Reply to the referee Dr. F. Masci

General replies：

We fully agree with Dr. F. Masci that the reports of earthquake precursors have a serious social responsibility, and that the identification of actual and reproducible precursors is the key point for evaluating the potentiality of an earthquake prediction method.

The dynamic geosystem is very complex and extremely uncertain, which makes earthquake be difficult to be predicted. However, the integrated observations (such as Global Earth Observation System of Systems, GEOSS) is providing us more and more data of multiple parameters on planet Earth, among which some are embed with hints on seismogenic meanings and shocking precursors. We are stepping into an era of big data endowing geoscientists in geophysics, seismology, remote sensing, etc., with unprecedented opportunity to explore the possibility of earthquake prediction by way of mining potential EQ precursors from multiple observations and various data sets. Although there are still debates on the existence of earthquake precursors, it's worthy of going forward and seeking for seismicity-related anomalies at the first step. Who can say no before doing our best?

In this paper, we investigate the hydrothermal anomalies before the 2009 Mw 6.3 L'Aquila earthquake by means of retrospective analyses of assimilation datasets (soil moisture, soil temperature, near-surface air temperature, and precipitable water). After comparing them to historical data of preceding nine year and referring to ground-based observations of temperature and atmospheric aerosol, as well as to seismic data (*b*-value), we interpret the anomalies as possible precursors of the main shock of 2009 Mw 6.3 L'Aquila earthquake. We are not alleging the reported hydrothermal anomalies be definite EQ precursory, but showing a good example how to link objectively multiple parameters for seeking potential EQ precursors.

Point-to-point replies：

1) We affirm something true, i.e. "a large number of precursory anomalies of the 2009 L'Aquila EQ were reported", and we mention 15 references, as an incomplete list of references. In fact, our paper is not about discussing all previous work but analyzes some multi-parameter observations taken in and around L'Aquila epicentral area to detect unexpected changes with respect to the normal behaviors.

- We thank the referee about the presumed anomaly in LF radio signals. We removed Biagi et al. 2009 from the text of paper and the list in Table 1.

- We agree with the referee that the analysis by Eftaxias et al. (2009) is based on a rather distant EM station from L'Aquila, but we think is worth maintaining because this kind of analysis is quite original, with a rather different approach with respect to other papers. By the way, there is some works that is based on the geomagnetic data of L'Aquila Observatory that provides some interesting results (e.g. Cianchini et al. 2012), so we cannot completely confirm that those data contain significant precursory information but its extraction might depend on the data analysis.

-We are aware of the paper by Dahlgren et al 2014. There was only one kind of igneous rock (Gabbro) tested in the experiment of Dahlgren et al, while the geological body of L'Aquila is carbonate units (limestone and dolomite). Prof. Freund and his collaborators had comments (e.g. Scoville et al., Nat.

Hazards Earth Syst. Sci., 15, 1873–1880, 2015) to the work of Dahlgren et al 2014. We have no intention to go into this dispute so we preferred to cite the most important papers on this subject.

2) The interactive processes behind the lithosphere-atmosphere-ionosphere coupling are very complex and we admit there is still great discussion on its real presence or not, and, in the former case, even about which coupling processes are in act. However, we actually provide a general and rigorous definition of "anomaly" in a statistical sense, in terms of a deviation with respect to a given threshold (least 1.5), quantitatively defined through a certain number of standard deviation, the latter estimated on the base of the previous 9 years (2000-2009) of data in the same period of the mainshock year for checking that anomalies appear frequently, more or less at random.

- From previous works on satellite thermal data, the best observation times are usually those in the night or early morning, in order to keep avoid of disturbance from ground surface reflectance at day times, which could submerge any pre-EQ thermal anomaly. After careful check, we found that the detected thermal anomalies emerge more clearly at 06:00 UTC, so we preferred to consider and show the result for this time of the day. A possible reason could be that ground radiation at 06:00 UTC is relatively low in favor of detecting weak anomalies possibly related with the earthquake.

- We admit that there is no physical reason to define the anomalous signal as that above 1.5 or, better, above times standard deviation However we find this definition quite operative, and general enough to be applied to all analyzed parameters, and confidence probabilities is 86.6% or 95.5% when 1.5 or 2 standard deviation from statistics concepts. It is also true that some trends in the ASPR parameters agree well each other, we notice that the most of times the single deviations are different. What is instead interesting is that around a week before all ASPR data overcome 1.5 or even 2 standard deviation, while the general climatic conditions were not such as to explain this anomalous behavior.

The referee is misleading (perhaps by accident) when he says that we show one month of data before the EQ, because we actually compare the two month period around the EQ in 2009 with the same period of the previous 9 years (2000-2008). In addition we also show the behavior of the 2006 when no significant seismicity occurred in the Abruzzi region.

- We agree with the referee that the ground based datasets shown by us are not indicative of the climatic conditions of the L'Aquila area, only. Instead they are expected to be indicative of a larger area, and this explains why we used even weather station which are around 40 km from L'Aquila EQ epicenter (but within the Dobrovolsky area; see also below).

By the way, as showing in the referee's Google map the air temperature station is not so close to two small lakes but in the mountain areas. The distances between the station and the two lakes are about 8 km and 20 km, respectively, which is not likely for the lakes to suppress the transient rapid temperature variations at station place (at meteorological scale). Of course, the lakes will have effect on air temperature at station place in climate scale.

In addition, regarding the aerosol optical depth data with a station in the periphery of Rome (about 150 km to the L'Aquila epicenter), it is again surprising that the corresponding general signal was rather regular but with anomalies at times in agreement with the ASPR parameters. According to our previous study (*Qin, K., Wu, L.X., Zheng, S., et al., Is there an abnormal enhancement of atmospheric aerosol before the 2008 Wenchuan earthquake? Advance in Space Research, 2014),* the satellite observed abnormal AOD related to the 2008 Wenchuan EQ covers more than 200 km (see the figure below). Hence, the AOD anomaly could be regarded as potentially related with L'Aquila earthquake.

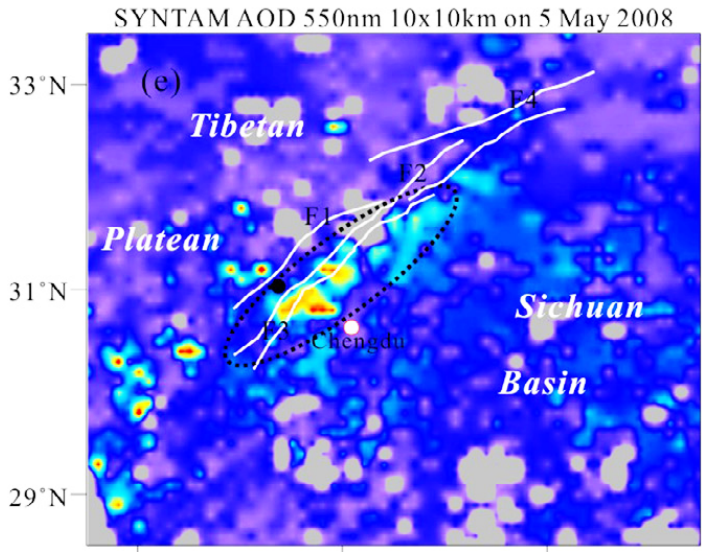

Fig.D1 Abnormal satellite-based AOD pattern one week before the 2008 Wenchuan EQ (Qin et al., 2014b)

3) For Dobrovolsky et al. (1979) model and strain radius concept, this paper and the corresponding topic would require a dedicated discussion, but that we summarized for evident limits of space. That paper is theoretical and is based on a mechanical model of the volume of rock around the impending fault that will slip and cause the EQ. Under the tectonic stress that always acts at the lithospheric plates (reaching forces of the order of 10^{12}-10^{13} N for each meter of tectonic margin), under reasonable hypotheses, there is a deformation over a larger presumed spherical volume, identified by the strain radius. This radius is the distance from the fault after which the strain is comparable with terrestrial tides. Its value has only a practical importance to define the area where the strain effect during the preparation phase is not negligible and identified by instrument. It is instead clear that in general the closer to the fault the distance, the greater the expected effect. It is obvious that once there is a deformation, which is the driving effect, it could imply some other possible effect, such as thermal, EM, gas release etc., depending on the rocks, the geological and tectonic conditions, the fault styles and their synergic interactions and configuration.

We admit that the larger the magnitude of the impeding EQ the larger the area interested in its preparation phase, so paradoxically the greater the size of the expected EQ and the wider the area interested, so the more difficult to identify the precise site of the impending EQ. But this does not mean that the research is not worth doing. Rather, our opinion is that the complexity of the phenomenon does not preclude to understand it in the next future, especially attempting to connect and explain the quasi- synchronism of the appearance of different anomalies, which are not only those ASPR but also seismic. The latter are consolidated and serve as optimal indication of the subsequent phases preceding the L'Aquila mainshock.

Therefore we disagree firmly to what the referee affirms in his last sentence. Our paper is not another paper that attempts to find EQ precursors in geophysical parameters. This would be a too simple generalization that will reduce the importance not only of our work but even that of any kind of researches in this field. It is clearly a "one sided position".

Of course it is not our intention to solve all still open questions. We instead attempt to connect temporally and spatially the behaviors of different parameters, seismicity included. We also provide a possible reasonable logic that relates these observations under the umbrella of space-and-time referring to lithosphere-coversphere-atmosphere-ionosphere coupling. We believe our efforts can be useful to the scientific community working on this difficult but interesting and important subject. We finally agree with

one of the first sentences of the referee, i.e., that if we “investigate the possible occurrence of precursors of the 6 April 2009 L’Aquila earthquake in atmospheric and soil parameters and in ground-based observations of temperature and atmospheric aerosol, as well as in seismic data”, and we improve our understanding, the implications on the Society would be great.

Very Sorry for the delayed response because my travelling to Vienna to participate the EGU 2016 assembly.

Sincerely yours

Lixin Wu (on behalf of all co-authors)

April 24, 2016