SATELLITE AND GROUND-BASED MAGNETIC FIELD OBSERVATIONS RELATED TO VOLCANIC ERUPTIONS

K. Schwingenschuh[1], W. Magnes[1], X. Shen[2], J. Wang[3], B. Cheng[7], A. Pollinger[1], Chr. Hagen[1], R. Lammegger[5], M. Ellmeier[5], Chr. Schirninger[1], H.-U. Eichelberger[1], B. Mandl[1], M. Y. Boudjada[1], B. P. Besser[1], A. A. Rozhnoi[4], T. Zhang[1], M. Delva[1], I. Jernej[1], Ö. Aydogar[1], and R. Leonhardt[6]

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In this study we investigate volcanic eruption phenomena related to ionospheric disturbances, e.g. Heki (2006) used total electron content (TEC) measurements for this task. In particular, a model is developed how discharge phenomena (e.g. Houghton etal, 2013) can produce magnetic field variations at SWARM and CSES satellite orbits, i.e. altitudes of ~500 km in the F-region. Several coupling mechanism between lithosphere, atmosphere, and ionosphere are discussed by Simões etal (2012). Experimental evidence is based on magnetic field observations aboard CSES mission in the time frame July 2018 to July 2019. The theoretical considerations include the source mechanism, propagation path, and the signal strength at low earth orbit satellite altitude.

CSES HPM MAGNETIC FIELD MEASUREMENTS

- China Seismo Electromagnetic Satellite (CSES) launched Feb. 2nd, 2018; altitude 507 km, inclination 97.4 deg, Sun synchronous polar orbit, 3 axes stabilized, 8 payloads, among them the High precision magnetometer (HPM) with two Fluxgates and scalar CDSM (Shen et al., 2018), data latitude range -65 deg to +65 deg
- Main objective of the mission is the study of ionospheric response (electromagnetic and plasma phenomena) related to natural hazards, e.g. in particular earthquakes (precursors) and volcanic eruptions (this study)
- Coupled Dark State Magnetometer (CDSM), scalar magnetometer based on two-photon spectroscopy, instrument noise level ~50 pT/sqrt(Hz) @ 1 Hz, accuracy 0.19 nT (1σ), 1 Hz data product, 5 m nadir pointing magnetometer boom, total magnetic field 1000 - 100000 nT. (Pollinger et al., 2018) (Zhou et al., 2018)

B-FIELD VARIATIONS AT CSES ALTITUDE

- SOURCES: Microfracture crustal electrification (Molchanov and Hayakawa, 1998); volcanic plume charging (Houghton et al., 2013); displacement of magnetized solid material, for the point source $\mathbf{B} = \mu_0/4\pi\ (3\mathbf{Mr}\ \mathbf{r}/r^5 - \mathbf{M}/r^3)$, linear source (prop $1/r^2$) or planar source (prop 1/r); and atmospheric waves (acoustic- and gravity modes)
- PROPAGATION & COUPLING: As discussed by Simões etal (2012), in particular ionospheric fluctuations (electromagnetic, density) triggered by volcanic acoustic waves, see Schirninger etal (2019), and for seismic investigations Kherani etal (2009)

VOLCANIC ERUPTIONS AND ACTIVE PERIODS

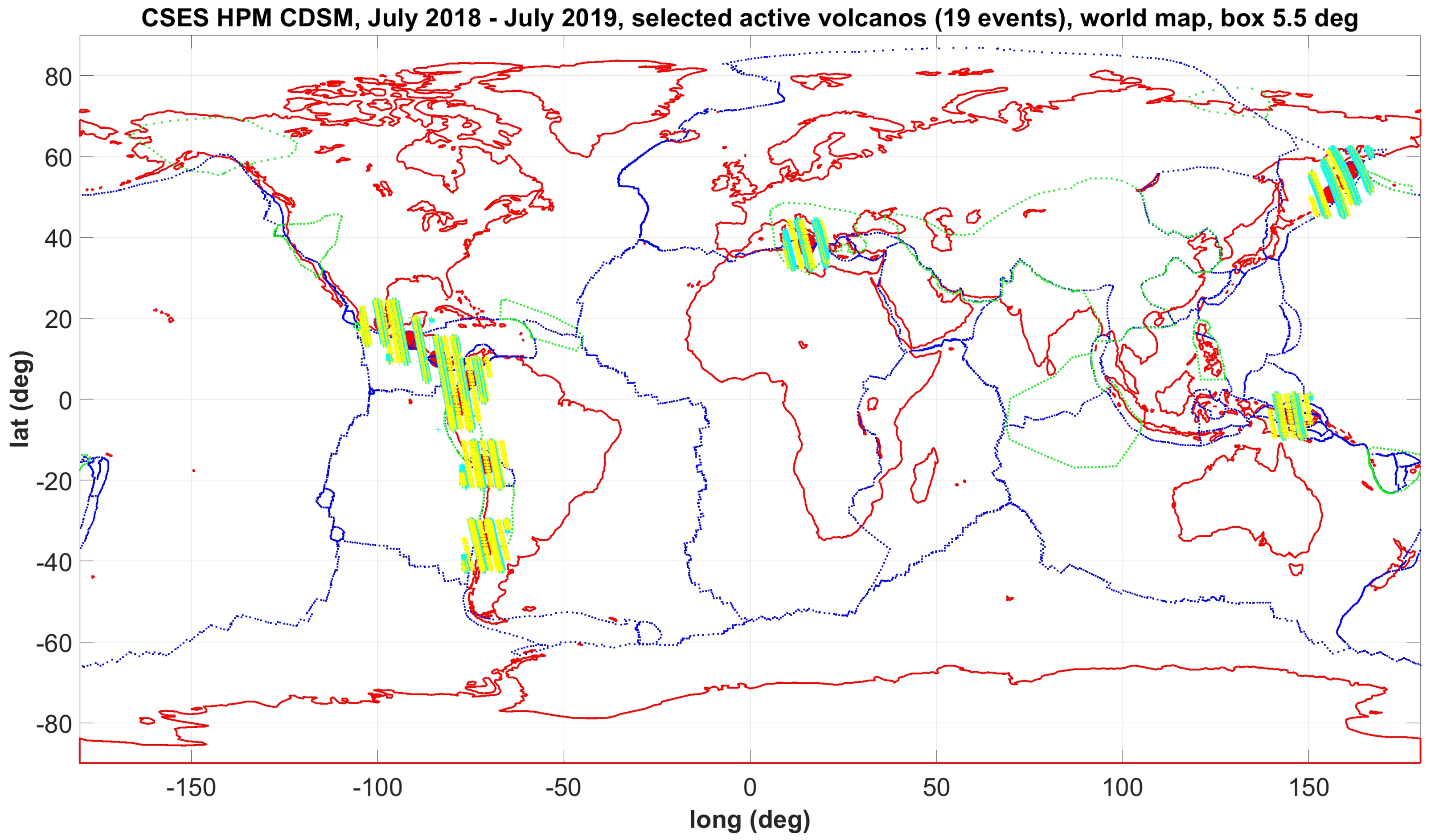

Figure 1: Selected 19 volcanos with projected CSES paths in a spatial box with 5.5 deg, night-time magnetic field CDSM data shown in yellow/cyan color for major pre/post eruption periods.

CSES HPM magnetic field variations at ionospheric altitude 507 km: volcano list, time span July 2018 – July 2019				
No.	Lat. (deg)	Long. (deg)	Volcano, Country	Data Annotation (Database GVP Reports)
1	19.02	−98.62	Popocatépetl, Mexico	Variations in Bx and Bz
2	56.65	161.36	Shiveluch, Russia	Narrowband disturbances
3	−0.08	−77.66	Reventador, Ecuador	Variations in CDSM, Bx, and Bz; Spikes
4	−35.24	−70.57	Planchón–Peteroa, Argentina/Chile	Variations in CDSM, Bx, and Bz; Spikes
5	−15.78	−71.85	Sabancaya, Peru	Spikes (artificial)
6	50.68	156.02	Ebeko, Russia	Narrowband disturbances
7	−4.08	145.04	Manam, Papua New Guinea	Spikes (artificial)
8	14.47	−90.88	Fuego, Guatemala	Spikes (artificial)
9	55.98	160.59	Bezymianny, Russia	Spikes (artificial)
10	56.06	160.64	Klyuchevskoi, Russia	Spikes (artificial)
11	10.03	−83.77	Turrialba, Costa Rica	Variations in CDSM, Bx, and Bz
12	−36.86	−71.38	Nevados de Chillán, Chile	Variations in CDSM, Bx, and Bz
13	4.90	−75.32	Nevado del Ruiz, Colombia	Spikes (artificial)
14	38.79	15.21	Stromboli, Italy	Variations in Bx and Bz
15	37.75	14.99	Etna, Italy	Variations in Bx and Bz
16	−2.00	−78.34	Sangay, Ecuador	Variations in CDSM, Bx, and Bz; Spikes
17	−16.36	−70.90	Ubinas, Peru	Spikes (artificial)
18	54.05	159.44	Karymsky, Russia	Spikes (artificial)
19	14.76	−91.55	Santa María, Guatemala	Spikes (artificial)

Table 1: Selected volcanos with eruptions and unrest periods in the time frame July 2018 – July 2019 (Database GVP), annotations for CSES/HPM data. The color coding in the first column indicates nearby volcanos, i.e. the spatial mapping at CSES altitude (~ 507 km) is difficult to resolve because of nearly same data segments.

Parallel ground based magnetic field observations (magnetometer networks) nearby volcanos can be means to characterize eruptions and unrest periods, similar as for earthquakes (Prattes et al., 2008), but future studies have to demonstrate this in detail.

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- Database: Global Volcanism Program (GVP), Smithsonian Institution, https://volcano.si.edu/ as of May 2020

SUMMARY

Satellite B-field meas. can be a tool to observe volcanic eruptions

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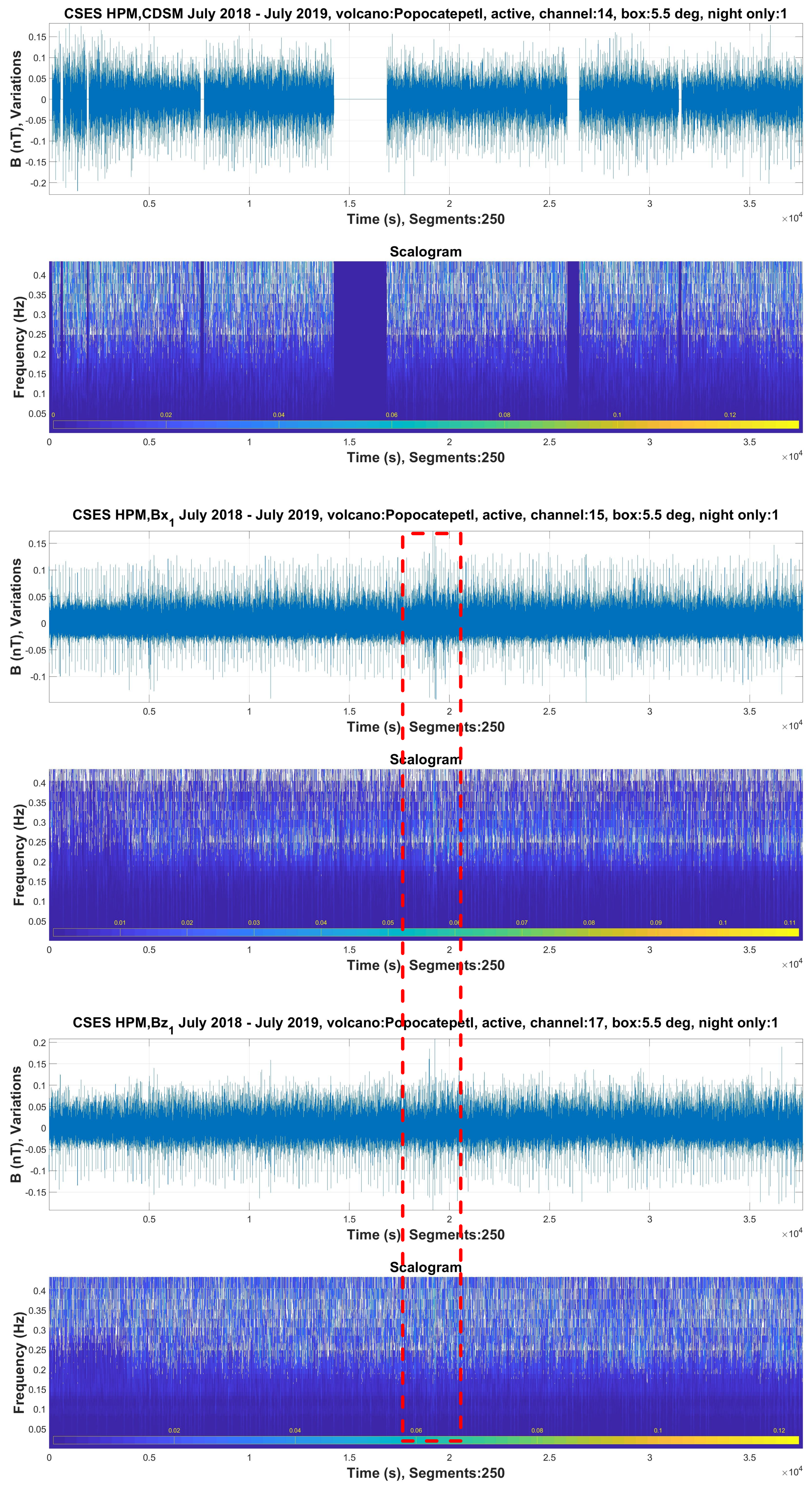
POPOCATÉPETL

Time series and Scalogram // Top: CDSM – Center: Bx – Bottom Bz



SHIVELUCH

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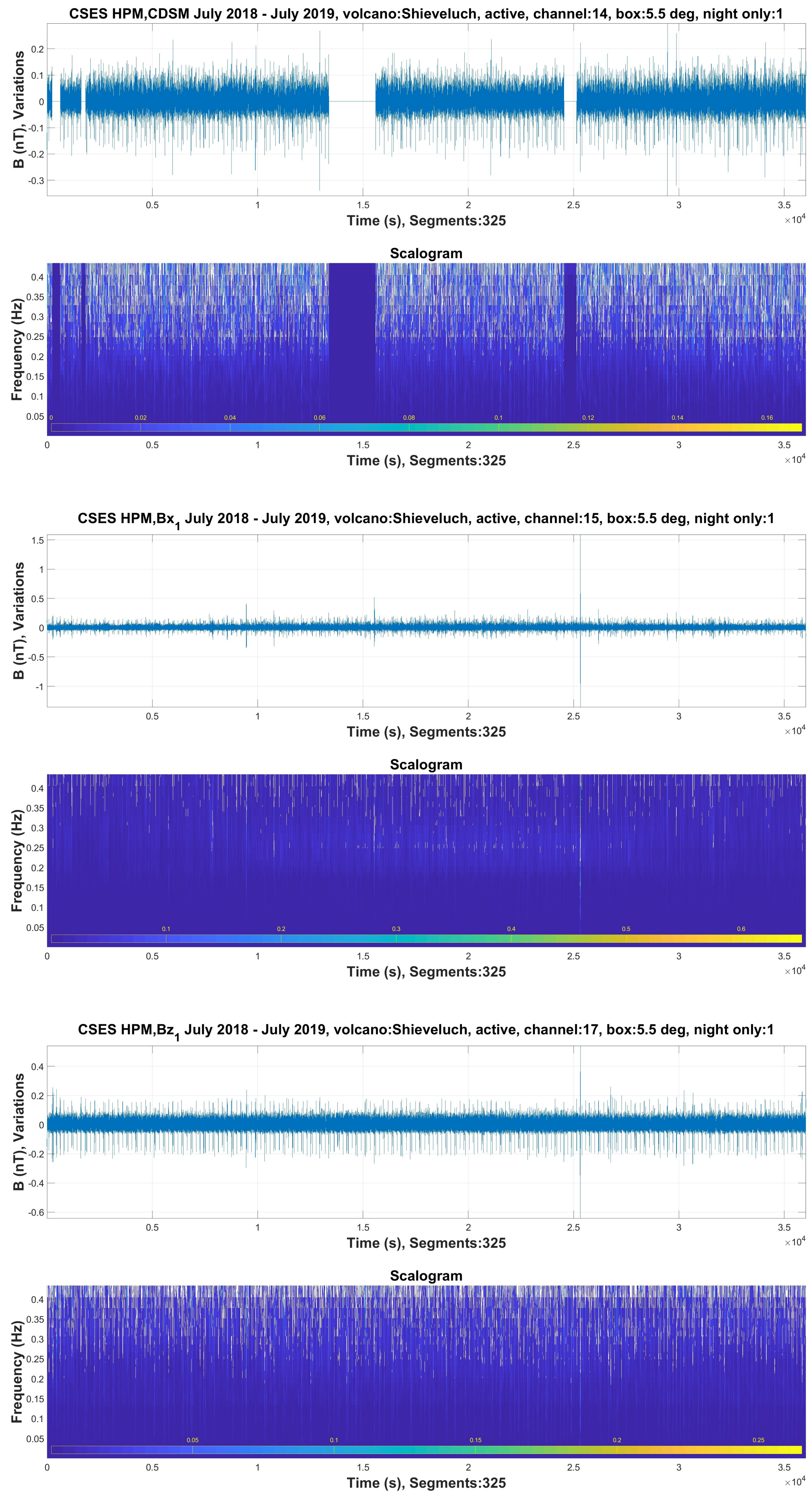

REVENTADOR

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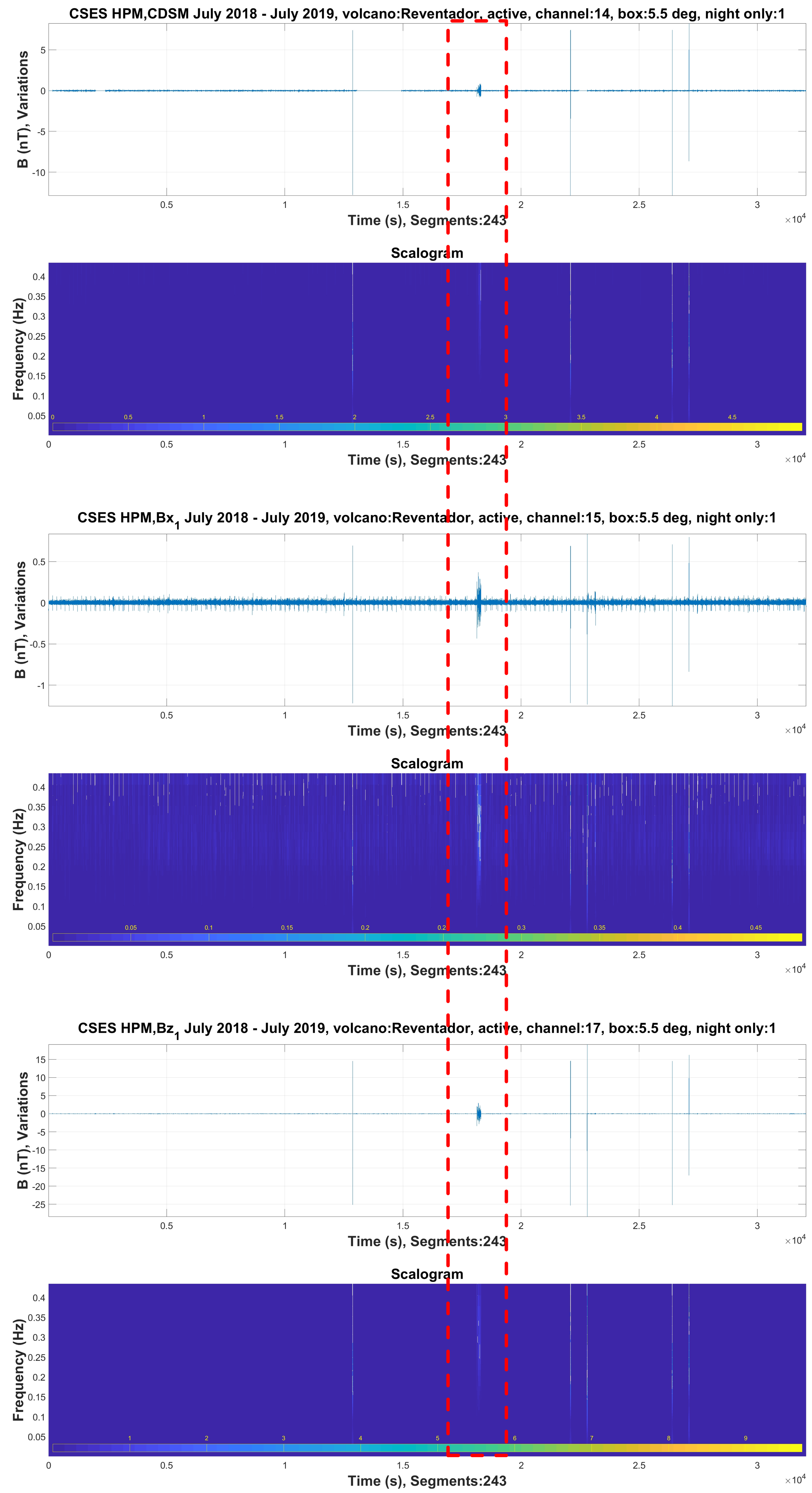

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PLANCHÓN-PETEROA

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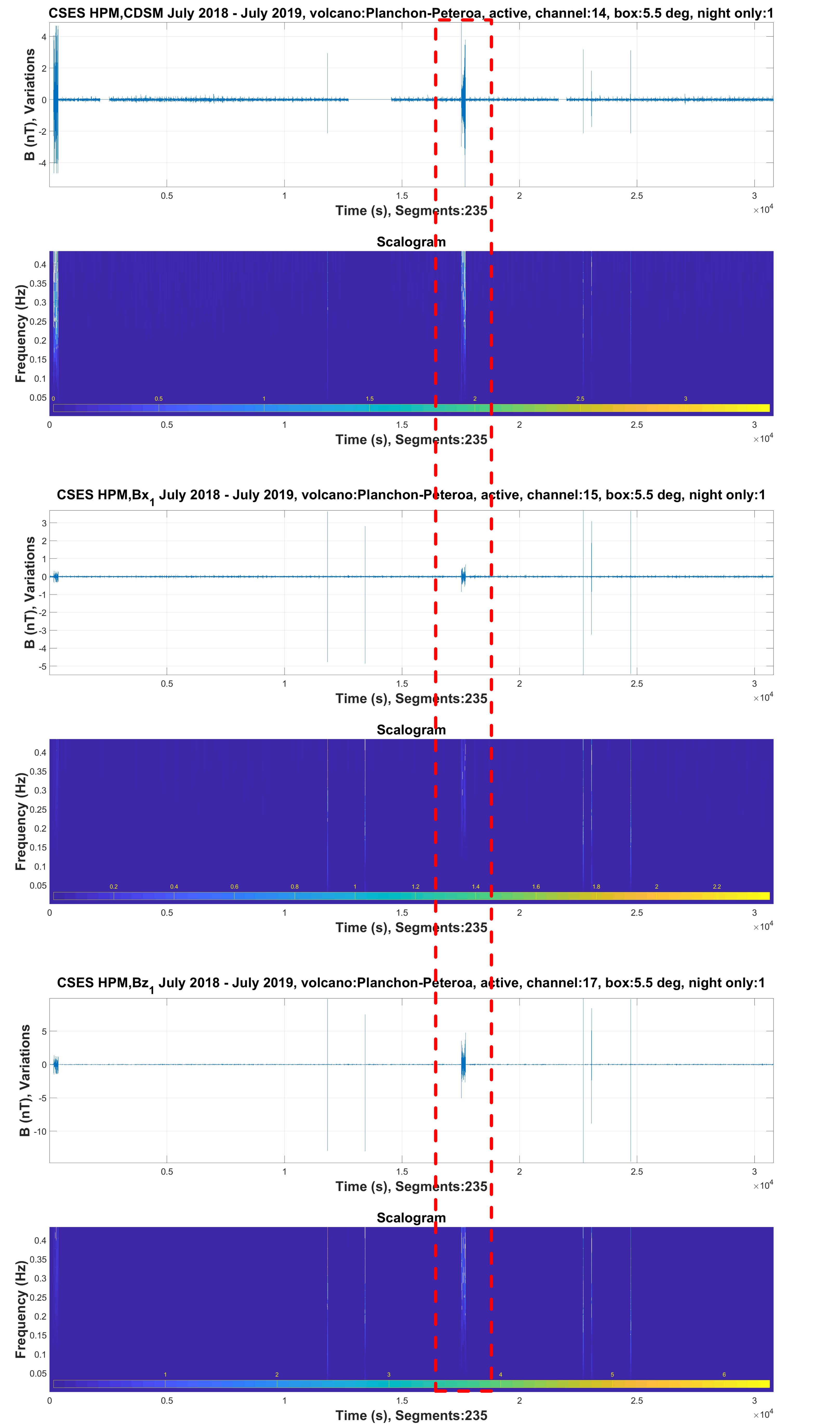

SABANCAYA

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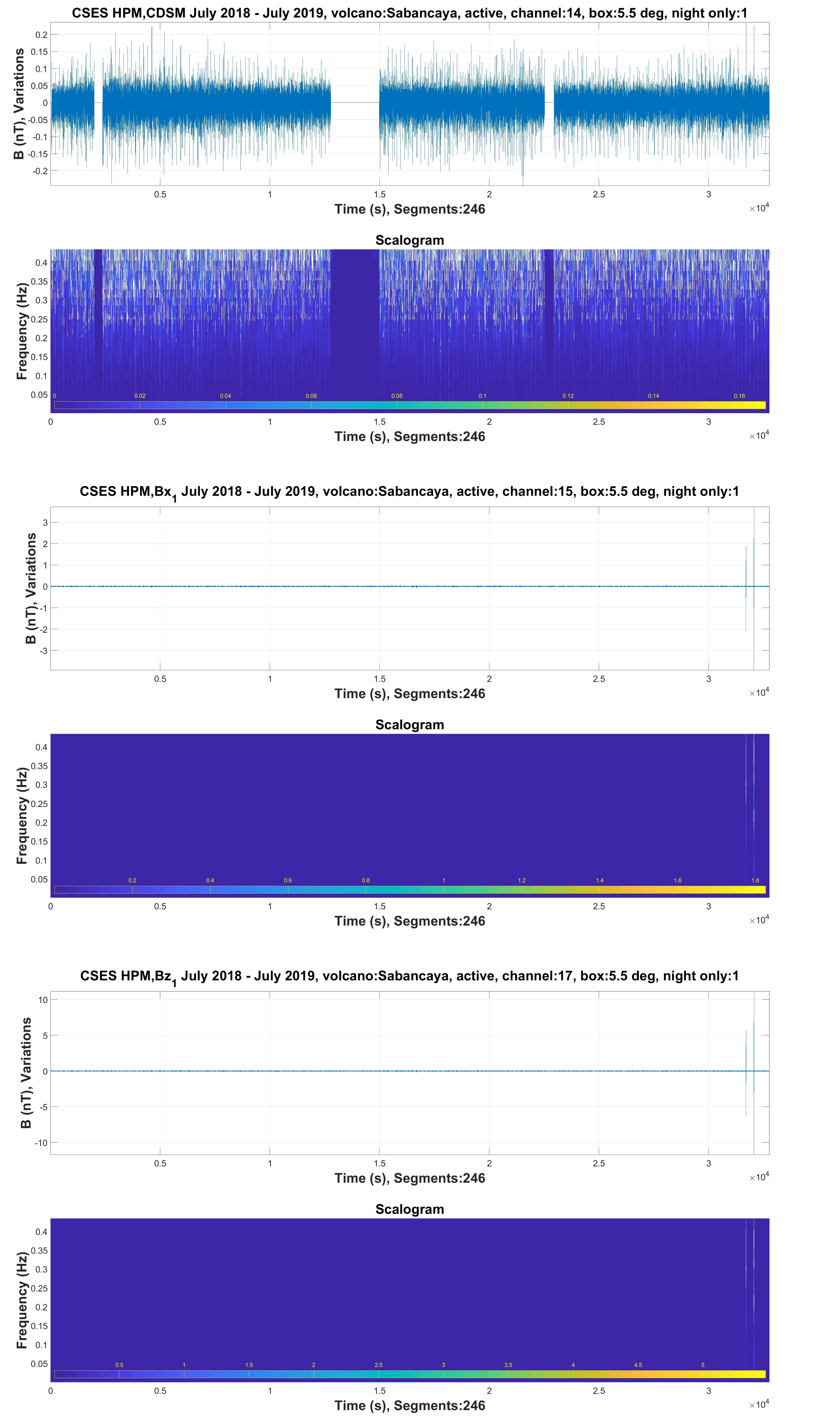

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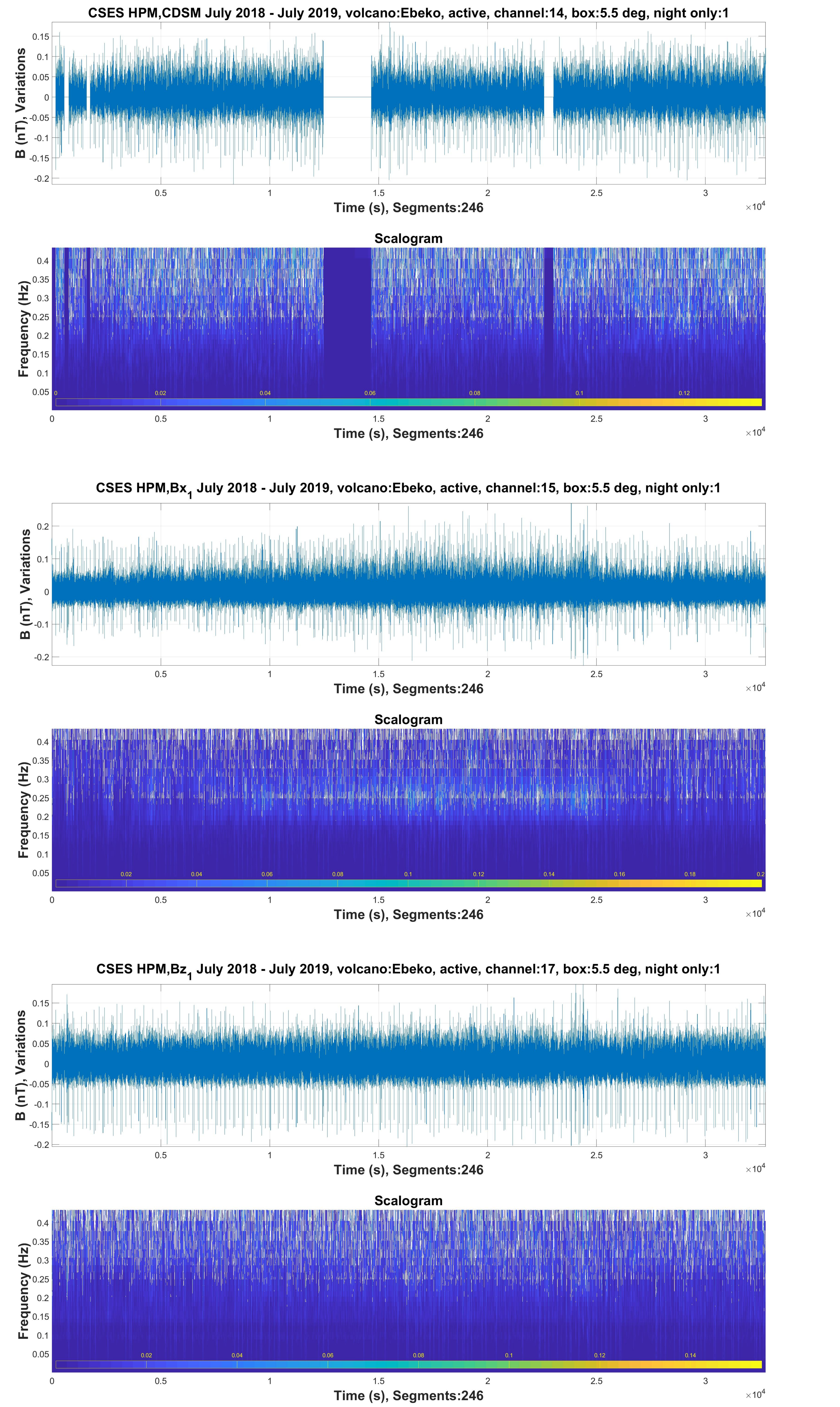

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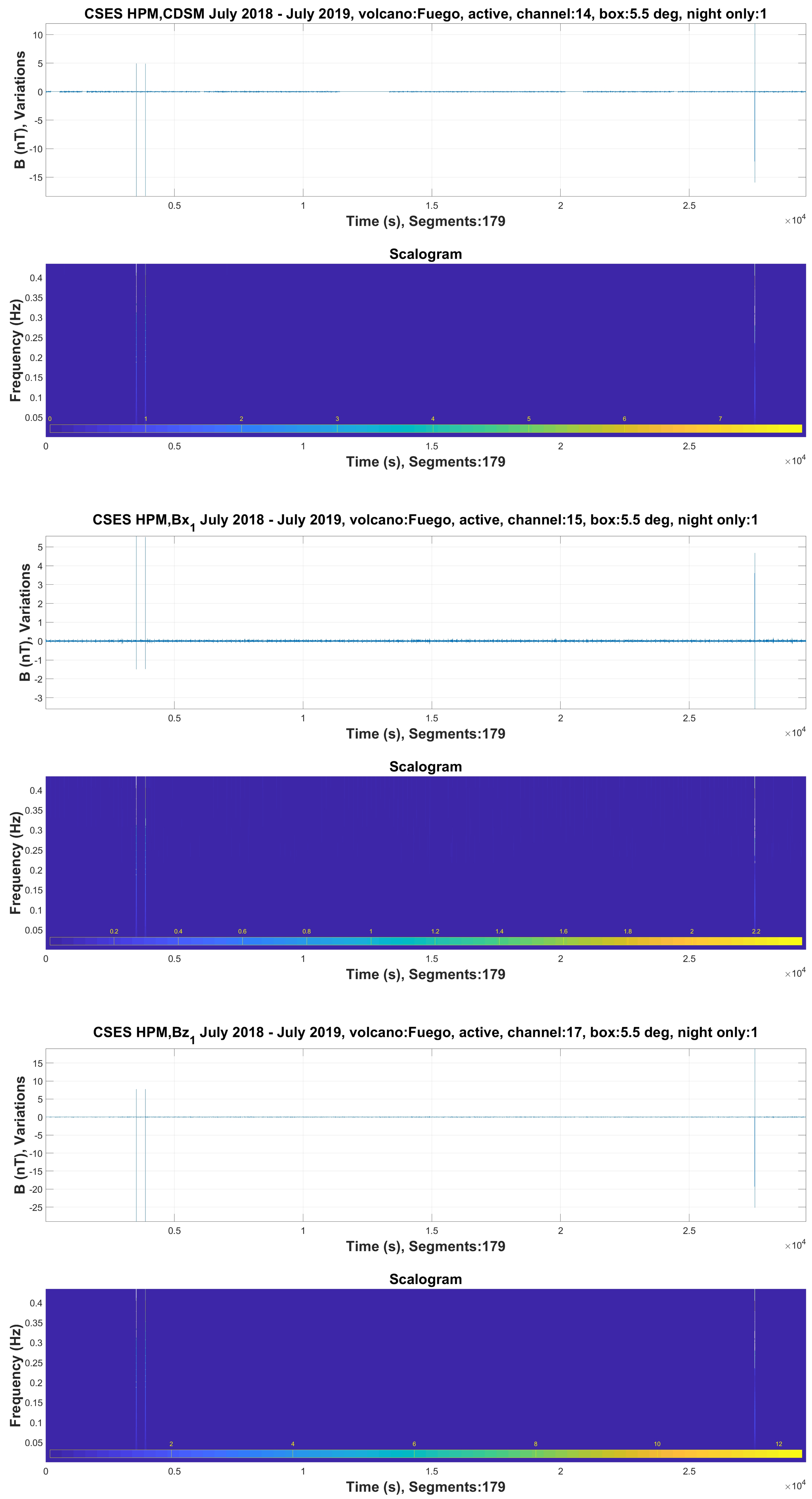
MANAM

Time series and Scalogram // Top: CDSM – Center: Bx – Bottom: Bz



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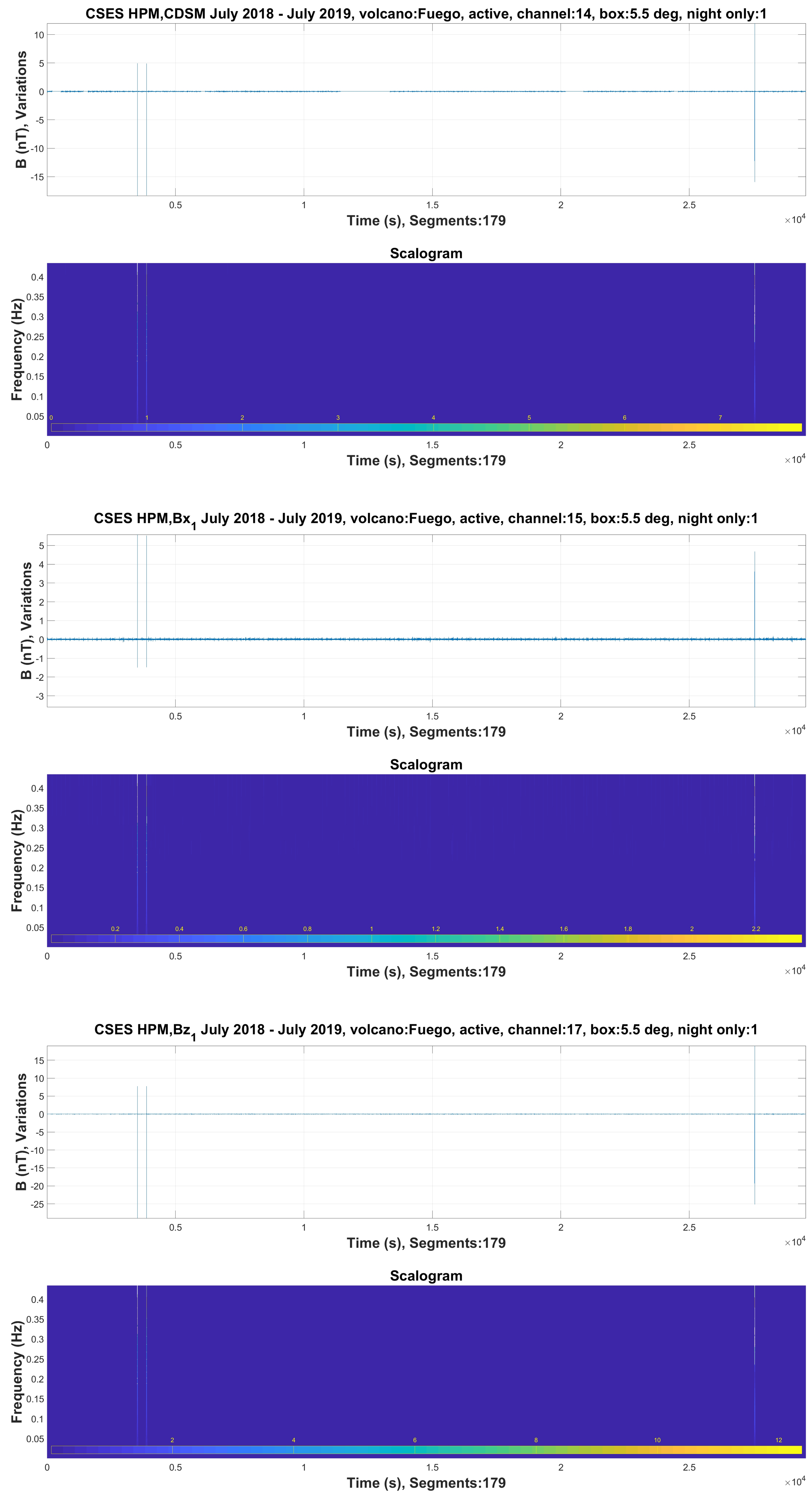

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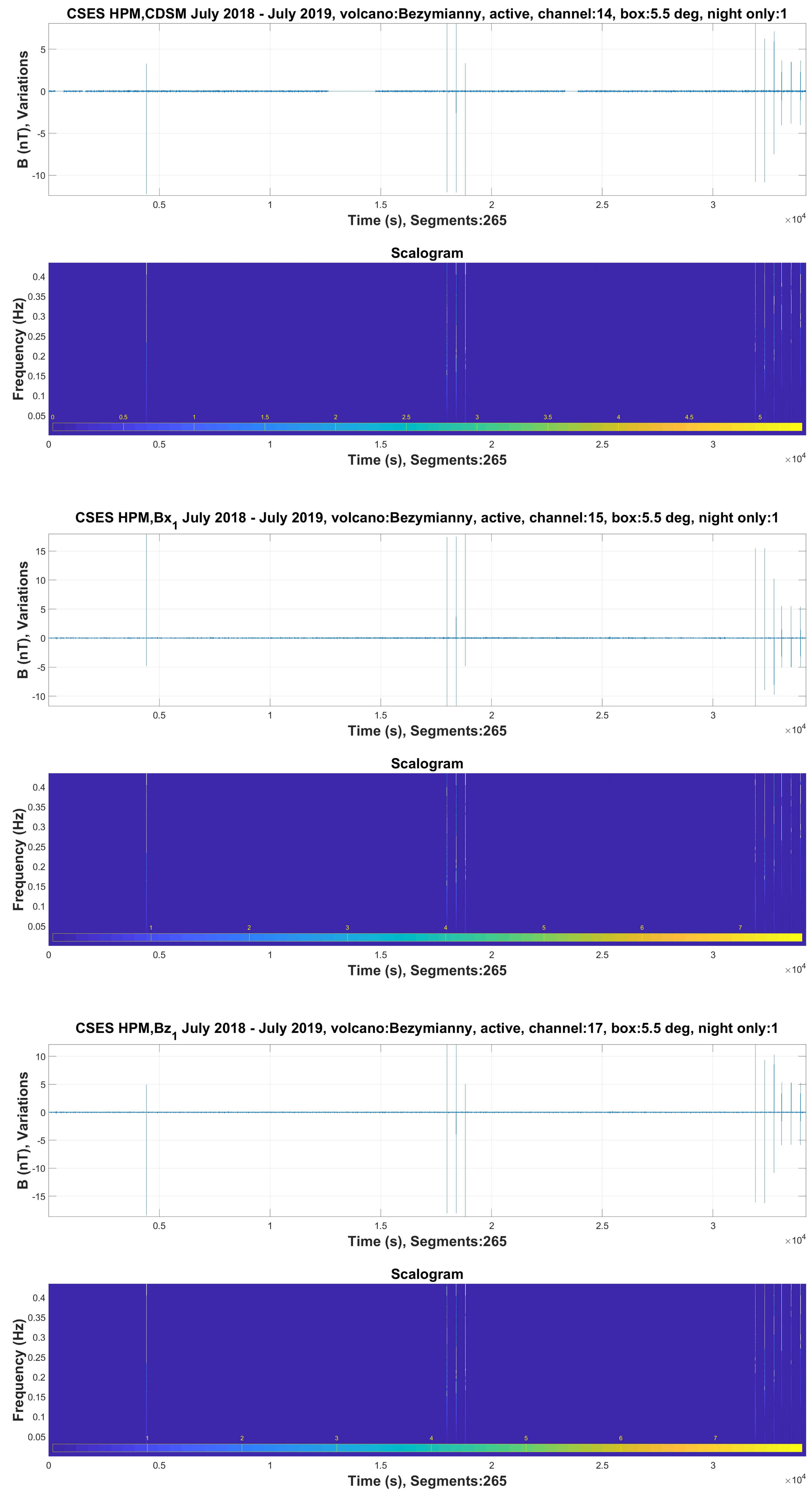

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KLYUCHEVSKOI

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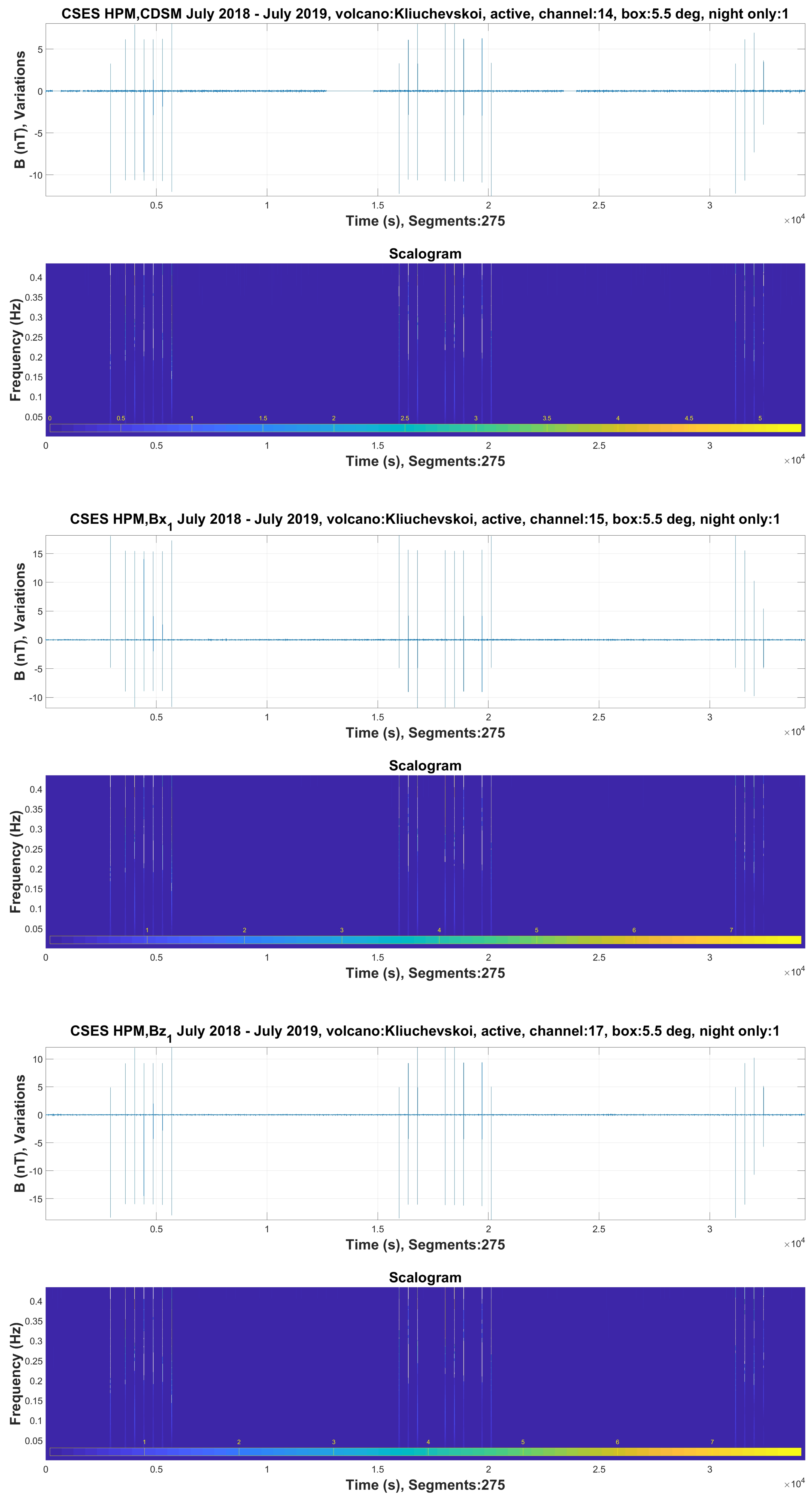

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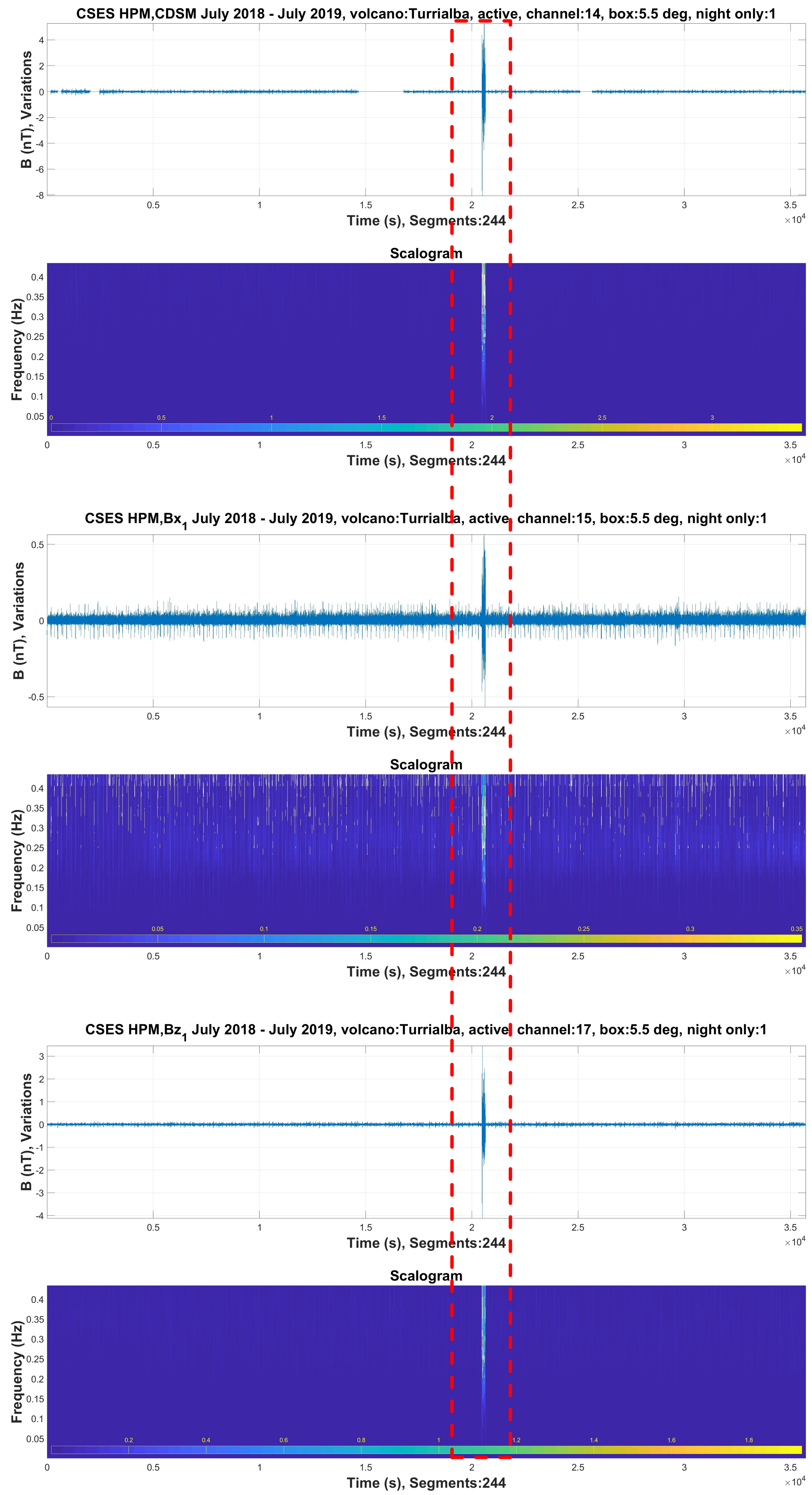

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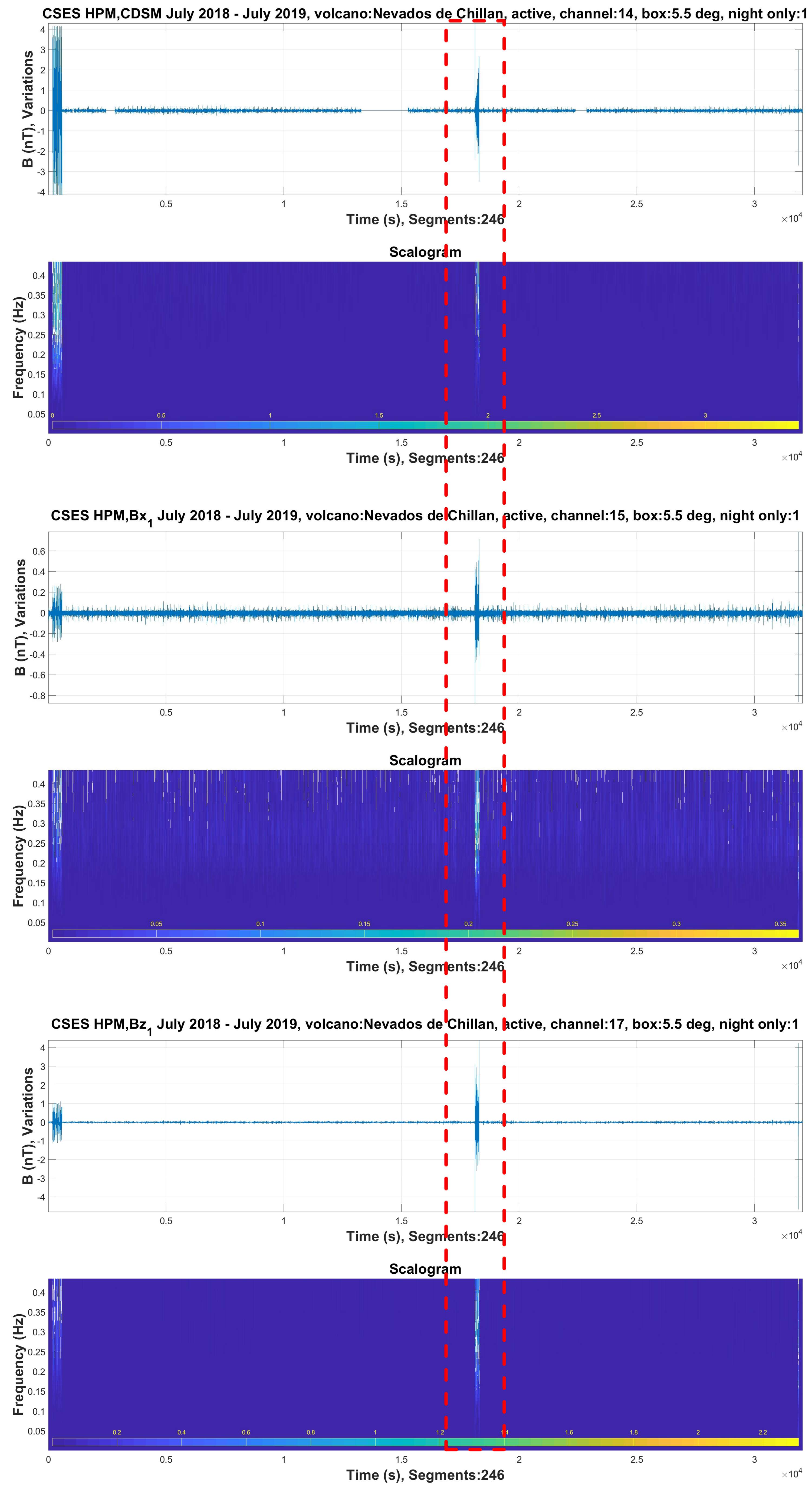

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NEVADO DEL RUIZ

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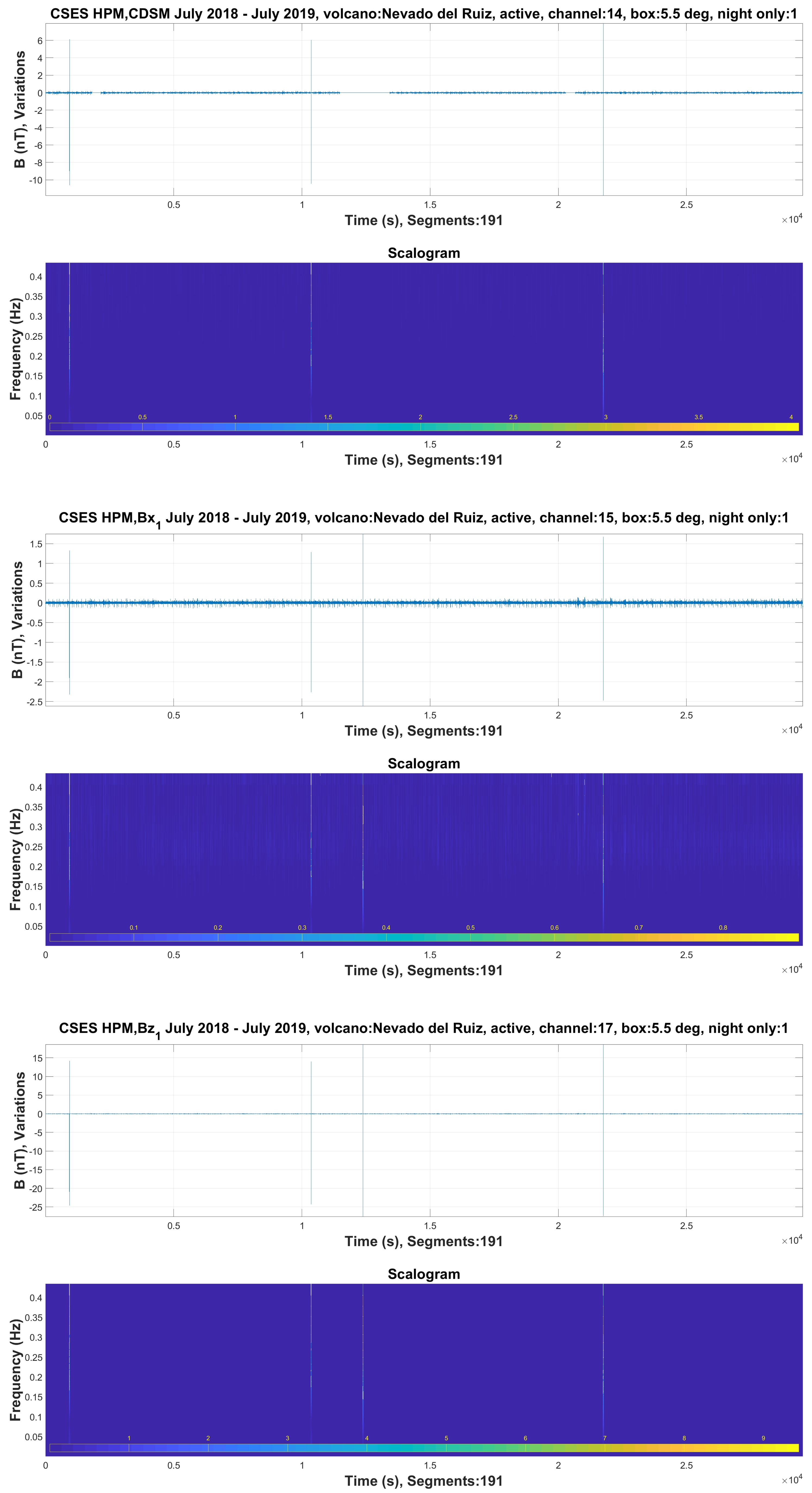

STROMBOLI

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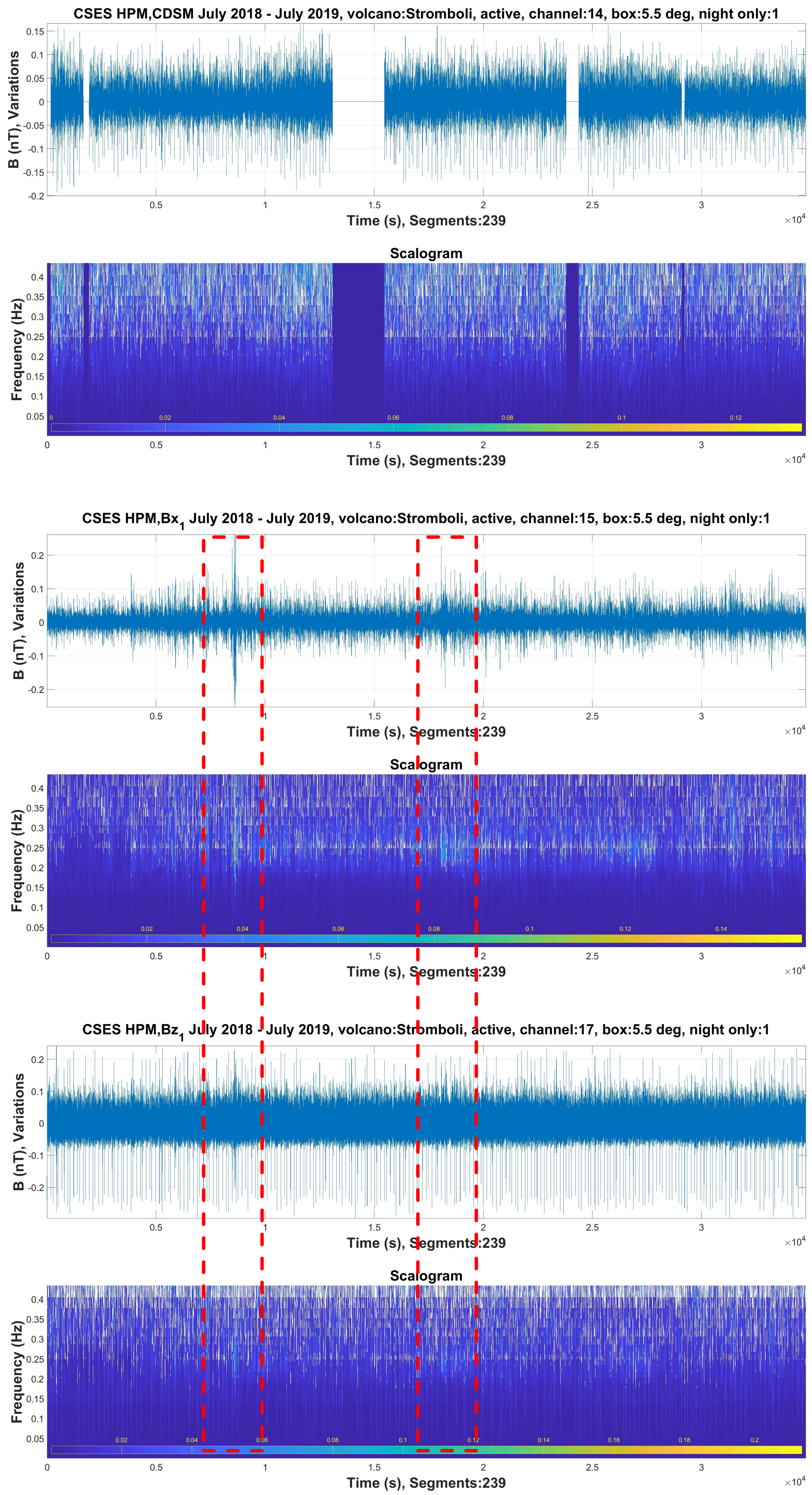

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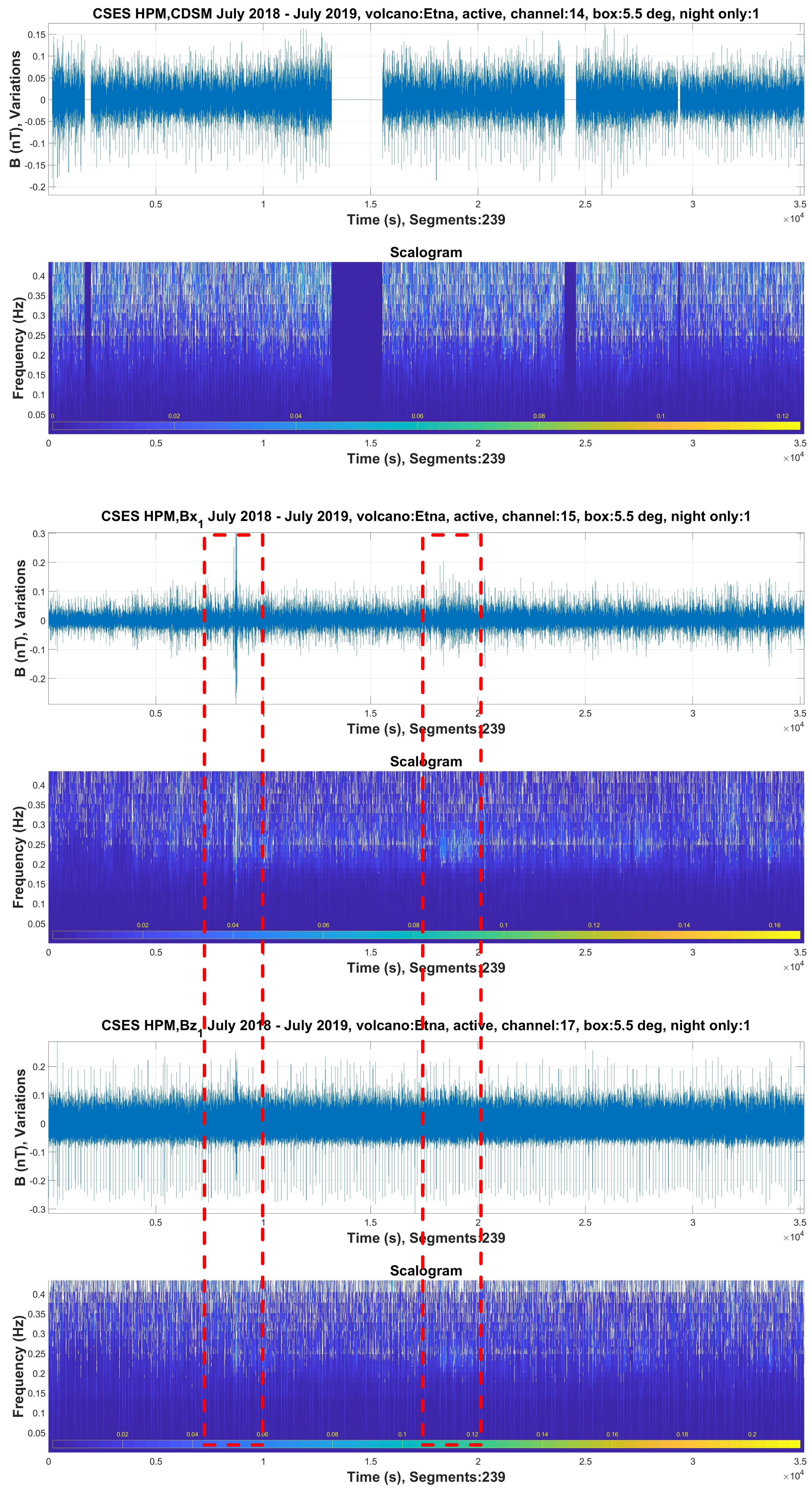

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SANGAY

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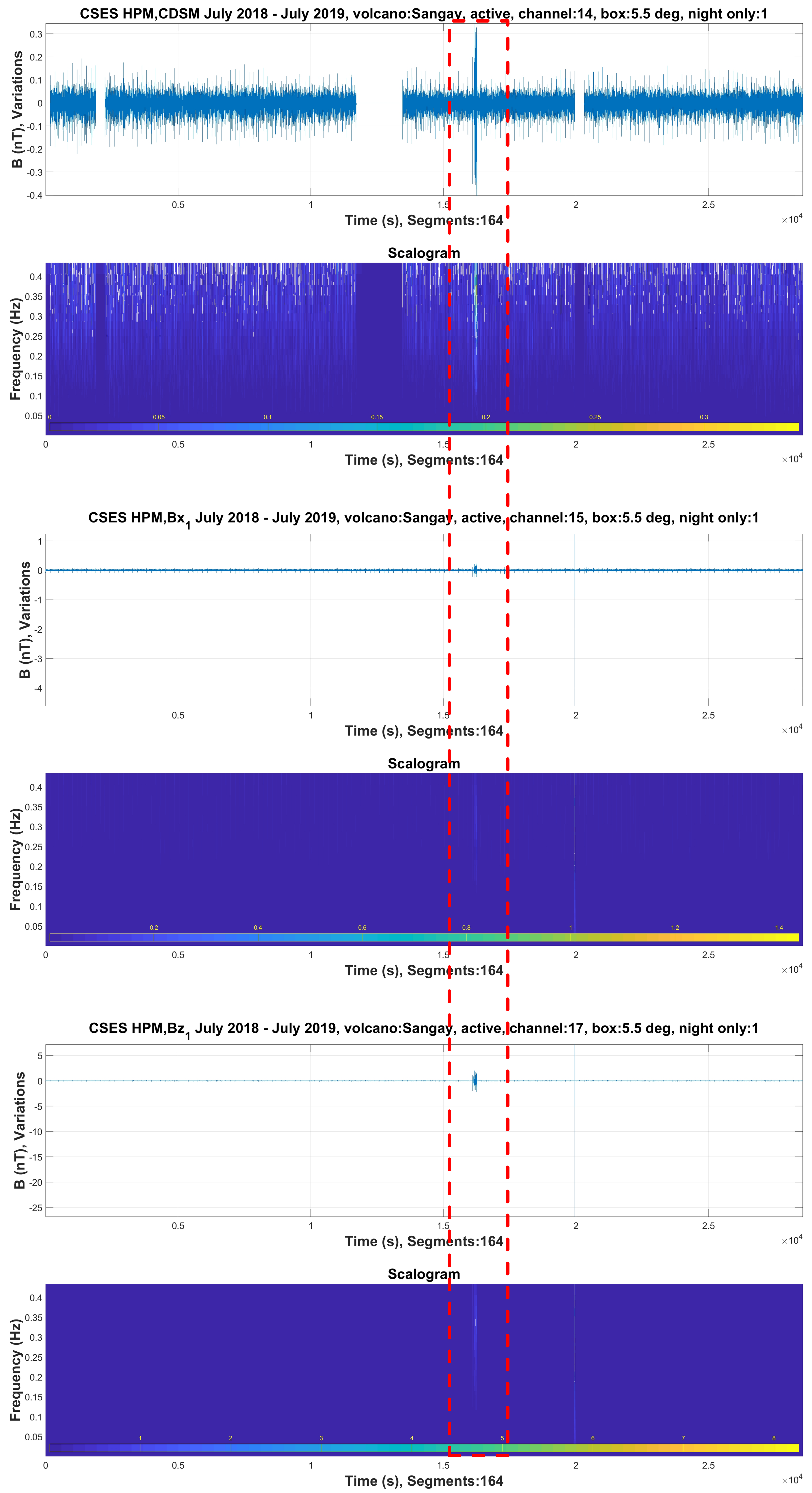

UBINAS

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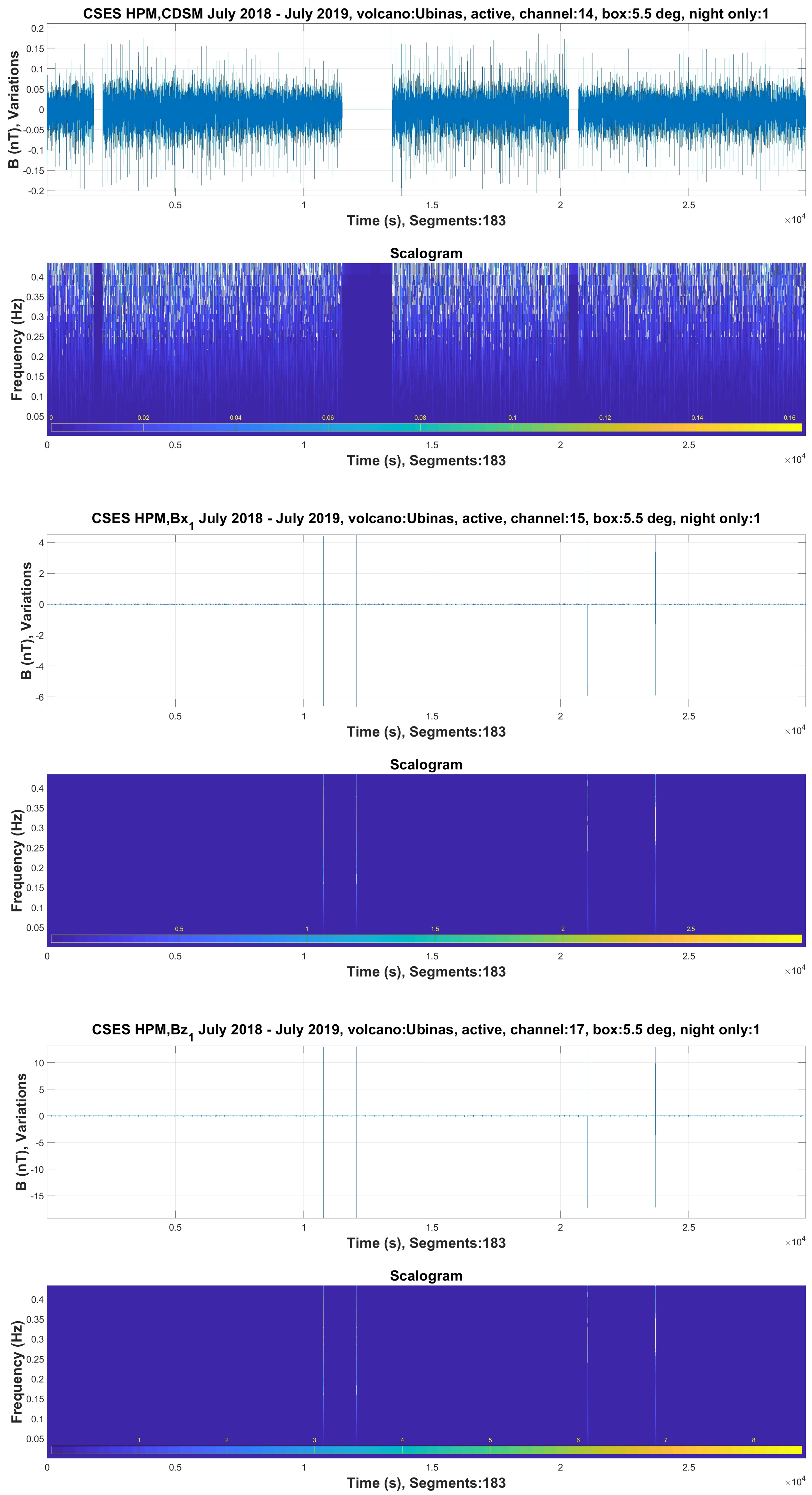

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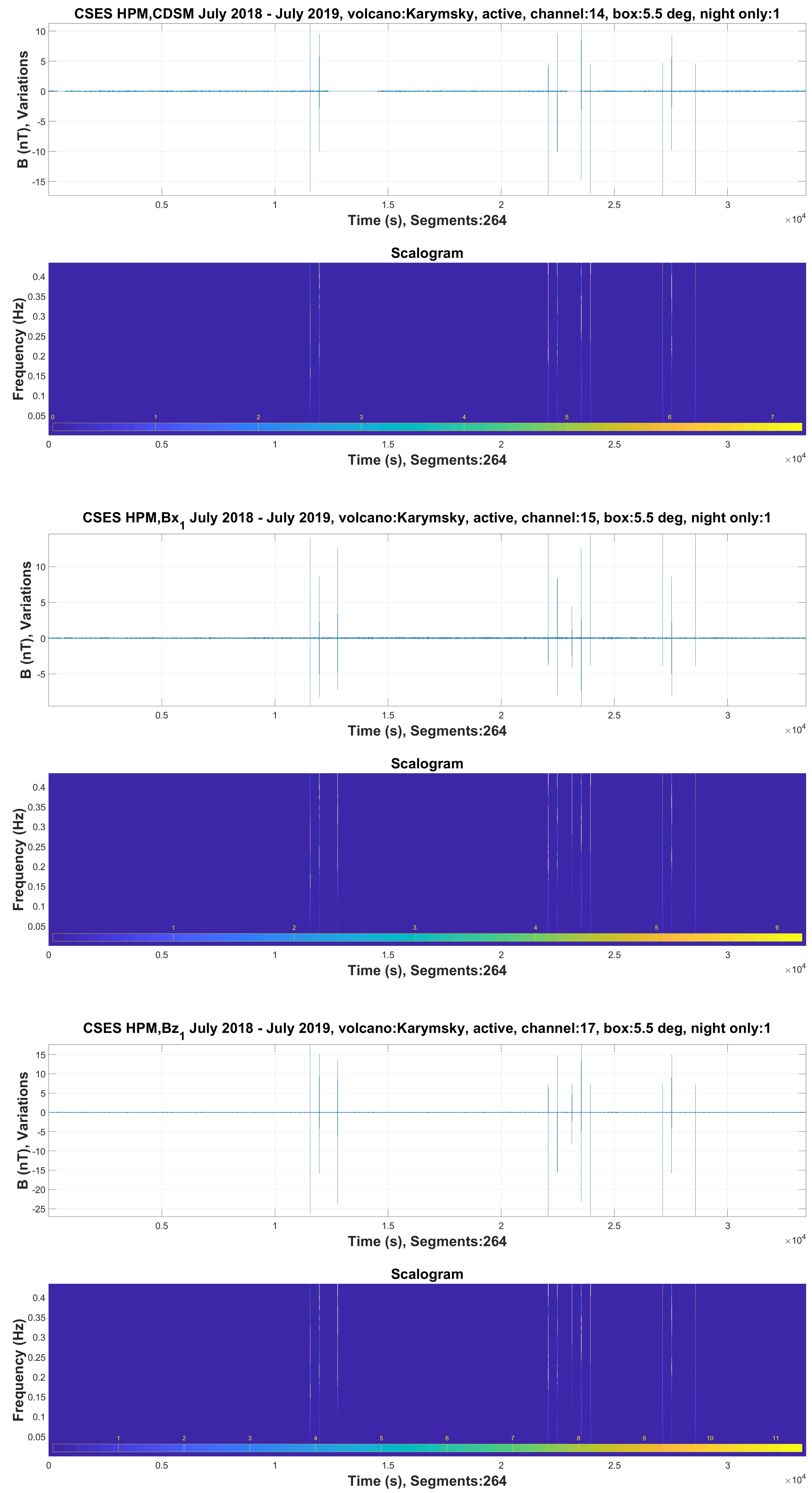

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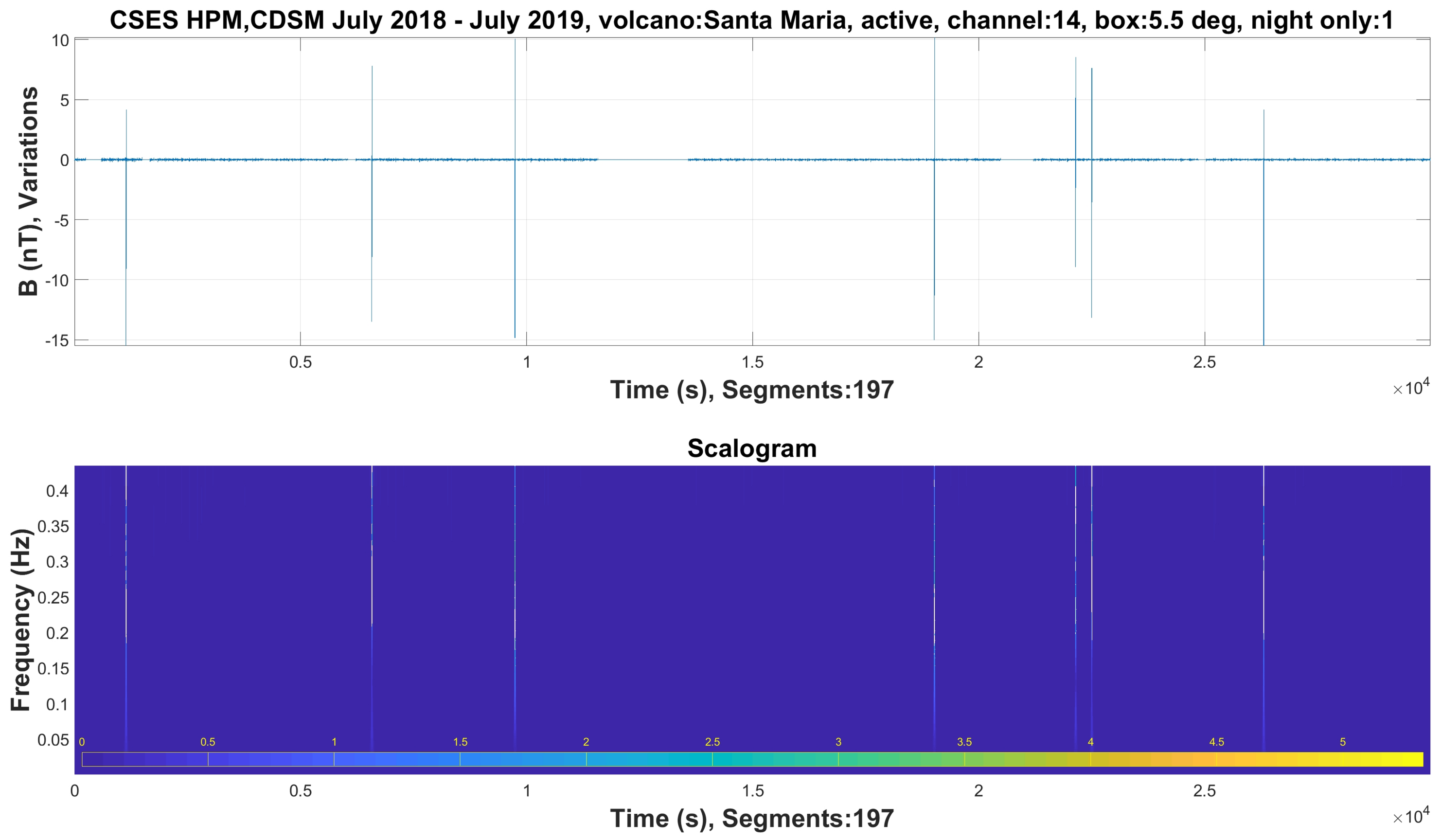
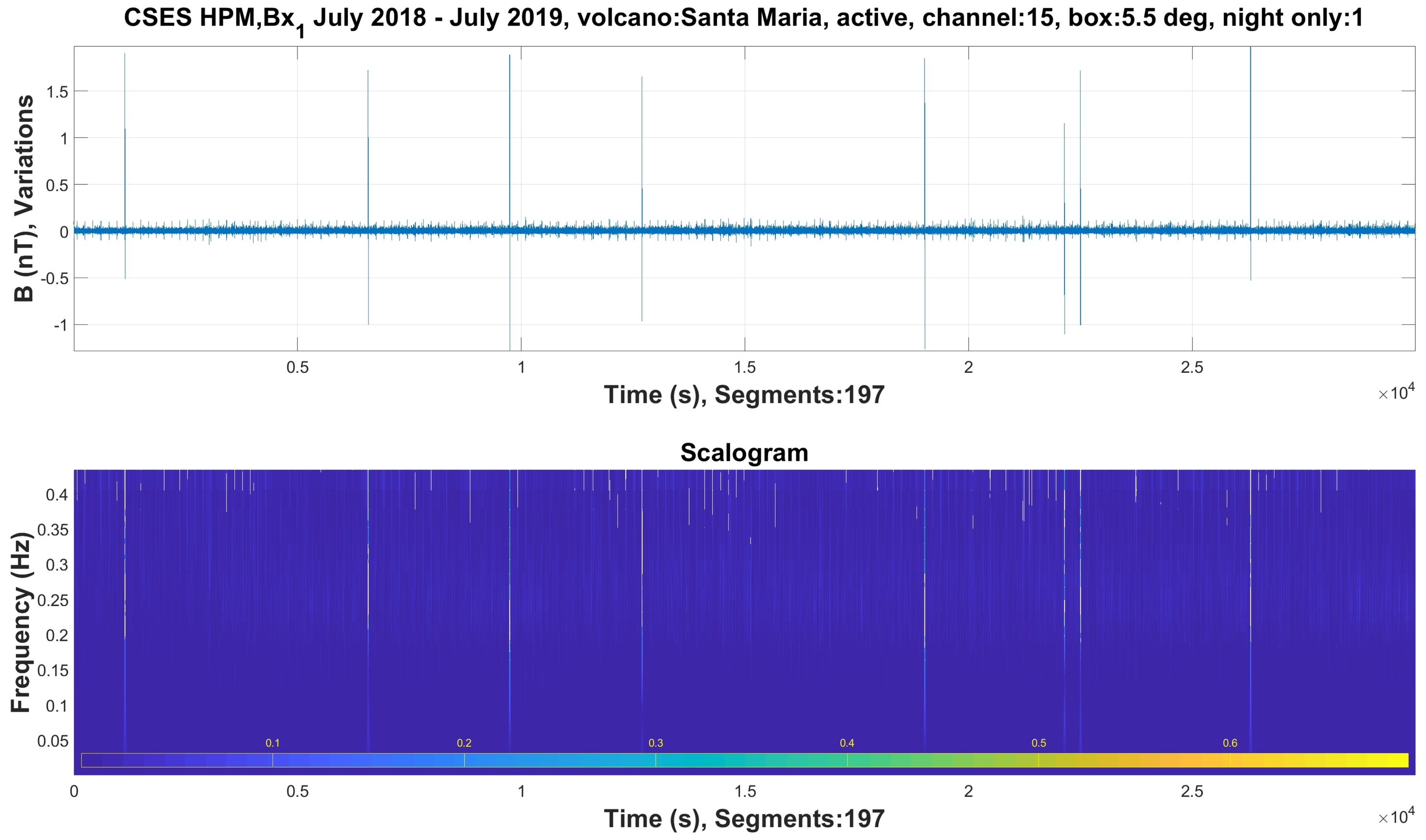
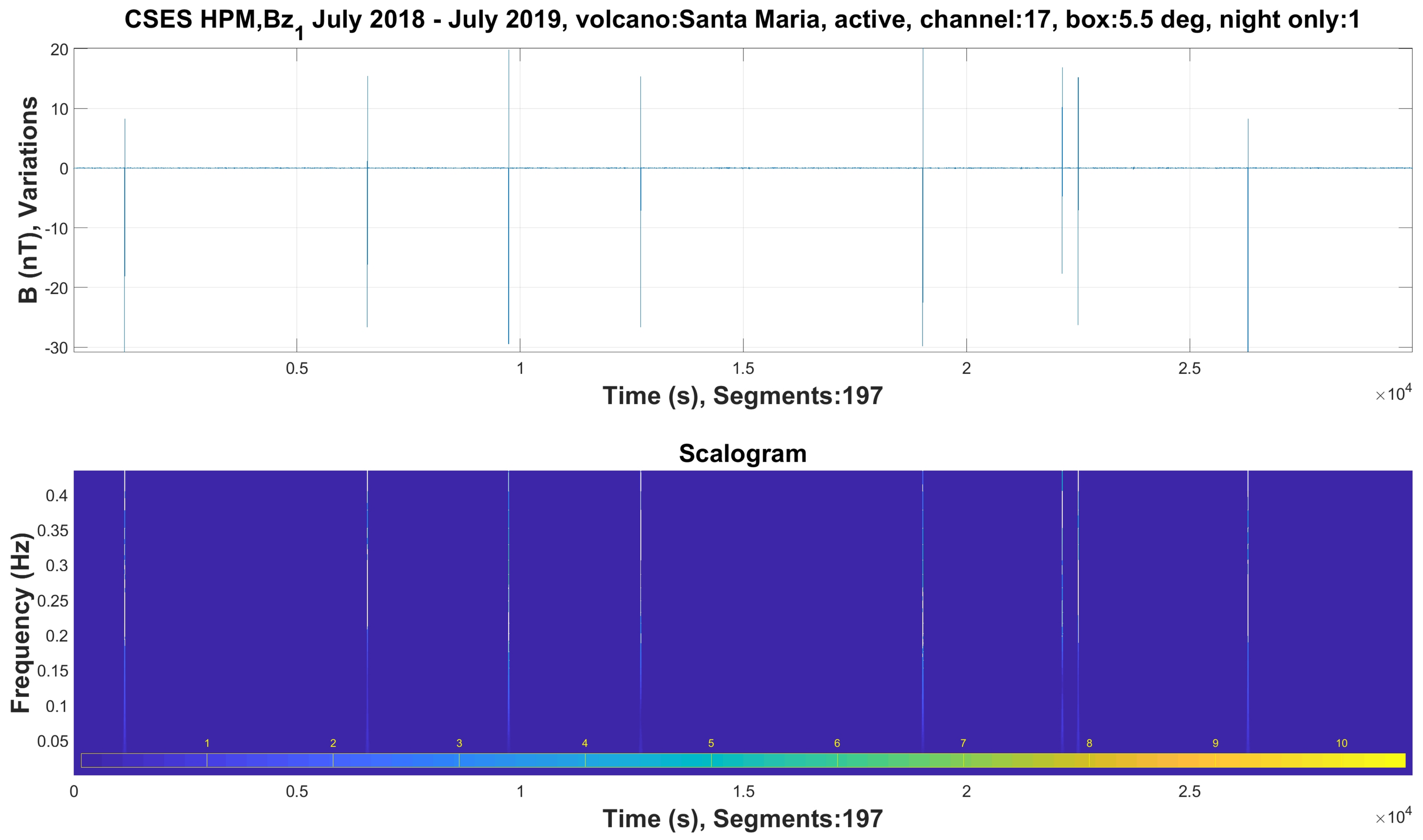
SANTA MARÍA

Time series and Scalogram // Top: CDSM – Center: Bx – Bottom: Bz







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