ISSN-2249 5460

INTERNATIONAL JOURNAL OF MATHEMATICAL SCIENCES, TECHNOLOGY AND HUMANITIES

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International eJournals

International Journal of Mathematical Sciences, Technology and Humanities 9 (2016) Vol. 6, Issue 4, pp: 81 – 87

MJO using Radiosonde data over a low latitude station

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Abstract

The study of atmosphere cannot be ignored, it is our environment. The lowest region in contact with solid earth, Troposphere, is characterized by a lapse rate such that temperature decreases with height. One of the most important dynamical properties of the atmosphere is its ability to support wave motion. Owing to the importance of dynamics of atmosphere the study of MJO over low latitude station is essential. Many observations have been carried out across the globe to explore MJO in the tropics. In the tropical atmosphere there are several modes of low-frequency oscillations such as interannual, annual, and intraseasonal oscillations. Of these, the MJO (30 to 90 day period) continues to be a topic of significant interest because of its complex dynamics and a wide range of atmospheric physical processes with which it interacts. It is the large scale coupling between atmospheric circulation and tropical deep convection propagating east wards at approximately 5m/s above warm parts of Indian Ocean. Wind and temperature profiles collected by India Meteorological Department over Hyderabad for about two years (Feb 2013 – Sep 2014) has been procured. The continuous data sets of two years will be subjected to FFT analysis to obtain amplitudes and phases of different oscillations. The data collected have been analysed in the present study. Both zonal and meridional components are studied. The multi-annual values of wind for each month are obtained. Meridional velocities in the troposphere between 10km and 20km appears to be predominantly southerly with a maximum speed of 5m/s near tropopause. Above 20 km the circulation turns into northerly for almost all months. Temperature for the same period has been observed sharp inversion at 16km which is tropopause. It is found that the troposphere is dominated by oscillations in two period bands namely (6-8) and (3-4) weeks in meridional wind. The wave amplitude height profiles show that the waves have maximum amplitude below the height of tropopause at about 13-14 km. The wave energy density profile indicates that the sources of these waves are in the troposphere and that a part of the energy might be leaked into the stratosphere through vertical propagation. Further observation and modelling are required to understand the intraseasonal behaviour of wind oscillation and their propagation.

Keywords: Atmosphere, Oscillation, Troposphere, stratosphere, Zonal and Meridional winds Radiosonde etc.

1. Introduction

Troposphere is the lowest region of the atmosphere and is characterized by negative vertical temperature gradient it extends from the earth’s surface up to an altitude at which there is temperature minimum known as the tropopause. The decrease in temperature with increasing altitude in the troposphere is due to the strong heating effect radiation. The troposphere contains 90% of total mass of the atmosphere. It also contains virtually all of the water contents, particularly within the lowest few kilometres.

Meteorological soundings have shown that the temperature decrease with the altitude in the troposphere, reaching a temperature of above 220K in Polar regions and 190K at the equator. The tropopause however varies as function of latitude, from below 10km in the Polar Regions to more than 15km in the equatorial belt.

Earth and atmosphere receive heat from the Sun. As they radiate same amount of heat into space but this heat balance applies only to the globe as a whole and not to any specific area. On the Earth, The equatorial region receives an excess radiation than at the poles, which leads to the formation of raising currents of air at the equator. Heat flows from warm to the cold region, maintaining the observed average temperature. This exchange of heat implies motion of atmosphere and ocean currents and this motion, when summarized over the earth as whole, is called general circulation. This sets up global circulation which essentially moves warm air from the equator to the poles. The simplest observed global characteristics of the atmosphere are that the tropics are much warmer than poles.

The flow of heat towards the poles increase from the equator to about latitude 35deg . From there it decreases as some of the imported heat remains in each belt of the higher latitudes. Outside the tropics, the wind systems of large storms carry out most of the heat exchange. These storms travel mainly from west to east. They form a never ending succession of low pressure centres with winds revolving counter clockwise, followed by high pressure centres with clock wise circulation in the southern hemisphere. Inequalities in heating start the basic north-south motion from warm to cold air. But the rotation of the Earth also generates east west motions in the atmosphere. The air moving toward the pole is deflected to the right in the northern hemisphere), looking along the direction it is moving, so that its path curves eastwards. Air moving toward the equator also deflected to the right and it turns toward the west. Thus we encounter winds near the Earth’s surface from the east in the tropics, the trade winds, and winds from the west in the middle latitudes, the polar westerlies.

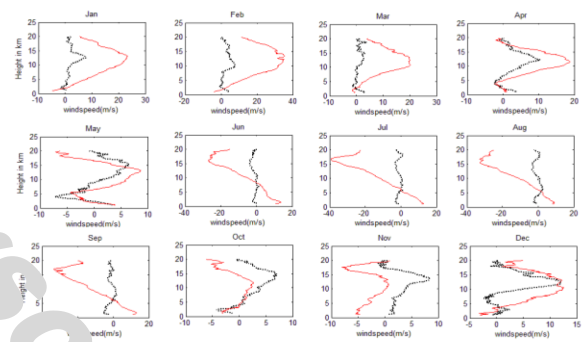
Madden and Julian (1971, 1972) identified a 40-50 day oscillation using spectral analysis of tropical radiosonde data in the zonal wind. Since then, many efforts have been made to explore the characteristics and origin of these oscillations, (Yasunari, 1979; Krishnamurti et al., 1985; Murakami and Nakazawa, 1985; Lau and Chan, 1985, 1986 and others). Until recently these waves were observed only at the tropospheric heights. However, in the last few years, these waves have been noticed than at tropospheric heights (Nagpal and Raghavendra Rao, 1991; Kumar and Jain, 1994).

It has also been observed Madden-Julian oscillation occurs throughout the year with no systematic seasonal variation in amplitude or periodicity (Anderson et al., 1984). However, it was pointed out by several authors that the 30-50 day oscillation is amplified during the northern hemisphere summer over the Indian monsoon region (Yasunari, 1981; Krishnamurti and Subramanyam, 1982) and over the western pacific (Murakami, 1984; Chen, 1987) and is initially related to enhanced convection and rainfall (Madden, 1986). Hartmann and Michelson (1989) have reported that the precipitation exhibits a statistically significant spectral peak at about 40 days over most of the southern half of India during summer.

2. Data Description

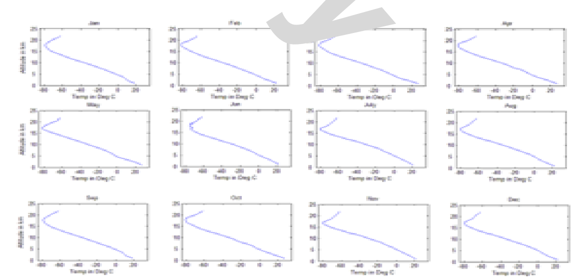
High altitude radiosondes were launched systematically by ISRO from a few Indian stations during middle atmospheric program. Wind and temperature data between Feb 2013 – Sep 2014 over Hyderabad have been used for the present study. There were two flights every day for the complete period Feb 2013 – Sep 2014, weekly averaged values of zonal and meridional wind and temperature provided 83 weeks of continuous data. The altitude region of the study has been restricted to 22 km since all the flights reached this height. Both wind and temperature data sets have been interpolated to yield wind values at every kilometre. Good agreement can be observed between the interpolated and real sets.

The monthly mean wind profiles shown in figure 1 for one year. The data collected from Feb 2013 – Sep 2014 have been analysed in the present study. 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 and southerly for meridional wind case. Model wind profiles for each month are obtained by averaging all profiles in a particular month of all the years. These are called multi-annual values of wind for each month. The model zonal wind profiles have been compared with CIRA – 1986 model for a latitude of 20 deg N which is the closest available to Hyderabad latitude.



1 Monthly mean wind profiles.Solid lines represents Zonal and doted lines Meridional

It is seen that the zonal wind circulation in the troposphere (below 18 km) over Hyderabad has an annual cycle. Westerlies prevail for seven months from June to October. In the lower troposphere between altitude of 1km and 7km, easterlies are observed more frequently. Circulation in the months (June-September) are mostly easterlies. In the stratosphere region, the wind circulation over Hyderabad is predominantly easterly for all months of the year. This has already been reported by Gokhale et.al, (1967), Kumar and Nagpal (1984) and Aleem Basha (1999). The magnitude of wind velocity is found to increase by a factor of two during monsoon months as compared to winter months.



Meridional velocity in the troposphere between 10km and 20km appears to be predominantly southerly with a maximum speed of 5m/s near the tropopause. Above 20 km the circulation turns into northerly for almost all months.

Below 10km, i.e. in the lower troposphere, meridional wind velocity appears to be mostly northerly. Fig 2.Monthly mean Temperature profiles

Temperature Profiles

The temperature data for the same period i.e. Feb 2013 – Sep 2014 for each month are shown in figure 2. The model temperature profiles for each month have also been obtained and are shown in figures. Figure 3 shows mean temperature profile where a sharp inversion can be observed at 17km which is a typical feature of tropics.

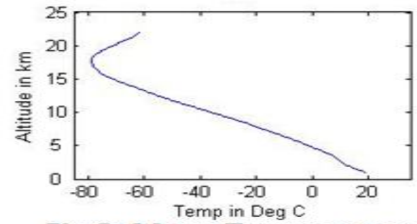


Fig 3: Mean Temperature

The first temperature inversion takes place at the tropopause which is the top of the troposphere and bottom of stratosphere. The tropopause height at extra-tropic are lower than tropics. The formation of tropopause is due to radiative processes influenced by water vapour and ozone in the tropical region, there is more water vapour in the lower troposphere than in the extra-tropical regions. Due to the presence of convective instability in the tropical atmosphere, there is also more convective activity in the tropical regions than elsewhere. Both these factors combine to inject more water vapour into the upper troposphere over the tropics. Hence a sharp tropopause is observed.

3. Data Analysis

Fourier analysis is a powerful tool for the spectral representation of a given time series. It is the process of extracting from the signal the various frequencies and amplitudes present. The Fourier analysis is based on the Fourier transform of the signal into frequency space. The purpose of doing this is to find whether the signal is composed of any periodic influence. Further, its implementation on a computer is easy and with the advent of the Fast Fourier Transform (FFT) it can be done quickly.

For a data series of N points sampled at regular intervals, the Fourier Transform pair is defined as

$$X_k = \sum_{j-0}^{N-1} x_j e^{-2\Pi jk/N} \qquad x_j = \frac{1}{N}\sum_{j-0}^{N-1} X_k e^{2\Pi jk/N}$$

Where X_k denotes the frequency coefficient and x_j represents the time series. The frequencies from which the time signal can be integrated are restricted to the range defined by the length of the data set. The resolvable frequencies are defined as

$$f = \left(\frac{1}{N\Delta t}, \frac{1}{z\Delta t}\right)$$

Where Δt is the time scale and N is the window length of the time series. The factor

fmax = 1/2Δt, is the highest frequency estimate, called Nyquist frequency before aliasing occurs. For the finite data set aliasing occurs, which cause an effective replication of the frequency spectrum at intervals of 2 fmax, thus folding energy from higher frequencies back into the range of ± fmax. The spectral estimates are generated by the modulus of the frequency coefficients.

3.1. Altitude Variation of Wave Amplitude

The continuous data set of 83 weeks have been subjected to spectral analysis and the wave amplitude corresponding to two period bands have been picked up for each height. Averaged altitude profiles of wave amplitude in the two period bands for zonal and meridional winds are found. It can be noticed that these waves have significant amplitudes in the troposphere with maximum amplitude below the height of tropopause near 14km for zonal and 13km for meridional wind case. 6-8 weeks and 3-4 weeks oscillations show maximum amplitude 3m/s and 2m/s for meridional wind. This indicates that 6-8 weeks oscillation is stronger in zonal wind compared to meridional wind. Maximum amplitude of 30-70 days wave observed in troposphere by Kumar and Jain(1994) for Thumba (8.5oN), SHAR(13.7oN) and Balasore (21.5oN) range between 5-7 m/s in zonal wind and 3-7m/s in meridional wind. Their observations show comparable wave amplitude in both zonal and meridional winds for stations SHAR and Balasore. The wave amplitudes obtained by H.Aleem Basha (1999) for the same stations using a shorter data set (50 weeks) is 3 to 6.5m/s) for zonal wind 2-2.5m/s for meridional wind.

4 Results and Disscussion

The 30-60 day oscillation in the troposphere has been intensively studied and is referred to as the Madden-Julian oscillation (MJO) after its discovered by Madden and Julian (1994). It occurs when a large region of convective ascent moves eastward from the Indian Ocean into the Western Pacific (Madden and Julian, 1972), producing 30-60 day periodicities in regional convective activity as it passes (Hartmann and Gross, 1988; Salby and Hendon, 1994; Dunkerton and Crum, 1995). This disturbs the Climatological walker circulation, producing a planetary-scale response of similar period in the equatorial velocity field.

In the forcing region in and around Indonesia and India, MJO activity is characterised by a combined Kelvin-Rossby wave response, whereas at longitudes well away from the forcing region, the activity is dominated by a pure (zonal) Kelvin wave response (Heldon and Salby, 1994, 1996). Our study show strong intraseasonal (7-8 weeks) oscillation in tropospheric zonal wind and week oscillation in meridional wind which can be interpreted as a coupled Kelvin-Rossby mode. Similar results were obtained by Kumar and Jain (1994) for the station Thumba.

3-4 weeks oscillation observed in the present study is found to have comparable amplitudes in both zonal and meridional winds. It should be noted that the MJO's period range can vary considerably and occasionally approaches 25 days (Hayashi and Golder 1993; Madden and Julian, 1994).

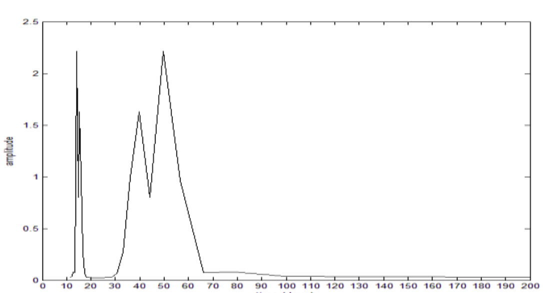


Fig 4

It is well known that MJO activity attenuates rapidly above the tropopause (Madden and Julian, 1971). Studies using rocket and radiosonde data from Indian stations produced similar results (Nagpal and Raghav Rao,1991; Nagpal et.al, 1994; Kumar and Jain, 1994). Kumar and Jain (1994) suggested that the waves leaked into the upper stratosphere from the tropical troposphere via vertical propagation. Fig.4 in the present study supports this explanation.

Zernike and Standford[11] (1991) studied Rossby waves of intraseasonal period (1-2 monts) in eight years of daily global geopotential height data from British Meteorological office analysis. They focussed on strong wave activity in a longitude zone near the east coast of India. This activity initially concentrated in the equatorial troposphere, propagated into the extra-tropical upper troposphere and stratosphere to form a regional dipole pattern about the equator. Similar patterns are also observed at periods ~25 days (Anyamba and Weare, 1995). Eckerman et.al.,[4] (1997) analysedroposphere, propagated into the extra-tropical upper troposphere and stratosphere to form a regional dipole pattern about 86868686 five region over Chrismas Island and detected clear intraseasonal variation in both zonal and meridional winds. They suggested that 30-60 days, 2-25 day and diurnal variations in tropical tropospheric convecvtion produce intraseasonal cycles in the intensity of gravity waves and non-migrating diurnal tides entering the middle atmosphere.

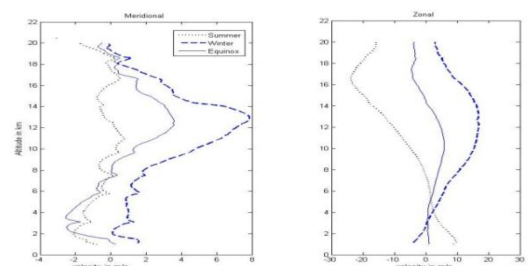


Fig 5: Height profiles of zonal and meridional winds for summer, winter, Equinox

H.Aleem Basha[1] (1999) studied Madden and Julian oscillation over the same station Hyderabad using a short data set of 50 weeks. They identified MJO in two period bonds namely (7-8) and (3-4) weeks in zonal wind and (8-10) and (4-5) weeks in Meridional wind. The amplitudes ranged between 3-6.5 m/s for zonal and 2-2.5m/s for meridional wind.

5. Conclusion

Some important features of the intraseasonal oscillations observed in the present study over a tropical India station, Hyderabad are as follows:

The troposphere is dominated by oscillations in two period bands namely (6-8) and (3-4) weeks in zonal wind and (8-10) and (4-5) weeks in meridional wind. The MJO peaks in the troposphere are broad. It was originally named 40-50 day oscillation by Madden and Julian (1971) although later studies have often referred to it as the 30-60 day oscillation to stress the variable and broad-band nature to the peak. The wind profiles have then been grouped season wise May to Aug (summer); Nov to Dec (winter); and Mar, Apr, Sep, Oct (Equinox) as shown in figure 5.

The wave amplitude-height profiles show that these waves have maximum amplitude below the height of tropopause at about 13-14 km. Studies conducted by Kumar and Jain (1994) using rocketsonde data till 60km show that the wave amplitude in the zonal wind at stratospheric heights just below stratosphere is about 2-3 times larger than at tropospheric heights. Simultaneous studies of these waves in both zonal and meridional winds in the troposphere, their source region, show that the waves in longer period band is stronger in zonal wind and hence, can be considered as a coupled Kelvin-Rossby mode.

Mohammed *et al*[13] also observed winds during January to April are found to be eastward in the troposphere which changes to westward after ~15-16 km. During May-September winds changes to westward.

The magnitude and position of MJO given by Wheeler and Hendon using MJO index. The index is intended to efficiently describe and extract the atmosphere variability directly related to MJO. Principal components of empirical orthogonal functions, real time multivariate MJO (RMM1

&RMM2), are useful indices of MJO. Intraseasonal fluctuations due to the MJO dominate the variation of RMM1 &RMM2. Easterly anomalies persisted across southern Africa and south West Indian Ocean at 850 hPa. MJO was active from late August 2013 through early October 2013 with enhanced phase propagating eastward from Indian Ocean to western Pacific Ocean. MJO Index recent Evolution is the RMM index indicates eastward propagation of a MJO signal ending during the final week of February 2014.

Further observations and modelling are required to understand the intraseasonal behaviour of wind oscillations and their propagation.

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