STUDIES OF GRAVITY WAVES AT FERRAZ STATION (62° S) AND RECENT OBSERVATIONS

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Abstract: In this study we will present a brief review of mesospheric gravity waves that have been observed at Comandante Ferraz Antarctica Station, EACF (62.1° S and 58.4° W). First, we will show the main results of a campaign conducted from April to October of 2007, with more than 230 events. The main characteristics of the gravity waves are presented as follows: horizontal wavelengths between 10 and 65 km; periods between 5 and 35 minutes, and phase speed ranging from 5 to 120 m/s. Later, we will show the recent advances related to the observations of temperature, winds and gravity waves in the Mesosphere and Lower Thermosphere (MLT) over Ferraz station. In this sense, examples of temperature and wind data will be presented. Finally, we will show the partial conclusions and future prospects.

Keywords: airglow, gravity waves, temperature, winds

Introduction

The middle atmosphere is a region rich in chemical interactions and with a large variability in terms of dynamics. A wide variety of structures are found in this region, amongst which can be pointed out the airglow layers, metals layers and, at high latitudes a special type of phenomena known as noctilucent clouds. Recent studies suggest that the increase in the concentration of CO and CH during this century can result in significant changes in temperature, density and composition of the atmosphere. Thus, the middle atmosphere has received considerable attention mainly due to the circulation system and global climate change (Gardner, 1995). Considerable progress has been made in the last decades in the study and understanding of the phenomenon of gravity waves in the middle atmosphere (Fritts & Alexander, 2003). Gravity waves are found primarily in the lower atmosphere, and can propagate through the atmosphere until they reach the region of the mesosphere and lower thermosphere (70-100 km height). These waves occur as a result of a displacement of air masses, caused by cold fronts, winds blowing over mountains or by jet streams in the stratosphere. Gravity waves are well known and studied in the meteorology field. However, this phenomenon has received great attention due to its important role in the transporting of energy and momentum from the lower to the upper atmosphere, varying the thermal structure and general circulation in the middle and upper atmosphere (Takahashi et al., 1999). Among the several techniques available for the observation of gravity waves in the middle atmosphere, we can mention meteoric and medium frequency radars, laser techniques,
in-situ observations by rockets, optical measurements from
the ground and from satellites. However, each technique
has its own limitation related to the observation of gravity
waves and only a fraction of the spectrum of these waves can
be solved within a wide spectrum of frequencies and wave
number (Nakamura et al., 1999). Thus, the combination of
observational methods is very important in order to study
the characteristics of gravity waves (Taylor & Gardner,
1998). This paper presents results from a campaign of
atmospheric gravity waves conducted in 2007 at Ferraz
station (62.1° S, 58.4° W). We will also show and discuss
briefly some examples of temperature and winds observed
at Comandante Ferraz station.

Data and Methodology
The main data used in this study was from the airglow
images, from which it was possible to identify the gravity
wave activity in the atmosphere at the altitudes where
the airglow emissions occur. In this study, the observed airglow
emission is the hydroxyl in the near infrared spectrum
(OH NIR, 715-930 nm), with emission peak around 87 km
high. Recently, a meteor radar that operates at a frequency
of 36.90 MHz was installed at Comandante Ferraz station
with the aim of observing and studying the wind field over
the King George Island in the MLT altitude range. The
installation and operation of this radar is a collaborative
effort between National Institute for Space Research (INPE),
Brazil, and Colorado Research Associates (CoRA), United
States of America. Simultaneous observations of wind
and gravity waves will be valuable to better understand
the dynamics of the MLT region on King George Island,
and consequently in the Antarctic Peninsula region.
Furthermore, the temperature structure in the Mesopause
region (~87 km high) has been monitored at Comandante
Ferraz station since 2002. Since 2005 an airglow CCD camera
that observes the OH(6-2) emission through an annular field
of view of 22.6° centred at the zenith has been in use.

The methodology used to extract the wave parameters
was based on analysis of the airglow all-sky images. This
analysis uses the well established Fast Fourier Transform
(FFT) technique, but prior to the application of this analysis
it was necessary to see the images in an animation (”.avi”
file format) to identify the gravity waves occurrence, and
subsequently select a time interval and a spatial region on
the images where each wave was identified. Furthermore,
after this pre-visualization, it was necessary to apply a
pre-processing of the images before the application of the
FFT. The pre-processing basically consists of a rotation in the
images in order to align the top to the geographic north, and
then mapping the image at the height of the airglow emitting
layer to correct the effects of distortion in the images due
to the optical system effects. This process is known as
linearization, and the corrected images are called unwarp
images. The next step is the removal of the stars, followed by
a filtering in the images, and finally the FFT analysis can be
applied to a chosen region on the image, portion on which
a gravity wave event is occurring (identified previously in
the ”.avi” animation). The details of this methodology can
be found in the thesis work of Bageston (2010) and in the
pertinent references.

Results and Discussion
The main results already obtained are related to the
characterization of gravity waves for those observed in
2007. We will also show some recent observations of winds
and gravity waves. The waves characteristics observed at
Comandante Ferraz during 2007 were obtained from the
analysis of the images observed trough the NIR OH airglow
emission, including a total of 234 wave events. Figure 1
shows the observed parameters, that is, the horizontal
wavelength, period and phase speed for these waves. The
intrinsic parameters were also inferred and showed a
similar behaviour to the observed characteristics, but with
a maximum occurrence slightly shifted due to the wind
effect (Doppler shift).

The horizontal wavelengths were distributed from
10 to 65 km, with a maximum occurrence between
20 and 40 km. The observed periods were mainly distributed
between 5 and 35 minutes, but the maximum concentration
was between 5 and 15 minutes. The observed phase speed
has a distribution that extends from 5 to 120 m/s. The
majority of the waves had velocities between 10 and 70 m/s.
The results presented in Figure 1 are very similar to the observations reported in the literature, especially considering the results of observations conducted at other Antarctica stations: Halley (76° S and 27° W) (2000-2001) and Rothera (68° S and 68° W) (2002-2003) (Nielsen, 2007; Nielsen et al., 2009). The horizontal propagation directions showed an anisotropic behaviour during the winter (Bageston et al., 2009), with similarities to the observations conducted at Rothera and Halley, i.e., with preferential propagation direction to southwest and south (Nielsen, 2007).

Temperature in the MLT region has been monitored at Comandante Ferraz since 2002, and from 2005 with a airglow camera, in order to study effects of gravity waves in this parameter and also to investigate, in the future, the long term variability in the Mesopause region. Figures 2 (a) and (b) shows one example of temperature and airglow intensity, respectively, during one entire night during 2007. The small scale variability in the temperature and OH intensity during the night could be related to small scale gravity waves. The large and abrupt decrease in the OH(6-2) intensity and temperature, denoted by the arrows, were related to the passage of a mesospheric wall (extensive gravity wave event) above Ferraz (Bageston et al., 2011). Recently, gravity wave and wind observations at Comandante Ferraz station are registering good quality recordings, and this data will be used soon for a detailed investigation of the dynamics of the MLT region over Comandante Ferraz. However, this data, including temperature data, are still in Antarctica, and will be sent to Brazil by the end of this year. Fortunately, some examples of winds data were obtained remotely from Comandante Ferraz. Figure 3 shows one example of winds observed during two days, 12-13 September 2010. The main characteristic observed from Figure 3 is the well defined semi-diurnal tide, that is, oscillations in the zonal and meridional wind components over a period of about 12 hours. In addition, it is possible to identify that the winds

![Figure 1. Histogram plots of the gravity wave characteristics observed at Comandante Ferraz station in 2007. The panels show, from top to bottom, the horizontal wavelength, observed period and horizontal phase speed.](image-url)
in the upper altitudes (94 km) are more intense than at lower altitudes (85 km).

Gravity wave activity observed last year, by analysing some observed nights, seems to be similar to the activity observed in 2007, but with less useful data in 2010 in comparison to the observations carried out in 2007.

Conclusions and Future Prospects

In summary, the present study has shown the main characteristics of the gravity waves observed at Comandante Ferraz station in 2007, which were consistent with previous observations in Antarctica, in particular to the wave parameters obtained from the observations at Rothera. Currently, three instruments are in operation at Comandante Ferraz with the objective of studying the dynamics and the thermal structure of the mesosphere and lower thermosphere over the King George Island. The most recent instrument installed at Comandante Ferraz, at the beginning of last year, was the meteor radar that is currently in operation through a collaborative effort between the Colorado Research Associates (CoRA), from United States, and National Institute for Space Research (INPE), from Brazil. The primary objective of this radar is to observe the wind structure between 80 and 100 km altitude. Besides the radar, other two airglow cameras (which belong to INPE) are in operation with the aim of monitoring the gravity wave activity in the mesosphere, and then characterize these waves, and observe the mesopause temperature structure. By using temperature observations it is possible to monitor the long term variability of the thermal structure, and conduct
Figure 3. Examples of winds observed on 12-13 September 2010 by the meteor radar installed at Comandante Ferraz station in March 2010.

studies to identify signature of waves of different scales in the temperature and in its day-to-day variability. Future investigation will include the use of local winds, as observed by the meteor radar, to study the wave filtering process due to the background winds. Moreover, these winds also will be useful in investigations of the gravity wave sources with the reverse ray tracing modelling.

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