STATISTICAL STUDIES OF SURFACE LATENT HEAT FLUX AS A PRE EARTHQUAKE PRECURSOR IN SEISMOLOGI.

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Abstract: The affiliation between variations in surface latent heat flux (SLHF) and ocean unstable activity has been a classy issue of recent seismologic studies. So far, there are 2 issues, the way to determine the abnormal SLHF variations from troublesome background signals and the way to make sure that the irregularity outcome from unstable activity. During this paper, we have a tendency to planned four adjustable parameters for identification, classified the affiliation and analyze SLHF changes many months before six ocean unstable activities by using daily SLHF information. Besides, we have a tendency to additionally quantitatively value the future affiliation between unstable activity and SLHF anomalies for the six study areas over a twenty amount of period preceding every unstable activity. The results suggest: (1) before the South Sandwich Islands, Papua, Samoa and Haiti unstable activity, the SLHF variations on top of their individual background levels have comparatively low amplitudes and are troublesome to be thought-about as prophetical anomalies; (2) once removing the bunch result, most of the anomalies before these six unstable activity are not temporally connected to any unstable activity in every study space in time sequence; (3) for every case, apart from Haiti, over part of studied unstable activity that were cheap even devastating unstable activity (Mw = 5.3) had no prophetical variations in SLHF; and (4) the association between SLHF and unstable activity depends for the most part on info correctness and parameter settings. Before any application of SLHF information on unstable activity prediction, we advise that anomaly distinctive standards ought to be established supported future regional analysis to eliminate is graciousness. What is more, alternative factors which can end in SLHF variations additionally ought to be fastidiously thought-about.

Index Terms - SLHF, unstable activity, precursors, satellite, radiation.

I INTRODUCTION

Among an outsized variety of therefore known as unstable activity precursors (such as geomagnetism, gas composition and magnetic force radiation), thermal variations are of specific interest within the last many decades. within the earlier Eighties, temperature information obtained from ground meteoric stations were wont to study the affiliation between earth quakes and soil or air temperature changes at totally different depths and elevations (Hao et al., 1982; Wang and Zhu, 1984). In recent years, the event of satellite and sensing element technologies has allowed observation at a lot of higher abstraction and temporal resolutions. By exploitation NOAA-AVHRR satellite thermal pictures, Tronin used thermal remote sensing information to watch abnormal infrared light during a seismically active region in central Asia (Tronin, 1996). Analogous remotely detected pictures were additionally utilized in Russia, China, India, North American nation and alternative countries. what is more, thermal remote sensing product have additionally been utilized within the study of the affiliation between thermal variations and unstable activity, such as outgoing radio wave radiation (OLR) and temperature of black body (TBB) (Ouzounov et al., 2007; Zhang et al., 2010). As a key element of Earth's energy budget, SLHF (surface heat flux) that represents the warmth flux ensuing from changes in water part, has been recently planned as a potential precursor to sea/coastal unstable activity. Dey and Singh first found that some abnormal SLHF peaks a few days before 5 unstable activity that occurred close to the ocean, inflicting them to propose SLHF as a precursor to unstable activity in coastal regions (Dey and Singh, 2003). supported their discovery, though some data processing technologies, as well as riffle transformation and spatial/temporal continuity analysis, have been consequently introduced to explore the temporal and abstraction variations of SLHF before and once unstable activity (Cervone et al., 2004, 2005; Singh et al., 2007), there are quite an few of scientists still specializing in purpose and short term analysis. Most of the current study of affiliation between unstable activity and SLHF precursors typically consists of specializing in one or additional specific unstable activity; scrutiny their individual daily SLHF for many months before the unstable activity to background values (calculated otherwise by totally different authors); declaring anomalies; displaying many pictures of the variation in SLHF before and following the earthquake; and analyzing the abstraction patterns of SLHF variations during a sure space. during this study, the analysis procedure was carried out in 3 steps: distinctive short term anomalies primarily based on alternative studies; decisive if they are unstable activity induced anomalies exploitation long-run data; modification some parameters to research their result on the correlation foundation. As a result, this paper is organized as follows: unstable activity and SLHF product are introduced in Sect 2; the quantitative short connections are illustrated, classified and evaluated in Sect 3; the discussion is extended to SLHF information and connected parameters to deal with the importance of knowledge pertinence and threshold settings in Sect 4; and conclusion are given in Sect 5.

II DATA DESCRIPTIONS

2.1 unstable Seismic Activities

During the past decade, dozens of calamitous unstable activity occurred in shut proximity to associate Degree Ocean or below the seafloor. During this paper, we have a tendency to take six unstable activities into consideration: Sumatra, Papua, Samoa, Haiti, Tohoku and one east of the South Sandwich Islands (hereafter noted as ESSI). The most choice criteria embody a magnitude of Mw = 7.0 or larger, similar focal depth within the crust associate degreed close to or to a lower place an ocean. Figure one shows the epicentral locations of the chosen unstable activity, and Table one offer their basic info (http://seismic activity.usgs.gov/).

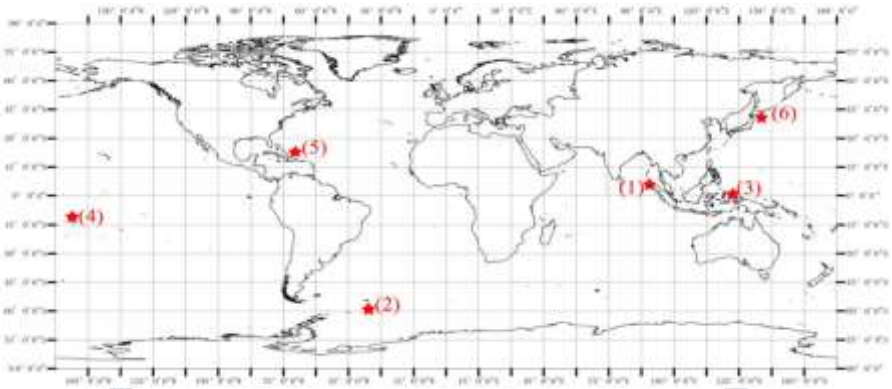

Figure1. Locations of unstable activity space Index identifies the corresponding unstable activity delineated in Table 1.

Table1. Basic information's of studied unstable activity regions.

Name	Time (UTC)	Location (Lon, Lat)	Magnitude (M_W)	Depth (Km)	NCEP grid (Lon, Lat)
Sumatra (1)	26 Dec 2004 00:58	95.982° E, 3.295° N	9.0	30	51, 49
ESSI (2)	2 Jan 2006 06:10	21.606° W, 60.957° S	7.4	13	107, 15
Papua (3)	3 Jan 2009 19:43	132.885° E, 0.414° S	7.7	17	70, 47
Samoa (4)	29 Sep 2009 17:48	172.095° W, 15.489° S	8.1	18	187, 39
Haiti (5)	12 Jan 2010 21:53	72.571° W, 18.443° N	7.0	13	134, 57
Tohoku (6)	11 Mar 2011 05:46	142.369° E, 38.322° N	9.0	32	76, 67

2.2 SLHF

Earth's surface not solely absorbs and releases heat by radiation however additionally exchanges energy with the atmosphere through smart and heat exchange. The previous is caused by air turbulence or convection, and therefore the latter is especially caused by water part changes. The term "surface heat flux" (SLHF) is employed to explain the flux of warmth from the surface of the land or ocean to the atmosphere that's related to the activity, melting and transpiration of water (Bourras, 2006; Charles Schulz et al., 1997). Thanks to the homogeneity of ocean medium, SLHF may be simply wont to monitor heat variations at the ocean atmosphere interface. SLHF information may be obtained in varied ways that. Historically, SLHF has been computed from bulk formulas that use ship or ground-based measurements. However, thanks to the low temporal and abstraction resolution of this point-type information, the provision and accuracy of station-derived fluxes are comparatively restricted (Singh et al., 2001). By assimilative land surface, ship, aircraft, remote sensing information and alternative on the market information, the NCEP/NCAR (National Centers for Environmental Prediction)/(National Center for Atmospheric Research) Reanalysis System provides world integrated reanalysis information series at associate degree accuracy of 10–30 W m−2, appropriate for future surveys (1979 and newer information the third part of the evolution of the worldwide observant system, i.e. the "modern satellite era"). the information utilized during this paper were downloaded from the FTP Server ftp://ftp.cdc.noaa.gov. Daily mean SLHF information are drawn by a mathematician grid of ninety four lines from 88.542o S to 88.542° N, with regular 1.875° longitudinal spacing and projected onto an oblong grid (Kalnay et al., 1996; Kistler et al., 2001). Corresponding NCEP grid values may be calculated from the meridian and latitude of individual earth quake epicenters (refer the last column of Table 1).

III METHODS

3.1 Classification

To evaluate the correlation between unstable activity and SLHF anomalies statistically, we have a tendency to assume their behaviors' to be 2 freelance events and classified their relationships into four categories: 00, 01, 10 and 11. To our issues, solely anomalies that occurred inside a nominative time window before a given unstable activity were thought-about. The definition of "anomaly" also "time window" are given within the next Sect. 3.2.

Figure 2 shows the four varieties of affiliation within the space of the Tohoku unstable activity over a amount of over 20yr. DOT stands for "day of total years", that spans from one Jan one991 (DOT = 1) to 1 Jan 2012 (DOT = 4383).

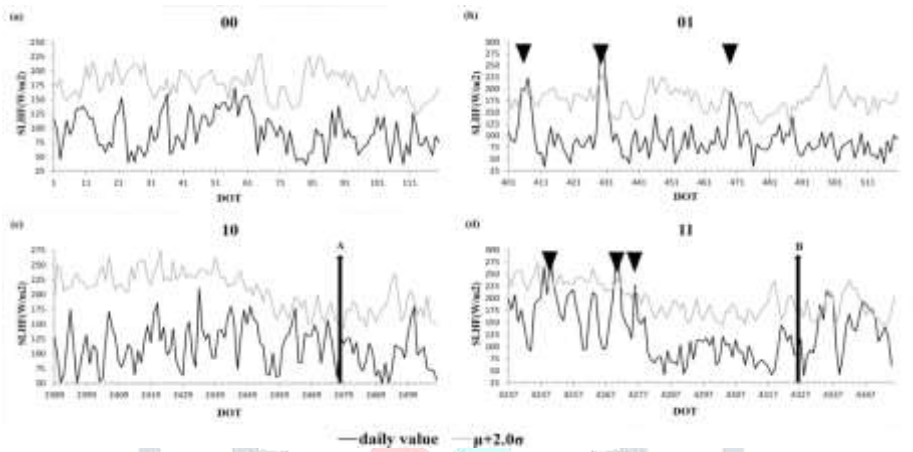

Figure2. The four sorts of connections between SLHF and unstable activities are. Unstable activity A (15 October 1990, Mw = 6.5, 92.249° E, 2.211° S), unstable activity B (8 November 1995, Mw = 6.8, 95.050° E, 1.833° N).

Dark triangles mark values that surpass the anomaly threshold, which might be taken as abnormal signals. The arrows indicate specific unstable activity throughout the study amount. because the "00" class indicates a amount of no seismicity or anomalies, solely classes "01", "10" and "11" are mentioned within the following sections.

3.2 Establishment of parameters

To outline the thermal anomaly exactly, we have a tendency to first designated four adjustable parameters before the formal evaluating procedure: (1) M is associate degree unstable activity with a magnitude (Mw) or larger is enclosed within the unstable activity list associate degree is taken into account for correlation examination; (2) associate degree anomaly threshold prices on the far side this threshold are considered as associate degree anomalies; (3) time window the length of days between the start of an anomaly and an unstable activity; and (4) E the extent/amplitude of an abnormal value. For SLHF information, the unit of E is W m−2.

Secondly, for all of those unstable activities, the values of former 2 parameters were preliminarily fastened in keeping with previous researches. A comprehensive review of the literature on the identification of thermal anomalies, coupled with data of geophysical science and statistics, suggests that: (1) the parameter M will be set at a magnitude of five.0, that could be a moderately sized unstable activity; and (2) the anomaly threshold will be outlined because the norm of SLHF information over tens of years, as well as the study amount, plus 2.0 times the quality deviation (i.e. $\mu + 2.0\sigma$).

Thirdly, considering the varied earth science and climatically backgrounds of those six unstable activity thought-about here, the values of your time window, ΔDOT and E were established supported the short term SLHF variations adore every unstable activity. The variation in SLHF for ninety days before and thirty days following every main shock is displayed in Fig3. The higher grey line shows the reference most values (i.e. anomaly thresholds). The lower black line represents the daily values of NCEP-SLHF grid points encompassing the geographic point of every unstable activity. The daring black arrow indicates the date of every unstable activity and therefore the triangle highlights SLHF anomalies. For the Sumatra unstable activity, there was just one anomaly sixty nine days before the most shock. This anomaly lasted for six days and has a mean price of 22.79 W m−2. Compared to the anomaly before the Sumatra unstable activity, the anomaly related to the ESSI earth quake was less significant; it lasted solely two days and had norm of 7.77 W m−2. However, given the amplitude of the SLHF variations within the ESSI space, this anomaly continues to be notable. The 2 anomalies before the Papua unstable activity are troublesome to spot, and each has low ΔDOT and abnormal ranges.

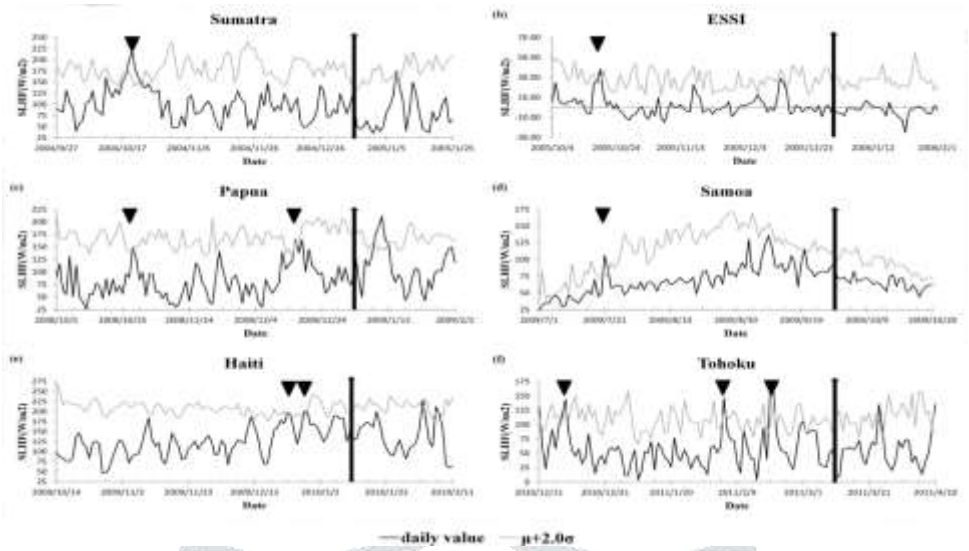

Figure3. SLHF variations of six unstable activities graphs.

Interestingly, associate degree anomaly occurred seven days once the main shock, that was close to the peak price for the 3 months encompassing the most shock. However, we have a tendency to solely specialize in prophetical SLHF anomalies and don't discuss this anomaly more. Seventy days before the Samoa unstable activity, there was one obvious anomaly that continuing into consecutive day and averaged 18.04 W m−2, that is comparatively important. 2 peaks occurred before the Haiti unstable activity, however they're each little. 3 peaks exceed the noise level before the Tohoku unstable activity. The mean values of those anomalies are larger than 30 W m−2, extraordinary its μ + 2.0σ threshold by nearly two hundred nothing. For every main shock, the values of your time window and ΔDOT are the utmost, whereas E is that the average of anomaly values.

3.3 Identification and long term evaluating

Based on the parameters established earlier during this paper, the future analysis for connected SLHF variations and seismicity was distributed in 2 stages of comparison: "01" vs. "11" and "10" vs. "11".

In the 1st stage, we have a tendency to computed the possibilities of "01" and "11" occurring, i.e. we have a tendency to calculated the quantity of times that prophetical changes in SLHF happy the standards of being associate degree anomaly and the chance of unstable activity that occurred inside the given time window. The variations in SLHF inside one NCEP grid cell can be plagued by many factors, as well as seasonal changes, monsoons, and unstable activity. To assess the impact of unstable activity close to the epicentral NCEP grid space, all unstable activity larger than a given magnitude (M) and inside a region of roughly one million km2 round the geographic point of every of the six unstable activity (roughly 10° meridian by 10° latitude; the individual area varies with the latitude of every epicenter) were taken into thought. The domino effects of this examination are given in Table2. To get rid of the earth tremor main shock earth tremor result and its influence on later changes in SLHF, we have a tendency to additionally combined unstable activity inside thirty days of every alternative (referred to as solo unstable activity).

Table 2 offers the possibilities of "01" and "11" situations of connections between SLHF anomalies and unstable activity. There are several instances within which the SLHF price surpassed the anomaly threshold. Haiti had the fewest anomalies. Even so, it had forty two abnormal variations over the past twenty time period. Before the removal of the unstable activity result,

Name	Study period	Study area	No. of AN	No. of EQ	"01"% %	"11"%
Sumatra	1 Jan 1984–31 Dec 2003	2° S–8° N, 90–100° E	81	251	22.2 %	77.8 %
ESSI	1 Jan 1985–31 Dec 2004	56–66° S, 17–27° W	100	375	12.0 %	88.0 %
Papua	1 Jan 1984–31 Dec 2003	5° S–5° N, 127–137° E	77	61	56.0 %	44.0 %
Samoa	1 Jan 1989–31 Dec 2008	10–20° S, 167–177° W	86	866	9.3 %	90.7 %
Haiti	1 Jan 1989–31 Dec 2008	13–23° N, 67–77° W	42	31	92.9 %	7.1 %
Tohoku	1 Jan 1990–31 Dec 2009	33–43° N, 137–147° E	149	998	2.7 %	97.3 %

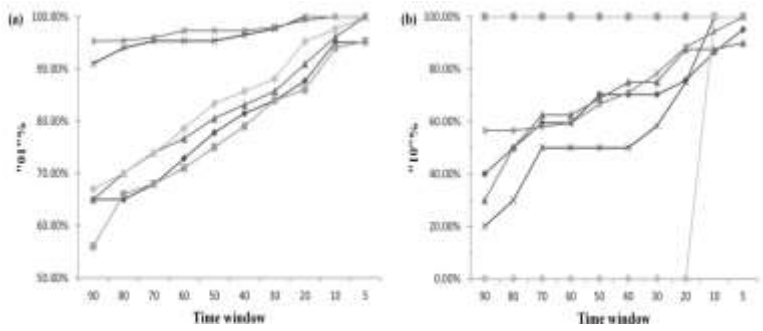

Figure4.graph of Time window verses % of "01"/"10".

The numbers of unstable activity giant than M for every of the six cases were outstanding large. Apart from Haiti, the odds of "11" situations were important, indicating that several unstable activity occurred once SLHF anomalies. Once the de-clustering method, each the quantity of unstable activity and therefore the share of "11" situations weakened considerably, and therefore the correlation is statistically insignificant (see Table 3).

Table3. Probabilities of "01" and "11" after de-clustering.

Name	Sumatra	ESSI	Papua	Samoa	Haiti	Tohoku
No. of solo EQ	37	31	28	3	22	4
"01"%	67.9 %	66.1 %	74.1 %	95.2 %	95.3 %	95.4 %
"11"%	32.1 %	34.2 %	26.1 %	4.71 %	4.81 %	4.69 %
Ave. surpass value ($W m^{-2}$)	19.39	9.57	20.21	26.17	17.04	23.75

Comparing average surpassing values of SLHF. That were no associated with the anomalies before these unstable activity (i.e. "01"), it shows that the atypical peaks previous to the ESSI, Samoa and Haiti unstable activity are numerically inapplicable. The values of E for ESSI, Samoa and Haiti in brief term were in turn 7.77, 18.04 and 11.48, whereas in future were 9.57, 26.17 and 17.04. In alternative words, these SLHF fluctuations at such degrees could also be terribly traditional for these areas.

IV. Discussion

4.1. Data applicability.

Although the employment of a homogenized dataset (i.e. NCEP-SLHF) would have relieved the error thanks to totally different SLHF observations, the NCEP information set contains assimilating data whose accuracy depends on many factors. The accuracy of one variable at totally different periods varies reckoning on the initial information assortment technique.

Although the NCEP reanalysis information assimilation system is consistent, the observant system has evolved well over time. The evolution of the worldwide observant system is split into 3 major phases: the "early" amount from the Nineteen Forties through the International geology Year in 1957, once the primary higher air observations were made; the "modern radiosonde network" from 1958 to 1978; and therefore the "modern satellite era" from 1979 to the current (Kalnay et al., 1996).

Therefore, the accuracy of reanalyzed surface heat fluxes is of course time dependent. Given the evolution of knowledge accuracy, the SLHF anomalies preceding the ESSI, Papua and Haiti unstable activity were measured exploitation less correct NCEP-SLHF information thus, these variations might not be true anomalies. as a result of the history of NCEP information is incredibly short compared with the unstable activity catalog, the date of a given unstable activity ought to be thought-about before using the NCEP/NCAR information within the study of SLHF variations before unstable activity. The output variables in NCEP/NCAR information are classified into four categories, reckoning on the degree to that they are influenced by the data-based information and/or the assimilation model. sadly, surface fluxes are among the "C" variables, which implies that they rely heavily on the model throughout information assimilation (issue to the as simulation of alternative observations) and ought to be used with caution (Kistler et al., 2001). If the model and its physical parameterizations are realistic, the SLHF information will offer correct estimates, even on a daily continuance. However, it'll be regionally biased if the model is biased. Hence, the model feasibleness ought to be checked before exploitation SLHF information from NCEP/NCAR to check any SLHF variations during a specific space.

V. Summary and conclusion

In lightweight of those analysis results obtained from this study, many conclusions may be drawn: (1) though some SLHF variations might surpass the background varied level, they still cannot be recognized as thermal anomalies in keeping with their

little surpassing amplitudes and SLHF information accuracy; (2) the bunch result of unstable activity sequence ought to be paid enough attention throughout the analysis of affiliation between SLHF variations and unstable activity; (3) the correlation of SLHF anomaly and unstable activity is comparatively low (due to chance) and for the most part depends on many factors as well as information and parameter. We have a tendency to powerfully suggest that normal SLHF anomaly detective work criteria ought to be established. Whereas many changes to parameters at the educational stage are acceptable, one should make sure that the corresponding criteria are clearly set and strictly utilized before any development is formally outlined as a precursor. Notwithstanding the geology theory isn't understood completely, preset distinctive and analyzing procedures still ought to be taken under consideration and addressed.

Based on the on top of findings, a lot of more work may be effectively distributed. We are going to perform additional evaluations on many alternative connected thermal parameters that are derived by remote sensing or assimilation technology. Alternative connected factors as well as the seasonal differences in wind and stream, regional salinity concentration and ratio are taken under consideration. Moreover, keeping the advantage of remote sensing information in abstraction resolution in mind, more long term abstraction analysis for the mentioned unstable activity are carried out. almost like one single NCEP grid analysis, parameters such as time window and anomaly threshold are designated to check the abstraction and temporal affiliation between unstable activity and thermal variations. Additional data processing technologies also will contribute to the subsequent work.

VI. Reference.

[1]. Bourras, D.: Comparison of five satellite derived latent heat flux products to moored buoy data, J. Climate, 19, 6291–6313, doi:10.1175/JCLI3977.1, 2006.
[2]. Cervone, G., Kafatos, M., Napoletani, D., and Singh, R. P.: Wavelet maxima curves of SLHF associated with two recent Greek seismic activity, Nat. Hazards Earth Syst. Sci., 4, 359–374, doi:10.5194/nhess-4-359-2004, 2004.
[3]. Cervone, G., Singh, R. P., Kafatos, M., and Yu, C.: Wavelet maxima curves of surface latent heat flux anomalies associated with Indian seismic activity, Nat. Hazards Earth Syst. Sci., 5, 87–99, doi:10.5194/nhess-5-87-2005, 2005.
[4]. Chen, M., Deng, Z., Yang, Z., and Ma, X.: SLHF anomalies prior to the Indonesia Mw 9.0 seismic activity of 2004, Chinese Sci. Bull., 51, 1010–1013, doi:10.1007/s11434-006-1010-y, 2006.
[5]. Choudhury, S., Dasgupta, S., Saraf, A. K., and Panda, S.: Remote sensing observations of pre-seismic activity thermal anomalies in Iran, Int. J. Remote Sens., 27, 4381–4396, doi: 10.1080/01431160600851827, 2006.
[6]. Dey, S. And Singh, R. P.: Surface latent heat flux as a seismic activity precursor, Nat. Hazards Earth Syst. Sci., 3, 749–755, di:10.5194/nhess-3-749-2003, 2003.
[7]. Freund, F. T.,Takeuchi, A., Lau, B. W. S., Al-Manaseer, A., Fu, C. C., Bryant, N. A., and Ouzounov, D.: Stimulated infrared emission from rocks: assessing a stress indicator, eEarth,2, 7–16, doi:10.5194/ee-2-7-2007, 2007.
[8].Geller, R. J.: Earthquake prediction: a critical review, Geo-phys. J. Int., 131, 425–450, doi:10.1111/j.1365-246X.1997.tb06588.x, 1997.
[9]. Genzano, N., Aliano, C., Filizzola, C., Pergola, N., and Tramutoli, V.: A robust satellite technique for monitoring seismically active areas: the case of Bhuj–Gujarat earthquake, Tectonophysics, 431, 197–210, doi:10.1016/j.tecto.2006.04.024, 2007.
[10]. Hao, S., Gao, H., and Wang, C.: Isothermal surface of Curie temperature around the Beijing area and its relation to earthquakes, Acta Geophys. Sinica 264–269,1982.
[11]. Jackson, D. D.: Hypothesis testing and earthquake prediction, P. Natl. Acad. Sci. USA, 93, 3772–3775, doi:10.1073/pnas.93.9.3772, 1996.
[12]. Kagan, Y. Y. and Jackson, D. D.: Statistical tests of VAN earthquake predictions comments and reflections, Geophys. Res. Lett., 23, 1433–1436, doi: 10.1029/95GL03786, 1996.
[13]. Ouzounov, D. and Freund, F.: Mid-infrared emission prior to strong earthquakes analyzed by remote sensing data, Adv. Space Res., 3, 268–273, doi:10.1016/S0273-1177(03)00486-1, 2004.
[14]. Ouzounov, D., Liu, D., Kang, C., Cervone, G., Kafatos, M., and Taylor, P.: Outgoing long wave radiation variability from IR satellite data prior to major earthquakes, Tectonophysics, 431, 211–220, doi:10.1016/j.tecto.2006.05.042, 2007.