A comparative study of the wind structure in the stratosphere at Sonmiani vis-a-vis CIRA 1965

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ABSTRACT

All available wind data from seventy meteorological rocket firings conducted during the period 1964–70 from Sonmiani (latitude 25°11′38″ N and longitude 66°44′47″ E) have been analysed for studying the zonal wind structure in the stratosphere. The salient features of the mean zonal circulation for all the months have been studied and the results compared with COSPAR International Reference Atmosphere 1965. Fluctuations in the zonal wind during winter are discussed in detail.

1. Introduction

The Pakistan Space and Upper Atmosphere Research Committee (SUPARCO) has been conducting meteorological rocket firings from Sonmiani (latitude 25°11′38″ N and longitude 66°44′47″ E) since March 1964 as part of the International Indian Ocean Expedition (IIOE) 1963–64. Under this programme meteorological rocket firings were planned to be conducted from rocket ranges around the Indian ocean for studying general circulation of the upper atmosphere and correlating it with tropospheric wind circulation. The results from the meteorological rocket firings conducted from Sonmiani range were so encouraging that the programme was continued during IQSY (International Quiet Sun Year) and has been further extended under the IUCSTP and GARP programme of WMO and COSPAR.

Pakistan has so far launched seventy meteorological rockets with chaff or instrumented dart payloads. All available wind data from these firings have been analysed for studying the stratospheric zonal wind circulation at Sonmiani. Most of the firings have been conducted on Priority Regular World Days and cover the periods from the solar minimum to the solar maximum and are thus fairly representative of the structure of the stratosphere in the subtropics. Data from all firings conducted in each month have been used to compute monthly mean zonal wind profiles and the results are compared with the global means published in CIRA 1965. It may be stated that CIRA data are based on monthly means computed on the 1st of each month. The details of the zonal wind circulation at Sonmiani in each season are discussed below.

2. Summer circulation

The summer circulation in the upper atmosphere is characterised by strong easterlies in the northern hemisphere as represented in several models and cross-sections notably those of Groves (1970), Batten (1961) and Murgatroyd (1957). Although the easterlies at Sonmiani appear in the stratosphere in May, they get well established as the summer season advances from June to August. The mean zonal wind at Sonmiani for the month of June is represented by a solid curve in Fig. 1. The dotted curve gives the mean zonal wind profile as compared with CIRA (1965). The easterlies which are of the order of 5–10 m/s in the lower stratosphere increase to 40–45 m/s in the upper stratosphere. Comparing with the CIRA profile it is clear that the mean zonal wind at Sonmiani in June is in general 5–10 m/s stronger than the zonal wind based on CIRA data. Data above 55 km is based on comparatively fewer observations and, hence, is more likely to be modified in the light of future firings.

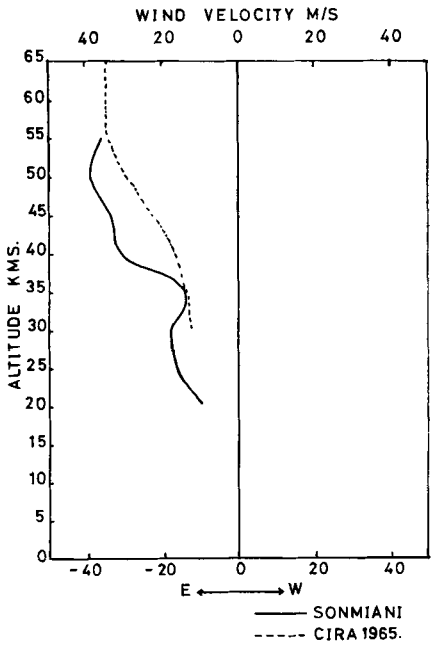

Fig. 1. Mean zonal wind profiles—June.

The mean zonal wind at Sonmiani in July, represented in Fig. 2, follows a pattern similar to that in June except that the easterly circulation is most pronounced during this month. The mean maximum easterly wind at 50 km is of the order of 49 m/s. As compared to CIRA profile, the mean zonal wind at Sonmiani is 5 m/s stronger upto 50 km but decreases in strength above the stratopause level around 50–55 km. As the summer season advances marked changes take place in the zonal wind circulation at Sonmiani in the stratosphere. Although the easterlies continue to increase in strength in the lower stratosphere in August, as shown in Fig. 3, there is considerable decrease in their strength in the upper stratosphere. The maximum zonal wind of the order of 30 m/s is attained at 40 km. It decreases in strength above that level and finally changes to westerly around 55 km. According to CIRA model in general the zonal wind profile in August remains practically unchanged except for a slight decrease in wind strength above the stratopause level. The mean zonal wind continues to be easterly of the order of 33 m/s at 65 km. As most of the CIRA data are based on the firings conducted over the western hemisphere the difference in the stratospheric circulation as observed at Sonmiani can be attributed to the peculiarities of the general circulation over the Indian Ocean area.

3. Autumn circulation

The commencement of autumn season is marked by further important changes in the zonal wind in the stratosphere. The easterlies in the lower stratosphere in September (upto 45 km) decrease to 10–13 m/s but change over to westerlies in the upper stratosphere with maximum west wind of the order of 13 m/s at 50 km as shown in Fig. 4. On the other hand, the zonal east wind as given in CIRA profile shows decrease in strength to about 20 m/s during September, but even at the highest level it does not show any westerly component. In October the easterlies at Sonmiani are confined only to lower stratosphere and do not exceed 8 m/s. The westerlies above 40 km steadily increase in intensity attaining maximum speed of about 20 m/s at 55 km. The CIRA zonal wind profile as given in Fig. 5 is in general agreement with that at Sonmiani. The results at Sonmiani show a slight decrease in intensity of around 55 km, whereas in the CIRA model zonal westerlies go on increasing steadily upto 65 km. It

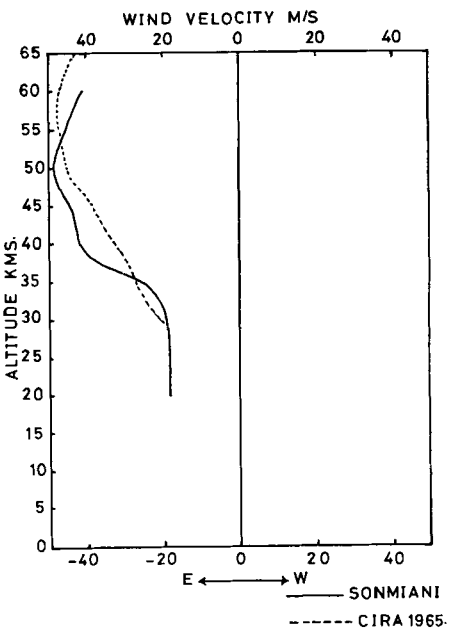

Fig. 2. Mean zonal wind profiles—July.

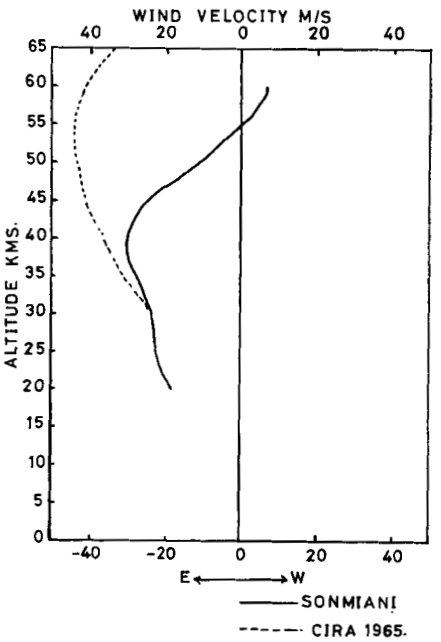

Fig. 3. Mean zonal wind profiles—August.

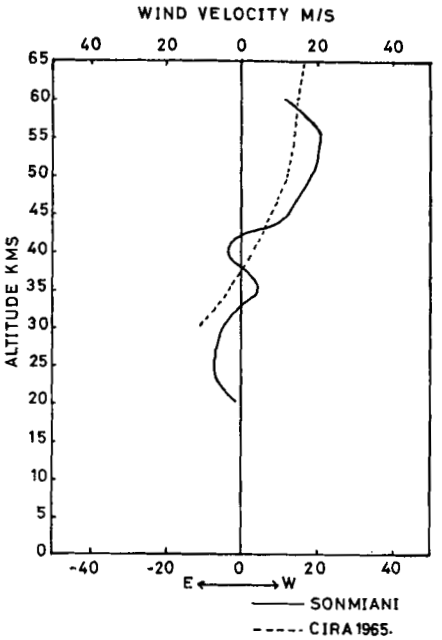

Fig. 5. Mean zonal wind profiles—October.

can, however, be stated that during October the change over from summer to autumn circulation is virtually complete.

By November the zonal westerlies at Sonmiani steadily increase in strength in the upper stratosphere and messosphere with maximum

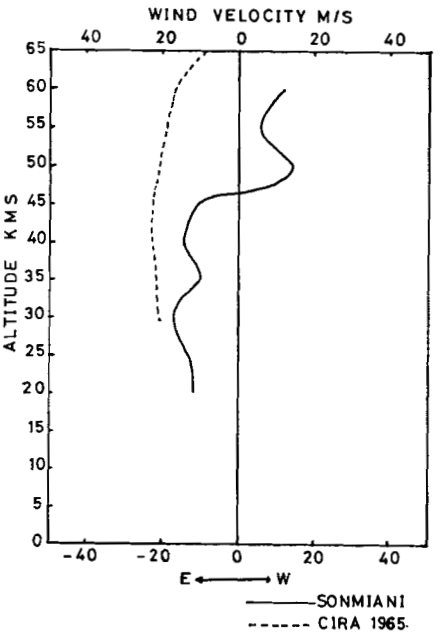

Fig. 4. Mean zonal wind profiles—September.

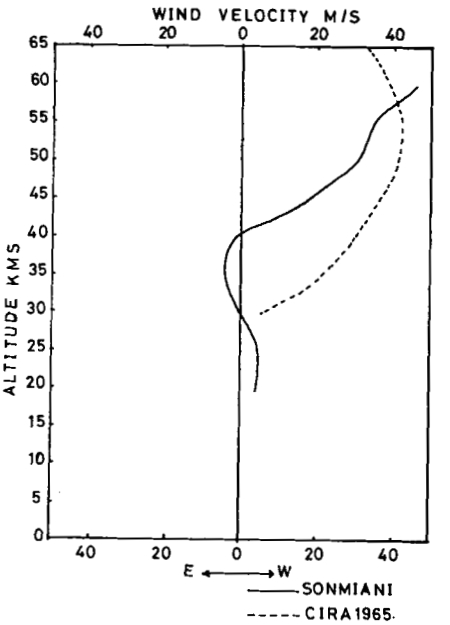

Fig. 6. Mean zonal wind profiles—November.

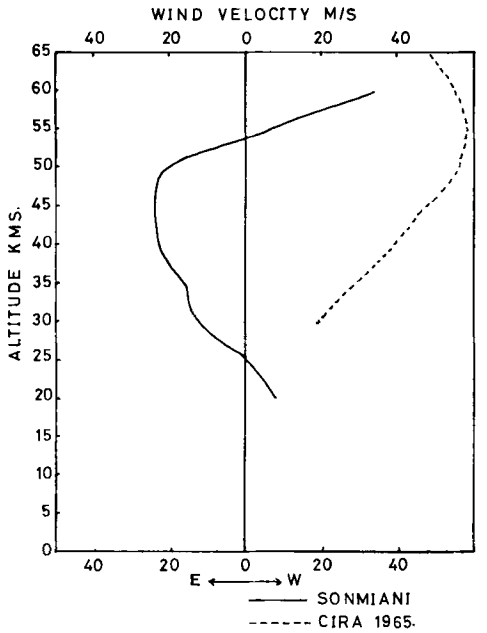

Fig. 7. Mean zonal wind profiles—December.

wind speed of 46 m/s reported at 60 km as shown in Fig. 6. In the lower stratosphere weak easterlies about 5 m/s still persist. The CIRA profile for this month shows that the westerlies prevail throughout the stratosphere and are generally stronger than those observed at Sonmiani.

4. Winter circulation

The mean zonal wind circulation at Sonmiani in December is shown in Fig. 7. The remarkable feature of the stratospheric winter circulation at sonmiani is that zonal westerlies which get well established by the end of November change over, again, to easterlies about 20 m/s around 40–45 km during December. Above the stratopause level the easterlies decrease rather rapidly and change over to westerlies which increase steadily to about 34 m/s at 60 km. The zonal wind from CIRA model shows that the zonal westerlies prevail throughout the stratosphere and mesosphere, although their maximum strength (58 m/s) is attained around 55 km. The re-establishment of easterlies in December at Sonmiani is probably due to global changes in the stratospheric circulation and the shifting of the position of the anti-cyclonic ridge extending from North Africa and Saudi Arabia to Indo-Pakistan as has been discussed by Rahmatullah (1969). Webb (1964) has noted that low latitude easterlies around ridges of high pressure affect deep penetration of the winter hemisphere over oceanic regions, while troughs of low pressure with associated westerly wind dip to low latitude over continental regions. Morris & Miers (1969) have also observed that the circulation at White Sands is interrupted for brief periods in either December, January or February by the winter storm period which may vary in behaviour, intensity and duration from one place to another in the hemisphere. The sudden reversal of zonal wind from westerly to easterly during the winter storm period could also be due to Sudden Warming Phenomena which has been observed on global scale during mid-winter. It would require a more elaborate temperature sounding system to study this phenomenon in the subtropics.

The zonal wind circulation at Sonmiani again, shows important changes in January as shown in Fig. 8. Weak and variable winds about 5 m/s prevail in the lower stratosphere during this month, whereas in the upper stratosphere above 40 km westerlies about 26 m/s have been observed. According to CIRA model the zonal circulation in the stratosphere in

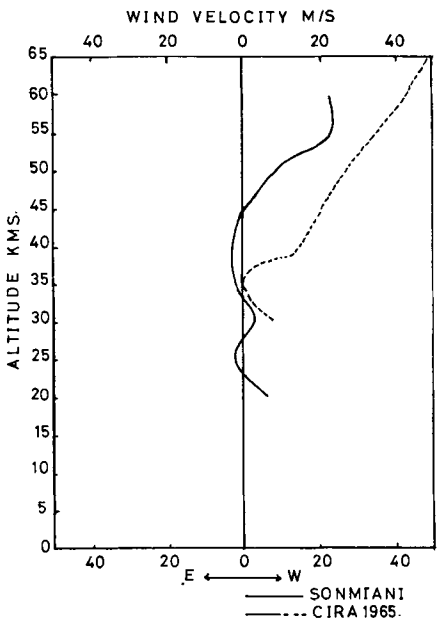

Fig. 8. Mean zonal wind profiles—January.

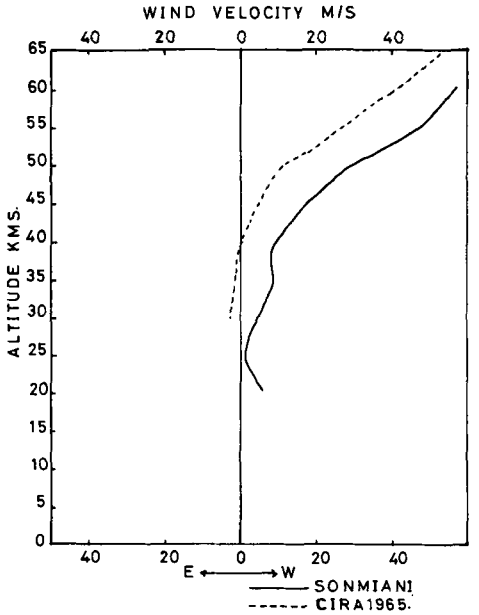

Fig. 9. Mean zonal wind profiles—February.

January continues to be westerly and steadily increases in strength from 35 km to 65 km where the maximum wind speed (49 m/s) is attained. The cause for such divergences in the two cases could be attributed to the position of the Circum-Polar-Vortex which is most pronounced over the North American continent in the stratosphere. Under the influence of the Circum-Polar-Vortex strong zonal esterlies penetrate to the subtropics over the western hemisphere which provides the principal data for the CIRA model.

During February the zonal westerlies typical of the Winter circulation in the stratosphere are re-established at Sonmiani. In the lower stratosphere light westerlies about 5–10 m/s prevail upto 40 km. They, however, steadily increase to 57 m/s at about 60 km as shown in Fig. 9. The stratospheric zonal wind circulation in February is characterised by a strong mesospheric jet and is thus the mirror image of the July circulation, the winter westerlies replacing the summer easterlies. The features of the stratospheric wind circulation according to CIRA model in February are in general agreement with those observed at Sonmiani except that the zonal wind at Sonmiani is about 10–15 m/s stronger.

In March the zonal wind at Sonmiani decreases further in intensity in the lower stratosphere, but continues to be fairly strong in the upper stratosphere and the mesosphere as is clearly shown in Fig. 10. The zonal westerlies attain maximum speed about 50 m/s around 60 km. In the CIRA model zonal west wind in the stratosphere and mesosphere increases steadily from 30 km to 65 km attaining the maximum intensity (53 m/s) at 65 km.

5. Spring circulation

With the onset of spring in April important changes in the zonal wind circulation in the stratosphere take place at Sonmiani. Weak easterlies about 5 m/s prevail in the lower stratosphere upto 30 km, but westerlies persist in the upper stratosphere. Their strength, however, decreases as compared to March with maximum wind speed about 24 m/s reported at 60 km (Fig. 11). Thus a considerable decrease in the strength of the zonal wind takes place during this month as compared to the March circulation. The zonal west wind in CIRA model is generally stronger than that observed at Sonmiani, the maximum zonal wind, 38 m/s, being reported at 65 km.

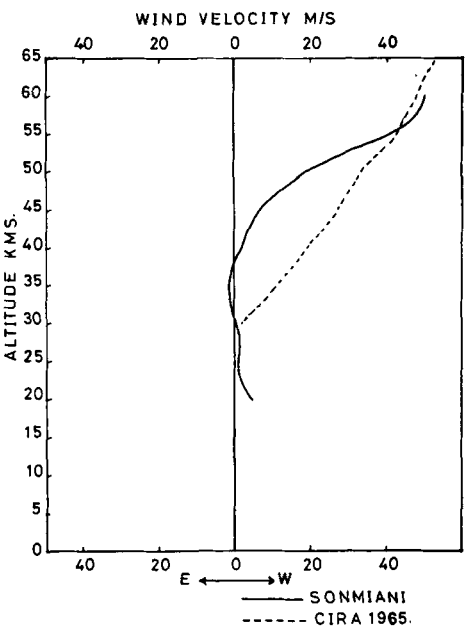

Fig. 10. Mean zonal wind profiles—March.

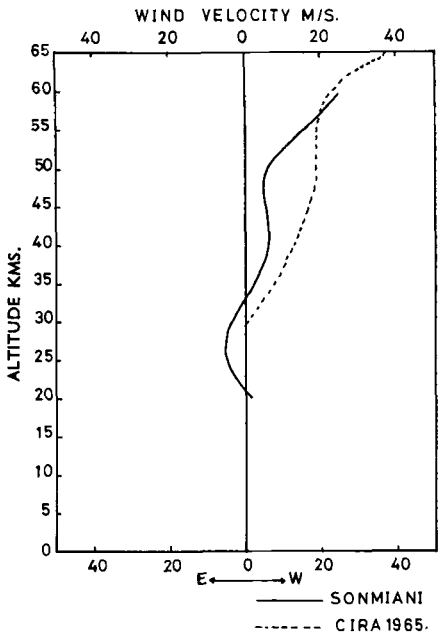

Fig. 11. Mean zonal wind profiles—April.

In May the transition from spring to summer takes place rather abruptly both at Sonmiani as well as in CIRA model as shown in Fig. 12. In the CIRA model the zonal east wind does not exceed 5 m/s at any level, whereas at Sonmiani easterlies of the order of 10–20 m/s prevail during this month. Thus we can say that May is precursor of the summer circulation in which easterlies are established and gradually built up in strength as the summer season advances.

6. Conclusion

The zonal wind circulation at Sonmiani in summer is characterised by easterlies. In May easterlies only 10–20 m/s prevail, but as the summer season advances they build up in strength through June to July. The easterlies in July attain wind speed of the order of 49 m/s at 50 km. During these months the zonal wind of the CIRA model in the stratosphere is weaker than Sonmiani wind by 5–10 m/s. In August the divergence between the two becomes quite marked. At Sonmiani a general weakening of the easterlies takes place during this month with maximum wind speed (30 m/s) reported at 40 km. Above that level sharp decrease in the strength of the easterlies takes place resulting in the change over to westerlies above 50 km. According to CIRA model fairly strong easterlies continue to prevail in the stratosphere and mesosphere during August.

With the approach of autumn the easterlies gradually give way to the westerlies. This change occurs rather more rapidly at Sonmiani than is observed in the CIRA model. By November strong westerlies are established in the upper stratosphere at Sonmiani with mean wind of the order of 46 m/s reported at 60 km. But weak easterlies, 5 m/s, still prevail in the lower stratosphere. In contrast westerlies prevail throughout the stratosphere according to CIRA model.

The most remarkable change in the zonal wind circulation at Sonmiani occurs in December, when westerlies break down and change over to easterlies about 20 m/s at 40–45 km. The easterlies weaken at the stratopause level and change over to westerlies about 34 m/s at 60 km. According to CIRA model strong westerlies prevail throughout the stratosphere during December with maximum wind speed, 58 m/s reported at 50 km.

The reversal of the westerlies to easterlies

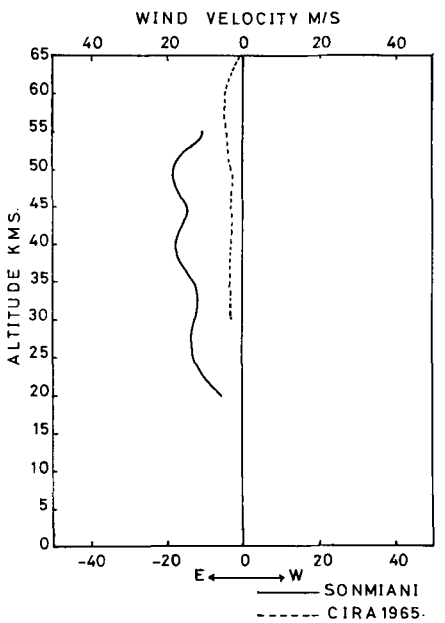

Fig. 12. Mean zonal wind profiles—May.

could be due to strong penetration of easterlies around the ridge of high pressure which extends in the stratosphere from North Africa across Saudi Arabia to Pakistan. It could also be associated with Sudden Warming Phenomena which usually leads to the breakdown of the Circum-Polar-Vortex resulting in the replacement of westerlies by easterlies in the winter hemisphere. According to CIRA model westerlies during the month of December increase steadily from 35 to 65 km attaining the maximum speed of 49 m/s.

In February the zonal westerlies characteristic of the winter circulation are re-established at Sonmiani with maximum speed of the order of 57 m/s at 60 km which is in fact 10–15 m/s stronger than the CIRA model. The circulation at Sonmiani in February is the mirror image of the July circulation with summer easterlies replacing the winter westerlies.

During March the zonal wind decreases in the lower stratosphere, but strong westerlies continue to prevail in the upper stratosphere at Sonmiani. However, the spring circulation according to CIRA model is in general agreement with that of Sonmiani except that the CIRA winds are somewhat stronger.

Acknowledgement

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СРАВНИТЕЛЬНОЕ ИЗУЧЕНИЕ СТРУКТУРЫ ВЕТРОВ В СТРАТОСФЕРЕ НАД СОНМИАНИ И МОДЕЛИ CIRA-1965

Для изучения структуры зонального ветра в стратосфере проанализированы все доступные данные о ветре, полученные при запусках 70 метеорологических ракет в Сонмиани (25°11′38″ с. ш. и 60°45′47″ в. д.) в период 1964–70 гг.

Повторяющиеся особенности средней зональной циркуляции изучались для всех месяцев и результаты сравнивались с коспаровской международной стандартной атмосферой 1965 года. Детально обсуждаются флуктуации зонального ветра зимой.