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Report - ARQL - 15/77

Analysis of Surface Parameters and Temperature Predictions for the 1977 Lake Simcoe Experiment

by

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Abstract

Predicted values of u_*, θ_* and L based on 1977 Lake Simcoe tower data are presented. Comparisons with those calculated from a sonic anemometer give excellent agreement on u_*. Predicted temperature profiles also agree well with those measured by a tethersonde. A brief summary on the method for predicting surface parameters without a priori knowledge of temperature profiles is also given.

1. Introduction

This report presents some of the scientific analysis of the tower data collected during the Boundary Layer Research Division's Lake Simcoe Experiment in early March of 1977.

The standard procedure for evaluating fluxes and other surface layer parameters requires the knowledge of both temperature and velocity profiles. During the Lake Simcoe Field Experiment, wind profile data were available from five Cassella anemometers. Unfortunately temperature profile data exhibited inconsistencies and could not be used for any scientific study. It was this reason that motivated an earlier study (Lo, 1977) to develop a method for evaluating the boundary layer parameters without a priori knowledge of the temperature profile.

2. Theory

A more detailed development of the theory has been given in Lo, (1977). Here only a brief outline will be presented.

Based on the similarity theory of Monin and Obukhov, both velocity and temperature profiles can be described as functions of a single variable, $\xi = \frac{z}{L}$. For example

$$k \frac{u}{u_*} = f(\xi) = f(\xi_o) \qquad (1)$$

and

$$\frac{k(\theta - \theta_o)}{\theta_*} = h(\xi) - h(\xi_o) \qquad (2)$$

where

$$L = - \frac{c_p \rho \theta_o u_*^3}{k g H} = \frac{\theta_o u_*^2}{\theta_* k g}$$

is the well known Monin-Obukhov length. By definition the Monin-Obukhov length should be a functional parameter related to both velocity and stratification.

However, if we assume that one of the profiles is of good accuracy, we can at least in principle, apply the similarity argument and use either (1) or (2) to evaluate "L". In the present case, equation (1) is used in conjunction with the wind data obtained during the experiment. The roughness length z_o for a uniform snow-covered surface is of a standard value. Accordingly it is considered here as a known constant with a value of .004 meters. The final equation used is given in the following form:

$$\sum_{i=1}^{N} \varepsilon_i \frac{d\,\varepsilon_i}{dL} = \delta \simeq 0 \quad , \quad N = 5 \text{ for the present case} \qquad (3)$$

where

$$\varepsilon_i = \frac{k}{u_*} u_i - \left[f(\xi_i) - f(\xi_o) \right] \neq 0 \qquad (4)$$

The numerical procedure is to first assume a value for L and to obtain an explicit expression for u_* as follows:

$$\frac{1}{u_*} = \frac{1}{kN} \sum_{i=1}^{N} \frac{f(\xi_i) - f(\xi_o)}{u_i} \qquad (5)$$

Substitute (4) and (5) into equation (3) and carry out the iterative process until δ approaches zero. This implies that the value of u_* and L used in the equation are the "near" correct values. With u_* and L known, we can readily calculate θ_*. Accordingly the temperature profile can be predicted by using (2).

3. Results and Discussion

Values of u_*, T_* and L for the period from 1430 to 2130 of March 7 and from 1500 to 1700 of March 8 are presented in tabular form. Comparisons with those obtained from a sonic anemometer are made. Due to the extremely small sensible heat flux at the time the comparison of the Monin-Obukhov length L does not look good. In most cases the differences are almost an order of magnitude.

The comparisons of the values of u_*, on the other hand, are excellent. Comparisons of the predicted temperature profiles with the tethersonde temperature profiles are also presented. Due to some uncertainty in the heights recorded by the tethersonde, accurate comparisons are difficult to make. However, the predicted temperature profiles are consistently similar to that of the tethersonde profiles. It is therefore believed that the temperature predictions produced by this study is of good quality.

4. Conclusions

With the excellent results demonstrated from the comparison of the friction velocities u_*, we feel confident that the method used in this study is a dependable one. It is also believed that the Monin-Obukhov lengths, L, predicted in this study are more dependable than those calculated from the sonic anemometer. It is known that under similar meteorological conditions over a snow surface, values of L similar to that predicted in this study have been reported (e.g., McKay, 1977). The predicted temperature profiles resulting from this study are also very useful as they can practically fill in the place of the missing tower temperature data which are frequently needed for other data analysis work.

5. Acknowledgment

The author would like to thank Drs. R.E. Mickle and D.C. McKay for providing the tethersonde profiles and results from sonic anemometer measurements respectively. Helpful discussions with and encouragement received from other BLRD colleagues are also appreciated.

6. References

Lo, A.K., 1977: A method for fluxes and temperature profile predictions using wind profile as the sole information. To be published.

McKay, D.C., 1977: Measurements of the structure of atmospheric turbulence and energy fluxes involved in the energy budget of a snow cover. Ph.D. Thesis, Univ. of Guelph.

Simcoe Exp. March 7, 1977

Run No.	U_* (M/sec) Measured	U_* (M/sec) Predicted	T_* (°K) Measured	T_* (°K) Predicted	L (Meter) Measured	L (Meter) Predicted
1430	.131	.17		.0904		74.0
1500	.132	.224		.139		87.6
1530	.182	.273		.157	645	108.3
1600	.215	.286		.207	884	96.0
1630	.236	.299		.248	1187	82.5
1700	.237	.285		.213	869	86.0
1730	.262	.301		.192	529	105.7
1800	.179	.333		.198	219	124.5
1830	.234	.256		.166	401	90.0
1900	.245	.174		.273	612	25.3
1930	.073	.157		.292	286	19.2
2000	.094	.194		.243	346	36.0
2030	.101	.165		.179	78	34.7
2100	.141	.14		.15	195	29.5
2130	.134	.141		.151	184	29.3

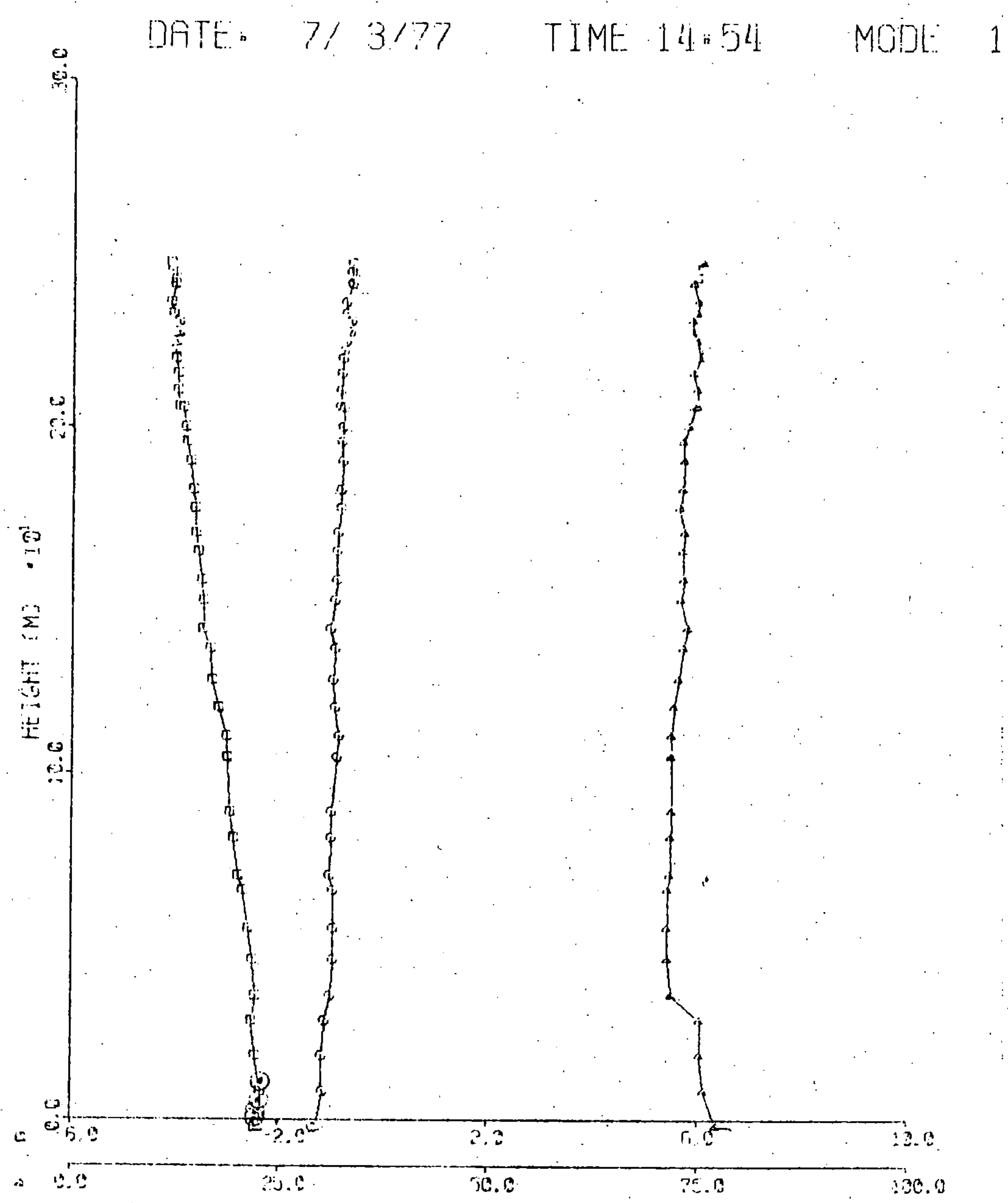
Simcoe Exp. March 8, 1977

Run No.	U_* (M/Sec)		T_* (°K)		L (Meter)	
	Measured	Predicted	Measured	Predicted	Measured	Predicted
1500	.176	.221		.334	249	33.0
1530	.146	.206		.326	139	30.0
1600	.175	.195		.331	189	25.9
1630	.177	.206		.361	153	26.4
1700	.143	.208		.339		28.7

TEMPERATURE PROFILE

○ PRESENT PREDICTION

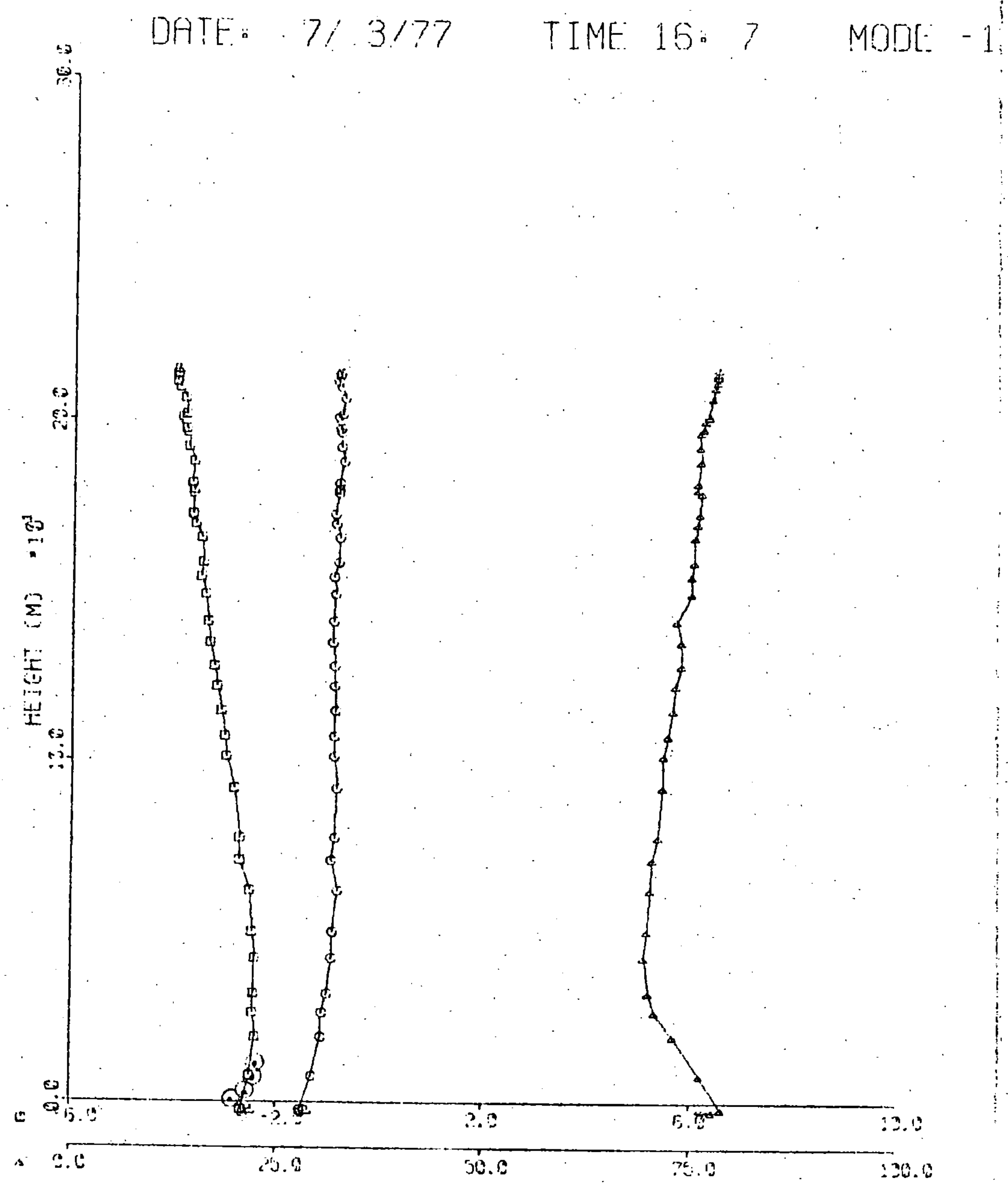
□ TETHERSONDE



TEMPERATURE PROFILE

⊖ PRESENT PREDICTION

□ TETHERSONDE



TEMPERATURE PROFILE

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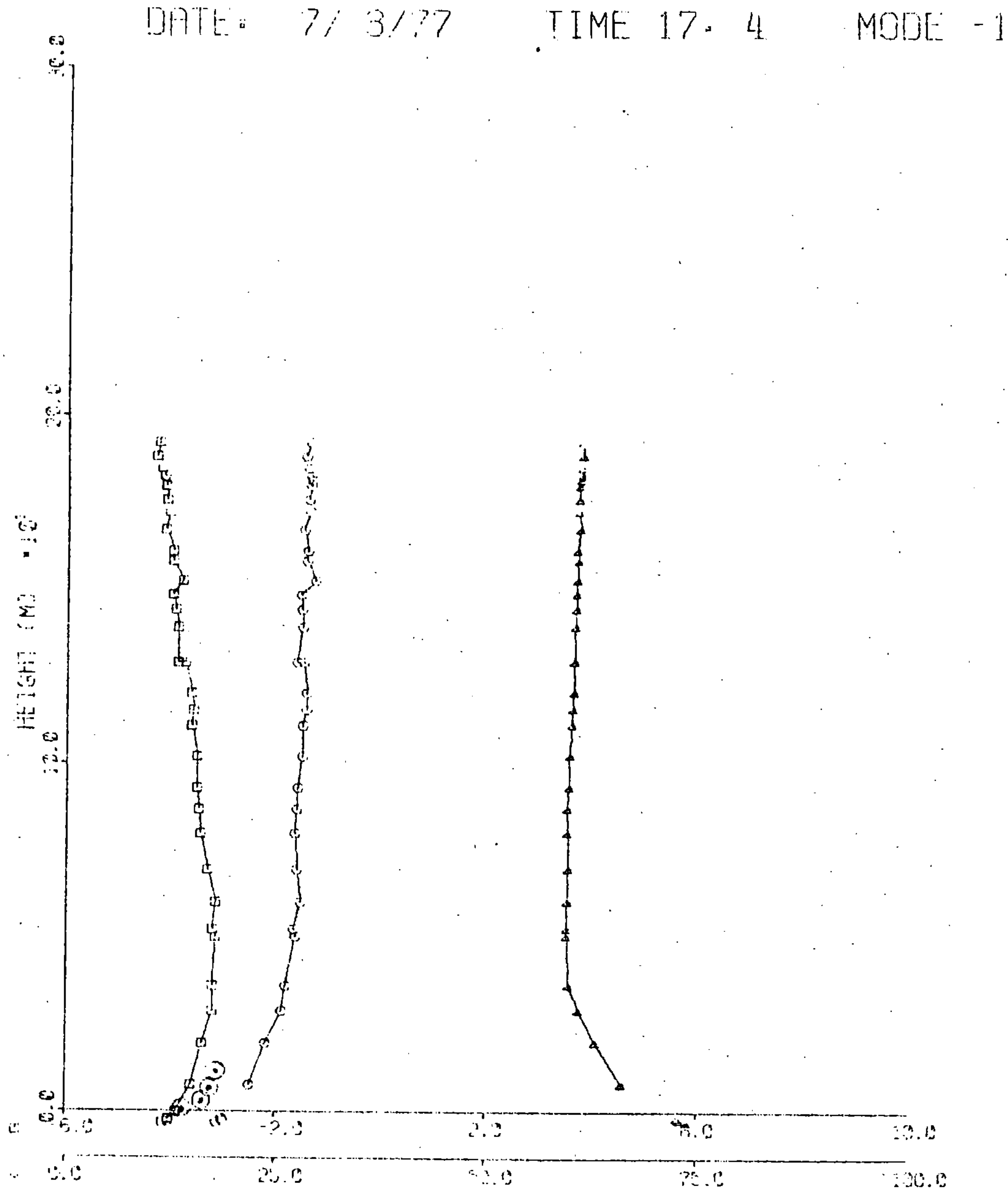
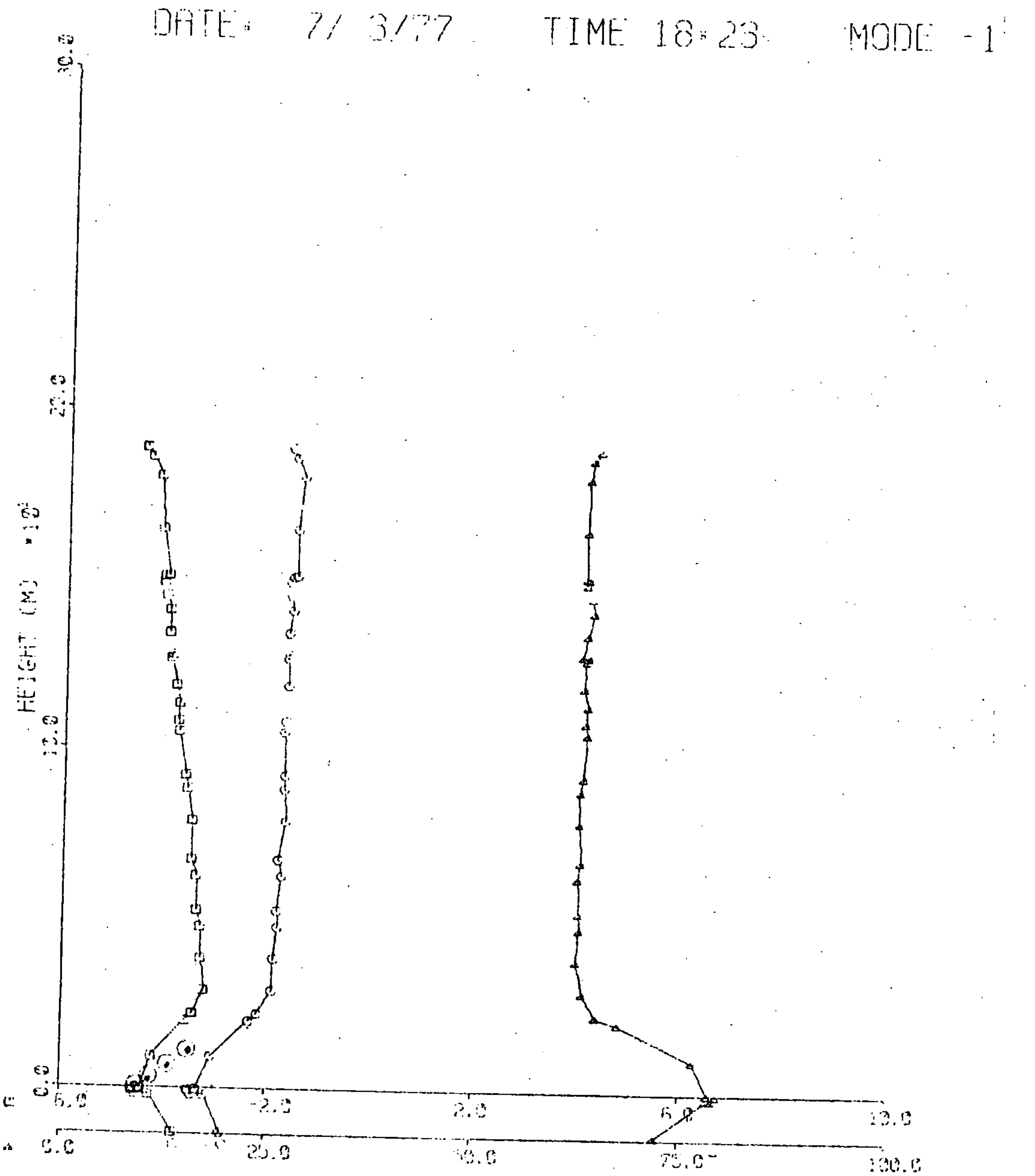
□ TETHERSONDE



TEMPERATURE PROFILE

○ PRESENT PREDICTION

□ TETHERSONDE



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○ PRESENT PREDICTION

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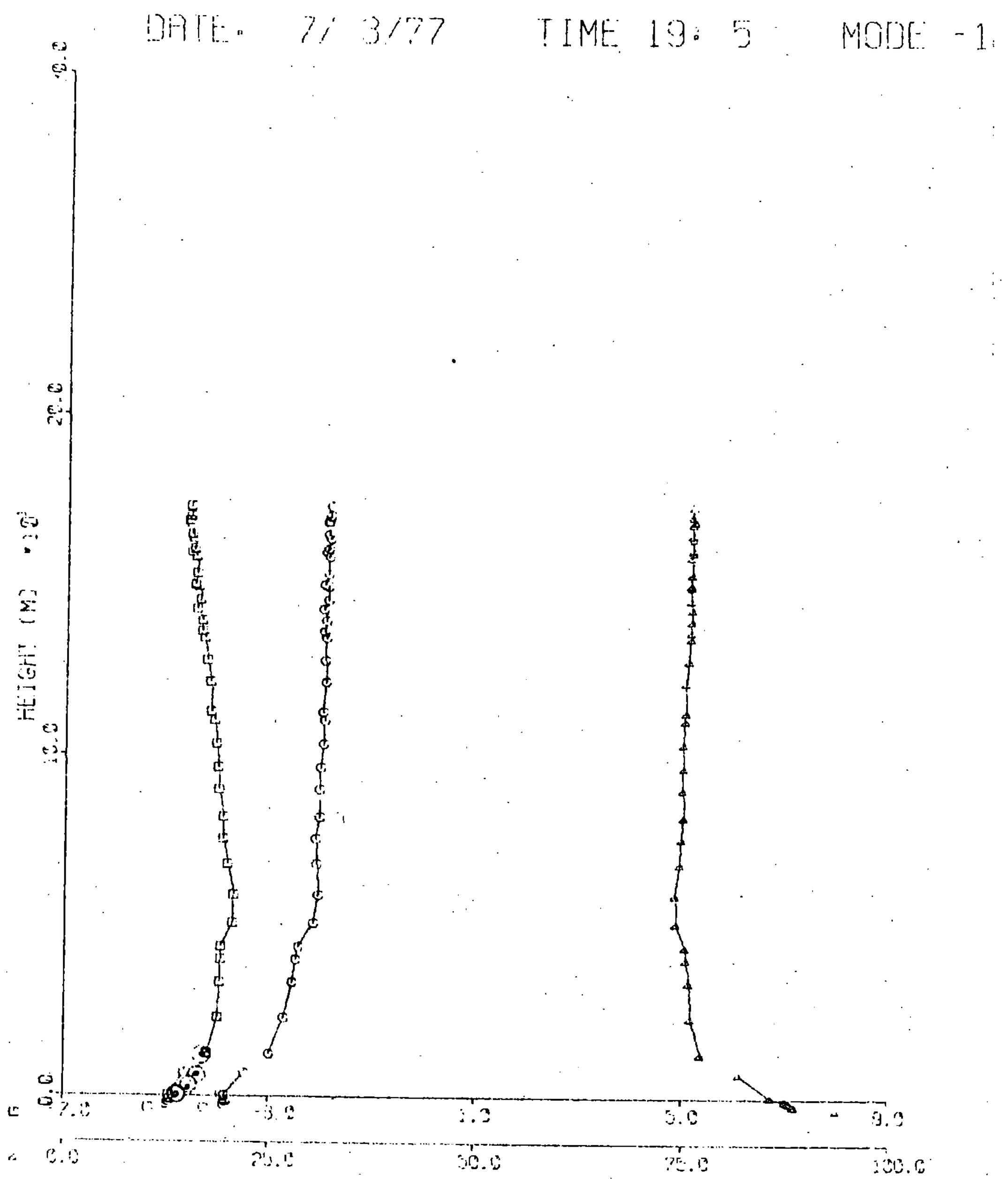

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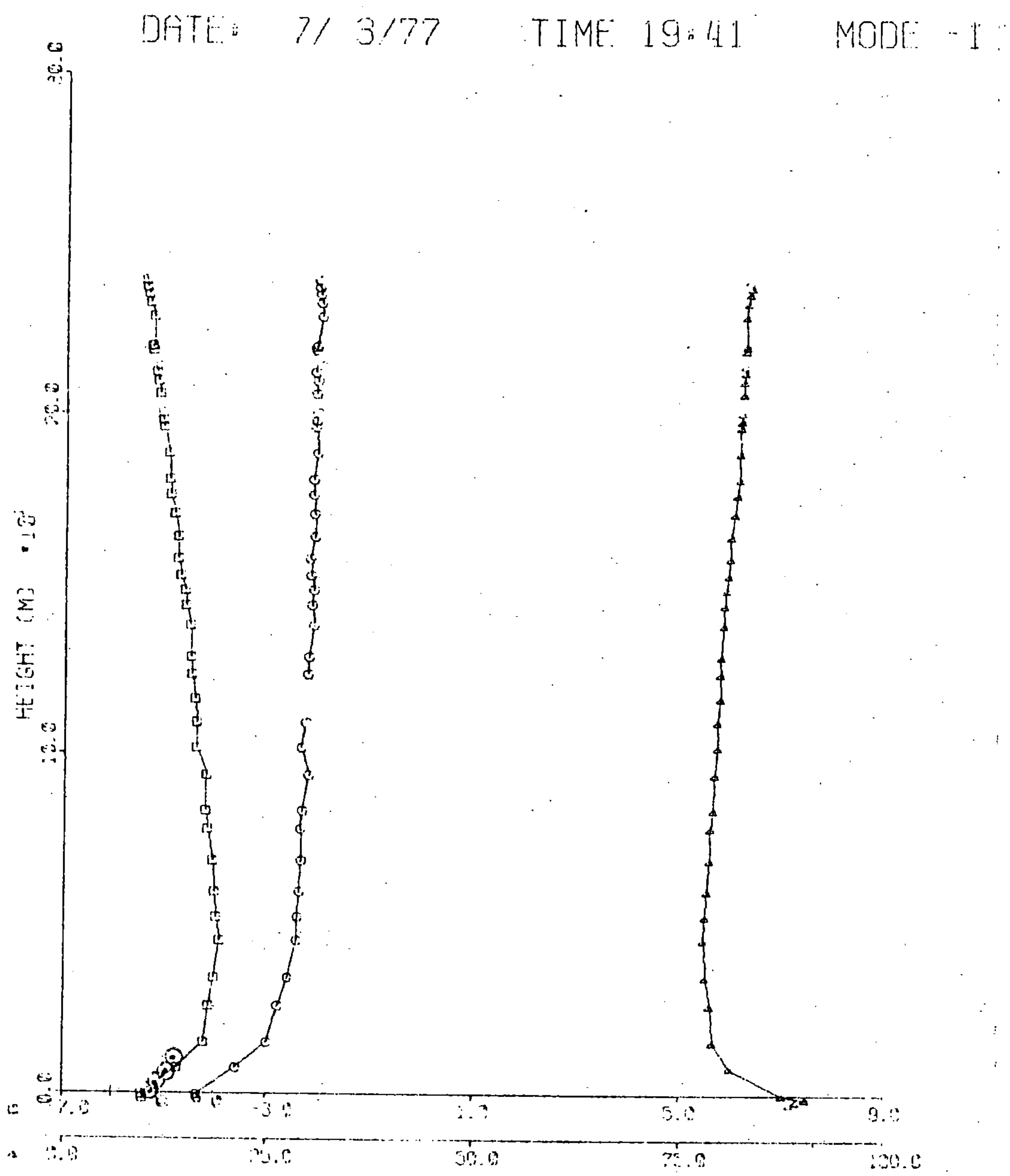
○ PRESENT PREDICTION

□ TETHERSONDE



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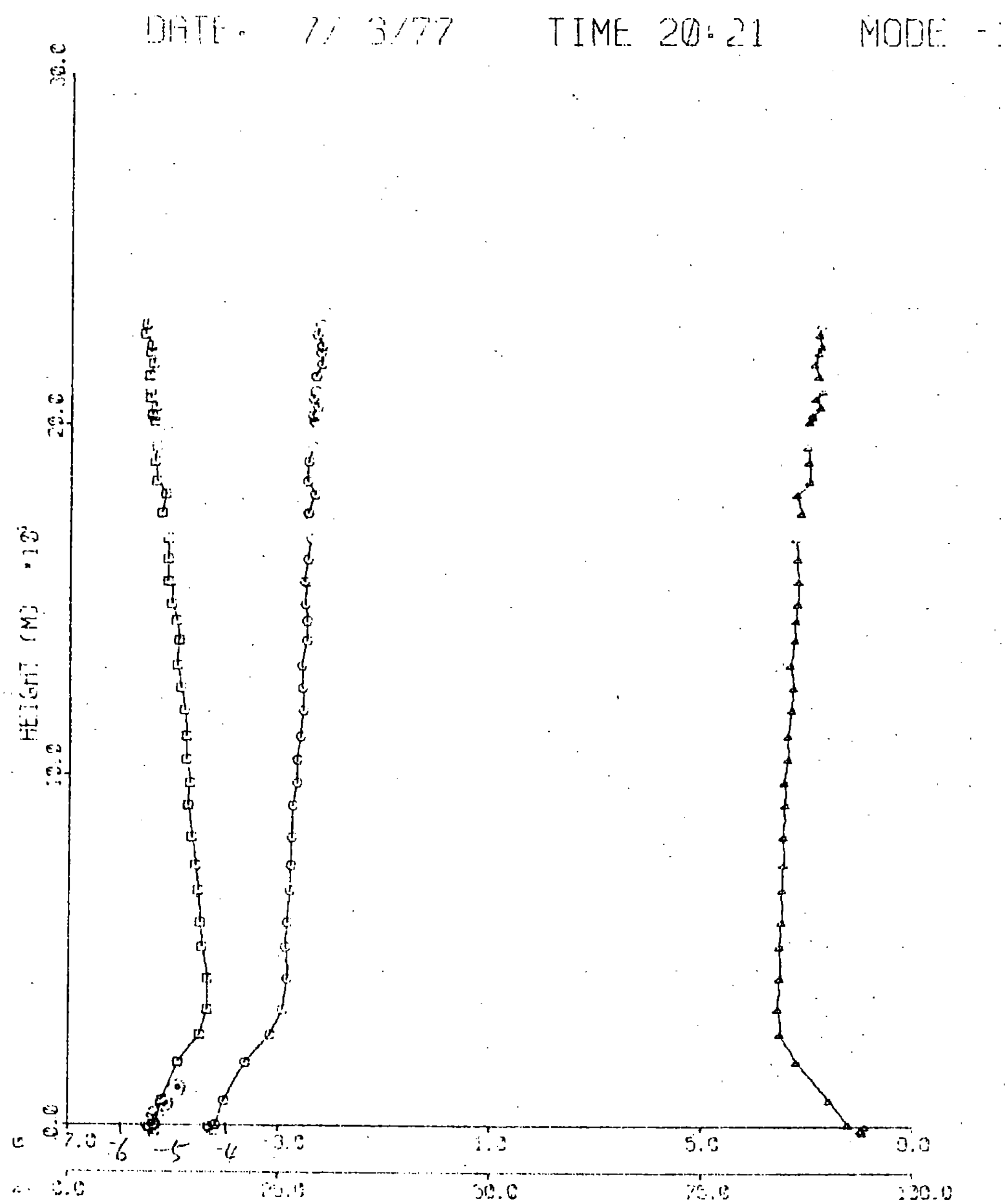

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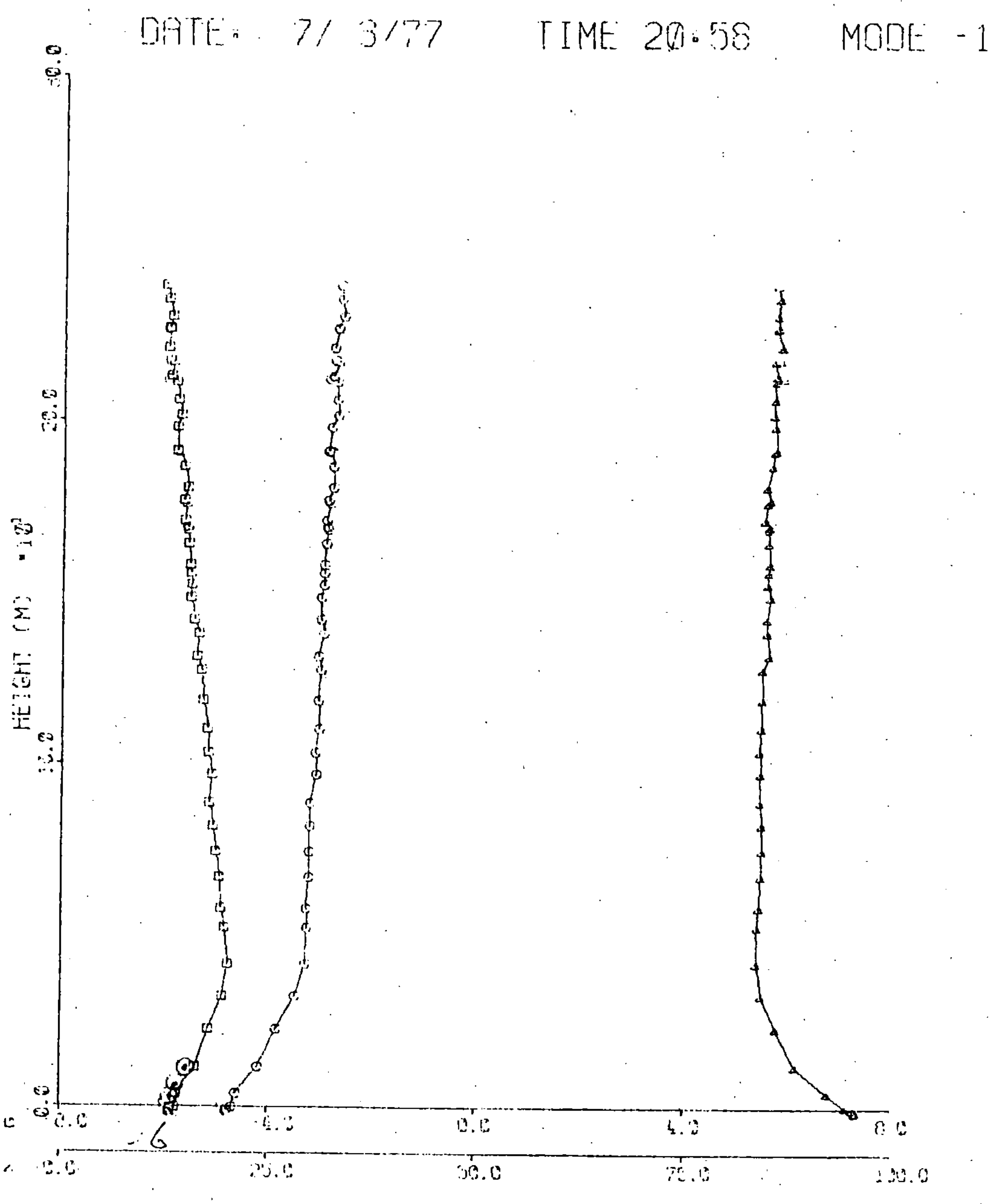

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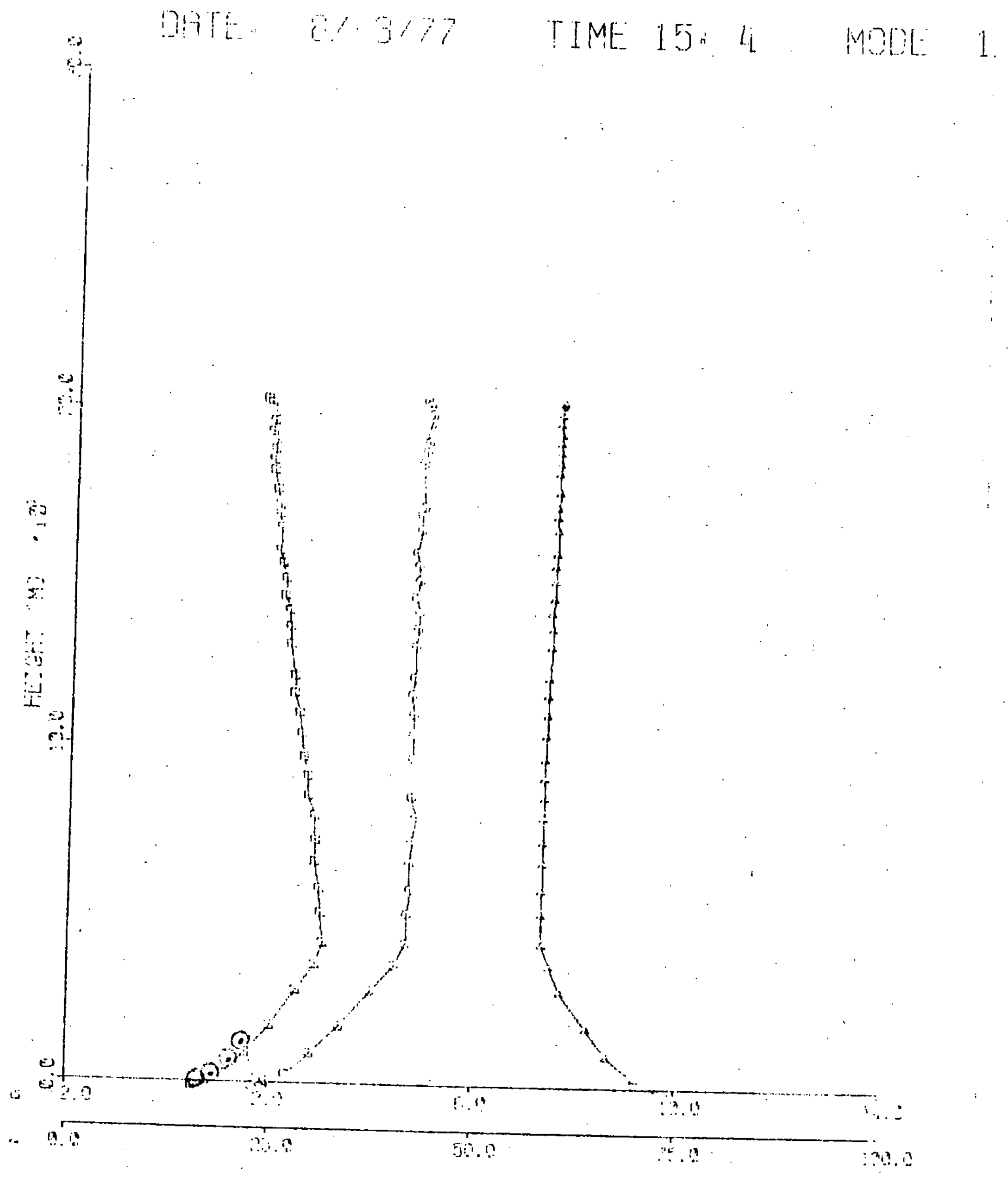

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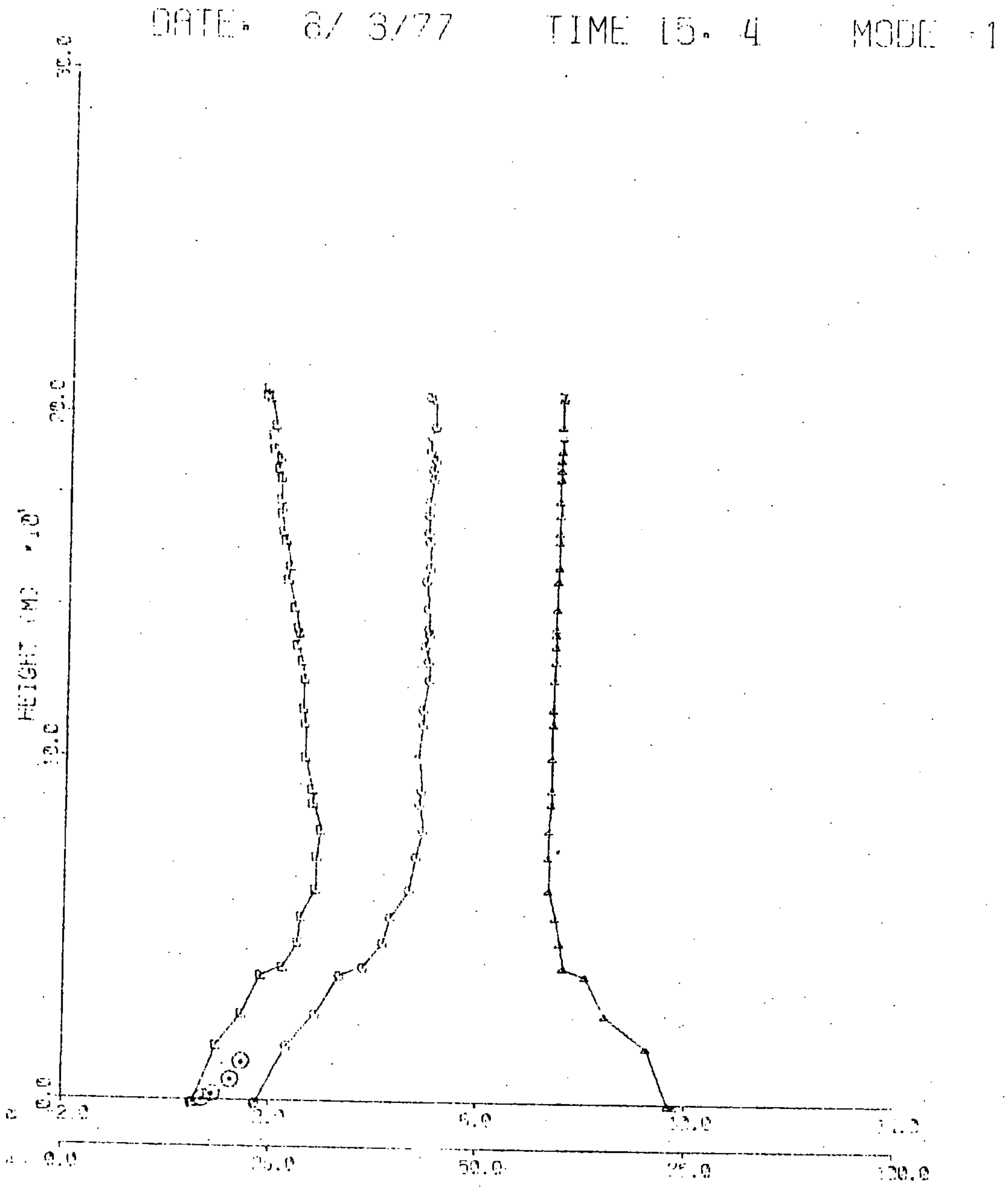
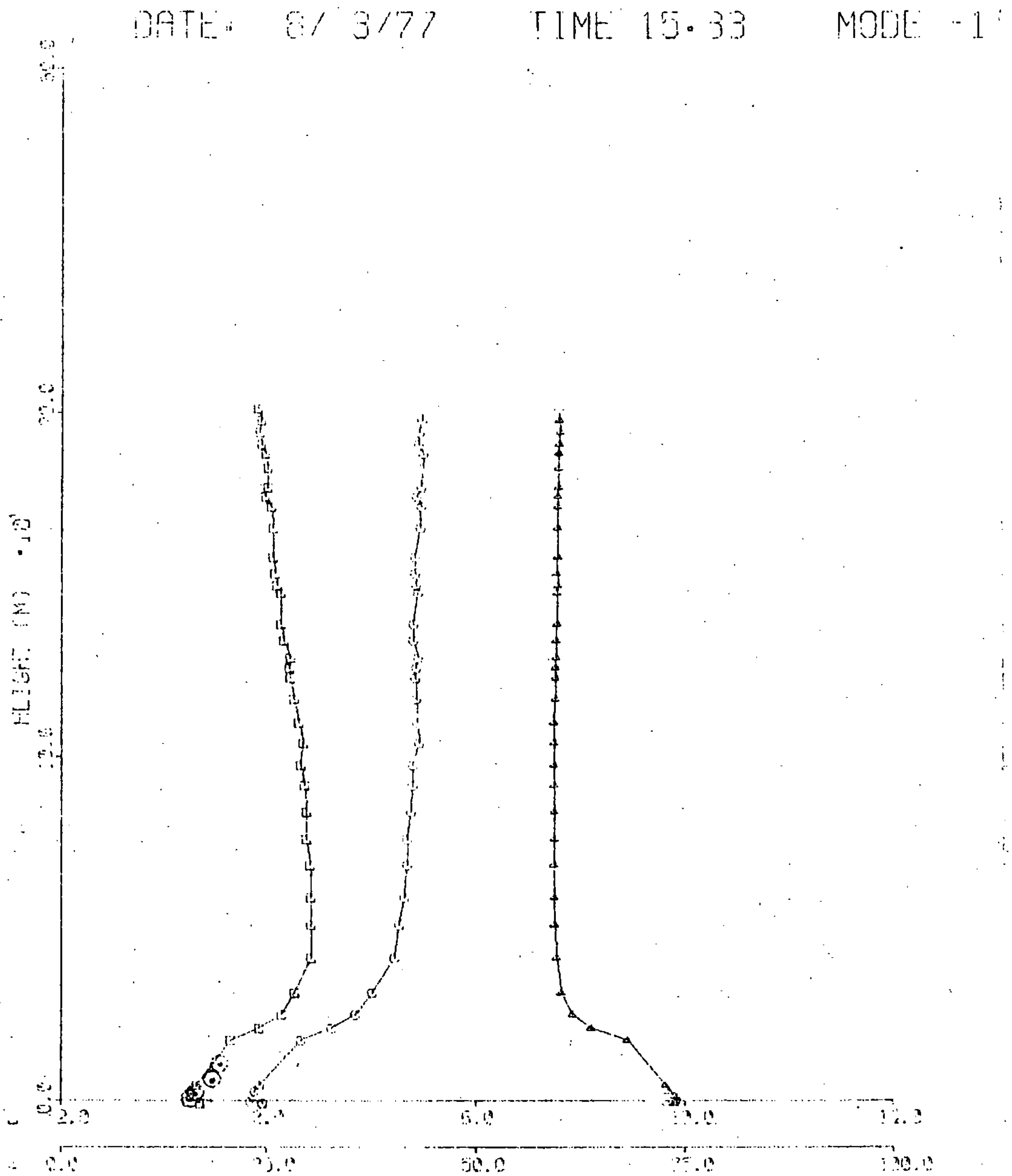


NC. ANAHEIM CALIFORNIA

TEMPERATURE PROFILE

○ PRESENT PREDICTION

□ TETHERSONDE



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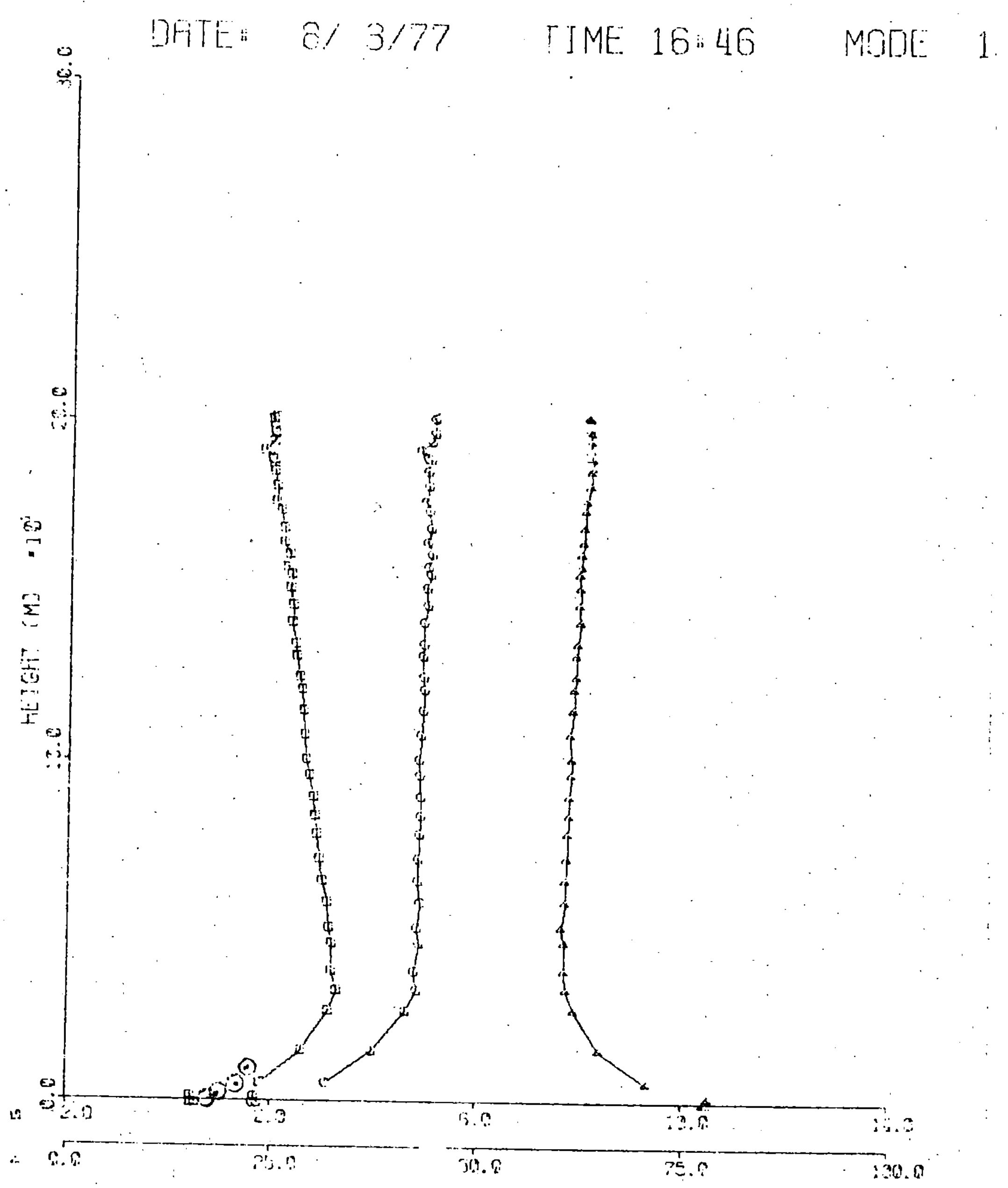

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