The research processing of TOVS data in the Hydrometeorological Centre of the USSR

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Abstract

This paper describes the research retrieval systems on the base of locally received TOVS data in their TIP form (HRPT regime) developed in the Satellite Meteorology branch of the Hydrometeorological Centre in Moscow. The algorithms, software package for processing of TOVS data and some results of retrievals are considered. Plans for ongoing development of data handling are under discussion.

Introduction

The implementation of reception device (direct readout receiving groundstation C.I.R.) has stimulated the development of software package for processing TOVS data (TIP formatting) in the Satellite Meteorology branch of the Hydrometeorological Centre in Moscow. Over the past three years considerable efforts were made to design different schemes for TOVS data processing which provide retrievals of atmospheric parameters in regional scale for limited area. Arguments for constructon of such local area sounding systems are evident. Firstly it is possible to account some regional features (like relief, "local" statistics etc.) to augment the quality of retrievals. It is possible also to reduce time taken for processing and producing final products. These two points are of great benefit to local modeliers.

Having in mind the potential utility of retrievals for input into mesoscale numerical models or regional short-range forecasting systems, two processing schemes have been developed and tested. Scheme I provides processing of HIRS/2 data in low cloud conditions. It is research version. Scheme II provides processing of combined HIRS/2 and MSU data for different weather conditions. It is basic version of processing schemes and is supposed to be installed as operational one.

In this report the description of these two schemes is presented. The results of experimental running the scheme II are described. Problems still to be overcome are also discussed.

Description of processing schemes

a) Scheme I. The design of processing scheme I (Karpov e.a., 1988) has yielded the elaboration and testing of some algorithms and programs (software). Note some original algotithms, which were tested using simulated and real information. These algorithms provide: - nonparametric identification of clouds on the base of HIRS/2 data; - "clear" radiance estimation (Karpov e.a., 1988), dynamic correction and adjustment the radiance model and data (Plokhenko, Uspenski, 1987); - statistical quality control of data and retrievals.

Software package provides
- preprocessing the HIRS/2 raw data (decoding, navigation, calibration);
- processing the HIRS/2 data and temperature retrival in low cloud conditions.

The results of experimental running the scheme I show rather efficient vehicle has been derived for cloud detection and adjustment of model and data (so called "radiance correction"). The quality of soundings is satisfactory inasmuch the minimal information support was used. We engaged mean clymatic estimates for temperature and mixing ratio profiles T(P), q(p). The accuracy of retrieval is approximately $2,0 \div 2,5$ C for 700-300 mb levels and near 3,0 C for higher and lower levels in low cloud conditions. Quality of retrievals still suffers from the contamination of the sounding radiances by clouds.

b) Scheme II, described in (Uspenski, Tret'jakov, 1988, 1989) is adapted and revised version of physical retrieval package (Smith e.a., 1985). The most essential extension and modifications of original algorithms and software consist in
1) incorporation the retrieval algorithms for cloudy conditions similar to (Huang e.a., 1986) into the processing scheme;
2) data editing or filtering based on adjustment and polynomial smoothing;
3) incorporation the original correction procedures.

Preprocessing of MSU data and amalgamation of HIRS/2 and MSU data have been supplemented to the scheme I. Note that software for preprocessing of TOVS is original (Karpov e.a., 1988).

Consider shortly (without details) the procedures providing p.2). These procedures conduct the two succesive steps: the step 1 - the adjustment of estimates $\hat{D}$ (dew point depression) and $\hat{N}$ (amount of clouds); the step 2 - the polynomial smoothing of data and derivation of estimates on regular grid.

The method for adjustment of D and N is similar to the one used for conventional data and based on empirical relations between D and N. As a result of retrivals of D and N from "NOAA-9" information for several dates, the folloving formulae is established:

$$N(p) = (10 - D(p))_+ \pm 3, \qquad (1)$$

$$\text{where } (x)_+ = \begin{cases} x, \text{if } x>0, \\ 0, \text{if } x<0 \end{cases}$$

To validate (1) the satellite estimates of cloud parameters $\hat{N}$, $\hat{h}$ ($\hat{h}$ is cloud top pressure) have been compared with coincident RAOB data D^{rs} (p). We suppose that $\hat{N}(p) = 0$ if $p>\hat{h}$; $\hat{N}(p)$ - is unknown if $p<\hat{h}$. Results of such analysis for central area of European part of the USSR and several dates in winter 1987 are presented in table 1.

Table 1

p, mb	$N=(10-D)_+ \pm 3$	$N > (10-D)_+ +3$	$N < (10-D)_+ -3$	M	η(%)
1	2	3	4	5	6
850	27	0	12	39	69
700	81	10	17	108	75
500	88	3	33	124	77

The values in table are the number of pairs $\{\hat{N}$ (p), D^{rs}(p) ;M is total number of pairs; η is a percentage of pairs, for which (1) take place. The data in table 1 enable us to conclude that (1) is a satisfactory approximation of "truth" relation between N and D.

Numerical experiment has been done to prove the utility of formulae (1). The sample of colocated pairs of satellite and RAOB data $\{\hat{D}$ (p), $D^{rs}(p)\}$ was divided on two groups: Pairs for which the relation (1) fulfils compile group 1, the other form group 2. The values $\delta = M^{-1} \cdot \sum |\hat{D}_i - D_i^{rs}|$ for total sample and two other are presented in table 2.

Table 2

Accuracy of $\hat{D}$ for different samples

Samples	pressure levels, mb					
	850		700		500	
	M	δ	M	δ	M	δ
group 1	15	1,9	41	2,2	57	2,1
group 2	13	3,9	38	3,5	34	3,7
total sample	28	2,8	79	2,8	91	2,7

Here M is a number of cases in corresponding sample. Note that values of δ for group 2 is higher than for group 1. Probably, the most essential cause for this is the errors in cloud parameter estimates. According to table 2 it is possible to use (1) as a rejection test for filtering estimates $\hat{D}$. The main drawback of such filtering is that it rejects many realisations.

The method used for editing or space filtering of retrievals is based on polynomial smoothing. The procedure of smoothing is local and similar to procedures of polynomial objective analysis /Rizzi, 1986/ Extensive details of the analysis scheme can be found in /Uspenski, Tret'jakov, 1989 a,b/. We use variational approach and for derivation of smoothed fields $\tilde{T}$ or $\tilde{D}$ minimize regularized functional of least square method. According to experiments with real data it is rational to use the following formulae for weights W_i in regularized functional:

$$w_i = \gamma \cdot (\theta + r_i^2)^{-1}$$ (temperature smoothing)

$$W_i = \frac{\gamma_1}{(\theta_1 + r_i^2)(\theta_2 + \hat{D})}$$ (dew point depression smoothing)

where $\gamma, \gamma_1, \theta, \theta_1$ are empirical constants and r_i is the distance between the grid point (central for local area of smoothing) and sounding point.

Consider the results of this procedure testing Its application was made to the test region limited by 50 - 62 of north latitude and 25 - 52 degrees of east longitude. This area containes 221 regular grid point with 1 degree latitude and 1,5 degree longitude steps. In this area nearly 30 radiosondes are available.

The efficiency of polynomial filtering was estimated by intercomparison the colocated smoothed and initial data. The values of mean absolute differences between $\tilde{T}$ and $\hat{T}$ (noted as ε_T), between $\tilde{D}$ and $\hat{D}$ (noted as δ_D) are presented in lines 1,2 of table 3. The same values for RAOB data are presented in lines 3,4.

Table 3

Accuracy of polynomial filtering procedure

n	Type of data		pressure level, mb				
			1000	850	700	500	400
1	Satellite	δ_T	0,5	0,6	0,6	0,5	0,4
2	retrievals	δ_D	0,2	0,4	1,1	1,4	0,7
3	RAOB	δ_T	0,6	0,2	0,3	0,7	0,6
4	data	δ_D	-	1,6	2,2	1,5	-

According to table 3 the method of smoothing has demonstrated its capability.

Results in the retrieval of atmospheric parameters

The experimental running the scheme II has been made in 1986-1988 using data from "NOAA-9,-10". The retrievals were compared with the nearest data produced by hemispheric objective analysis scheme of Hydrometeorological Centre /Bagrov e.a.,1986/. The statistics ($\bar{\delta}$=mean,σ=standard deviation) for the differences between retrievals $\hat{T}$ and analysis data T^a are presented in table 4.

Table 4

Retrievals vs numerical analysis data for three days in 1986

Pressure,mb	14.05		16.05		26.05	
	$\bar{\delta}$	σ	$\bar{\delta}$	σ	$\bar{\delta}$	σ
1000	-	-	-4.1	3.7	-3.2	1.9
850	-3.4	2.8	-2.4	2.3	-2.3	1.8
700	-1.6	2.1	-1.5	2.0	-2.4	1.6
500	-0.8	1.9	-0.9	2.0	-1.7	1.5
400	-1.8	2.5	-1.7	2.4	-2.1	1.7
300	0.1	3.1	-0.7	2.1	0.1	2.8

The retrievals were made for test region described above. The editing procedures (smoothing) was not used for data in table 4,5. The table 4 demonstrates that systematic biases in retrievals are quite similar for each date. Their removal enables to attain the values of 2,0 - 2,5 C for root mean square differences (averaged for 11 levels up to 100 mb).

The supplementary accuracy estimates are presented in table 5. It contains the values of standart deviation and relative error $\text{æ}_q = \sigma_q \cdot \bar{q}^{-1}$ for several dates in october 1986.

Table 5

Accuracy of estimates $\hat{T}, \hat{q}$

p, mb	σ_T, °C	æ_q(%)
1000	3,3	26
850	1.9	42
700	2,0	51
500	2,0	26
400	2,1	30
	M=507	M=152

The comparison of data in tables 4,5 showes that the dependence of retrieval accuracy on atmospheric condition is not strong. Some retrievals were produced with utilisation of editing (filtering) procedures. The values of mean absolute differences between filtered retrievals and RAOB data are presented in table 6. The values in lines 1-3 refer to retrievals derived with incorporation of near ground measurements of air temperature T . The systematic biases in T were removed.

Table 6

Compaarison of fields $\tilde{T}$, $\tilde{D}$ obtained from satellite and RAOB data

nn	Date	Diffe-rence	pressure level				
			1000	850	700	500	400
1	16.10.86	δ_T	0.8	1.6	1.2	0.9	0.8
2		δ_D	-	4.1	4.9	3.4	-
3	26.01.86	δ_T	1.3	1.5	0.8	2.0	2.1
4		δ_T	2.0	1.3	1.0	2.0	2.0
5	18.02.87	δ_T	1.6	1.9	1.4	1.5	2.2
6		δ_D	1.9	2.6	2.1	2.6	2.9
7	26.02.87	δ_T	3.1	1.4	1.5	1.7	1.9

According to table 6 the incorporation the supplementary data (Ta) and filtering procedures enhaces the accuracy of retrivals.

To visualize results of sounding the charts of fields T, D, H for standart pressure levels were plotted using "Pericolor-2000", see fig.1-8. The charts of differences $\tilde{T}-\tilde{T}^{ra}$ are presented at fig.4,6. It is possible also to use standard plotter for visualization of retrieval after their smoothing, see fig.9-11.

Conclusions

Experiments with TOVS data processing highlighted a number of weaknesses of methods and algorithms in scheme II. It is necessary to continue the development of more sofisticated algorithms for cloud detection, models adjustment etc. It seems rational also to install TOVS data processing scheme on PC/AT. These refinements are now under development.

There is actual problem concerning data assimilation: how much mesoscale information is contained in satellite data and how best to use them. To answer these questions it is rational to make close links between mesoscale model and retrieval scheme.

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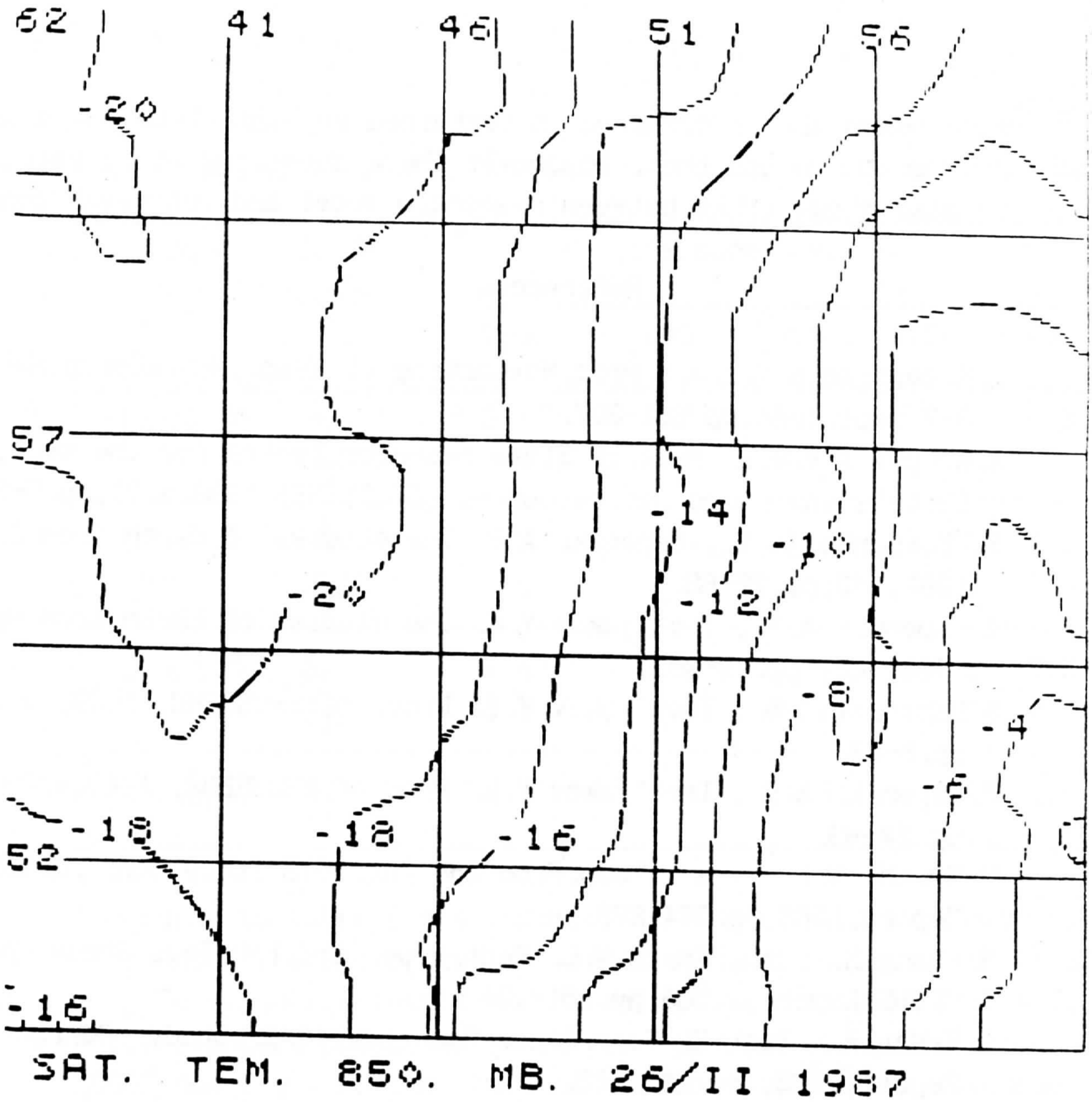
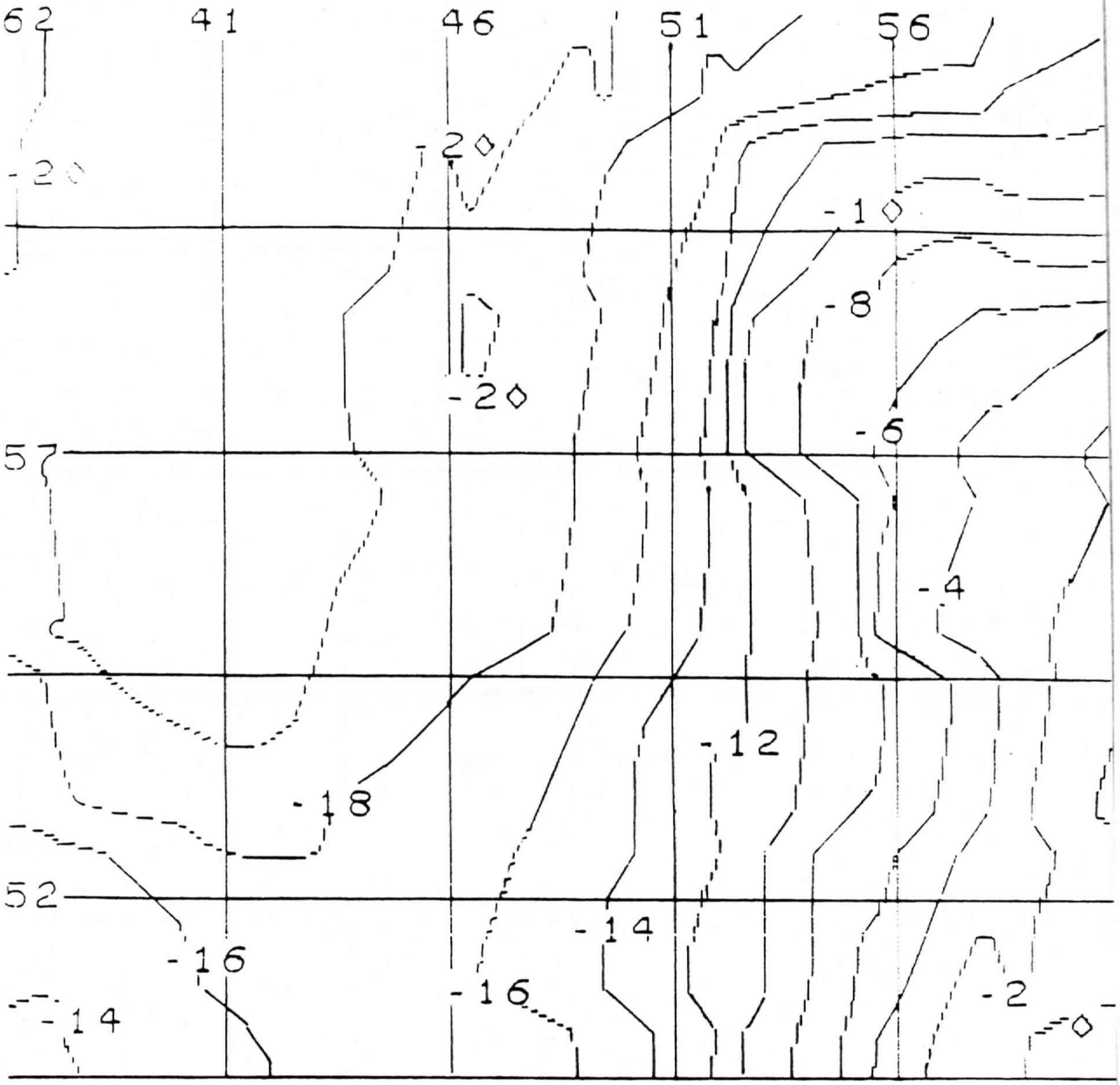


Рис. 1

Поле температуры воздуха на стандартной изобарической поверхности 850 гПа, полученное по спутниковым данным (26.02.1987.11.30GMT).



RZ. TEM. 850 MB. 26/II 1987

Рис. 2.

Поле температуры воздуха на стандартной изобарической поверхности 850 гПа, полученное по данным аэрологических наблюдений (26.02.1987.12.00 GMT).

TEMP.
700 MB.
NOAA9
16 OKT.
1986

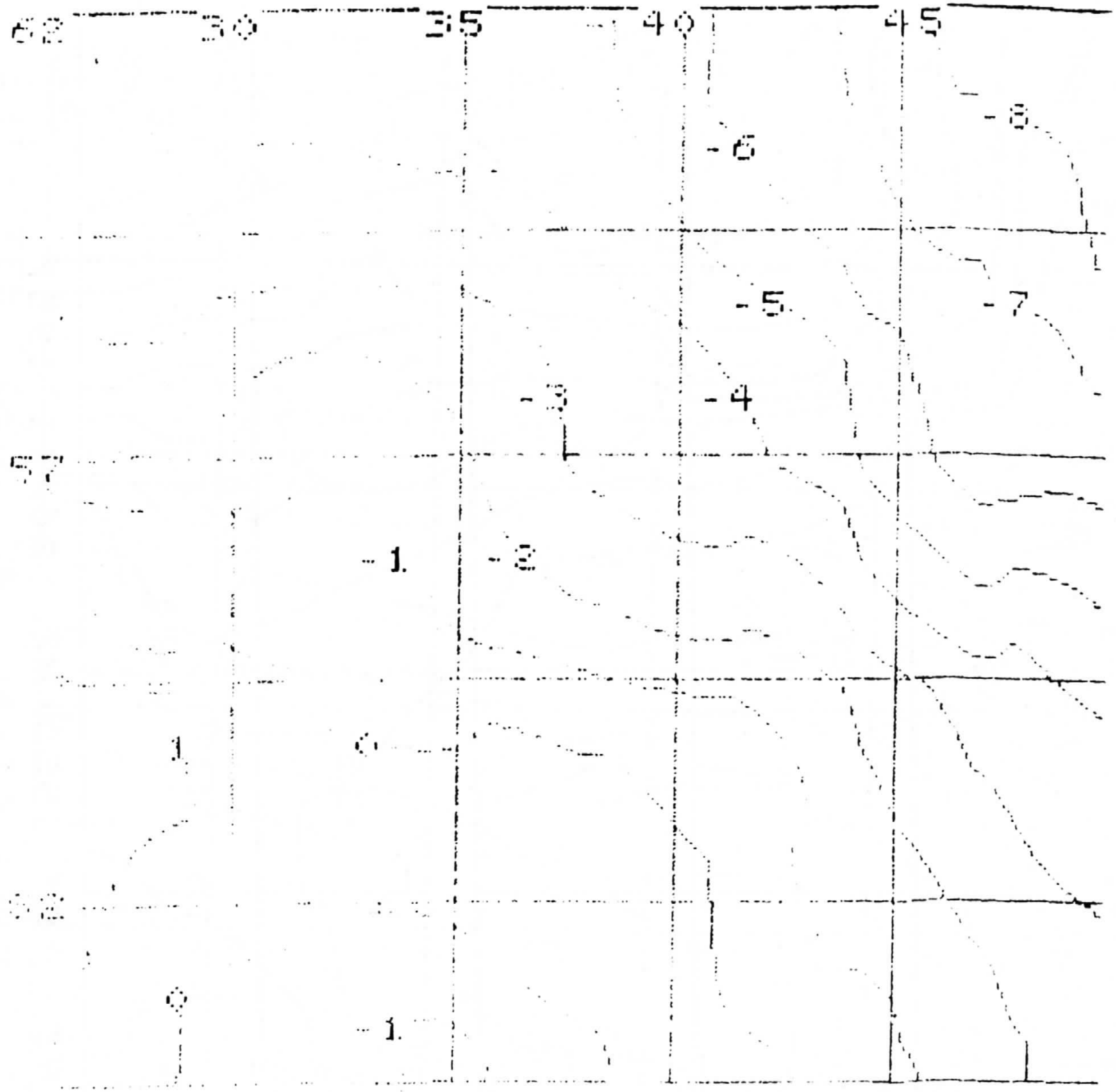


Рис. 3

NOTE: poor quality image

TEMPERAT.
RZND-NOAA9
700 MB

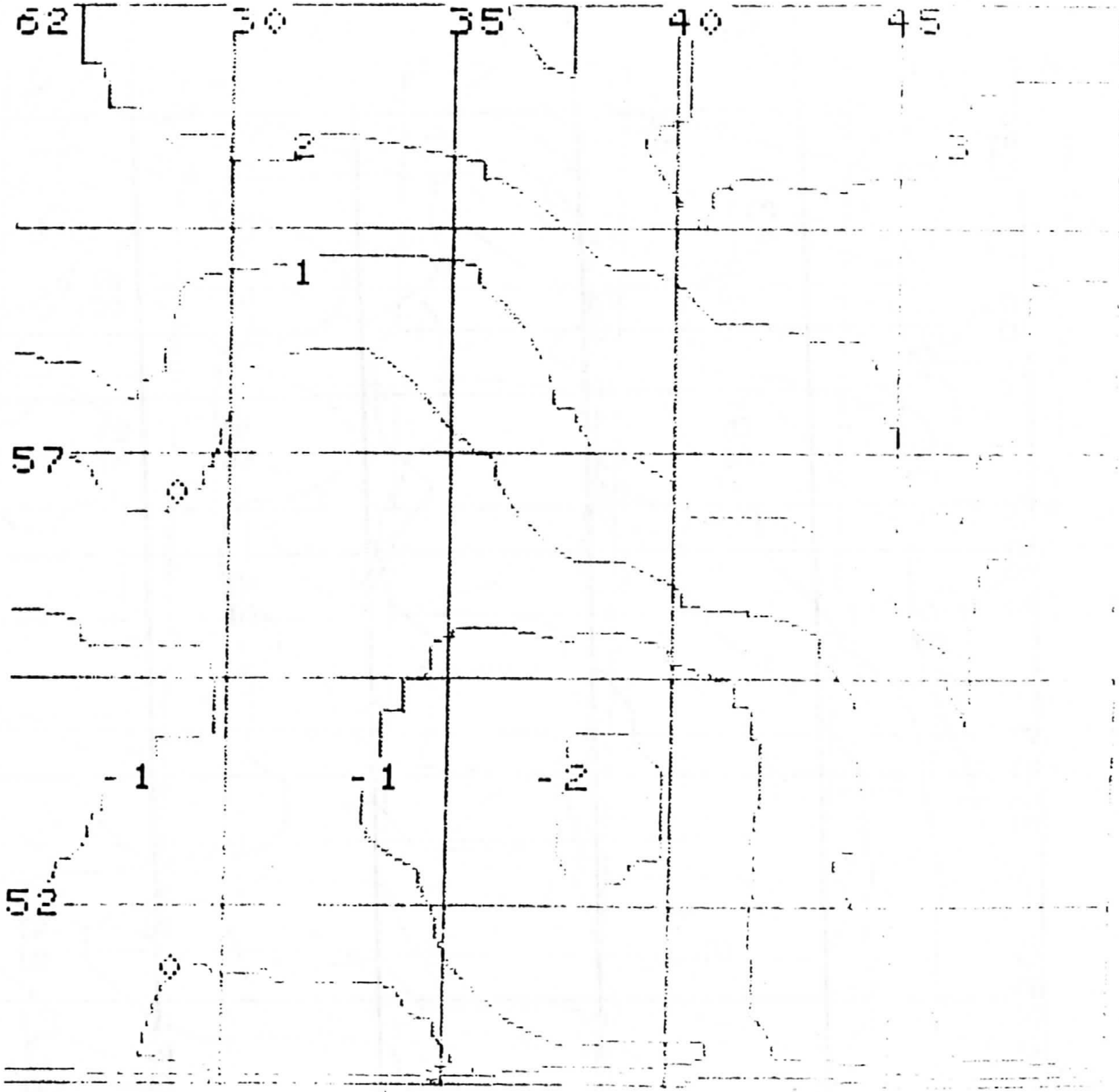


Рис. 4

NOTE: poor quality image

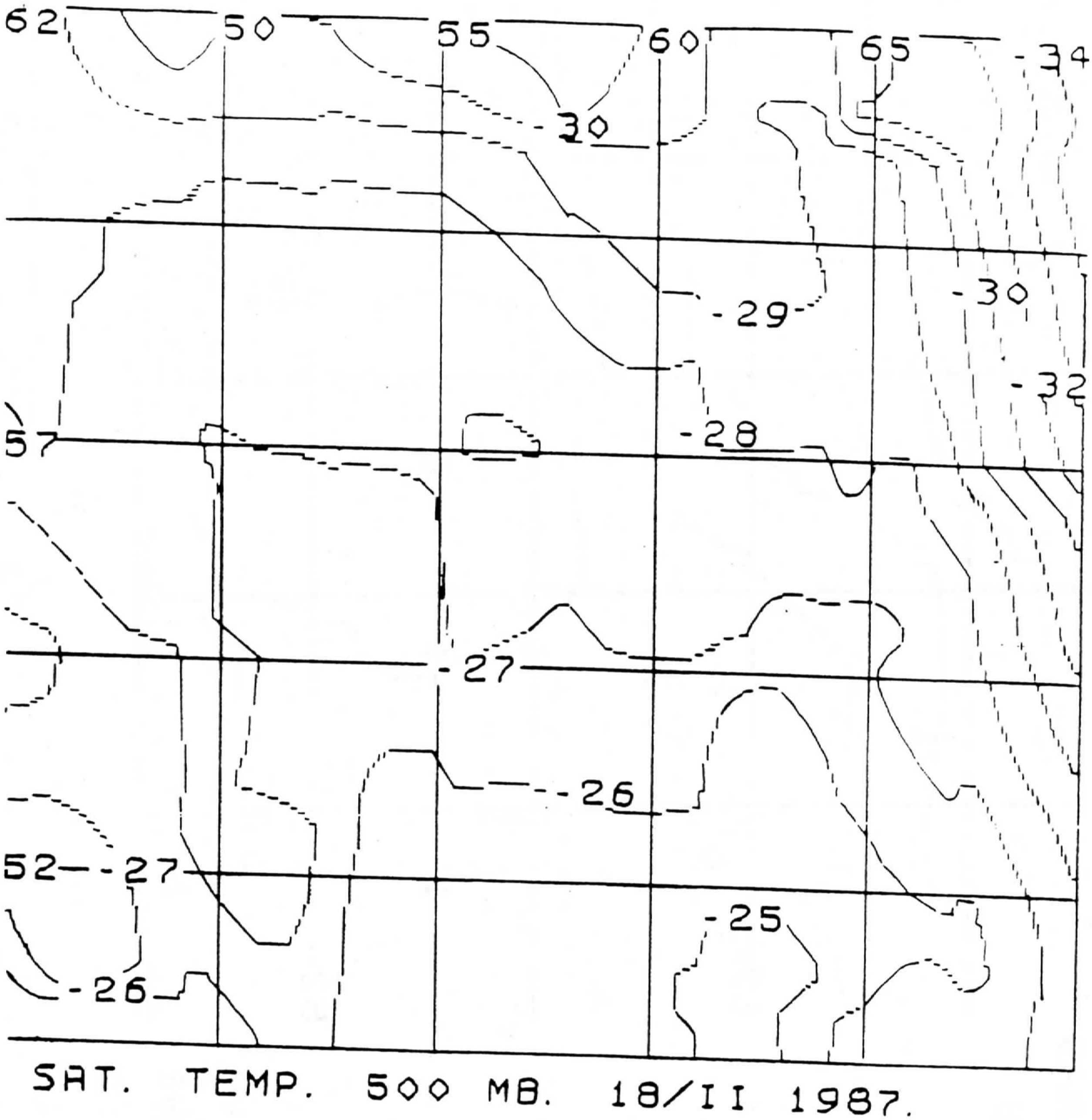
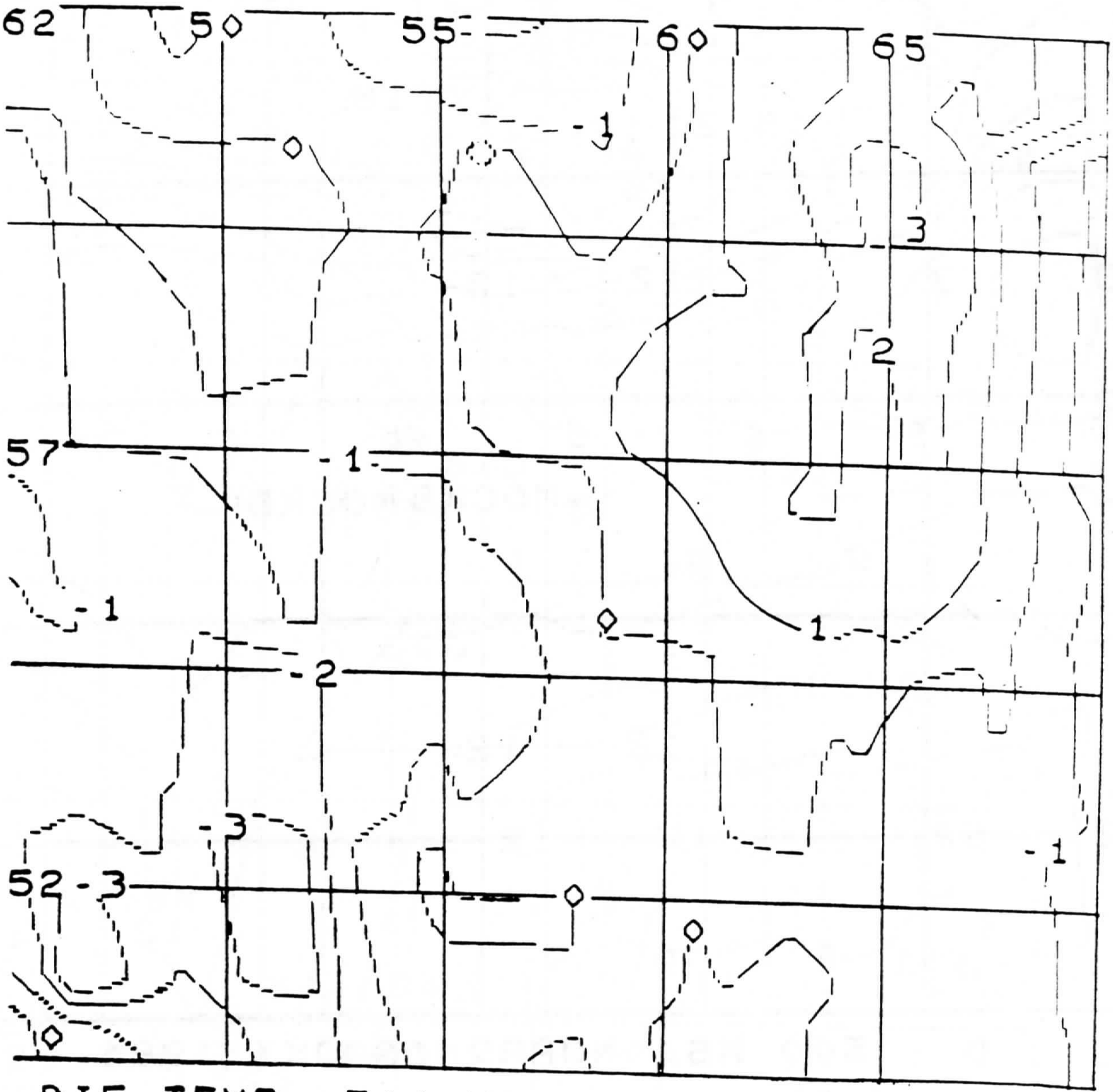


Рис. 5

Поле спутниковых оценок температуры воздуха на стандартной изобарической поверхности 500 гПа (I8.02.I987. II.IO GMT).



DIF. TEMP. 500 MB. 18/II 1987

Рис. 6

Поле разностей между спутниковыми оценками температуры воздуха на стандартной изобарической поверхности 500 гПа (см. рис. 2.5) и данными радиозондирования за срок I8.02. I987. I2.00 GMT.

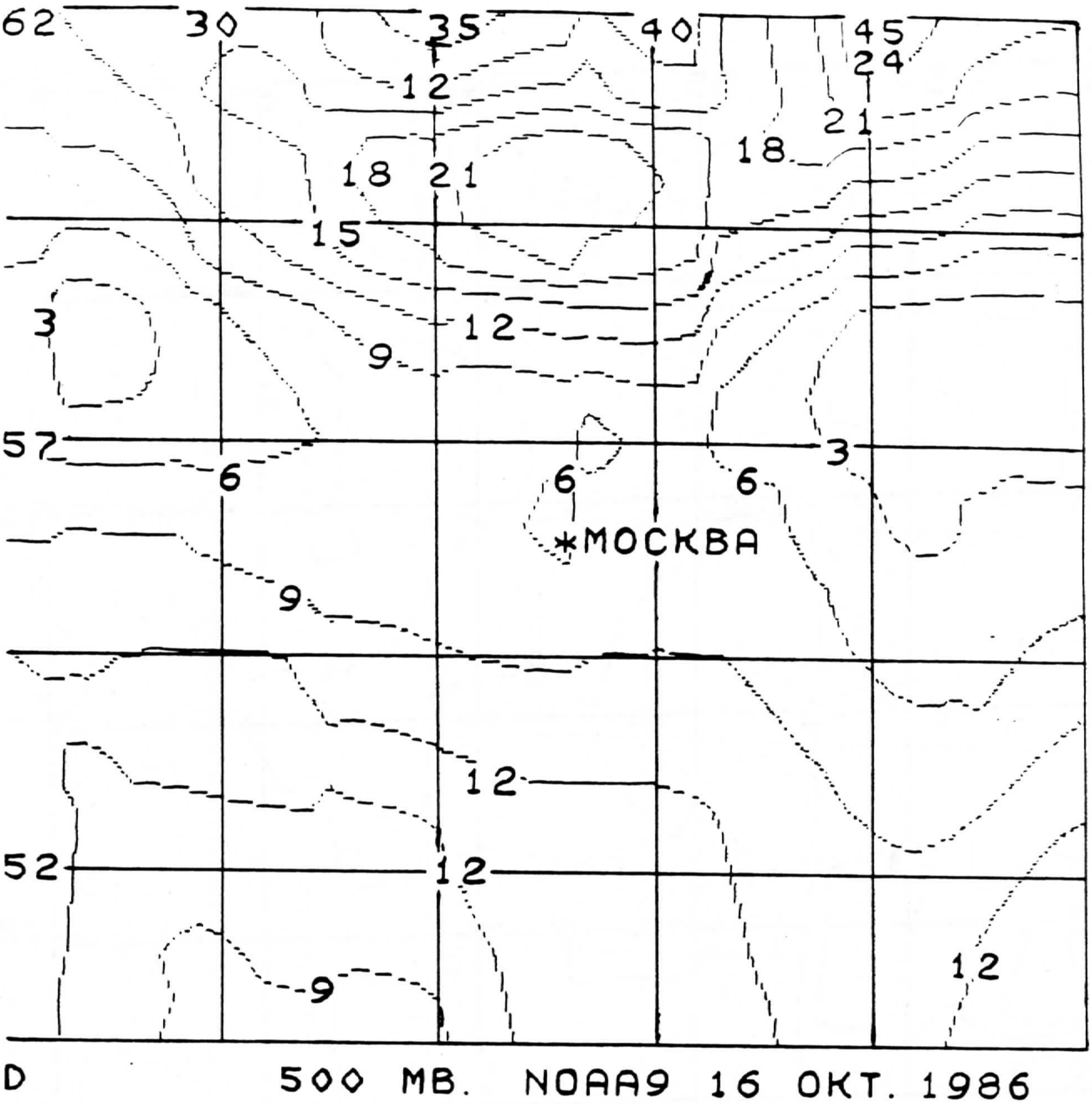


Рис. 7

Поле спутниковых оценок дефицита точки росы на стандартной изобарической поверхности 500 гПа (16.10. 1986. 11.50 GMT).

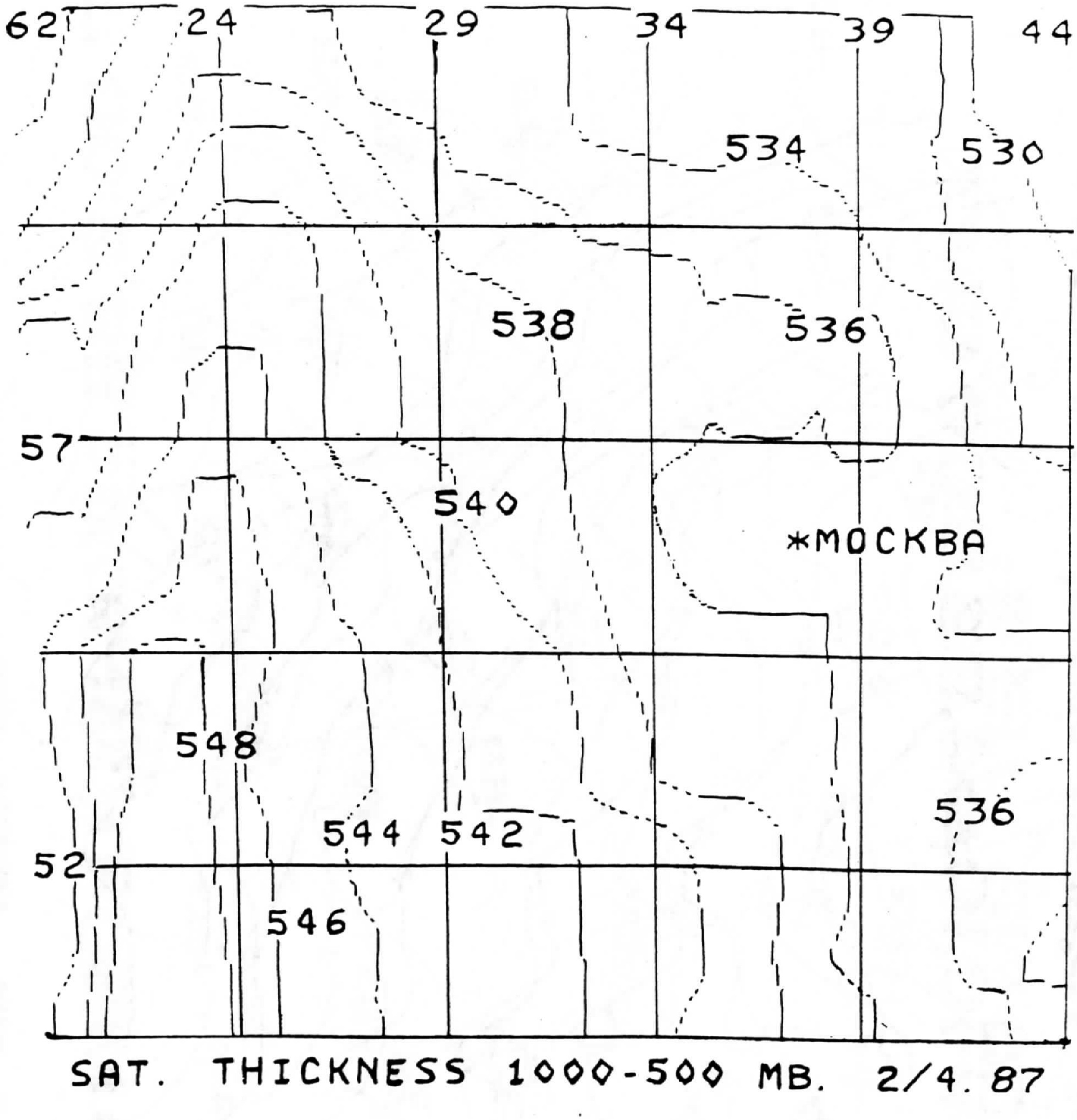
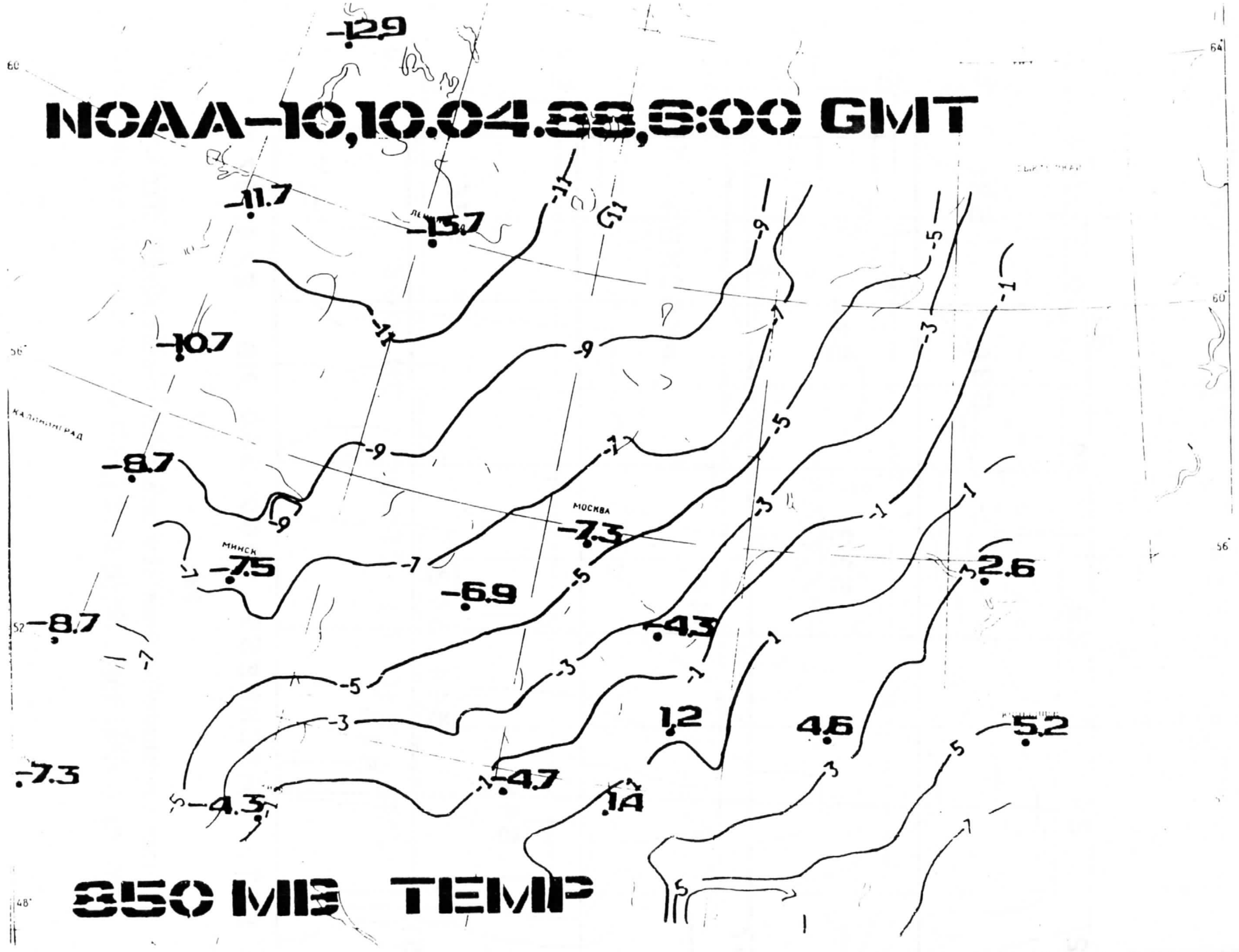


Рис. 8

Поле спутниковых оценок относительного геопотенциала 1000 - 500 гПа (2.04. 1987. 06.00 GMT).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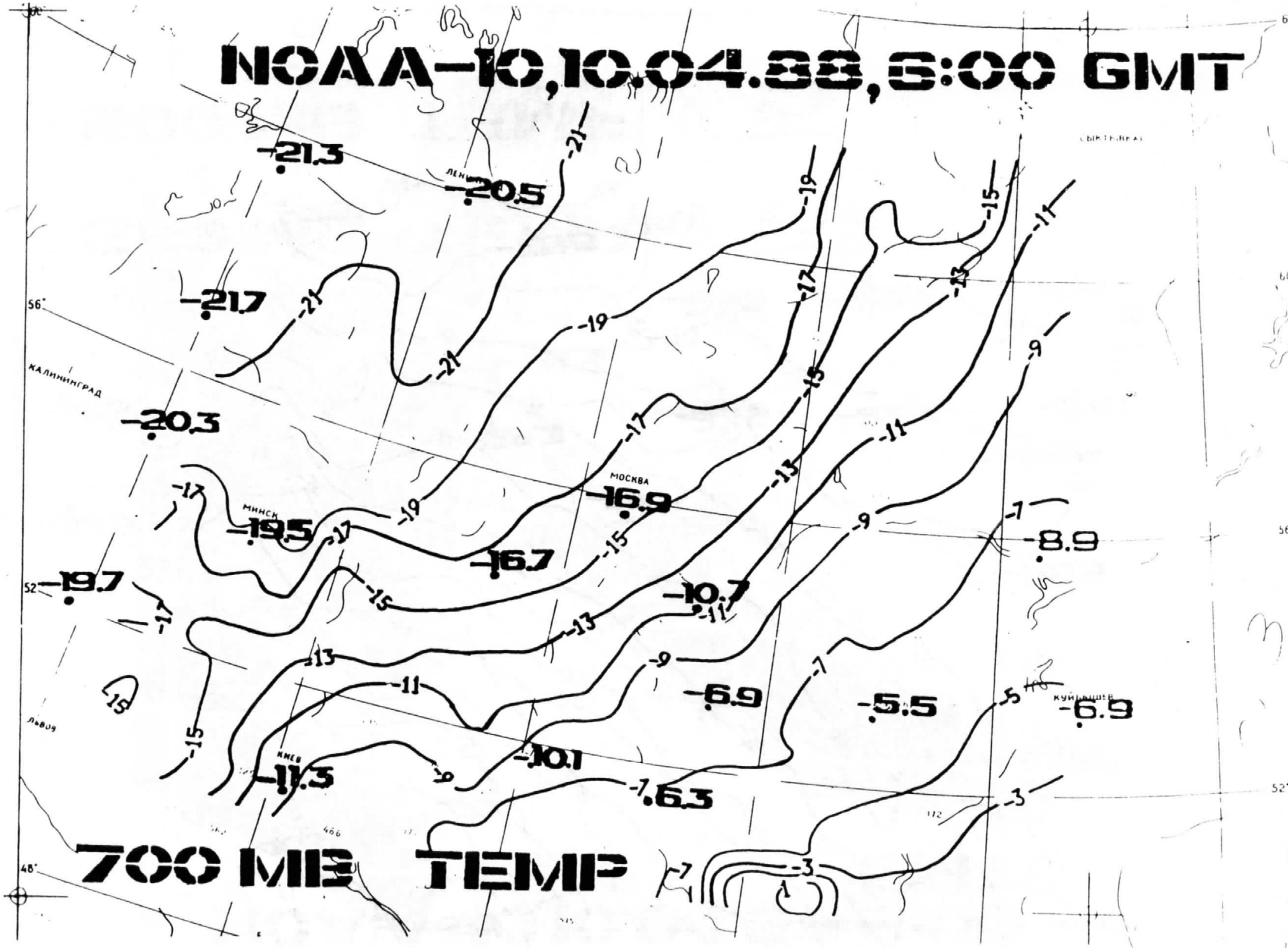
850 MB TEMP
-12.9
-11.7
-13.7
-10.7
-8.7
МИНСК
-7.5
МОСКВА
-7.3
-6.9
-8.7
-7.3
-4.3
-4.7
-4.3
1.2
1.4
4.6
2.6
5.2

Fig 9


NOAA-10,10.04.88,6:00 GMT
700 MB TEMP
КАЛИНИНГРАД
МИНСК
МОСКВА
КИЕВ
ЛЬВОВ
КУЙБЫШЕВ
-21.3
-20.5
-21.7
-20.3
-19.5
-19.7
-16.9
-16.7
-10.7
-11.3
-10.1
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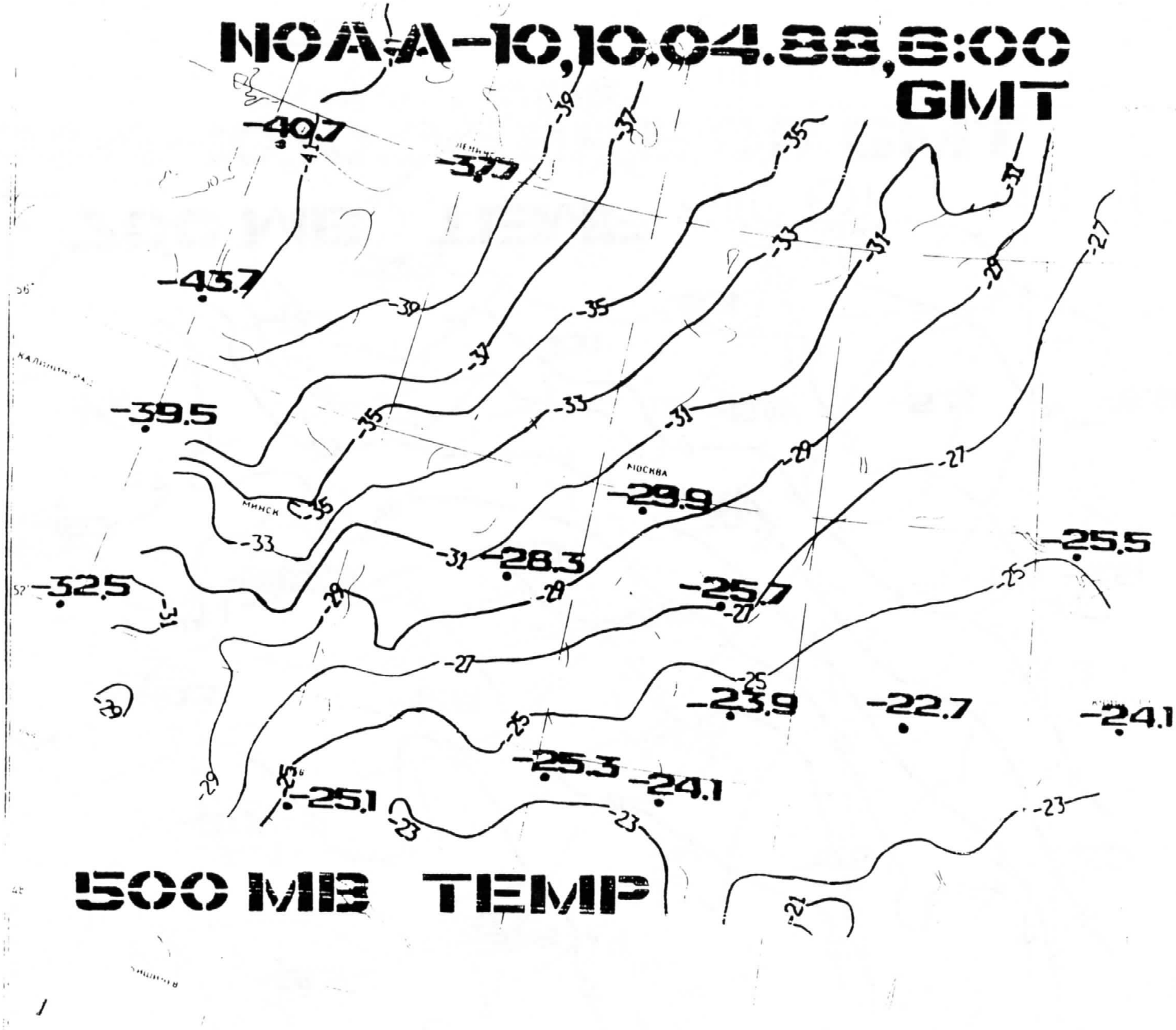
-6.9
-6.3
56°
52°
48°
60
64

Fig 10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500 MB TEMP
-40.7
-37.7
-43.7
-39.5
-32.5
-29.9
-28.3
-25.7
-25.5
-23.9
-22.7
-24.1
-25.3
-24.1
-25.1
МОСКВА
МИНСК

Fig 11

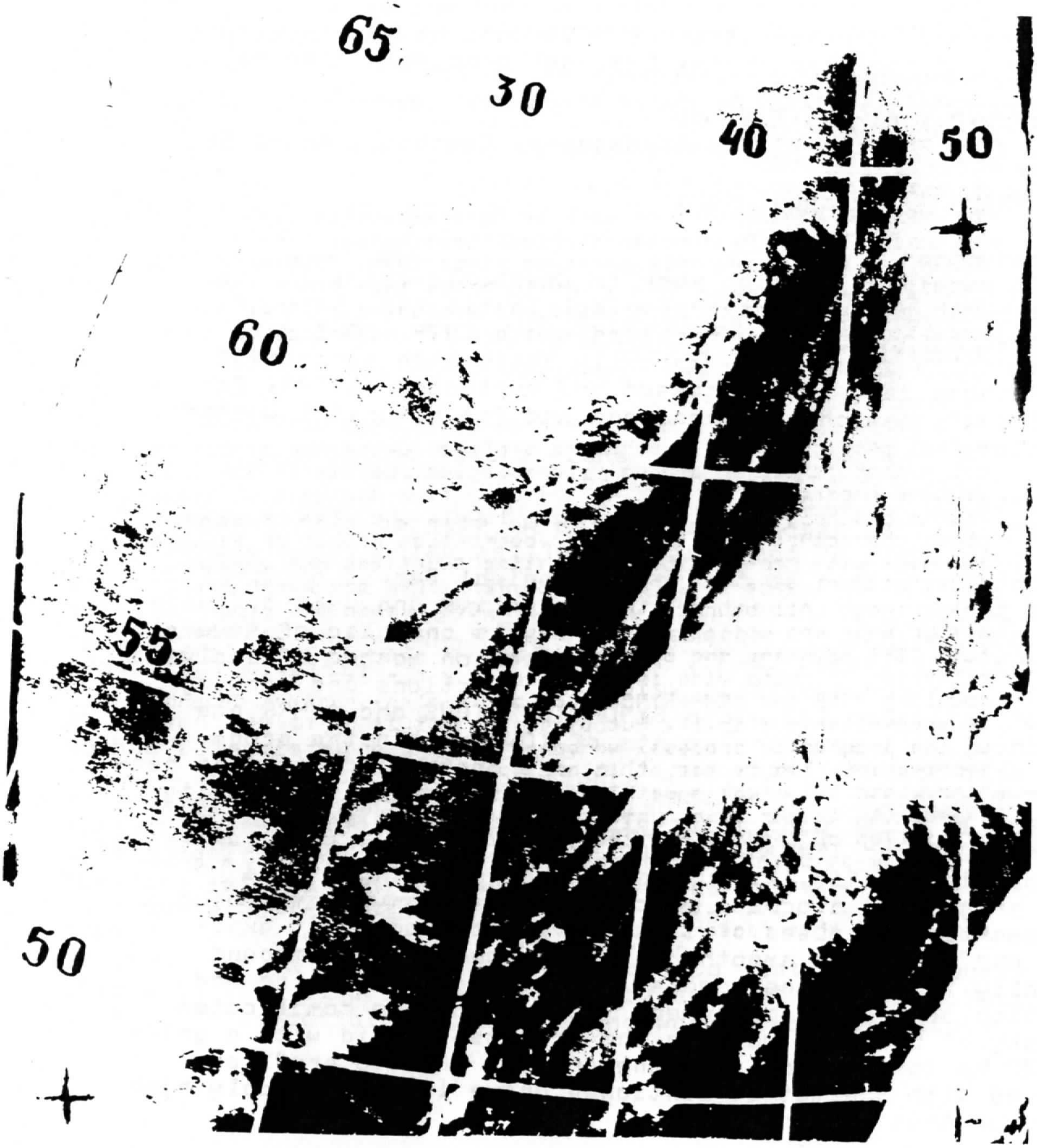

Fig 12

THE TECHNICAL PROCEEDINGS OF THE FIFTH INTERNATIONAL TOVS STUDY CONFERENCE

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