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Airglow observations of orographic, volcanic and meteorological infrasound signatures

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ABSTRACT

Infrasound is generated by several different natural hazards as, e.g., volcanic eruptions and severe weather, but also due to orography (flow over mountains) or anthropogenic sources (e.g. explosions). It propagates from the surface to the middle and upper atmosphere, is characterized by pressure and temperature fluctuations on its path and is reflected back to the ground in so-called ducts. The effects of infrasound in terms of temperature fluctuations in the middle atmosphere, especially in the mesopause altitude region (80–100 km), can be observed using ground-based airglow spectrometers as, e.g., the GRIPS (GRound-based Infrared P-branch Spectrometers) instruments of the German Aerospace Center (DLR).

A method to identify and spectrally analyse infrasound signatures in mesopause temperature time series derived from nocturnal GRIPS airglow observations is presented. The automatic identification of spectral features in the observations and association to distinct infrasound sources is described. Source verification is performed by considering weather situations, volcanic activity and infrasound propagation modelling.

The results in terms of identified infrasound sources of orographic, volcanic and meteorological origin are presented and discussed for a number of different case studies.

1. Introduction

Airglow observations of orographic, volcanic and meteorological infrasound signatures have been performed within a project of the Bavarian State Ministry for Environment and Health called CESAR ("Charakterisierung des differentiellen Energiegehaltes von Vb-Zyklonen über die Quantifizierung abgestrahlter Schwere- und Infraschallwellen in der Atmosphäre" , translated: characterization of the differential energy content of Vb cyclones by quantifying emitted gravity and infrasonic waves in the atmosphere). The quantification of gravity wave and infrasound activity of Mediterranean storm systems and the characterization of their differential energy content have been performed to improve the medium-range forecast of severe weather events and storm tracks. The emission of atmospheric waves by the convective activity of thunderstorms, frontal passages and cyclones has been investigated to distinguish these signatures from other natural or anthropogenic wave signatures and thus to identify and quantify severe weather activity in the vicinity of the different measurement sites.

Data from airglow measurements, radiosonde ascents and satellite observations have been analysed within the project to derive infrasound and gravity wave features with a set of different spectral analysis techniques. An automatic procedure for the analysis of airglow observations, identification of potential wave signatures and verification of associated infrasound sources is presented within this study.

Infrasonic waves are sub-audible sound waves with frequencies of 20 to 0.003 Hz corresponding to periods between 0.05 and 300 s (see e.g. Le Pichon et al., 2010 for a recent and comprehensive overview on infrasound topics). Infrasound is generated by a variety of different sources of natural or anthropogenic origin as, e.g., earthquakes, volcanic activity, aurora, severe weather and man-made explosions (see e.g. Gossard and Hooke, 1975; Blanc, 1985). Infrasonic waves are small-scale pressure fluctuations which propagate over long distances in the atmosphere following certain propagation patterns described, e.g., by ray-tracing methods (see Drob et al., 2003; Jones et al., 2004; Pilger and Bittner, 2009). Infrasound effects can be observed in situ, e.g., by high resolution surface pressure measurements of microphones or microbarometer

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arrays (see Le Pichon et al., 2009; Christie and Campus, 2010) and also by remote sensing techniques observing atmospheric temperature or ionospheric electron density variations with high temporal resolution (see Bittner et al., 2010; Sindelarova et al., 2009). Therefore, infrasound is also observable in temperature time series derived from airglow intensity observations of the mesopause altitude (80–100 km).

The airglow emission (see Khomich et al., 2008 and references therein) is electromagnetic radiation in the visible and infrared spectrum, generated by the de-excitation of atoms and molecules concentrated in certain layers of the atmosphere. The most prominent airglow originates from a layer of hydroxyl (OH) molecules with a half width of approximately 4 km centred in around 87 km altitude, in the mesopause altitude region. The OH airglow emission can be observed by ground-based infrared spectrometers as, e.g., the GRIPS (GRound-based Infrared P-branch Spectrometers) instruments used within this study (see Bittner et al., 2010; Schmidt et al., 2013).

The identification and discrimination of infrasound by different sources in airglow measurements is illustrated in exemplary observations in the course of this paper. Considered infrasonic sources are mountain-associated waves, volcanic eruptions and severe weather sources.

The paper is organized as follows: details of airglow observations are described in Section 2. A combination of spectral analysis techniques and source verification methods for infrasound signal detection is elaborated in Section 3. Results in terms of example cases for orographic, volcanic and meteorological infrasound signatures are presented and discussed in Section 4. Section 5 gives a final summary and outlook.

2. Observation method

Airglow observations are performed using infrared spectrometers observing the nocturnal hydroxyl (OH–) emission originating from an altitude layer of about 87 ± 4 km, located in the mesopause altitude region of the middle atmosphere (height of ~80–100 km). The airglow emission in terms of visible and infrared radiation is generated by the rotational–vibrational relaxation of excited OH-molecules formed by an exothermic reaction of ozone and atomic hydrogen (see e.g. Bates and Nicolet, 1950; Baker and Stair, 1988). The intensity of the OH emissions can be used to derive rotational temperatures, which are a good tracer for the actual kinetic temperature in the emission altitude (see Meinel, 1950; Pendleton et al., 1993). Time series of

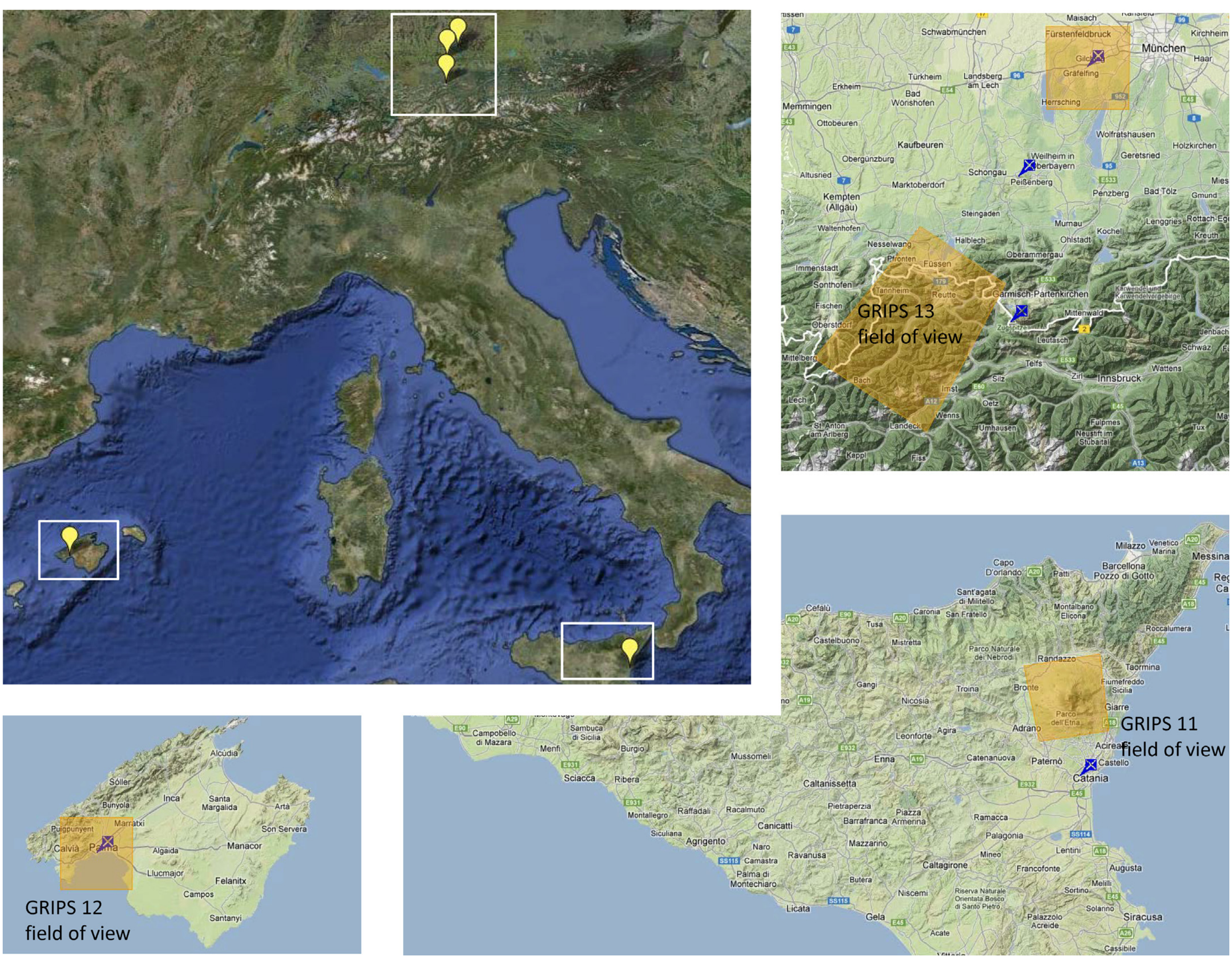

Fig. 2.1. Map [©Google] of the GRIPS 11, 12 and 13 instruments and fields of view on Sicily, Mallorca and in southern Germany. Instrument locations are shown by yellow/blue markers (uppermost one for GRIPS 13), fields of view by labelled orange rectangles/trapeziums. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)