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A study of performance of different types of radiosondes used over Indian sea areas during Monex-79

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सार – हिन्द महासागरीय क्षेत्रों में मानेक्स-79 के दौरान अनेक प्लेटफार्मों से विभिन्न प्रकार के रेडियो सोन्दों का उपयोग कर उपरितन वायु के उष्मागतिक के अभिलेखित आंकड़ों का अध्ययन कर सुसंगता को ज्ञात किया गया है। सोवियत रूस के अनुसंधान पोतों पर से रेडियो सोन्दों द्वारा भारतीय मानेक्स जलयानों पर से वैशाला ओमेगा सोन्द द्वारा और संयुक्त राष्ट्र अनुसंधान वायुयान पर से अमेरिकी ड्रापसोन्दों द्वारा अरब सागर और बंगाल की खाड़ी क्षेत्रों पर अंकित प्रेक्षणों को भारत के तटीय भूस्टेशनों से भारतीय रेडियो सोन्द प्रेक्षणों से मिला कर अध्ययन किया गया है। विभिन्न प्रकार के सोन्दों में उपयोग में लाए गए संवेदकों पर आवश्यक सूचना भी दी गई है। भारतीय रेडियो सोन्द और वैशाला ओमेगा सोन्द के आंकड़ों की आंतरिक तुलना के परिणामों को भी प्रस्तुत किया गया है।

यह अध्ययन भू और समुद्री क्षेत्रों पर उपरितन वायु साउंडिंग के क्षेत्र में भारतीय रेडियो सोन्दे का दूसरी स्थापित रेडियो सोन्दे तकनिकों के साथ कार्यों की तुलना कर मूल्यांकन करने का अवसर प्रदान करता है। अभिलेखित आंकड़ों के संदर्भ में भारतीय रेडियो सोन्दे में उपयोग में लाए गए तापमान और आर्द्रता तुलना संवेदकों का कार्य, दूसरी स्थापित प्रणालियों की अपेक्षा काफी विश्वसनीयता स्थायित्व और सुसंगति को प्रदर्शित करता है। परिणामों की आन्तरिक तुलना में भारतीय सोन्दे से लिए गए पवन के प्रेक्षण वैशाला ओमेगा सोन्दे से लिए गए ओमेगा पवन के प्रेक्षण एक दूसरे से काफी मिलते जुलते दर्शाए गए हैं।

ABSTRACT. An attempt has been made to study and evaluate the compatibility of the upper air thermodynamic data recorded using different types of Radiosondes during Monex-79 from the various platforms over Indian sea areas. The observations recorded over the Arabian Sea and Bay of Bengal areas using Russian Radiosondes from USSR research vessels, Vaisala Omegasonde from Indian Monex ships, and American dropsonde from the US research aircraft together with the Indian Radiosonde observations from coastal Indian land stations have been studied. The essential information on the sensors used in the different types of sondes is also given. The results of intercomparison between the Indian Radiosonde and Vaisala Omegasonde data has also been presented.

This study provides an opportunity to evaluate the comparative performance of the Indian Radiosonde with that of other established radiosonde techniques in the field of upper air sounding over land and sea areas. The performance of the temperature and humidity sensors used in the Indian radiosonde have showed a very high degree of reliability, stability and compatibility in respect of data recorded by the other established systems. The wind observations taken by the Indian sonde have also shown very close agreement with the Omega winds of Vaisala Omegasonde as brought out by the results of inter-comparison.

1. Introduction

During the Global Weather Experiment and Monex-79, four Indian ships were deployed in the Arabian Sea and the Bay of Bengal. Two of these ships, INS *Darshak* and INS *Deepak*, equipped with complete FGGE Navaid Sounding Systems capable of producing real time upper air data were deployed initially over the Arabian Sea during SOP-II (1 May to 30 June 1979). At the end of the Arabian Sea phase, these two ships along with RV *Gaveshani* (with an indigenous omegasonde equipment) moved into the Bay of Bengal. The fourth ship INS *Betwa* fitted with only a data acquisition module of Navaid Sounding System was positioned in the Bay of Bengal during Monex-79. The data generated were processed in delayed mode. The US research aircraft and USSR ships deployed over the Indian sea areas had real time data processing facilities on board. The Indian land stations also produced real time data using semi automated techniques. An attempt has been made to evaluate the compatibility of upper air thermodynamic data recorded by the FGGE Navaid Sounding Systems on board Indian Monex ships,

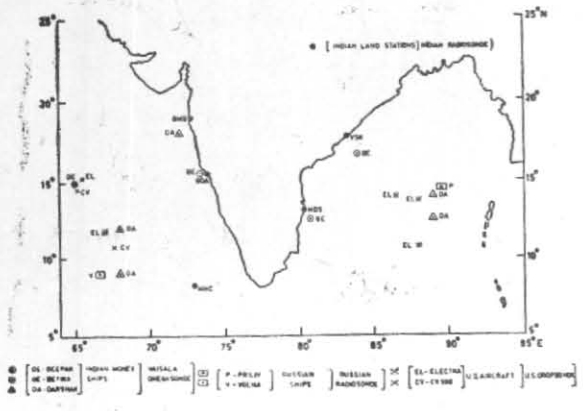

Fig. 1. Locator chart (Indian radiosonde land stations)

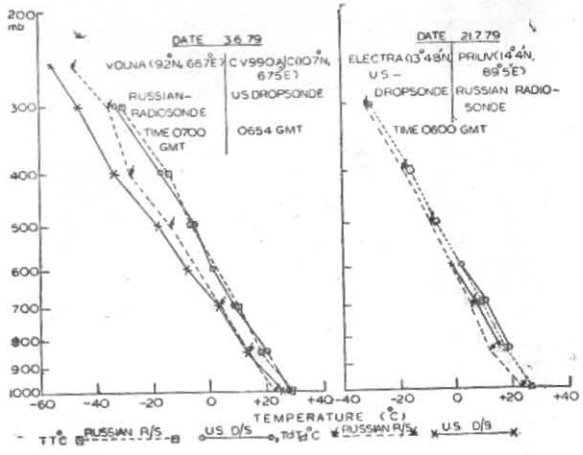

Fig. 2

using the Vaisala Omegasonde, the measurements made by USSR ships using Russian Radiosondes, and measurements of the two US research aircraft CV 990 and Electra using the US dropsonde and the radiosonde measurements from the Indian coastal land stations using audio modulated Indian rediosonde in the near vicinity of operation of the Indian Monex ships.

2. Data used

2.1. The upper air data collected from the various platforms over the Indian sea areas as detailed below have been studied :

(*i*) Data from five USSR research vessels using radar systems on board in a stationary polygon in the southeast Arabian Sea from 2-14 June 1979, and in the Bay of Bengal during 11-23 July 1979.

(*ii*) Vaisala omegasonde data from INS *Darshak* (9° N, 68° E) in the Arabian Sea using the FGGE Navaid sounding system, in close proximity to the USSR ship polygon on 2 and 3 June 1979 and at 12 deg 30′ N, 89 deg. E in the Bay of Bengal closest to the USSR ship '*Priliv*' on 21-23 July 1979.

(*iii*) The dropsonde data of US research aircraft CV 990 and 'Electra' taken almost concurrently in close proximity to the Indian Monex ships over the Arabian Sea and only from NCAR 'Electra' over the Bay of Bengal near INS *Darshak* on 21 and 24 July 1979.

(*iv*) Data from Indian coastal stations using Indian radiosondes in close proximity of the above observational platforms.

2.2. The object of this study is to compare mainly the above upper air data of temperature and dew point recorded by the sensors used in the four different systems of radiosondes used on various platforms during Monex-79, and to establish a correlation and performance compatibility of the sensors used in the audio modulated Indian radiosonde with that of Vaisala omegasonde, Russian radiosonde and US dropwindsonde. In addition, the results of intercomparison of the Vaisala Omegasonde with Indian radiosonde has been presented.

2.3. The details of meteorological sensors used in the different types of radiosondes used during Monex-79 are given in Table 1.

3. Presentation of results

3.1. The locations at which the observations were taken from the various platforms using different types of radiosondes, which have been studied are given in the Locator Chart (Fig. 1).

3.2. The comparative temperature and dew point data collected by the Russian radiosonde from the ships '*Volna*' and '*Priliv*' and the US dropsonde from CV 990 and Electra aircraft are given in Fig. 2. It is seen that the profiles obtained by these two systems of sensors are in good agreement.

3.3. The data collected by Vaisala omegasonde from the Indian Monex ships and the Russian ship radiosonde data collected either at the same location or in the near proximity during June-July 1979 in the Arabian Sea and Bay of Bengal areas, are presented in Fig. 3. Reasonable compatibility in the temperature profiles between Vaisala and the Russian systems of radiosondes is seen.

3.4. The observations taken by Vaisala omegasonde on board Indian Monex ships and the US dropsonde from the two US research aircraft, more or less at the same locations, are presented. Both these systems of sondes, *viz.*, the Vaisala and US dropsonde used the same Omega Navaid signals for the upper air measurements of temperature, humidity and wind.

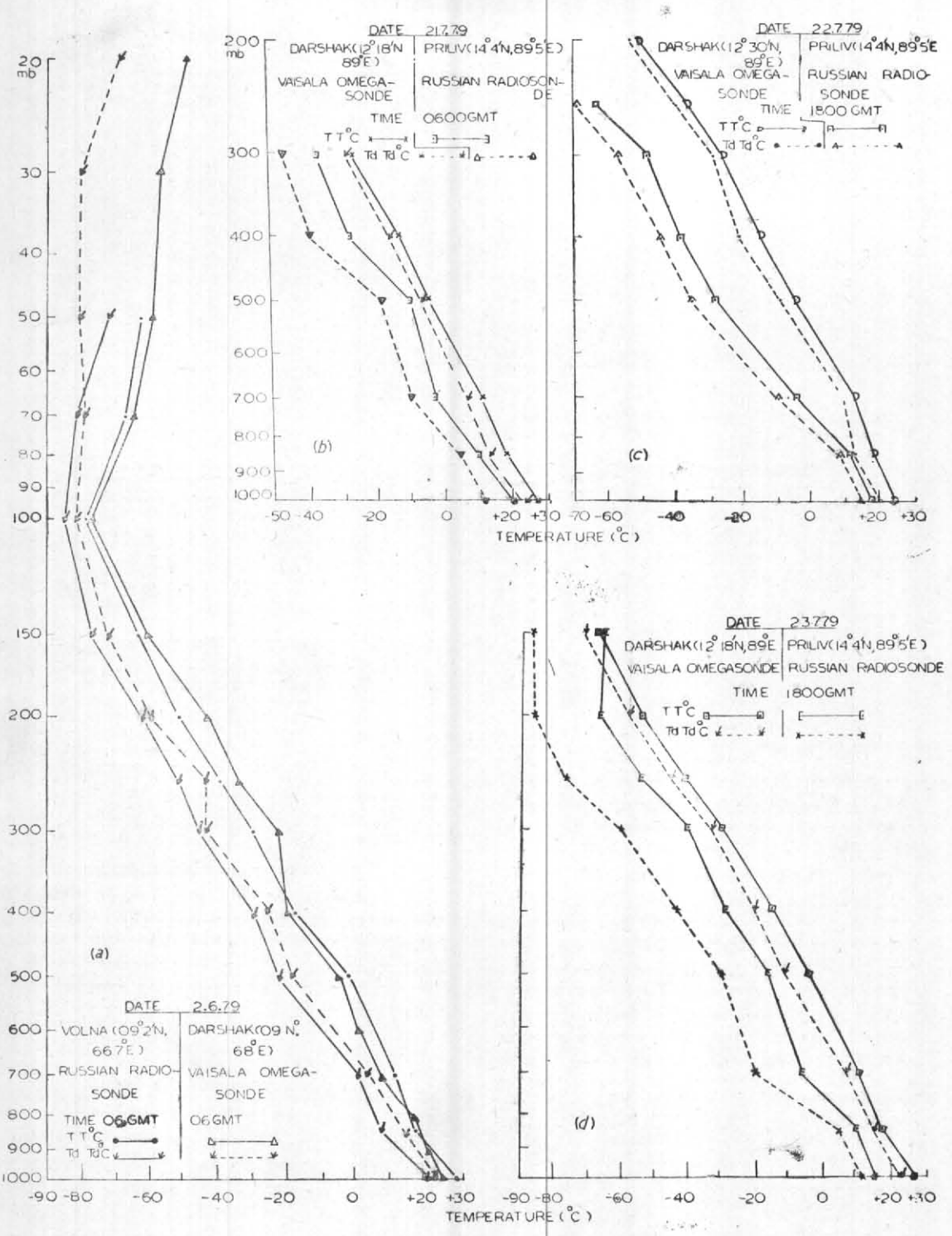

Fig. 3

The dropsondes were deployed from two aircraft (CV 990/Electra) at fixed flight levels of either 300 or 500 mb and they were tracked during the downward descent by the equipment on board the aircraft. The temperature and dew point profiles obtained by these two types of sondes are given in Fig. 4. It may be seen that in the Arabian Sea and Bay of Bengal areas, these two measurements were found quite compatible and temperatures profiles were in good agreement with each other.

3.5. Along the coast of the Indian sub-continent, a large number of land radiosonde stations were taking routine radiosonde ascents, numbering 2-4 per day using Indian made radiosonde.

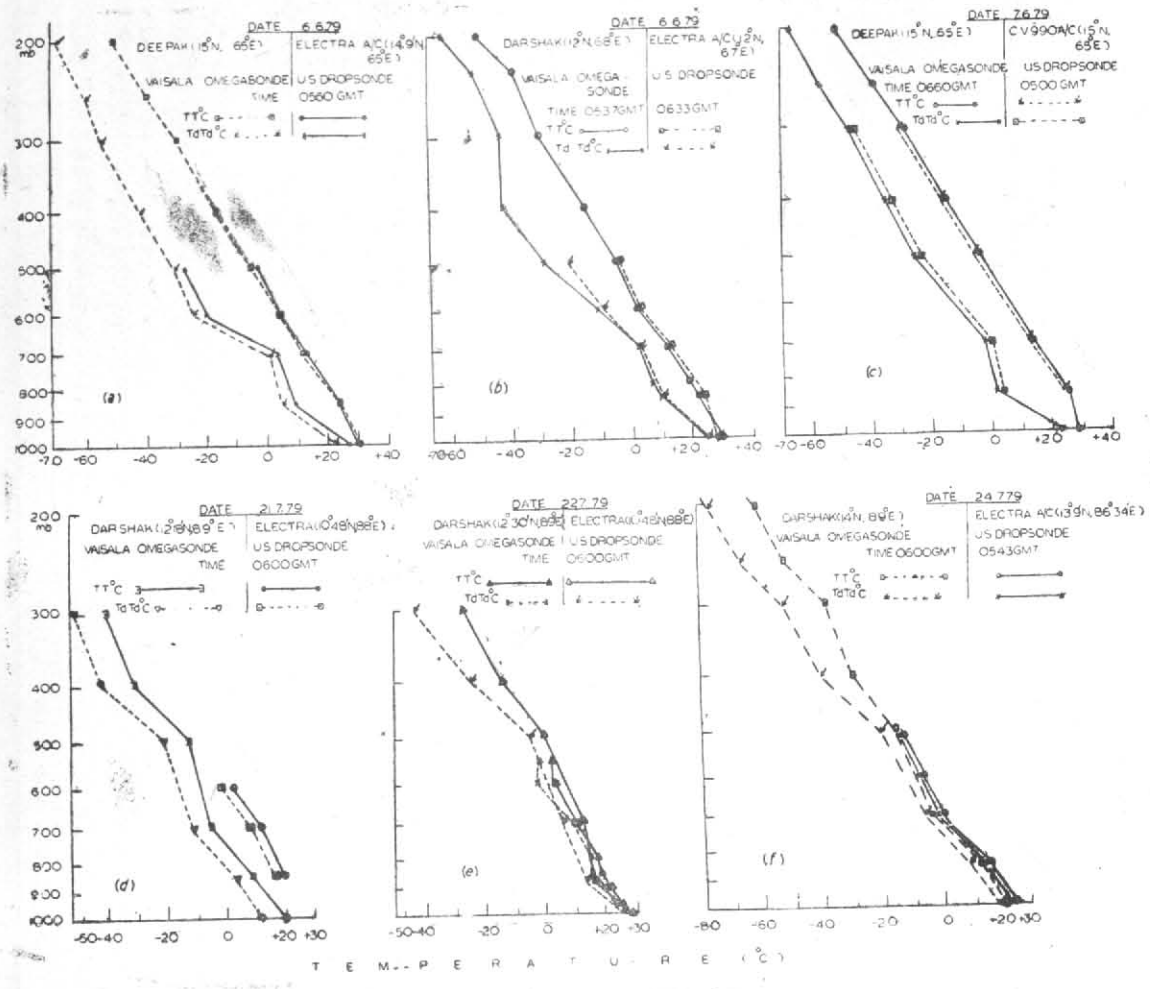

Fig. 4

The stations taken for comparison deploynig the audio modulated Indian radiosonde during Monex-79 are indicated in the Locator Chart (Fig. 1). The temperature profiles obtained between the Vaisala omegasonde on board Indian Monex ships and the Indian radiosonde used at land stations during Monex-79 in the Arabian Sea and Bay of Bengal are presented in Fig. 5. The temperature profiles obtained by Indian radiosonde agrees well with that of the Vaisala omegasonde even though the two types of radiosondes are using different types of sensors for temperature and humidity.

4. Result of analysis

4.1. A statistical analysis of the temperature and dew point measurements made by the different types of radiosondes used in Monex-79 was made and the results are given in Table 2. Keeping the Vaisala omegasonde, Russian radiosonde and US dropsonde as more established versions for reliable upper air measurements, a comparison was made of the departures of the Indian radiosondes are in good agreement and systems. It may be seen from Table 2 that the measurements made by the Vaisala Omegasonde and the audio modulated Indian radiosonde show high degree of compatibility. An attempt was also made to examine as to how far the Vaisala omegasonde measurement differs from the Russian radiosonde as well as the US dropsonde. Mutual compatibility has been established between the other types of radiosondes deployed during Monex-79. The details are discussed below :

(a) *Vaisala omegasonde — Indian radiosonde (Audio modulated)*

The upper air temperatures recorded by the Vaisala omegasonde upto 150 mb were warmer by 0.8 to 1.2 deg. C. The values varied between 1.5 to 2 deg. C above this level. Whereas the dew point recorded by Vaisala sonde showed a drier atmosphere than that indicated by the Indian Radiosonde upto levels of 150 to 200 mb. The dew point variations have been of the order of 2 to 3 deg. C thereby showing drier atmosphere by about 5 to 10 per cent less in humidity. This shows that the temperatures recorded by the sensors used in the Vaisala omegasonde and the Indian radiosondes are in good agreement and well within the accuracy limits required for synoptic purposes.

TABLE 1

The details of meteorological sensors used in the different types of radiosondes deployed during Monex-79

Name of sonde and platform	Parameter	Sensor	Accuracy	Range
US dropsonde from NCAR 'ELECTRA' and CV 990 aircraft	Pressure	Ni-Fe Aneroid constant modulus alloy	± 2 mb	150-1050 mb
	Temperature	Thermister	± 0.5°C	— 55 to + 40°C
	Humidity	Carbon Hygrister	±0.3° to 1.1°C (dew point)	—
Vaisala omega-sonde from Indian Monex Ships (INS *Darshak, Deepak* and *Betwa*)	Pressure	Ni-Fe Aneroid capsule constant modulus alloy	±1.0 mb ±0.2 mb	10 mb-1060 mb above 100 mb
	Temperature	Bimetal Ni-Fe alloy	±0.15°C	— 90°C to 55°C
	Humidity	Humicap thin film capacitive dielectric Polymer	±2.0%	0 to 100%
Russian radio-sonde from USSR Research ships (*Priliv, Volna, Shirshov, Priboy*)	Pressure	Be-Cu Aneriod capsule	±2.0 mb ±0.5 mb	upto 100 mb above 100 mb
	Temperature	Thermister	±1°C	— 80°C to +50°C
	Humidity	Membrane sensitive to moisture	—	15% to 100%
Indian radiosonde from coastal land stations	Pressure	Ni-Fe Aneroid capsule constant modulus alloy	±2.0 mb ±0.5 mb	1050-150 mb above 150 mb
	Temperature	Rod Thermister	±1°C	+50° to — 85°C
	Humidity	Lithium chloride film hygrister	±5%	15% to 100%

TABLE 2

Upper air temperatures' and dew point

S. No.	Mean differences in temperature TT°	S.D.	*t* statistics (Absolute)	*t* observed from the table at 90 % confidence level	Mean differences in dew point Td Td	S.D.	*t* statistics (Absolute)	*t* observed from the table at 95% confidence level
		Vaisala omegasonde (V) *minus* Indian radiosonde (I)						
	(V-I)				(V-I)			
1	1.0	1.83	1.55	2.30	1.67	7.65	0.65	2.30
2	1.33	0.87	0.62	2.30	0.89	1.54	1.74	2.30
3	0.86	1.21	1.87	2.44	— 0.71	1.70	1.11	2.44
4	— 0.11	1.60	0.20	2.30	— 0.89	2.30	1.32	2.30
5	— 0.22	1.30	0.51	2.30	— 1.78	2.23	1.58	2.30
6	0.67	1.12	1.79	2.30	1.30	0.87	0.62	2.30
7	0.48	1.20	1.33	2.30				
8	0.96	1.01	1.88	2.30				
	(R-I)	**Russian radiosonde (R) *minus* Indian radiosonde (I)**						
1	— 1.86	3.58	1.24	2.34	—1.88	3.62	1.22	2.38
		Russian radiosonde (R) *minus* Vaisala omegasonde (V)						
	(R-V)				(R-V)			
1	3.60	7.23	1.11	2.77	4.80	5.26	2.04	2.77
2	— 1.92	4.21	1.58	2.20	3.08	4.17	2.56	2.82
3	1.0	1.85	1.53	2.36	1.00	3.46	0.82	2.36
		U.S. dropsonde (A) *minus* Vaisala omegasonde (V)						
	(A-V)				(A-V)			
1	1.20	1.30	2.06	2.77	0.0	8.34	0.0	2.77
2	5.60	7.27	1.72	2.77	3.20	11.55	0.60	2.77
3	1.60	0.55	0.53	2.77	3.0	4.0	1.88	2.77
4	— 1.20	1.10	2.45	2.77				
		Russian radiosonde (R) *minus* US dropsonde (A)						
	(R-A)				(R-A)			
1	0.2	1.64	0.27	2.77	5.0	4.53	2.47	2.47
2	— 0.80	1.64	1.09	2.77	—1.80	1.92	2.09	2.77

(b) *Russian radiosonde - Indian radiosonde (Audio modulated)*

The comparison between the Russian and the Indian radiosonde also showed that the Russian sonde measurements were warmer than the Indian radiosonde varying from 1 to 3 deg. C for the entire range of the atmosphere from the ground to 100 mb. The Russian radiosonde also indicated drier atmosphere than measured by the Indian radiosonde. The dew point values recorded were varying by 2 to 4 deg. C especially indicating a drier atmosphere by 5 per cent upto 500 mb and 10 per cent above. In spite of this indication of warmer atmosphere, the compatibility of observations between these two systems is high. An earlier intercomparison of audio modulated Indian radiosonde (1680 MHz) with the Soviet radiosonde RKZ-2 (1790 MHz) done during Monsoon-77 at Bombay on 24 June 1977 also indicate similar results. The Indian and Soviet sondes were simultaneously released at Bombay and from the Soviet Flag Ship RV *Shirshov* berthed at Bombay docks respectively. The results of the two ascents showed very close agreement in the temperature within 3 deg. C upto 700 mb and 1 deg. C upto 300 mb. The relative humidity recorded were within a variation limit of 5 per cent upto 300 mb and 10 per cent upto 700 mb.

(c) *Vaisala omegasonde - US dropsonde*

It was noticed while comparing the upper air temperature measurements made by the Vaisala omegasonde and US dropwindsondes, which used the same omega Navaid signals, that the US dropsonde always indicated higher temperature values than Vaisala omega upsonde widely varying by 2 to 4 deg. C from the flight level to the ground. However, the US dropsonde measurements indicated more moist atmosphere than the Vaisala omegasonde values at all levels from the drop level. The humidity values were even 20 per cent to 30 per cent more than that of Vaisala omegasonde. A possible explanation for the indication of higher humidity values by the US dropsonde sensors may be due to the deposition of water on the sensors forming an envelope vitiating the measurement and not allowing the true dew point temperatures to be recorded.

(*d*) *Russian radiosonde - Vaisala omegasonde*

The observations taken by the Russian radiosonde and the Vaisala omegasonde indicated that Vaisala measurements were warmer than the Russian radiosonde values at all levels. It was noticed that upto 450 mb temperature values were higher by 1 to 2 deg. C. Whereas the observations of dew point temperatures recorded by Vaisala omegasonde showed drier atmosphere than indicated by the Russian radiosondes especially at levels between 750 mb to 200 mb. The dew point temperatures were varying from 1 to 3 deg. C indicating a drier atmosphere by about 10 per cent of humidity.

(*e*) *Russian radiosonde - US dropsonde*

The comparison between the Russian radiosonde temperatures and the US dropsonde measurements indicated that the values recorded by the Russian sonde were cooler below 750 mb by 1-2 deg. C than that of the US dropsonde. But no appreciable difference in the temperature values recorded by these two systems of sondes were noticed between the flight levels and 750 mb level. Whereas the dew points recorded by these two sondes did show an appreciable difference of 20 per cent from the level of drop to the ground. Again the US dropsonde values were moist.

5. Intercomparison of Vaisala omegasonde and Indian radiosonde

An attempt was also made to intercompare the Vaisala omegasonde with that of the Indian radiosonde at New Delhi during December 1980 by releasing both the sondes more or less at the same time on four days. The results of the upper air temperature and dew point measurements taken by these two systems of sondes on these days of intercomparison are given in Fig. 6. It is evident from the intercomparison that the measurements done by these two systems of sondes are highly compatible as already borne out from the compatibility studies done on the observations taken during Monex-79. The striking coincidence of the profile shapes consequtively during these four days of intercomparison in Fig. 6 is highly indicative of the performance stability of the Indian radiosonde temperature and other sensors.

5.2. The intercomparison data were analysed to work out the compatibility of the upper winds obtained from the Vaisala omegasonde and the Indian radiosonde. The Indian radiosonde recorded the winds using the WBRT 1680 MHz equipment which is in routine use at New Delhi. Whereas the Vaisala omegasonde observations were recorded and processed in the FGGE modules A & B of the Navaid Sounding Systems, installed at New Delhi. The results of the statistical analysis of the omega winds and the WBRT winds are given in Table 3. It is seen that the wind values recorded by these two systems are in close agreement and the deviation of the wind velocities from the surface upto 150 mb levels is of the order of $\pm$ 0 to 1.5 mps. The wind directions recorded by the Vaisala omegasonde and the Indian radiosonde were also quite consistent and well within $\pm$ 10 deg. generally.

6. Conclusions

The above study of performance compatibility of the various types of temperature sensors used in the four different radiosondes used in Monex-79 indicate the following :

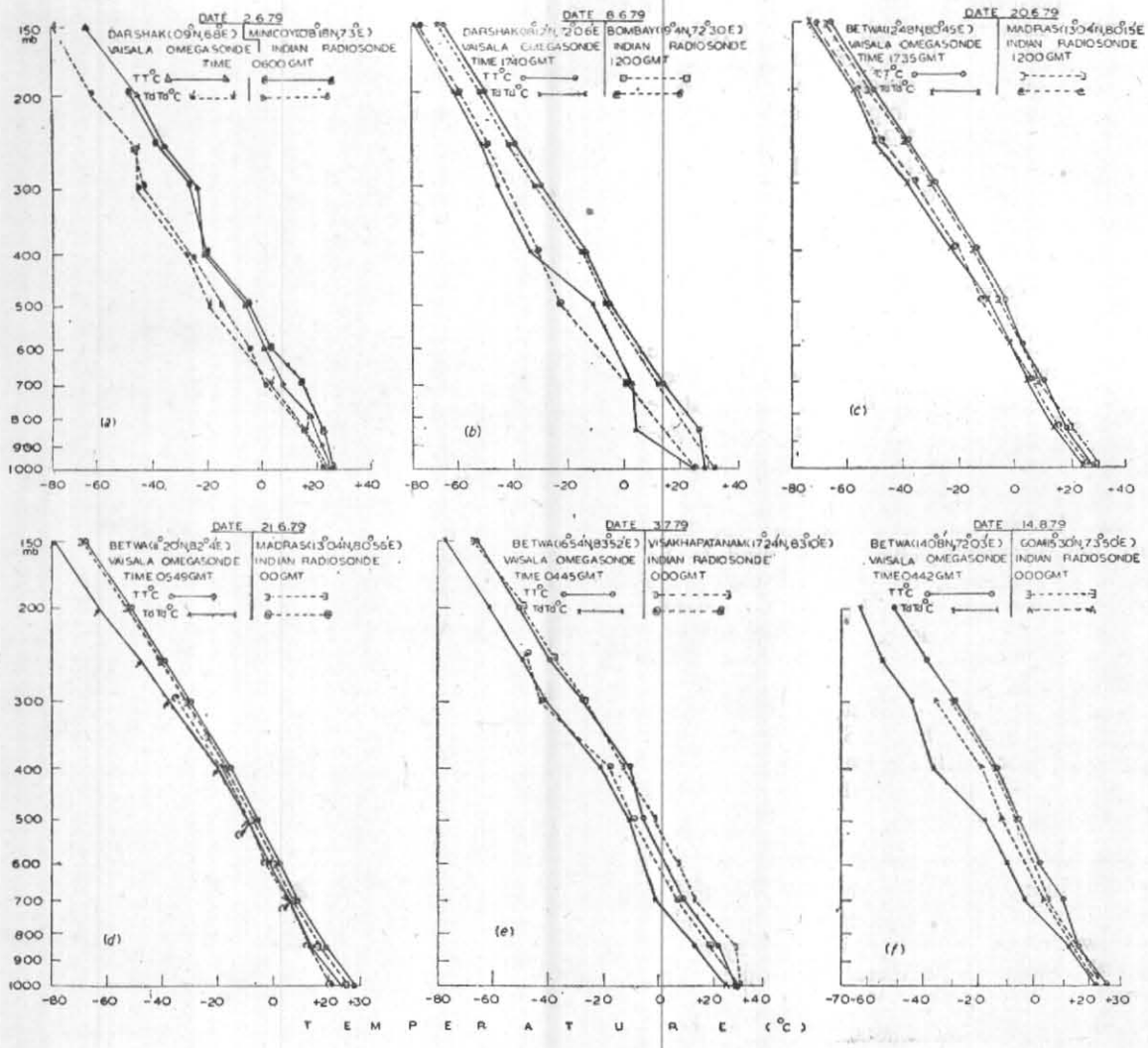

Fig. 5

TABLE 3

Upper wind speeds and direction

Vaisala omega sonde (V) *minus* Indian radiosonde (I)

S. No.	Mean differences in wind speed (mps) *V minus I*	S.D.	*t* statistics (Absolute)	*t* observed from the table at 95% confidence level	Mean differences in direction degrees *V minus I*	S.D.	*t* statistics (Absolute)	*t* observed from the table at 95% confidence level
1	— 1.50	1.57	1.60	1.79	6.33	8.68	2.33	1.79
2	0.70	4.11	0.54	1.79	0.90	2.1	1.13	1.79
3	2.40	5.26	1.42	1.83	5.90	2.42	0.77	1.83
4	— 1.00	2.16	1.46	1.83	9.40	21.0	1.38	1.83
5	— 0.82	1.54	1.40	1.83	0.20	38.4	1.0	1.83
6	— 1.38	1.60	1.60	1.83	3.70	23.4	0.84	1.83

(*a*) The performance of Indian radiosonde temperature sensors show high degree of reliability and compatibility with that of Vaisala omegasonde even though the sensors are of different type. The differences in temperatures lay within the range of 0.8 deg. C to 1.2 deg. C upto 150 mb and 1-2 deg. C beyond. However, the dew point temperature variation were of the order of 2-3 deg. C.

(*b*) The Indian radiosonde temperature values compared well with the Russian radiosonde varying 1-3 deg. C from ground to 100 mb. The variation in the dew point values were between 2-4 deg. C. The compatibility of temperature observations between the two systems was noteworthy.

(*c*) The Indian radiosonde sensors for temperature measurements have been found to be comparable in stability, reliability and accuracy with those of the other well known and established systems of radiosondes.

(*d*) The two systems of sondes using omega signals namely Vaisala and US dropsonde however showed wide variation in temperatures 2-4 deg. C and 20-30 per cent differences in humidity.

(*e*) The intercomparison between the Indian radiosonde and Vaisala omegasonde at New Delhi showed a consistent and noteworthy agreement in the shape of temperature profiles. This confirmed the high degree of stability and reliability in performance of the Indian temperature sensors. The temperature differences were less than 1 deg C.

(*f*) The omega winds recorded by Vaisala sonde were in close agreement with the Indian radiowind measurements done during the intercomparison. The differences in wind speeds were less than $\pm$ 1. 5 mps upto 150 mb level and in directions less than $\pm$ 10 deg. C generally at all levels.

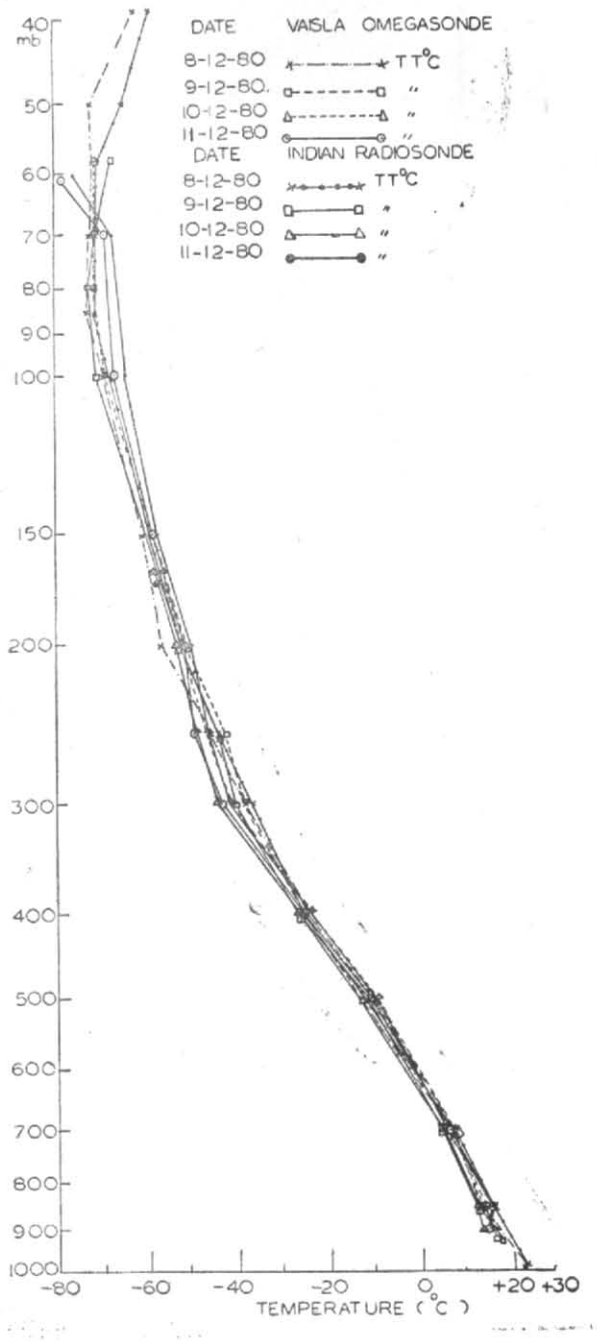

Fig. 6

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