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Brief Communication: An exclusive example of surface latent heat flux variation before Russia M6.1 earthquake

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Abstract

Recently surface latent heat flux (SLHF) data is widely used to study the anomalies before earthquakes. Most researches use the daily SLHF data, here we use both daily data and high temporal resolution (four times one day) SLHF data, and compare the 5 SLHF change with satellite image at the first time. We check the data from 1 September to 30 October 2011 and the result shows that there is really a very high SLHF anomaly (bigger than 2σ) just 5 days before the M6.1 Russia earthquake which occurred on 14 October 2011. It should be considered as a preseismic precursor if judged with previously published methods. But our comparison between SLHF change and satellite 10 image shows that the SLHF anomaly is just caused by a thick cloud. This result tells us that scientists must know the data's meaning before they use it, if not, they may get a wrong conclusion. Based on this example, we suggest that previously published SLHF anomaly before earthquake should be reanalyzed by our method to exclude the false anomaly.

15 1 Introduction

Earthquake is the result of stress increase and rock fracture, prior to an earthquake the stress accumulation results in the thermal infrared emission (Freund and Ouzounov, 2009), which enhances the rate of energy exchange between surface and atmosphere, and leads to increase of surface latent heat flux (SLHF). SLHF is the heat released by 20 phase changes due to solidification or evaporation or melting. The energy transport between the earth, ocean and atmosphere through the evaporation at the surface-atmosphere interface partly compensates for energy losses due to radiation processes in the atmosphere (Schulz et al., 1997). The energy loss at the surface through simultaneous exchange of water vapor and heat with the atmosphere is higher at the ocean 25 surface compared to those over the land; hence SLHF is always higher at the ocean surface and lower in the land area.

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The SLHF can be retrieved accurately from satellite data (Schulz et al., 1997), which provides an opportunity for long-term monitoring of the parameter, in order to develop future precursor model. Variations in SLHF are also controlled by the changes in surface temperature (ST), which is believed to be a precursor parameter during an earthquake (Tronin, 2000). The ST anomaly based on thermal infrared satellite data as a precursor has been found during earthquakes in China (10 January 1998) and Japan (17 January 1995) (Tronin et al., 2002; Qiang et al., 1991), Algerian (Saraf and Choudhury, 2004), Turkey (Tramutoli et al., 2005), Italy (Qin et al., 2012b).

Dey and Singh (2003) analyzed the daily SLHF from the epicentral regions of five recent earthquakes occurred close to the oceans, and found a maximum increase of SLHF 2–7 days prior to the main earthquake event. They considered that this increase is likely due to an ocean-land-atmosphere interaction and the anomalous behavior of SLHF is only associated with the coastal earthquakes. Qin et al. (2011, 2012a) analyzed the daily SLHF anomalies before Ms7.1 New Zealand earthquake. Xu et al. (2011) and Cervone et al. (2006) analyzed the SLHF anomalies before M9.0 Sendai earthquake on 11 March 2011 and M8.3 earthquake on 25 September 2003 in Japan. In all of these researches the temporal resolution of SLHF data is daily, here we analyzed SLHF data variation before Russia M6.1 earthquake with high temporal resolution which is four times one day, and found some new result which is different with previously published results.

2 Data

The SLHF data is provided by the National Center for Environmental Prediction (NCEP) of NOAA. The NCEP/NCAR Reanalysis project uses a state of the art analysis system to perform data assimilation using past data from 1948 to the present. It provides four times measurements at 0Z, 6Z, 12Z, and 18Z everyday, and its spatial coverage is 0° E–358.125° E, 88.542° N–88.542° S with 192 × 94 points totally (Kalnay et al., 1996).

The M6.1 earthquake occurred on 14 October 2011 at 54.1° N, 123.7° E with 12 km depth, which is close to Russia-China border. It occurred in high latitude area which has little earthquakes than that of mid-low latitude. This quake is the only one quake bigger than M5.0 in the area 50–55° N, 120–125° E in the last 50 yr. So it is a very rare event. It is about 720 km to the closest coast, but there are many lakes and rivers in this area because it is in high latitude and the weather is cold and wet.

3 Method and result

First we extract the SLHF data at the epicenter point, plot the time series curve and try to find the anomalous day, the daily values of SLHF have been considered from

¹⁰ 1 September to 30 October 2011. We can see that the SLHF on 9 October is the maximum.

Second, we subtract the daily SLHF from the multi-years mean values which representing a normal background, to get Δ SLHF as Qin's method:

$$\Delta \text{SLHF} = \text{SLHF}_{\text{EQ}} - \frac{1}{n} \sum_{i=1}^n \text{SLHF}_i \quad (1)$$

15 where $\Delta\text{SLHF}_{\text{EQ}}$ is the daily SLHF of 2011; ΔSLHF_i is the corresponding daily SLHF for 2001–2010; n is the number of years analyzed, i.e. 10 (Qin et al., 2011). We analyze the long time series of SLHF data on the epicentral pixel (54.1°N , 123.7°E). For the comparison of the data for 2011 with historical data, the mean (μ) and standard deviation (σ) are also calculated using the multi-years (2001–2010) data on the same day. The result is listed in Fig. 2 and we can see that a clear anomaly appeared on 9 October.
 20

Third, we plot the SLHF data with 6 h resolution to get a detailed analysis. The data show that the maximum SLHF is at 00:00 UTC on 9 October. This is an important point which is different from previous researches; we will address this in detail in the following text.

Finally we plot the spatial distribution map at 00:00 UTC 9 October (Fig. 4). The spatial distribution of the SLHF anomaly prior to the main shock is studied in a 40° by 20° area (about 8 000 000 km 2) around the epicenter, we can see that there are two areas with high SLHF value, one is located at 136° E, 47° N, it is in the ocean-land border and maybe it is caused by ocean, the other is 124° E, 54° N, it is located in the epicenter exactly. So maybe the second area with high SLHF is related with the earthquake on 14 October. From Fig. 2 we can see that there is a maximum SLHF on 9 October, just 5 days before the quake, from the spatial map, we can see that the maximum SLHF is located in the epicenter exactly. This conclusion is perfectly well accordance with Dey and Singh's result (2003) and when people see this result most of them will consider it as an earthquake precursor.

Because the maximum SLHF data is at 00:00 UTC, so we check the satellite data at 00:00 UTC on 9 October (Fig. 5). The satellite image shows that there is a thick cloud at the epicenter area, and the high SLHF value seen in Fig. 4 is due to thick clouds. That means this cloud is undergoing a very intensely phase change due to solidification, so large amount of energy is released (Schulz et al., 1997). This phenomenon is first reported. Previous researches just plot the SLHF data, use mathematical methods to compare the SLHF data with background. If the data is bigger than the threshold, then it is considered as an anomaly. They did not point out whether the atmosphere weather is clear or cloudy. Here we checked the satellite data and find that the high SLHF was related with a thick cloud. Because of the limited data, we did not know whether this cloud is related with the quake. If it is, then it means clouds activity can be affected by earthquake activity, as Morozova (1997) and Shou (1999) found. If it is not, that means the weather change can lead to SLHF variation, and this will be misunderstood sometimes. What ever it is, this example shows that, no matter how complex and how advanced the method is, such as wavelet transform, principle component analysis, neural network and so on, before these methods are used, it is important to know what does your data means, or you will get a wrong conclusion.

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4 Conclusions

We analyze the daily and 6 h SLHF data before the M6.1 Russia earthquake, and find that the SLHF data gets to the maximum 5 days before the quake. It is also the biggest value in the 60 days from 1 September to 30 October, and the high SLHF area is located in the epicenter exactly. All these result are well accordance with previously published research. But when we check the SLHF data with 6 h resolution we find that the maximum SLHF value appeared at 00:00 UTC. This high temporal resolution makes it possible that we can check the satellite data at the same time with SLHF data. We find that the high SLHF is due to a thick cloud. This finding has important meanings.

It tell us before analyzing the data you have to know what does the data mean, if not, maybe you will get a wrong conclusion, for example considering normal clouds as earthquake precursors.. A similar situation is thermal anomaly before earthquake is widely studied, while Blackett et al. (2011) checked their data and methods and found that some anomalies are caused by the presence of MODIS LST data gaps which is attributed to cloud cover and mosaic of neighboring orbits of data. Here our research shows a similar conclusion. This is more important in this Big Data era, because some famous organizations such as NASA and NOAA provide thousands of satellite data products every year, the data volume is too big and the data production progress is too complex that few people can know every step of the data production. Especially in earthquake research, geologists try to use the data from meteorology satellite data; this is an inter-discipline area so it has more chance to be wrong. So we suggest that all previously published papers about SLHF should be reanalyzed with our method, to exclude the false precursors.

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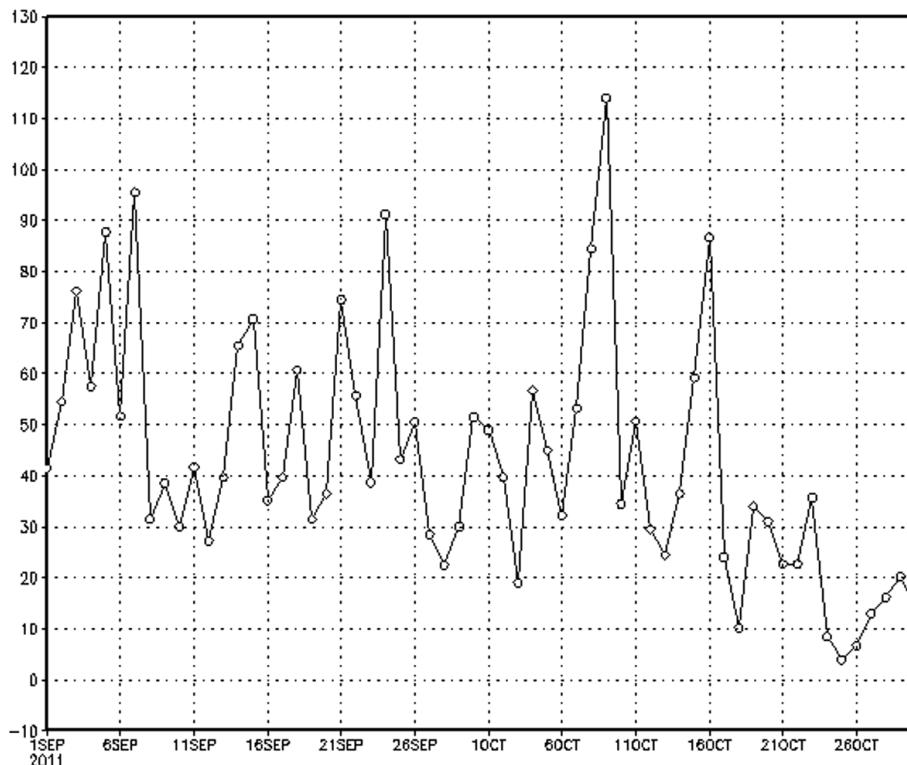


Fig. 1. Daily SLHF time series of the epicenter grid from 1 September to 30 October 2011, a clear sharp increase appeared on 9 October.

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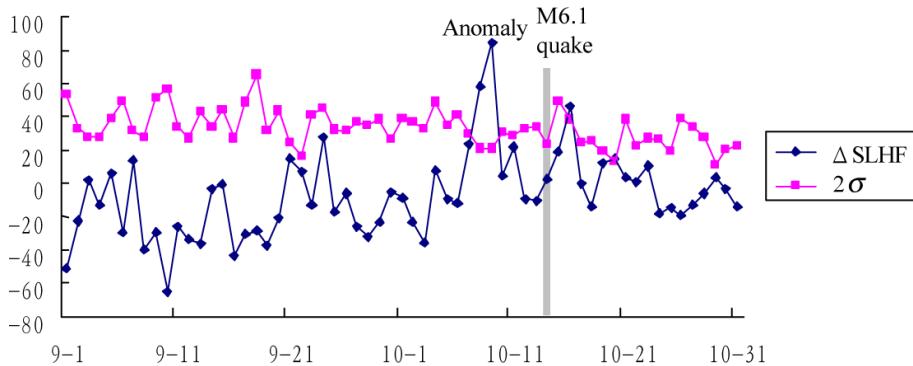


Fig. 2. SLHF change from 1 September to 31 October 2011 compared with the 2σ curve during the last 10 yr, a clear anomaly bigger 2σ appeared on 9 October, just 5 days before the M6.1 quake.

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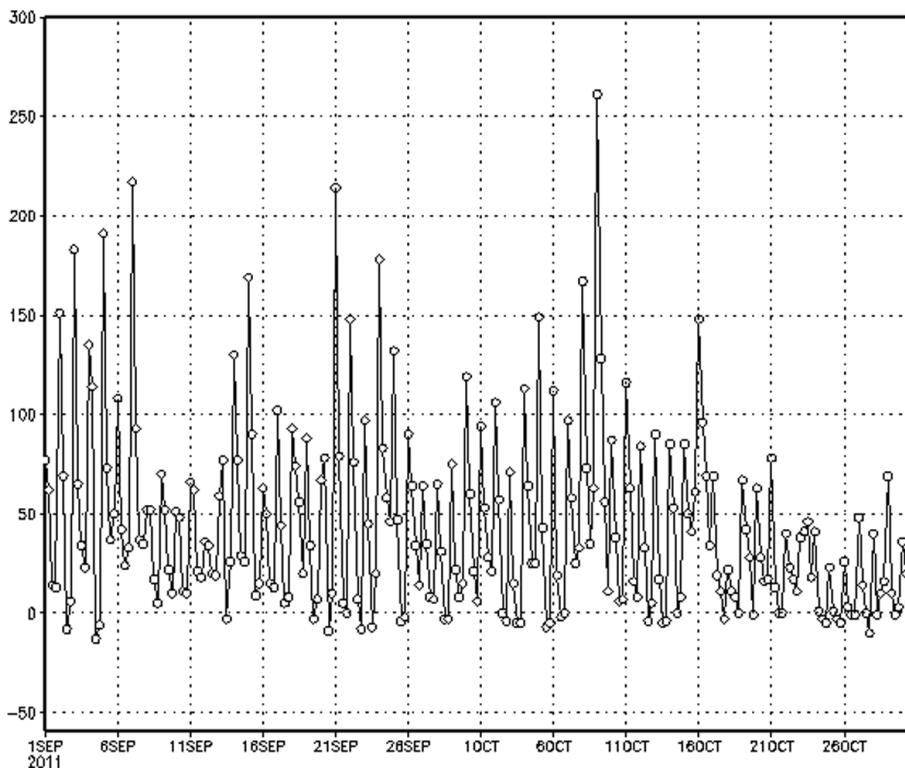


Fig. 3. SLHF time series of the epicenter grid with 6 h resolution from 1 September to 30 October 2011, the maximum SLHF is shown at 00:00 UTC on 9 October.

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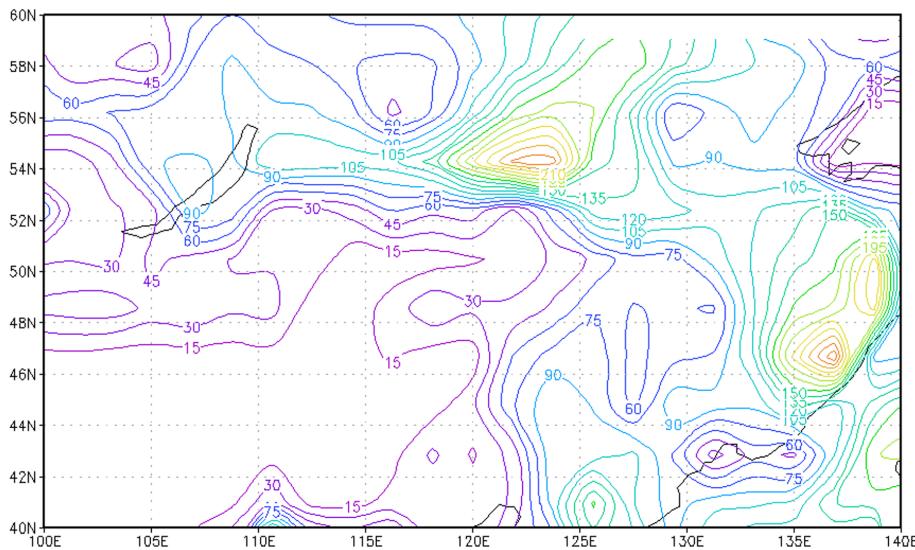


Fig. 4. SLHF spatial map at 00:00 UTC on 9 October, a high SLHF area located exactly in the epicentral area at 54.1°N , 123.7°E .

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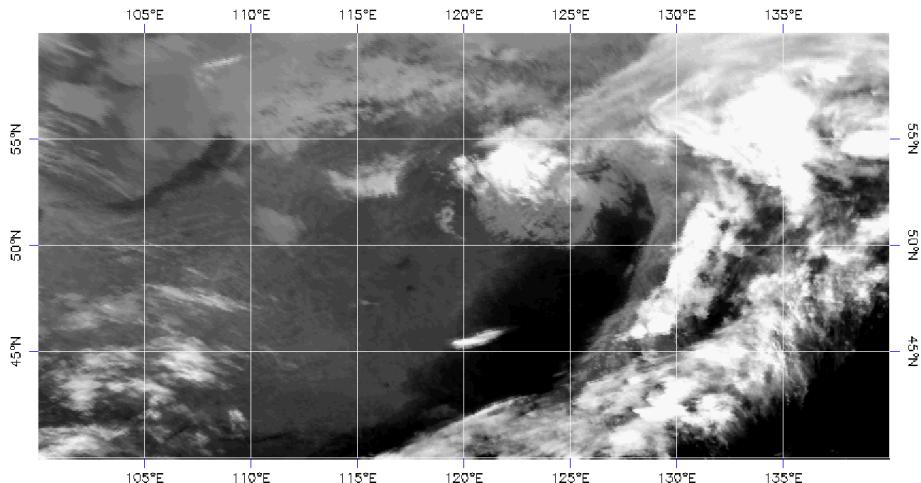


Fig. 5. Satellite image of Russia and Northeast China at 00:00 UTC on 9 October 2011, the area is the same as Fig. 4, a thick cloud appeared at $53\text{--}55^{\circ}\text{N}$, $121\text{--}124^{\circ}\text{E}$ epicentral area.

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