4122 SPRITE-ATTRIBUTED INFRASONIC CHIRPS -THEIR DETECTION, OCCURRENCE AND PROPERTIES BETWEEN 1994 AND 2004

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Abstract

During the last 10 years, infrasonic chirps in the frequency range 0.5 – 8 Hz were occasionally observed by arrays belonging to the Swedish Infrasonic Network (SIN). These chirps have been attributed to certain types of thunderstorm activity associated with the high altitude discharges, red sprites (Liszka, 2004).
In this report, a method for automatic detection of chirps in the recorded data has been developed and applied to 10-year data from two arrays belonging to the SIN: Jamton and Lycksele. The temporal and directional distribution of the phenomenon is demonstrated. Also, long-term variability and possible relation to the solar cycle is studied.

1. Introduction

Infrasound chirps from sprites

(examples of recent works)

- Liszka, 2004: Observed chirps in Sweden are from high altitude according to Ray-tracing calculation.
- Farges et al., 2005: Confirmation of infrasound chips from red sprites from simultaneous observation of infrasound with the optical images (Euro sprites).

Aims of current work

- Applying automatic detection technique to sprite related (high-altitude origin) infrasound chirps.
- Locating the infrasound sources by using well-established infrasound chirp event to relate them with sprites.
- Demonstrating the long-term variability of numbers, source distribution of infrasound chirps to be compared with the solar activity.

Approach

- Ten-year data from Swedish Infrasonic Network (SIN).
- The rule system applied to the scalogram to detect the chirps.
- Ray-tracing calculation to determine the propagation and source characteristics of the observed chirps.

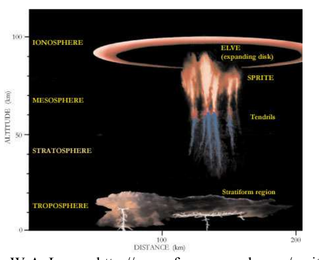


Fig. 1. W.A. Lyons: http://www.fma-research.com/spriteres.htm

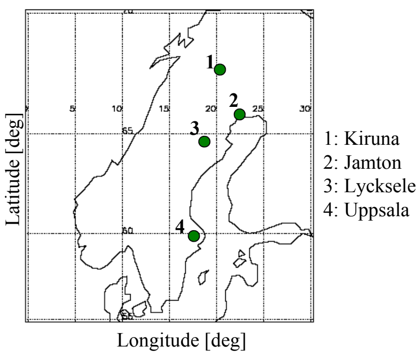


Fig. 1(b). Distribution map of the Swedish infrasound network (SIN).

2. Possible generation mechanism of chirps from sprites

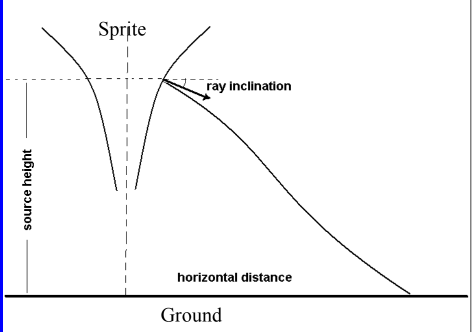


Fig. 2. The geometry of the infrasound generation by red sprite.

Red sprite:

- Transient luminous event in the altitude range from 55-80 km.
- Life time of milliseconds to tens of milliseconds.
- Predominantly associated with large positive ground flash.

Sprite as an Infrasound source:

- Two possible mechanisms (e.g. Farges et al., 2005).
  - -Expansion of the rapidly heated lightning channel.
  - -The drag due to the motions of the charged particles.

Formation of chirp:

- Rather narrow angular range of infrasound emission.
  - e.g. Case of carrot or bomb sprite shown in Fig. 2.
  - -Low altitude source: Wave vector ~ horizontal
  - -High altitude source: Wave vector ~ negative inclination
- Frequency dependence of the propagation time.
  - -Low frequency component: Short propagation time
  - -High frequency component: Long propagation time

3. Search for chirps from sprites

Procedures:

- Running Morlet wavelet transform for 30-minute data record.
- Generating scalograms with 200 samples window (e.g. Fig. 3(a)).
- The rule system is applied to analyze the data.

Search algorithm:

- Time limitation: Time duration > 2.78 sec (50 samples)
- Frequency limitation: Moving across at least 6 dilations

Chirp parameters calculated:

- Highest frequency (lowest dilation) : Minimum source altitude
- Lowest frequency (highest dilation) : Maximum source altitude
- Duration and slope
- Epoch
- *Arrival angle from the north
- *Phase velocity
- *Average amplitude
- Maximum product of all 3 cross-correlations within the array

*At the maximum cross-correlation

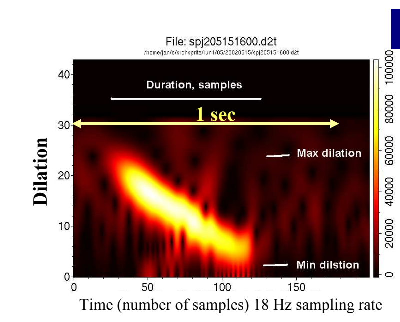


Fig. 3(a). A typical infrasonic chirp.

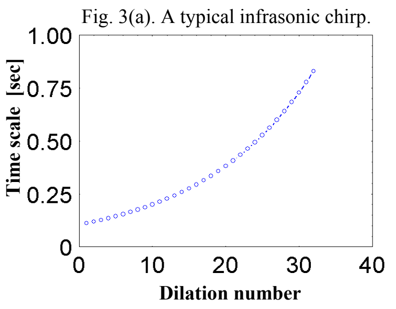
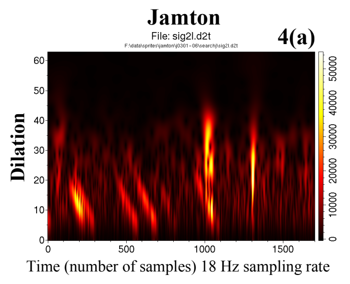


Fig. 3(b). Conversion of the dilation number into the time scale in second.

4. Case study on May 13, 2003

4.1. Infrasound observation



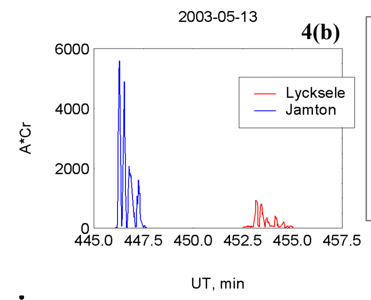
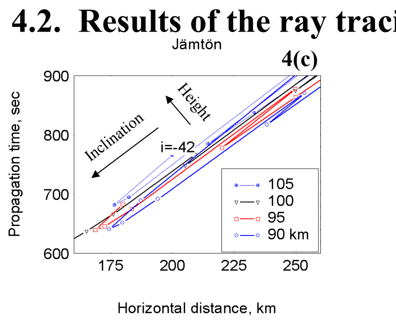


Fig. 4(a). Scalogram from Jamton.

Fig. 4(b). The average signal amplitude of same events at two different stations.

4.2. Results of the ray tracing



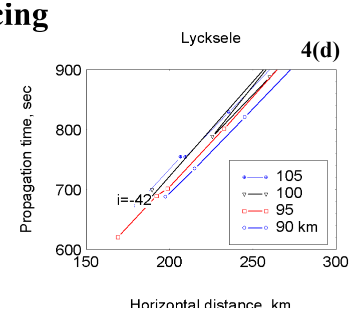


Fig. 4(c). Results of ray tracing computation for Jamton station. Propagation time as a function of the horizontal distance for varying incident angle and source altitude.

Fig. 4(d). Same variations as 4(c) but for Lycksele station.

- Rather clear 5 infrasound chirps in the Jamton station (Figs. 4(a)), no chirps but the emissions observed in Lycksele.
- The source position of the infrasound emission was determined (64.42 N 23.53 E, over the Gulf of Bosnia) by using the triangulation technique from signals from two different stations (Fig. 4(b)).
- Increasing the infrasound source altitude moves the curve upwards to the left (Figs. 4(c) and 4(d)).
- For Jamton, the chirp may be formed at the upper branch due to increase of source altitude with decreasing inclination angle (Fig. 4(c) and Fig. 2).
- For Lycksele, the chirp was not observed because there is only the lower branch on the curve (Fig. 4(d)).

4.3. Comparison with the meteorological data

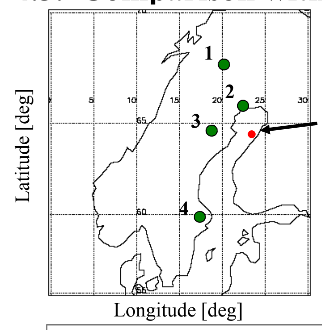


Fig. 4(d)

Source location of the infrasound emission (red circle).

Onset time: ~07:26 UT

Geographical Coordinate: [64.42 N, 23.53 E]

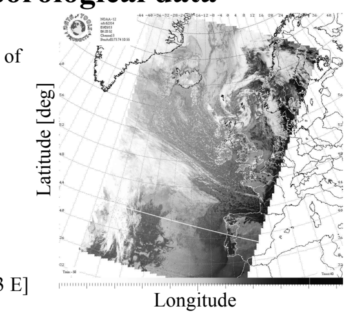


Fig. 4(e) Cloud distribution from the NOAA 12 satellite at 0620 UT on May 13, 2003.

- The sharp front of cloud system is clearly identified near the infrasound source location (northern part of Gulf of Bosnia) according to the NOAA data around the observation time (Fig. 4(d) and 4(e)).
- There were remarkable thunderstorm activity reported in the morning over the Gulf of Bosnia and southern costal area of Sweden.

5. Statistical study between 1994 and 2004

5.1. Search results

Station	Number of chirps from 1994 to 2004
Jamton:	114
Lycksele:	4
Uppsala:	2
Kiruna:	0

- Large number of events observed in Jamton.
- Small number of events in Kiruna and Uppsala due to rather high background noise level.
- Small number of events in Lycksele despite of the low background noise is due to the propagation effect from the source region (See interpretation of Fig. 4(d) in the slide 6).

5.2. Occurrence of chirps at Jamton

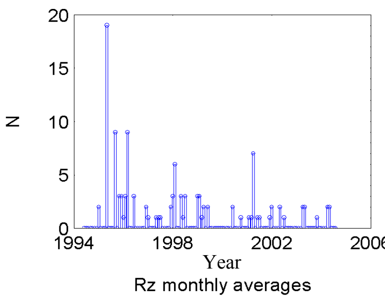


Fig. 5(a). Monthly occurrence frequency of infrasonic chirps at the Jamton station during the period 1994-2004.

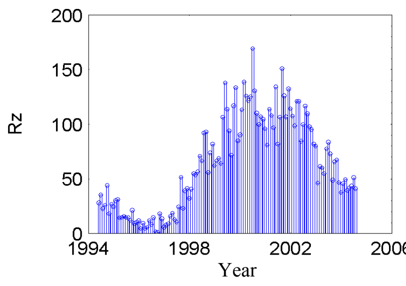


Fig. 5(b). Monthly averages of sunspot numbers during the period 1994-2000.

Occurrence frequency of infrasound chirps may be anti-correlated with the degree of solar activity indicated by the sunspot numbers.

-Occurrence frequency of chirps is very high and the sunspot numbers is small in ~1995.

-Occurrence frequency of chirps is very low and the sunspot numbers high small in ~2000.

5.3. Arrival angles of chirps at Jamton

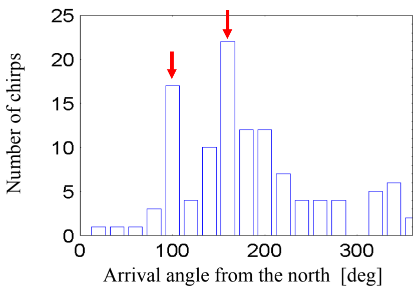
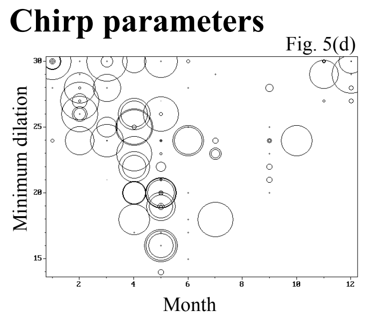
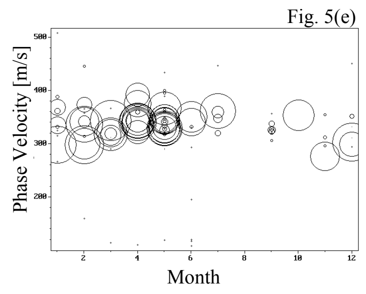


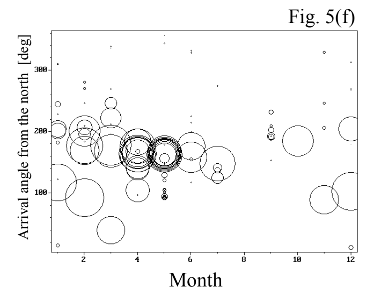
Fig. 5(c). The distribution of angle-of-arrival of infrasonic chirps observed at Jamton from 1994 to 2004.

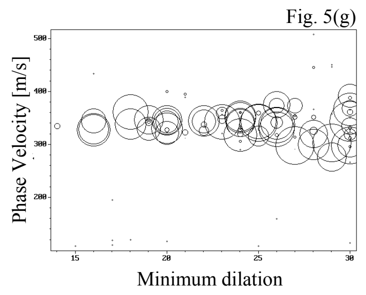
- Most chirps seem to be generated from the narrowest part of the Gulf pf Bosnia.
- Two distinct peaks in arrival angles (shown in red arrows) seem to coincide with the Finnish and Swedish coastlines within the Gulf pf Bosnia.

5.4. Chirp parameters









*The size of the symbol: SN ratio (proportional to the maximum product of all three cross sections)

Following points are in good agreement with the hypothesis that the infrasound chirps are from the high altitude sources such as red sprites.

Phase velocity (*Vp*) as a proxy of the incident angle of the ray from the sprite is controlled by two parameters:

(1) Minimum dilation of the chirp (~starting altitude of the ray from the sprite) slightly decreases with increasing *Vp* (Fig. 5(g)).

-Ray inclination angle increases with decreasing altitude.

(2) Arrival angle from the north decreases with increasing *Vp* (Figs. 5(e) and 5(f))

-Chirp phenomenon is sensitive to the infrasound propagation across the complicated wind system.

6. Summary

Case study on May 13, 2003:

- Ray tracing results indicate that the formation of the infrasound chirp depends on the propagation from high altitude source to the observer against the background wind direction.
- The geographical location of the infrasound source determined by the triangulation technique is around the sharp front of the cloud system over the Gulf of Bosnia being capable of generating parent lightning discharge for the red sprite.

Statistical study between 1994 and 2004:

- Automatic detection system for infrasound chirps works well and captures more than 100 events between 1994 and 2004.
- Occurrence frequency of the infrasound chirps may be anti-correlated with the magnitude of solar activity.
- Statistical parameters of the infrasound chirps indicate that the observed chirps were generated from high altitude source such as red sprite.

References

Farges, T., E. Blanc, A. Le Pichon, T. Neubert, and T. H. Allin, 2005, Identification of infrasound produced by sprites during the Sprite2003 campaign, *Geophys. Res. Lett.*, 32, doi:10.1029/2004GL021212

Liszka, L., 2004, On the possible infrasound generation by sprites, *Journ. of Low Frequency Noise, Vibration and Active Control*, *23*, 85-93.