1. Classification *INPE-COM.2/NTI* *CDU.: 551.501*	2. Period	4. Distribution Criterion internal [X] external [X]
3. Key Words (selected by the author) *AIR WEATHER INTERACTIONS* *METEOROLOGICAL PARAMETERS* *WEATHER STATIONS*		
5. Report No. *INPE-1137-NTI/096*	6. Date *October 1977*	7. Revised by *Luiz Carlos B. Molion*
8. Title and Sub-title *AIR-SEA INTERACTION STUDIED AT THE STATION OCCUPIED BY R/V "SIRIUS"*		9. Authorized by *Nelson de Jesus Parada* *Director*
10. Sector *DME* Code		11. No. of Copies *9*
12. Authorship *Nandamudi Jagan M. Rao* *A. S. Mascarenhas* *Y. Yamazaky*		14. No. of Pages *15*
13. Signature of first author		15. Price

16. Summary/Notes

Regularly observed sea surface meteorological parameters are used in the transfer formulas to compute the main heat exchange coefficients, the sensible heat exchange and the latent heat exchange. Also the values of eddy shearing stress of the wind on the sea surface, Bowen's ratio and dissipation of kinetic energy are computed. The computation involved are for the periods July 29 to July 31, 1974; August 4 to August 17, 1974; September 1 to September 7, 1974; and September 11 to September 13, 1974. These comprise part of the GATE period for the stations occupied by the Brazilian Naval Ship R/V SIRIUS in the Equatorial Atlantic (07N). Hourly observations are used in the computations for the above periods. The variations in the computed values studied in relation to the variations of rainfall measured at the stations.

17. Remarks

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ABSTRACT

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1. INTRODUCTION

The energy exchanges between the ocean and atmosphere have been studied by Pyke (1965), Wyrtki (1966), Brocks et al (1970) and Chandrakant (1974) who related the air-sea exchange to the synoptic changes in weather. These exchange properties, especially the exchange of sensible heat and latent heat from the ocean to the atmosphere, can be computed by utilizing the routinely measured meteorological parameters and substituting them in the transfer formulas (Malkus, 1962).

The present authors attempted to associate the air-sea exchanges with rainfall, using the data of N/oc SIRIUS. The ship occupied station No.20 (Fig. 1), during GATE period, changing its locations for each of phase. Hourly observations of marine meteorolotical parameters were collected during the period. In addition to the exchange properties, the values of kinetic energy. Bowens ratio and wind Stress, are also computed. Their variations are described and presented, for the selected periods July 29 to July 31, August 04 to August 07, September 01 to September 07 and September 11 to September 13, all for 1974. The results of the period of July 29 to July 31 are presented in this article.

2. COMPUTATIONAL PROCEDURE

The tranfer formulas method has been used to compute transfer of latent heat (Q_e) and sensible heat (Q_s), between ocean and atmosphere, from the knowledge of routinely observed meteorological parameters. The formulas essentially consider the rate of transfer of water vapour and sensible heat, from above the ocean surface, through the process of turbulence. The form and accuracy of these formulas have been a subject of controversy, they appear in various forms and there is no general agreement as to which forms of equations are most useful.

In this study the so called transfer/exchange/Bulk aerodynamic formulas, as listed by Malkus (1962), are used:

$Q_e = PL_eE = L_eC_D(q_s - q_a)\ V$

$Q_s = PC_pC_D(T_s - T_a)\ V$

The notation and dimensions are:

Q_e = Latent heat transfer between ocean and atmosphere in cal cm^{-2} day^{-1}.

Q_s = Sensible heat transfer between ocean and atmosphere in cal cm^{-2} day^{-1}.

L_e = Latent heat of evaporation at sea surface in cal gm^{-1}

($L_e = 596.73 - 0.601\ T_s$) .

T_a = Temperature of the air in ^oC.

T_s = Temperature of sea surface in ^oC.

C_D = Drag coefficient (dimensionless).

V = Scalar wind speed in knots.

C_p = Specific heat of air at constant pressure in cal g^{-1} ^oC.

V_s = Mixing ratio of the air at anemometer level (dimensionless).

V_a = Mixing ratio of the air at sea surface (dimensionless).

P = Density in g cm^{-3}.

The values of density and mixing ratio are computed for each observation. The following coefficients have been taken as constant:

$C_D = 2 \times 10^{-3}$ (dimensionless)

$C_p = 0.240$ cal g^{-1} $^oC^{-1}$

The kinetic energy (K), wind stress (W_s) and Bowens' ratio (B_o) are also computed using the following expressions (in MKS units):

$$K = \frac{1}{2} V^2$$

$$W_s = 12.85\ C_D\ V^2$$

$$B_o = \frac{Q_s}{Q_e}$$

3. ANALYSIS AND DISCUSSION
28.07.74 to 31.07.74

Fig. 2 shows the variations of air-sea exchanges alongwith other parameters. The purpose of the study is to relate these with fluctuations of rainfall and, in turn, to any synoptic system. For this, the period 29 July to 31 July 74 is selected, using the hourly values of marine meteorological parameters. At the ship station 20, occupied by "SIRIUS" (0730N, 4000W), it rained most of the time from 29 July (09 GMT) till 30 July (15 GMT). The synoptic maps are looked into for 09, 12, 18 and 24 GMT of 29, 30 and 31 July 74. Fig. 3 shows the location of ITCZ on 29 July at 09 GMT. It is noticed from the maps that the ITCZ is either over the station or near it, except on 29 July at 24 GMT when it moved to 220 km south of the station and, on 30 July at 24 GMT, moved to 385 km south of the station. This shows the oscillatory nature of the ITCZ and its effect when near or over the station. Table I shows the position of ITCZ as observed from the surface synoptic maps (TASA).

TABLE I

POSITION OF ITCZ

DATE	HOURS			
	09	12	18	24
29.07.74	OVER THE STATION	OVER THE STATION	OVER THE STATION	220 KM SOUTH OF THE STATION
30.07.74	OVER THE STATION	OVER THE STATION	OVER THE STATION	385 KM SOUTH OF THE STATION
31.07.74	OVER THE STATION	OVER THE STATION	OVER THE STATION	OVER THE STATION

Table II presents the hourly variations of air-sea exchanges and other parameters of interest. It is observed that T_s is always greater than T_a. Winds are moderate, occacionally reaching 5 m/sec. The distribution of sea surface is shown in Figures 4, 5 and 6, indicating no significant variation (DHN, 1974). Air temperature varied. The difference $T_s - T_a$ increased and, with slight increases in winds peed, resulted in higher values of Q_e and Q_s. Both exchanges are found to be from the sea to the atmosphere throughout the period. T_a is often decreased by evaporation of falling precipitation. Hence $T_s - T_a$ is increased and also Q_s. During precipitation, Q_e increases and $V_s - V_a$ becomes insignificantly small.

4. CONCLUSIONS

1. At the ship station, T_s is found to be greater than T_a.

2. The variations in air-sea exchanges are associated with the variations of rainfall.

3. The rainfall is related to the presence of the ITCZ over or near the station.

4. Large amount of heat transfer can take place at the station from sea to the atmosphere, on the approach of the ITCZ.

5. A currious fact noticed in this period is that the Latente heat flux seems to be given by $Q_e \simeq | \vec{v} | \cdot Q_{e_1}$ where Q_{e_1} is the latent heat flux for 1 m/sec wind. Then a rough estimate for Q_e could be made with the knowledge of wind speed. For example for v = 3 m/sec, $Q_e \simeq 750$ cal cm^{-2} day^{-1} (see Table II).

TABLE II

VARIATIONS OF AIR-SEA EXCHANGES AT SHIP STATION "SIRIUS"

D	M Yr	Hr	PRES	T_s °C	T_a °C	T_u °C	RH%	Vel m/s	T_s-T_a	Mix. Ratio $WS(T_s)$	Mix. Ratio $W(T_a)$	Q_s	Q_e	BR	K	λ
29	774	1	1013.1	27.5	26.1	24.2	85.4	3.0	1.4	0.023	0.002	19.745	735.708	0.027	4.500	0.231
29	774	2	1014.1	27.2	26.0	24.2	86.1	3.0	1.2	0.023	0.002	16.930	721.652	0.023	4.500	0.231
29	774	3	1013.5	26.7	25.5	24.0	88.3	2.0	1.2	0.022	0.002	11.209	466.724	0.024	2.000	0.103
29	774	4	1012.5	27.4	26.0	24.6	89.1	4.0	1.4	0.023	0.002	26.294	971.954	0.027	8.000	0.411
29	774	5	1011.0	27.4	26.2	24.2	84.7	4.0	1.2	0.023	0.002	22.490	974.591	0.023	8.000	0.411
29	774	6	1012.0	27.2	26.0	23.0	77.4	3.0	1.2	0.023	0.002	16.897	727.930	0.023	4.500	0.231
29	774	7	1012.0	27.0	26.0	22.8	76.0	3.0	1.0	0.023	0.002	14.081	719.628	0.020	4.500	0.231
29	774	8	1013.0	27.3	26.4	24.4	84.8	3.0	0.9	0.023	0.002	12.667	724.913	0.017	4.500	0.231
29	774	9	1013.0	27.0	26.0	24.0	84.7	2.0	1.0	0.023	0.002	9.396	475.617	0.020	2.000	0.103
29	774	10	1014.0	27.0	24.0	23.0	91.8	3.0	3.0	0.023	0.002	42.612	720.515	0.059	4.500	0.231
29	774	11	1014.0	27.0	24.6	23.2	88.8	4.0	2.4	0.023	0.002	45.360	958.542	0.047	8.000	0.411
29	774	12	1014.0	27.5	25.0	23.6	88.9	2.0	2.5	0.023	0.002	23.592	493.333	0.048	2.000	0.103
29	774	13	1014.3	27.5	25.6	23.4	83.1	4.0	1.9	0.023	0.002	35.799	987.205	0.036	8.000	0.411
29	774	14	1013.9	27.8	27.5	25.0	81.6	2.0	0.3	0.024	0.002	2.807	496.206	0.006	2.000	0.103
29	774	15	1013.5	28.2	28.4	25.0	75.8	4.0	-0.2	0.024	0.002	-3.730	1017.041	-0.004	8.000	0.411
29	774	16	1013.2	28.0	24.5	23.5	91.9	5.0	3.5	0.024	0.002	82.648	1275.500	0.065	12.500	0.643
29	774	17	1013.0	27.4	24.6	23.8	93.5	5.0	2.8	0.023	0.002	66.081	1224.363	0.054	12.500	0.643
29	774	18	1012.8	27.1	24.6	23.6	92.0	4.0	2.5	0.023	0.002	47.192	962.044	0.049	8.000	0.411
29	774	19	1013.0	27.4	25.0	23.4	87.4	2.0	2.4	0.023	0.002	22.627	490.868	0.046	2.000	0.103
29	774	20	1013.2	27.5	25.4	24.0	89.0	2.0	2.1	0.023	0.002	19.775	491.673	0.040	2.000	0.103
29	774	21	1013.5	26.9	24.2	23.2	91.9	3.0	2.7	0.023	0.002	38.305	714.662	0.054	4.500	0.231
29	774	22	1014.2	27.0	24.2	23.2	91.9	2.0	2.8	0.023	0.002	26.501	479.527	0.055	2.000	0.103
29	774	23	1015.0	27.4	24.6	23.4	90.4	4.0	2.8	0.023	0.002	52.971	982.215	0.054	8.000	0.411
29	774	24	1015.2	27.3	24.6	23.4	90.4	4.0	2.7	0.023	0.002	51.089	975.887	0.052	8.000	0.411
30	774	1	1015.6	26.8	24.6	23.7	92.7	0.0	2.2	0.022	0.002	0.000	0.000	0.000	0.000	0.000
30	774	2	1015.0	26.7	24.6	23.7	92.7	4.0	2.1	0.022	0.002	39.728	936.593	0.042	8.000	0.411
30	774	3	1014.2	27.0	24.6	23.6	92.0	5.0	2.4	0.023	0.002	56.709	1194.719	0.047	12.500	0.643
30	774	4	1013.6	25.8	24.5	23.2	89.6	3.0	1.3	0.021	0.002	18.426	664.944	0.028	4.500	0.231
30	774	5	1013.2	26.5	24.0	22.9	91.0	3.0	2.5	0.022	0.002	35.482	698.048	0.051	4.500	0.231
30	774	6	1012.8	27.2	24.7	22.8	85.0	2.0	2.5	0.023	0.002	23.590	466.819	0.048	2.000	0.103
30	774	7	1012.8	27.0	25.0	23.0	84.3	2.0	2.0	0.023	0.002	18.852	479.713	0.039	2.000	0.103
30	774	8	1013.0	27.5	25.4	23.8	87.5	3.0	2.1	0.023	0.002	29.657	738.566	0.040	4.500	0.231
30	774	9	1014.0	27.5	25.8	23.8	84.6	2.0	1.7	0.023	0.002	15.999	492.085	0.033	2.000	0.103
30	774	10	1011.3	27.5	25.4	24.0	89.0	2.0	2.1	0.023	0.002	19.796	491.653	0.040	2.000	0.103
30	774	11	1015.0	27.5	25.2	23.6	87.4	4.0	2.3	0.023	0.002	43.424	986.354	0.044	8.000	0.411

CONTINUATION

TABLE II

30	77412	1015.0	26.5	25.8	23.8	84.6	2.0	0.7	0.022	0.002	6.505	461.175	0.014	2.000	0.103
30	77413	1015.0	27.2	24.2	23.6	95.1	2.0	3.0	0.023	0.002	28.415	484.376	0.059	2.000	0.103
30	77414	1015.0	27.0	24.6	23.8	93.5	5.0	2.4	0.023	0.002	56.753	1192.939	0.048	12.500	0.643
30	77415	1014.5	27.5	24.8	24.0	93.6	2.0	2.7	0.023	0.002	[illegible]	492.063	0.052	2.000	0.103
30	77416	1013.5	27.6	25.2	24.2	92.1	3.0	2.4	0.024	0.002	33.932	741.430	0.046	4.500	0.231
30	77417	1013.0	28.2	25.6	24.0	87.5	3.0	2.6	0.024	0.002	36.693	771.293	0.048	4.500	0.231
30	77418	1012.5	28.2	26.0	23.8	83.2	2.0	2.2	0.024	0.002	20.661	514.603	0.040	2.000	0.103
30	77419	1012.1	28.0	26.9	24.0	78.6	1.0	1.1	0.024	0.002	5.148	253.347	0.020	0.500	0.026
30	77420	1012.1	27.6	26.5	23.8	79.8	0.0	1.1	0.024	0.002	0.000	0.000	0.000	0.000	0.000
30	77421	1013.9	27.3	26.0	23.4	80.3	0.0	1.3	0.023	0.002	0.000	0.000	0.000	0.000	0.000
30	77422	1013.2	27.5	25.8	24.0	86.1	0.0	1.7	0.023	0.002	0.000	0.000	0.000	0.000	0.000
30	77423	1014.0	27.3	26.0	24.0	84.7	0.0	1.3	0.023	0.002	0.000	0.000	0.000	0.000	0.000
30	77424	1014.5	27.5	25.8	23.6	83.1	1.0	1.7	0.023	0.002	8.664	246.386	0.032	0.500	0.026
31	774 1	1015.0	27.2	25.6	23.4	83.1	1.0	1.6	0.023	0.002	7.542	242.070	0.031	0.500	0.026
31	774 2	1015.0	27.2	25.8	23.0	78.8	3.0	1.4	0.023	0.002	19.785	726.059	0.027	4.500	0.231
31	774 3	1014.0	27.2	25.8	23.4	81.7	5.0	1.4	0.023	0.002	32.941	1210.063	0.027	12.500	0.643
31	774 4	1013.2	27.2	26.0	23.6	81.7	3.0	1.2	0.023	0.002	16.916	724.625	0.023	4.500	0.231
31	774 5	1013.0	27.0	25.9	23.6	82.4	2.0	1.1	0.023	0.002	10.339	477.076	0.022	2.000	0.103
31	774 6	1012.8	27.2	25.7	23.1	80.2	2.0	1.5	0.023	0.002	14.106	485.135	0.029	2.000	0.103
31	774 7	1012.6	26.8	25.8	23.4	81.7	2.0	1.0	0.022	0.002	9.399	471.690	0.020	2.000	0.103
31	774 8	1013.0	27.5	26.2	23.7	81.1	2.0	1.3	0.023	0.002	12.207	492.174	0.025	2.000	0.103
31	774 9	1013.4	27.4	25.0	23.7	89.7	2.0	2.8	0.024	0.002	26.408	502.622	0.053	2.000	0.103
31	77410	1013.8	27.6	25.2	24.0	90.5	4.0	2.4	0.024	0.002	45.257	989.977	0.046	8.000	0.411
31	77411	1014.0	27.5	25.0	23.4	87.4	3.0	2.5	0.023	0.002	35.389	741.037	0.048	4.500	0.231
31	77412	1014.5	27.6	26.4	24.4	84.8	3.0	1.2	0.023	0.002	16.914	739.090	0.023	4.500	0.231
31	77413	1014.5	27.7	27.2	24.4	79.4	3.0	0.5	0.024	0.002	7.029	743.045	0.009	4.500	0.231
31	77414	1014.0	27.7	25.6	23.8	86.0	3.0	2.1	0.024	0.002	29.666	747.913	0.040	4.500	0.231
31	77415	1013.5	27.9	25.6	24.0	87.5	3.0	2.2	0.024	0.002	31.063	751.704	0.041	4.500	0.231
31	77416	1013.0	28.0	26.2	24.0	83.3	2.0	1.8	0.024	0.002	16.901	507.193	0.033	2.000	0.103
31	77417	1012.0	29.0	27.4	25.0	82.3	2.0	1.6	0.026	0.002	14.907	536.093	0.028	2.000	0.103
31	77418	1011.5	28.5	26.0	24.6	89.2	4.0	2.5	0.025	0.002	46.907	1043.511	0.045	8.000	0.411
31	77419	1011.3	29.2	26.2	24.4	86.2	4.0	3.0	0.026	0.002	56.240	1092.377	0.051	8.000	0.411
31	77420	1011.5	29.0	27.0	24.2	79.3	2.0	2.0	0.026	0.002	18.701	539.303	0.035	2.000	0.103
31	77421	1011.7	29.0	27.0	24.0	77.9	2.0	2.0	0.026	0.002	18.705	540.001	0.035	2.000	0.103
31	77422	1012.7	28.4	25.7	23.8	85.3	2.0	2.7	0.025	0.002	25.387	521.460	0.049	2.000	0.103
31	77423	1013.2	28.3	25.4	23.8	87.5	3.0	2.9	0.025	0.002	40.963	777.538	0.053	4.500	0.231
31	77424	1014.0	27.2	26.4	24.0	81.9	0.0	0.8	0.023	0.002	0.000	0.000	0.000	0.000	0.000

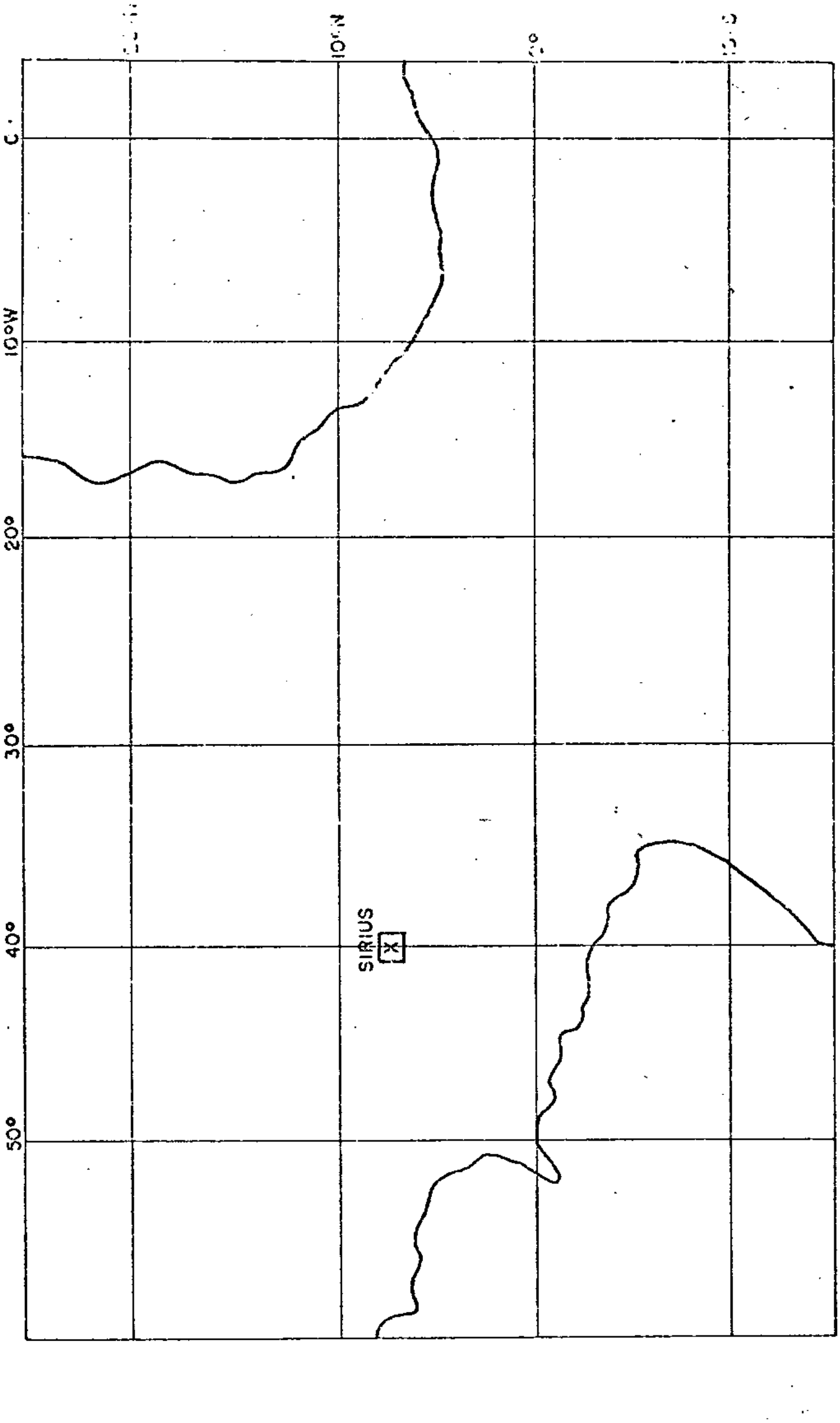


FIG.1. LOCATION OF SHIP STATION SIRIUS DURING GATE II DURING JULY 28–AUGUST 16, 1974

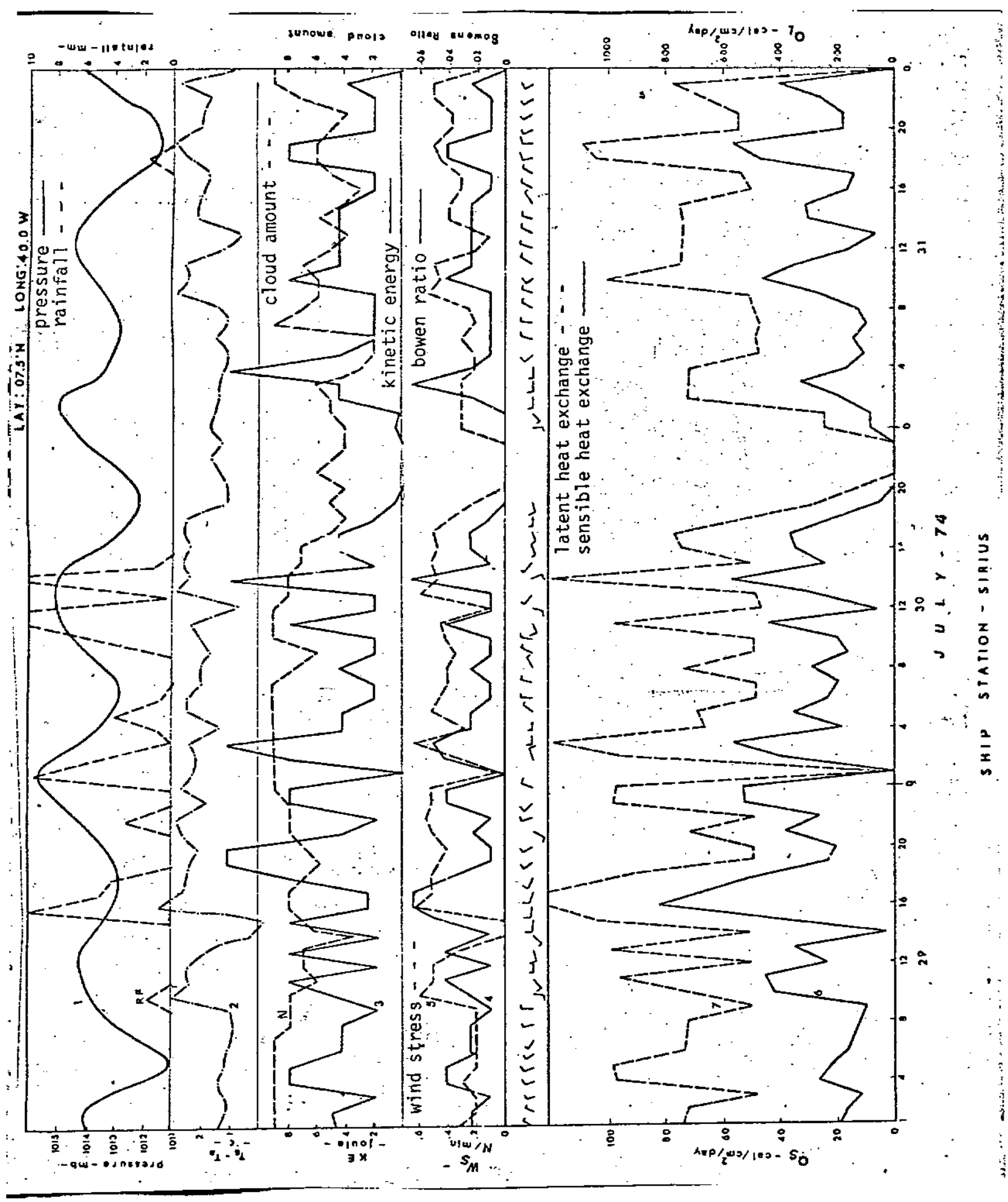


Fig. 2 - Variations of air-sea exchanges

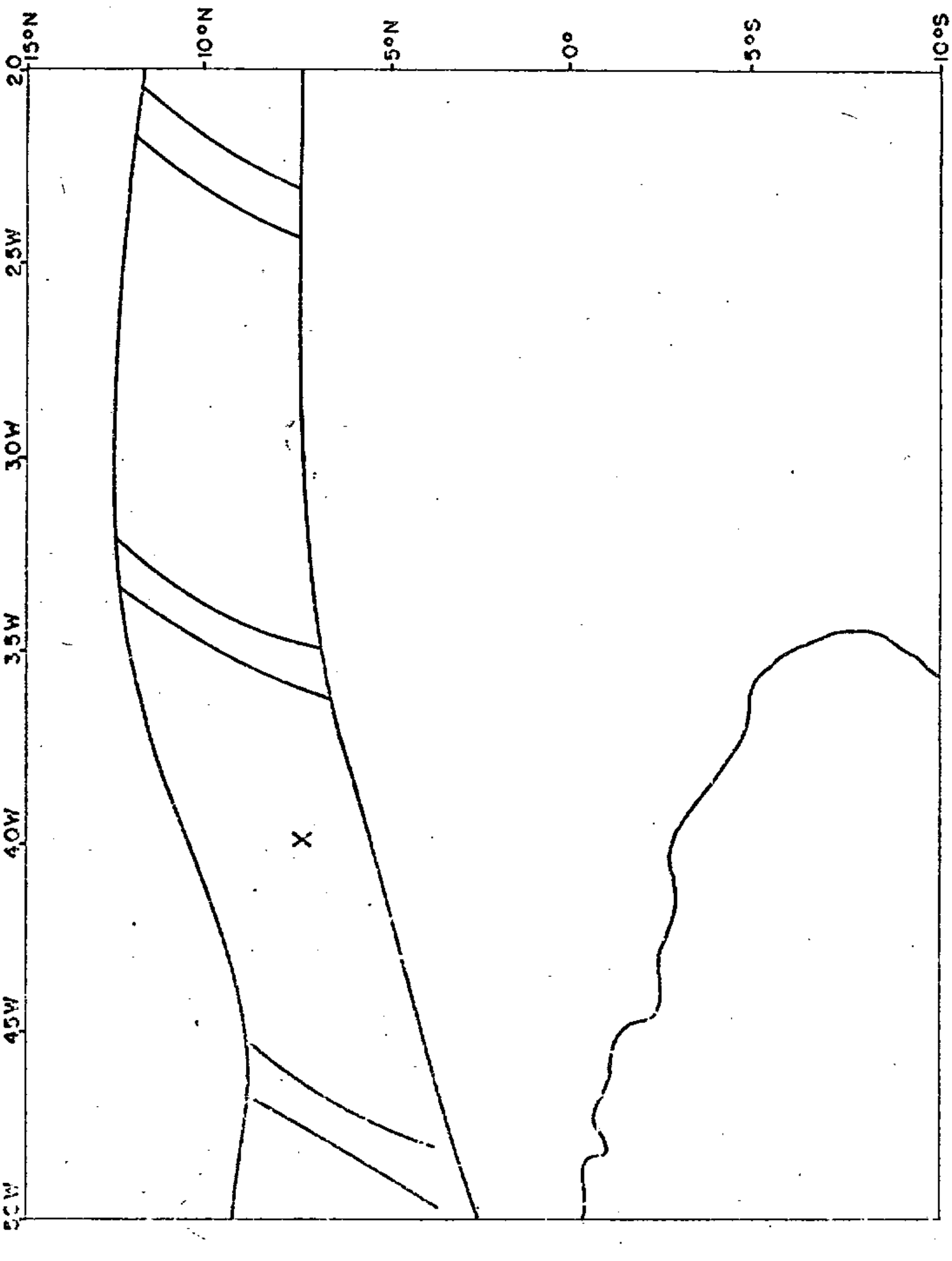
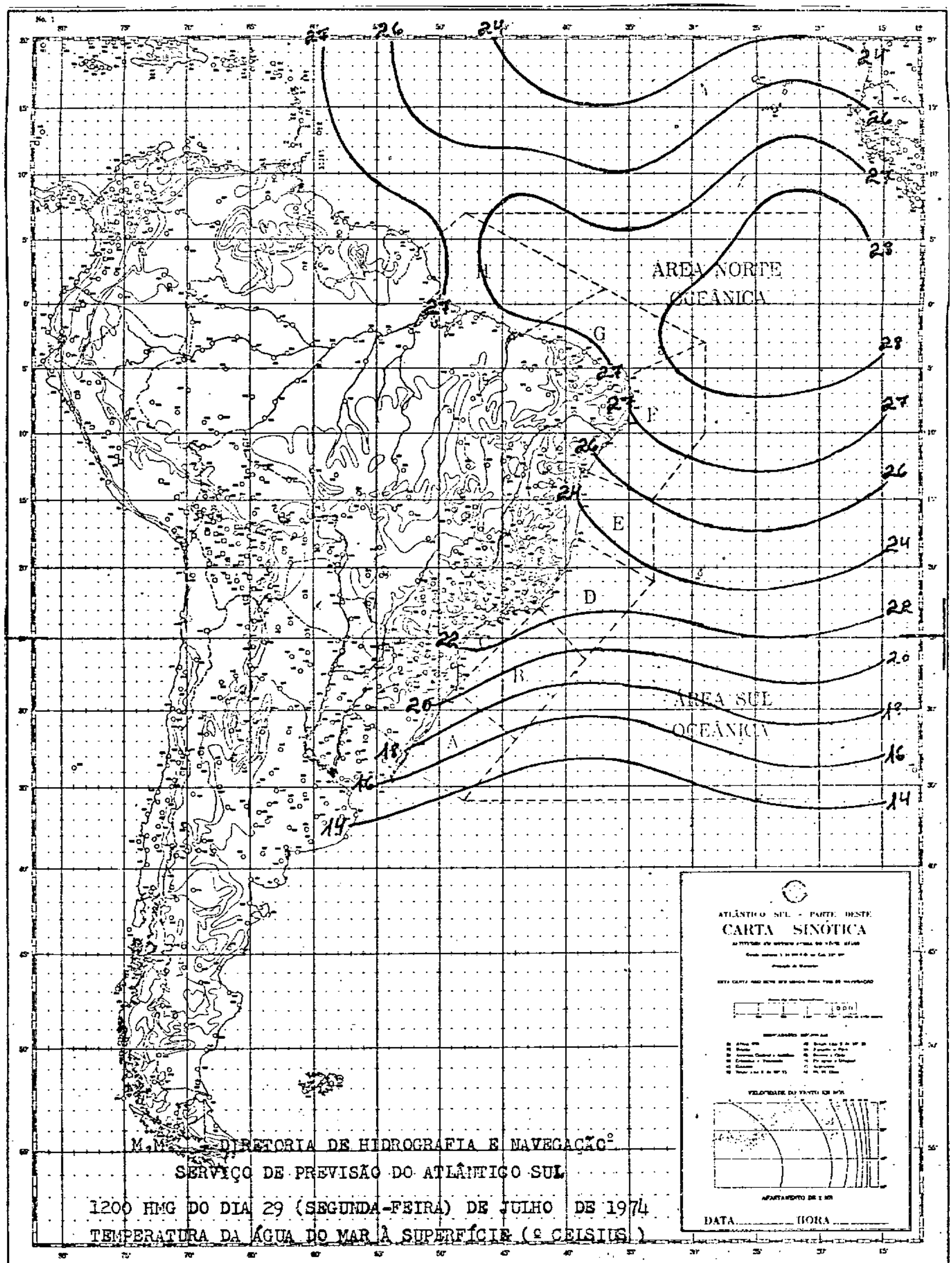


FIG.3. LOCATION OF ITCZ OVER THE STATION (X) AT 07.30N, 40-00W ON 29 JULY 1974 AT 0900Z (courtesy TASA)



DHN 5927

Fig. 4 - Carta Sinótica - DHN, 1974

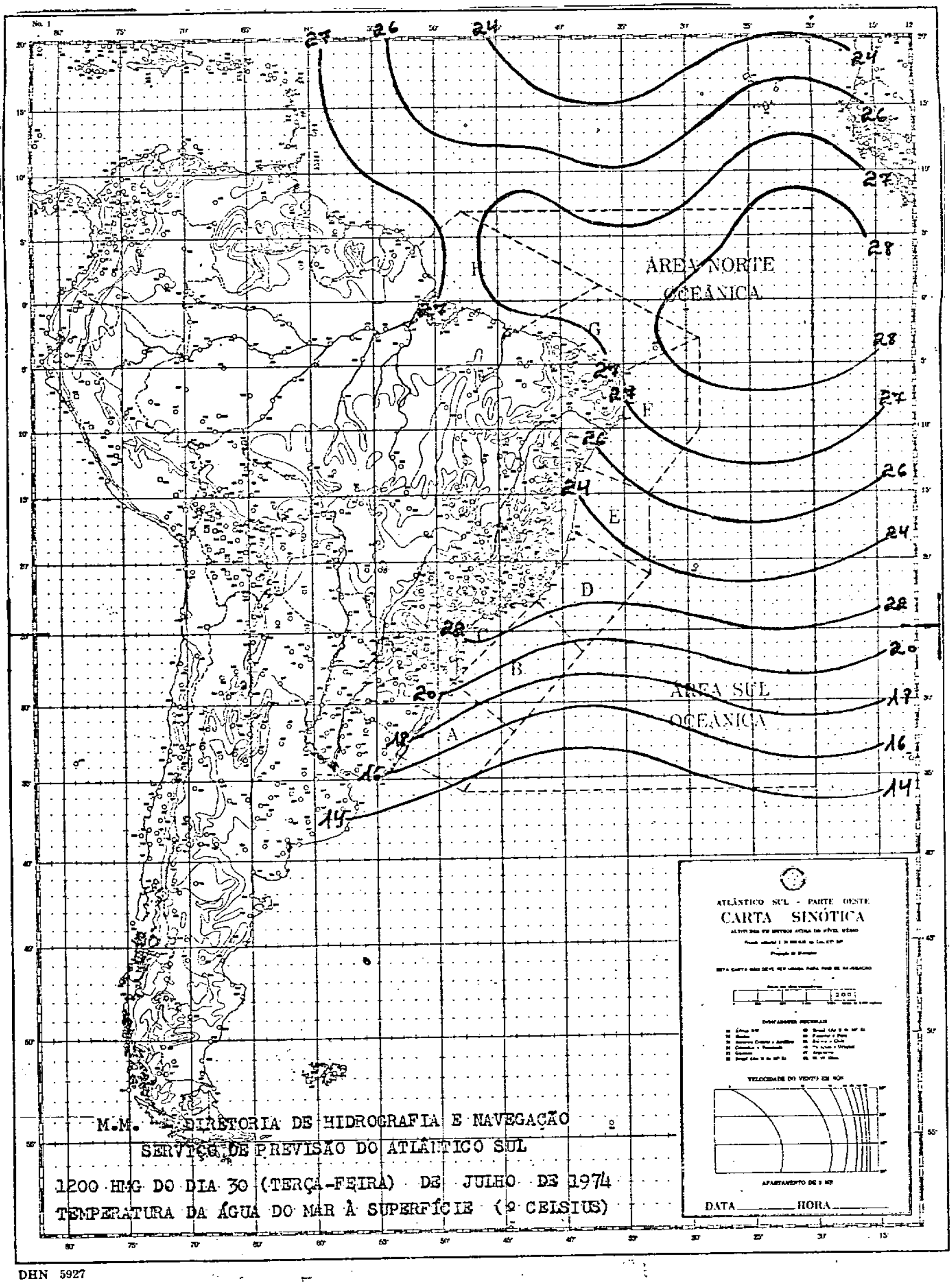


Fig. 5 - Carta Sinõtica - DHN, 1974

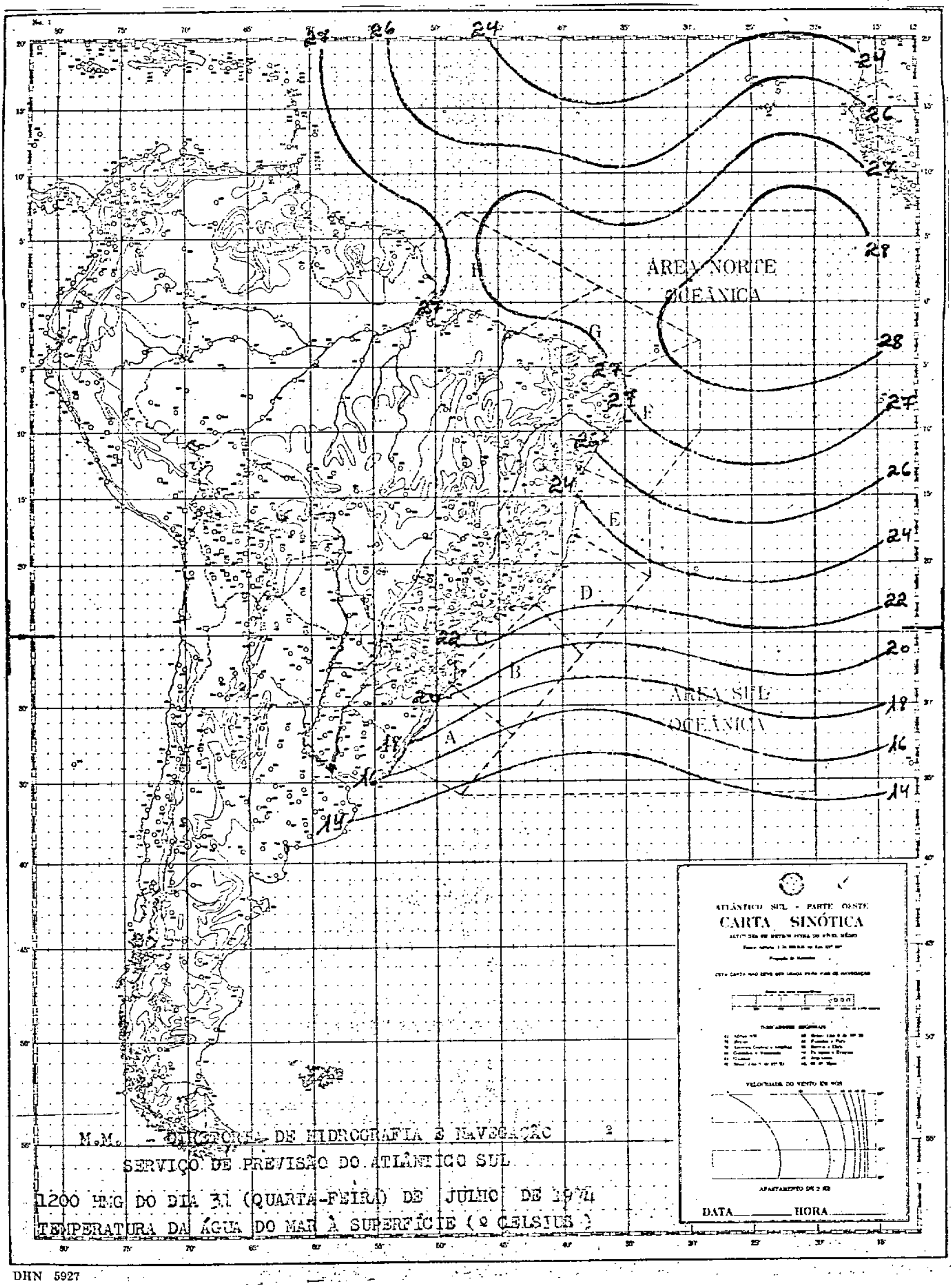


Fig. 6 - Carta Sinótica - DHN, 1974

ACKNOWLEDGEMENT

The authors wish to thank Dr. Luiz Gylvan Meira Filho and Dr. Antonio Divino Moura for their interest in the work and for Dr. Luiz Carlos B. Molion for going through the manuscript. Thanks are also due to the personnel of N/oc "SIRIUS" for their contribution to data collection during GATE, 1974.

REFERENCES

BHUMRALKAR, C.M. *Relation between air-sea exchanges over the arabian sea and the fluctuations of the western Indian summer monsoon.* Rand Corp., Santa Monica, Cal., 1974. 63p. RAND p-5210.

BRASIL. MINISTÉRIO DA MARINHA. DIRETORIA DE HIDROGRAFIA E NAVEGAÇÃO. Serviço de Previsão do Atlântico Sul. *Carta Sonótica.* Rio de Janeiro, 1974.

BROCKS, K.; AUGUSTIN, E.; KRUGERMEYER, L. Turbulent vertical fluxes in the planetary boundary layer and their relation to sinoptic scale process during ATEX 1969. In: *Symposium on Tropical Meteorology Proceedings*, University of Hawaii, Honolulu, Hawaii, June 2-11, 1970. American Meteorological Society, Boston, Mass., 1970. p. cIII-1-cIII-8.

MALKUS, J.S. Large scale interactions. In: HILL, M.N., ed. *The sea.* New York, John Wiley, 1962. v. 1, p. 88-294.

MYRTKI, K. *Seasonal variations of heat exchange and surface temperature in the North Pacific Ocean.* Honolulu, Univ. of Hawaii, Institute of Geophysics, 1966.

PYKE, C.B. On the role of air-sea interaction in the development of cyclones. Bulletin of American Meteorológical Society, 46(1): 4, 1965.