# * Ionospheric precursors (short comments)

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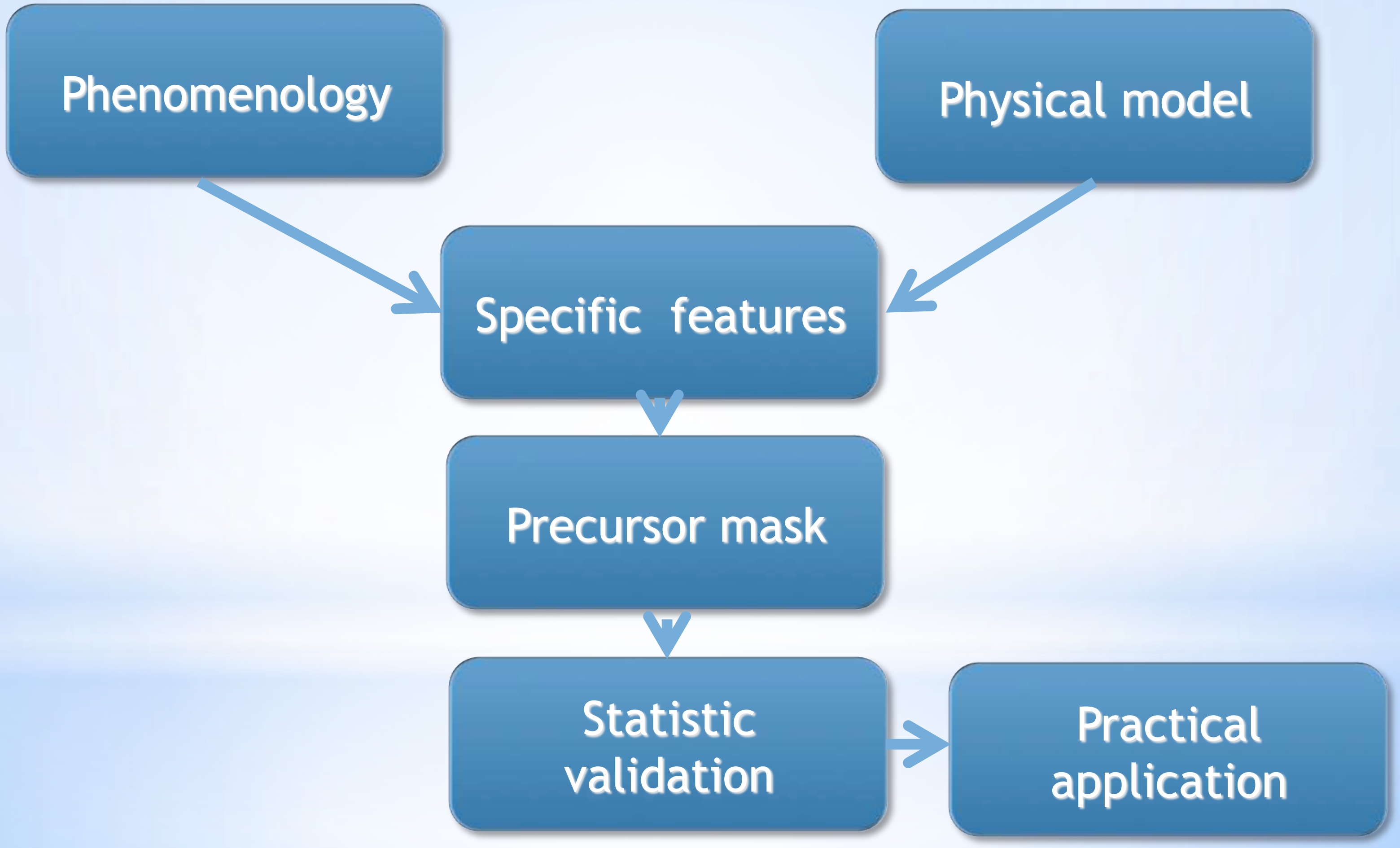
# *From observation to prediction

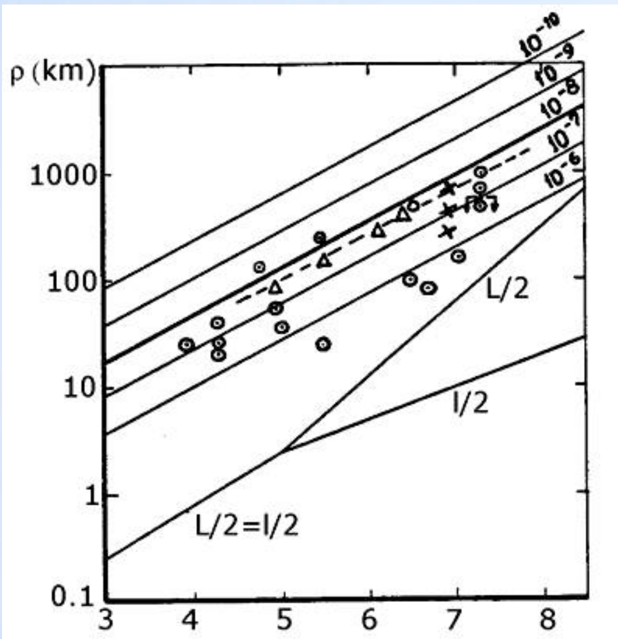


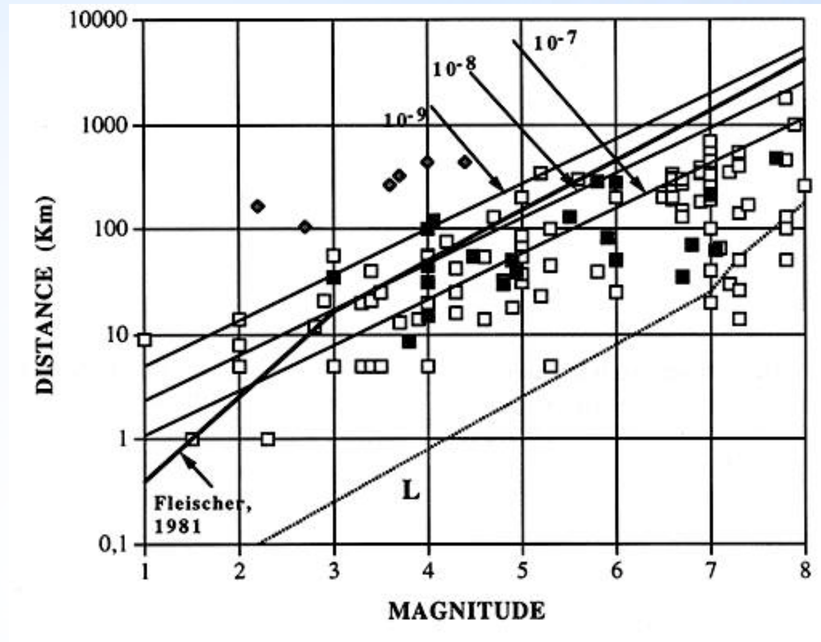
$a = 10^{0.414M - 1.696}$ km *Dobrovolsky et al., 1989*

$\rho = 10^{0.43M}$ km *Dobrovolsky et al., 1979*

$l(M_0) = \exp(M_0 - c) + 2\varepsilon$ *Keilis-Borok and Kossobokov, 1990*

$\xi = 10\, A_E^{1/2}$ *Bowman et al., 1998* *Toutain and Baubron, 1999*

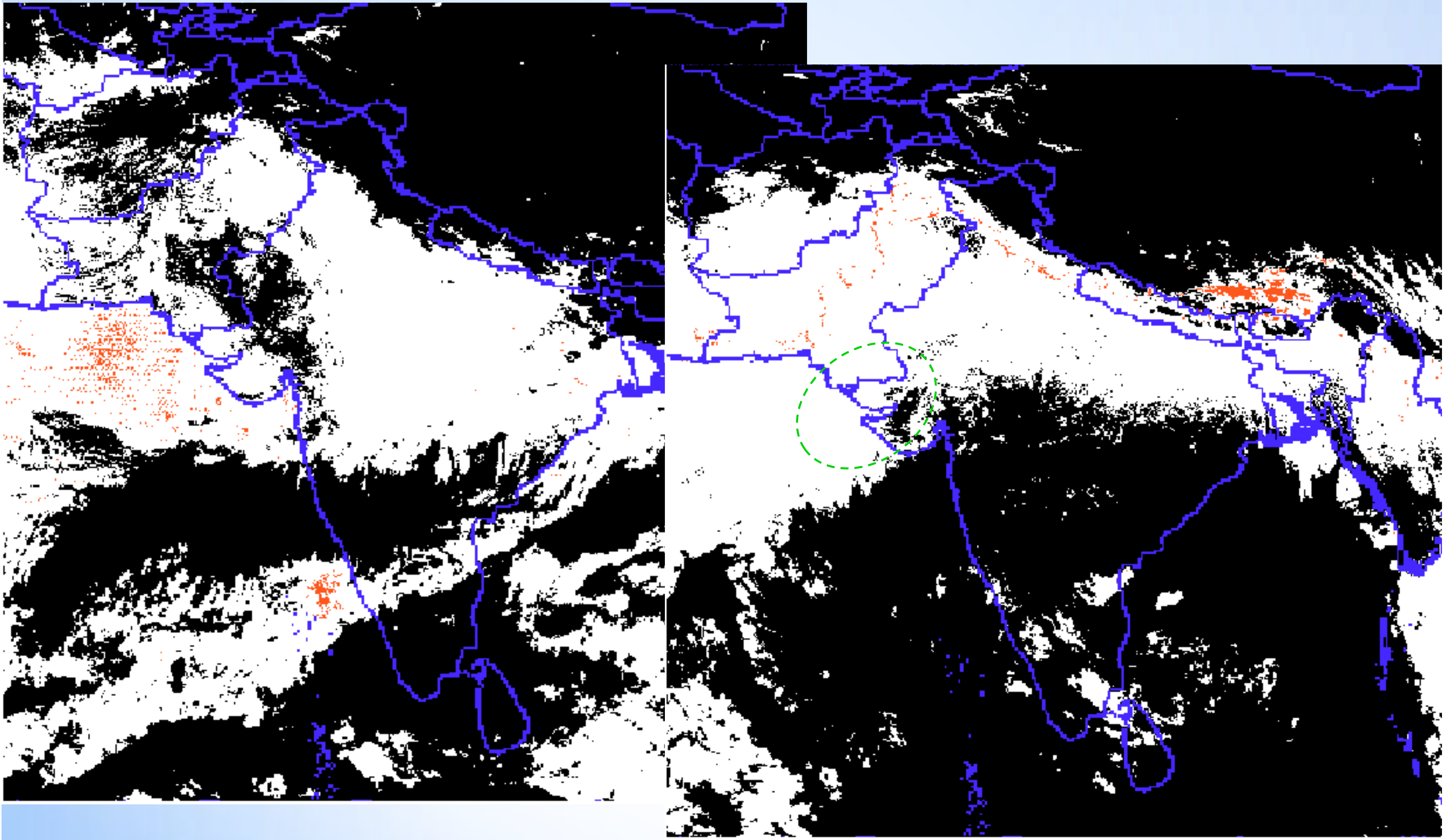


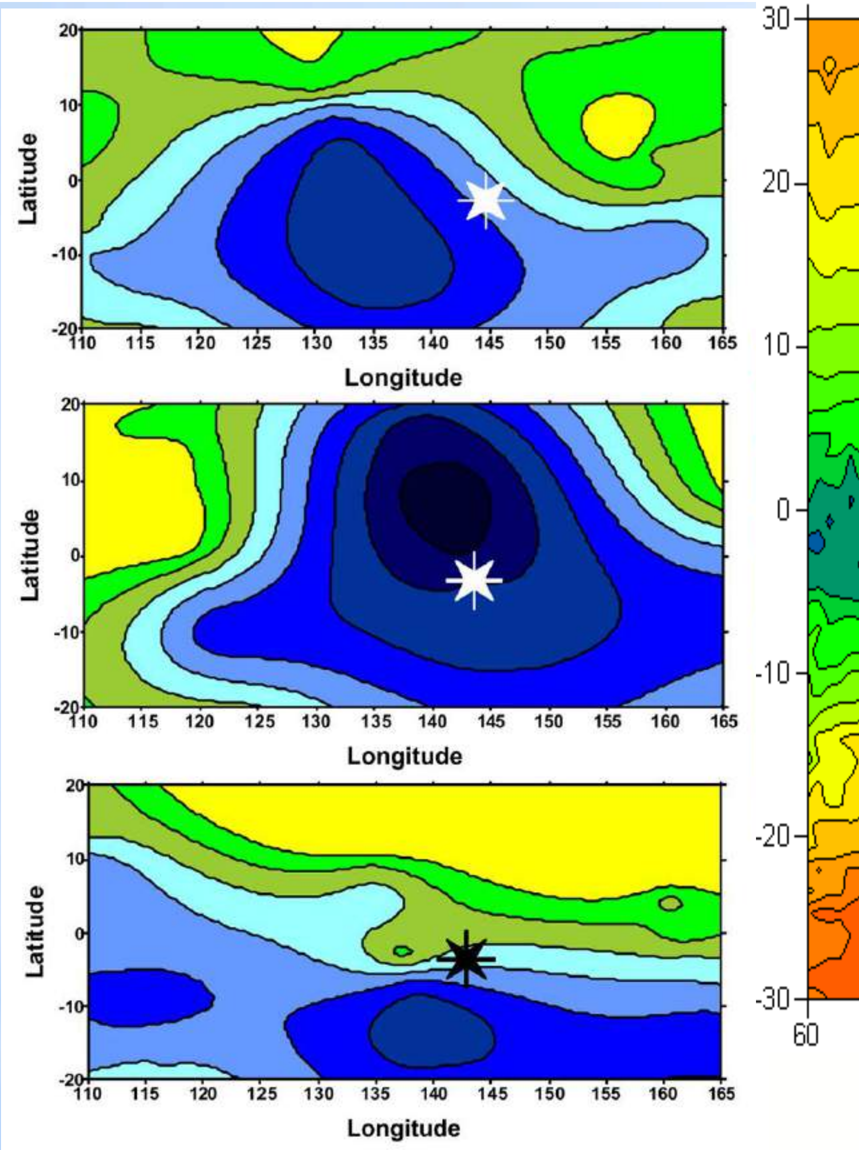

| Magnitude | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|
| Earthquake preparation zone radius ρ (km) | 19.5 | 52.5 | 141 | 380 | 1022 | 2754 | 7413 |

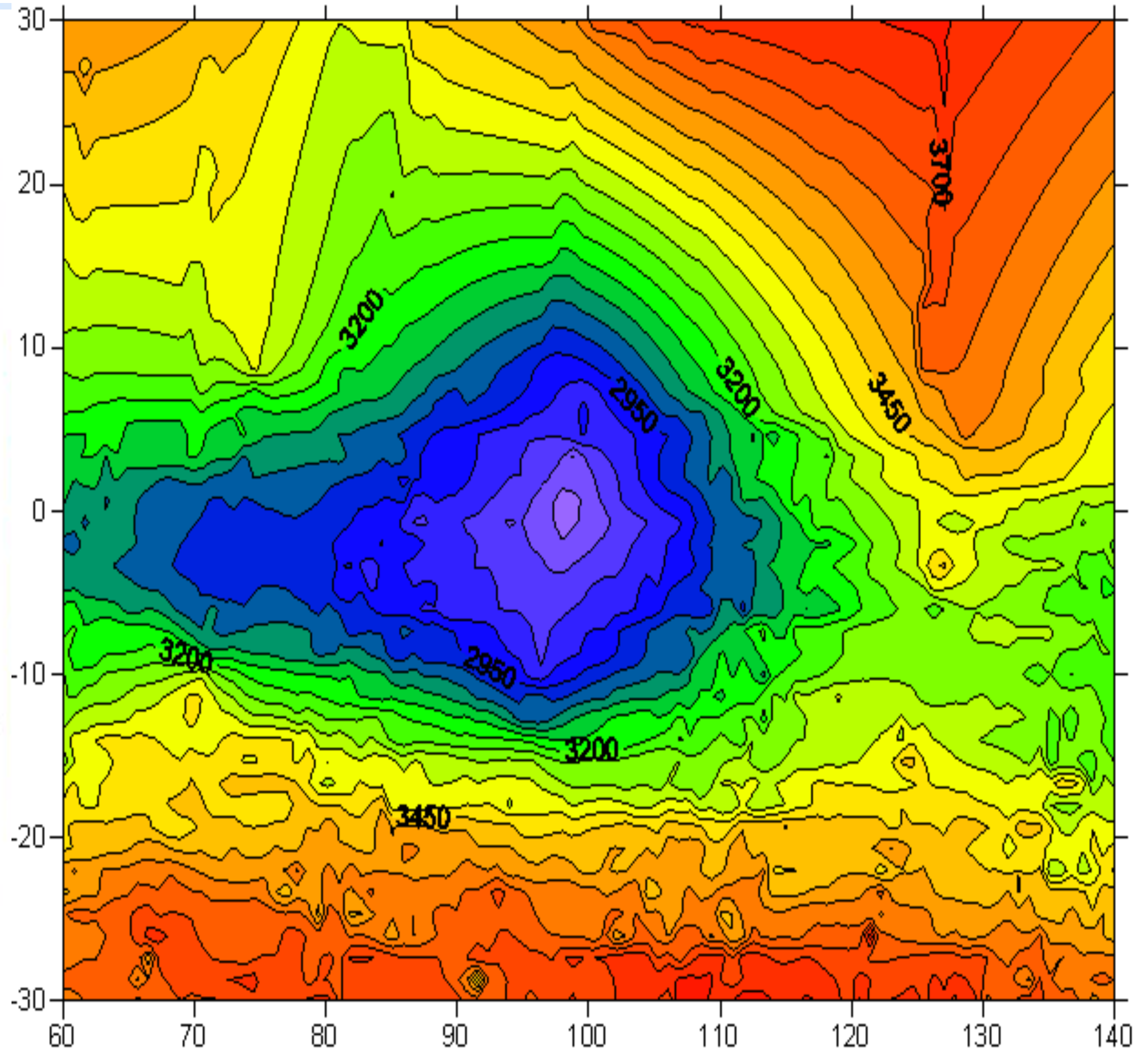
# *Earthquake preparation area conception

# *Gujarat earthquake Jan 26, 2001



Genzano et al., 2006

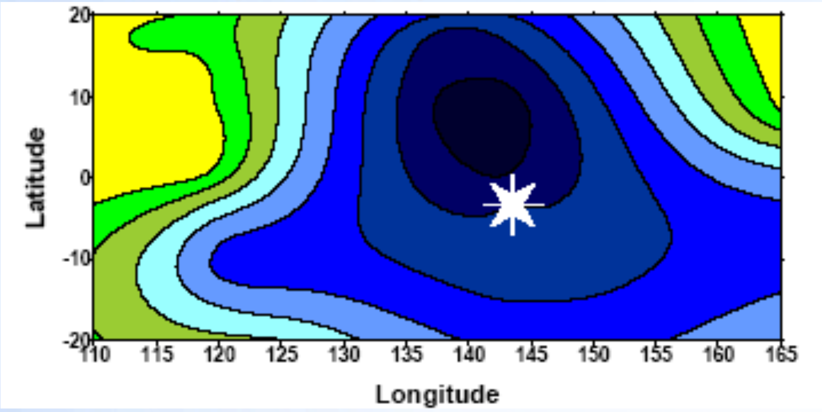


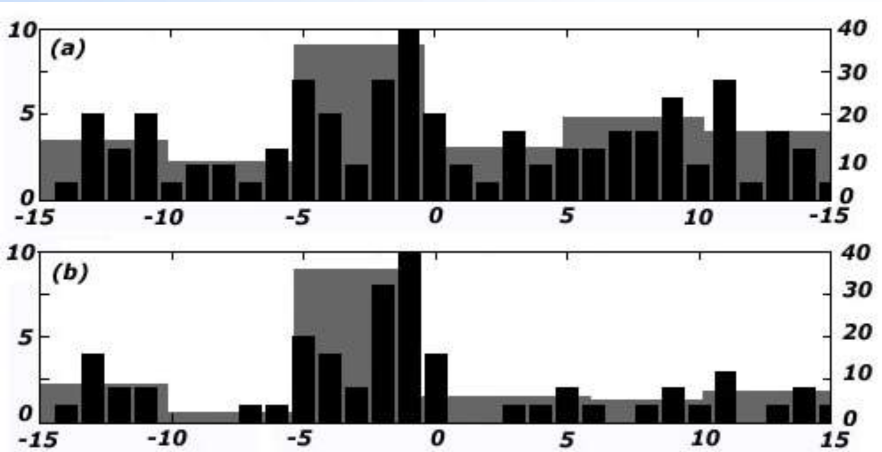

# *ρ in ionosphere as and estimate for magnitude

# Determination of the earthquake parameters from ionospheric anomaly

Epicenter position



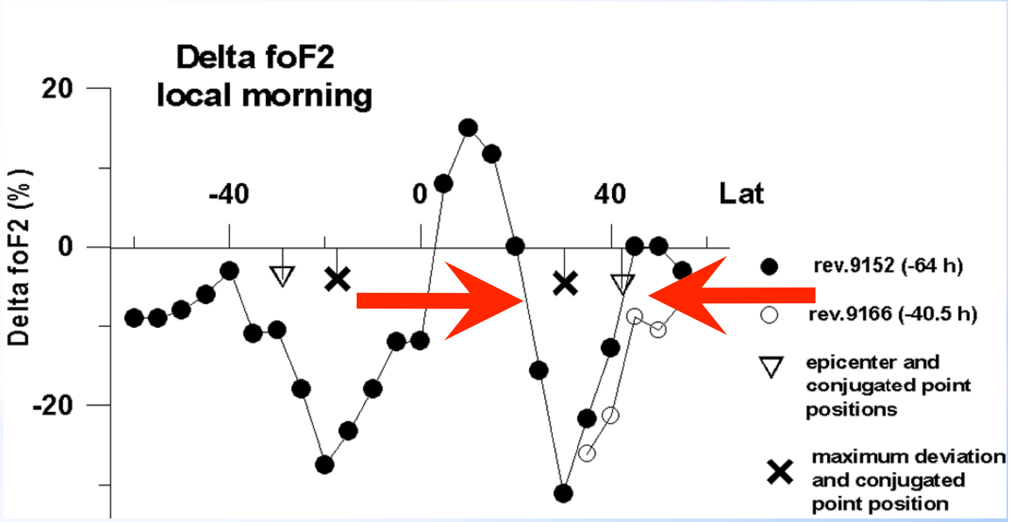

Time of earthquake determination




Magnitude estimation

$\rho = 10^{0.43M}$ km  Dobrovolsky et al., 1979

Irpinia, Italy, 23 Nov. 1980, M6.9



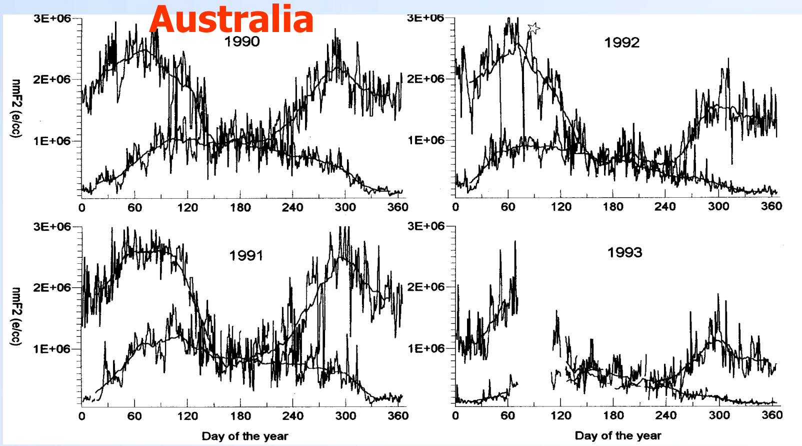

$M = [\log(900)]/0.43 = 6.9$

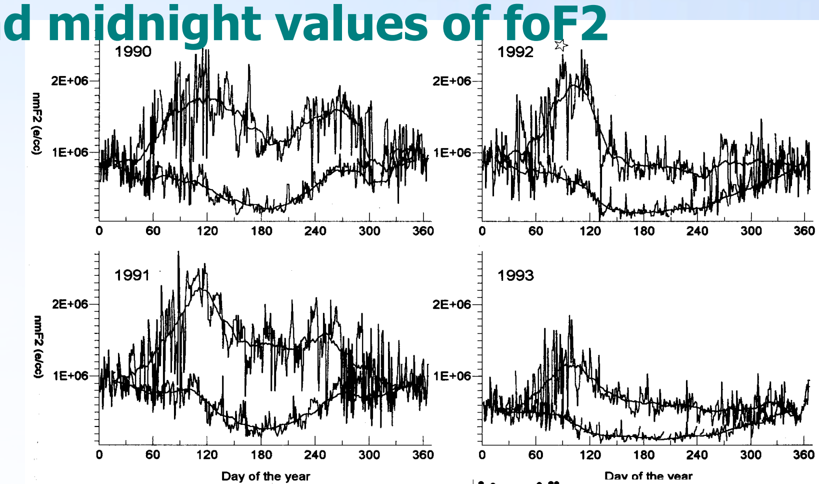
# * Ionosphere variability

## Seasonal and solar cycle variations of noon and midnight values of foF2

Japan

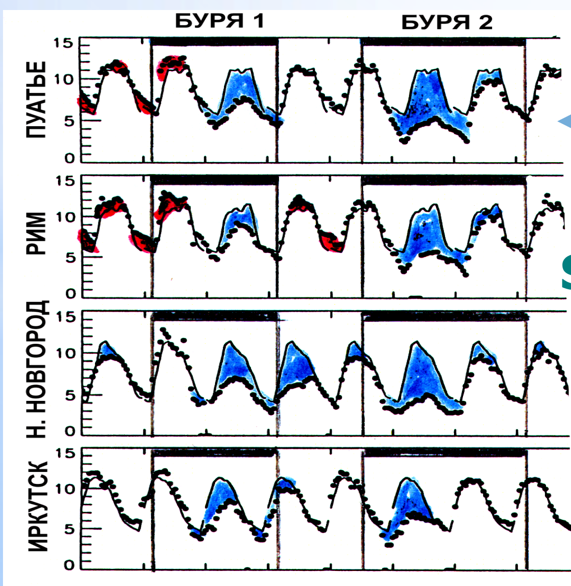
Australia



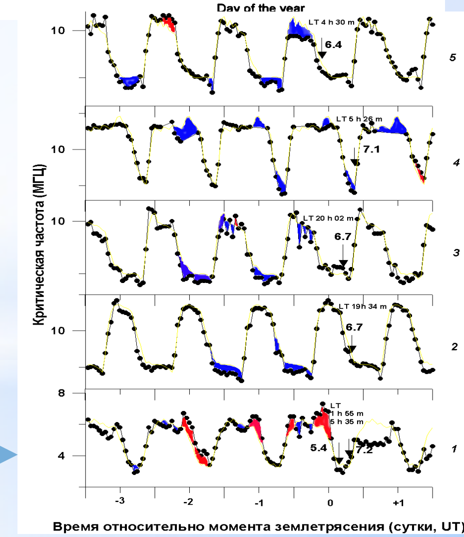

## Storms

Long lasting (8-36 h) intensive variations



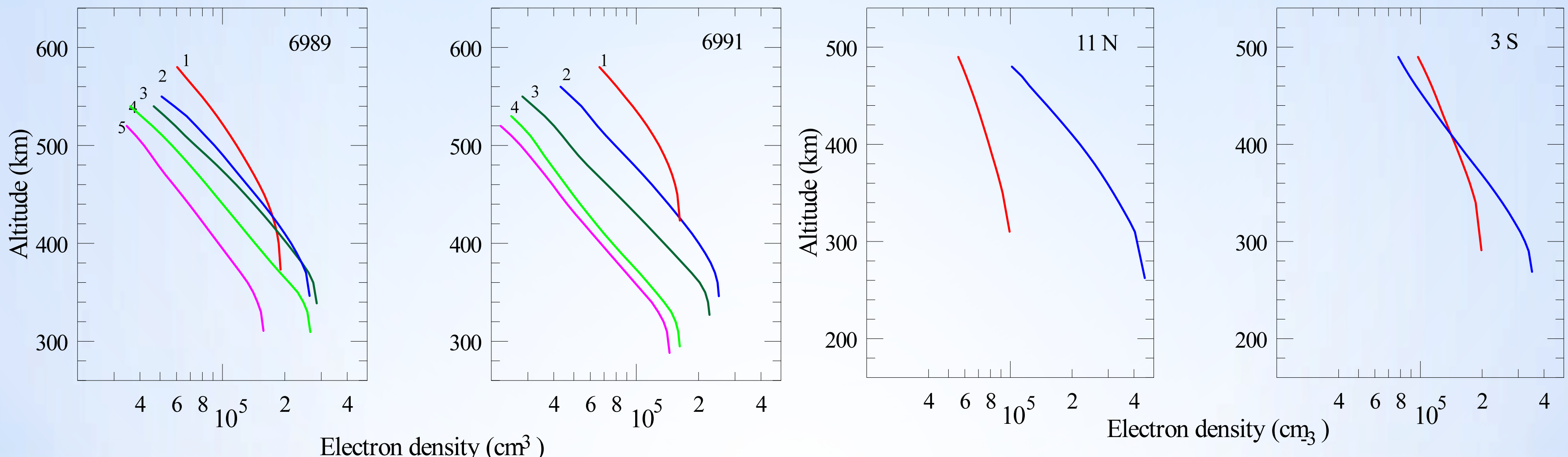

## Seismoionospheric variations

Short time (4-8 h) less intensive (in general) variations



$$N(z) = 4.0 * \frac{\exp\left(\frac{z}{B2u}\right)}{\left(1+\exp\left(\frac{z}{B2u}\right)\right)^2}$$

where *B2u* characterizes the topside layer thickness and changes linearly with the height: $B2_u = B_0 + k \cdot z$, $z = h - h_{max}$




| | lat | hmF2 | foF2 | B2u | k2u |
|---|---|---|---|---|---|
| 1. | 8.4 | 375 | 12.4 | 75.8 | 0.02 |
| 2. | 0.6 | 345 | 14.6 | 47.1 | 0.14 |
| 3. | -3.3 | 340 | 15.2 | 43.3 | 0.13 |
| 4. | -7.2 | 310 | 14.6 | 44.4 | 0.12 |
| 5. | -15.1 | 310 | 11.3 | 46.5 | 0.15 |

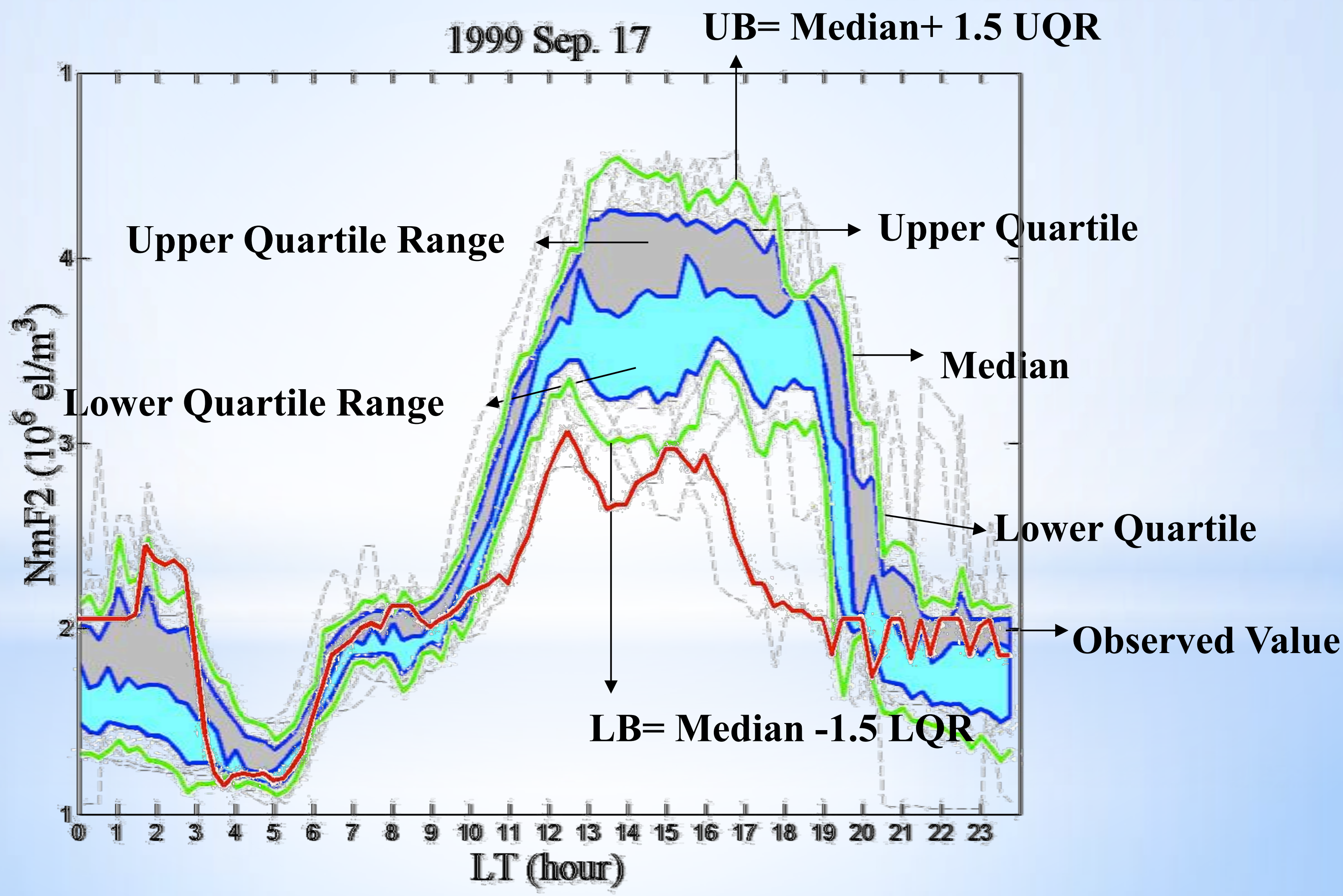
| | lat | hmF2 | foF2 | B2u | k2u |
|---|---|---|---|---|---|
| 1. | 9.6 | 425 | 11.5 | 61.7 | 0.17 |
| 2. | 1.8 | 345 | 14.2 | 47.5 | 0.12 |
| 3. | -2.2 | 325 | 13.5 | 40.6 | 0.12 |
| 4. | -10.0 | 295 | 11.4 | 44.6 | 0.13 |
| 5. | -14.0 | 290 | 10.8 | 48.4 | 0.11 |

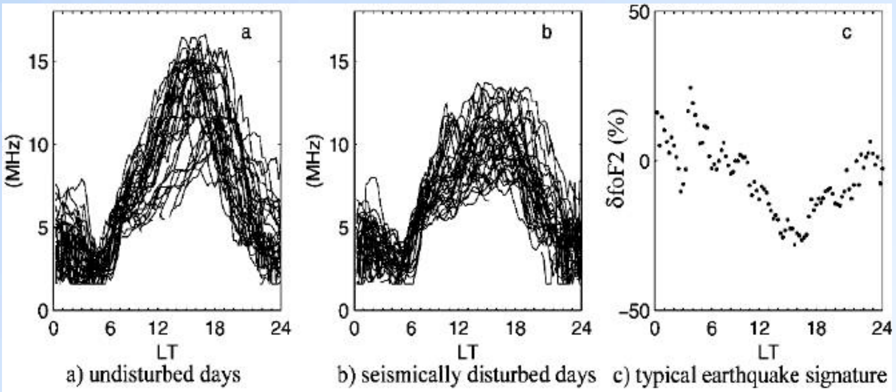
| hmF2 | foF2 | B2u | k2u |
|---|---|---|---|
| 260 | 6.0 | 54.0 | 0.16 |
| 320 | 2.8 | 87.0 | 0.29 |

| | hmF2 | foF2 | B2u | k2u |
|---|---|---|---|---|
| 7286 | 270 | 5.3 | 44.7 | 0.17 |
| 7301 | 290 | 4.0 | 69.0 | 0.26 |

# *Height scale effect

# *Lower Anomaly Detection





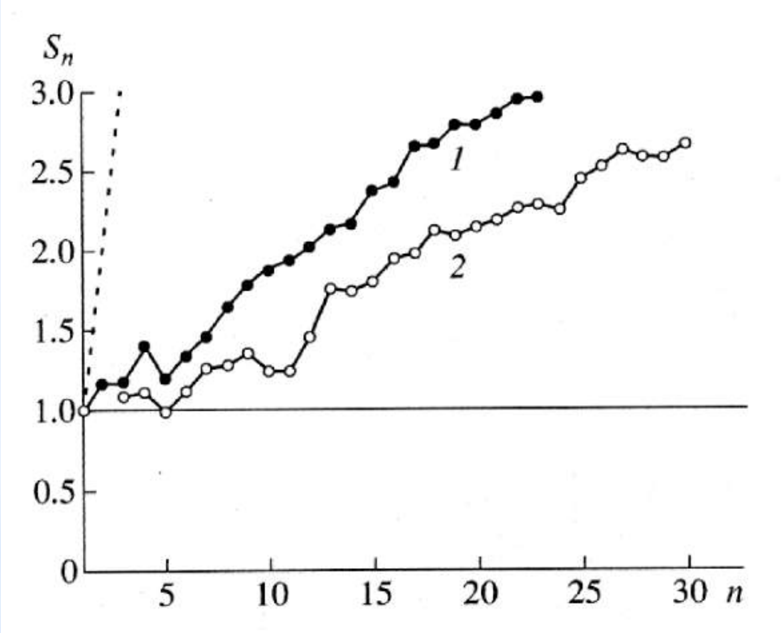
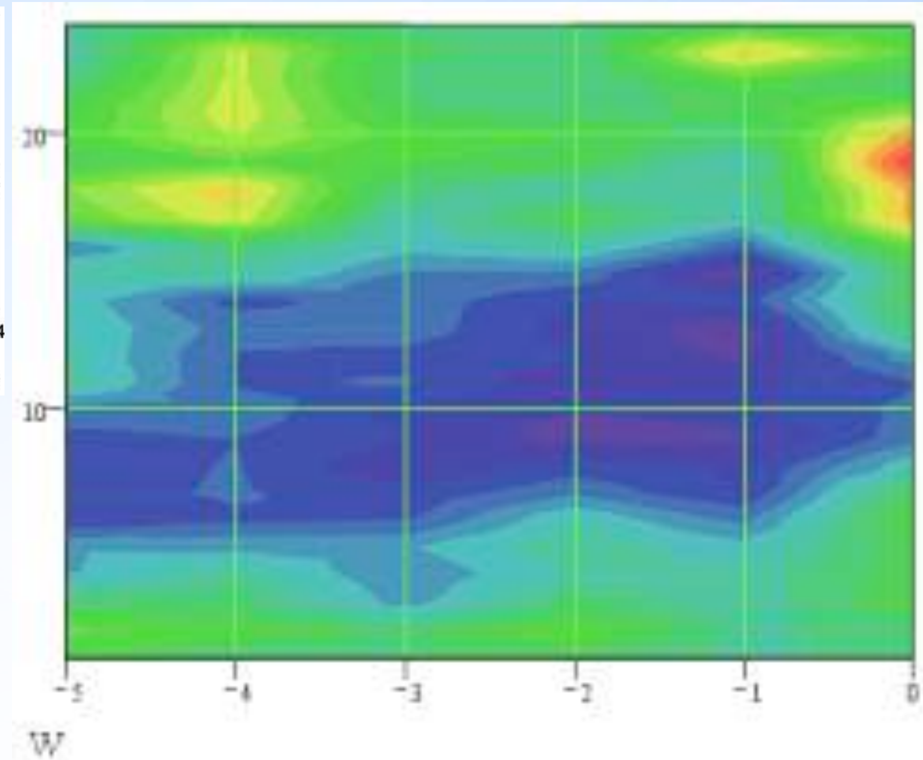
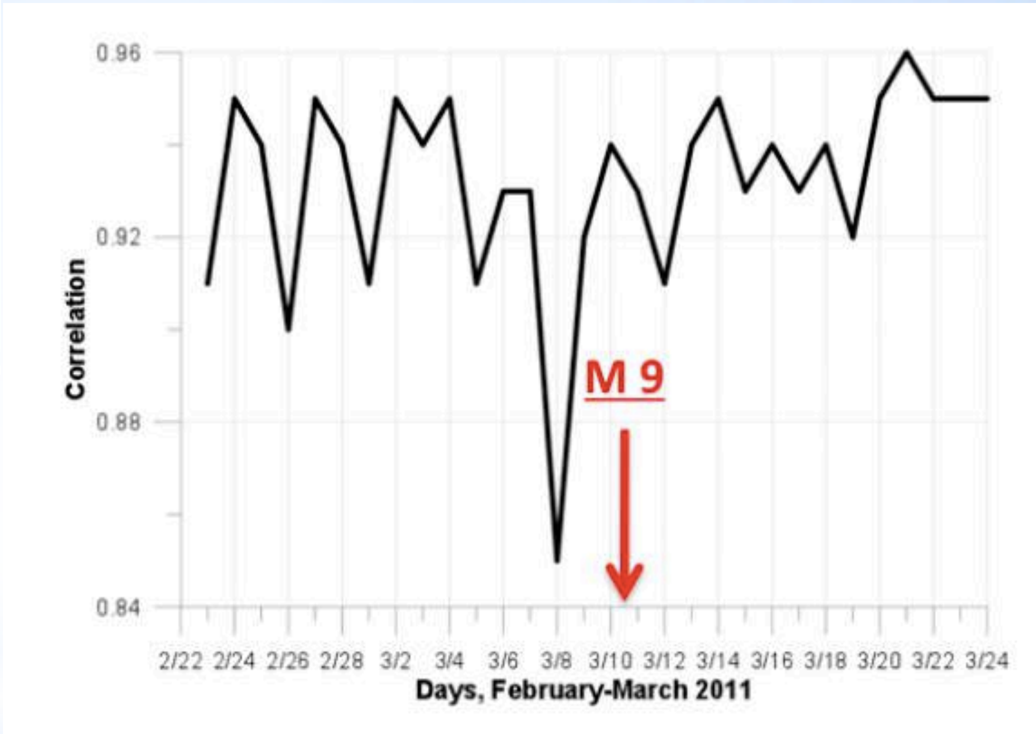




**Fig. 2.** Behavior of the $S_n$ parameter for two groups of deep-focus earthquakes: a series of 23 (curve 1) and 30 (curve 2) events. Dashed and solid curves: theoretical curves for a similar state and noncorrelated states of the ionosphere prior to any earthquake in the series, respectively.

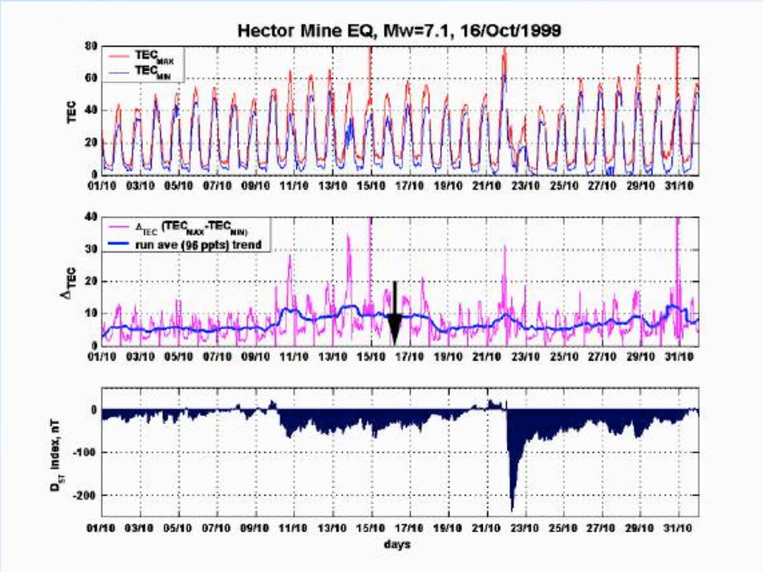


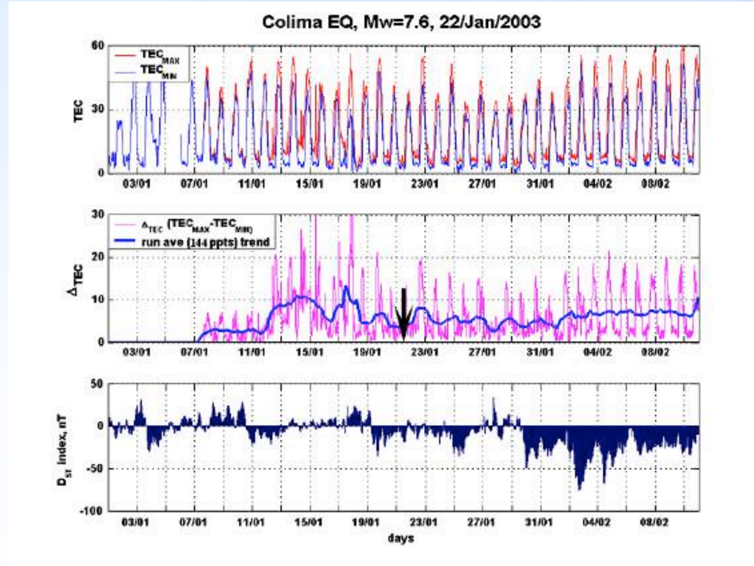
# One-point observation, using historical data

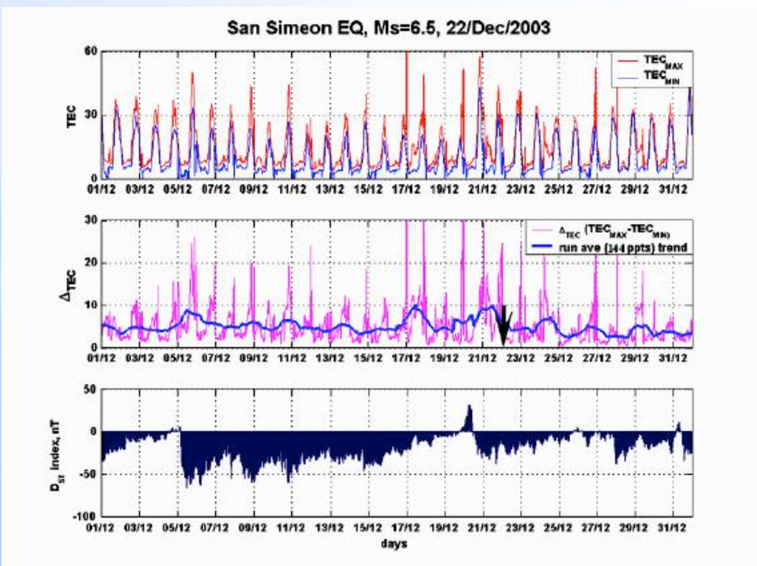



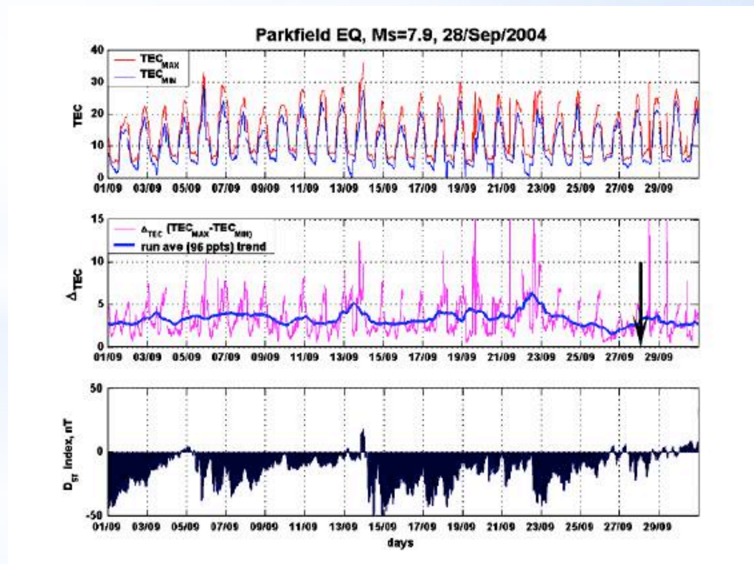

# *Two-points cross-correlation analysis

# * Local ionosphere variability index

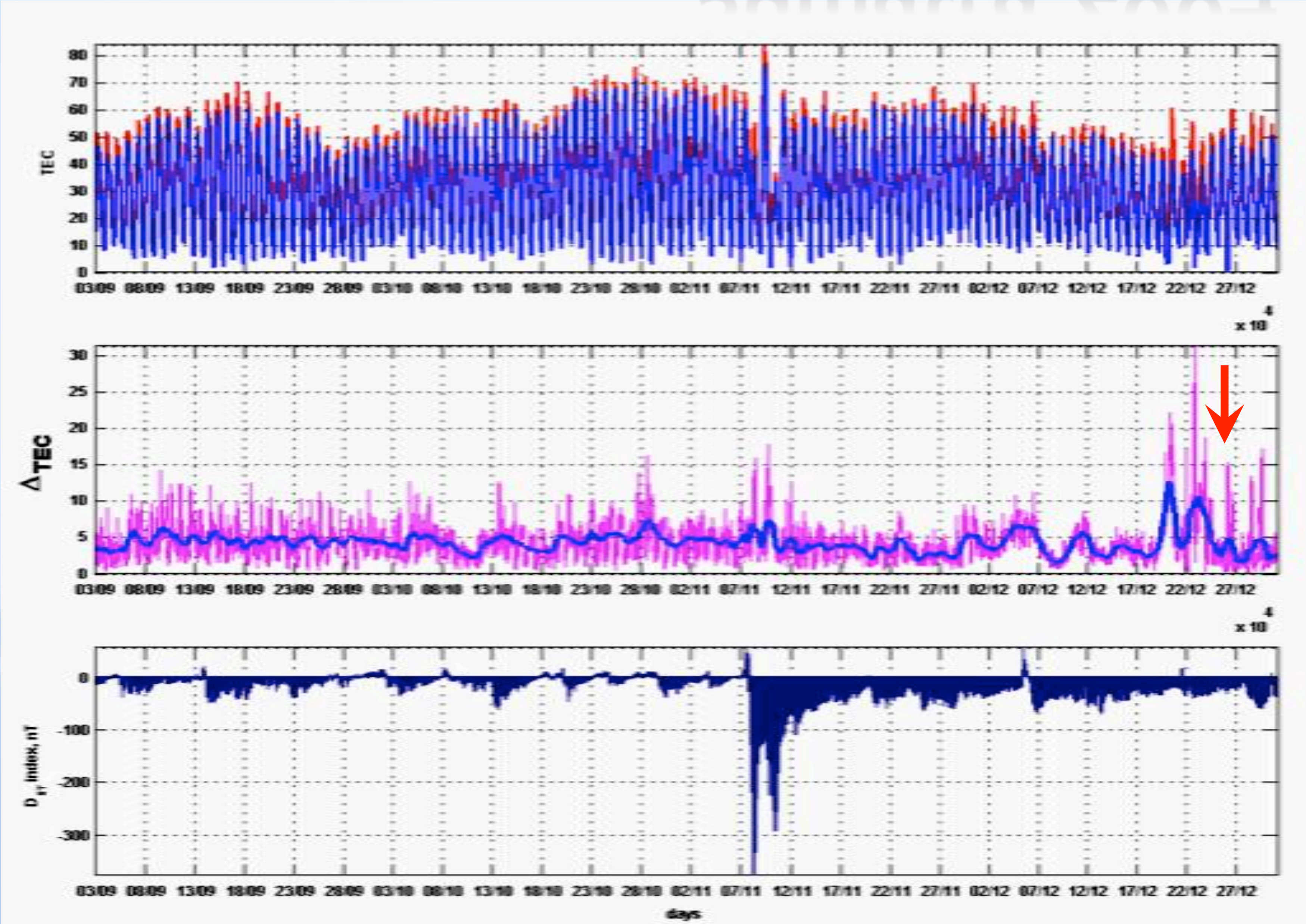


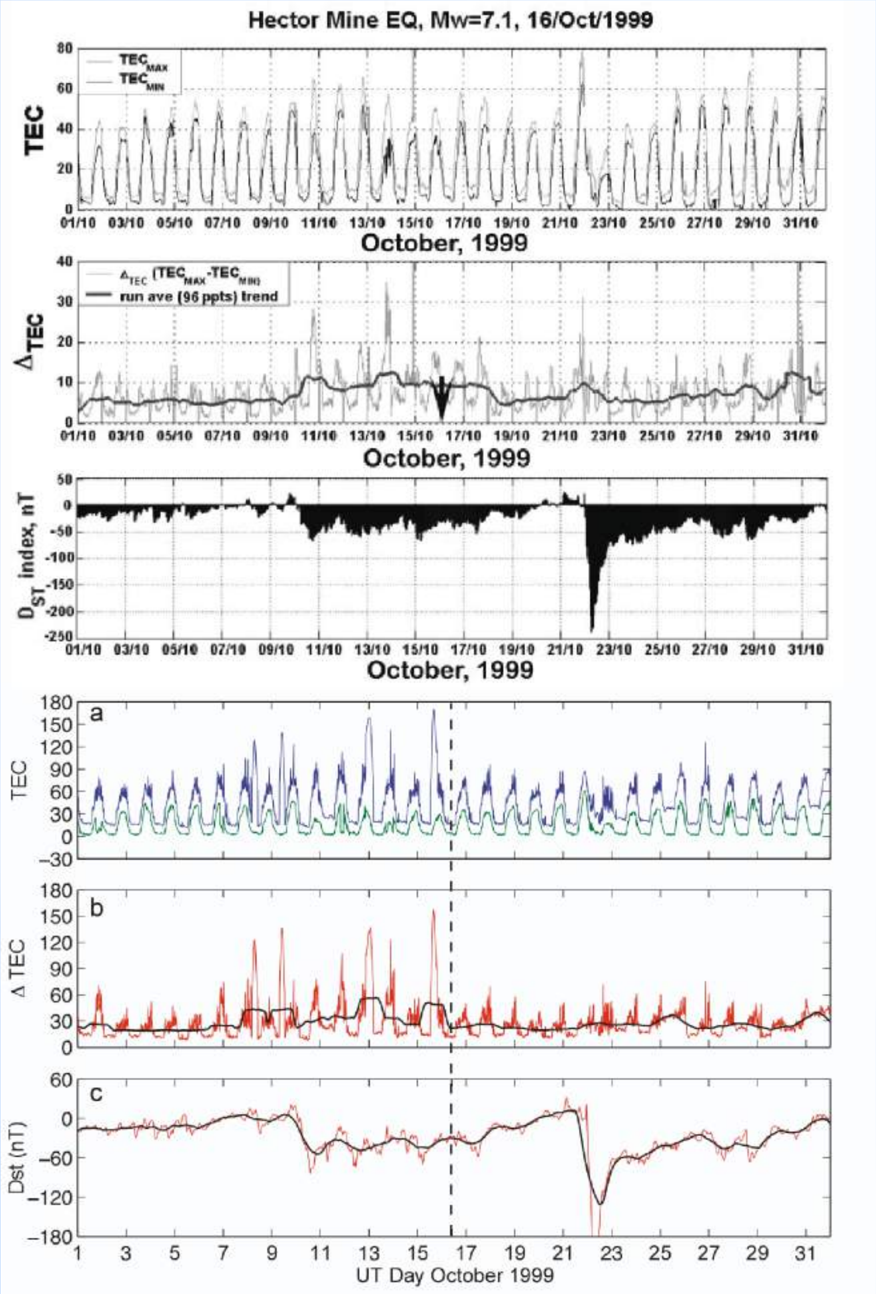



# *Sumatra 2004



* # Comments on the paper of J. Love et al.

*On the Reported Ionospheric Precursor of the 1999 Hector Mine, California Earthquake*




* The paper of J. Love et al. is and attempt to re-analyze the GPS TEC data for period around the Hector Mine earthquake and to prove that results presented in the paper S. A. Pulinets, A. N. Kotsarenko, L. Ciraolo, I. A. Pulinets, Special case of ionospheric day-to-day variability associated with earthquake preparation, Adv. Space Res., 39 (5), 970-977, 2007 are not correct. As a first approach they try to repeat our calculations and obtain the same results

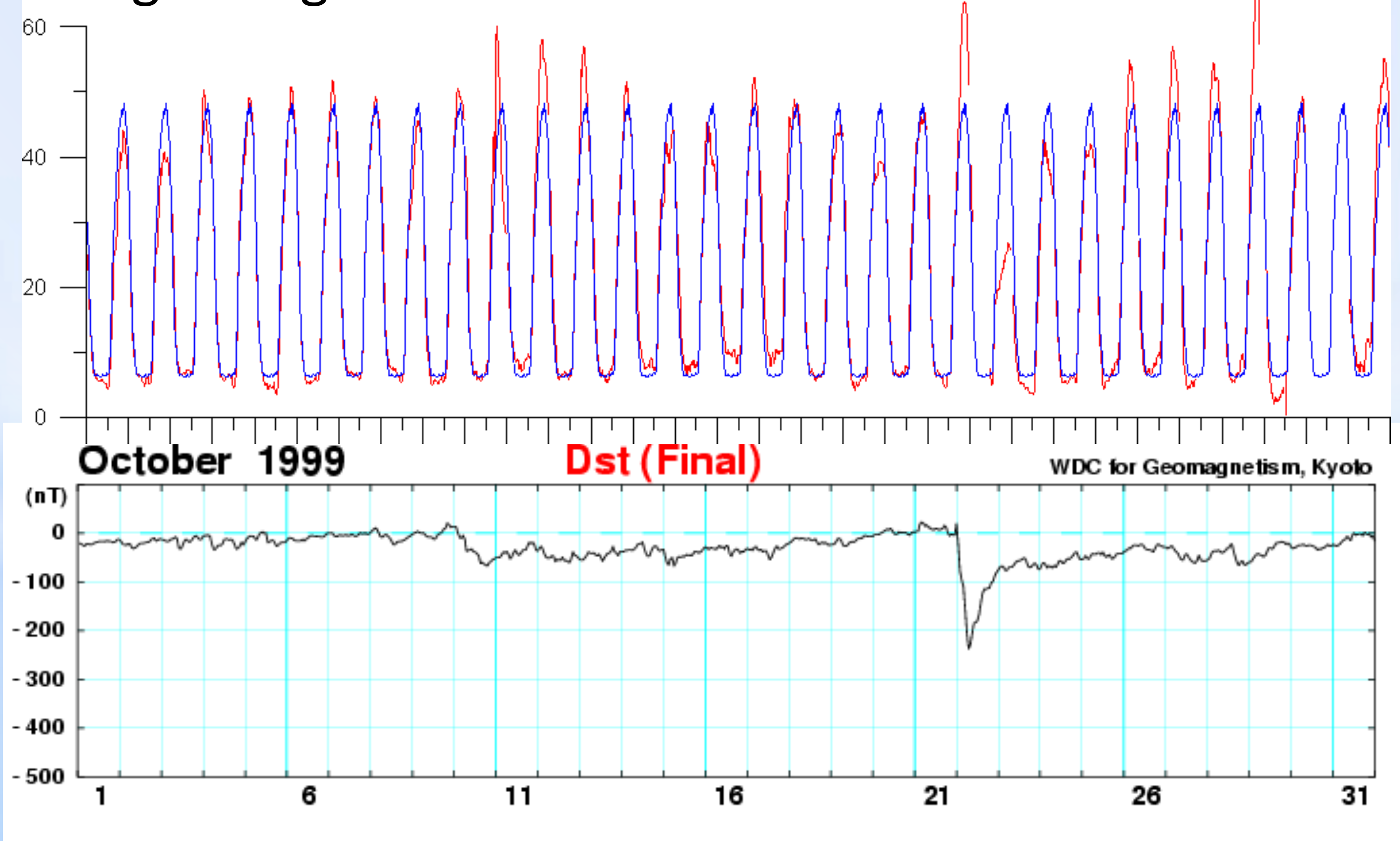
**Very good correspondence, even their index looks better.**

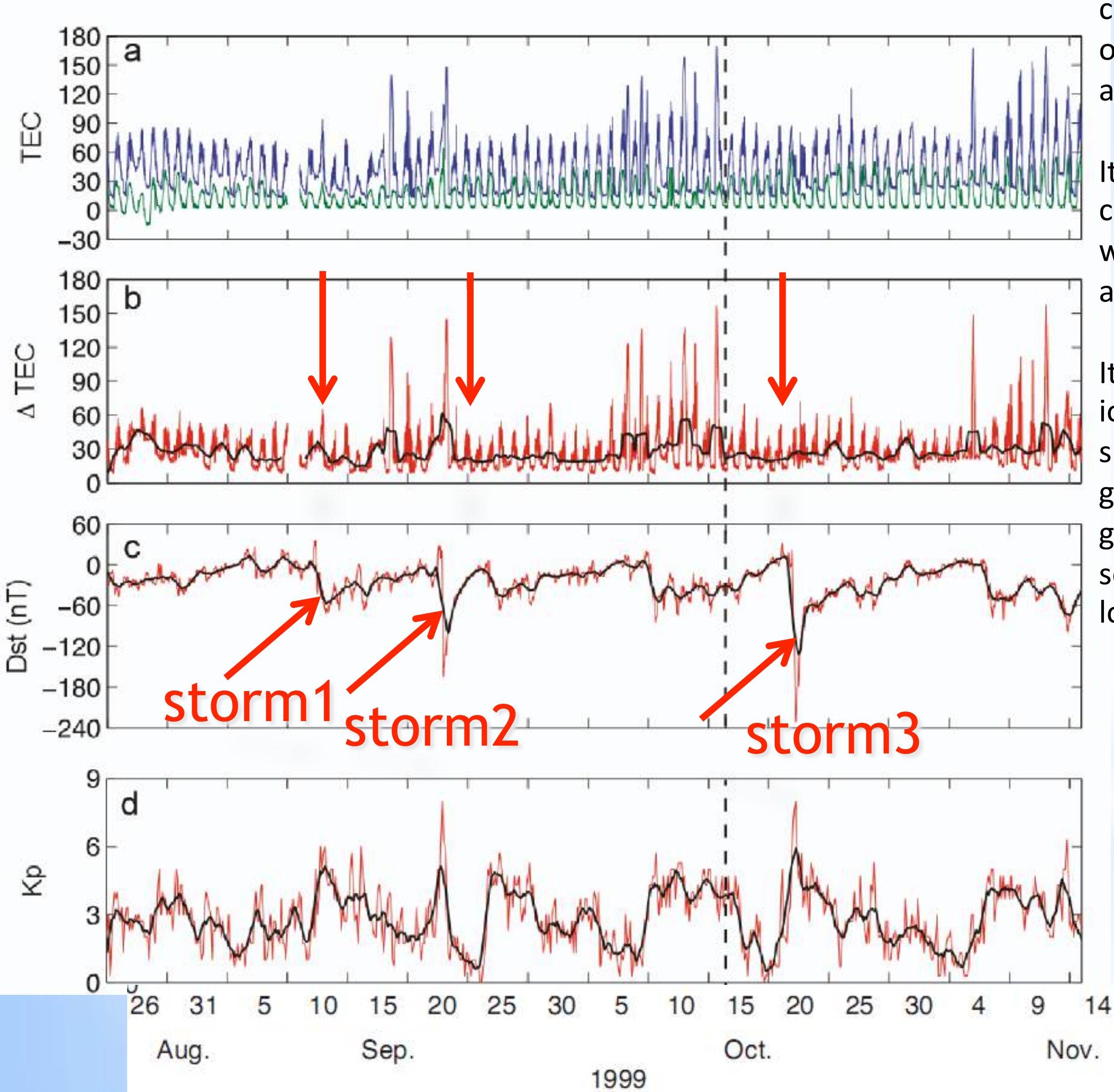
**Questions:**

**1.** Why authors average the Dst index? It is absolutely incorrect because the strength of geomagnetic storm (and corresponding ionosphere reaction) are determined by the maximum value of Dst which for this storm was -237 nTl – very strong storm (by averaging authors obtained -120 – two times less)

**2.** Top panel of the bottom figure (blue line) if it is really TEC as it is written is absolutely incorrect. TEC **SHOULD** show reaction on geomagnetic storm on 22 October.

Here is demonstration how should look the TEC as a results of geomagnetic disturbance. Red line – vertical TEC calculated for the station *cosa1*, blue line – monthly median. Bottom panel – Dst index for October 1999. One can see one-to-one correspondence of the positive TEC deviations to the geomagnetic disturbances.






The authors extend time interval to 4 months and claim that other periods of increased variab. index indicate that it coincides with increase of Kp index and other indices of solar and geomagnetic activity.

It would be interesting to see at least one calculation of any correlation coefficient with any of indices. Otherwise it is simple allegation.

It is obvious that the strongest reaction of ionosphere and correspondent variability should coincide with the strongest geomagnetic storms. Red arrows show geomagnetic storms start and we do not see reaction both at upper panel (blue) and lower panel (red)

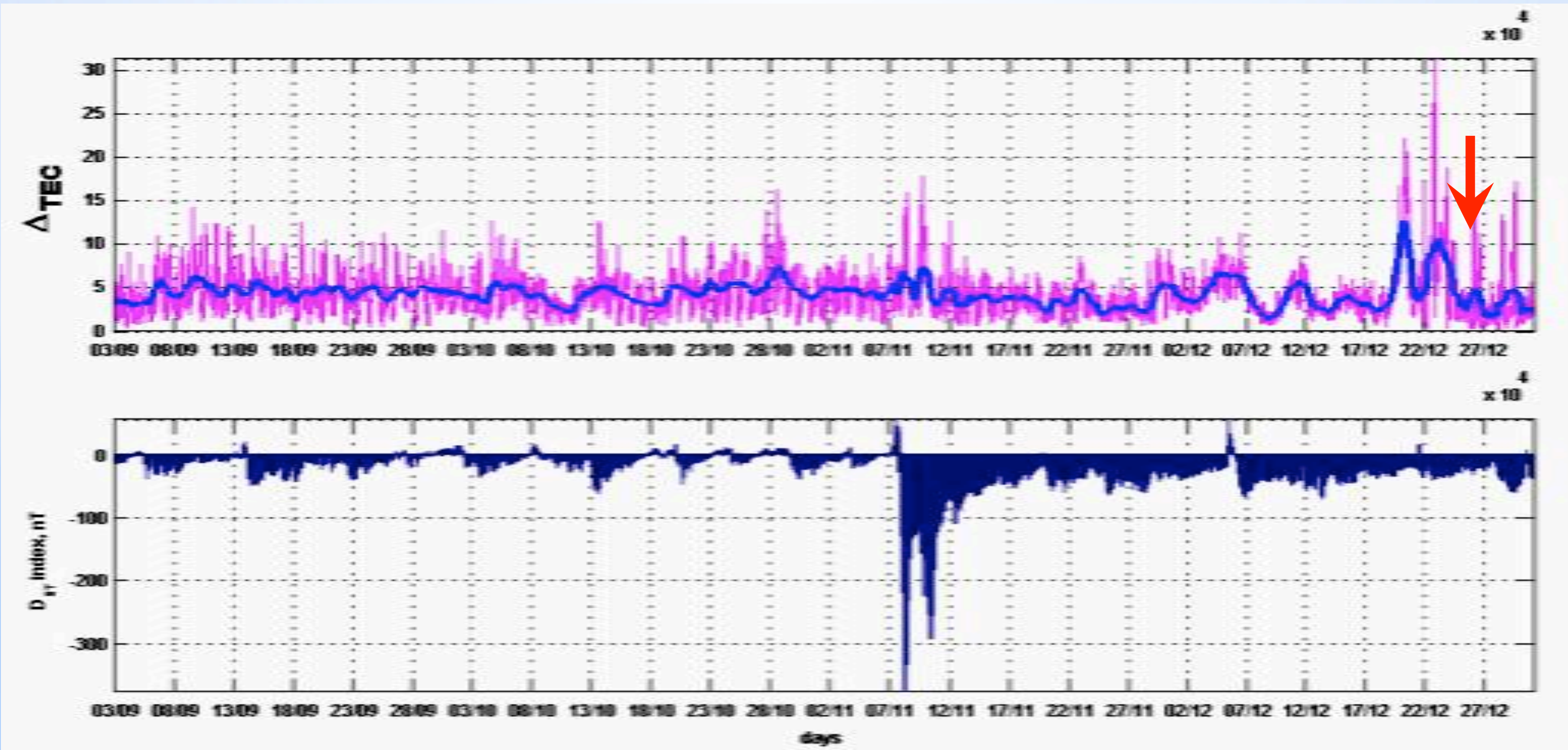
**Storm 1 no reaction**

**Storm 2 ionospheric disturbance BEFORE the storm starts**

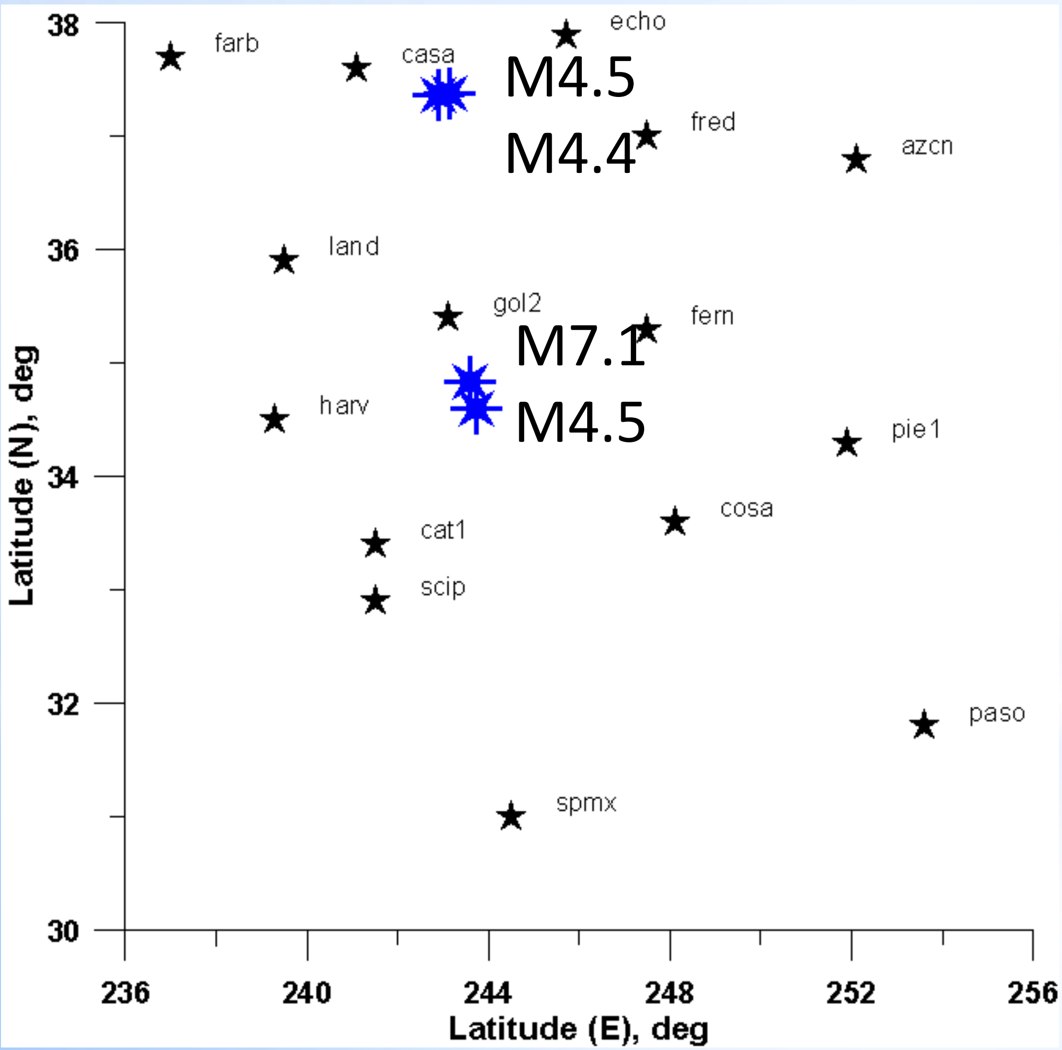
**Storm 3 – strongest storm for the whole period of 4 months – no reaction**

**So where authors see correspondence to geomagnetic actitvity?**

The regional variability index was created especially to diminish effects of geomagnetic activity onto ionosphere and to underline the variability connected with the earthquake preparation. It is based on the fact that geomagnetic activity has global character while the seismo-ionospheric variability - the local character. It means that ionospheric variations stimulated by geomagnetic activity will be similar at all stations while seismo-ionospheric variability will be stronger at stations closest to the position of impending epicenter. That's why the spread in data for set of stations situated at different distances from epicenter will be larger than during geomagnetic disturbance. The most bright example – variability index before Mega-Sumatra earthquake on 26 Dec 2004. No reaction on geomagnetic storm – strongest in the year and increase before EQ.



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PDE | 1999 | 09 26 161538 | 37.38 | -117.10 | 9 | 4.5 | MLBRK | ... ....... | 318 |
| PDE | 1999 | 09 26 201122 | 37.37 | -117.09 | 9 | 4.4 | MLBRK | ... ....... | 316 |
| PDE | 1999 | 10 16 094644.13 | 34.59 | -116.27 | 0 | 7.1 | MwHRV | ...... | 0 |
| PDE | 1999 | 11 14 142009.41 | 34.84 | -116.40 | 6 | 4.5 | MLPAS | .F. ....... | 29 |




We analyzed the situation to find what could create increase of variability index within the extended time interval. Usually it considered the threshold of ionosphere sensitivity to the seismic events with M>5. But for such magnitude we see the clear area of disturbed variability. The small-scale variability (if we have station close to epicenter could be detected for lower levels. From the USGS catalog we selected double M4.4-4.5 event on 26 of September, main event on 16 October and M4.5 event on 14 November, and result is presented in the next slide.

* One can clearly see that observed variability perfectly fits to our theory.