

Estimation of Sea Surface Wave Height from Bhaskara II SAMIR Data*

M VENKATESWARA RAO, N K VISWAMBHARAN & L V GANGADHARA RAO

National Institute of Oceanography, Dona Paula, Goa 403004

Received 12 April 1984

Brightness temperature data from satellite microwave radiometer (SAMIR) onboard Bhaskara II have been analysed for 15 orbits over the North Indian Ocean during Jan.-June 1982 for which seartruth data on surface waves (shipborne wave recorder data from *R V Gaveshani* and visual observations from other ships as reported in IDWR) are available. Using this, an attempt has been made to obtain an empirical relation between brightness temperature and significant wave height. Linear correlation between significant wave height and brightness temperature at 19 and 22 GHz, and multiple correlation at 19 and 22 GHz are studied. Significant wave height derived from the linear regression at 19 GHz as well as from multiple regression at 19 and 22 GHz, yields better estimate.

Bhaskara II (India's second satellite for earth observations) has onboard a passive microwave radiometer system (SAMIR) for measuring upwelling radiation from the earth's/ocean's surface (brightness temperature) at 19.35, 22.235 and 31.4 GHz. SAMIR has¹ a spatial resolution of 125 km and temperature resolution of 1° K.

Brightness temperature measured by SAMIR is useful in obtaining information on a number of oceanographic and meteorological parameters like sea surface wind, sea state, atmospheric water vapour and liquid water content²⁻⁵. The usefulness of SAMIR data for deriving information on sea surface winds has been reported⁶. The relation between wind speed and brightness temperature at 19 GHz has already been studied⁷⁻¹². In fact the brightness temperature at 19 GHz is mainly sensitive to surface emissivity variations which in turn depend on surface slope distribution and the latter can be related to wave heights. In view of this, in the present study, an attempt has been made to obtain an empirical relation between brightness temperature and significant wave height using SAMIR data of the Bhaskara II orbits for which seartruth data on sea surface waves are available.

SAMIR data were obtained from SAMIR Data Utilisation Cell, Space Applications Centre, Ahmedabad. Data on brightness temperature at 19.35 and 22.235 GHz ($\pm 2.8^\circ$ look angle) for 15 orbits of Bhaskara II over the North Indian Ocean during Jan.-June 1982 for which seartruth data on sea surface waves were available (Fig. 1), were analysed. It was made sure that the data used were collected during cloud free period and free from land contamination. Data on

brightness temperature at 31 GHz frequency were noisy and hence were not used in this study. The seartruth data on sea surface waves were derived from the shipborne wave recorder onboard *R V Gaveshani* and visual observations from other ships as reported in Indian Daily Weather Reports (IDWR). The analogue records of sea surface waves¹³ obtained from shipborne wave recorder at selected stations during the 107 cruise of *R V Gaveshani* in June 1982 were digitised and significant wave height was computed using zero up-crossing method. In respect of wave data from other ships (published in IDWR)¹⁴, the wave height reported is taken as significant wave height. It is presumed that the sea state/wave height remains fairly constant up to about 3h and does not change significantly within 125 km (spatial resolution of SAMIR being 125 km) and data for regression analysis was chosen accordingly.

Correlations between significant wave height and brightness temperature at 19 and 22 GHz were studied by linear regression analysis. Multiple regression analysis was also made using data at 19 and 22 GHz¹⁵.

From the regression analysis, it is seen that the significant wave height (H_s) and brightness temperature (T_B) can be correlated under moderate sea conditions as in the present case. The values of correlation coefficient ($r=0.9415$) as well as RMS error (± 0.205 m) obtained by Eq. 1

$$H_s = -8.7138 + 0.0631 T_{B19}$$

explain clearly that the significant wave height and brightness temperature at 19.35 GHz are well correlated. Correlation between significant wave height and brightness temperature at 22 GHz, as expressed by Eq. 2:

$$H_s = -3.3229 + 0.0228 T_{B22}$$

*Initial results presented at the NIO-NAS seminar on *Oceans and climate* 28-29 Oct. 1983, NIO, Goa

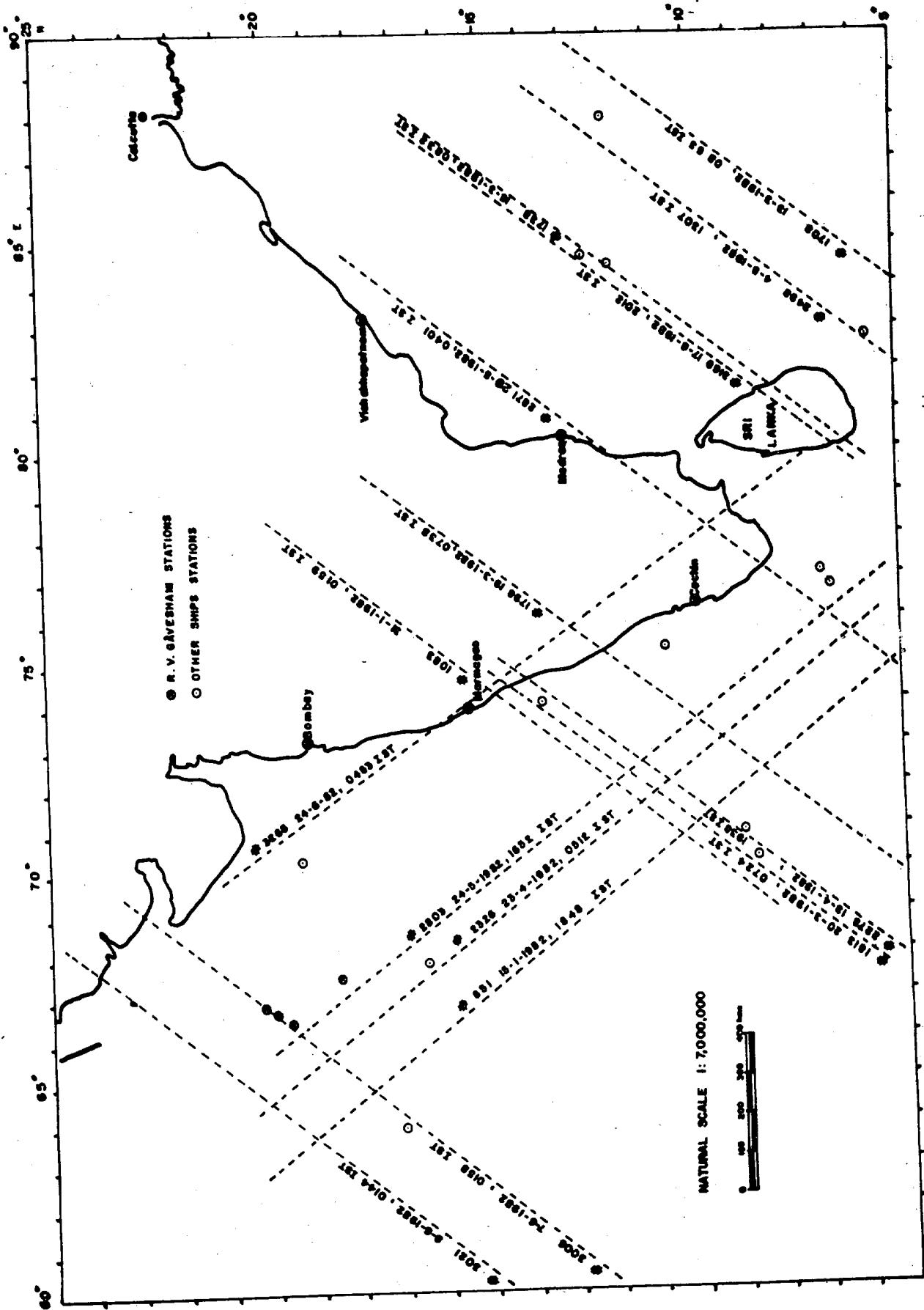


Fig. 1—Chart showing Bhaskara II orbits and sea truth station positions

is poor ($r=0.5910$ and RMS error = ± 0.493 m). It can be seen from the multiple regression (Eq. 3)

$$H_s = -8.6758 + 0.0696 T_{B19} - 0.0053 T_{B22}$$

that the significant wave height increases with brightness temperature at 19.35 GHz and slightly decreases with brightness temperature at 22.235 GHz resulting in $r=0.9467$ and RMS error = ± 0.197 m.

The accuracies envisaged in the estimation of wave height from the present study in comparison with those from other methods are as follows:

Linear regression at 19 GHz	: ± 0.205 m
Multiple regression at 19 and 22 GHz	: ± 0.197 m
Shipborne wave recorder data (zero up-crossing analysis)	: ± 0.135 m
Wave data from IDWR	: ± 0.250 m

Nordberg *et al.*⁸ have measured brightness temperature at 19.35 GHz during 6 low altitude passes over the Atlantic and North Sea at significant wave height ranging from <1 m to about 7.8 m. They have reported that brightness temperature at 19 GHz increases with significant wave height as well as wind speed and that it is almost same at winds <7 m.sec⁻¹. It may be noted that these conclusions are based on limited data. The present study which is based on comparatively more data suggests that even at lower wind speeds there is significant variations in brightness temperature (Table 1). The poor correlation found at 22 GHz is due to the presence of water vapour resonance at this frequency making it more sensitive to water vapour than sea surface characteristics¹⁶. Of course the brightness temperature at 19 GHz is also affected to some extent by water vapour. The measurements at 19 GHz from the low aircraft flights by Nordberg *et al.* must have involved relatively smaller water vapour depths than in the case of satellite borne SAMIR. Hence error due to the atmospheric effect might have been less important in their case. But the brightness temperature at 22 GHz used in conjunction with that at 19 GHz (in multiple regression) appears to help to remove the minor effect of the atmospheric water vapour on the brightness temperature at 19 GHz. This may be the reason for arriving at a slightly better results from multiple regression at 19 and 22 GHz over simple linear regression at 19 GHz. In general, from the present study, it may be concluded that fairly better estimates of significant wave height can be obtained from the linear regression at 19 GHz as well as from the multiple regression at 19 and 22 GHz.

The authors thank Drs V V R Varadachari and J S Sastry for their interest and encouragement. Thanks

Table 1—Brightness Temperature at 19 GHz and Sea Surface Wind Speed (seatruth) during 1982

Date	Time (IST, hrs)	Brightness temp. (°K)	Surface wind speed (m.sec ⁻¹)
15 Jan	1843	149	2.68
31 Jan	0201	149	3.00
13 March	0855	149	2.68
15 March	0834	156	3.63
19 March	0734	150	2.66
20 March	0728	146	2.12
19 April	1940	153	3.66
23 April	0508	147	2.06
4 May	1301	156	4.21
24 May	1701	164	3.57
29 May	0402	159	3.06
7 June	0150	171	4.38
8 June	0147	173	4.83
8 June	0147	171	4.75
17 June	2012	167	3.87
24 June	0454	165	4.18

are due to Dr Shubha Sathyendranath and Mr V Ramesh Babu for their useful comments. Thanks are also due to Drs T A Hariharan, Pranav S Desai, P C Pandey, P N Pathak and Dr A Sarkar of Space Applications Centre (ISRO) for their suggestions. Assistance provided by CSIR through fellowships to the first two authors is gratefully acknowledged.

References

- 1 Bhaskara II SAMIR Data Users Guide (SAC, Ahmedabad), July 1982.
- 2 Sarkar A, Sharma A K & Gohil B S, *Mahasagar—Bull Natn Inst Oceanogr*, 14 (1981) 149.
- 3 Pandey P C, Sharma A K & Gohil B S, *Proc Indian Acad*, 89 (1980) 231.
- 4 Pendey P C, Gohil B S & Sharma A K, *Proc Indian Acad*, 89 (1980) 293.
- 5 Pandey P C, Gohil B S & Sharma A K, *Mausam*, 32 (1981) 17.
- 6 Viswambharan N K, Venkateswara Rao M & Gangadhara Rao L V, *Mahasagar—Bull Natn Inst Oceanogr*, (Communicated).
- 7 Stogryn A, *IEEE Trans Ant Prop Ap*, 15 (1967) 278.
- 8 Nordberg W, Conaway T, Ross D B & Wilheit T, *J Atmos Sci*, 28 (1971) 429.
- 9 Williams G F (Jr), *J Geophys Res*, 74 (1969) 4591.
- 10 James H P, *J Geophys Res*, 75 (1970) 5209.
- 11 Thomas W T (Jr) & Fowler M G, *IEEE Trans Ant Prop Ap*, 25 (1977) 111.
- 12 Pandey P C, Gohil B S & Sharma A K, *Mahasagar—Bull Natn Inst Oceanogr*, 13 (1980) 91.
- 13 *Data report of 107th oceanographic cruise of R V Gaveshani*, June 1982, NIO, Goa.
- 14 *Indian daily weather reports* (India Meteorological Department, Pune).
- 15 Croxton F E & Cowden D J, *Applied general statistics*, (Prentice-Hall of India P Ltd, New Delhi) 1966, 541.
- 16 Pandey P C, Gohil B S & Sharma A K, *Mausam*, 31 (1980) 539.