Zonal and meridional winds over Hyderabad

Gopa Dutta¹, M N Joshi², J V Subba Rao¹ & H Aleem Basha¹
¹Nawab Shah Alam Khan Centre for Post-Graduate Studies and Research (Anwarul-uloom College),
Hyderabad 500 001
²Tata Institute of Fundamental Research, Balloon Facility, Hyderabad
Received 15 May 1995; revised 7 December 1995; accepted 14 March 1996

The wind data, collected from stratospheric balloon flights over Hyderabad (17.2° N, 78.2°E) for the past two decades (January 1977 to April 1994) have been consolidated. The results in the form of monthly mean values provide reliable reference wind profiles for the tropospheric and stratospheric heights up to 36 km. Wind shears between two adjacent-kilometre levels have been calculated and presented in graphical forms. A long term oscillation of about 5-year periodicity has been noticed in zonal wind. Wind values do not show significant correlation with solar activity. These reference wind and shear profiles may form the basis of further investigations in the dynamics of the lower atmosphere and would also prove to be helpful in better planning of the balloon launch experiments.

1 Introduction

Atmospheric circulation in the stratosphere and troposphere has been of considerable interest, both in understanding the dynamics of lower atmosphere and providing upper wind data for several other purposes¹. The aim of this paper is to present the general circulation pattern at tropospheric and stratospheric heights over Hyderabad (17.2°N, 78.2°E), a low latitude station. Normal meteorological balloons reach up to 20 km. But the high altitude balloon flights carried out by National Scientific Balloon Facility of Tata Institute of Fundamental Research (TIFR) uses special type of imported rubber balloons (made up of natural latex and synthetic rubber) which are capable of reaching altitudes over 30 km with standard meteorological payload of 1.5 kg. For obtaining wind data up to about 42 km, TIFR manufactures polyethylene balloons out of special polyethylene resin of 5.8 μ thickness which can reach up to that height. The balloon is tracked by x-band radar of IMD, Hyderabad station. The data collected by TIFR during 1983-1994 have been analysed in the present study. The previous 7 years (1977-1983) data have been taken from the published scientific report². Total 17 years data (1977-1994) have been used to derive reference wind profiles over this station. Attempts made earlier to evaluate wind models used only a limited data of 7-9 years².³. Wind shear plays an important role in the atmospheric dynamics. The long data series has been utilised to compute reference wind shear profiles. The effect of solar activity on wind velocity has also been studied.

2 Method of analysis

The raw data consist of the values of range, elevation and azimuth of the balloon at 1-min interval of time. These raw data from January 1984 to April 1994 have been used to calculate the wind velocity components from 7 to 36 km altitude. Data for the previous years have been taken from scientific report² as mentioned earlier. To obtain the model wind profiles, the following procedure is adopted:

(i) Generally, there are few flights every month. Height profiles given by these flights are averaged to obtain a series of monthly mean profiles.
(ii) There are 208 months in the period January 1977-April 1994. Average values for the data gaps have been obtained by cubic spline interpolation method.
(iii) Model wind profiles for each month are obtained by averaging all profiles in a particular month of all the years, i.e. 17 years. These are called multi-annual values of wind for each month.
(iv) The same procedure is adopted for zonal and meridional wind components separately.

Average monthly wind profiles for May, June, July and August showed kinks and hence they have been smoothened. This is probably due to scanty data, as TIFR conducts the sounding flights obtaining wind data for main experimental
flights, and balloon launching experiments are mostly closed between May and September. Number of flights reaching beyond 36 km being very less, reference profiles have been computed up to 36 km. These model wind profiles are shown in Figs 1-3. These model zonal wind profiles have been compared with CIRA-1986 model for a latitude of 20°N which is the closest available to Hyderabad latitude. Good agreement is observed between them for the period December-September, though wind values given by CIRA model appear to be slightly on the higher side compared to observed values. Large departure is, however, observed for the months of October and, particularly, November.

3 General features of circulation

In the model wind profiles as shown in Figs 1-3, both the zonal and the meridional components are presented together by solid and dashed lines, respectively. A positive value of the wind means westerly for zonal wind case and southerly for meridional wind case. Monthly break-up of balloon ascents have been shown in Table 1. In

Fig. 1 Model wind profiles over Hyderabad for Jan. - Apr. [Solid line represents zonal wind velocity, and the dashed line represents meridional wind velocity]

Fig. 2—Same as Fig. 1, but for May - Aug.

Fig. 3—Same as Fig. 1 but for Sep. - Dec.
addition to the height profiles, months, height, and velocity magnitude contour plots for zonal and meridional winds have been shown in Figs 4 and 5.

It is observed that the zonal wind circulation in the troposphere (below 18 km) over Hyderabad has an annual cycle. Westerlies prevail for seven months from November to May and easterlies for the remaining five months, from June to October. In the lower troposphere between altitudes of 1 and 7 km, easterlies are observed more frequently. Tropospheric jets are seen between 12 and 16 km with wind strengths reaching up to 30 ms\(^{-1}\). Circulation in the monsoon months (June-September) are mostly easterlies.

In the stratospheric region between 18 and 36 km, the zonal wind circulation over Hyderabad is predominantly easterly for all months of the year. This has been earlier reported by Gokhale et al.\(^3\) up to the altitude of 30 km and using data from 1956 to 1964. Kumar and Nagpal\(^2\) also reported similar features using data from 1977 to 1983. The magnitude of wind velocity is found to increase by a factor of two during monsoon months as compared to winter months.

### Table 1—Number of balloon ascents attaining different heights in different months

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>42</td>
<td>79</td>
<td>72</td>
<td>68</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>11</td>
<td>7</td>
<td>34</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>30</td>
<td>37</td>
<td>74</td>
<td>74</td>
<td>69</td>
<td>30</td>
<td>18</td>
<td>14</td>
<td>12</td>
<td>7</td>
<td>32</td>
<td>45</td>
<td>56</td>
</tr>
<tr>
<td>35</td>
<td>6</td>
<td>29</td>
<td>41</td>
<td>30</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>11</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>40</td>
<td>—</td>
<td>5</td>
<td>17</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

---

**Fig. 4**—Month, height and velocity contour for zonal wind. [Solid lines represent westerlies and dashed lines represent easterlies]

**Fig. 5**—Month, height and velocity contour for meridional wind. [Solid lines represent southerlies and dashed lines represent northerlies]
Meridional wind velocity in the troposphere between 10 and 20 km appears to be predominantly southerly with a maximum speed of 5 ms\(^{-1}\) near the troposphere jet altitude. Above 20 km the circulation turns to northerly for almost all months in the entire region of the stratosphere below 40 km. Below 10 km, in the lower troposphere, meridional wind velocity appears to be mostly northerly. There are, however, some exceptions. Besides, in some zero-pressure-instrumented large balloon flights, floating at constant ceiling altitude for several hours over Hyderabad, a diurnal variation of wind velocity has been observed\(^4\).

A long term oscillation of about 5 year periodicity has been observed in the zonal wind data. Recently Krzyscin\(^5\) has analysed the monthly means of 30 hpa temperature data over north pole for the years 1964-1991 and averaged over 70°N to 90°N region and reported a 6 yearly periodic fluctuation of unknown origin.

### 4 Comparison with other observations
Mean seasonal behaviour of zonal and meridional winds over Hyderabad has been compared with those of Thumba, Shar and Balasore. Jain et al\(^6\) have reported wind characteristics over Indian tropical atmosphere considering three low latitude stations, namely, Thumba, Shar and Balasore. The comparison is shown in Table 2. It is clearly seen that the wind behaviour at Hyderabad fits in very well with the latitudinal variation of tropospheric circulation. While at Thumba weak easterlies prevail during winter months, these turn into westerlies at Shar and gradually becomes strong westerlies at Balasore. So even though the data available for Shar were of a short duration (3 years), it appears that the average trend of the wind behaviour is quite reliable. Wind behaviour at Hyderabad and Balasore seem closer to what is seen at extra-tropics, where westerlies during winter are replaced by easterlies during summer.

### 5 Effect of solar activity
Since the available data span over more than one solar cycle, we have examined whether the changes in wind velocity are related to solar activity changes or not. Cross-correlation studies of zonal wind velocity with sunspot number \(R_s\) and with 10.7 cm solar flux \(F_{10.7}\) show negative result as given in Table 3. It appears that there is practically no solar activity dependence of wind velocity in the troposphere and stratosphere till about 30 km. At 34 km, however, it shows low positive correlation. But since the data available between 36 and 40 km are very scanty, it could not be tested whether the correlation improves in higher stratosphere or not.

### 6 Wind shear
Wind shear poses serious problem for balloon and rocket launching by producing mechanical stress during their ascents. Shear between two ad-
adjacent-kilometre levels is calculated as the vectorial difference in speed between a particular level and the lower level winds and is expressed in units of m/s/km (Ref.7). The multi-annual values of zonal and meridional wind for each month have been used to compute total horizontal wind profiles for different months of the year. These profiles have been used to compute reference shear-height profiles which are presented in Fig.6. It is found that wind shear over Hyderabad has quite significant values ranging between 1 and 4 m/s/km. Wind shear maximizes near tropopause level and high values of the order of 7-8 m/s/km are observed during monsoon months. Wind shear coefficient observed at Gadanki (13°N) at 8 km altitude in the zonal wind is ~0.021 s⁻¹. Month, height and magnitude contour of shear is shown in Fig.7 which is useful for practical purposes.

7 Summary and conclusion
The main features of the wind characteristics brought out in this study are:

(i) Tropospheric circulation of the zonal component below 18 km is found to be westerly between November and May and turns into easterly between June and October. At times, jet velocities as high as 30 m/s are observed between 12 and 16 km altitude. The meridional component is found to be predominantly southerly with a jet velocity of 5 m/s near the tropopause level.

(ii) Stratospheric circulation of the zonal wind is found to be easterly throughout the year. A periodic fluctuation of the order of 5 years has been noted. The meridional circulation in the stratosphere is northerly throughout the year.

(iii) In the troposphere there is large latitudinal variation in the wind behaviour. The characteristics of wind over Hyderabad is compatible with other stations.

(iv) The cross-correlation study of the wind velocity with sunspot number and 10.7 cm solar flux do not show any significant correlation.

(v) Significant wind shear is observed in the zonal wind particularly in the months of June, July and August. Shear in meridional wind is less compared to zonal wind.

It is thus inferred that these reference wind and shear profiles would form the basis of further investigations in the dynamics of lower atmosphere and would also be helpful in the planning of balloon experiments in a better way.

Acknowledgements
The authors express their sincere thanks to Prof. S V Damle of TIFR, Bombay, for providing
the data used in this study and also for his valuable comments about the work. Two of the authors (GD and HAB) express their deep gratitude to Nawab Shah Alam Khan, Chairman and to Mr Mehboob Alam Khan, Secretary of Anwaruloom College for their active support and kind encouragement. Thanks are also due to anonymous referee for his constructive comments which led to substantial improvement of the paper.

References