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Prediction of Cyclone Pairs by Global Spectral Model of JMA
- A Case Study with the Cyclone Pair Formed in January 1992 -

Shoji Kusunoki
Numerical Prediction Division, Japan Meteorological Agency

Abstract

A pair of tropical cyclones (or a cyclone pair) formed in January 1992 was successfully predicted by the global spectral model of JMA (Japan Meteorological Agency). This study examines the capability of the model in tropical cyclone forecasting with their occurrence, and discusses the relationship between cyclone pairs and El Niño/Southern Oscillation (ENSO).

1. Introduction

Increase in resolution, along with improvements in initial fields and cumulus parameterization, is of critical importance for numerical models to attain the higher accuracy of tropical cyclone forecast (Krishunamurti and Oosterhof, 1989; Krishunamurti et al., 1989). Although the horizontal resolution of JMA's current global prediction model (GSM; Global Spectral Model), 100 km, is not fine enough for the forecast of typhoons, substantial improvements have been achieved as compared with the former global model of which the resolution was 180 km. Bengtsson (1993) reported that a 100 km-resolution global model at Max-Planck-Institut für Meteorologie had the capability of climatological simulation of tropical cyclone occurrence. Iwasaki (1991) suggested the possibility of further improvement in typhoon track forecast utilizing an experimental global model which has a resolution of about 50 km.

Operationally, JMA has employed Numerical Typhoon Model (TYM), a limited-area model with a resolution of about 50 km, as a principal model for tropical cyclone forecast. However, limited-area models are spatially restricted; TYM is not adequate to deal with interaction between two cyclones or more. Further, the integration of those models is limited in time due to the inevitable effect of the lateral boundary of which the conditions are from global models. Global models are therefore more practical for operational tropical cyclone forecast if their resolutions are sufficiently increased.

The purpose of this study is to examine the potential ability of the current GSM in tropical cyclone forecasting.

2. Cyclone Pairs Represented by the Global Analysis of JMA

A pair of tropical cyclones that symmetrically form over the Pacific ocean in the Northern and Southern Hemisphere with respect to the equator is called a cyclone pair (or a twin cyclone). Rare phenomena as they are, the cyclone pairs were already recognized in the last century (Reid, 1849) and are now observed much more explicitly by the meteorological satellites. Palmer (1952) described cyclone pairs are likely to occur in April, May, November and December. Keen (1982) indicated they are seldom observed during the northern summer season.

During the El Niño event which developed in the spring of 1991 and ceased in the summer of 1992, cyclone pair formation was frequently observed; on 7 May 1991, 27 September 1991, 18 November 1991, and 5 January 1992. Figure 1 shows the sea level wind and pressure analyses given by the operational global analysis of JMA at 24-hour intervals from 12 UTC on 31 December 1991 to 12 UTC on 11 January 1992. As presented in these figures, the analyses illustrate a cyclone pair occurrence and their movements towards the west. It should be noted that westerly winds began to strengthen on 2 January and two cyclones were generated north and south of the equator on 5 January with the outbreak of westerly bursts between these two systems. The northern system migrated towards the west subsequently followed by the southern one. Intensifying steadily, the northern system became Tropical Storm AXEL (9201) at 00 UTC 6 January and reached the peak intensity on the 8th, while the southern system became Tropical Cyclone BETSY and peaked on 10 January. The IR imagery of the cyclone pair taken by the GMS-4 at 12 UTC 8 January is shown in Figure 2. The cyclone in the southern hemisphere showed considerable intensification more than that in the northern hemisphere as indicated by the eye in the imagery. A cloud band formed over the equator corresponding to the strong westerly winds between the cyclones. In addition, the area of cloud clusters extended to the east of the cyclone pair, indicating active convection in the region.

As presented in the first article of this volume, bogus observations are assigned to make up for the data sparsity over the tropical ocean in the process of objective analyses at JMA (Ueno (1989)). In the present study no bogus observation was used, and nonetheless, the objective analysis provided reasonable tropical cyclone structures (Figure 1). It denotes that the data assimilation system of JMA has the capability of representing cyclone pairs, which is endorsed by Krishnamurti and Oosterhof (1989) who described that the resolution of about 100 km or finer is required for data assimilation systems to reasonably represent tropical cyclones.

3. Sea Surface Temperature

Figure 4 illustrates the distribution of sea surface temperatures (SSTs) and SST anomalies on 8 January 1992. Warm SSTs of 29°C or higher prevail around the date line in latitudes from the equator to 10°S, and positive SST anomalies are predominant east of the date line with maximums located over the equator from 150°W to 160°W. In Figure 4, corresponding to the warm SSTs east of the date line, deep convective clouds are found in that area, which exhibits enhanced convective activities there. Keen (1982) pointed out that low SOI (Southern Oscillation Index) with warm SSTs of 29°C or higher extending eastward across the date line encourages cyclone pair formation near the date line. Figure 4-(a) certainly illustrates the same SST pattern as indicated by Keen.

4. Cyclone Pairs and El Niño

Close relationships between cyclone pairs and El Niño have been discussed for the last decade. Ramage (1986) noted that cyclone pairs are crucial both in initiating and in prolonging El Niño. Miller *et al.* (1988) and Nitta (1989) suggested that the cyclone pair which occurred in May 1986 triggered the 1986-87 El Niño. In this case, the westerly bursts associated with this cyclone pair induced Kelvin waves in the equatorial Pacific and generated an atmosphere–ocean coupling disturbance. Eventually, warm water piled in the equatorial Western Pacific was pushed towards the east and formed the typical SST pattern of El Niño.

For the 1991–92 El Niño, premonitory symptoms of the phenomenon had already been observed in early 1991, the events of cyclone pair in particular. In September 1991, JMA confirmed the occurrence of an El Niño event in accordance with the low SOI and the positive SST anomalies dominating over the Eastern and Central Pacific; the anomalous features of the SST resemble the conditions indicated by Keen (1982) as above. However, there was no evidence of eastward movement of the warm water in conjunction with the series of cyclone pair formation during the El Niño.

5 Prediction by the GSM

Figure 3 shows results of a series of operational prediction performed by the GSM for the same valid time, 12 UTC 8 January 1992, with initials at 12 UTC 7 January 1992 (1–day forecast) back to 12 UTC 31 December 1991 (8–day forecast). Compared with the analyses illustrated in Figure 1, these results indicate that the model successfully predicted the cyclones behavior in 1– to 4–day forecasts, whereas it produced increasing errors in positions and central pressures of the cyclones in 5– to 6–day forecasts, and ultimately failed in prediction in 7– to 8–day forecasts.

It is apparent this contrast in forecast performances is attributed to the difference in initials that definitely change at 12 UTC 3 January when the two cyclones are first identified (Figure 1). Namely, the cyclone pair was poorly represented in forecasts with initials at 12 UTC 3 January or earlier where cyclogenesis is not discernible, but it was well reproduced with initials at 12 UTC 4 January and later where an incipient disturbance is already embedded. The forecast failure as a result of having no embryo of disturbance in initial fields in this study holds true in the forecast of blocking in mid–latitudes.

6. Discussions and Remarks

The wind and pressure patterns derived by Gill (1980) and Zebiak (1982) in their studies to examine the atmospheric response to an equatorial heat source are quite similar to those patterns shown in Figure 1 (Lander 1990). Yamagata (1987) demonstrated that the burst of westerly winds, with the moisture convergence in front, generates wind and pressure patterns similar to those of cyclone pairs. Tropical atmosphere is naturally abundant in moisture supplied from the warm oceans below, whereas cyclone pairs are occasional events. It suggests that cyclone pairs require some inducements to be formed.

Madden and Julian (1971, 1972) found an atmospheric oscillation in equatorial regions that propagates eastward with 30–60 day period and zonal wave number 1. This 30–60 day oscillation in the tropics called the "Madden–Julian (MJ) oscillation" is closely linked with tropical cyclone activities (Nakazawa 1986; Storch and Smallegange 1992). Figure 5 presents the time–longitude cross section of 5–day mean velocity potential at 200 hPa for the eleven months from April 1991 to February 1992. We note that the MJ oscillation is delineated by eastward propagation of the velocity potential distributions at intervals of one to two months. Hatched are the areas with enhanced upper–level divergence associated with strong low–level convergence and active convection. Indicated by "X" are the serial formations of a cyclone pair on 5 May 1991, 27 September 1991, 18 November 1991, and 8 January 1992. These cyclone pairs were fixed subjectively based on the global analysis and the satellite imagery. The figure depicts the eastward movements of active convection areas originating from 60°E and subsequent formations of cyclone pairs to the west of the date line.

Figure 6 shows the time-longitude cross section of the zonal wind anomaly at 850 hPa level as in Figure 5, where anomaly is defined as the deviation from longitudinal mean. Hatched areas indicate westerly bursts in the lower troposphere. Although the MJ oscillation is not clear in this figure, it is evident that cyclone pairs accompany westerly bursts. Accordingly, Figures 4 and 5 suggest that the MJ oscillation and associated westerly bursts gave some incentive to the formation of the cyclone pairs.

Considering that the socio-economic impact of El Niño is being significant, increasing emphasis should be laid on the improvement of numerical models' performance in the tropics. Currently, GSM is one of the few numerical models capable of predicting the MJ oscillation (Tsuyuki 1990). The MJ oscillation is no doubt closely related with the occurrence of tropical cyclones, while the cyclone pairs, the special forms of tropical cyclones, seem to play crucial roles in onset and development of El Niño.

Thus, the co-existence of phenomena with different scales in time and space together with their mutual interactions leads to the difficulty in numerical weather prediction. Although the El Niño and La Niña occurring in 2- to 3-year intervals are successfully simulated by several atmosphere-ocean coupling models, it is imperative to simulate phenomena with a time-scale of about one week including cyclone pairs for the prediction of the onset of El Niño.

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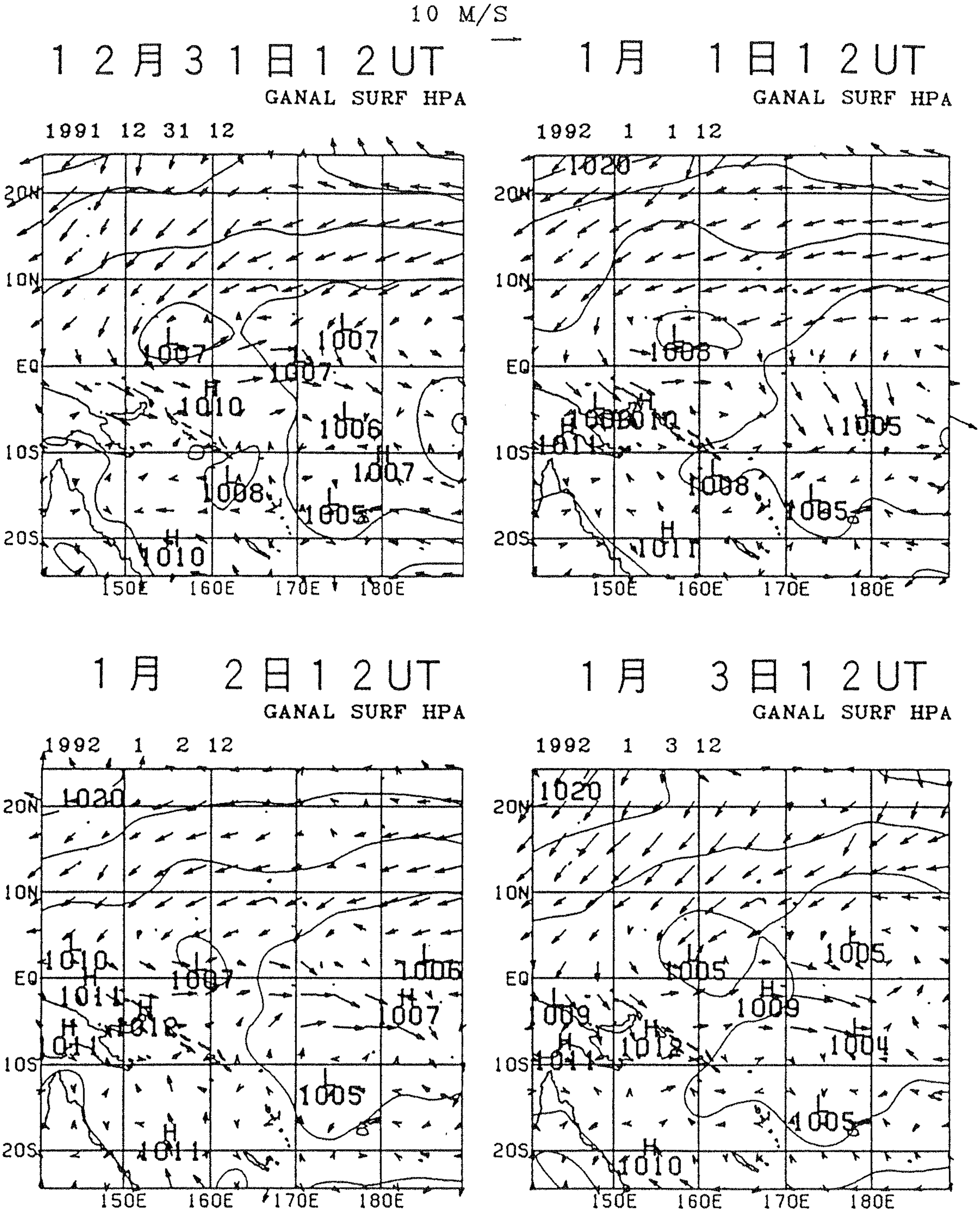

Fig. 1. The sea level wind and pressure analysis from 12 UTC 31 December 1991 to 12 UTC 11 January 1992.

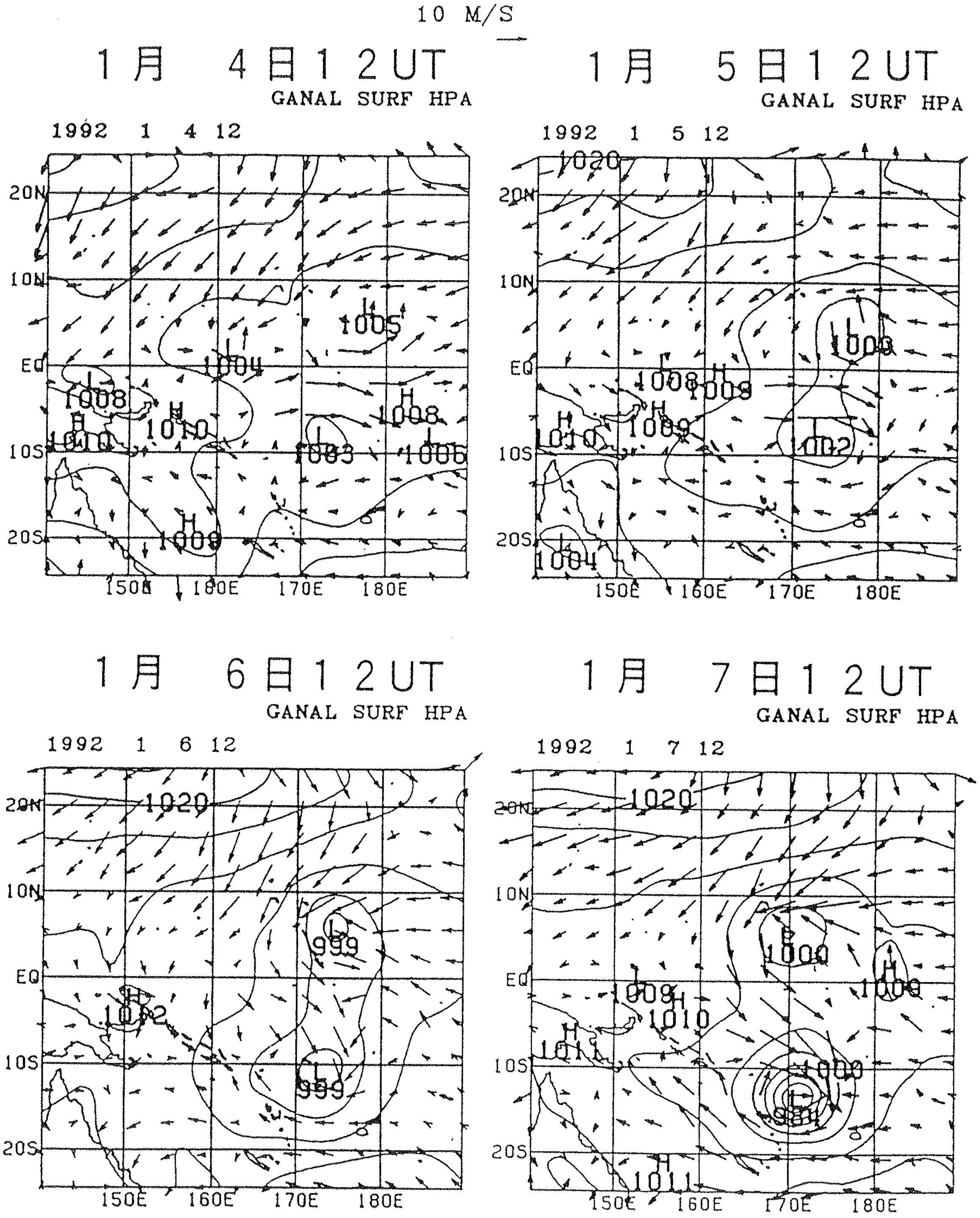

Fig. 1. (Continued)

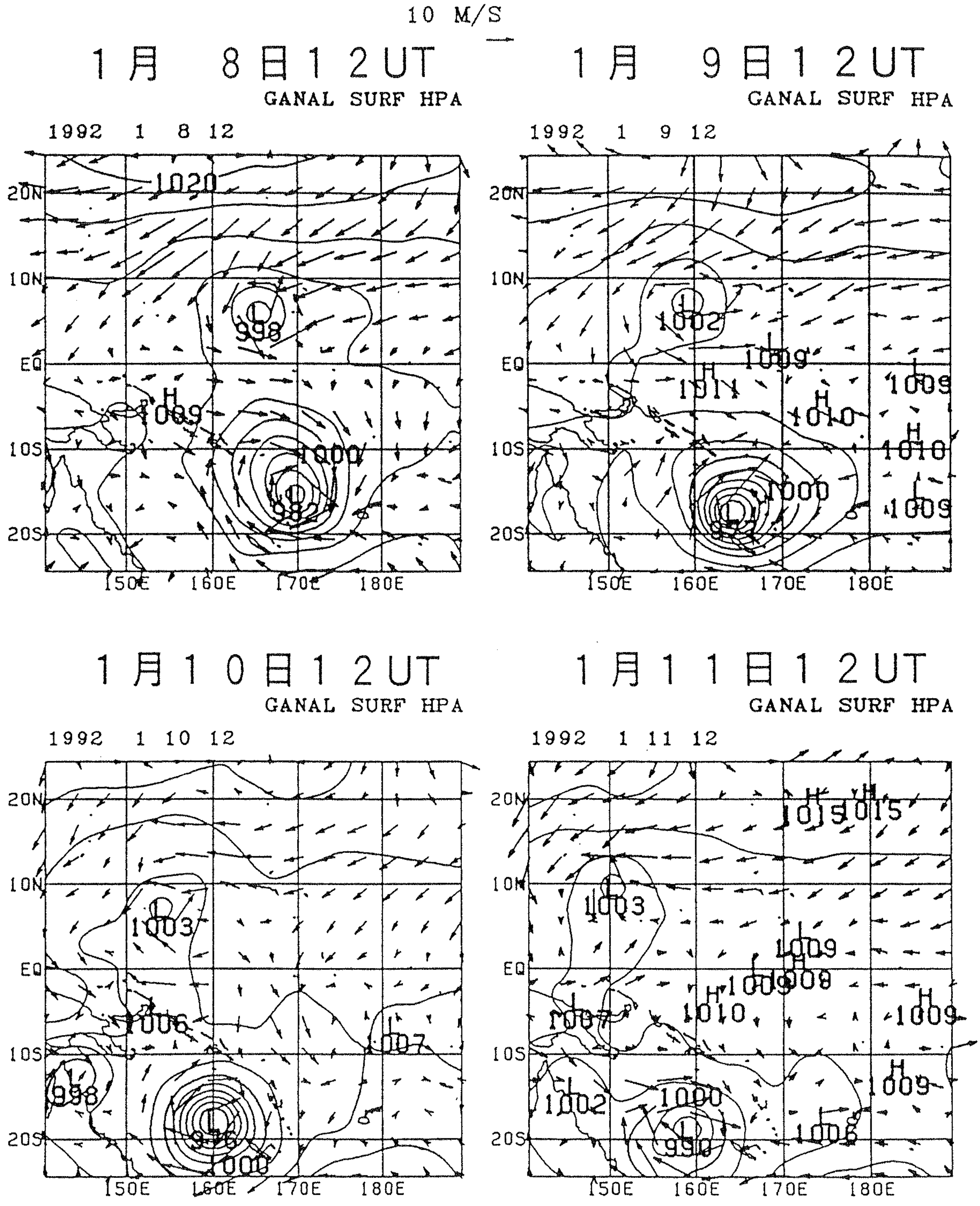
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Fig. 1. (Continued)

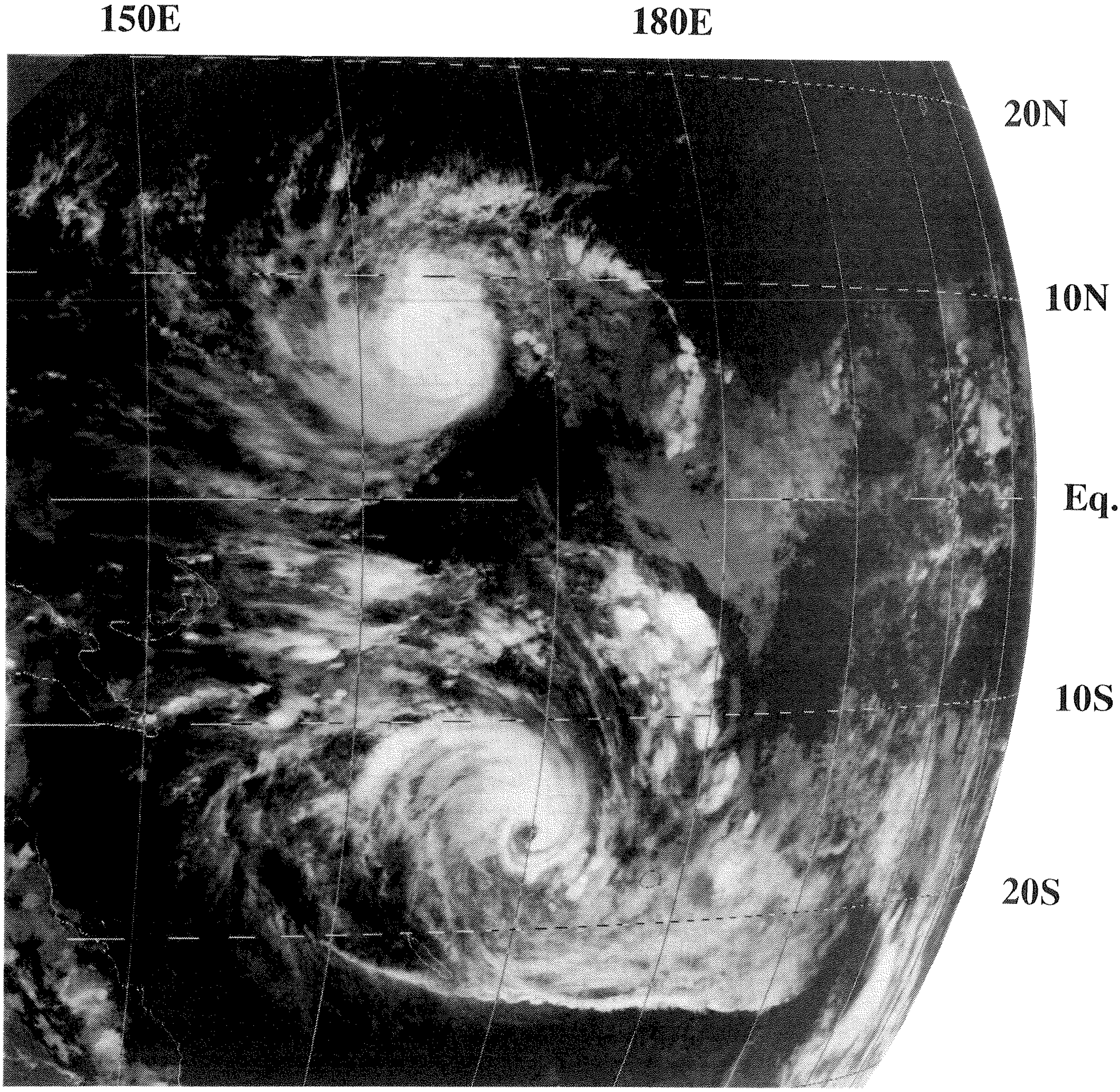
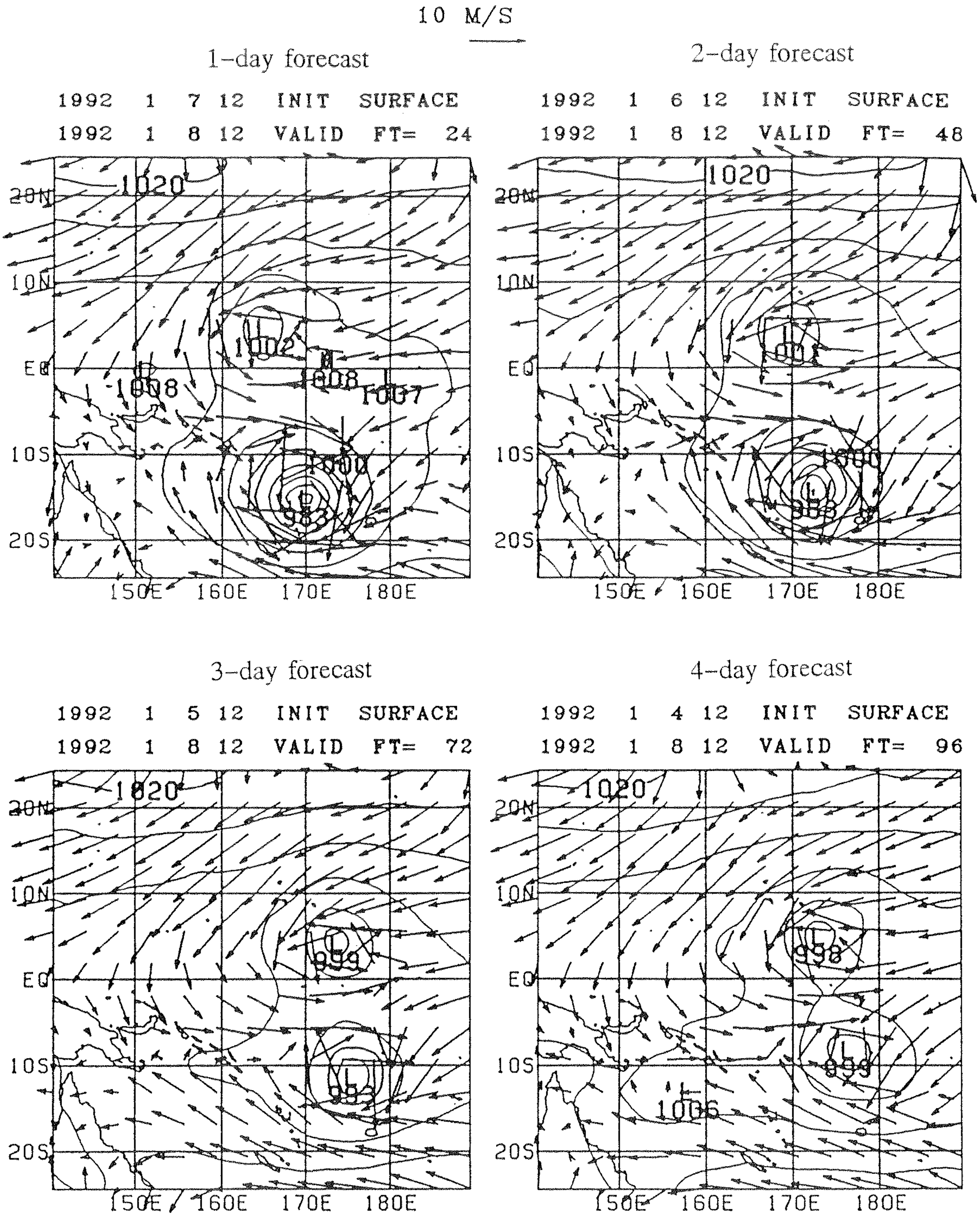


Fig. 2. Satellite image taken with GMS-4 at 12 UTC 8 January 1992.



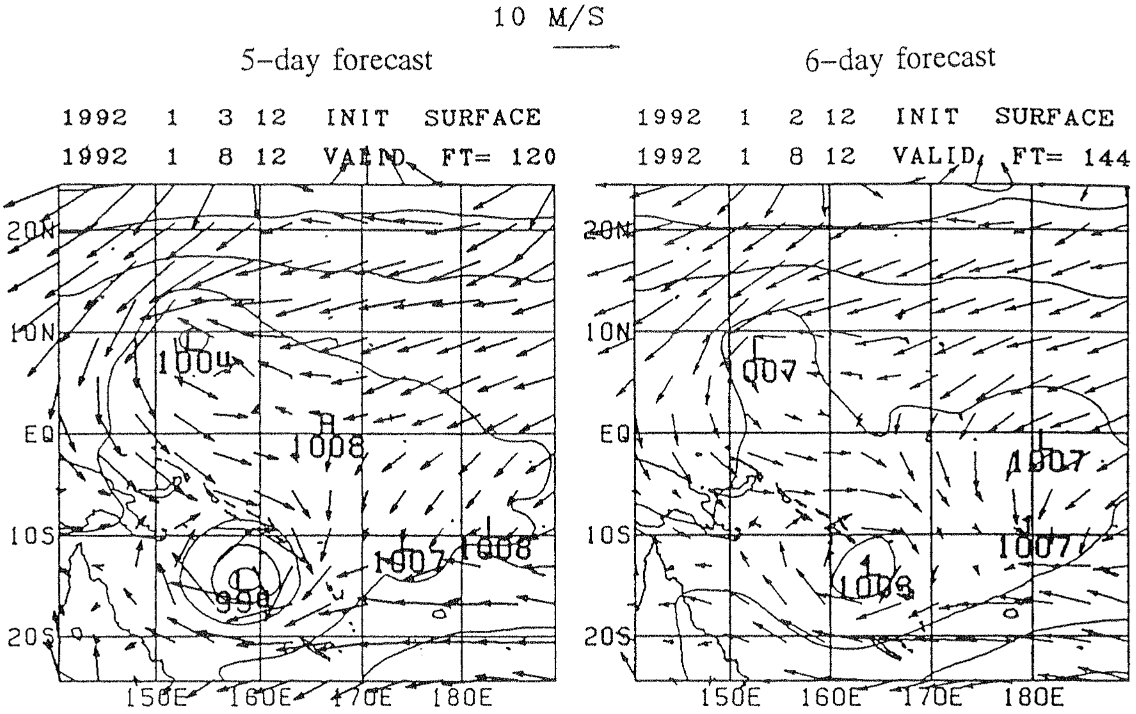
1-day forecast

2-day forecast

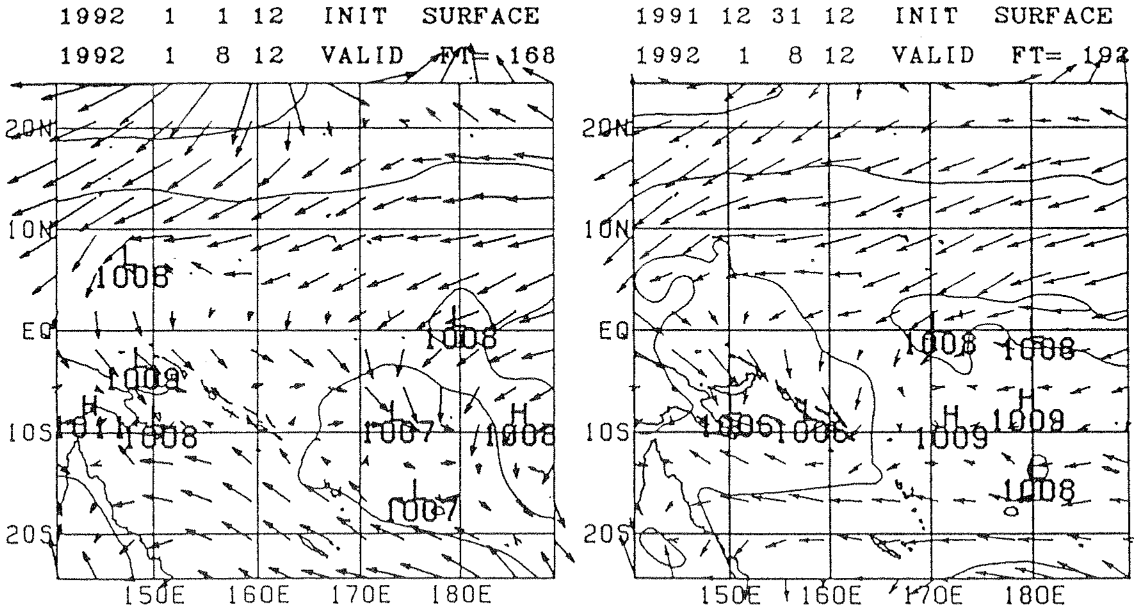
3-day forecast

4-day forecast

Fig. 3. Operational predictions by GSM for the valid time; 12 UTC 8 January 1992.


5-day forecast

6-day forecast


7-day forecast

8-day forecast

Fig. 3. (Continued)

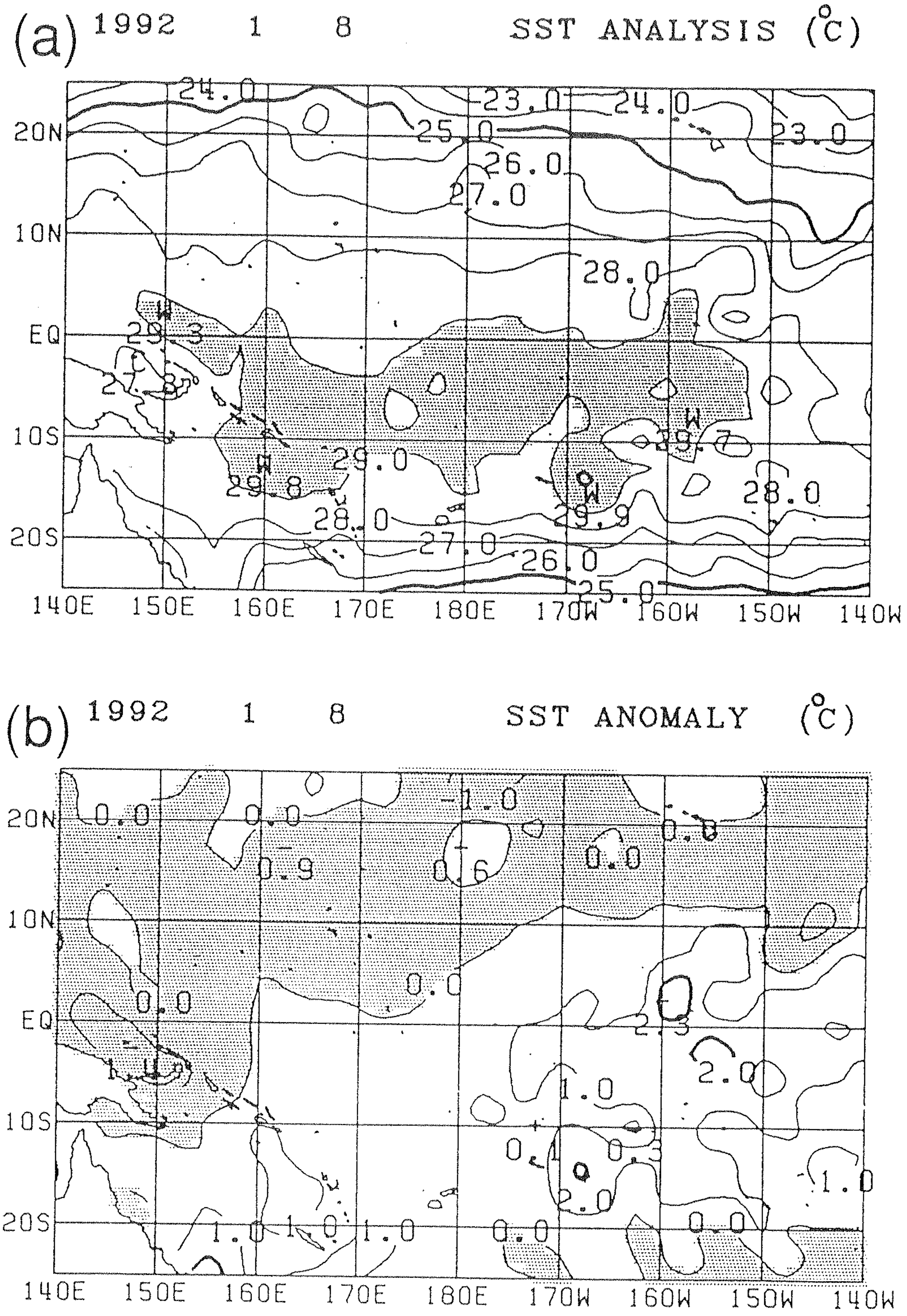


Fig. 4. Sea surface temperature (a) and its anomalies (b) for 12 UTC 8 January 1992.

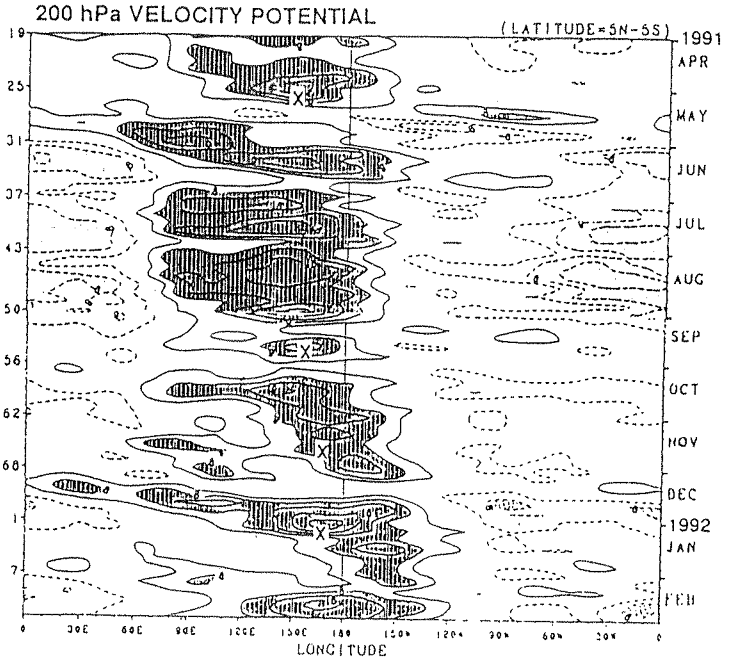


Fig. 5. The time–longitude cross section of 5–day mean velocity potential at 200 hPa for eleven months from April 1991 to February 1992.

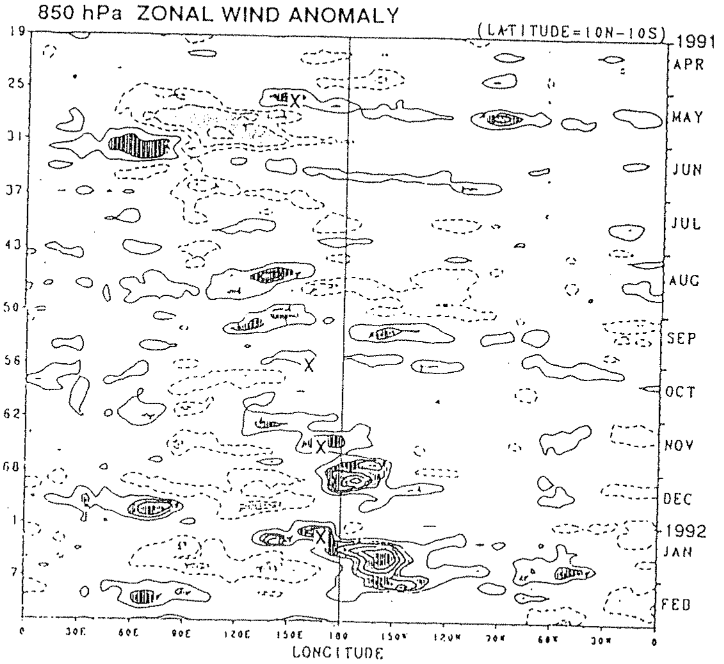


Fig. 6. The time–longitude cross section of 5–day mean velocity potential at 850 hPa for eleven months from April 1991 to February 1992.