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History of Observations of Seismogenic Phenomena in the Atmosphere and Formalization of Their Decryption

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Abstract: Since ancient times, observers, including Babylonians, residents of the environs of Vesuvius, Japanese, have noted specific phenomena in the atmosphere, on the ground, in water and in the behavior of animals in anticipation of earthquakes or volcanic eruptions. In the atmosphere, it is a haze, narrow dark cloud stripes of great length, black mists, slots in the clouds. The languages of the flame from the slots in the ground, hot springs, the change of river channels, various noises, excitement, the smell of hydrogen sulfide in standing waters, the mass release of fish from the water, the restless behavior of animals. Aristotle suggested that these phenomena in the atmosphere are caused by gas emissions from the Earth, Humboldt associated with seismogenic changes in atmospheric electricity. Later, researchers linked them to activated faults of the earth's crust, the local concentration of ions in radiation. Modern geological analysis showed the presence of methane in those areas, faults of the earth's crust, and the growth of electromagnetic fields several times before earthquakes. However, the decryption of atmospheric precursors remained at the level of author decryption of satellite images of atmospheric formations, which did not exclude the mass of noise estimates, for example, orographic and long-range clouds, aircraft traces. There was no identification of the "blackness" of clouds and fogs. Our analysis of the spectral characteristics of atmospheric formations showed that the water intake of some narrow extended clouds above the faults of the earth's crust is zero, in their zone the local minimum of the integral humidity of the atmosphere. The phenomenological representation of the components of solar radiation made it possible to identify the characteristic size of the cloud atmospheric aerosol from spectral data from the NOAA series, thereby concluding the predominantly dry dust composition of seismogenic clouds, their "blackness." The presence of narrow extended breaks in wet meteorological clouds over activated faults of the Earth's crust is also associated with the reaction of atmospheric moisture to electromagnetic disturbances - clouds diverge, visible dust formations do not form since atmospheric dust is previously "disassembled" by meteorological clouds into condensation nuclei. The discussed atmospheric anomalies precede local earthquakes.

Keywords: Activated Faults of Earth's Crust, Clouds, Breaks in Clouds, Dry Atmospheric Dust, Electromagnetic Disturbances

1. Ancient Greece and Rome

According to the views of *Aristotle*, earthquakes are caused by movements of the pneuma (fluids); emission of the pneuma leads to formation of linear clouds and underground hum, clouding and dimming of sun (increased aerosol concentration), appearance of dense local fog in the area of the earthquake epicenter, but clear sky in a few meters from the fog. Turbidity in the atmosphere is a forerunner of an earthquake because many gases locked in the earth come out of the ground. Marvelous phenomena follow a variety of movements: sometimes flame or hot springs appear on the surface; course of rivers change; a variety of noises can be heard, waves and stale smell appear at stagnant waters, a thin line of long clouds appears on the sky. Modern geological analysis of the areas showed presence of methane and ethane that could come to the surface. At all times, residents living close to Vesuvius were able to predict its eruption a few days before by wells drying. According to Babylonians, earthquakes, gaping cracks and all other natural disasters are caused by the force of the planets. Medieval scientists held Aristotle's position that earthquakes are caused by dry vapor emerged from the earth, they also added their observation of unusual behavior of animals [10, 26].

2. XVIII - XX Centuries

In the XVIII century, in *Europe*, following was observed before earthquakes "... existence of a close relationship between earthquakes and volcanic eruptions and state of the atmosphere... earthquakes and volcanic eruptions can have a significant impact on the atmosphere... a remarkable calm, a strong fog and unusually gray or red color of the sky" [26].

Humboldt "said that we are still not quite clear about genetic relationship between meteorological processes and processes happening inside the Earth's crust.... Are these meteorological processes the essence of the action disturbed by an earthquake of atmospheric electricity?" He observed reddish fog for several times in the earthquake day and shortly before it; in his opinion, earthquakes are accompanied by changes in atmospheric pressure only in those countries where earthquakes are rare [26]. He "wrote in "*Cosmos*" that it was possible to see during the earthquake a column of fire and smoke that wallow in the vicinity of the city from the newly formed crack in the rock" [26].

Musketov I. (1850-1902) observed that seismic indicators often appear in the form of linear or angular cloud structures tracking the activated at the boundaries of lithospheric plates, blocks or faults that is due to the local concentration of ions at radiation [3, 21].

When characteristic fog suddenly appears in the Japanese *Sado* island, miners quickly escape from the coming earthquake [10]. "*M. S. Di Rossi* notes that we have the highest temperatures in the years when earthquakes are most frequent. So, in 1873, during the earthquake in central and northern *Italy*, unusually high temperatures were observed. Japanese scientists noted unusual heat that accompanied the earthquake. They found that for the 387 earthquakes observed in Northern Japan, the average monthly temperature curve showed a small maximum before the strike" [26].

3. Popular Beliefs

1 November 1755, *Lisbon*. "After the earthquake, which destroyed three-quarters of Lisbon, wise men of the country had not found the means more suitable to prevent the final destruction than to give the population a beautiful auto-da-fe. University in *Coimbra* ruled that the spectacle of burning several people on a small fire with a large ceremony is an undeniable means to stop the shuddering of the earth" [26].

4. Current Views of the Seismic Index in the Atmosphere

4.1. Moisture Analysis of Seismogenic Clouds

In recent decades, the scientific community has renewed its interest in the provided in chronicle atmospheric geoindicators of earthquakes - linear cloud structures and gaps in the clouds. Their lifetime is tens of minutes; width - up to several kilometers; time of appearance to 3 weeks before the earthquake. Because of lack of clarity in earthquake indicator genesis they are analyzed on a personal, sometimes intuitive basis, not excluding orographic, coastal phenomena, condensation trails of aircraft, etc., painful visions or feelings of operators. Necessary technologies are hardly implemented in the operational practice, mainly because of such false alarms [3, 21, 23].

In order to get a formalized objective understanding of these structures, we conducted their situational and spectral analysis. It was found that local minima of the integral content of water vapor in the atmosphere (*W*), water storage (*Q*) of clouds following the activated faults is zero in the vicinity of activated faults of the crust [17-19].

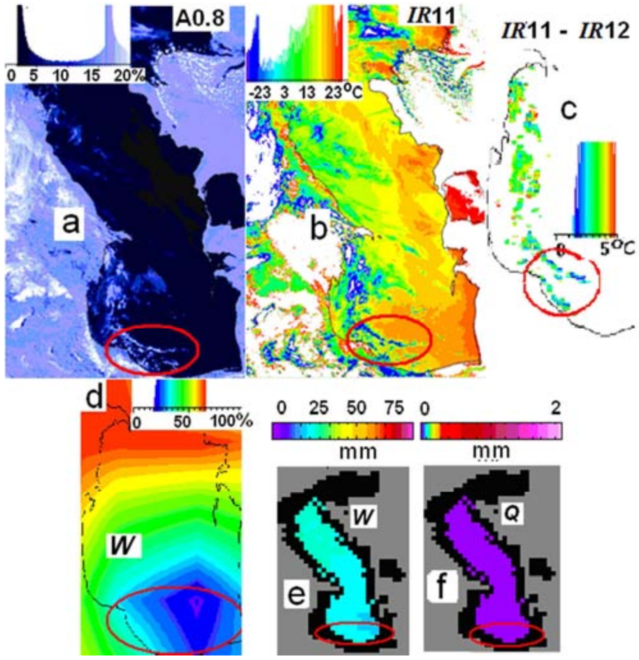

Figure 1. Image of the Caspian region made by NOAA/AVHRR on 27.05.2004 in the near (0.8 μm) and far (11 μm) infrared (IR) ranges (a, b), in the cloud ellipse - tracers; difference of radiation IR temperatures at 11 and 12 μm (c); relative humidity field (W), %, at 500 mbar, according to radio probe and radiation sensing data (d), W and Q (e, f).

For example, on 27 may 2004, according to measurements made by *AVHRR* multi-spectral radiometer of *NOAA* satellite, clouds of the upper and middle layers were observed over the southern part of Caspian Sea (Figure 1), and some of them followed the faults of the crust; oil and gas slick was seen on the apsheron rift (speed of the near-water wind - 5÷8 m/s). The next day, an earthquake occurred in the region. The southern cloud structure over the fault turned out to be dry –

a relative humidity at height of the structure was less than 40% that is insufficient for meteorological clouds (Figure 1 *d*). The fact that this structure was low-water resulted both from the low value of the *IR temperature* difference measured at wavelengths 11 and 12 µm (for cloudless atmosphere *T11-T12 ~ W*) and from integral field Q≈0 (Figure 1 e, f) [9]. The clouds along the Iranian coast were not meteorological, but dry dusty. The dust was not watered; magnitude of its albedo was lower than that of the neighboring clouds located in the same layer. Such dust clouds are perceived as dark, they are called (in Japan) "black" in chronicle sources and today.

To formalize the search for optical seismogenic clouds features, we carried out the following simulation of the cloud atmosphere albedo. The Earth's albedo is formed by solar radiation, reflected and scattered by the underlying surface ($A_{blik\ \lambda}$) which is distorted by the atmosphere influence, including cloudless atmosphere and translucent cloud ($A_{atm.\lambda}$) and, for wavelengths (λ) shorter than 3 microns, by radiation which emerges from the lower layer of the underlying translucent surface ($A_{post.pov.\lambda}$) as well. For spectral measurements made by *AVHRR/NOAA* at wavelengths of 0.6, 0.8, 3.7 µm, corresponding equations system is as follows:

$$A_{0.6}=A_{atm\cdot 0.6} + (A_{blik\ 0.6} +(A_{post.pov.0.6}) * \exp^2(-\tau_{0.6}{}^{k\lambda}) \quad (1)$$

$$A_{0.8}=F_{0.8} * A_{atm.0.6} + (A_{blik\ 0.6} + A_{post.pov\ 0.8}) * \exp^2(-\tau_{0.6}{}^{k\lambda}) \quad (2)$$

$$A_{3.7}=F_{3.7} * A_{atm.0.6} + A_{blik\ 0.6} * \exp^2(-\tau_{0.6}{}^{k\lambda}), \quad (3)$$

where τ_λ – optical thickness of the atmosphere, k_λ – parameter related to the aerosol size. All atmospheric parameters are calculated using the "*LOUTRAN*" procedure, and their numerical values are interdependent. The value of k_λ parameter for the atmosphere without aerosol changes along the spectrum inversely proportional to the ratio of the wavelengths in 4-th power, for a cloudless atmosphere - in - 2÷1.2 power, for dust and clouds of liquid droplet - 1.5÷0.8 power, for crystalline clouds - 1.2÷0.5 power. For clouds, values $A_{post.pov.\lambda}$ and $A_{blik\ \lambda}$ in the analyzed part of the spectrum are close to 1. The value of the parameter F_λ, taking into account the spectral behavior of the distorting effect of the dusty atmosphere, is interdependent with τ_λ (for an atmosphere without dust F_λ=1, with dust - $F_\lambda \approx 0.3$). Introduction of this parameter is due to the fact that, in calculations of the atmosphere distorting effect using *MI* theory, there is no concept of shadow, even the obvious - the solar eclipse [13, 22].

As a result of such approximations, only the atmosphere distorting effect remains variable along the spectrum. Number of AVHRR/NOAA spectral measurements of albedo is equals to number of the required parameters of the environment $A_{blic\ 0.6}$, $A_{post.pov.0.6}$ and iteratively selected value τ_λ depending on the characteristic size of the aerosol. The albedo value in the mid-IR range is calculated after the corresponding temperature-humidity correction of the IR temperature at 3.7 µm wavelength according to the measurements at the 11 and 12 µm wavelengths - T_{11} and T_{12}. In the calculation of the spectral behavior of the atmospheric parameters values, not standard estimation methods for the marine and continental atmospheres, depending on the transparency, with software packages such as "LOUTRAN" or "MODTRAN", should be used, but characteristic sizes of aerosol recalculated for the time of day. This is due to the fact that the morning aerosol is usually smaller than the evening because of the day watering. This was not taken into account in the course of gross collection of experimental data for atmospheric optics software packages, and this led to chaos in the estimates of the spectra of the distorting effect of the atmosphere.

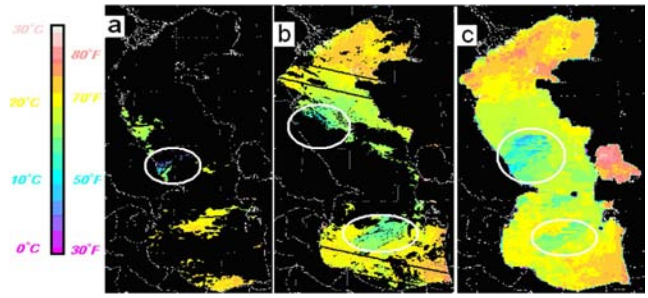

Figure 2. *SST map of Caspian Sea, 16.05, 14.42 GMT (a), 16.05, 03.08 GMT (b), a composite map of 10 images, 16.05.2016 (c); in ellipses - noisy data due to clouds.*

With this approach, interpretation of the scenes of the cloud border (when only part of the radiometer resolution element is occupied by cloud) and translucent clouds remains a problem. For example, on Caspian maps in white ellipses, water surface temperatures (*SST*) are clearly noisy with clouds; in the central part of the sea, the *SST* does not drop below in mid-May 15°C (Figure 2) [6, 7]. Use of equations (1-3) for estimation of *SST* fields allows filtering out of under-cloud water areas taking into account a distorting effect of translucent aerosols. In the north of the *Caspian Sea*, decreased *SST* values observed under the translucent aerosol clouds are identified as a distorting effect of the atmosphere (Figure 3).

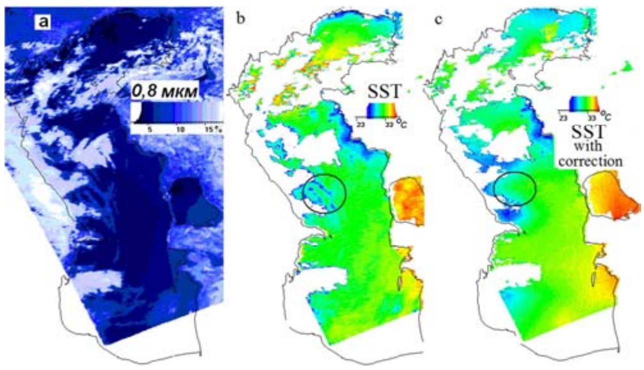

Figure 3. *a - image at 0.8 µm, 27.08.1999 (AVHRR); b – SST without reduced insolation correction; c - SST with correction. In ellipses - semi-translucent clouds.*

On 11.07.2004, during active upwelling, in the clear water on the traverse of *Karabogazgol* bay, fishing for sprat was effectively carried out. Suddenly, without storm activity, the water became muddy, divers saw the plowed bottom, and, according to the Deputy Director of *CaspNIRKh* D. *Katunin*, there was a mass fish suffocation [12, 17]. This phenomenon coincided in time and place with a semicircular fracture of the crust, and on the continuation of this fracture, at a distance of hundreds of kilometers from the fishing area, on the shore of the *Krasnovodsk* bay, earthquake occurred. From the earthquake place, linear clouds followed this and the next fracture (Figure 4). On the same day, a radar image of the apsheron rift (area of mud volcanoes) recorded a slick of oil genesis of tens squire kilometers in size (Figure 4 *d*), westward of the *Kura* river mouth - a group of active volcanoes (the area is contoured by a rectangle). Analysis of *AVHRR/NOAA* spectral measurement data showed that semi-circular clouds (tracers) are characterized by a smaller aerosol particle size (k parameter values are larger), local minima of *IR temperature* differences at 11 and 12 µm wavelengths. According to the microwave satellite data, water storage in semicircular clouds ≈0, in the humidity field - local minima [9].

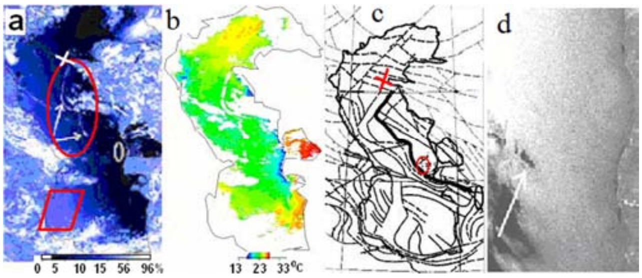

Figure 4. *AVHRR/NOAA image (0.8 µm, %) made on 11.07.2004. (a), arrows point to clouds tracing faults of the crust, ellipse near the Karabogazgol bay – position of the vessel, rectangle at the Kura river mouth - area of volcanoes). SST field according to AVHRR (b). Layout of the faults (c), activated faults are shown with bold lines; in the ellipse eastward of Krasnovodsk gulf - the epicenter. Radar image showing a slick on the apsheron rift (d), slick is pointed by arrow [5].*

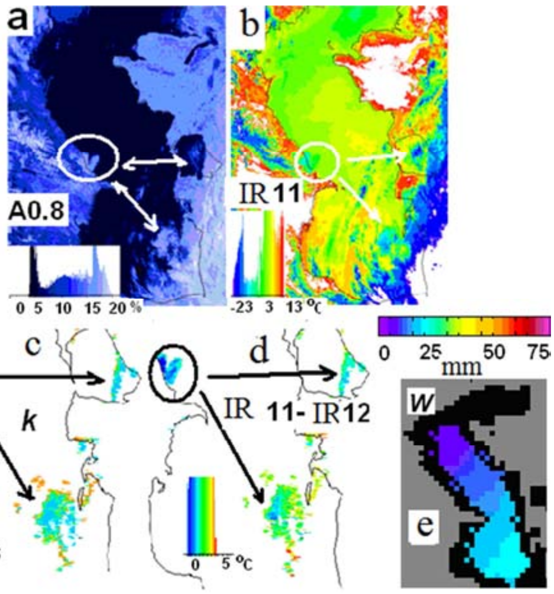

Figure 5. *Image of the Caspian region, 26.03.2001 in the near (0.8 µm) and far (11 µm) IR frequency ranges (a, b); parameter k (c);* T_{11}*-*T_{12} *(d); W (e).*

For clouds near the Sumgait road (a node of the crust faults), the aerosol particles are smaller (value of k parameter is larger), atmosphere is drier than that of the neighboring clouds of the same layer with positive temperatures. The reason is the lower water content of the aerosol due to water vapor deficiency. There are no anomalies in the *W* and *Q* fields over the Sumgait road (Figure 5) [9].

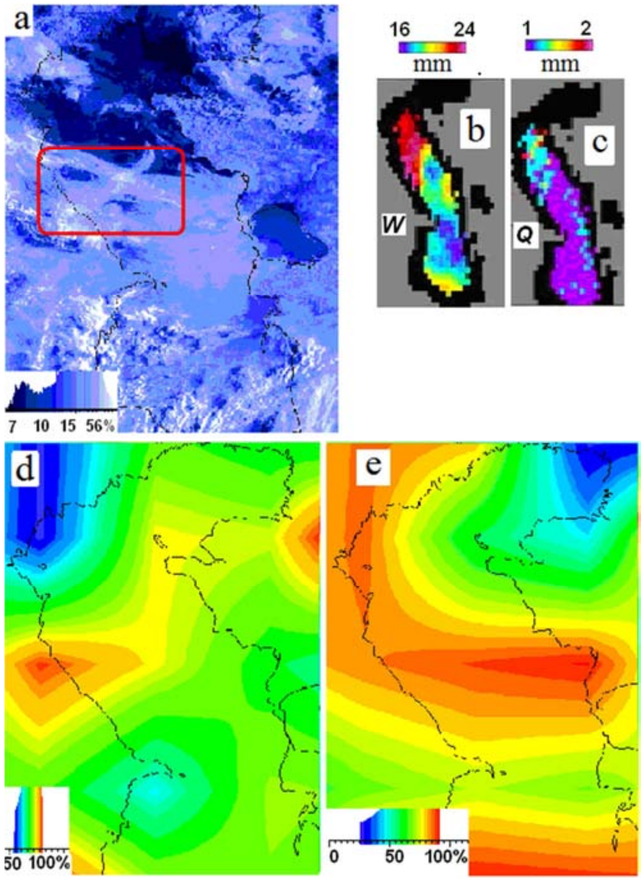

Figure 6. *Image of the Caspian Sea, (11.05.2001) (0.8 µm, albedo, %) (a); W and Q (b, c); relative humidity in the layer 925-850 mbar (d), in the layer 700-500 mbar (e).*

The situation with sickle-shaped clouds (11.05.2001) which partially followed the crust faults is questionable and not quite typical for seismogenic structures - cloud strips are wider than 30 km, clouds are not always surrounded with cloudless atmosphere (Figure 6 a), *W* and *Q* fields are blurred, although the sea part of the southern sickle is dry (Figure 6 *b, c*). For analysis of this situation, relative humidity field obtained from the World weather center were used (Figure 6 *d, e*). The northern strip of clouds was traced by a burst of relative humidity (>75%) in the 925-850 mbar layer. In the southern cloud structure, visually similar to the seismogenic one, there was also increased relative humidity (>85% in the 700÷500 layer mbar). It follows that the clouds are water, meteorological, and not seismogenic.

A day before and in the day of the Iranian earthquakes, there were dry clouds over part of the faults in the *Caspian Sea* (Figure 7). In 10.08.2012, over the apsheron rift, there was a local deficit of *W* (Figure 7 *c*). Over the *North* Sea, there were wet meteorological clouds (Figure 7 *d, e*), over the south part of the sea, a local minimum of W was not observed, as well – northern and southern clouds are not seismogenic.

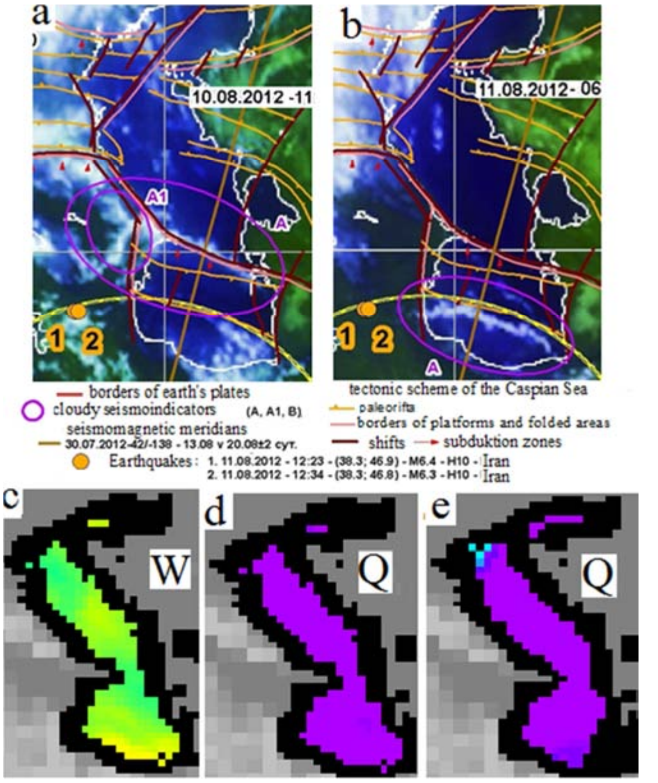

Figure 7. *Satellite images with geo-information and seismic indicators [9], 10.08.2012 and 11.08.2012 (a, b), 10.08.2012 (c) and Q (d); 11.08.2012 Q (e) [4].*

The southern part of the seismic indicators, 19.10.2011, between the *Korean* peninsula and *Japan* - dry clouds in the area of local minimum of *W* (Figure 8).

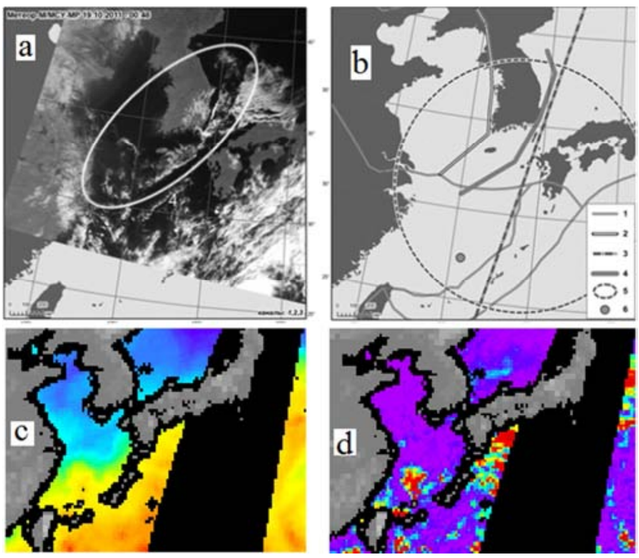

Figure 8. *Atmospheric seismic indicators, 19.10.2011 (a). Regional faults in the Okinawa zone (b) [1]. Q (c) and W (d) fields, 19.10.2011 (morning Passes, SSM/I - F15).*

On March 19, 2012, there was cloud dry seismic indicator of the earthquake in the area of water vapor local minimum over the Mexican region (the earthquake occurred the next day) (Figure 9).

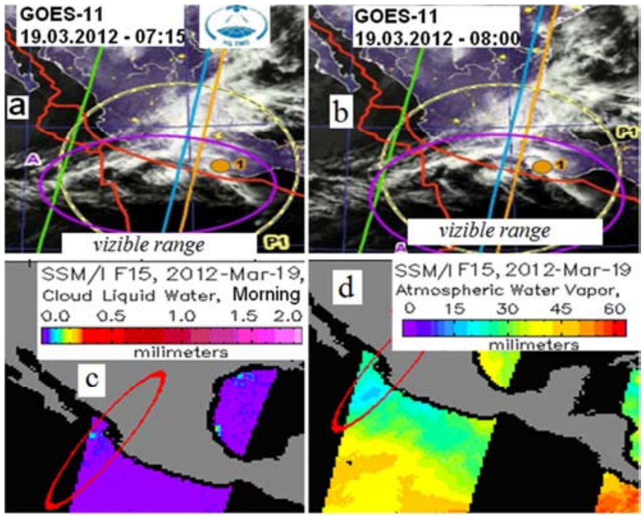

Figure 9. *Satellite images, 19.03.2012, in ellipses - cloud seismotectonic indicators over Mexico (a, b). Q (c) and W (d).*

Estimation of A_{blic} value allows making transition from the *IR temperature* of the upper cloud boundary to the thermodynamic one. The correction value reaches 6K, which corresponds to a change in the upper cloud assessment up to 1.5 km.

The author's interpretation showed that over 80% of clouds, especially clouds with positive temperatures, are recognized by using these criteria as meteorological ones and are filtered. There are limitations and shortcomings of the method and interpretation algorithm. In seismic *Peru* and *Chile*, the air that passes the high mountains is clean and dry. The limitations are also due to the size of the resolution elements in the *IR* (≈1-4 km) and microwave ranges (≈25-50 km), time difference between optical and microwave surveys, lack of available mass regular information about the humidity of the atmosphere at altitudes above 500 mbar. The relevance of the results obtained is due to the need to use formal criteria for indication of seismogenic atmospheric structures, as well as minimization of the human factor.

4.2. Seismogenic Gaps in the Wet Clouds

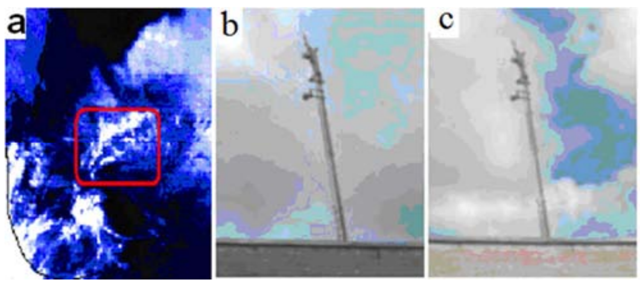

Figure 10. *Gap in meteorological clouds, 13.05.2001 (a). Change in cloud cover at artificial ionization (b – prior to ionization, c - after).*

In addition to seismogenic cloud structures which follow activated faults of the Earth's crust, there are gaps in wet weather clouds. They are associated with the impact of electromagnetic disturbances along the faults on atmospheric moisture. Mass absence of dust in the cloud gaps over the faults is due to the fact that the dust was previously bound by meteorological clouds for the condensation nuclei. Similar gaps in the clouds occur during artificial ionization (Figure 10) [28].

Near the *Kamchatka* peninsula - gaps in the meteorological clouds above crust faults (Figure 11).

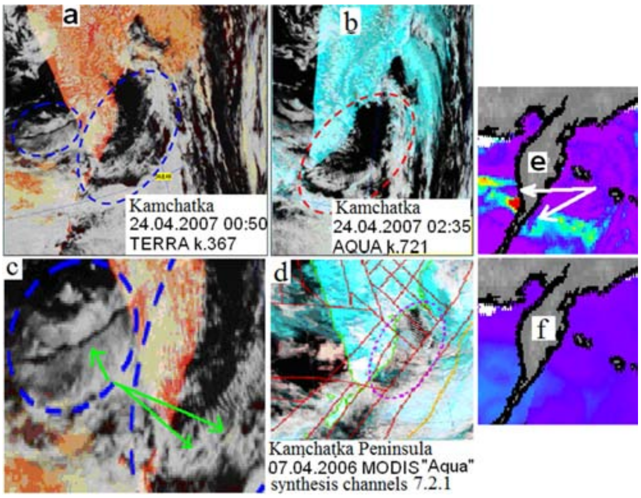

Figure 11. *a, b - cloud seismic indicators on the Kamchatka peninsula (in ellipses), c - 24.04.2007 - enlarged fragment (green arrow - gaps in the clouds). d - faults scheme in the image made on 07.04.2007. e, f - Q and W in the morning of 24.04.2007.*

It is believed that the bursts of radon concentrations are microseismic phenomena. In the north of *Tasmania*, amplitude of *222Rn* concentration reaches 10,000 *Bq/m*^{3} that is many times and orders of magnitude higher than in the mines of the northern *Urals*, in the *USA* in *San Andreas* and *Tien Shan*. In the *Alps*, *Malta* and on the southern coast of *Africa*, *222Rn* concentration is less than 10 Bq/m^3 [29]. In the days of the radon concentration bursts over *Tasmania* (>1000 Bq/m3), linear discontinuities in clouds and fires were observed in the region (Figure 12).

The described criteria for interpretation of seismic indicators are beginning to be used in the materials preparation for the *Antistikhiya Center of EMERCOM*.

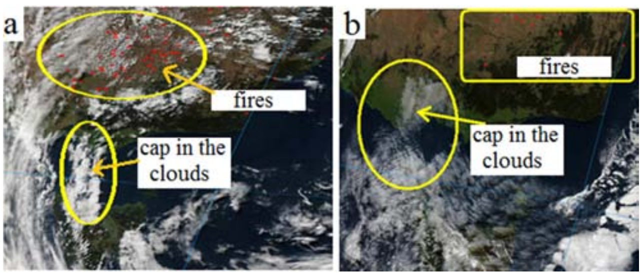

Figure 12. *Gaps in the clouds near Tasmania island and fires (red dots) in south-eastern Australia, 21.05.2011 (a), 29.06.2005 (b).*

4.3. Genesis of Atmospheric Seismic Indicators and Related Phenomena

Genesis of seismogenic atmospheric anomalies is the atmosphere ionization. It is originated in the area of activated faults of the Earth's crust, where the magnetic field exceeds the natural background (up to 500 - 900 nT, which is more than twice the natural background and by an order of magnitude more than usual daily variations of the magnetic field) [11, 14-16, 20, 25-27].

It was suggested in Japan, that increased conductivity of the air and thin elongated clouds, which seem to be "black" from the ground, are the result of the emanation of the earth's air, the forerunner of the earthquake [10]. The argument in favor of this hypothesis is growth of the geomagnetic field in the nobijskom earthquake of 1891 to 970 nT [26*, p. 169*]. In the 90's of XX century, it was found that intensity of electric field of electric substations, transformers and power lines increases to the level of an average magnetic storm. High-voltage power lines prevent distribution of atmospheric moisture.

Similar effects occur over earthquake foci, including earthquakes due to changes in the level of high-pressure dams. Before earthquakes, the above-ground atmosphere is ionized over the earthquake foci, electric field strength increases several times, reaching 500 nT, daily variations of the magnetic field increase by an order of magnitude. In *Turkey* and *Japan*, an unusual white and blue, sometimes green, glow is observed over earthquake epicenters similarly to short-wave short circuits on power lines in large cities. When earthquakes occur, household electrical appliances malfunction is increasing [10].

After these works [17-19], dusty dry linear cloud gaps and water clouds located right over the faults, as well as clouds along faults whose moisture is "squeezed out" from the fault zone, were mainly considered as forerunners of earthquakes. According to the authors' estimation, exactness of forecasts of earthquakes with magnitudes ≥6 exceeded 80% (with errors in possible dates of ±2 days, location - ±3° and magnitudes - 0.2) [2, 3, 8]. Improvement of time forecast, apparently, is possible using tidal data [24].

When such high-energy electromagnetic pulses influence aircraft, electronics fail. The latter was repeatedly tested during the planned landing. In the boeing pilots training system, information about the aircraft accidents in seismogenic meteorological situations is accumulated [19].

5. Conclusions

The present study succeeded in moving from the author's phenomenological indication of seismogenic precursors of earthquakes, which allowed a mass of false signals, to formalized decryption based on the consideration of humidity and water characteristics of objects, as well as estimates of spectral characteristics of aerosol.

In the zones of fault activation, atmosphere ionization occurs, local minima of water vapor are formed, and atmospheric dust is concentrated in these zones. Clumps of dust in some places look like black dust clouds. If meteorological clouds are located over the region they are parted above the faults. Dust clouds are not originated in cloudless gaps because atmospheric dust was previously used by meteorological clouds for the condensation nuclei.

Studies of atmospheric precursors of earthquakes are delayed. Apparently, this is due to departmental disunity, the fears of administrators that if you recognize atmospheric precursors, then without analyzing many related factors, speculation may begin, including the tricks of insurance companies, the paradigm of unpredictability will go away. The importance of the factor of unpredictability "convenient" for administrators will decrease, which was repeatedly mentioned in connection with the seismic events in Italy at the beginning of the XXI century [23]. However, in China, for example, through the collection of data on China through the collection of data on earthquake predictors in 1975. several hours before the earthquake, Haichen successfully evacuated people, saved about 100 thousand lives [10].

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