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IMADYN : A field campaign to evaluate the potential of infrasound monitoring for atmospheric dynamics studies

A. Hauchecorne[1], F. Dalaudier[1], C. Cot[1], E. Blanc[2], A. Le Pichon[2], J.-M. Perrin[3]

[1]LATMOS - IPSL, CNRS, UVSQ, Quartier des Garennes, 11, boulevard d'Alembert, 78280 Guyancourt., France
[2]Laboratoire de Géophysique, CEA DIF F-91297, Arpajon
[3]Observatoire de Haute-Provence, F-04870 St Michel L Observatoire

The infrasound monitoring is a new technique to study the dynamics of the upper atmosphere. Infrasound waves are refracted by the various atmospheric layers depending on the vertical profile of wind and temperature. The measurement of the characteristics of infrasound signals brings then very useful information on the structure and dynamics of the upper atmosphere. In the IMADYN project proposed to the French Agence National de la Recherche, specialists of atmospheric dynamics and infrasound atmospheric propagation will work together to assess the potential of the IMS network of microbarometers of the Comprehensive Nuclear-Test Ban Treaty-Organisation (CTBT-O), in order to improve our knowledge of the dynamics of the middle and upper atmosphere. The proposal is composed of two parts, the first one based on the exploitation of the existing IMS database in comparison with available meteorological and climatological atmospheric models. The second one is based on the organization of a field campaign at the Haute-Provence Observatory equipped with state of the art lidars and radars systems were microbarometers will be installed for a detailed study of infrasound propagation and atmospheric waves and perturbations.

1 Introduction

The infrasound monitoring is a new technique to study the dynamics of the upper atmosphere. Infrasound waves are refracted by the various atmospheric layers depending on the vertical profile of wind and temperature. The measurement of the characteristics of infrasound signals brings then very useful information on the structure and dynamics of the upper atmosphere. In the IMADYN project porposed to French Agence Nationale de la Recherche (ANR), specialists of atmospheric dynamics from LATMOS (CNRS) and infrasound atmospheric propagation from the Département Analyse et Surveillance de l'Environnement (CEA/DASE) will work together to assess the potential of the IMS network in order to improve our knowledge of the dynamics of the middle and upper atmosphere. During this project a field campaign will be organized at the Haute-Provence Observatory, an astronomical and geophysical site equipped with state of the art atmospheric lidar and radar systems and where we plan to install microbarometers for a detailed study of infrasound and gravity waves propagation.

2 Scientific background

Large-scale atmospheric waves affect the different layers of the atmosphere and play an important role in the global Earth dynamics. The vertical transport of gravity waves momentum produces a forcing of the stratosphere at low and middle latitudes and long-lived changes in the stratospheric circulation [3], transmitted towards high latitudes and leading to fluctuations in the strength of the polar vortex [15]. Such fluctuations in the Polar Regions move down to the lower stratosphere with possible effects on the troposphere and on climate [24]. The dynamics of the stratosphere is integrated in the most recent climate models. However, the wave parameterization, needed to represent the general circulation, is only poorly constrained by observational data [1]. Furthermore, most of meteorological and global climate models do not cover the upper stratosphere (30-60 km altitude) and the mesosphere (60-90 km), limiting the possibility to describe correctly the general circulation in this region.

The mesosphere is a key region to understand the relation between solar activity and earth atmosphere and climate. It is strongly affected by changes in UV solar spectrum and particle precipitation and a cooling is observed due to the increase of greenhouse gases [13, 16]. Atmospheric waves are, most of the time, measured locally or regionally by ground based stations and balloons with a good time resolution, while satellites provide global averaged statistics but are not adapted to measure fluctuations at the gravity wave scale with global coverage [26]. The wave systems are complex as several waves from different origin can often be observed at the same time [23]. Their observation is then difficult and need to be performed by instrumentation networks or complementary experiments for a better understanding of the source mechanisms and their propagation.

The new IMS (International Monitoring System) network of microbarometers of the Comprehensive Nuclear-Test Ban Treaty-Organisation (CTBT-O) offers global and long term observations of infrasound and gravity waves which have never been performed up to now [4, 14]. It permanently detects infrasound and large scale gravity waves associated with different kind of sources such as thunderstorms (about 2000 storms permanently on the Earth), ocean swells, wind over mountains or tsunamis [2, 5, 10, 11, 17]. Depending on the atmospheric wind structure, infrasound waves propagate in the acoustic wave-guides between the ground and the stratosphere and the lower thermosphere [9] up to thousands of kilometres. As examples, infrasound waves produced by winds over Andes Cordillera in Bolivia were observed in French Guyana and gravity waves produced by the eruption of Mount St Helens were observed after having propagated around the Earth [8].

The use of infrasound signals from quasi-permanent and well-identified infrasound sources as a remote sensing method to probe the atmosphere was suggested by the pioneer work of [22]. However, results were mainly quantitative. Taking advantage of new signal processing methods and efficient array design [14], measurements of quasi permanent sources of infrasound are now available and provide a basis for more accurate atmospheric investigations [18]. Because of the lack of observations above 50 km, the current techniques that are used to estimate the wind fields are not accurate. [19, 20] demonstrated that infrasonic waves from active volcanoes provide powerful means to reconstruct the vertical structure of the wind profiles in ranges of altitudes were operational observations are rare. Implications are then important for measuring fine temporal fluctuations of winds at scales of hours or days and adjusting the existing semi-empirical atmospheric models in the upper stratosphere and lower thermosphere [9]. Recent studies in Polar regions pointed out seasonal anomalies in the structure of the stratospheric wave guide, which could be explained by a large stratospheric disturbance [5, 6]. At a smaller time scale, lower than one day, a modulation of the wave guide by gravity waves is also observed. In Central Europe, the unique configuration of the existing infrasound network with respect to its density and homogeneous analysis has enhanced our understanding of the dynamics of the upper atmosphere at regional scale and their related effects on the network detection capability [21].

3 Field campaign at OHP: evaluation of the potential of infrasound sounding for atmospheric dynamics studies.

In the IMADYN project, specialists of atmospheric dynamics from LATMOS (CNRS) and infrasound atmospheric propagation from the Département Analyse et Surveillance de l'Environnement (CEA/DASE) will work together to assess the potential of the IMS network in order to improve our knowledge of the dynamics of the middle and upper atmosphere. The proposal is composed of two parts, the first one based on the exploitation of the existing IMS database in comparison with available meteorological and climatological atmospheric models. The second one is based on the organization of a field campaign at the Haute-Provence Observatory equipped with state of the art lidar and radar systems and where we plan to install microbarometers for a detailed study of infrasound and gravity waves propagation. We develop below the description of the field campaign.

Observatoire de Haute-Provence (OHP, 44°N, 6°E) is equipped with powerful instruments to sound the atmosphere from ground up to the upper mesosphere (90 km). This gives a unique opportunity to compare infrasound data with well-resolved wind and temperature local profiles from lidar, radar, balloon sounding and interferometer in order to characterize the effect of atmospheric phenomena on infrasound propagation:

- gravity waves and atmospheric tides
- planetary waves and stratospheric warmings during the winter season
- lightning and sprites during the summer season

We propose to install at OHP an experimental infrasound array. Summer and winter campaigns will be organized: one summer campaign from June to September will cover the thunderstorm period and one winter campaign from December to March will cover the period of planetary wave activity and sudden stratospheric warmings.

The experimental infrasound station used for the campaign will be composed of 4 microbarometer located in a triangle (1 km basis) with a central point. The station will be comparable with the station developed for the international IMS system. Sensors are MB2005 microbarometers. Data, transmitted from each station component to the central point via radio links will be archived in the central station on a removable disk. The disk will be sent each week at DASE where they will be processed by the operational methods developed by DASE.

During these campaigns the instruments dedicated to the monitoring of wind and temperature profiles at OHP will operate routinely. LATMOS developed two Lidars set-up at Haute-Provence Observatory (OHP) to study the temperature and wind structure of the middle atmosphere. The Rayleigh Lidar is operated routinely in the frame of NDACC (Network for the Detection of Atmospheric Composition Changes) allow to monitor the long term evolution of the stratospheric and mesospheric temperature in the altitude range 30 to 80 km with a good temporal coverage over long periods and are then well adapted for climate studies, trend detection as well as dynamics studies [12? 13]. The Doppler wind Lidar uses a two- zones-Fabry-Perot filtering two narrow spectral bands on each side of the Rayleigh spectrum and enables the measurement of horizontal wind speed by intensity difference. It provides vertical profiles from 5 to 45 km and is operated during dedicated field campaigns [7]. Both lidars provide simultaneously mean vertical profiles and perturbations associated with gravity waves. They are operated during night. These instruments are completed by a VHF radar providing horizontal wind profiles from 1km to 12-15 km during day and night [25]. This will allow a detailed description of the infrasound propagation and the comparison between the characteristics of gravity waves observed in altitude and on the ground using the experimental infrasound array.

4 Conclusion

The infrasound monitoring is a new technique to study the dynamics of the upper atmosphere. It offers exciting new perspective for the sounding of a region of the atmosphere where few measurements are available and that is very sensitive to global climate changes. During the IMADYN project proposed to ANR, specialists of atmospheric dynamics and from infrasound atmospheric propagation will work together to assess the potential of the IMS network in order to improve our knowledge of the dynamics of the middle and upper atmosphere.

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