URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020

Multiparameter analysis of the data collected around the time of 2019 Ridgecrest earthquakes

Sergey A. Pulinets[1,2], Dimitar P. Ouzounov[3], Marina N. Tsidilina[4], Alexander A. Rozhnoi[5] Dmitry V. Davidenko[1]
(1) Space Research Institute, Russian Academy of Sciences, Moscow, http://www.iki.rssi.ru/eng/index.htm
(2) Institute of Applied Physics, Russian Academy of Sciences, Nizhni Novgorod, Russia
(3) Chapman University, Orange, California, USA
(4) Institute for Scientific Research of Aerospace Monitoring "AEROCOSMOS", Moscow, Russia
(5) Shmidt Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia

Abstract

We are presenting a preliminary study on the multi-parameter analysts of transient phenomena observed in the Earth atmosphere-ionosphere environment plausibly associated with M6.4 of July 4, 2019, M5.4 of July 5, 2019, and M7.1 of July 6, 2019, in Ridgecrest California; the last one is the largest earthquake in California for last 20 years. We analyze the data from five sources which were recorded different time resolution (from 10 min for GPS TEC to daily record for OLR): 1. Radon level variations (two gamma stations in Southern CA); 2. Correction of chemical potential measured at the level 100 m over ground surface and air temperature and humidity from assimilative GEOS-FP NASA model 3. Very Low Frequency (VLF) modulated signals in the frequency range 10-50 kHz from several VLF/LF transmitters 4. Outgoing long-wavelength radiation (OLR obtained from NPOES) on the top of the atmosphere (TOA), and 5. GPS TEC calculated from the stationary GPS receivers network in California. We try to find the coherence/synergy between different types of precursors, We examine the conception of the earthquake preparation zone and spatial distribution of precursors within it. We consider the date of 20 June as a start of metastable state of the environment and as precursory period basing on the data of sub-ionospheric propagation of VLF waves and chemical potential variations as closest to the ground surface. Very clear indication of ionospheric night-time positive deviation of vertical TEC which we use as main ionospheric precursor lasts from 26 till 28 of June, and more complex behavior of OLR anomalies “dancing” around epicenter position with significant anomalies on 6 June, 10 June, 15 June and coinciding with GPS TEC 27 and 28 June.

1 Introduction

In the last 15 years the large progress in understanding the processes of short-term physical precursor generation processes has been reached [1, 2, 3]. It was established that strong modification of the near-ground layer of atmosphere takes place under the action of increased radon emanation within the earthquake preparation zone due to ionization produced by radon decay and release of energetic alpha-particles with the energy ~5.6 MeV. This modification is expressed mainly in thermal anomalies generation due to latent heat released by water vapor molecules condensing on the new formed ions, and changes of electro properties of the air due to variation of its conductivity (increase/decrease) during different phases of the process of Ion Induced Nucleation. All these launches the cascade processes propagating up and creating anomalies in troposphere and ionosphere which could be registered by different techniques. All this happens during short period of time (few weeks/days), and all precursors “work” together in synergetic manner characteristic to the open dissipative systems [4]. Within the framework of this conception we consider the collected multi-sensor data using approach described in [5].

2 Data assessment, analysis and interpretation

To estimate the spatial scale of the area where the anomalous variations of different parameters could be observed we usually explore the spatial distribution of the chemical potential correction described in [2]. From the earthquake preparation zone estimation [6] for magnitude 7.1 we may expect the radius of anomalous area extending 1000 km. From the apical distribution of the chemical potential we selected the day and time with the maximum spatial size of the chemical potential which is presented in the Fig. 1.

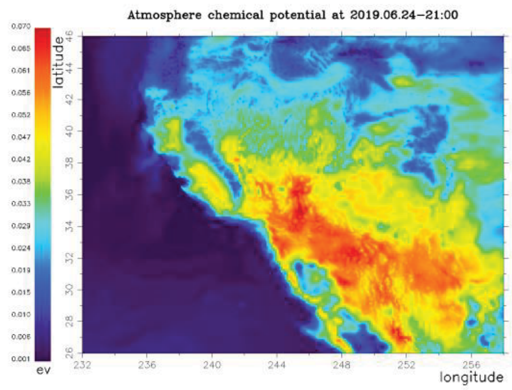

Figure 1. Chemical potential disttibution on 24 June 21 LT

We can see from the picture that the Mainly the anomaly spread in the south-east direction from the epicentral area. It means that we may expect the atmosphere disturbances in this direction which should make effect on the sub-ionospheric VLF waves propagation. VLF receiver situated in the Southern California was able to receive the VLF signal from four directions from different navigational transmitters, see Fig. 2.

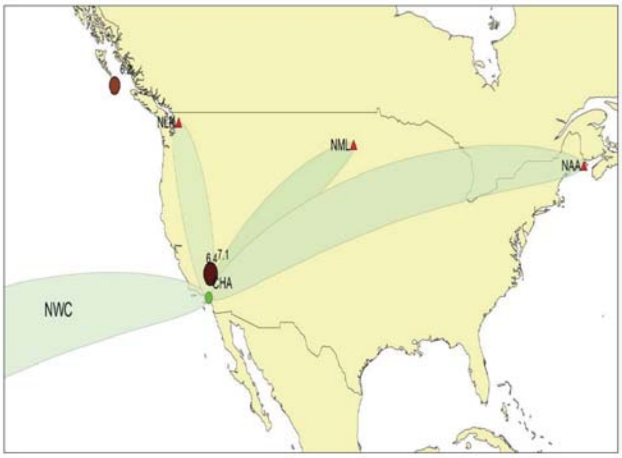

Figure 2. Configuration of the subionospheric propagation experiment in Southern California

The anomalies we registered from three directions with maximal amplitude anomalies within the interval 20-26 June, Fig. 3

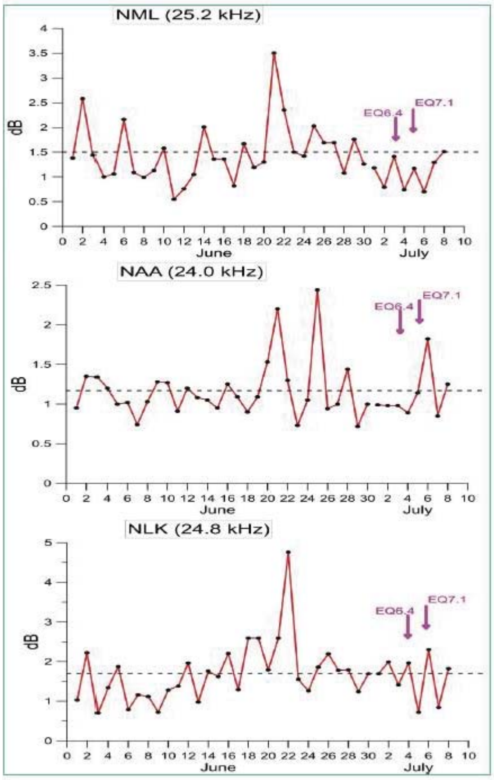

Figure 3. Amplitude anomalies of the subionospheric propagation of the VLF signals before the Ridgercrest earthquakes of 2019.

If we look to the time series of the chemical potential, relative humidity and air temperature registered at the earthquake epicenter and presented in the Fig. 4 (a-c), we clearly detect the anomalous variations of al three parameters during the same interval of time.

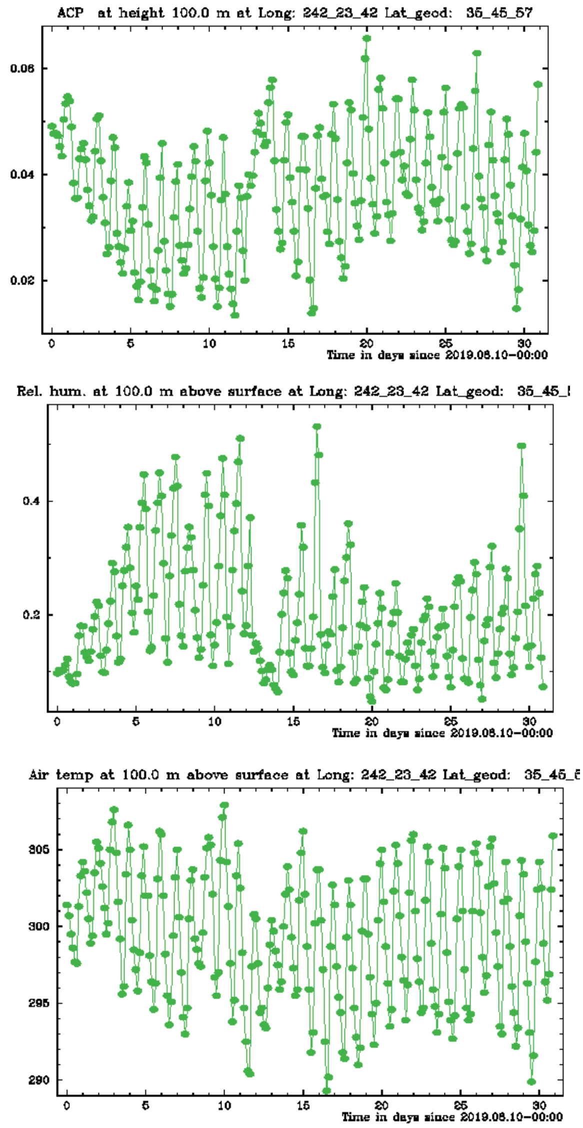

Figure 4 From top to bottom: atmospheric chemical potential, relative air humidity and air temperature in epicenter. All graphs start on 10 June 2019

To register the ionospheric precursors we used the network of stationary GPS receivers in California. The map of receivers used in the analysis is shown in the Fig. 5. We used the approach described in [7] and expected to see the night-time positive anomaly in the visual representation of vertical TEC residuals Local time versus days around the time of earthquakes, where residuals (in %) are color coded. These variations for several stations from the set are shown in the Fig. 6. One can see that the positive anomaly is concentrated within the time interval from 26 to 28 of June, i.e. it starts immediately after the period of VLF and chemical potential anomalies. The strongest effect we observe near 4 LT on 28 June. For this moment we constructed the map of the positive deviation using the data from all stations Fig. 7.

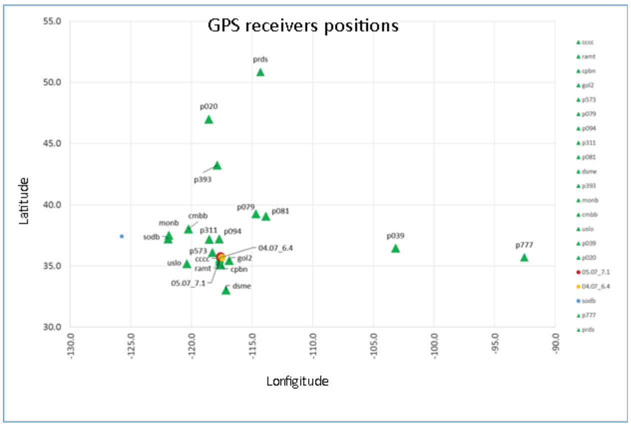

Figure 5. Positions of GPS receivers used in analysis.

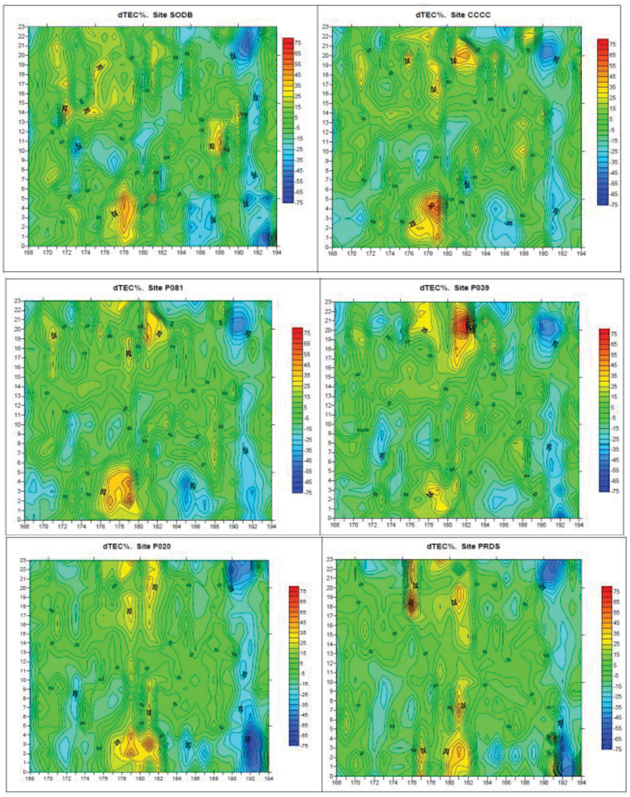

Figure 6. Ionospheric precursor mask calculated for the 6 stations from the California network.

Table 1. Coordinates of GPS receivers

Site	Coordinates	
	Latitude	Longitude
cccc	35.57°N	117.67 °W
p094	37.201°N	117.704°W
uslo	35.18°N	120.39°W
dsme	33.02°N	117.15°W
sodb	37.17°N	121.92°W
p081	39.067°N	113.871°W
p393	43.235°N	117.892°W
p020	47.00°N	118.57°W
p039	36.45°N	103.15°W
prds	50.87°N	114.29°W
p777	35.70°N	92.55°W

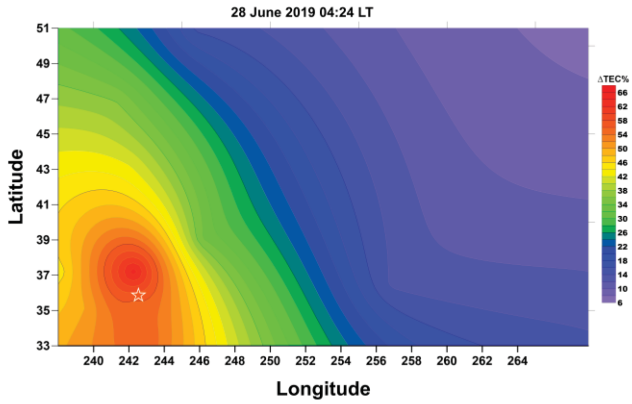

Figure 6. Ionospheric precursor mask calculated for the 6 stations from the California network.

To determine precursory period we use also the cross-correlation analysis calculating cross-correlation coefficient between the daily variations on the pair of receivers. This analysis demonstrates also the drop of the coefficient on 26-28 June which are 177-179 DOY (Fig. 7).

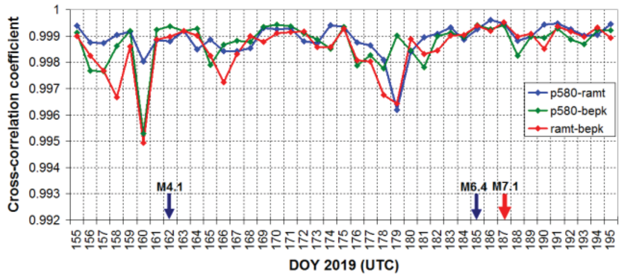

Figure 7. Cross-correlation coefficient for three pairs of stations (155-195 DOY)

The last parameter we would like to discuss is the OLR variations registered around the time of Ridgecrest earthquakes. Unfortunately the format of the paper does not give opportunity to demonstrate the continuous series of maps because lack of place. So we demonstrate only the maps for days when the strong anomalies were detected. The maps of OLR flux are shown in the Fig. 8 (a-d). We can see how the anomalies move around the epicenter position.

3. Conclusion

We have presented the multiparameter analysis of the short-term precursors in atmosphere and ionosphere of different physical nature and at different altitudes which show the development of environment modification before the strong earthquake, which show their coherence in time and place.

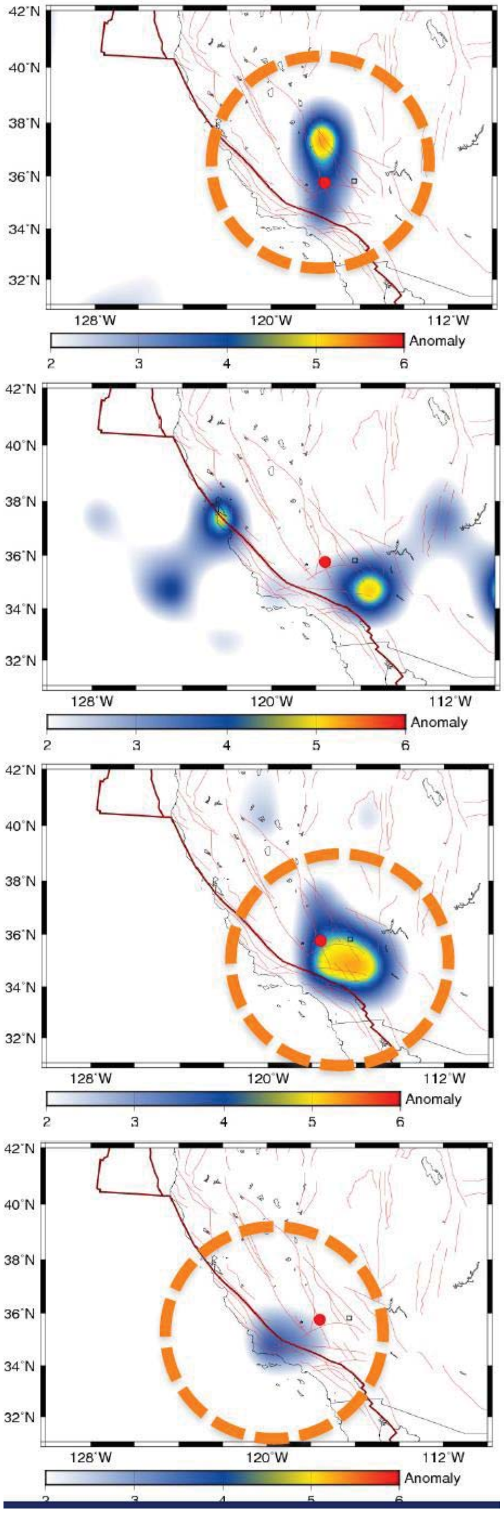

Figure 8 From top to bottom OLR anomalies on 6, 10, 15 and coinciding 27 June.

4 Acknowledgements

This work was supported by the Russian Science Foundation under grant 18-12-00441.

4. References

1. S. Pulinets, D. Ouzounov, “Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model - an unified concept for earthquake precursors validation”, *Journal of Asian Earth Sciences*, **41**, 4, 2011, pp. 371-382 DOI: 10.1016/j.jseaes.2010.03.005

2. S. A. Pulinets, D. P. Ouzounov, A. V. Karelin, D. V. Davidenko, “Physical Bases of the Generation of Short-Term Earthquake Precursors: A Complex Model of Ionization-Induced Geophysical Processes in the Lithosphere–Atmosphere–Ionosphere–Magnetosphere System”, Geomagnetism *and Aeronomy*, **55**, 4, 2015, pp. 540-558, DOI: 10.1134/S0016793215040131

3. S. Pulinets, D. Ouzounov, A. Karelin, and D. Davidenko, “Lithosphere–Atmosphere–Ionosphere–Magnetosphere Coupling – A Concept for Pre-Earthquake Signals Generation”, in: Pre-Earthquake Processes: A Multidisciplinary Approach to Earthquake Prediction Studies, Editors: D. Ouzounov, S. Pulinets, K. Hattori, and P. Taylor, Publisher: AGU/Wiley, 2018, pp. 77-98, doi.org/10.1002/9781119156949.ch6

4. E. N. Knyazeva, S. P Kurdyumov, “Peculiarities of the nonequilibrium processes in open dissipative systems”,in: Problems of Geophysics of XXI century, Editor A.V. Nikolaev, Nauka Publishing, Moscow, 2003, pp. 37-55

5. Dimitar Ouzounov, Sergey Pulinets, Jann-Yenq (Tiger) Liu, Katsumi Hattori, and Peng Han, Multiparameter Assessment of Pre-Earthquake Atmospheric Signals, in: Pre-Earthquake Processes: A Multidisciplinary Approach to Earthquake Prediction Studies, Editors(s): Dimitar Ouzounov, Sergey Pulinets, Katsumi Hattori, Patrick Taylor, Publisher: AGU/Wiley, 2018, p. 339-359, doi.org/10.1002/9781119156949.ch20

6. I. R. Dobrovolsky, S. I. Zubkov, V. I. Myachkin, “Estimation of the size of earthquake preparation zones” *Pure and Applied Geophysics*, **117**, 1979, pp. 1025–1044

7. S. A. Pulinets, T. B. Gaivoronska, A. Leyva Contreras, L. Ciraolo, “Correlation analysis technique revealing ionospheric precursors of earthquakes”, *Natural Hazards and Earth System Sciences*, **4**, 2004, pp. 697-702