Comment on "Signature of pending earthquake from electromagnetic anomalies" by K. Eftaxias et al.

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[1] *Eftaxias et al.* [2001], hereafter cited as "E01," claim to have observed VLF (very low frequency) radio waves that "might be considered as signatures of a pending earthquake." For the following reasons, this claim should not be accepted. (1) Previous such claims have proved groundless. In the absence of compelling evidence, which E01 do not provide, further such claims should be regarded skeptically. (2) The observed signals appear consistent with well known types of background noise that are unrelated to earthquakes. (3) E01 did not present a quantitative and objectively testable model of the relation between the observed signals and the earthquake source parameters. (4) E01's correlation between the observed signals and the earthquake appears to be arbitrary. (5) E01 did not present any objective evidence of a correlation beyond random chance, nor did they present any method by which objective tests might be made in the future. *INDEX TERMS:* 0699 Electromagnetics: General or miscellaneous; 6914 Radio Science: Electromagnetic noise and interference; 7223 Seismology: Seismic hazard assessment and prediction. **Citation:** Pham, V. N., and R. J. Geller, Comment on ''Signature of pending earthquake from electromagnetic anomalies'' by K. Eftaxias et al., *Geophys. Res. Lett.*, *29*(18), 1871, doi:10.1029/2002GL015328, 2002.

1. Previous Research

[2] Controversy over whether or not earthquakes are preceded by precursory electromagnetic (EM) signals has continued for over 20 years. Proponents, including *Eftaxias et al.* [2001], hereafter cited as "E01," take the existence of such phenomena as given ("In the past few decades there has been a number of reported occurrences of electromagnetic precursors. . ."). In contrast, a recent review [*Geller*, 1997] noted the following reasons for doubting such claims: (1) the absence of simultaneous geodetic or seismological precursors, (2) the absence of coseismic EM signals of the same type, but with larger amplitudes, than the alleged precursors, (3) the failure to exclude other natural or artificial sources of the EM signals, (4) the lack of consistency, (5) the lack of a quantitative and objectively testable relation between the EM signals and the earthquake source parameters. A systematic approach to resolving this controversy seems desirable.

[3] There is an inherent asymmetry in such controversies, as the existence of EM precursors could in principle be demonstrated, but non-existence can never be proven; opponents can only make the case that particular claims should not be accepted. The scientific method copes with this asymmetry by treating claims for a particular effect as a class, rather than as independent entities. This evaluation process can be formulated in Bayesian terms: each unsuccessful attempt to demonstrate the existence of EM precursors of earthquakes lowers the a priori probability for the next evaluation of a similar claim [*Anderson*, 1992]. In other words, each false or marginal claim raises the threshold of proof for the next claimant.

[4] The debate [*Lighthill*, 1996; *Geophysical Research Letters*, vol. 23, no. 11, 1996] over the work of the "VAN" group, who claim to be able to predict earthquakes on the basis of geoelectrical signals [*Uyeda*, 1996; *Varotsos et al.*, 1996], serves to illustrate the common problems afflicting claims of EM precursors. VAN's work has been criticized for the lack of clear rules for correlating EM signals with subsequent earthquakes [*Geller*, 1996] and for lacking statistical significance [*Mulargia and Gasperini*, 1996]. Studies by independent teams suggest that the signals being observed by VAN are industrial artifacts with no connection to earthquakes [*Gruszow et al.*, 1996; *Pham et al.*, 1999; *Pham et al.*, 2002]. As discussed below, E01's work appears to have similar problems.

2. Background Noise

[5] A recent review [*Johnston*, 1997] points out that known atmospheric disturbances and other effects must be identified and removed before claims of earthquake precursors in VLF signals can be accepted. The primary source of VLF noise is electromagnetic fields radiated by both distant and local atmospheric lightning discharges [*McNeil and Labson*, 1991]. "Since thunderstorm activity varies both with location on the earth's surface and with time, so do the received noise levels. . .Superimposed on this pattern is a diurnal variation in which the thunderstorm activity moves across the earth's surface from the east to the west following the passage of local afternoon or early evening. . . Radiation from nearby storms tends to be very spiky, reflecting the influence of individual discharges. . .In general the noise decreases slowly during the night to a minimum which usually takes place at around 08:00 local time, then rises fairly rapidly to a maximum at about 16:00 local time before again decreasing."

[6] The above VLF noise characteristics are similar to the characteristics of the EM signals shown in Figure 2 of E01,

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which suggests that these signals are due to local or atmospheric noise sources rather than precursors of earthquakes. As shown in Figure 1 of E01, the distance from E01's observatory to the epicenter of the earthquake of September 7, 1999 is well over 200 km. Before considering the possibility that earthquake precursors were recorded at such a distant observatory, E01 should have, but did not, presented quantitative arguments for excluding noise as the origin of their signals.

3. Questionable Points

[7] E01 state, in discussing their Figure 2, that "such unusual. . .anomalies had never been recorded" during the operation of their station (since 1994), but they present no objective analyses to support this assertion. They should have defined quantitative criteria for what constitutes an "anomaly," and should then have processed the previous five years of their data to demonstrate quantitatively the "anomalous" nature of their data. As they did not do this, the claim that these data are anomalous is subjective. Since this claim was only made after the earthquake occurred, it is questionable on general principles.

[8] E01 claim that there is a gap of twelve hours between two allegedly precursory EM signals in their Figure 2. On the other hand, they note that standard seismic analyses of the earthquake source show that there were two main subevents, separated in time by 3.5 s. For reasons that are unclear, they correlate what they claim as two separate EM anomalies with each of these subevents. This correlation seems purely arbitrary.

[9] Particularly in view of the long history of unsuccessful research in this field [*Geller*, 1997], researchers who claim to have observed earthquake precursors should demonstrate the statistical significance of their data as an integral part of their research. As E01 did not do this, they should, at a minimum, have presented their work in the form of an objectively testable hypothesis that could be confirmed (or rejected) by tests against future data. Objective hypothesis testing has served to reject other hypotheses in this field [*Michael*, 1997], and could presumably lead to a speedy resolution of E01's claims. Such hypothesis testing should not be the responsibility of the critics but, following normal scientific procedures, should be conducted by E01 themselves. In the absence of such objective hypothesis testing, it seems unlikely that further case studies of the type of E01 will lead to significant progress.

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