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ON THE POSSIBILITY OF POWERFUL UNDERGROUND EXPLOSIONS IMPACT TO RELEASE OF THE EARTH'S CRUST STRESSES AND ON THE DEVELOPMENT OF HURRICANES

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Keywords: *satellite, external ionosphere, space monitoring, nuclear experiments, earthquakes, mesoscale atmospheric processes, tropical cyclones, vertical formations.*

Abstract: *Observations from the Cosmos-1809 satellite of ionospheric effects in the summer of 1992 after nuclear experiments (NE) at the Nevada test site and subsequent earthquakes in California and changes in the dynamics of hurricanes in the Pacific and Atlantic Oceans are presented. It is considered how an earthquake in the area of Inland Empire 1992-04-22 stimulated the development of tensions in this area, which were dropped after the NE in June 1992. It is discussed how the stratosphere dustiness after the Pinatubo volcano eruption modifies cyclogenesis which intensifies after the nuclear explosions in September 1992.*

О ВОЗМОЖНОСТИ ВОЗДЕЙСТВИЯ МОЩНЫХ ПОДЗЕМНЫХ ВЗРЫВОВ НА СБРОС НАПРЯЖЕНИЙ ЗЕМНОЙ КОРЫ И РАЗВИТИЕ УРАГАНОВ

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Ключевые слова: *спутник, внешняя ионосфера, космический мониторинг, ядерные эксперименты, землетрясения, крупномасштабные атмосферные процессы, тропические циклоны, вихревые явления.*

Абстракт: *Представлены наблюдения ионосферных эффектов со спутника «Космос-1809» летом 1992 года после ядерных экспериментов (ЯЭ) на испытательном полигоне в Неваде и последовавших землетрясений в Калифорнии, а также изменение динамики ураганов в Тихом и Атлантическом океанах. Считается, что землетрясение в районе Inland Empire в Южной Калифорнии 1992-04-22 стимулировало развитие напряженности в этой области, которые были сброшены после ЯЭ в июне 1992 года. Обсуждается вопрос о том, как запыленность стратосферы после извержения вулкана Пинатубо изменяет циклогенез, который усилился после ядерных взрывов в сентябре 1992 года.*

Introduction

Earthquakes and tropical cyclones (TC) are the most powerful natural sources, leading to great environmental and economic damage. This paper examines how strong explosions can influence the development of TC and cause earthquakes by analyzing data from underground nuclear tests (UNT) on the Nevada Test Site (NTS). The following periods were chosen:

1. June 1992. At this time, according to the US seismic service, the movement of the crustal plates along the San Anders Fault was approaching a critical state preceding a strong earthquake. [1-3];
2. September 1992. During this period, due to the eruption of super volcanoes, an anomalous change occurred in the two-year stratospheric circulations [4–6].

According to the 1963 International Treaty, the capacity of an underground nuclear explosion (UNE) should not exceed 150 kilotons. Therefore, the magnitude of the earthquake caused by the UNE does not exceed 5–6 units. Electromagnetic, acoustic and seismic effects of UNE on the ionosphere are considered in monographs [7–8]. The authors of this report used both ground-based and satellite measurements. Ground-based measurements of electromagnetic radiation in the ELF range after each of the 11 UNT were performed at the Semipalatinsk test site [9]. Satellite (Cosmos-1809) measurements of the parameters of the ionosphere were obtained over the nuclear test sites of the USA, USSR and France after 20 UNT [9–10].

Various methods for earthquake predicting are discussed in the book [11]. Examples of unusual ionospheric observations made by the DEMETER satellite over seismic regions are presented in the work [12]. Currently method variations of the total electron content in the ionosphere from GPS data recorded during earthquake is widely used [13–14].

I. Particularities of ionospheric perturbations over California and Nevada in June 1992 according to data from the Cosmos-1809 satellite

Nearly the entire west coast of North America was dominated by a subduction zone. The plate margin that remains in California is that of the strike-slip San Andreas Fault. The 1992 Landers earthquakes began on April 23 with the M_W 6.1 1992 Joshua Tree preshock and form the most substantial earthquake sequence to occur in California in the last 40 years [2]. The largest earthquake sequence to occur in California in 1992 are presented in Table 1. The Landers mainshock occurred near the southernmost extent of the Eastern California Shear Zone, an 80km wide, more than 400km long zone of deformation.

Since the deformation zone extends northward to the NTS, the effect of UNT on the ionospheric precursors of the Landers earthquake should be analyzed. Table 2 shows the characteristics of the considered UNT [15, 16]. Changes in the some parameters of the upper ionosphere plasma inside the plasmasphere (L < 1.75), which projected on the E-layer over the NTS, before the Landers earthquake is shown in Fig.1. It should be noted strong fluctuations of the electron density Ne on L ~ 1.3 west of the San Andreas Fault on the meridian 226 E observed on June 10. Ne fluctuations (L ~ 1.5) on June 24 at the 241 E meridian seem to be related to the impact of the tropical storm Blias and hurricane Celia.

Table 1. The largest earthquakes sequence to occur in California in 1992

Date	Name	Area	Mag.	Time, UT	Epicenter	Depth, km
1992-06-29	Little Skull Mountain	Inland Empire	5.7 M_w	10:14	34.2°N 116.4°W	9.6
1992-06-28	Big Bear	Inland Empire	6.5 M_w	15:05	34.2°N 116,8°W	5
1992-06-28	Landers	Inland Empire	7.3 M_w	11:57	34.2°N 116.4°W	1.09
1992-04-26	Cape Mendocino	North Coast	6.6 M_w	11:18	40.4°N 124.4°W	21.7
1992-04-26	Cape Mendocino	North Coast	6.5 M_w	7:42	40.6°N 124.3°W	19.3
1992-04-25	Cape Mendocino	North Coast	7.2 M_w	18:06	40.4°N 124.1°W	10.5
1992-04-23	Joshua Tree	Inland Empire	6.1 M_s	04:51	34°N 116.3°W	11.6

Table 2. United States' Julin series tests and detonations [15, 16]

Name	Date time (UT)	Location	Elevation+ height	Delivery Purpose	Yield	Notes
Victoria	19 June 1992 16:45:00	NTS 37.01°N 116.01°W	1,179 m 244 m	underground shaft, weapons development	80 t	
Galena-Green - 3	23 June 1992 15:00:00.07	NTS 37.12°N 116.03°W	1,269 m 400 m	underground shaft, safety experiment	less 5 kt	Simultaneous, same hole.

***Galena-Orange* - 2**	23 June 1992 15:00:00.07	NTS 37.12°N 116.03°W	1,269 m 400 m	underground shaft, safety experiment	less 5 kt	Simultaneous, same hole.
***Galena-Yellow* - 1**	23 June 1992 15:00:00.072	NTS 37.12°N 116.03°W	1,269 m 400 m	underground shaft, weapons development	less 5 kt	Simultaneous, same hole.
Hunters Trophy	18 September 1992 17:00:00	NTS 37.21°N 116.21°W	1,827 m 385.3 m	underground tunnel, weapon effect	4 kt	
Divider	23 September 1992 15:04:00	NTS 37.02°N 115.99°W	1,208 m 426 m	underground shaft, weapons development	5 kt	Last U.S. nuclear test

The appearance of an anomalous ELF signal in the 140 Hz channel at L ~ 1.6 is a characteristic ionospheric precursor of an earthquake [9,11]. The trough in the 4600 Hz channel at L ~ 1.5 is observed over the Landers earthquake zone after UNT Victoria. Intensive oscillations at the lower hybrid frequency (NGR) are usually observed in 4600 Hz channel band. The injection of light hydrogen ions into the upper ionosphere shifts up the frequency of the NGR and intense oscillations leave the 4600 Hz channel band.

Signal changes in the canals of 4600 Hz and 15 kHz were observed the day after UNT Galena (a series of three UNEs). It was previously illustrated by the example of UNE Texarkana 11 Feb 1989 that ionospheric effects after UNT (with Yieid less than 10 kt) are recorded only on the experimental day before terminator pass [9].

Anomalous signals at L ~ 1.18 are associated with the impact on the ionosphere of the hurricane Celia. Its intensity reached the fourth category on June 27.

The following Fig.2 presents the Cosmos-1809 satellite instruments data in 4 and 6 hours after the aftershock on June 29. At 15:04 UT (L ~ 1.5), the satellite trajectory intersects a region whose projection onto the E-layer of the ionosphere is above the Landers earthquake zone. The following effects are found in this area:

1. Cavern of low density and high electron temperature up to 5 %;
2. Strong Ne fluctuations up to 2 %;
3. Strong cavity of the oscillation intensity in the 4600 Hz channel with a sharp boundary, which is typical after the passage of an acoustic wave from the UNE and an earthquake through the F-layer of the ionosphere [9];
4. Characteristic narrow jump in the 4600 Hz channel, which indicates a formed channel for the passage of whistlers along the magnetic field to the southern hemisphere;
5. Longitudinal electric field up to 5 mV/m, which confirms the presence of the magnetospheric channel.

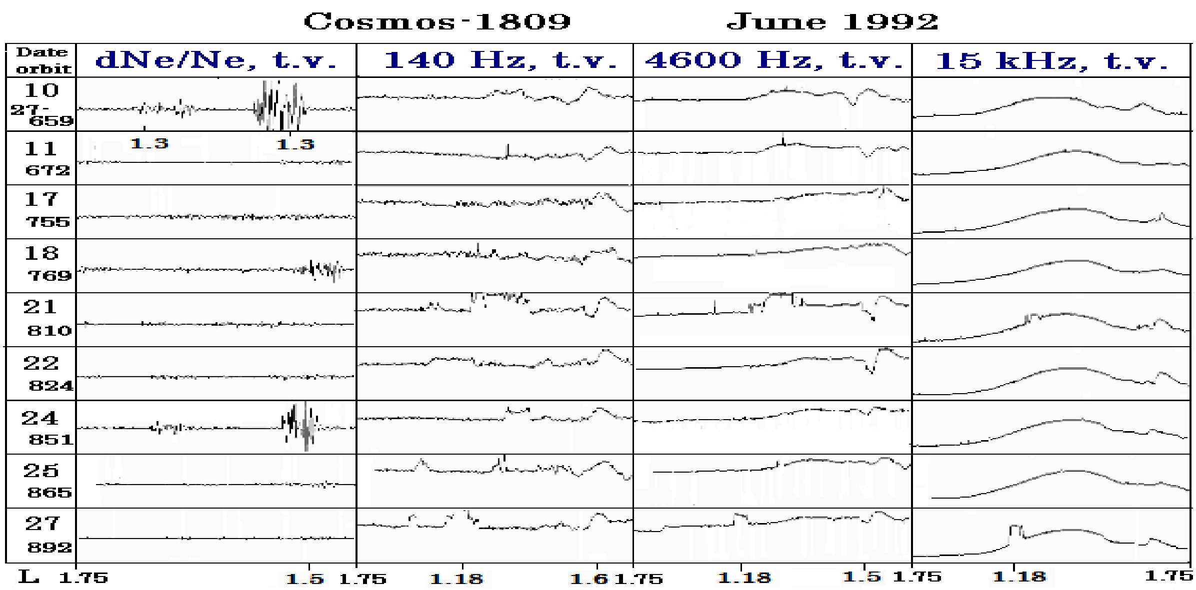

Fig. 1. Fluctuation sequence of Ne and the average amplitudes of electrical oscillations at some frequency intervals near the NTS meridian (116 W) and the magnetoconjugated region (L < 1.75) from June 10 to June 27, 1992 (LT = 10.5) before the Landers earthquake start

II. **Particularities of the development of tropical cyclones after nuclear testing in September 1992**

Though September is the climatological peak of hurricane season 1992, an increase in wind shear prevented tropical cyclogenesis in the first half of the month [17]. Fig. 3 shows the intensities of the TC in the Atlantic Ocean and the eastern part of the Pacific Ocean for this period. There were two TC around America before the Hunters Trophy UNT. The center of the tropical storm Roslin was 19.3 N, 126 W and the wind speed 60 knot June 18. TC Bonnie had its origins in a non-tropical weather system. TC Bonnie moved slowly along a counterclockwise path before strengthening into a hurricane at 18:00 UT September 18.

Figure 3 shows that the Bonnie, Tina, and Seymour TSs were sharply intensified after the UNT Hunters Trophy. The tropical wave which triggered the formation of Seymour moved off the African coast on 1 September. Tina formed from tropical wave over the west coast of Africa near Dakar and over the Cape Verde Islands on the 5-6th of September. Satellite images indicate that late 16 September the amount of deep convection associated with the wave increased and became concentrated over a small area centered about 650 кm to the south of Acapulco, Mexico. However, it was not until the 17th that the two interacting systems became a tropical depression. Seymour moved to the west-northwest and northwest reaching hurricane status at 12:00 UT 19 September.

Characteristics of the six TCs have changed sharply after the Divider UNT, which follows from Fig. 3 and Fig. 4. The acoustic impact of UNE on the atmospheric systems of Roslin, Seymour and Tina led to a simultaneous drop in intensity TC near the west coast of America. TC Seymour and Tina began to rotate relative to each other, since the distance between their centers was less than 1,400 km (Fujiwhara effect). Then Tina absorbed Seymour and the joint reinforcement of Tina and Roslin began. The behavior of interacting TCs in the stratosphere disturbed by the eruption of the Pinatubo volcano is explained by the change in the propagation of infrasonic waves [18]. It should be noted that there is another physical mechanism associated with galactic cosmic rays, affecting the development of the TC, where the content of aerosols in the atmosphere plays an important role [19].

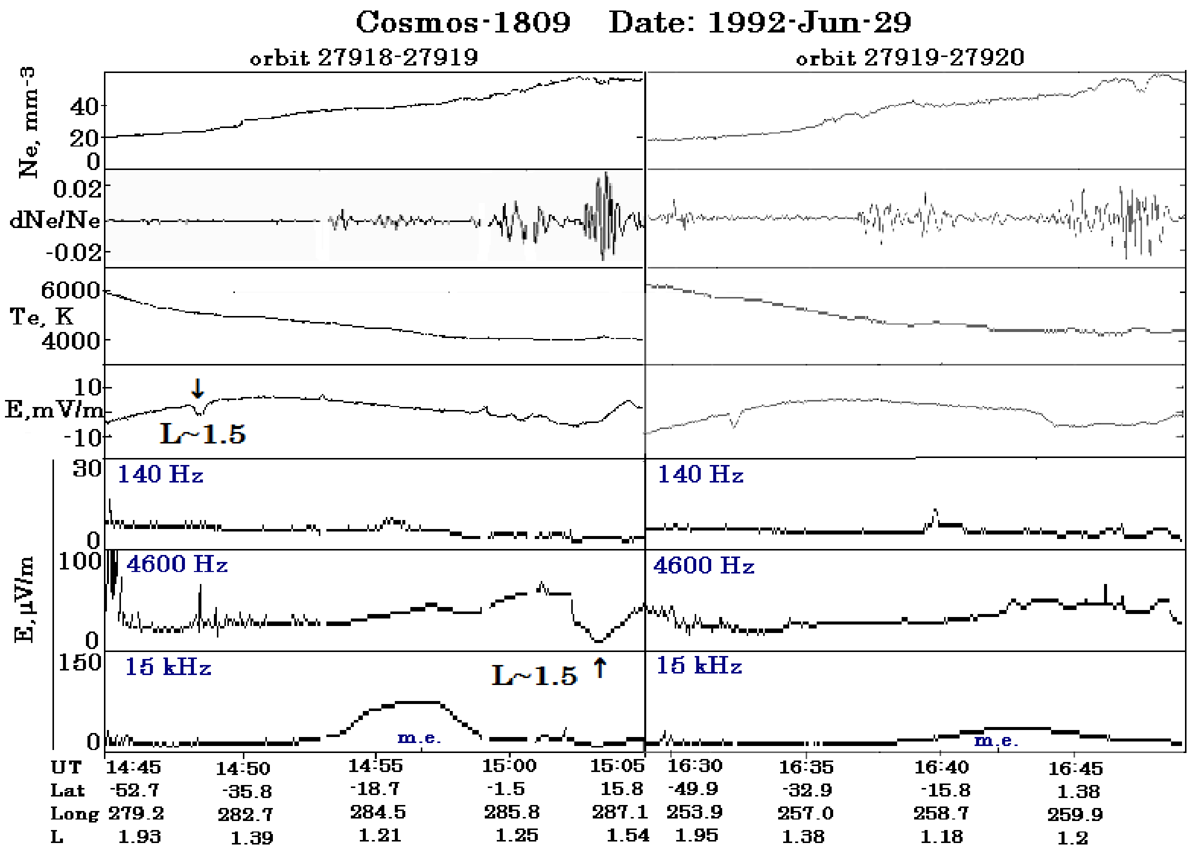

Fig. 2. Perturbations of the upper ionosphere at 4–6 hours after the Landers earthquake

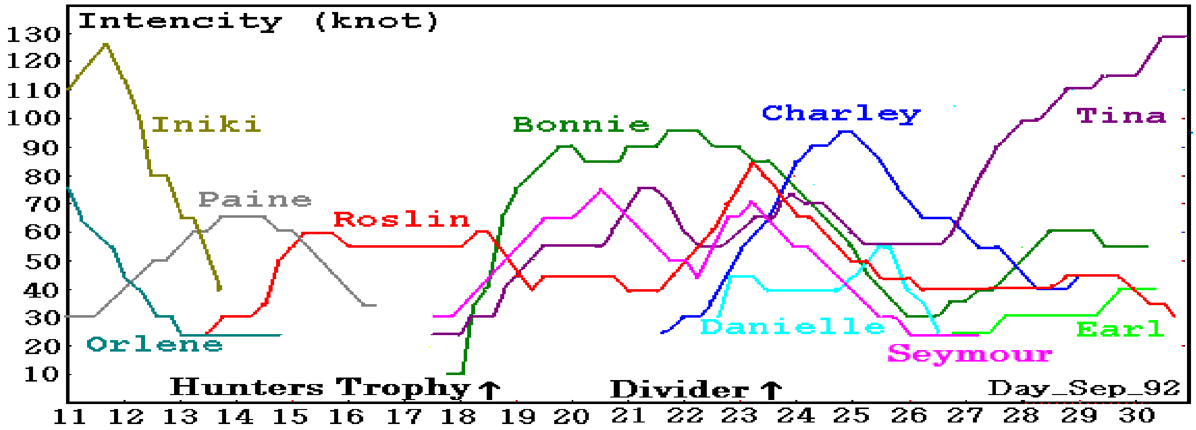

Fig. 3. TC intensities in the Pacific and Atlantic oceans from September 11 to September 30, 1992.
Arrows indicate the moments of the Hunters Trophy and Divider UNTs.

From the point of view of meteorologists the second cycle of intensification was underway on the 24th when Tina made a rather sharp turn to the north-northeast, onto a heading toward the west coast of Mexico. The turn coincided with a weakening of the ridge to the north and with a mid- to upper-level trough moving eastward to the north of Tina [17].

Near the east coast of America the acoustic impact of UNE on TC Danielle slightly reduced its intensity (Fig. 3) and sharply changed its trajectory (Fig. 4). The impact of UNE on the more distant interacting atmospheric systems Bonnie and Charley, which began to rotate, also sharply changed their trajectories. Comparison of electron density Ne on 10 consecutive orbits (Fig. 4), which took place at the same local time LT ~ 21: 40, shows that only on orbit 29116 its significant increase is observed. This orbit intersected the plane of the magnetic meridian passing through the NTS. The growth of Ne occurred over the zone of influence of Roslin, Seymour and Tina, which is associated with the acoustic impact of UNE. Separate narrow peaks of Ne over the TC which is typical for single strong non-interacting TC are not highlighted in Fig. 4 [9].

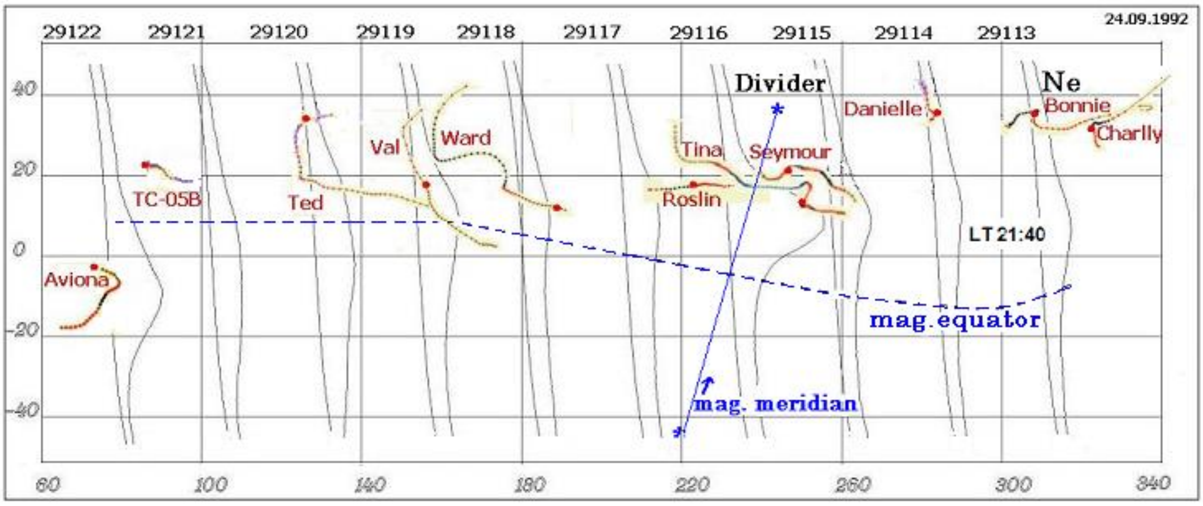

Fig. 4. Electron density after the UNT Divider. The points on the TC trajectories indicate the centers of the cyclones at the time of the satellite pass.

Fig. 5 presents some parameters of the ionosphere near the NTS meridian after the evening terminator on the day of the experiment. Due to the declination of the magnetic field, the height of the sun shadow in the plane of the satellite trajectory is higher in the northern hemisphere (2265 km at the NTS latitude) than in the magnetically conjugated region of the southern hemisphere (less than 1000 km). Therefore, the influence of UNE on the TC is better determined in the southern hemisphere. At orbit 29115 the periodic structure in the 4600 Hz channel apparently reflects the appearance of moving ionospheric disturbances after the acoustic wave enters the E-layer. Some of the maxima in the 15 kHz channel before the magnetic equator (m. e.) and behind it coincide with the projection of the magnetic field on the E-layer of the ionosphere above TC Seymour, Roslin and Tina. At orbit 29116 the appearance of a diffuse structure in the 15 kHz channel over the NTS (L < 1.7) is well distinguished, which apparently reflects the appearance of a sporadic E-layer due to precipitating electrons in the conjugate ionosphere. After the morning terminator passes through the NTS such particularities do not differ on orbits 29222 and 29223.

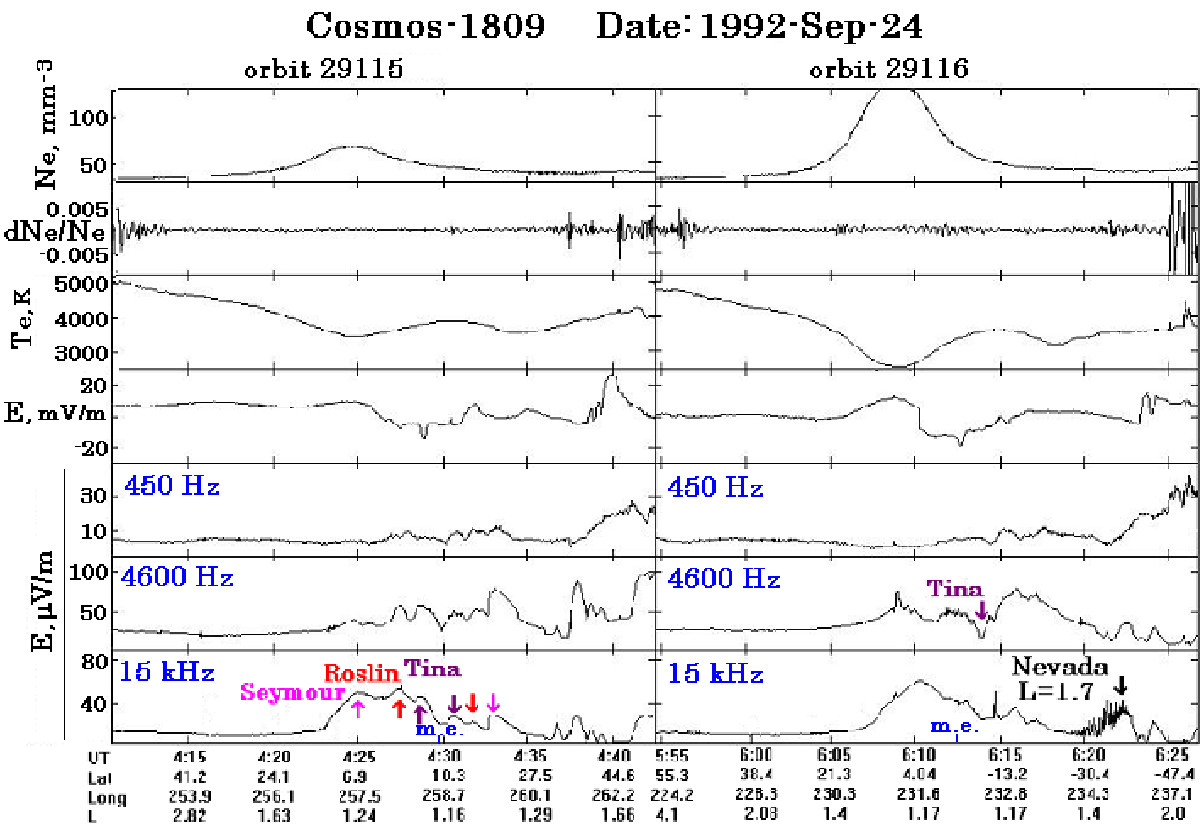

Fig. 5. Ionosphere parameters at satellite pass closest to the NTS after the Divider UNT

Summary

1. The seismic impact of the UNE Victoria and Galena in June 1992 on the San Andreas Fault, which has accumulated critical stress, appears to have caused the Landers earthquake. This conclusion confirms the appearance of ionospheric disturbances over California and Nevada, recorded from the Cosmos-1809 satellite. In the future, it is planned to compare this conclusion with the dynamics of the stress state in Southern California based on the geomechanical model and current seismicity [20].

2. The acoustic impact of the UNE Hunters Trophy and Divider on the global TC system is associated with the quasi-Biennial oscillation of zonal wind after the eruption of the Pinatubo volcano. A sharp change in the intensity and trajectory of the TC in the waters of the Atlantic Ocean and the eastern part of Pacific Ocean after UNE appears to be described by nonlinear dynamics of planetary magnetized Rossby waves [21], which requires additional investigation.

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