Radiosonde observations of gravity waves in the lower atmosphere over Istanbul (40º.97'N, 29º.08'E), Turkey

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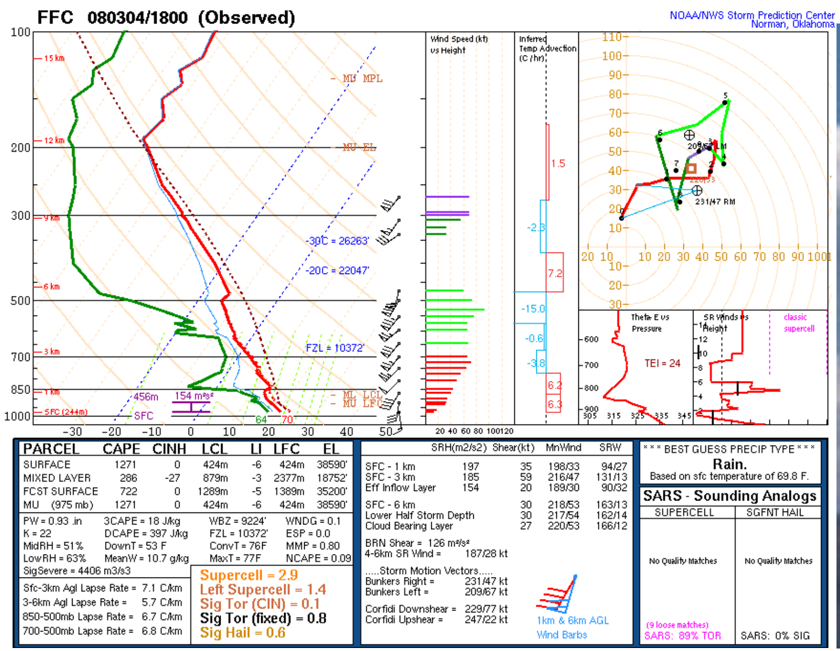

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Introduction

Atmospheric gravity waves are believed to significant impact on the local atmospheric clamotology (Alexander and Pfister, 1995; Alexander, 1998). Gravity waves play significant role for determining the global dynamical and thermal structures in the middle and upper atmosphere (MUA). Gravity waves in the MUA were believed to be generated mainly troposphere and lower stratosphere (TLS) by different sources such as convection, troposheric jet and topography (Fritts and Alexander, 2003). Later, many studies emphasized the importance of the gravity waves so as to understand the global atmospheric dynamics (Manzini and Mcforlane; 1998; Beras et al., 2005; Zhang and Yi, 2005,2007). In studies, radiosonde observations were used to contribute to the researchs due to the excellint height resolution (Tsuda et al., 1994b; Shimizu and Tsuda, 1997; Pfenninger et al., 1999; Vincent and Alexander, 2000; Yoshiki and Sato, 2000; Zink and Vincent, 2001a, b; Innes et al., 2004; Wang et al., 2005; Zhang and Yi, 2005, 2007; Zhang et al., 2006). In each measurement of radiosonde (twice in a day 00:00 and 12:00 UTC) meteorological variables such as pressure, temperature, relative humidity, wind direction and speed are measured from ground to the nearly upper level of 25-30 km. Radiosonde observations provide seasoal and geographical variations of GWs in the lower atmosphere and GWs (intrinsic frequency, amplitude, wave vector, energy density) are specified from the individual measured profiles wind and temperature fields (Allen and Vincent 1995).

Introduction

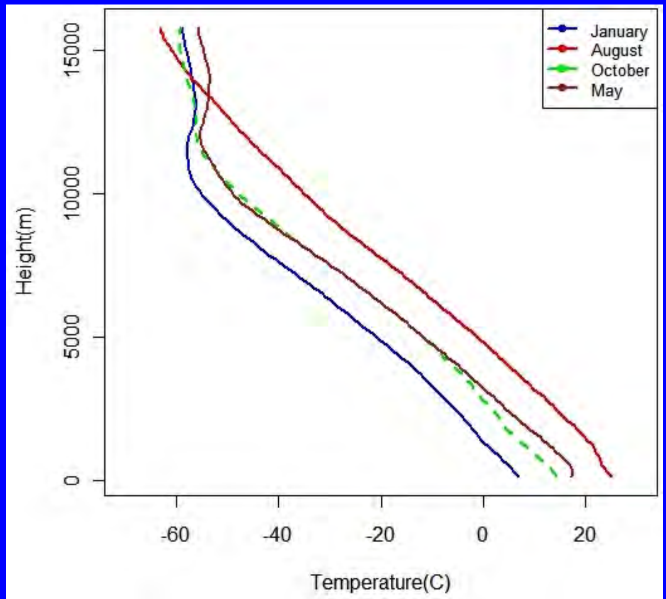
Radiosonde observations at different latitude locations showed that GWs have latitudional variation (Allen and Vincent 1995; Vincent and Alexander 2000, Vincent et al., 1997). Most GWs studies with using radiosonde observations were defined especially in the low-latitudional (or equatorial) (Tsuda et al., 1994 a, b; Shimizu and Tsudo, 1997) or high latitudional (or polar) regions (Pfenninger et al., 1999; Vincent and Alexander, 2000; Yoshiki and Sato, 2000; Zink and Vincent, 2001, a,b). For mid-latitude regions; VHF radars (Fritts et al., 1990; Murayama, 1994; Sato, 1994) generally were used to identify GWs.

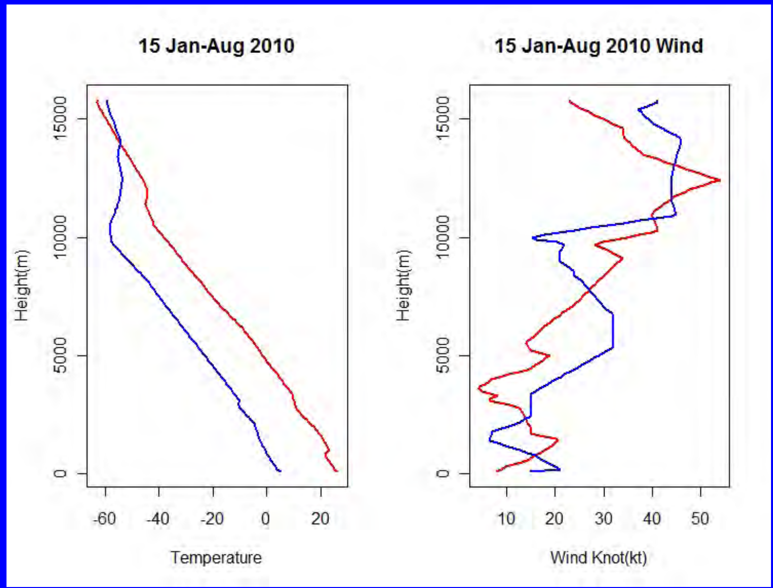
In Turkey, Gravity wave analysis and interaction between GWS and convection are studied in 1998 with using radiosonde data for istanbul between 1993 and 1997 (Aslan Z., Oguz O., 1998). İn this study, it showed that amplitudes of tempereture are lower at the stratosphere than troposphere, horizontal winds speeds at 300 mb level at higher than the other levels, amplitudes of u component at 500, 300 and 100 mb level are greater than 1000, 850 and 30 mb. İn 2002, fourier transform analysis for monthly average values of meteorological parameters have considered with using ground measurements in Turkey (Aslan Z., 2002). The study shows some local effects on meteorological parameters caused by large dam area and irrigation systems over the Eastern part of Anatolia.

In the present paper; we focus gravity wave activity from the radiosonde observation at İstanbul in the 2010 year. A detailed data description is presented in Section 2. methodology are given in Sect. 3. Statistical results are given in Sect. 4. Conclusions are given Section 5.

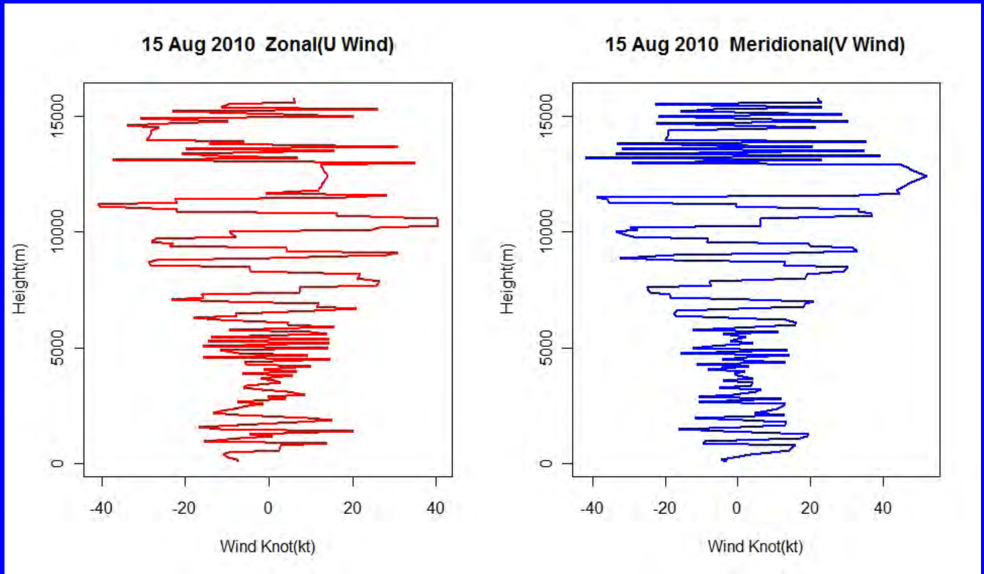
Data Description

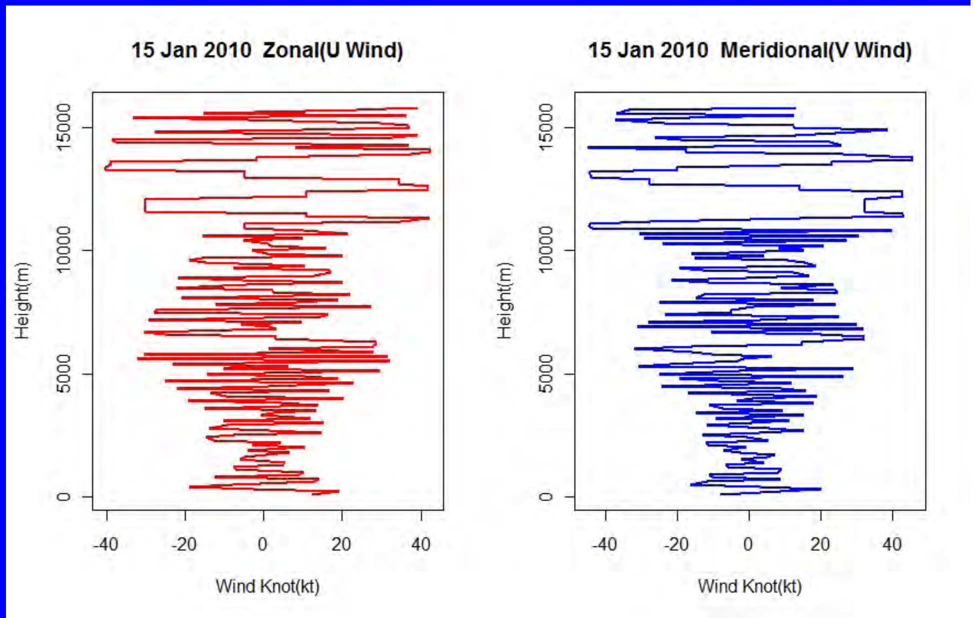
The data used in this paper are from istanbul radiosonde observations for the year 2010. observations were made twice in a day at 02:00 and 14:00 local time. We used 02:00 radiosonde datas. From the data, August, January, May and Nowember data used. Raw data are sampled 1-2 s interval and result uneven height resolution varies from severel to tens of meter. In this paper height resolution used 100 m by applying lineer interpolation temperature, wind measurements and meteorological variables measured in each height resolution. Nearly 365 measurements taken for 2010. The balon goes nearly 25-30 km from ground to the upper levels. In some days, balon can burst below levels. In our data set, we used meteorological variables from ground to the 16 kms up because of the taking whole 365 data without eliminate. To avoid extreme values of temperature and wind we neglect the between 9 and 13 kms because of the jet streams. So we studied from ground to the upper 10 km level





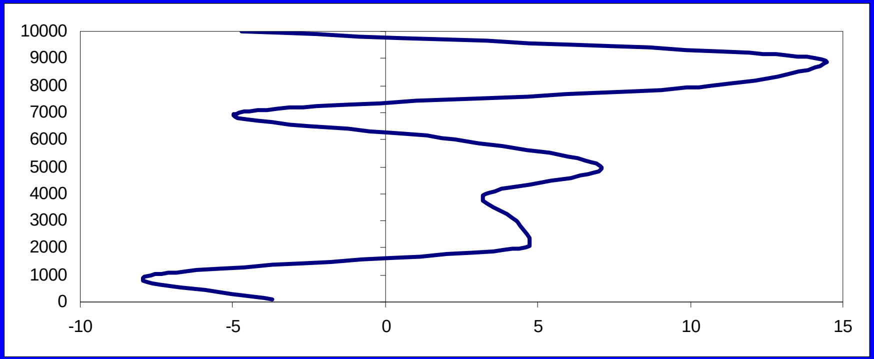
Data Description

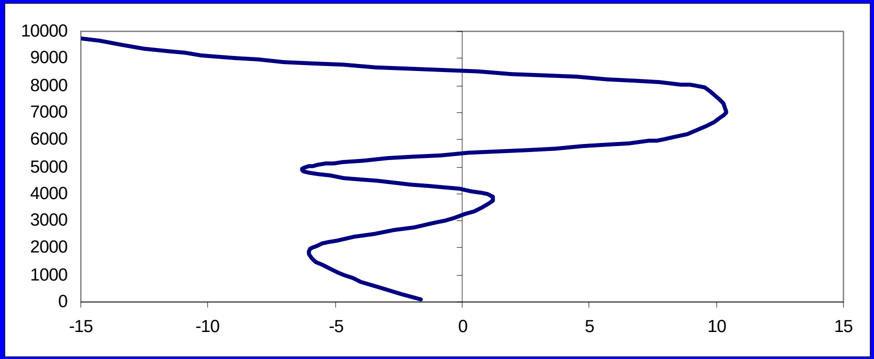




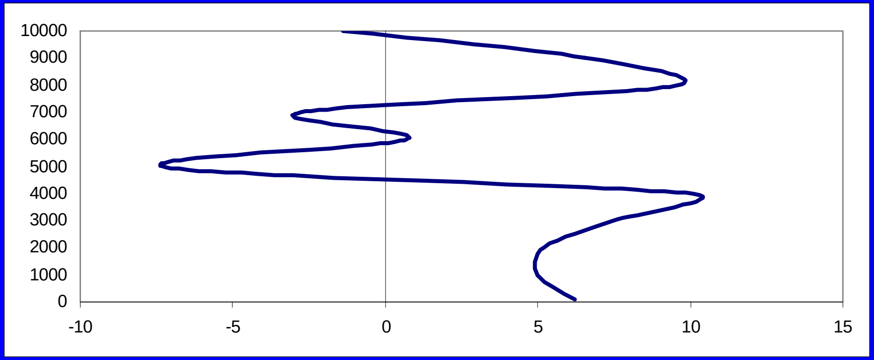
Data Description

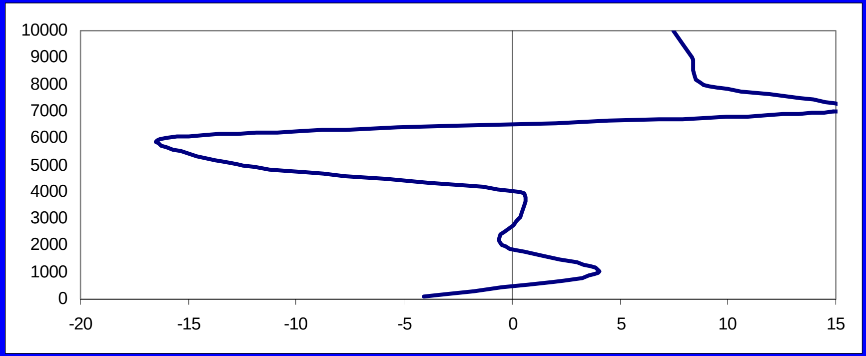
Zonal Winds 15 August 2010 Meridional Winds





Zonal Winds 15 January 2010 Meridional Winds





Harmonic Analysis

In meteorology, harmonic analysis is very significant to identify different climate regimes and transition regions. In harmonic analysis, while the first order shows long term variables, the higher orders identifies short term variables (Justino F. Et al., 2011). Harmonic analysis decomposes time dependet periodic phenemonen into a series of sinusoidal functions, each defined by unique amplitude and phase values (Aslan Z. Et al., 1997).

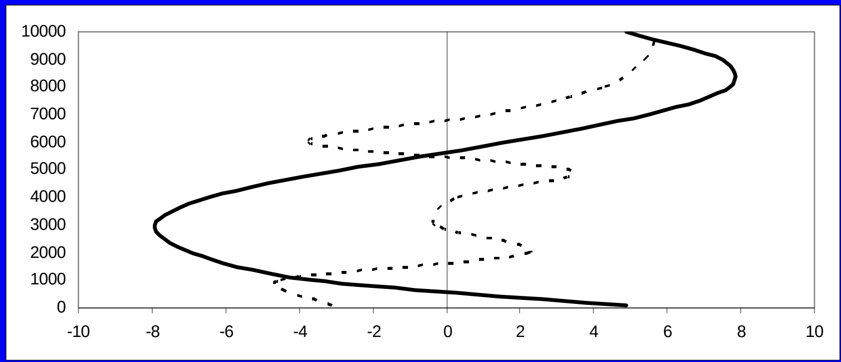
Gw extraction and analysis method in this paper is the same as that Vincent et al. (1997). Firstly, for quasi-monochromatic GWs, we should remove background atmosphere(u0,v0,t0) from the raw data (u,v,T). The fluctuation components (uf,vf,Tf) are taken from the raw data by removing background atmosphere. For remove background atmosphere, we remove the mean wind and tempreture fields from the individial profiles. Fluctuation components are importatant so as to calculate vertical wave number. The quasi monochromatic wave components (u’,v’, T’) are extracted by harmonic fitting to the fluctuation components as the following equation.

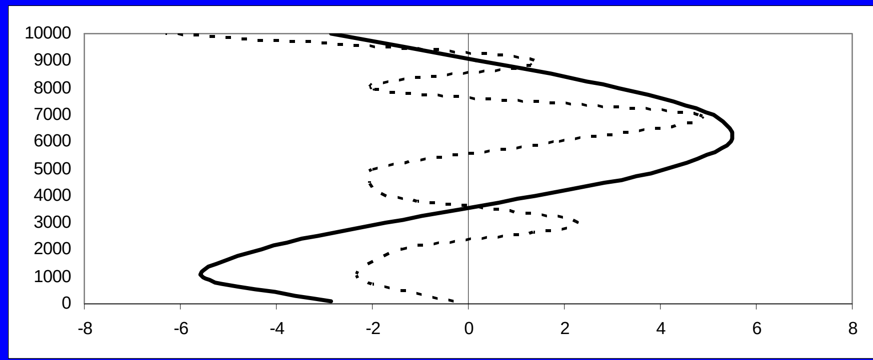
$$U=A\sin(2\pi/\lambda Z\ Z+\Theta)$$

Where U=(uf,vf,Tf) is the fluctuation component, A=(Au, Av, AT) and Ɵ=(Ɵu, Ɵv, Ɵt) are the fitted amplitude and phase of the quasi monochromatic gravity waves , λZ is the vertical wavelength.

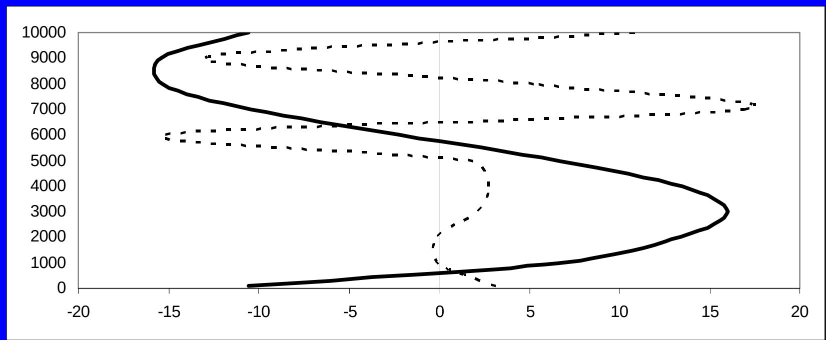
Harmonic Analysis

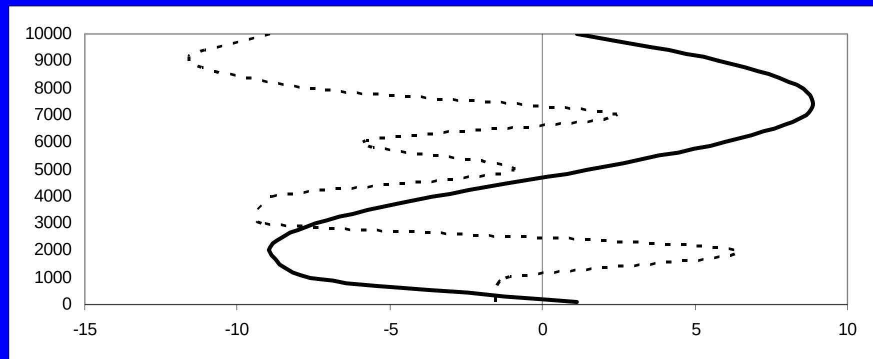
Zonal Winds 15 August 2010 Meridional Winds





Zonal Winds 15January 2010 Meridional Winds



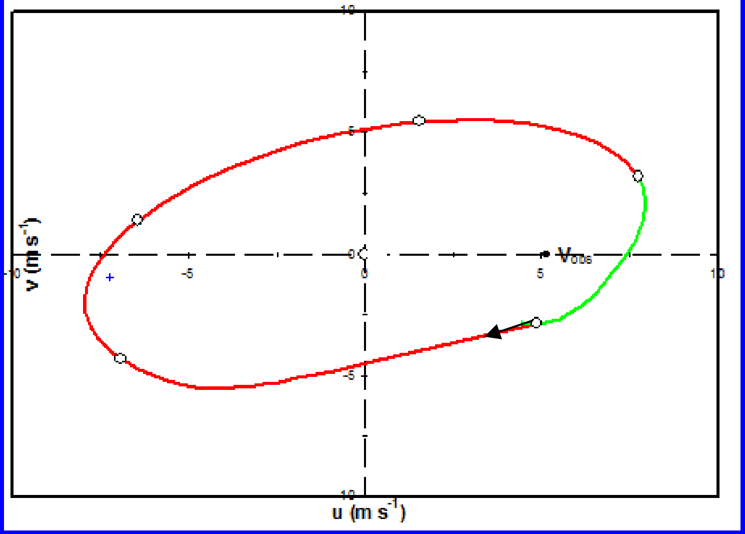


Vertical wind profiles of zonal (**a**) and meridional (**b**) for summer (15 august 2010) and winter (15 january 2010). The solid and dotted lines denote the wave disturbence and fluctuation components.

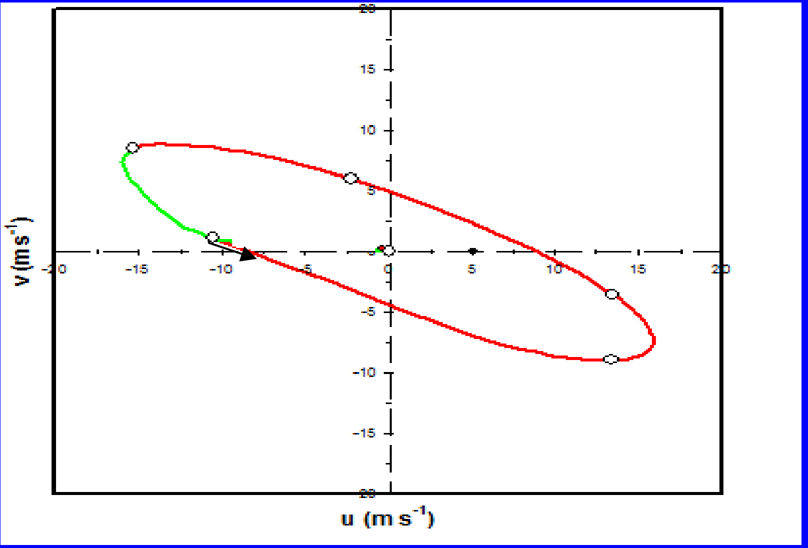
Hodograph Analysis

So as to estimate gravity wave parameters such as wave intrinsic frequency, vertical and horizontal wavelengths, direction of propagation, phase speed; hodograph analysis applied using the harmonic analysis from ground to the 10 km.

15 August 2010

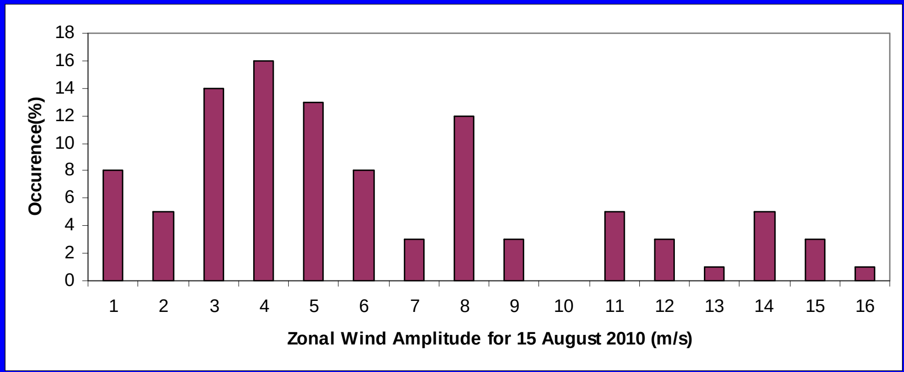


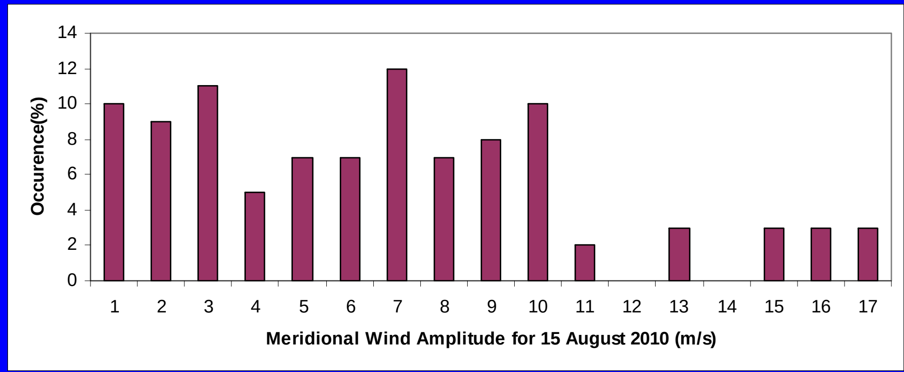
15 January 2010

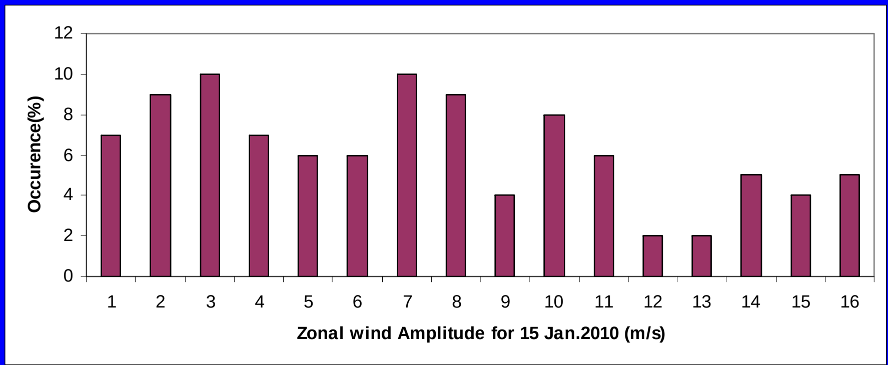


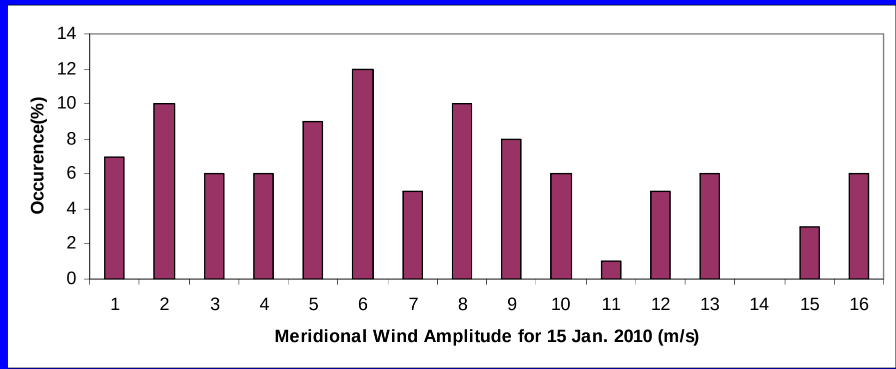
Vertical propagation direction are shown from the hodograph rotation. In the northern hemisphere the clockwise rotation of the wind vector hodographs indicates that the phase is propagating downward and the energy is popagating upward. During monsoon season in the height region of 18-25 km dominant phase propagation (%87) is downward whereas in troposphere (0-14 km) the dominant (%76) phase propogation is upward (Nath D. et al., 2009) From the Istanbul radiosonde observations in figure 4., 15 august 2010 hodograph, while the wave energy propagates upward the phase is propogate downward. And for 15 January 2010, energy propogates downward and phase is propogate upward due to the counterclockwise.

Wave Amplitudes

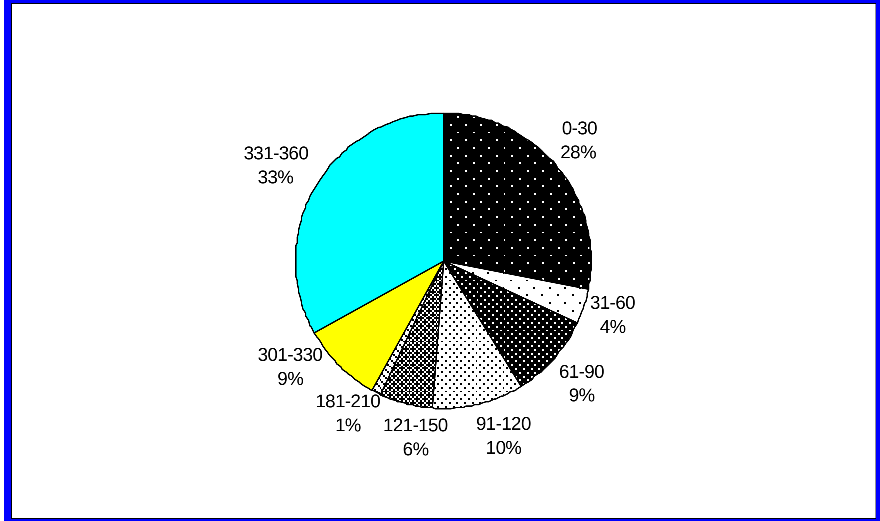


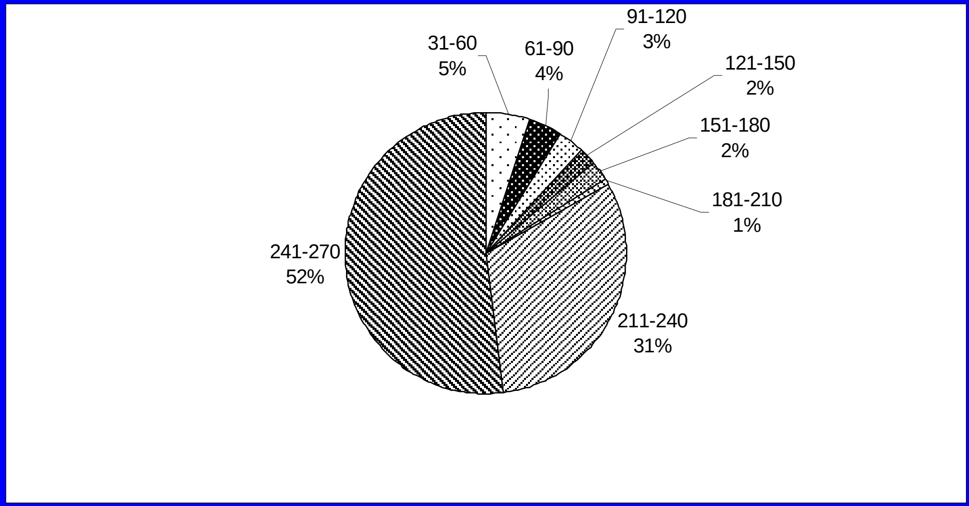






Horizontal Direction of Propogation





15 August 2010

15 January 2010

Horizontal direction of propogation of the gravity waves (in percentage) sorted for every 30º in troposphere. Values 0, 90, 180, and 270 are assigned as eastward, northward, westward, and southward directions.

The horizontal propogation direction of the GW is aligned toward the major axis of the wind vector hodograph. While south and west are taken pozitive, North and east are taken negative. In Figure 6., the mean propogation direction of the GWs is mainly eastward in August and southward in January

Conclusions

Istanbul radiosonde observations for 2010 yer at 00:00 UTC were used so as to statistically study of background atmosphere from ground to the 10 km level. The monthly averaged fluctuations shows below 13 km and the tropopese level estimated 13 km. the minimum temperature shown in summer months near 15 km level as a -61 C. There are not no significant changes between spring and autumn months above 5 km.

in summer profile, zonal winds from ground to the 2 km is eastward, after 2 km to 6 km westward, and magnitude is highest in 9 km nearly 15 ms-1. in winter profile, eastward zonal winds are dominant except between 5 km and 7 km. and magnitude of the zonal winds no larger than 10 ms-1. in meridinal winds in summer, northerly winds are dominant until 5 km and maximum wind speed are seen in near of tropopoze level. After removing the bacground atmosphere,the zonal and meridional fluctuation components for summer profile the magnitude is highest at 10 km nearly 6 ms-1 and highest at 7 km nearly 5ms-1. İn winter profile for zonal winds magnitude is highest after 6 km nearly 15 ms-1 and meridonala winds the highest magnitude is highest 9 km nearly 10 ms-1.

Harmonic analysis fitted the wave disturbance and with using harmonic analysis hodograph analysis extracted so as to estimete gravity wave parameters. And, it can be shown vertical propagation direction from the hodograph rotation. 15 august 2010 hodograph, while the wave energy propagates upward the phase is propogate downward. And for 15 January 2010, energy propogates downward and phase is propogate upward due to the counterclockwise.

Wave amplitudes for summer profile, maksimum seen wave amplitudes in zonal winds between 3-5 ms-1 and in merdional winds the maksimum amplitude 7 ms-1 wth %12 occurence. İn winter profile,the maksimum amplitude for zonal while 3 and 7 ms-1 with the %10 occurence, 6 ms-1 %12 occurence in merdional winds.

The horizontal propogation direction of the GW is aligned toward the major axis of the wind vector hodograph. While south and west are taken pozitive, North and east are taken negative. the mean propogation direction of the GWs is mainly eastward in August and southward in January.