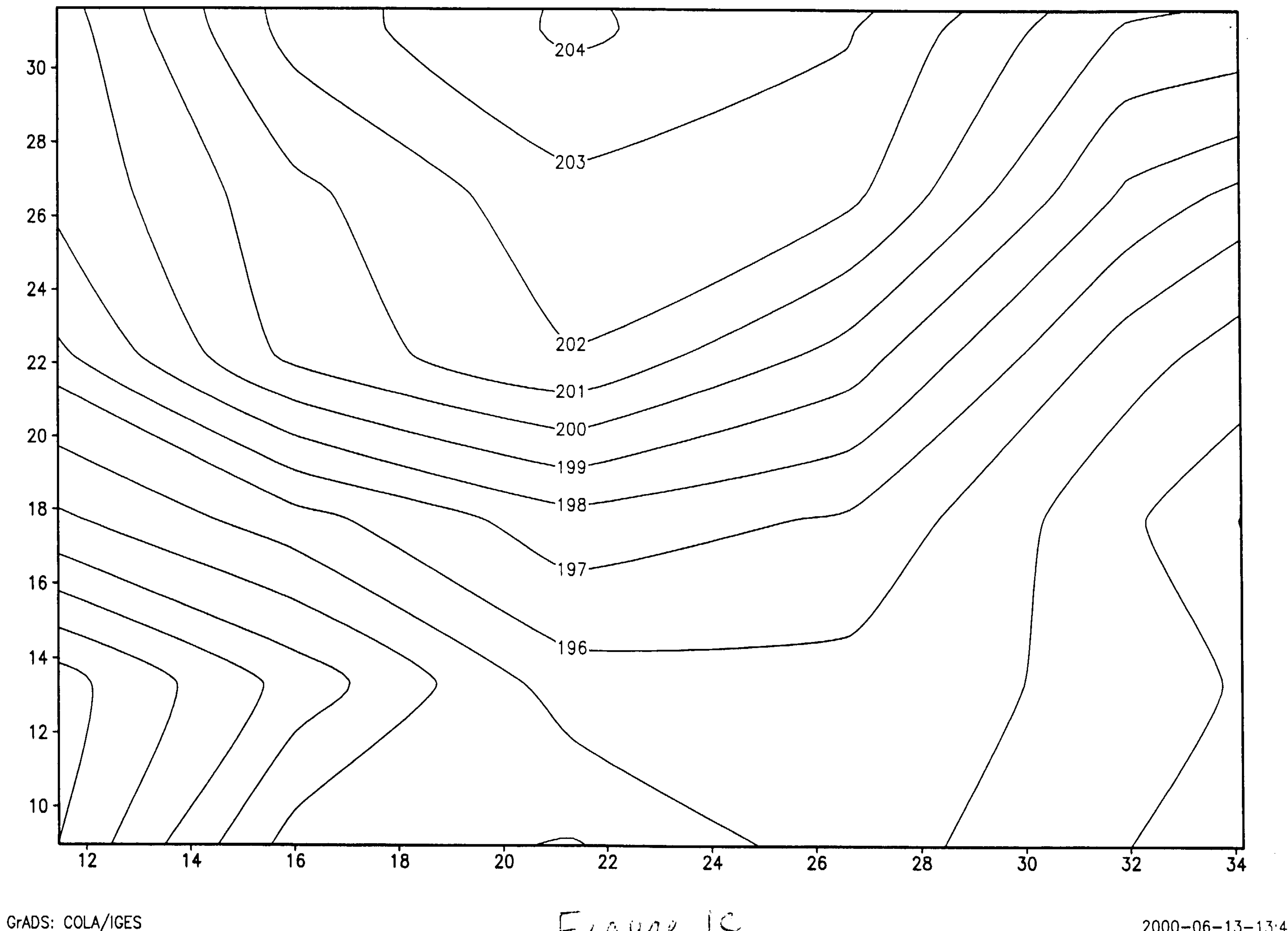

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Figure 1c

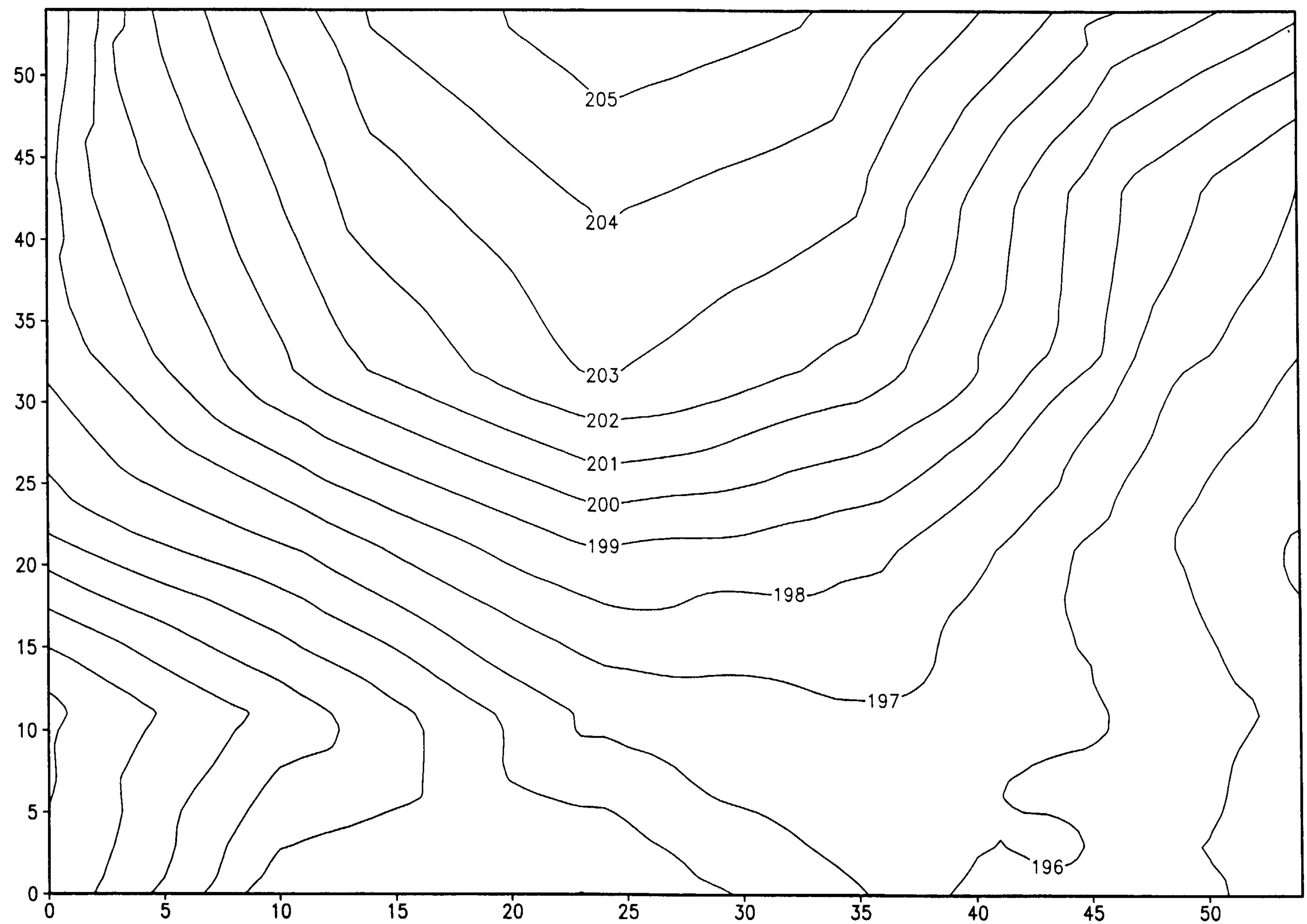

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Figure 1D

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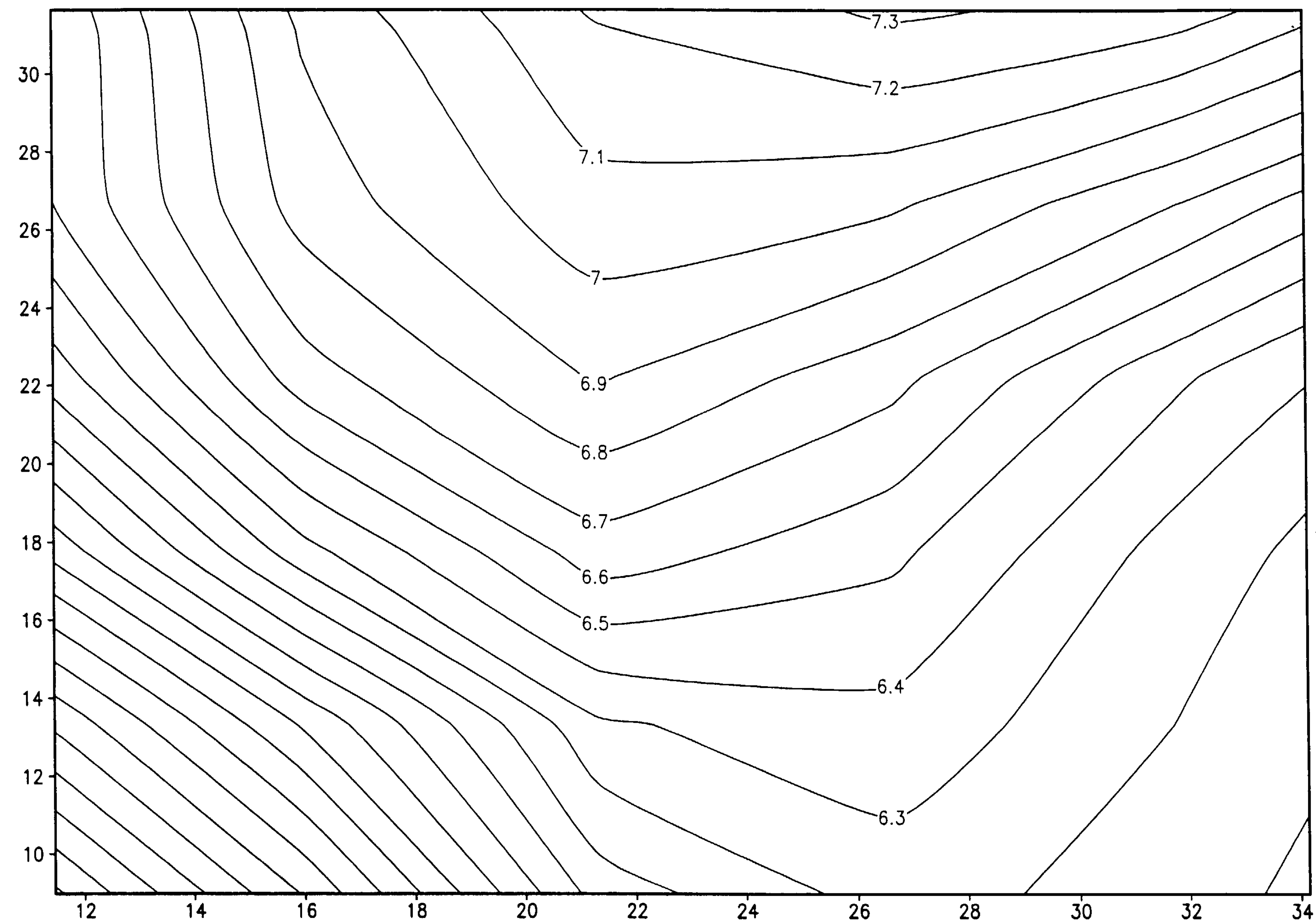

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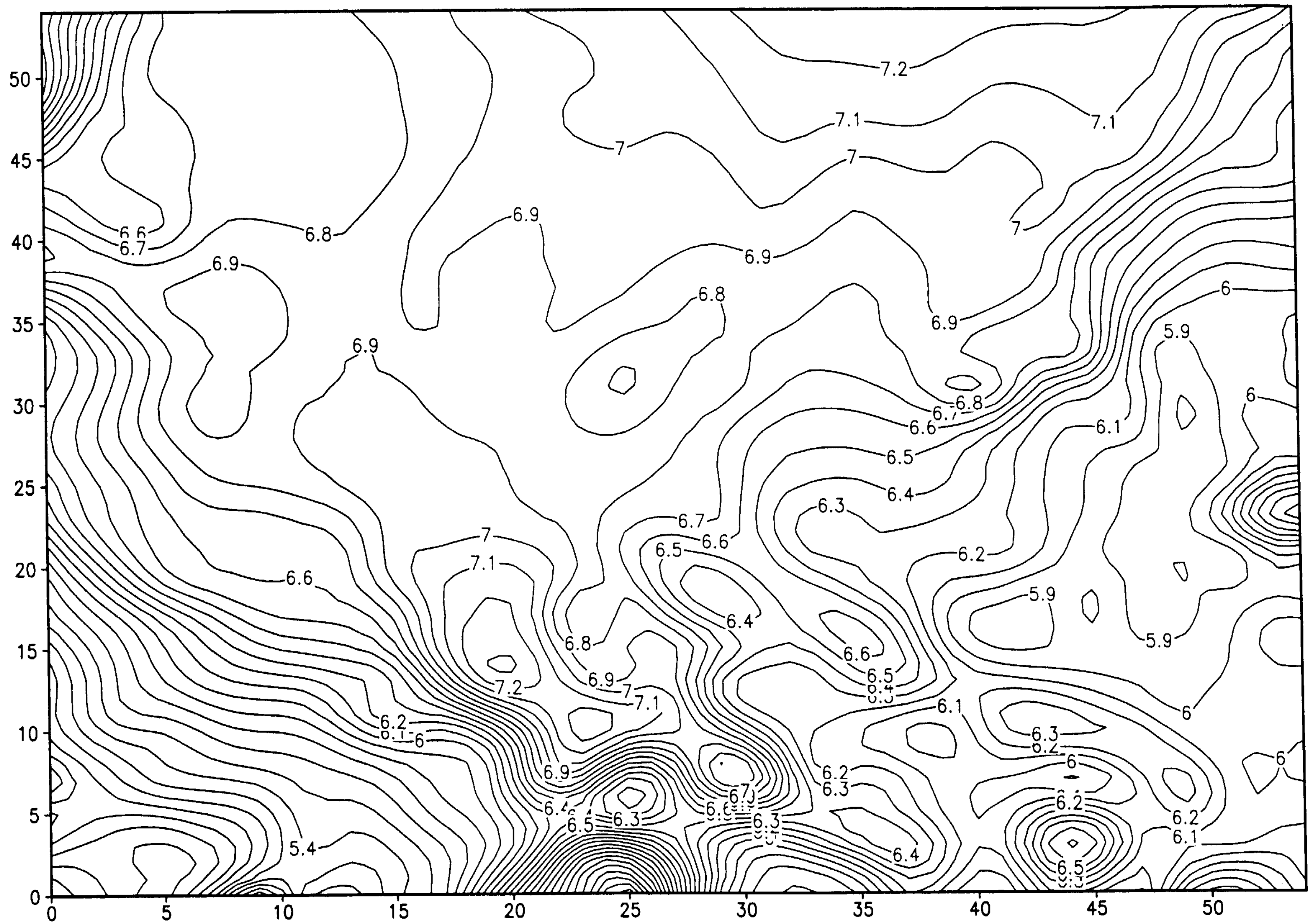

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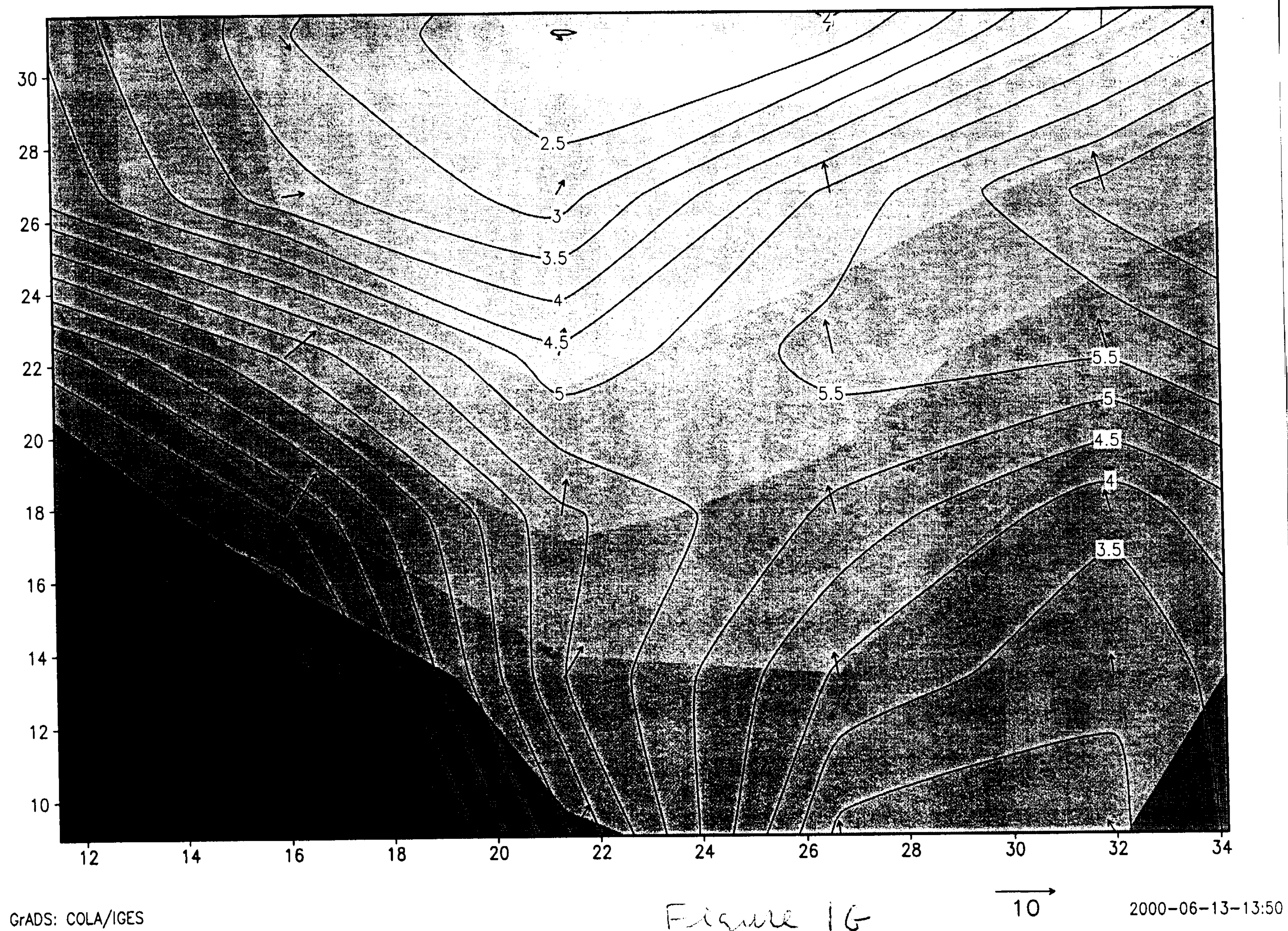
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Figure 1G

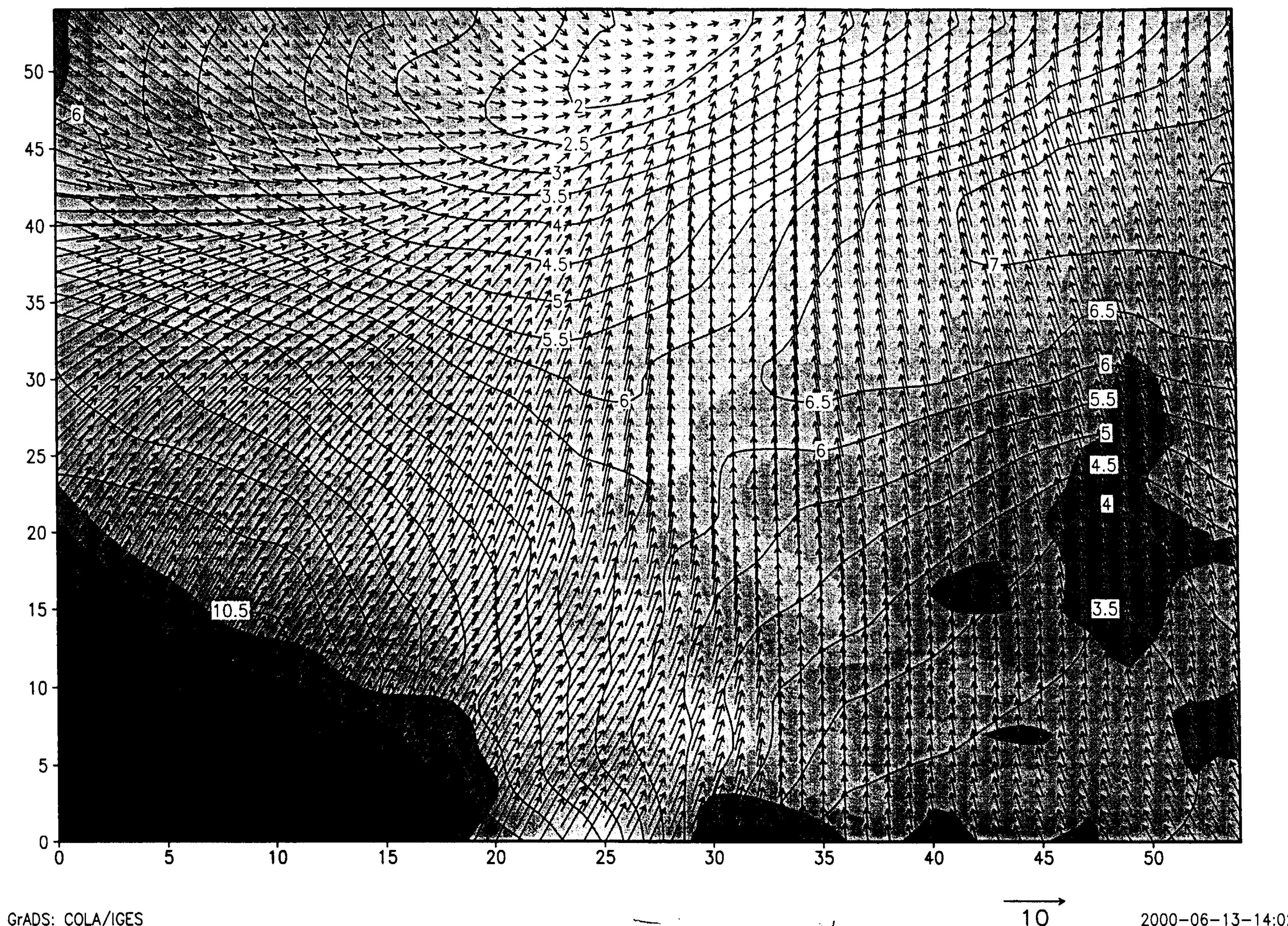

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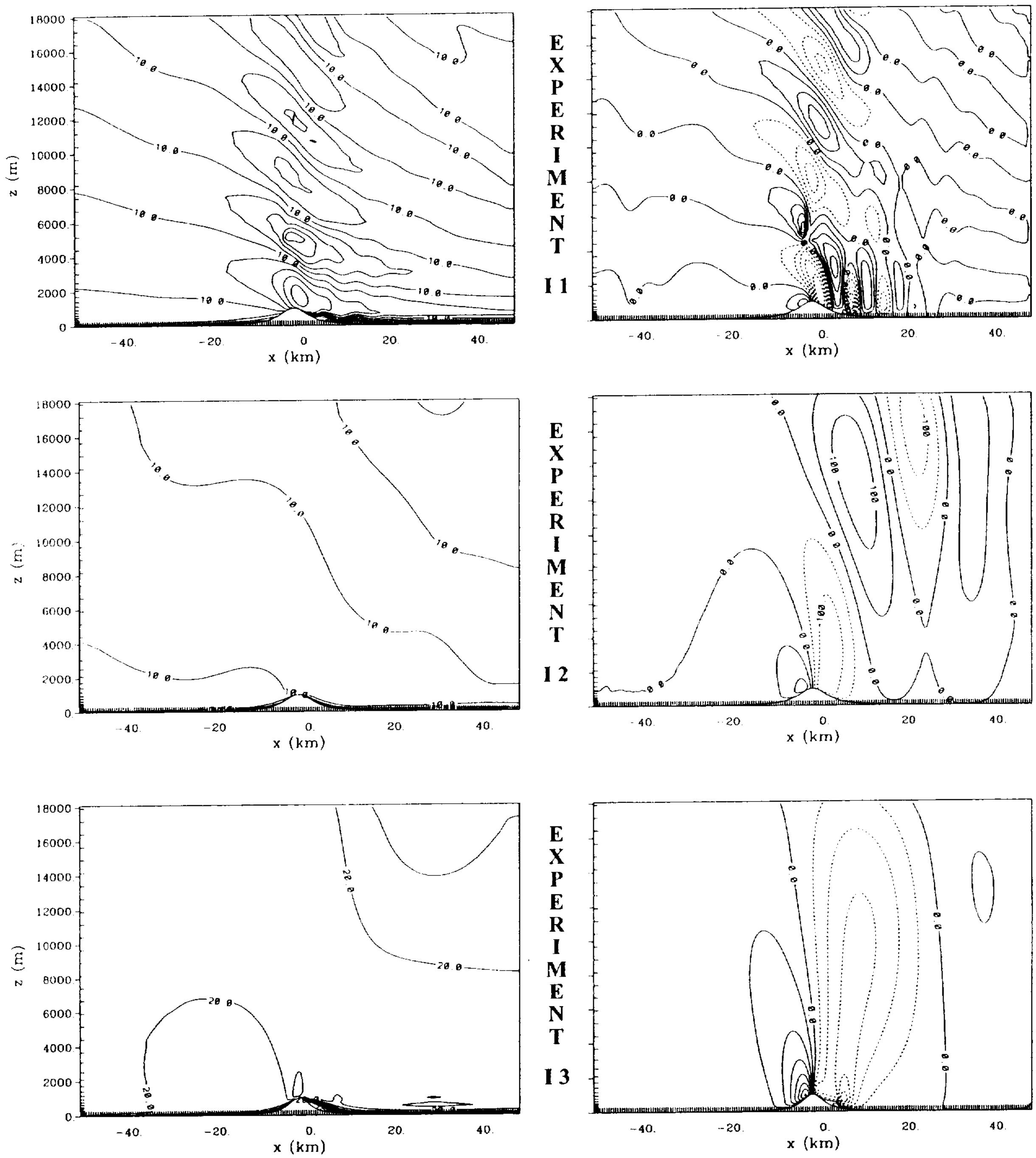
Figure 11t



Horizontal Wind Speed (m/s) **Vertical Wind Speed (cm/s)**

Figure 2

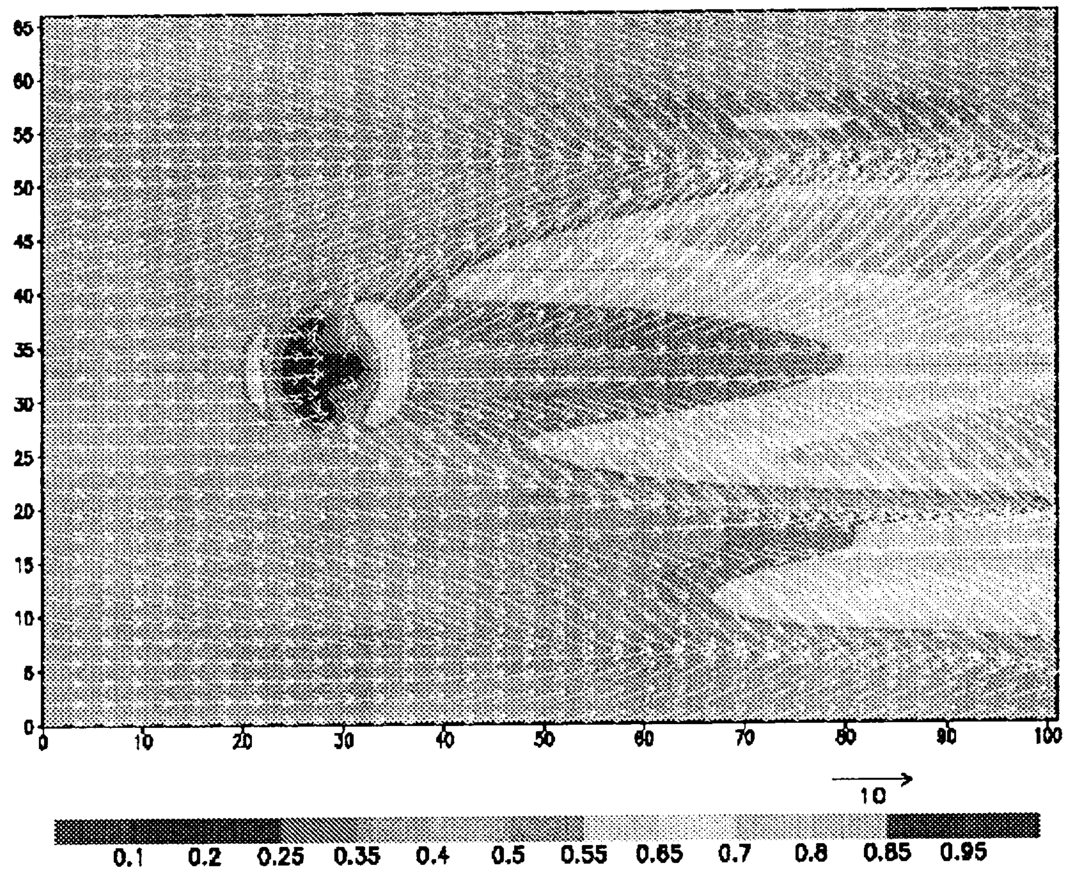


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Figure 3

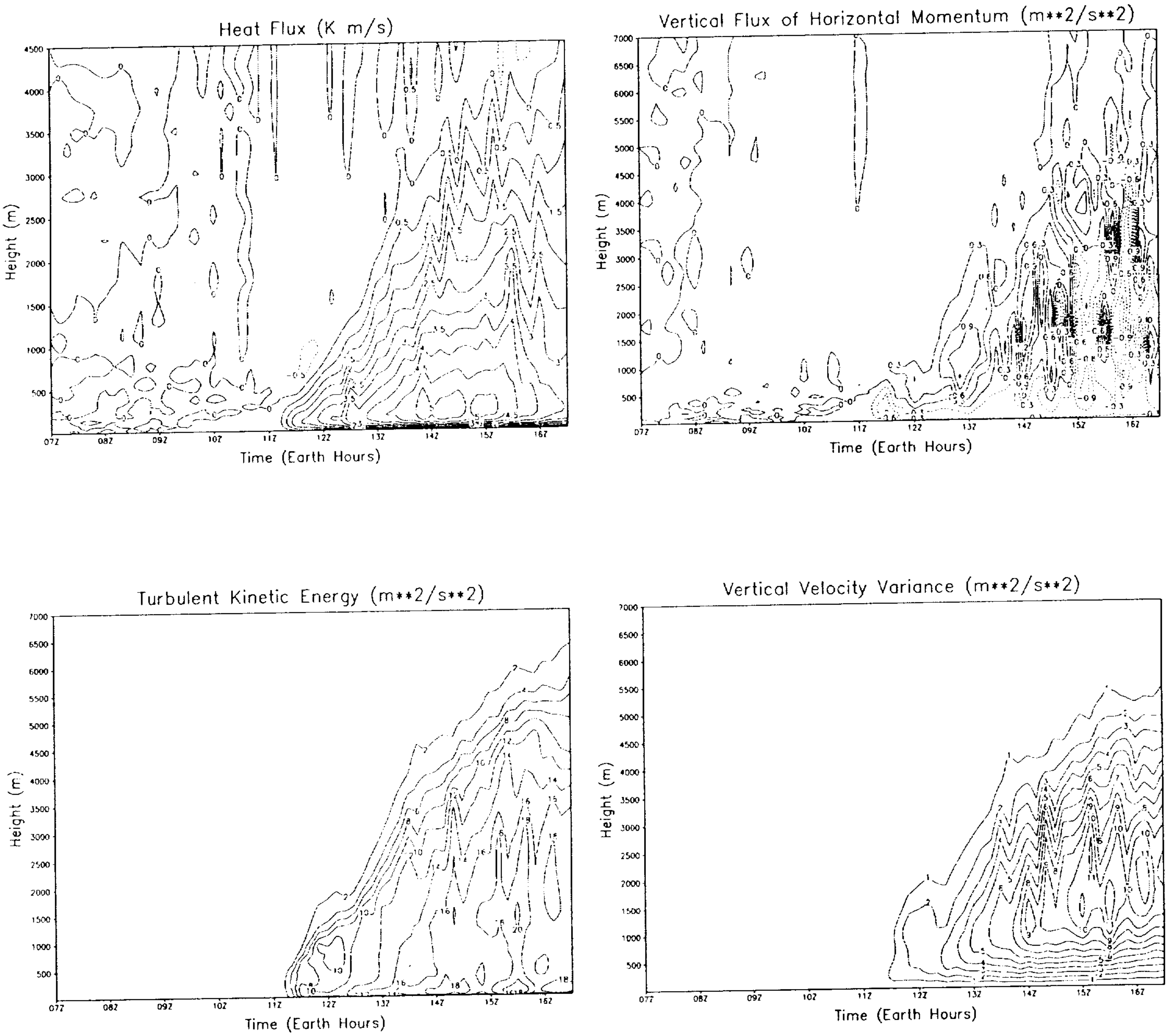
Heat Flux (K m/s)
Vertical Flux of Horizontal Momentum (m**2/s**2)
Turbulent Kinetic Energy (m**2/s**2)
Vertical Velocity Variance (m**2/s**2)
Height (m)
Time (Earth Hours)

Figure 4a

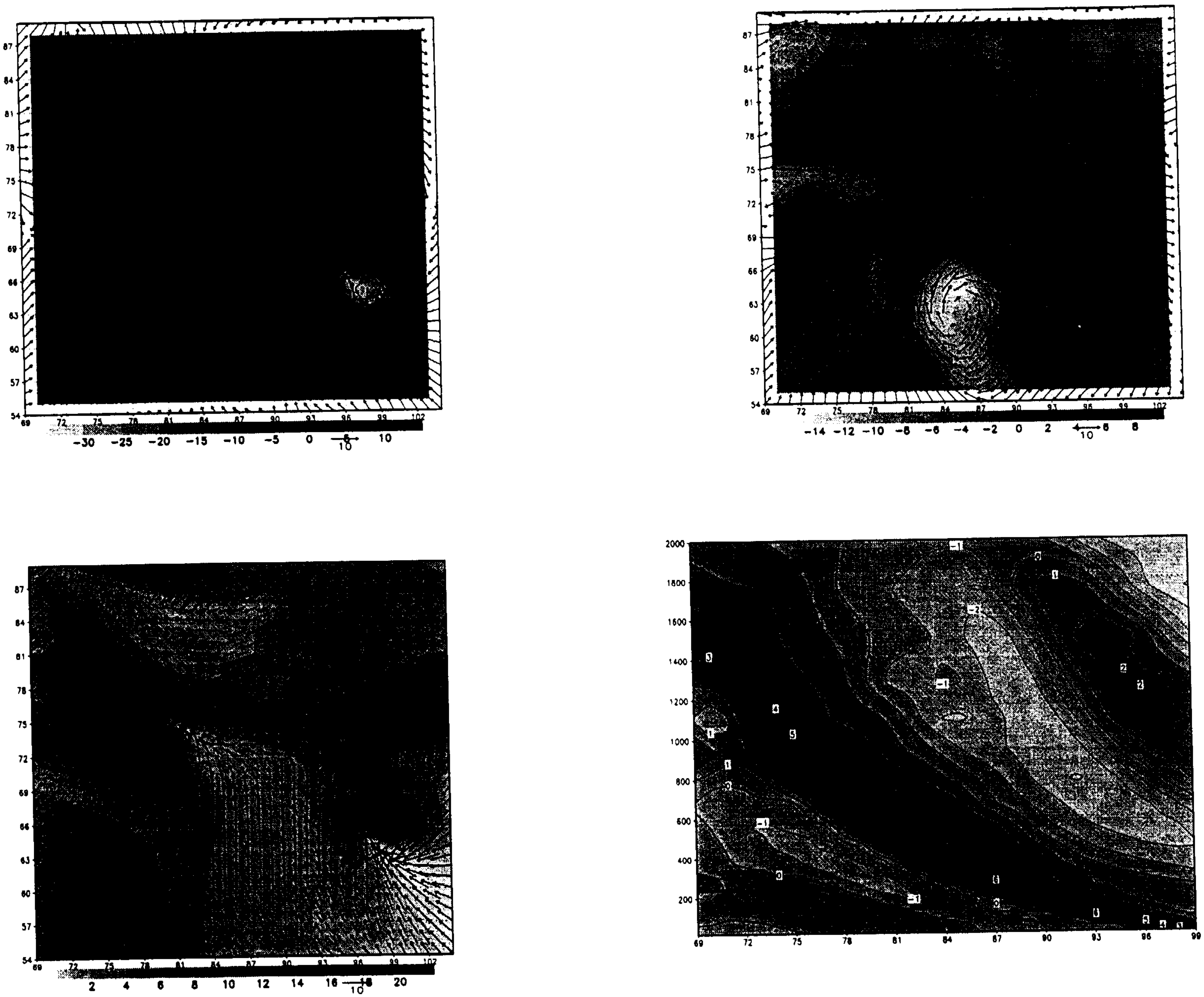

Figure 4b