



**The Abdus Salam
International Centre for Theoretical Physics**



2265-24

**Advanced School on Understanding and Prediction of Earthquakes and
other Extreme Events in Complex Systems**

26 September - 8 October, 2011

Validation of Forecast/Prediction Methods

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Validation of Forecast/Prediction Methods



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The Abdus Salam ICTP
Miramare ♦ 03/10/2011

Advanced School on Understanding and Prediction of Earthquakes and
other Extreme Events ♦ Adriatico GH Kastler Lecture Hall ♦ 09:00-09:45

PLANETS ALIGN:

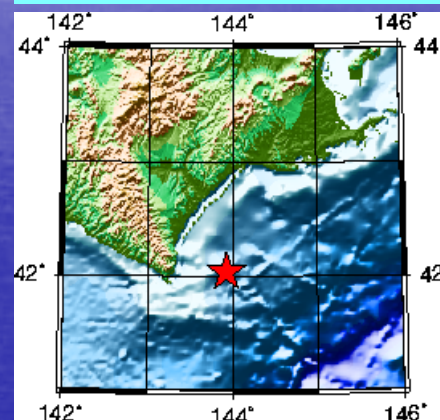
On Wednesday morning, September 24th, 2003 a lovely trio appeared in the eastern sky: **Jupiter, the crescent moon and Mercury...**



Is it a coincidence or a law?

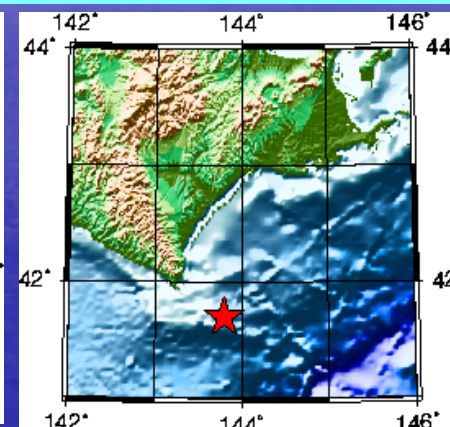
Two days later ...

防災科研Hi-net暫定処理による震源位置



本震

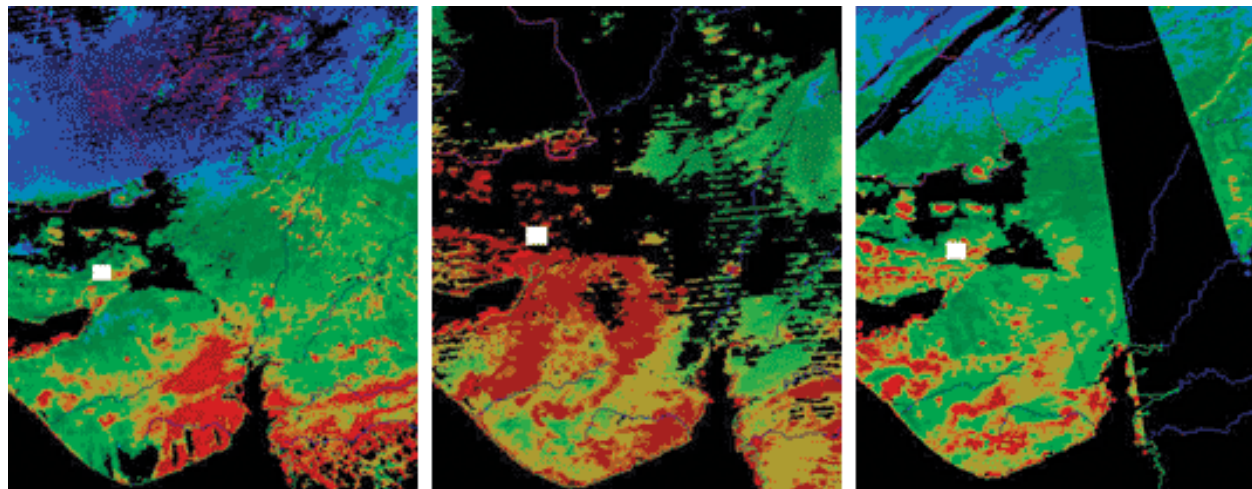
2003年9月26日04時
50分11秒
北緯42.0度
東経143.9度
深さ25km
M7.7



最大余震

2003年9月26日06時
08分03秒
北緯41.8度
東経143.9度
深さ35km
M7.4

Isn't it a coincidence ?



WARM BEFORE THE STORM: An earthquake killed more than 20 000 people on 26 January 2001 in the Indian state of Gujarat. NASA's Terra satellite made infrared maps of the region on 6, 21, and 28 January [left to right]. Five days before the earthquake [middle], the area near the epicenter [white square] gave off an unusual amount of infrared radiation [red]. Just two days after the quake [right], the radiation was gone.

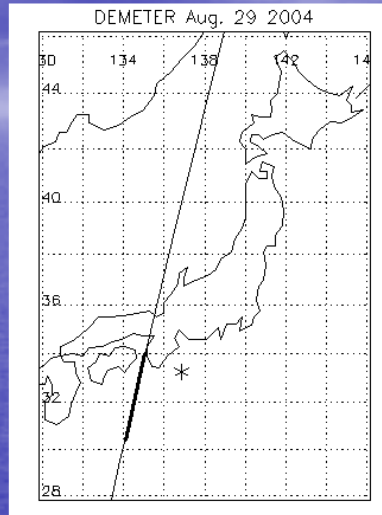
IMAGES: NASA

Isn't it a coincidence ?

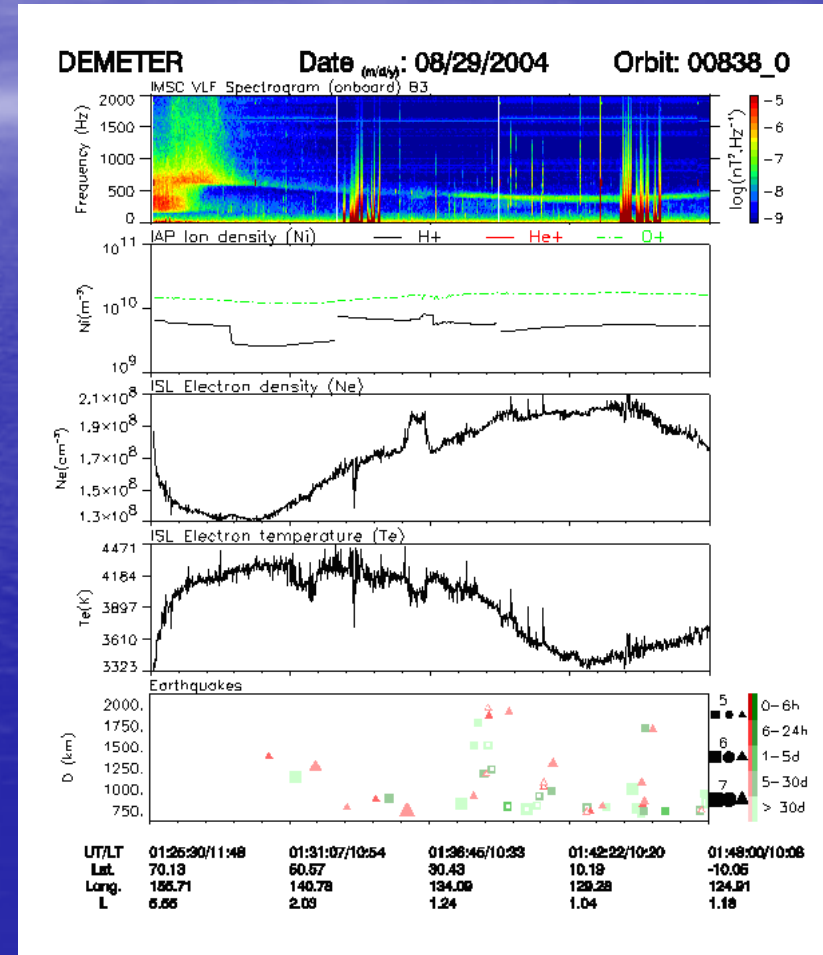
“Orbit of DEMETER above Japan on August 29, 2004.

The star indicates the epicenter of an earthquake of magnitude 7.1 which will occur on September 5, 2004 in the region of Kii-Peninsula (Lat=33.05N, Long=136.78E).

The thick line on the orbit corresponds to the period where an ionospheric perturbation is observed with DEMETER (next Figure).”



“From the top to the bottom the panels successively show a spectrogram of a magnetic component between 0 and 2 kHz, the ion density given by IAP, the electron density and temperature, and the earthquakes seen by DEMETER along the orbit. In this last panel, the Y-coordinate gives the distance between DEMETER and the earthquake hypocenter. The red color of the symbol which size is proportional to the magnitude shows that DEMETER is flying over the region before the earthquake. A large variation of the ionosphere parameters is observed when the satellite is above the seismic zone (in the top panel, the two bursts of interferences correspond to periods where wheels, which are used for the satellite attitude control, are desaturated).”

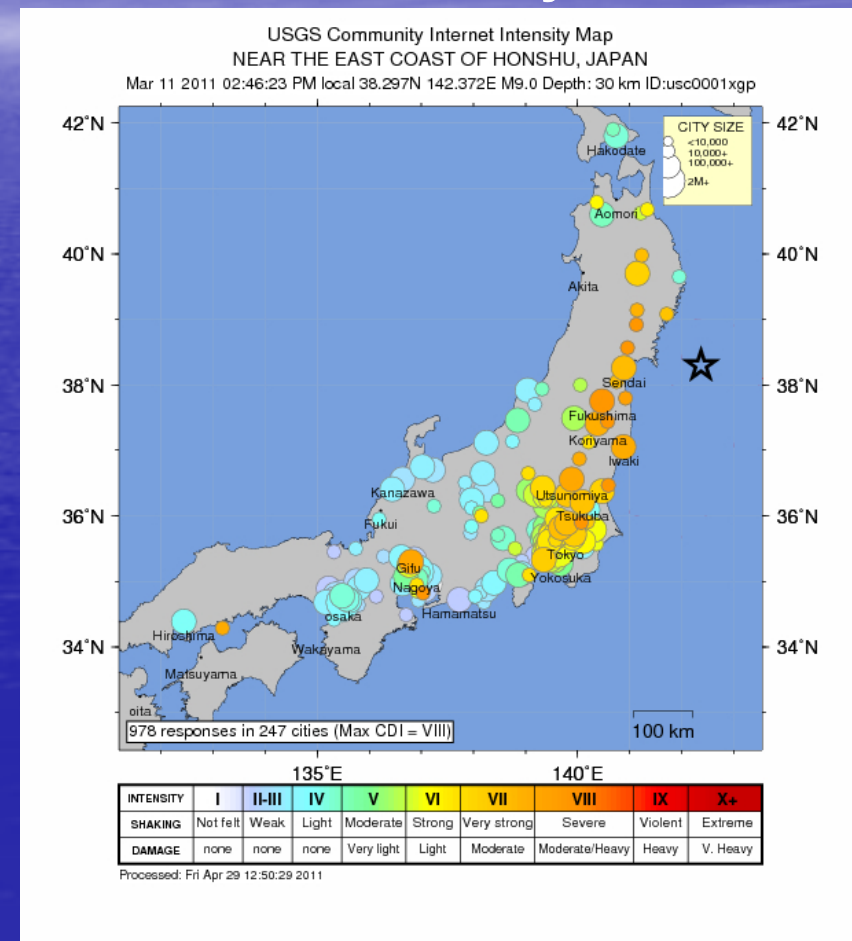
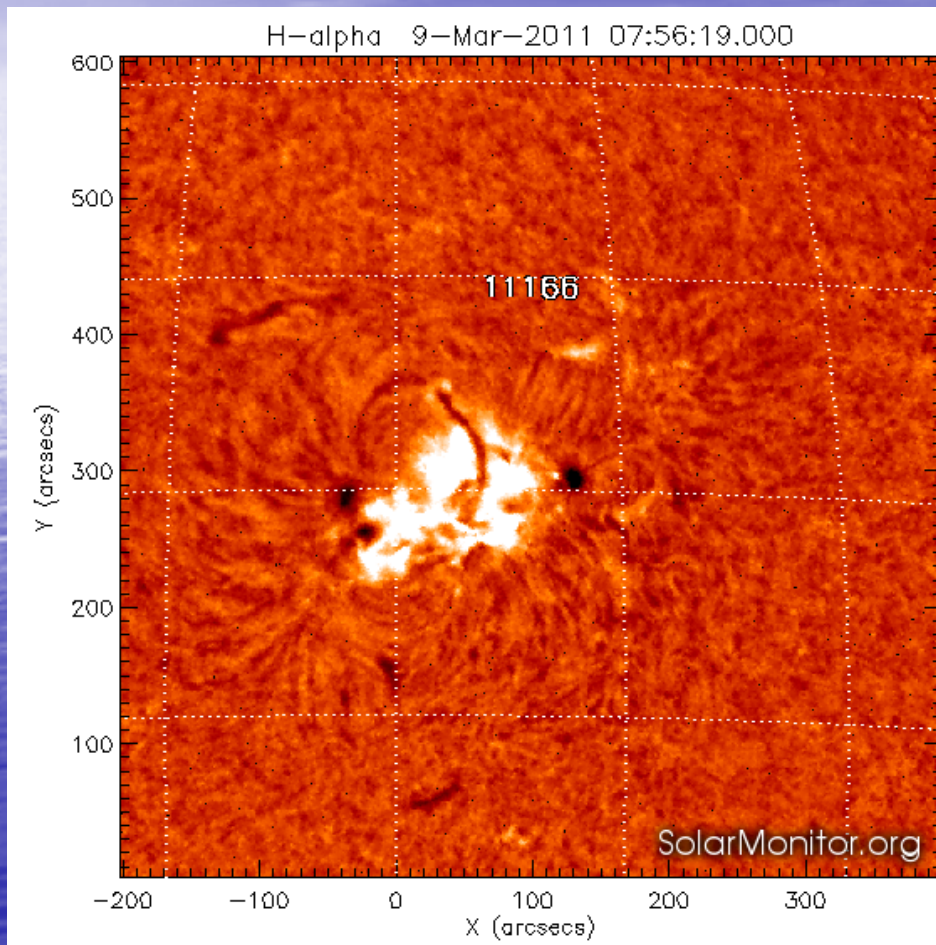


The explosive eruption of Asama volcano on September 01, which ash-fall covered a narrow elongated area reaching ca 250 km to Pacific Ocean seems a better alternative than the two earthquakes of M7.2 and M7.4 on September 05, 2004 in Japan, doesn't it ?

Solar Flare of the GOES Class X1.5
 gev_20110309_2313 started on
 2011/03/09 23:13:00 ended 23:23:00
 Peak intensity at 23:16:00 (N08W11)

Is it a coincidence or a law?

Less than two days later ...



Seismology is juvenile and its appropriate statistical tools to-date may have a "medieval flavor" for those who hurry up to apply a fuzzy language of a highly developed probability theory. To become "quantitatively probabilistic" earthquake forecasts/predictions must be defined with a scientific accuracy. Following the most popular objectivists' viewpoint on probability, we cannot claim "probabilities" adequate without a long series of "yes/no" forecast/prediction outcomes. Without "antiquated binary language" of "yes/no" certainty we cannot judge an outcome ("success/failure"), and, therefore, quantify objectively a forecast/prediction method performance.

Seismic Roulette null-hypothesis

Consider a roulette wheel with as many sectors as the number of events in a sample catalog, a sector per each event.

- Make your bet according to prediction: determine, which events are inside area of alarm, and put one chip in each of the corresponding sectors.
- Nature turns the wheel.
- If seismic roulette is not perfect...

then **systematically** you can win! 😊

or lose ... 😞

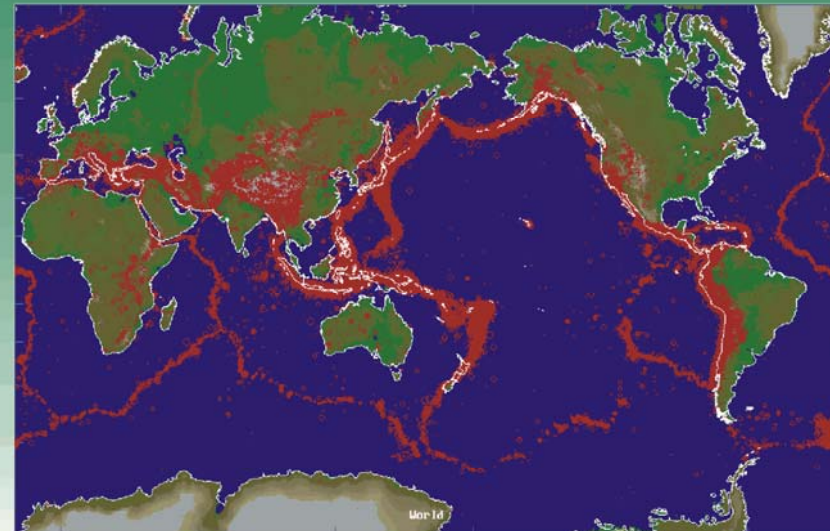
*If you are smart enough to know “antipodal strategy” (Molchan, 1994; 2003),
make the predictions efficient -----*

and your wins will outscore the losses! 😊 😊 😞 😊 😊 😊 😞 😊 😊 😊

Seismic Roulette



00	3	6	9	12	15	18	21	24	27	30	33	36	2 to 1
0	2	5	8	11	14	17	20	23	26	29	32	35	2 to 1
1	4	7	10	13	16	19	22	25	28	31	34	36	2 to 1
1st 12				2nd 12				3rd 12					
1-18		EVEN		RED		BLACK		ODD		19-36			



Regions of Increased Probability of Magnitude 8.0+ Earthquakes
as on July 1, 2000 (subject to update on January 1, 2001)

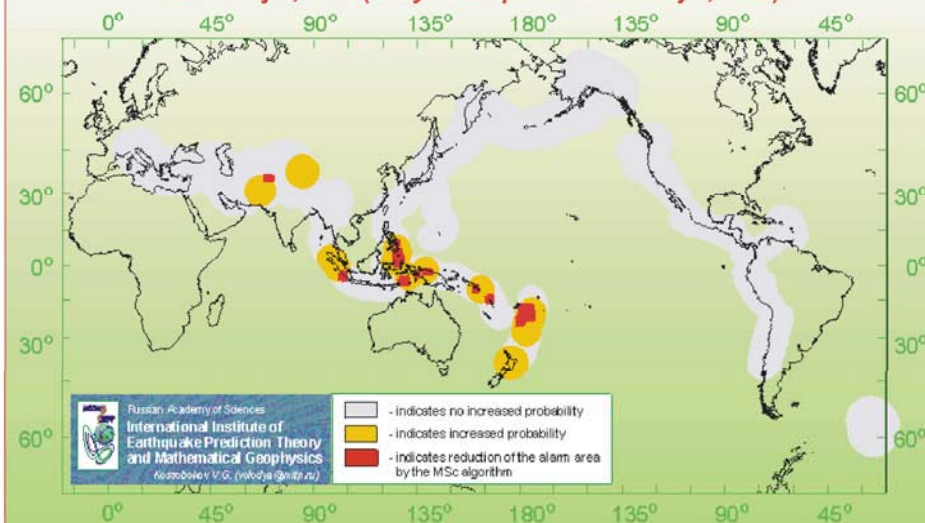
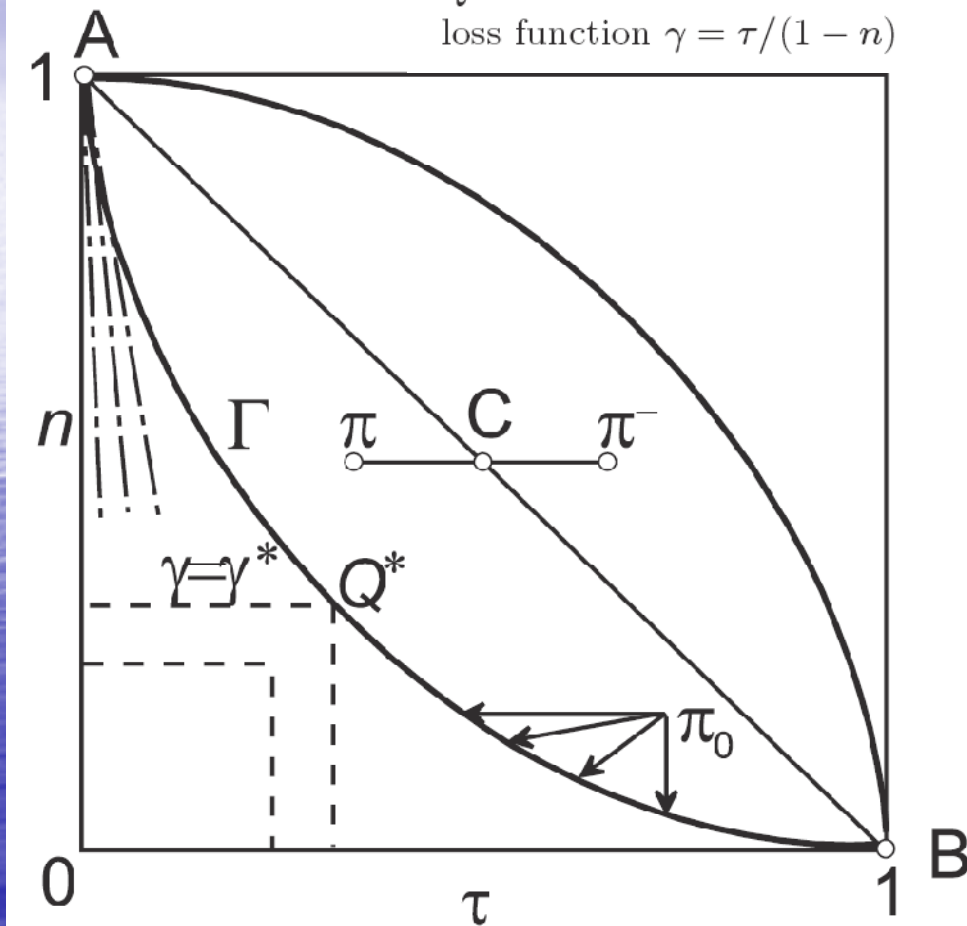


Fig. 5.1. Error set $\mathcal{E}(J)$ for prediction strategies based on a fixed type of information J . Point A corresponds to an optimistic strategy, point B to a pessimistic strategy, and the interval AB corresponds to strategies of random guess. C is the center of symmetry of $\mathcal{E}(J)$. π and π^- are a strategy and its antipodal strategy. Γ is the error diagram of optimal strategies. Arrows indicate a better forecast relative to the strategy π_0 . Dashed lines are contours of the loss function $\gamma = \max(n, \tau)$. Q^* are errors of the minimax strategy, $n = \tau$. Dash-dotted lines are contours of the loss function $\gamma = \tau/(1 - n)$.



Error diagram

Molchan, G.M. Earthquake Prediction as Decision-making Problem. *Pure Appl. Geoph.* **149**, 233-247, 1997.

Molchan, G.M. 5. Earthquake Prediction Strategies: a theoretical analysis. In: Keilis-Borok, V.I., and A.A. Soloviev, (Editors). *Nonlinear Dynamics of the Lithosphere and Earthquake Prediction*. Springer, Heidelberg, 208-237, 2003.



WHAT DO YOU WANT TO BE WHEN YOU GROW UP DANA?

A PRE-CONCEPTUAL SCIENTIST

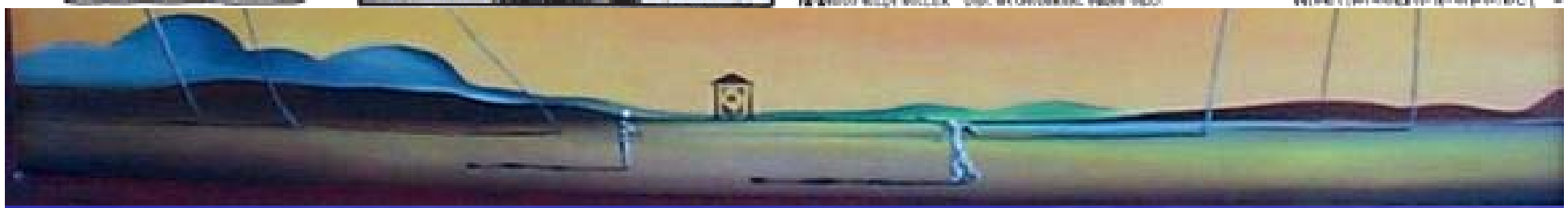
UH...WHAT'S THAT?

IT'S THE NEW SCIENCE OF REACHING A CONCLUSION BEFORE DOING RESEARCH, THEN SIMPLY DISMISSING ANYTHING CONTRARY TO YOUR PRECONCEIVED NOTIONS

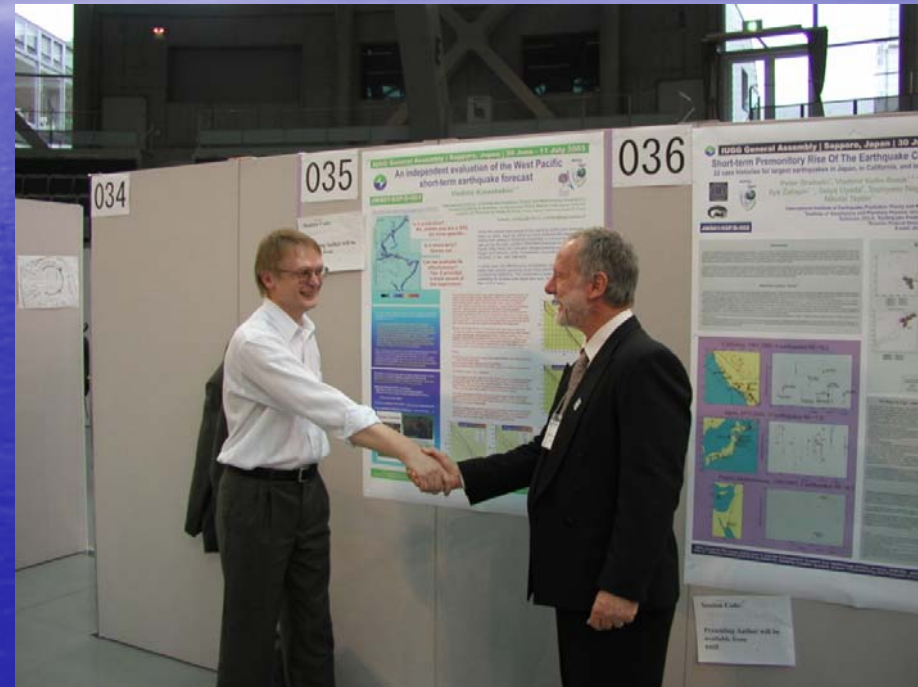
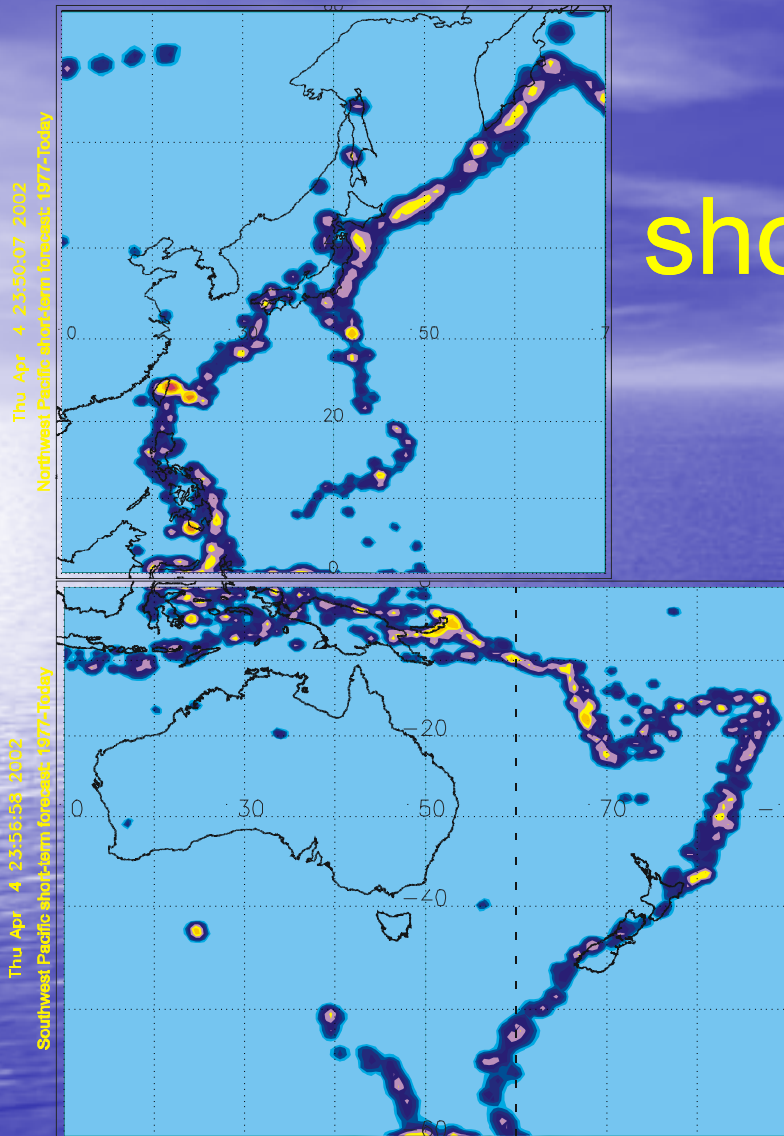
THAT'S GOT TO BE THE DUMBEST THING I HEARD

DISMISSED...

WILLY WILLY MILLER DIST. BY UNIVERSAL PICTURES INC. WILLYWILLYMILLER.COM



West Pacific short-term forecast



Jackson and Kagan "Testable earthquake forecasts for 1999", Seism. Res. Lett., 70, 393-403, 1999

Kagan and Jackson (2000) "Probabilistic forecasting of earthquakes", Geophys. J. Int., 143, 438-453

We have analyzed the predictions arising from setting a threshold probability or a threshold probability ratio on top the daily updated Short-term forecasts for NW and SW Pacific in April 2002 - September 2004

(http://scec.ess.ucla.edu/~ykagan/predictions_index.html; Kagan and Jackson, 2000. *Probabilistic forecasting of earthquakes*, *Geophys. J. Int.*, 143, 438-453) and the catalog of earthquakes for the same period and have come to the following conclusion:

The predictions based on the Yan Y. Kagan and David D. Jackson forecasts are hardly better than random guessing, when main shocks are considered, and could be used for effective prediction of aftershocks only.

The conclusion is based on the prediction outcome achieved for 218 shallow (with depth less than 70 km) earthquakes of $M_wHRV = 5.8$ or more. According to the definition from (Keilis-Borok et al., 1980), there are 67 aftershocks and 151 main shocks.

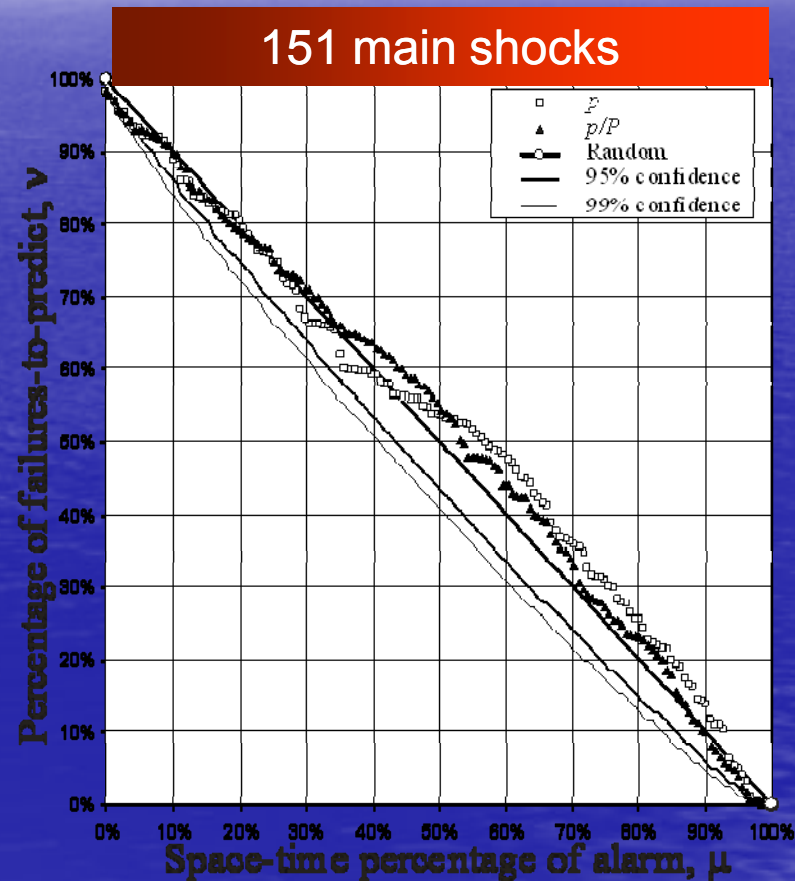
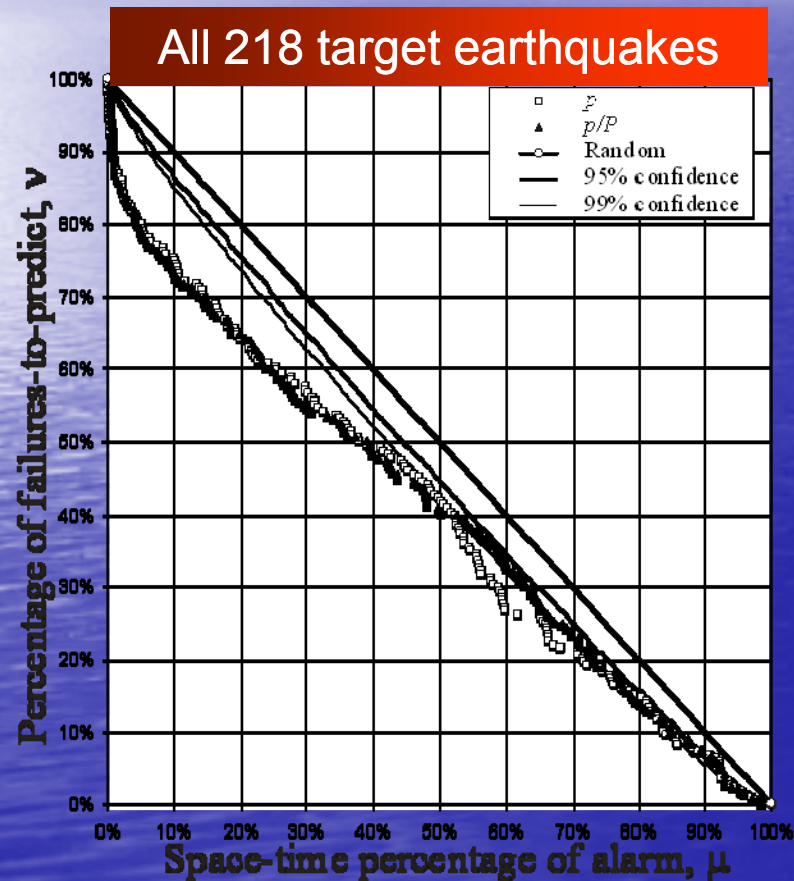
The territory of West Pacific short-term forecast is coarse-grained into cells, 0.5 by 0.5 degree each. Making a “bet” on a cell C , we pay $n(C)$, which is the number of earthquakes from the sample catalog. Each target earthquake E defines the threshold value - $p(E)$ (or $p/P(E)$) - being the value of short-term probability p (or the value of probability ratio p/P) determined in advance for the day of the earthquake. In its turn the threshold defines the minimal cost of a bet required for successful prediction of the target earthquake, $N(E)$, which is the sum of all bets $n(C)$ over the union of cells with p equal or above $p(E)$ (same for the ratio p/P). The track record of the experiment provides the set of bets $\{N(E)\}$ associated with target earthquakes that happened.

Denote μ being the bet sum normalized to the total sum of $n(C)$ and ν being the number of failures-to-predict normalized to the total number of target earthquakes that happened in the course of testing. The ν vs. μ diagram characterize the effectiveness of the prediction method, e.g., random prediction performance is associated with the diagonal that connects “optimist’s” $\{1,0\}$ and “pessimist’s” $\{0,1\}$ strategies (Molchan, G. M., *Earthquake Prediction as a Decision-making Problem, Pure Appl. Geophys.*, 149, 233-247, 1997).

Given -

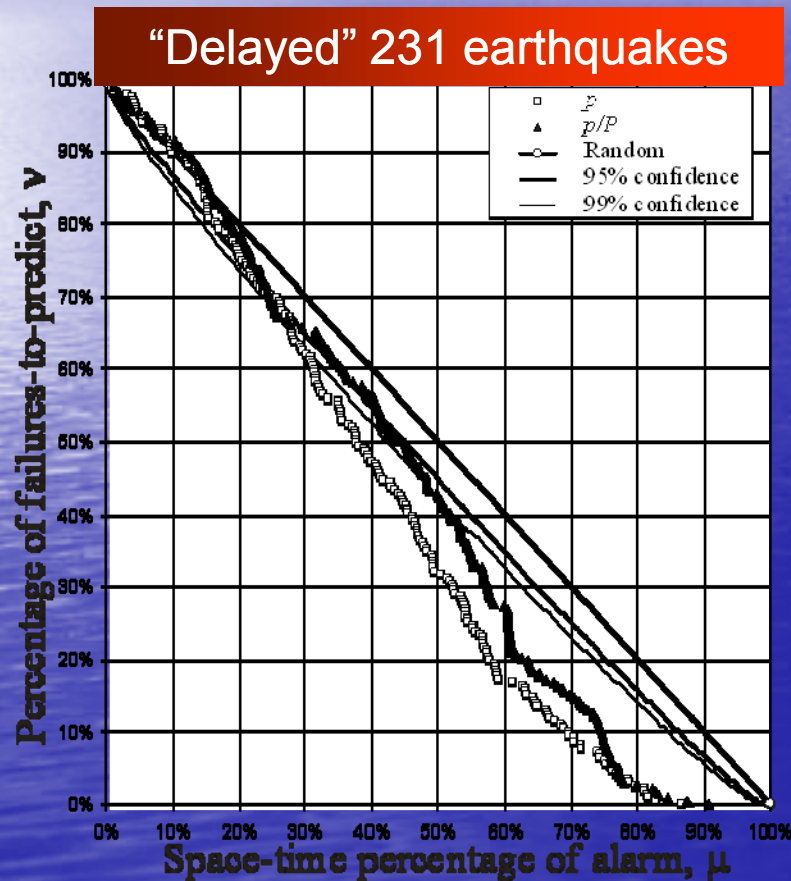
- (1) the track record of the West Pacific short-term forecasts in the period from April 10, 2002 to September 13, 2004;
 - (2) the Harvard CMT catalog for the same period of time;
 - (3) the counts of $n(C)$ based on the NEIC catalog of shallow earthquakes -
- we plotted several ν vs. μ diagrams.

The two figures show the performance of predictions based on p or p/P in the test period from April 10, 2002 to September 13, 2004. The total of 218 earthquakes of magnitude $M_w = 5.8$ or more with the depth of 70 km or shallower occurred in the West Pacific. According to definition from (Keilis-Borok et al., 1980), 67 of them are aftershocks and 151 main shocks.



The outcome of an “absurd” prediction:

The percentage of the failures-to-predict ν versus the percentage of the alerted space-time volume μ : $\{\mu_p(E), \nu_p(E)\}$ and $\{\mu_{p/P}(E), \nu_{p/P}(E)\}$ generated by “prediction” of the 231 earthquakes with magnitude $M_w \geq 5.8$ and depth ≥ 70 km in April 10, 1992-September 13, 1994 using the p and p/P maps computed for April 10, 2002-September 13, 2004.

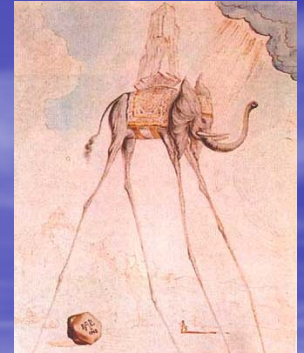


The observed deviation from the diagonal is about the same or larger than in the real-time applications.

Thus, we cannot reject random nature of the Jackson-Kagan “probabilistic” method and may conclude that

- (i) its effectiveness for predicting large earthquakes is doubtful, and
- (ii) the applicability of the underlying ETAS model is an ingrained bigotry.

Regional Earthquake Likelihood Models: A realm on shaky grounds?



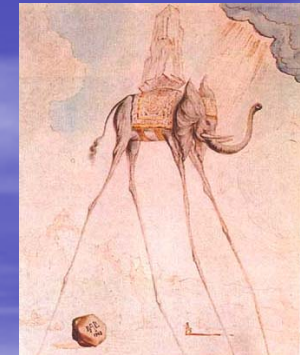
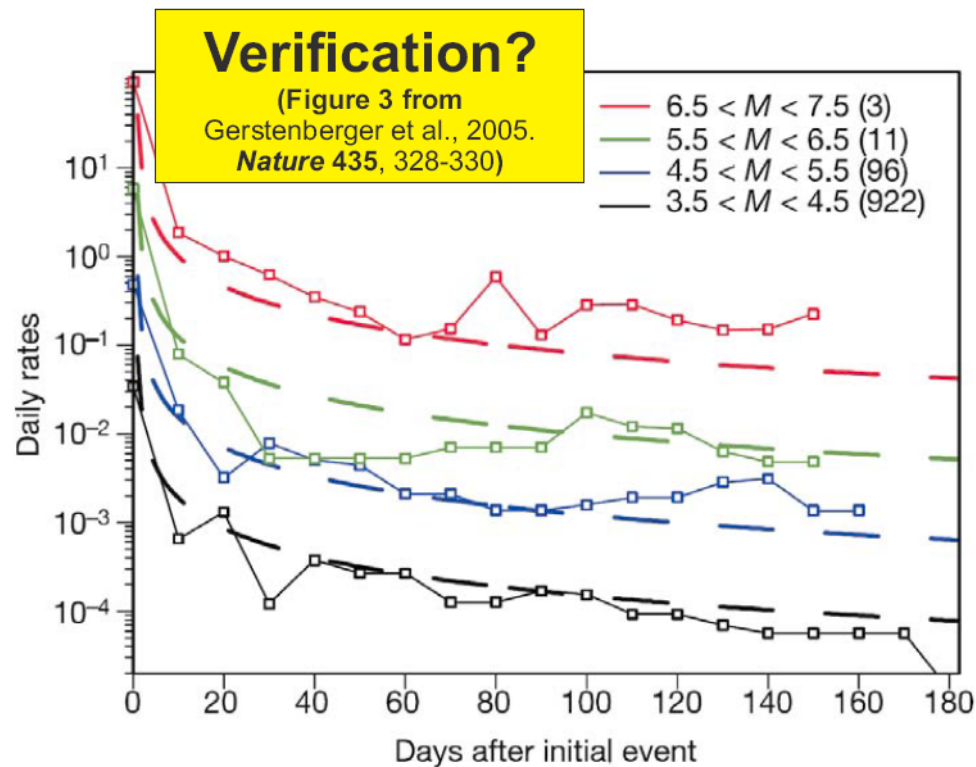
Likelihood scoring is one of the delicate tools of Statistics, which could be worthless or even misleading when inappropriate probability models are used. This is a basic loophole for a misuse of likelihood as well as other statistical methods on practice. The flaw could be avoided by an accurate verification of generic probability models on the empirical data. It is not an easy task in the frames of the Regional Earthquake Likelihood Models (RELM) methodology, which neither defines the forecast precision nor allows a means to judge the ultimate success or failure in specific cases. Hopefully, the RELM group realizes the problem and its members do their best to close the hole with an adequate, data supported choice.



On 19 May 2005, the United States Geological Survey began a public web site with forecasts of expected ground shaking for 'tomorrow' and *Nature* published the underlying work by *Gerstenberger et al.*

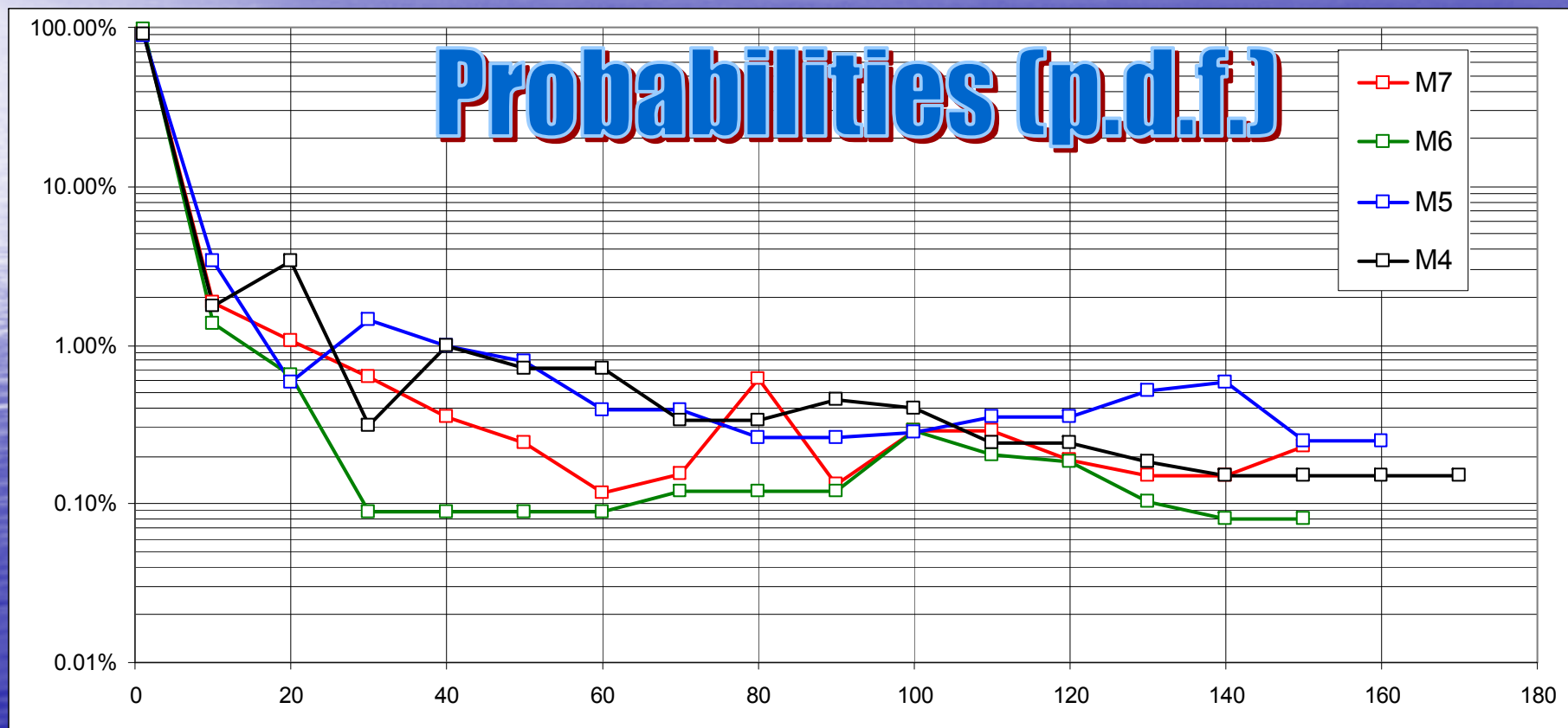
Gerstenberger, M. C., Wiemer, S., Jones, L. M. & Reasenberg, P. A. Real-time forecasts of tomorrow's earthquakes in California. *Nature* **435**, 328-331 (19 May 2005)

Figure 3 | Calculated and observed rates of events $M \geq 4$ in 24-hour intervals following mainshocks occurring between 1988 and 2002 in southern California. Dashed lines show the rates forecasted by the generic California clustering model (without cascades) for the mainshock magnitude (M) shown. For this test a simple circular aftershock zone implementation (solid lines) gives the observed rates of $M \geq 4.0$ aftershocks following all mainshocks with magnitude within 0.5 units of M . The aftershock zones are defined as the areas within one rupture length of the mainshock epicentre.

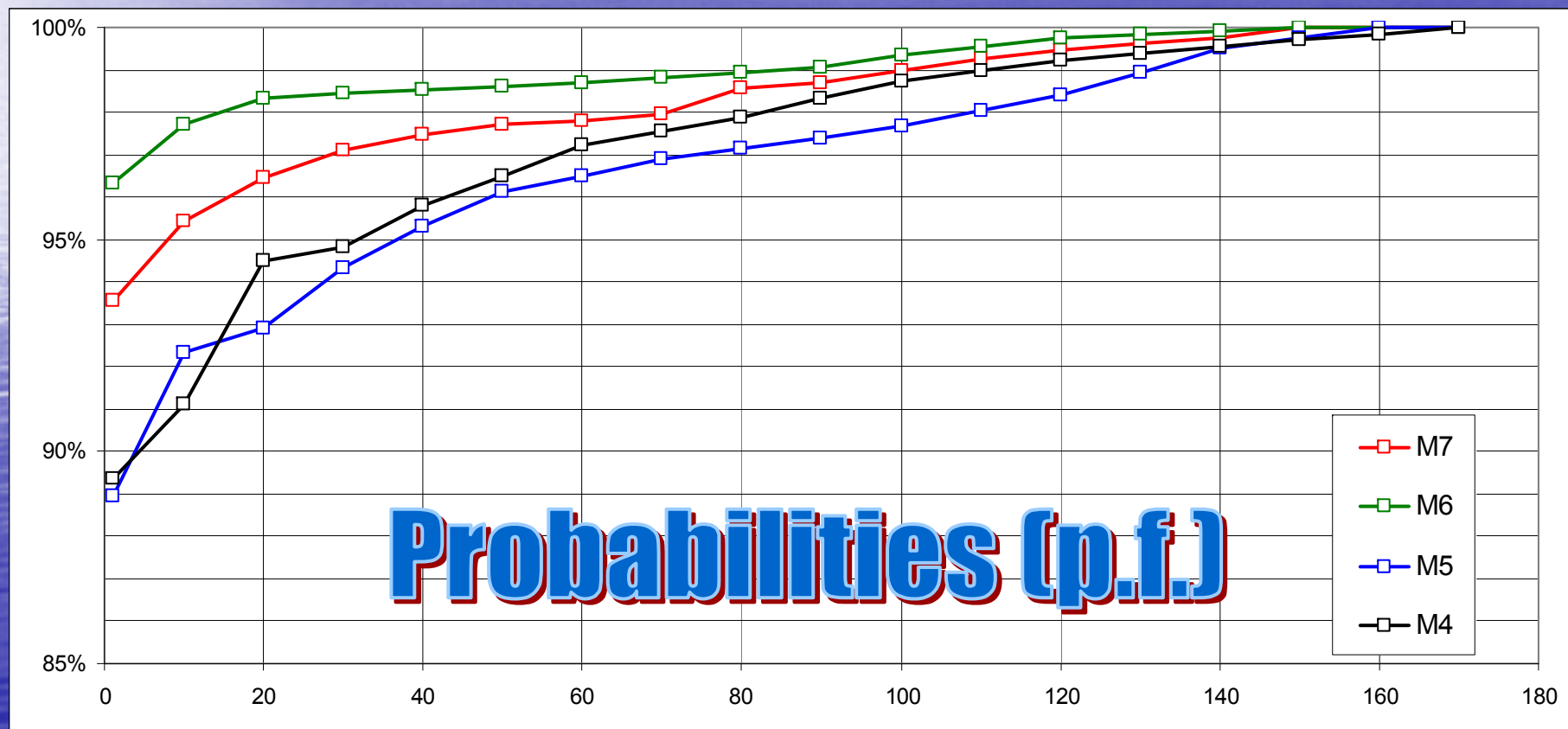


“As a first test, we verified that the generic clustering model describes the average clustering activity of California reasonably well. Using data from 1988–2002, after the period used to initially develop the model and thus independent data, we compute the average daily rate of events following an earthquake of a given size (Fig. 3).”

Probability density distribution functions of the random variable "Time after initial event" in different magnitude ranges of the initial event.



Probability distribution functions of the random variable "Time after initial event" in different magnitude ranges of the initial event.



Probabilities (p.f.)

Proof: Normalised by condition that the total integral of the p.d.f. (probability density function) increments equals 1, each of the four plots provides the minimum of positive p.d.f. increments, which are by definition either $1/N$ or its integer multiple (e.g., $2/N$, $3/N$, etc.). These are about 0.0012, 0.0008, 0.0025, and 0.0015, which values imply the sample sizes about 846, 1250, 401, and 665 or integer multiples of these values.

The probability of a smaller value of the Kolmogoroff-Smirnoff statistic D than that for the two samples used to plot the daily rates after $5.5 < M < 6.5$ (green plot in Figure 3) event and after $3.5 < M < 4.5$ (black plot) event (which D accounts to the value $D = \max | F_{\text{green}}(t) - F_{\text{red}}(t) | \cdot (N_1 N_2 / (N_1 + N_2))^{1/2} \geq 2.12$)

is larger than 97%.

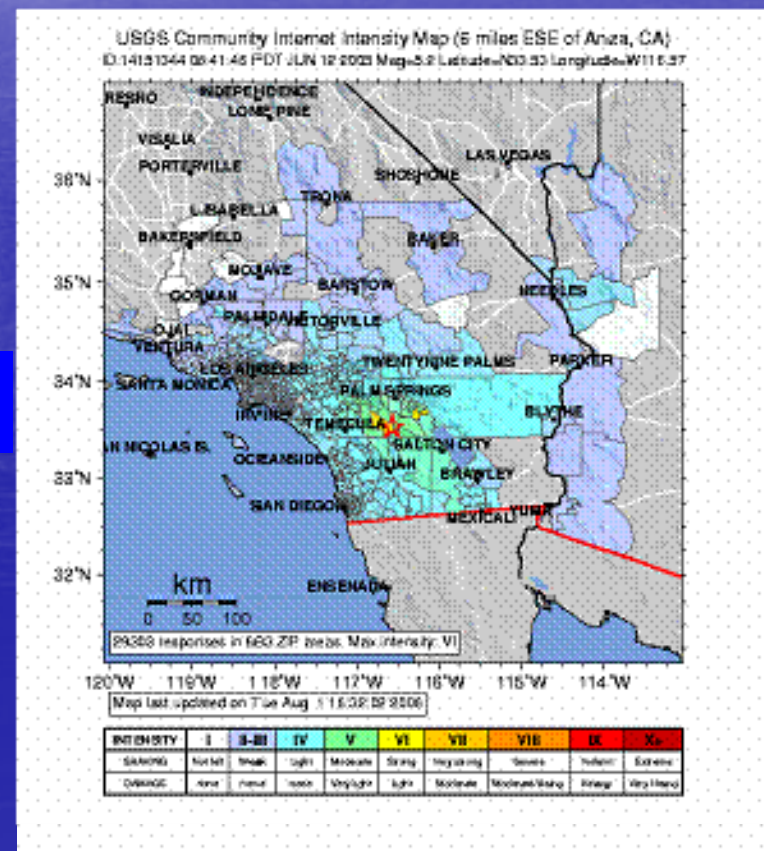
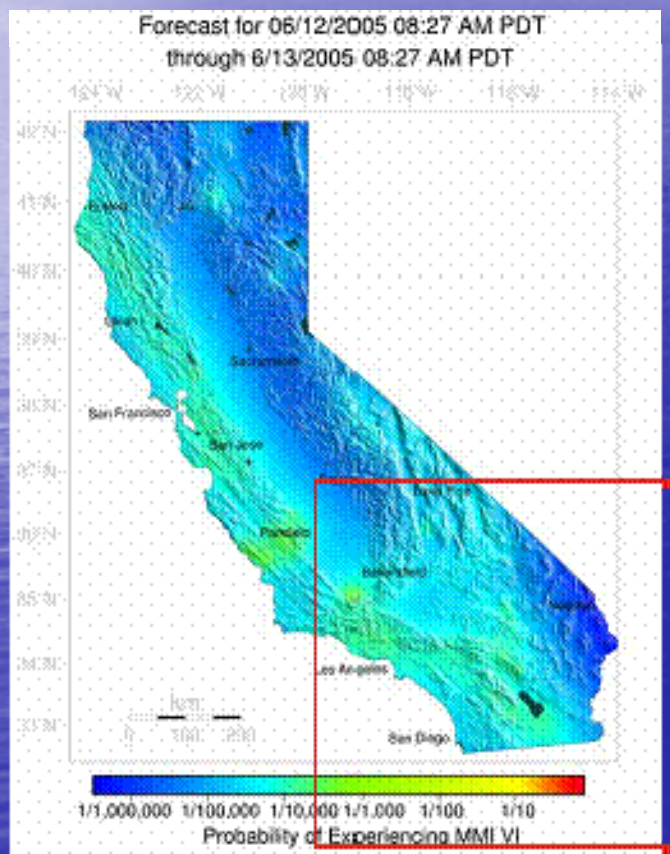
Therefore, the hypothesis that these two samples are drawn from the same distribution can be rejected at significance level of 0.03. ■

Thus, the statistics of the observed ground shaking in California, 2005-present, demonstrate that

- earthquakes of Modified Mercalli intensity VI in California keep occurring in the "sky blue" areas of the lowest risk ($p < 1/10000$),
- while the extent of the observed areas of intensity VI is by far less than the one expected from the calculations (currently a very crude low bound estimate of the ratio has surpassed a factor of 8.5...).

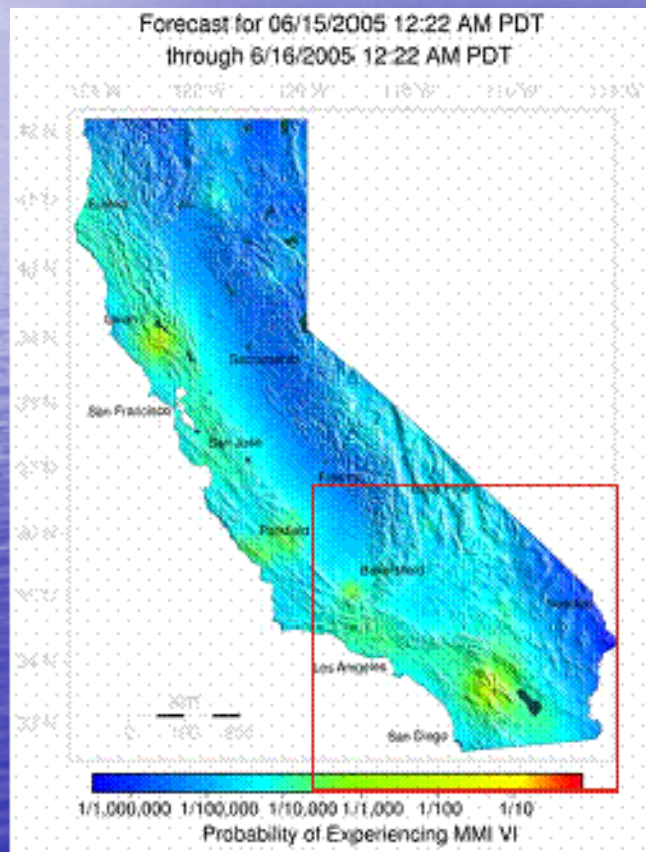
USGS Web Site Misleads Californians

Since the time of *Nature* published the work by Gerstenberger *et al* on May 19, 2005 -

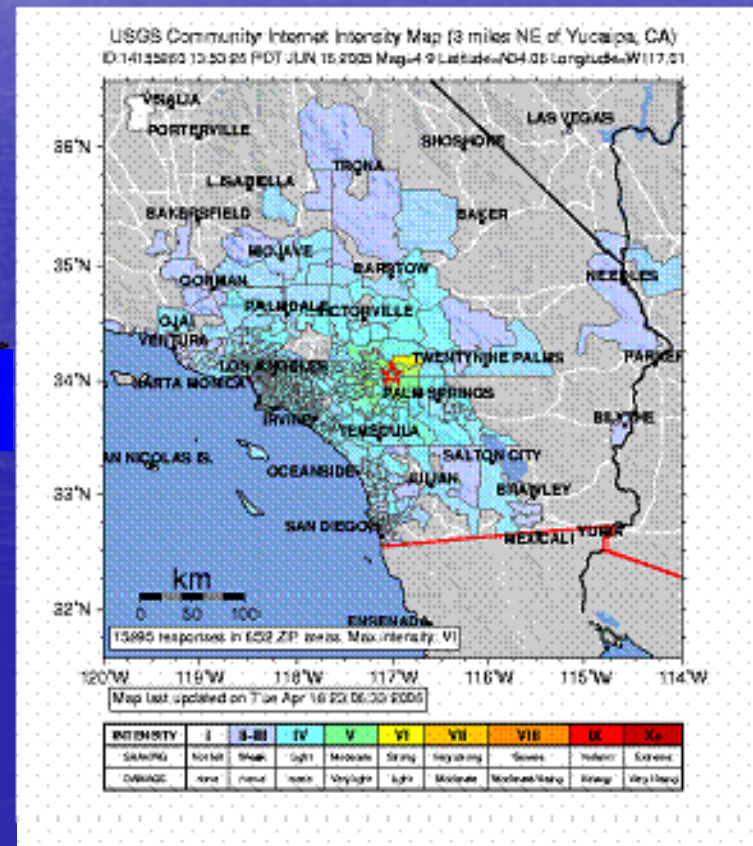


USGS Web Site Misleads Californians

Since the time of *Nature* published the work by Gerstenberger et al on May 19, 2005 -

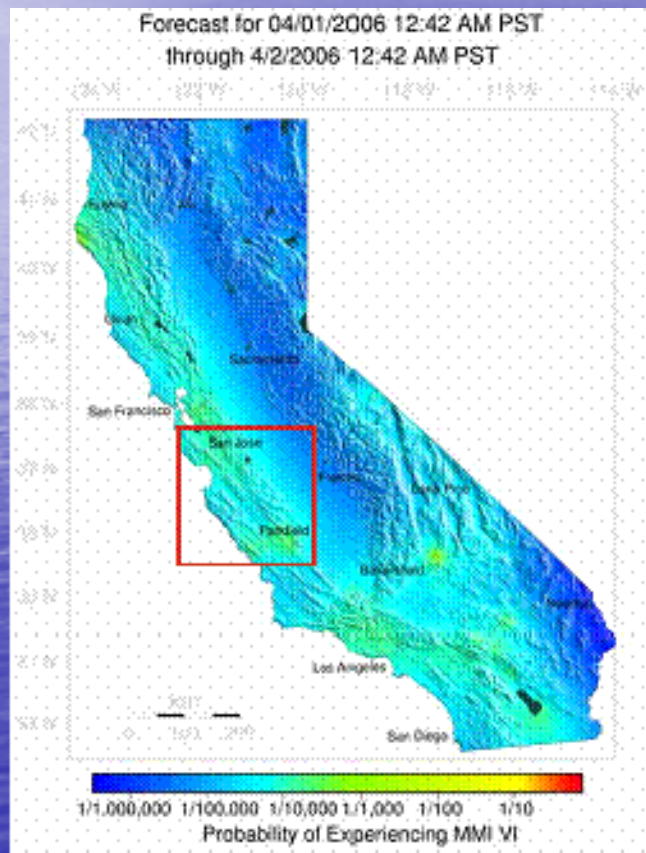


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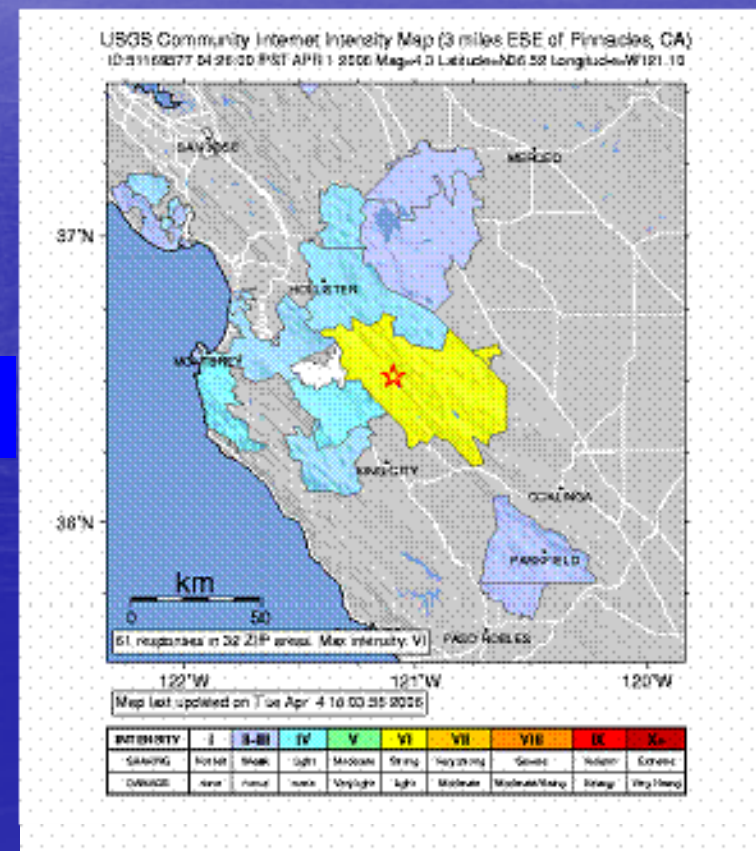


USGS Web Site Misleads Californians

Since the time of *Nature* published the work by Gerstenberger et al on May 19, 2005 -

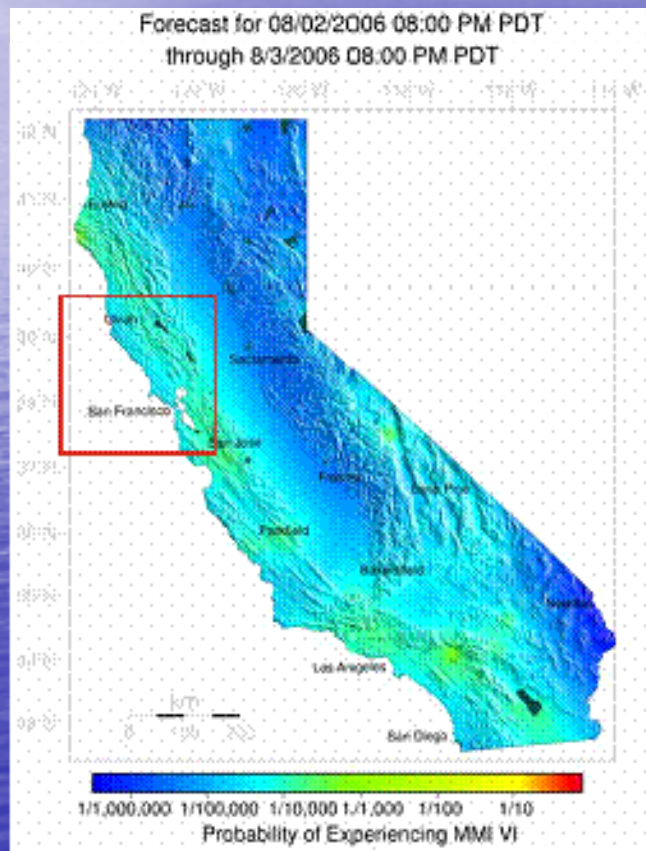


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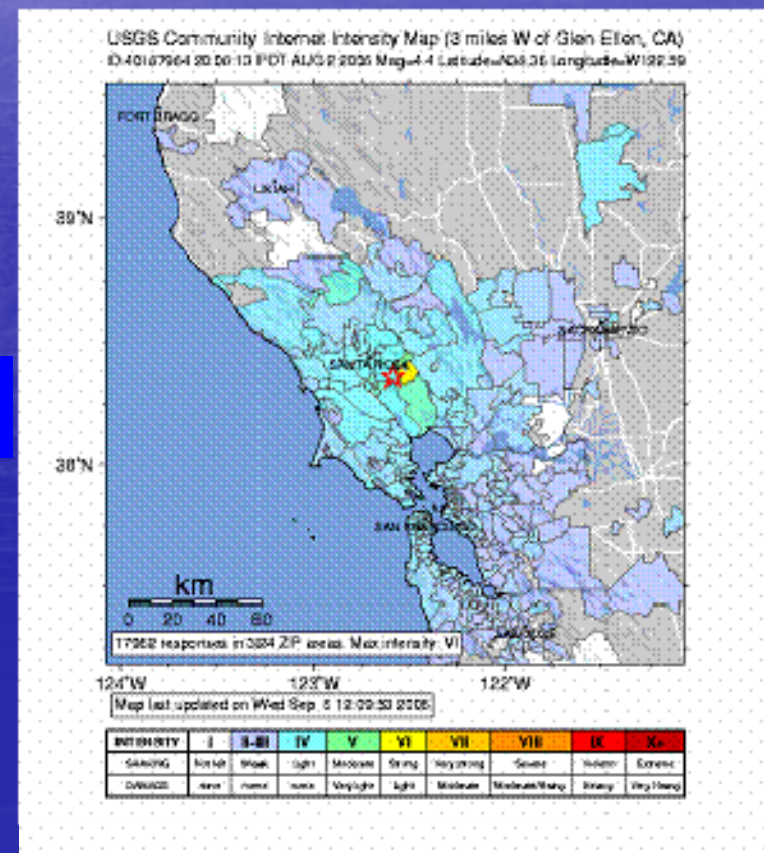


USGS Web Site Misleads Californians

Since the time of *Nature* published the work by Gerstenberger *et al* on May 19, 2005 -

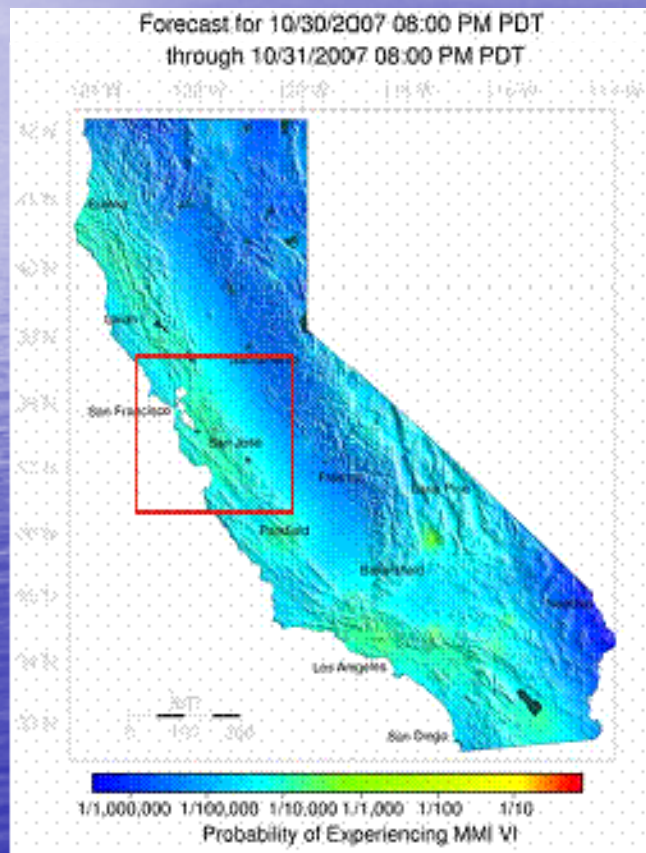


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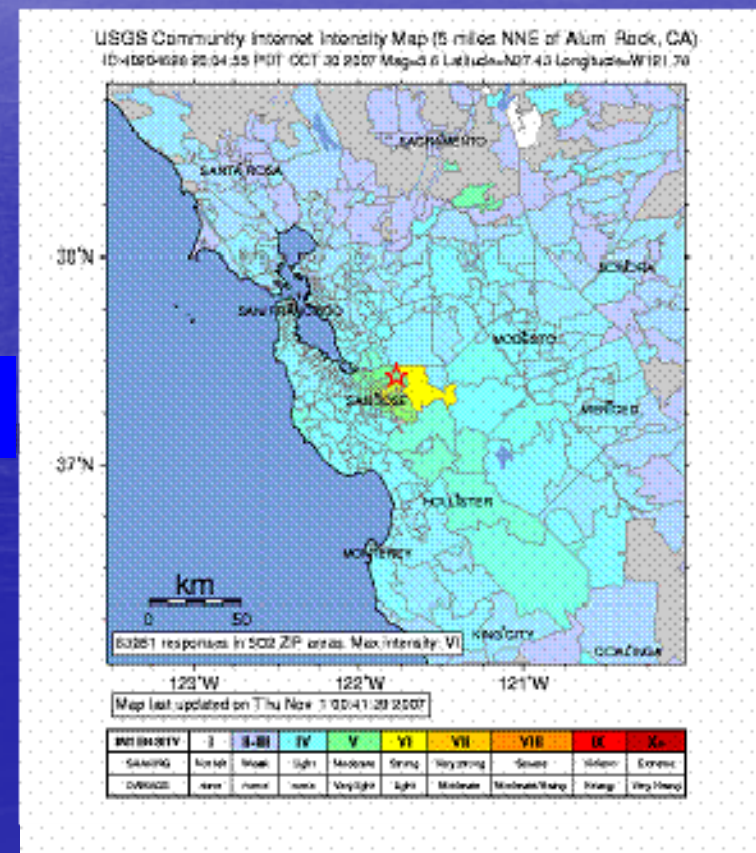


USGS Web Site Misleads Californians

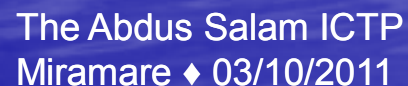
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5



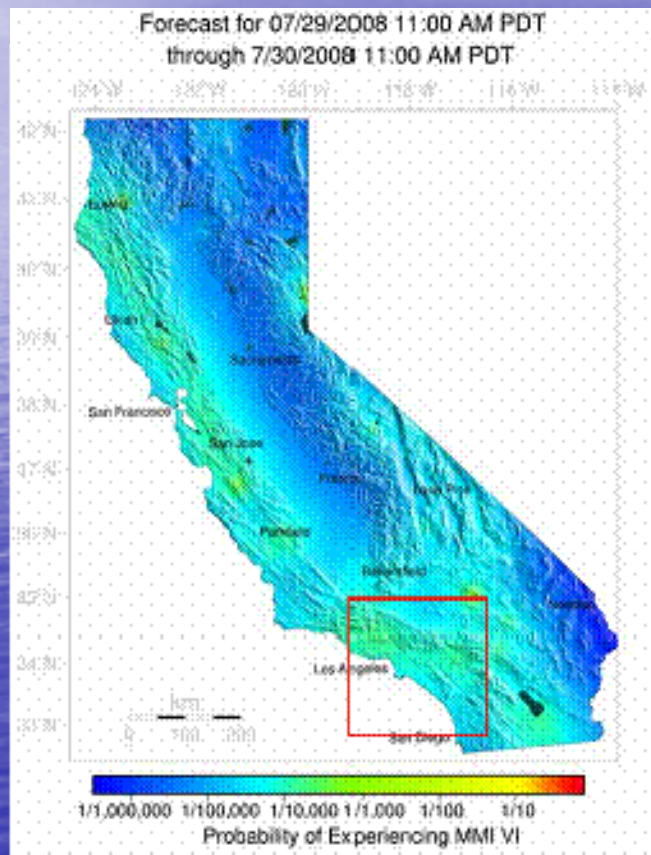
Since the time of *Nature* published the work by
Gerstenberger et al on May 19, 2005 -



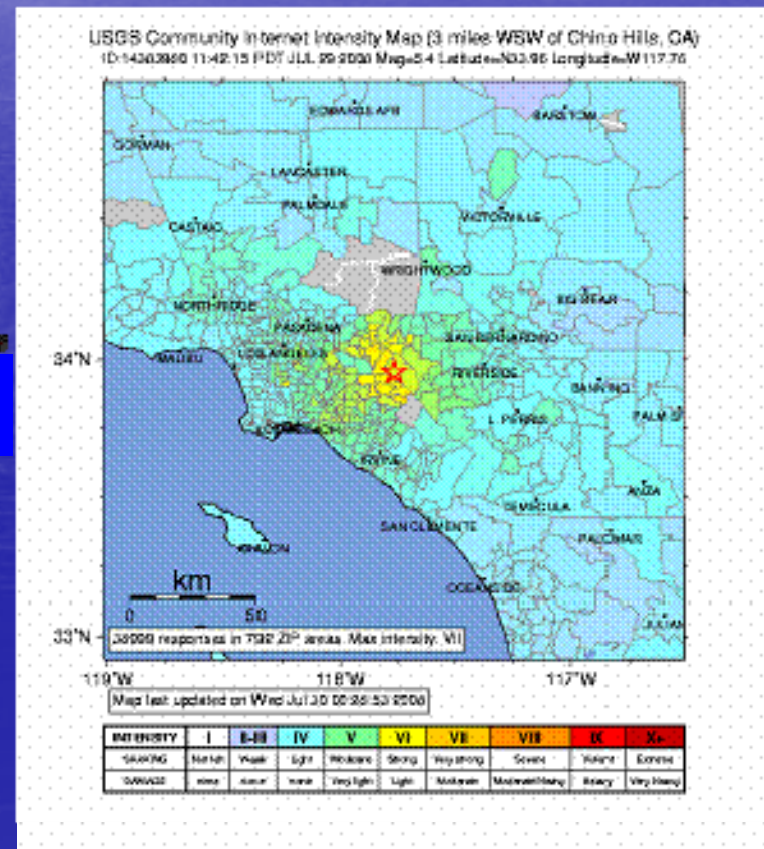
Advanced School on Understanding and Prediction of Earthquakes and other Extreme Events ♦ Adriatico GH Kastler Lecture Hall ♦ 09:00-09:45

USGS Web Site Misleads Californians

Since the time of *Nature* published the work by Gerstenberger *et al* on May 19, 2005 -



7



USGS Web Site Misleads Californians

Regretfully, USGS continues delivering to the public, emergency planners and the media, a forecast product, which is based on wrong assumptions, which violates the best-documented earthquake statistics in California, which accuracy was not investigated, and which forecasts were not tested by the authors in any rigorous way.

Moreover, the authors and their supporters continue to advocate and advertize this method by introducing “*the nominal probability gain*”.

“An example is the Short-Term Earthquake Probability (STEP) model, which the U.S. Geological Survey has applied to operational forecasting in California since 2005 [227]. STEP uses aftershock statistics to make hourly revisions of the probabilities of strong ground motions (Modified Mercalli Intensity \geq VI) on a 10-km, statewide grid. The nominal probability gain factors in regions close to the epicenters of small-magnitude ($M = 3-4$) events are on the order of 10-100 relative to the long-term base model (Figure 2.7).”

OPERATIONAL EARTHQUAKE FORECASTING - State of Knowledge and Guidelines for Utilization
Report by the International Commission on Earthquake Forecasting for Civil Protection
Submitted to the Department of Civil Protection, Rome, Italy - 30 May 2011
ANNALS OF GEOPHYSICS, 54, 4, 2011; doi: 10.4401/ag-5350

“Large uncertainties must also be attached to the time independent reference models. For these reasons, the illustrative values of G given here are labeled nominal probability gains to indicate that they are highly uncertain and largely unvalidated.”

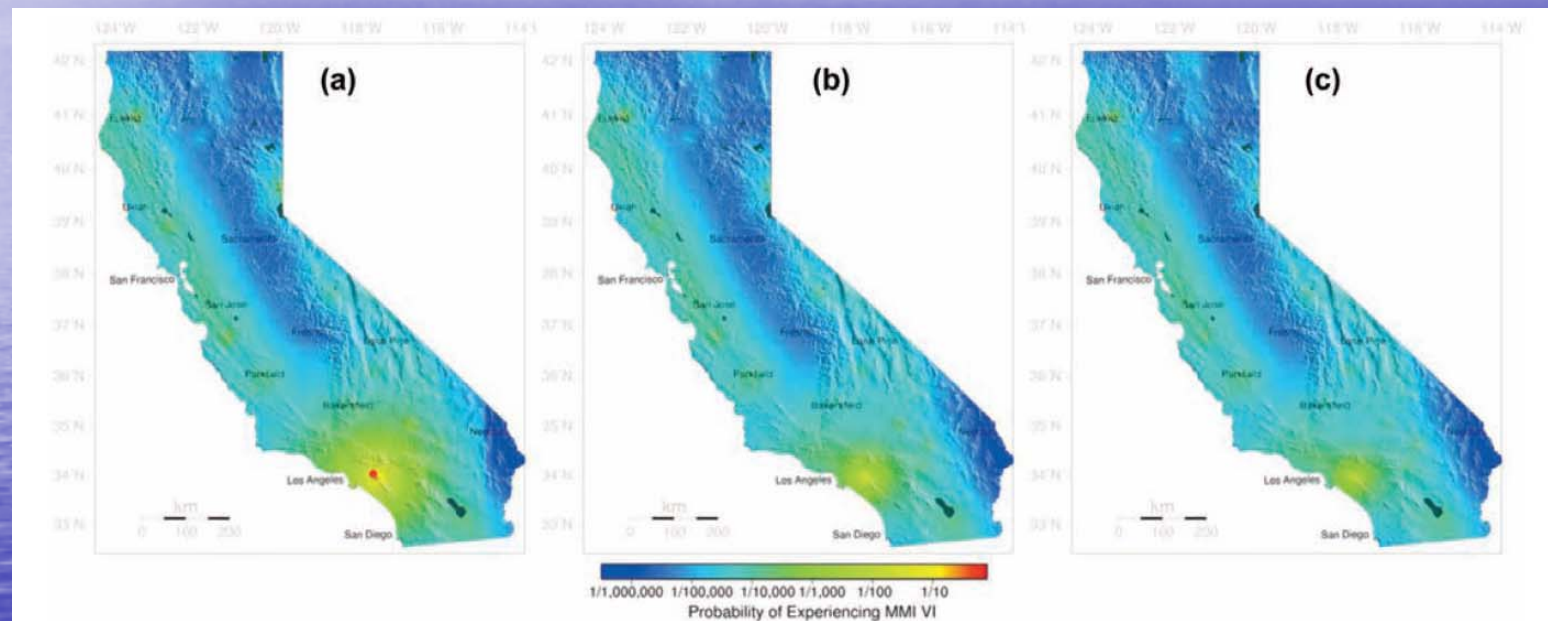
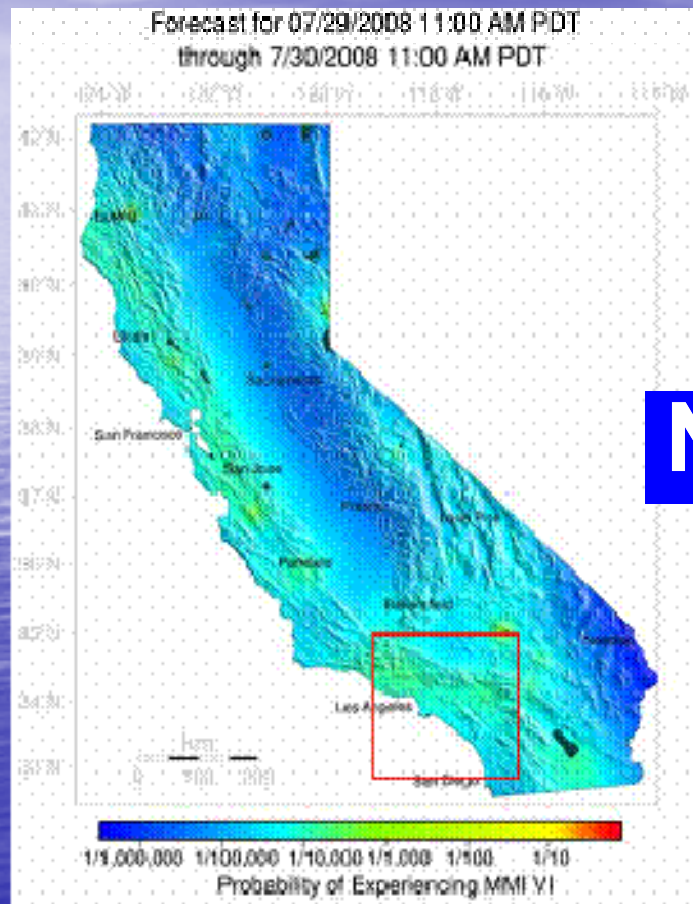


Figure 2.7. Short-term earthquake probability (STEP) maps published on-line by the U.S. Geological Survey following the M5.4 Chino Hills earthquake, which occurred in the Los Angeles region on 29 July 2008 at 11:42 local time. (a) STEP map released at 13:00 local time, 1 hr 18 min after the mainshock. Red dot is epicenter; yellow region indicates area where the probability of intensity VI shaking is more than 10 times the background model (blue colors). (b) STEP map released at 13:00 local time on 30 July 2008. (c) STEP map released at 13:00 local time on 1 August 2008, about three days after the earthquake. The decrease in the local shaking probability reflects the modified Omori scaling of aftershock decay used in this short-term forecast.

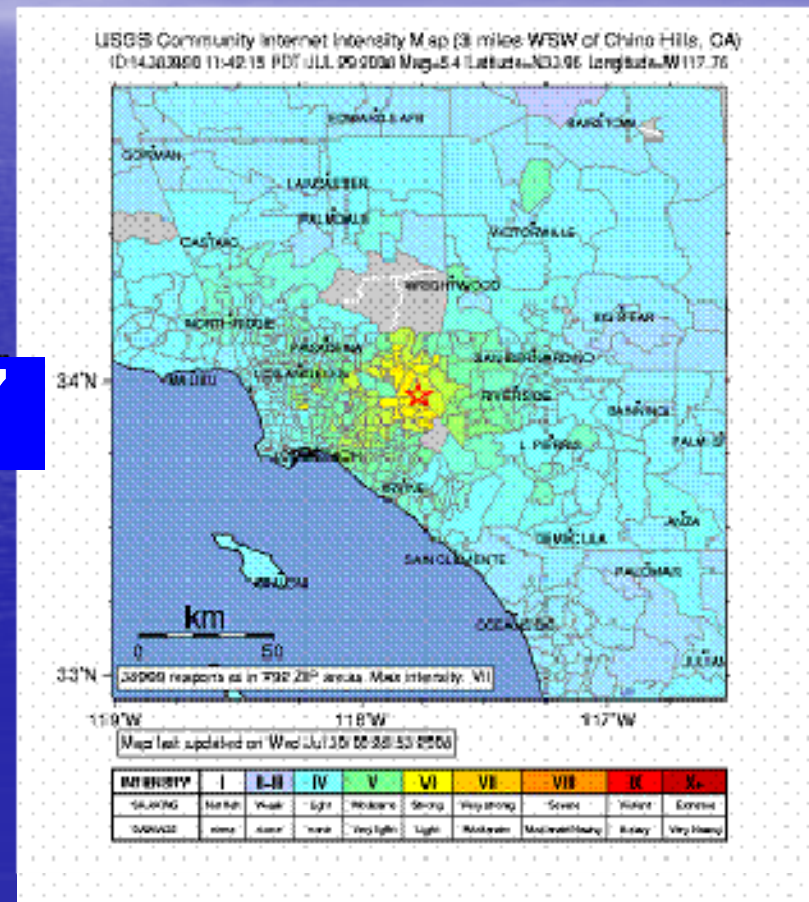
342 [ANNALS OF GEOPHYSICS, 54, 4, 2011; doi: 10.4401/ag-5350](#)

An example of the observed VI+ ground shaking in California

No 7 (29 Jul 2008, M5.4 WSW of Chino Hills) since the time of *Nature* published the work by Gerstenberger et al 2005 -



No 7

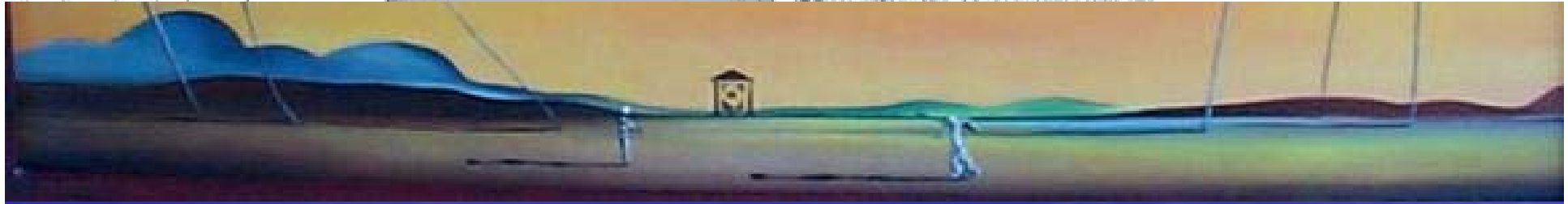
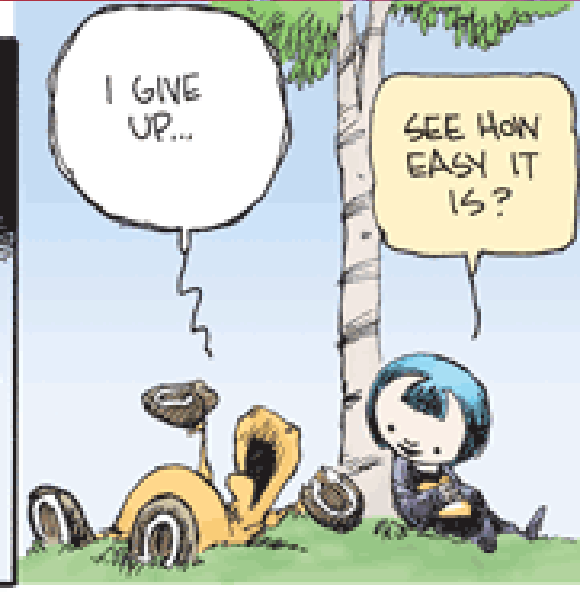




WICH/WWW.COMICBOOKS.NET 6-3



WWW.COMICBOOKS.NET 6-3





OK...SO GIVE AN EXAMPLE OF A PRE-CONCEPTUAL THEORY

WELL...WE DON'T COME UP WITH THEORIES. WE JUST DISMISS EXISTING SCIENCE THAT GETS IN OUR WAY

NOW, THE QUICKEST WAY TO GO HOME IS TO FLOAT ACROSS THIS RAVINE, AND I BELIEVE WE CAN DO THAT!

UM... SO YOU JUST DISMISS GRAVITY?

YEP. I SAY IT'S AN UNPROVEN THEORY THAT'S BEEN SHOWN DOWN OUR THROATS IN SCIENCE CLASS

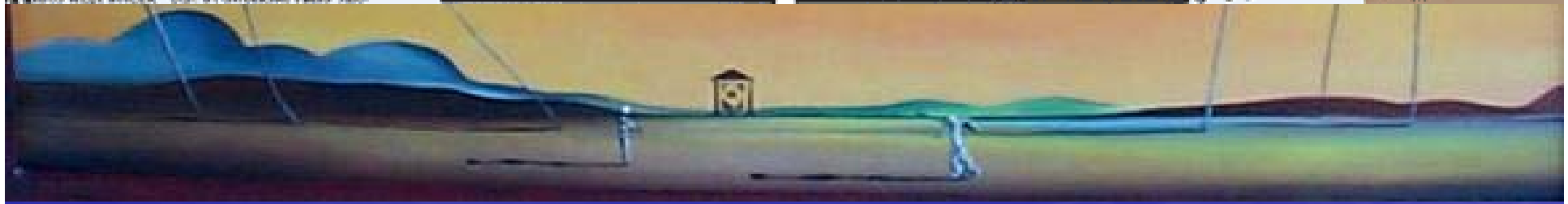
SO HOW ARE YOU GOING TO DISPROVE IT?

THAT'S WHERE YOU COME IN...

WILLIAM B. ELLIOTT FOR THE NEW YORK TIMES

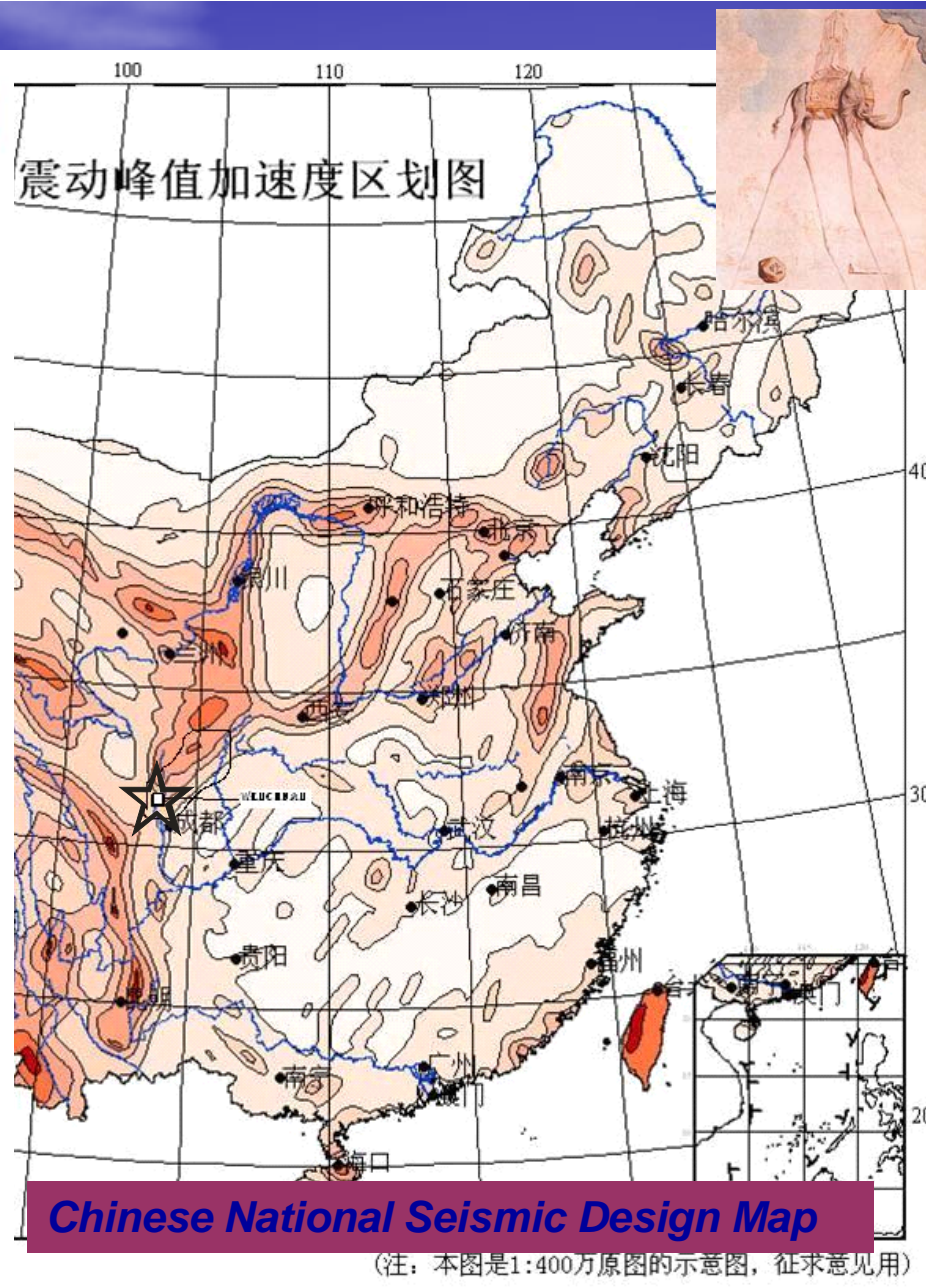
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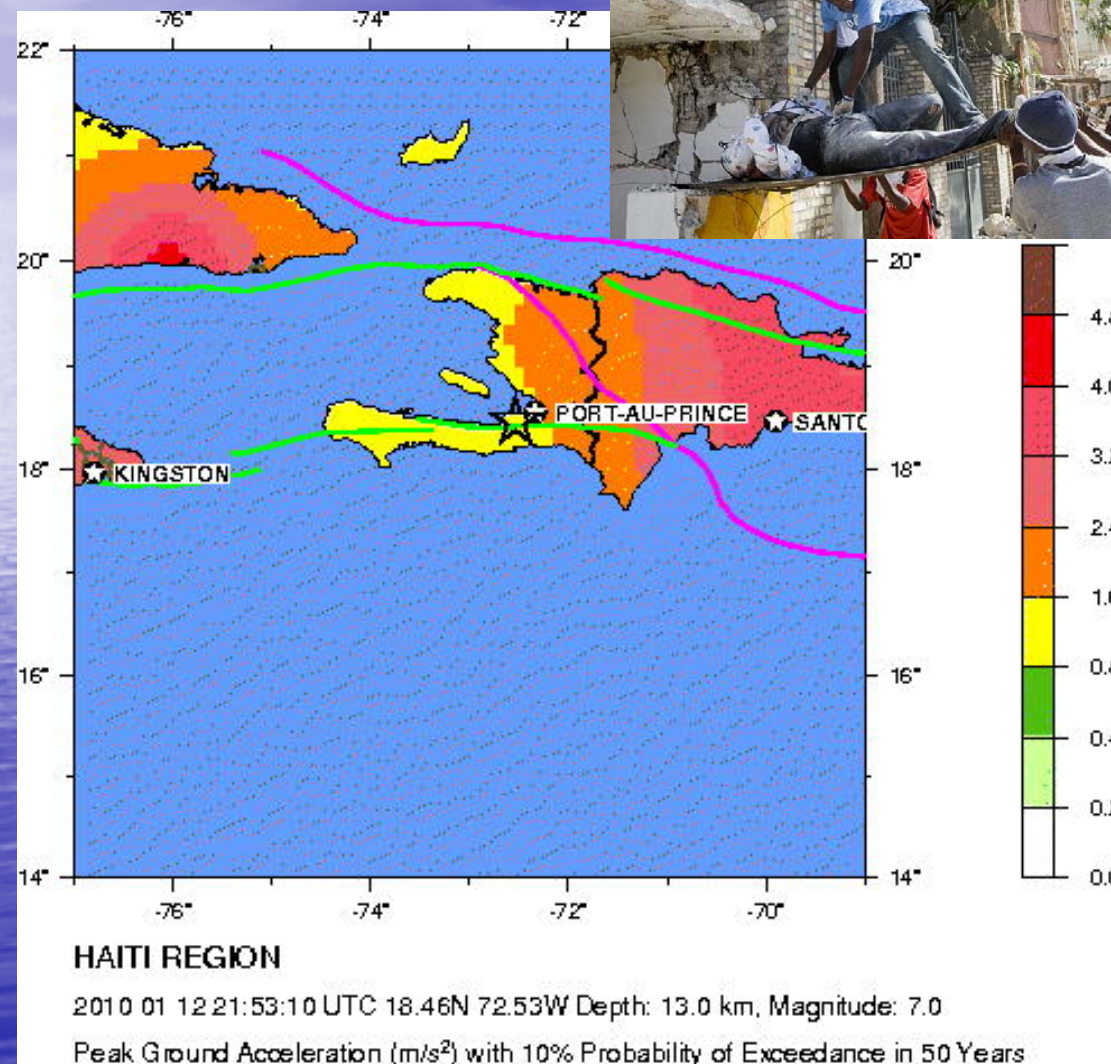
60COMICS.COM



“Top Twelve Deadliest Earthquakes, 2000-2011”

Region	Date	M	Fatalities	ΔI_0
Sumatra-Andaman “Indian Ocean Disaster”	26.12.2004	9.0	227898	4.0
Port-au-Prince (Haiti)	12.01.2010	7.3	222570	2.2
Wenchuan (Sichuan, China)	12.05.2008	8.1	87587	3.2
Kashmir (North India and Pakistan border region)	08.10.2005	7.7	~86000	2.3
Bam (Iran)	26.12.2003	6.6	~31000	0.2
Bhuj (Gujarat, India)	26.01.2001	8.0	20085	2.9
Off the Pacific coast of Tohoku (Japan)	11.03.2011	9.0	15815 (3966 missing)	3.2
Yogyakarta (Java, Indonesia)	26.05.2006	6.3	5749	0.3
Southern Qinghai (China)	13.04.2010	7.0	2698	2.1
Boumerdes (Algeria)	21.05.2003	6.8	2266	2.1
Nias (Sumatra, Indonesia)	28.03.2005	8.6	1313	3.3
Padang (Southern Sumatra, Indonesia)	30.09.2009	7.5	1117	1.8



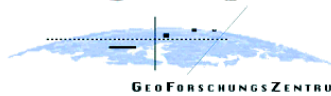
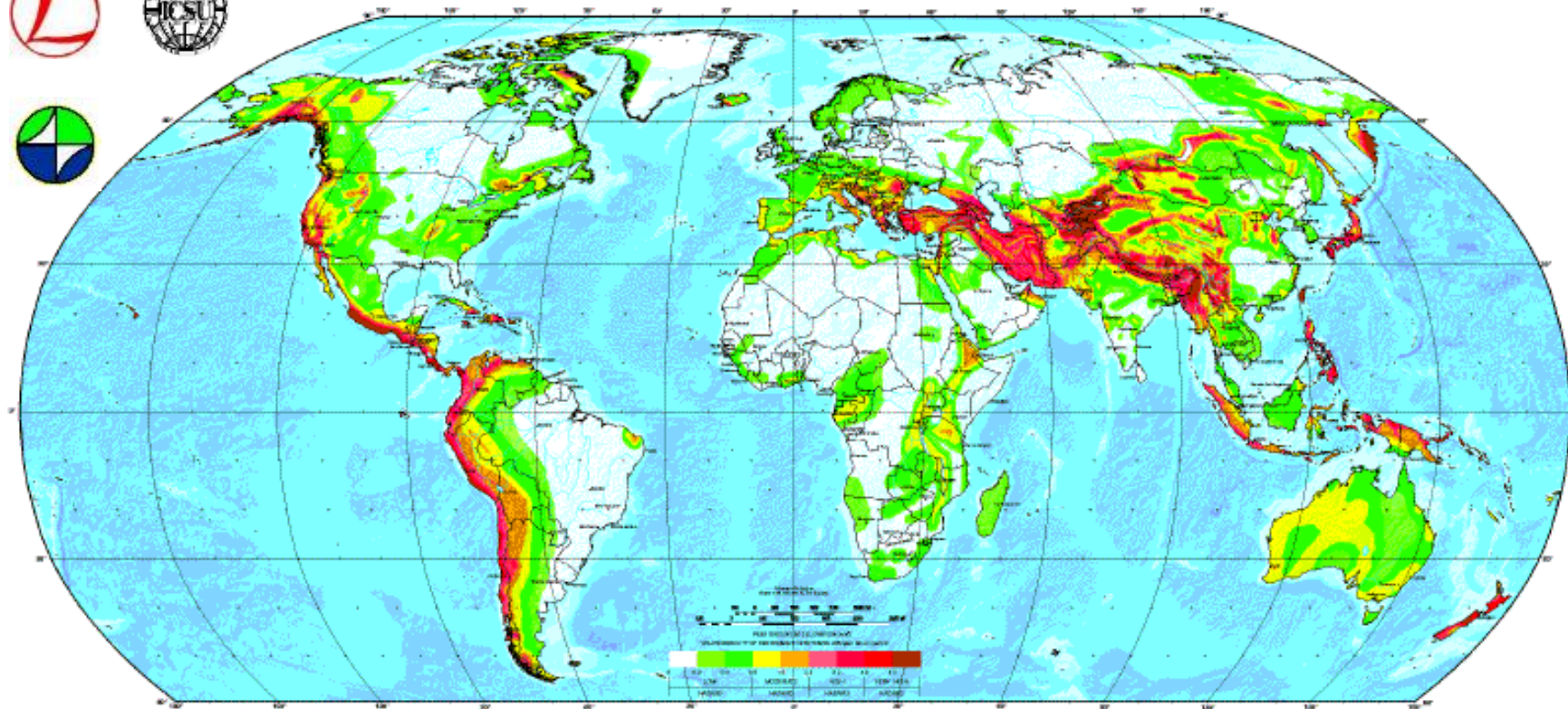
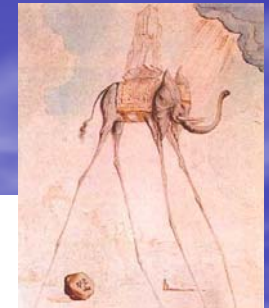


The Global Seismic Hazard Assessment Program (GSHAP) was launched in 1992 by the International Lithosphere Program (ILP) with the support of the International Council of Scientific Unions (ICSU), and endorsed as a demonstration program in the framework of the United Nations International Decade for Natural Disaster Reduction (UN/IDNDR). The GSHAP project terminated in 1999.

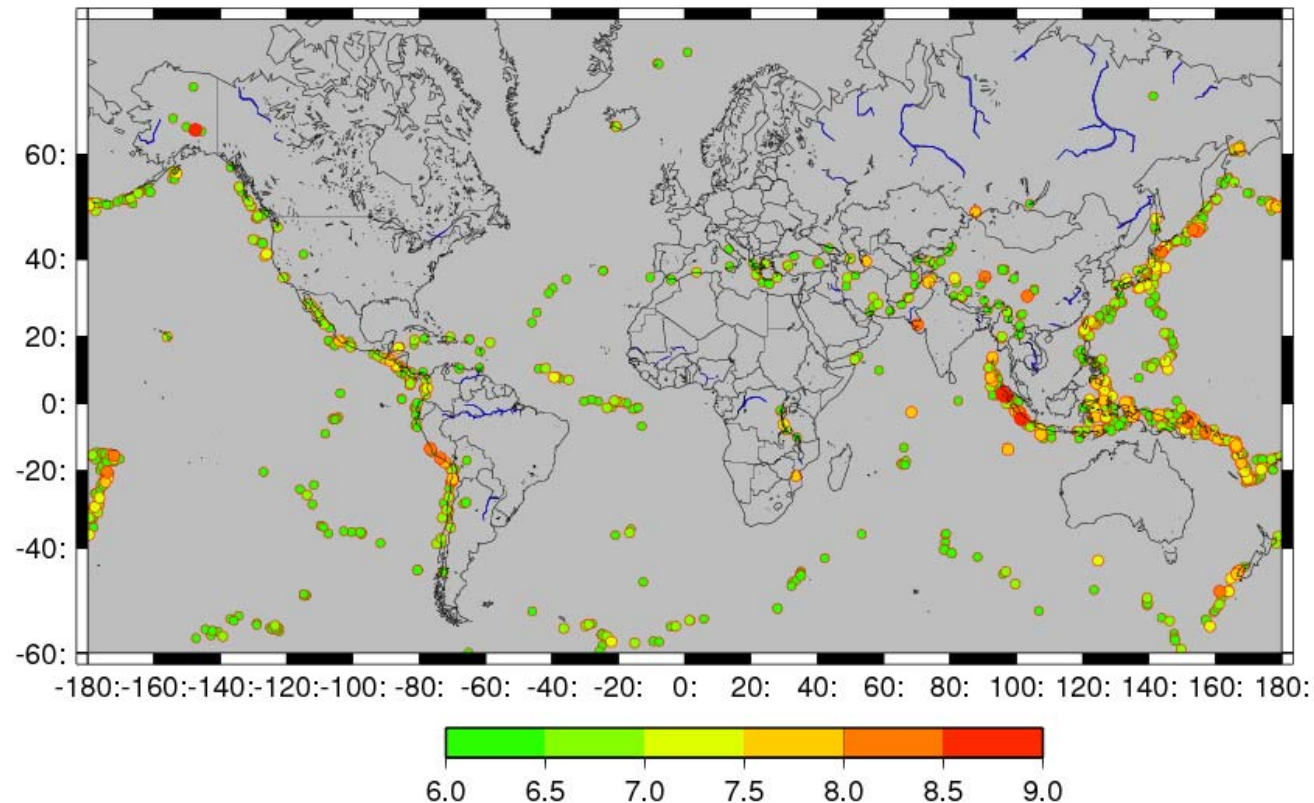
...endorsed as a demonstration program in the framework of the United Nations International Decade for Natural Disaster Reduction...



GLOBAL SEISMIC HAZARD MAP



Since the GSHAP terminated, seismic reality was testing the prediction given by Global Seismic Hazard Map.



USGS/NEIC Global Hypocenter's Data Base, 2000-2010

Data

- The results of GSHAP are provided as the Global Map of Seismic Hazard and the Table of PGA values (“peak ground acceleration with a 10% chance of exceedance in 50 years corresponding to a return period of 475 years”, *GSH PUB.dat*) at <http://www.seismo2009.ethz.ch/GSHAP/>. There are 5369091 values at the regular $0.1^\circ \times 0.1^\circ$ grid, of which 1739063 are “NaN” and 175275 are “0”. Therefore, we have used 3454753 GSHAP PGA estimates.
- Global Hypocenters Data Base, GHDB, System of the US Geological Survey and National Earthquake Information Center, USGS/NEIC (<ftp://hazards.cr.usgs.gov/>)

Method of comparison

- Each of the strong (magnitude 6 or larger) earthquakes may have up to $n = 9/\cos\phi$ values of GSHAP PGA in a cell $\frac{1}{4}^\circ \times (1/4\cos\phi)^\circ$ centered at its epicenter (ϕ, λ) . The maximum of these values, mPGA, and the magnitude of the earthquakes, M , are transformed by widely accepted empirical relationships to the Modified Mercalli Intensity of ground shaking at epicenter, I_0 .
- The pairs of the GSHAP expected maximum, $I_0(\text{mPGA})$, and the estimate of observed value, $I_0(M)$, linked by the strong earthquakes are analysed.

Results

- For each of 1181 out of 1347 strong crustal earthquakes from USGS/NEIC GHDB, 2000-2009, it is possible to determine the pair

$$\{I_0(\text{mPGA}), I_0(M)\}$$

and the difference

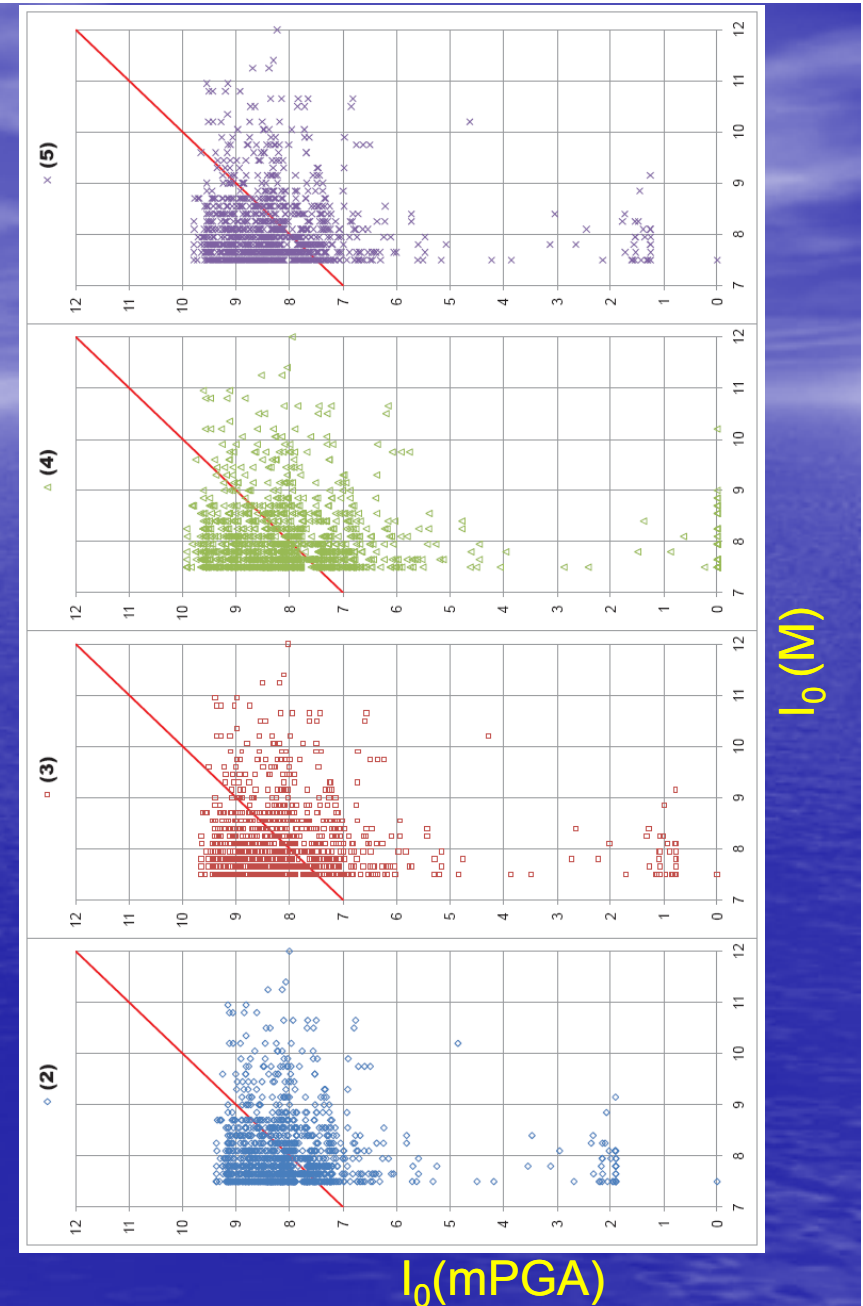
$$\Delta I_0 = I_0(M) - I_0(\text{mPGA}).$$

- Points above the diagonal

$$I_0(M) = I_0(\text{mPGA})$$

are “surprises” for GSHAP.

Qualitatively the results are independent of a choice of established empirical relations.



Each of 1181 strong crustal earthquakes in 2000-2009 has from 6 to 58 values of GSHAP PGA in the $\frac{1}{4}^\circ \times (1/4\cos\phi)^\circ$ cell centered at its epicenter (ϕ, λ).

The transformed values the GSHAP expected maximum, $I_0(\text{mPGA})$, and the estimate of observed value, $I_0(M)$, allow to count the number of “surprises”, the average difference ΔI_0 , and the median of ΔI_0 for earthquakes of different magnitude.

For example, each of the 59 magnitude 7.5 or larger earthquakes in 2000-2009 was a “surprise” for GSHAP Seismic Hazard Map; moreover, the minimum of the 59 values of ΔI_0 is 0.6.

The average and the median of ΔI_0 are about 2.

INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

The contributors to GSHAP could have evaluate the poor performance of their product before its publication in 1999...

Table 1. Number of shallow earthquakes (in a decade) that violate GSHAP PGA prediction.

	Total	$\Delta I_0 = I_0(M) - I_0(\text{mPGA})$											
		(2)			(3)			(4)			(5)		
		> 0	> 1	> 2	> 0	> 1	> 2	> 0	> 1	> 2	> 0	> 1	> 2
<i>2000-2009 (test on control sample, after publication)</i>													
M = 6 or more	1181	529	191	83	530	204	89	559	232	105	426	164	78
M = 7 or more	113	113	79	28	112	76	30	106	74	35	105	65	25
<i>1990-1999 (test on learning sample)</i>													
M = 6 or more	1021	471	182	66	463	185	69	487	203	91	385	137	61
M = 7 or more	129	124	74	15	120	65	16	117	63	22	115	46	11

Aptikaev et al, 2008 (2), Shteinberg et al, 1993 (3), Sauter and Shah, 1978 (4), and Murphy and O'Brien, 1977 (5)

Finally yet, rare cases of actual measurements of strong ground acceleration and field surveys of earthquake intensity at the sites of historically recent strong earthquakes, are in full agreement with our results, which we have achieved by a crude computation, and they essentially confirm the basic validity of our work.

E. Zuccolo et al.

Pure Appl. Geophys.

Table 1

Comparison between the expected and observed PGA for some recent strong earthquakes. Where available, the computed DGA is reported as well. Values marked with the asterisk () denote PGA inferred from intensity. If non-linear effects (e.g. liquefaction) are considered the PGA values may be smaller*

Earthquake	Expected PGA (g) with a probability of exceedance of 10% in 50 years (return period 475 years)	Observed PGA (g)	Computed DGA (g)
Kobe	0.40–0.48	0.7–0.8	
Gujarat	0.16–0.24	0.5–0.6	0.3–0.6
Boumerdes	0.08–0.16	0.3–0.4*	0.4–0.6
Bam	0.16–0.24	0.7–0.8	
Eastern Sichuan	0.16–0.24	0.6–>0.8 (Shakemap)	
Haiti	0.08–0.16	0.3–0.6*	

Japan faces up to failure of its earthquake preparations

Systems for forecasting, early warning and tsunami protection all fell short on 11 March.

BY DAVID CYRANOSKI IN TOKYO

Japan has the world's densest seismometer network, the biggest tsunami barriers and the most extensive earthquake early-warning system. Its population is drilled more rigorously than any other on what to do in case of earthquakes and tsunamis.

Yet this month's magnitude-9 earthquake surprised the country's forecasters. The grossly underestimated tsunami destroyed the world's deepest tsunami barrier and caught people by

surprise. And the early-warning system for earthquakes largely failed. What went wrong?

The first problem was the earthquake forecast. Japan's seismic hazard map, the latest version of which was released in March 2009, breaks the offshore area of northeastern Japan into five seismic zones and envisages seven different earthquake scenarios. Each is assigned a probability based on the historical record of earthquakes. The southern Sanriku offshore region, which included the origin of this month's earthquake, was given a 30–40%

chance of rupturing in the next 10 years and a 60–70% chance in the next 20 years.

As earthquake forecasting goes, these are very high numbers. "That basically means it could happen any day," says Yoshinori Suzuki of the Earthquake Disaster Reduction Research Division within the science ministry, which coordinates the map-making. But the fault was expected to unleash an earthquake of around magnitude 7.7 — about as large as any in the historical record for the area (see *Nature* 471, 274; 2011).

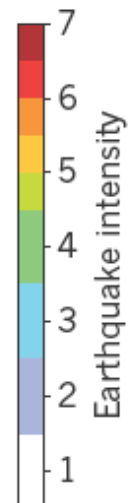
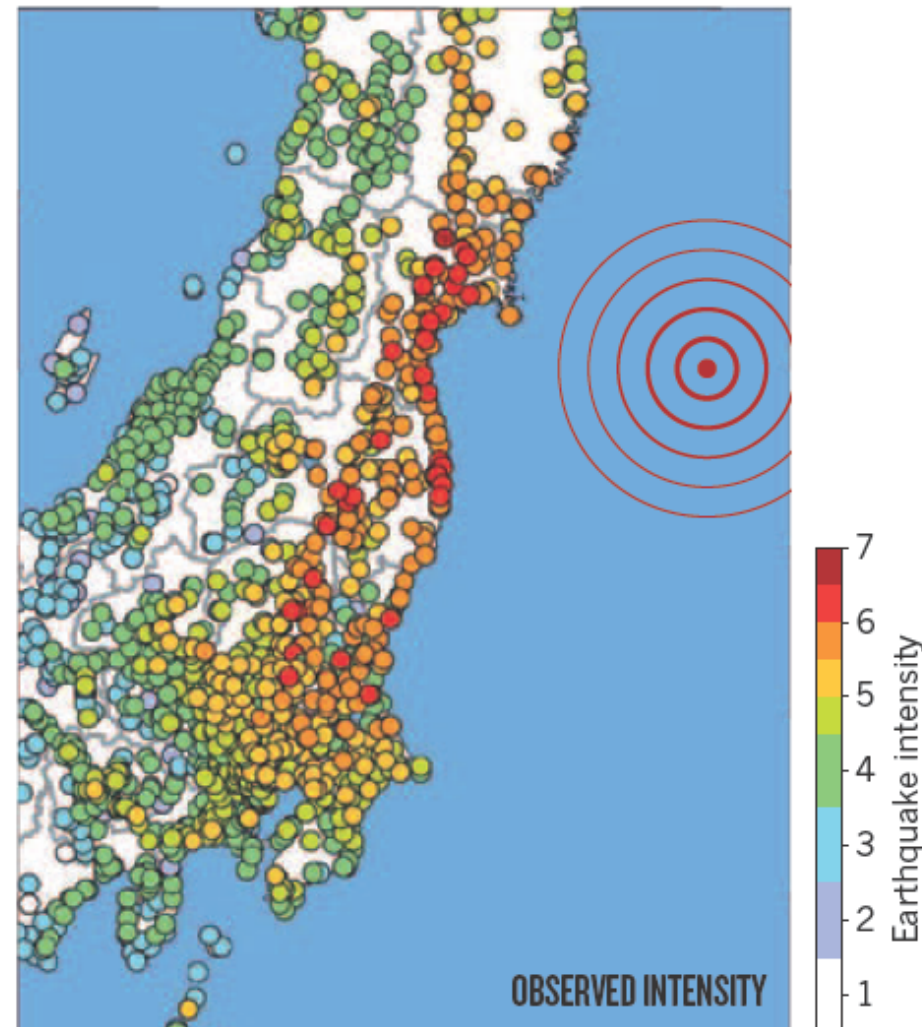
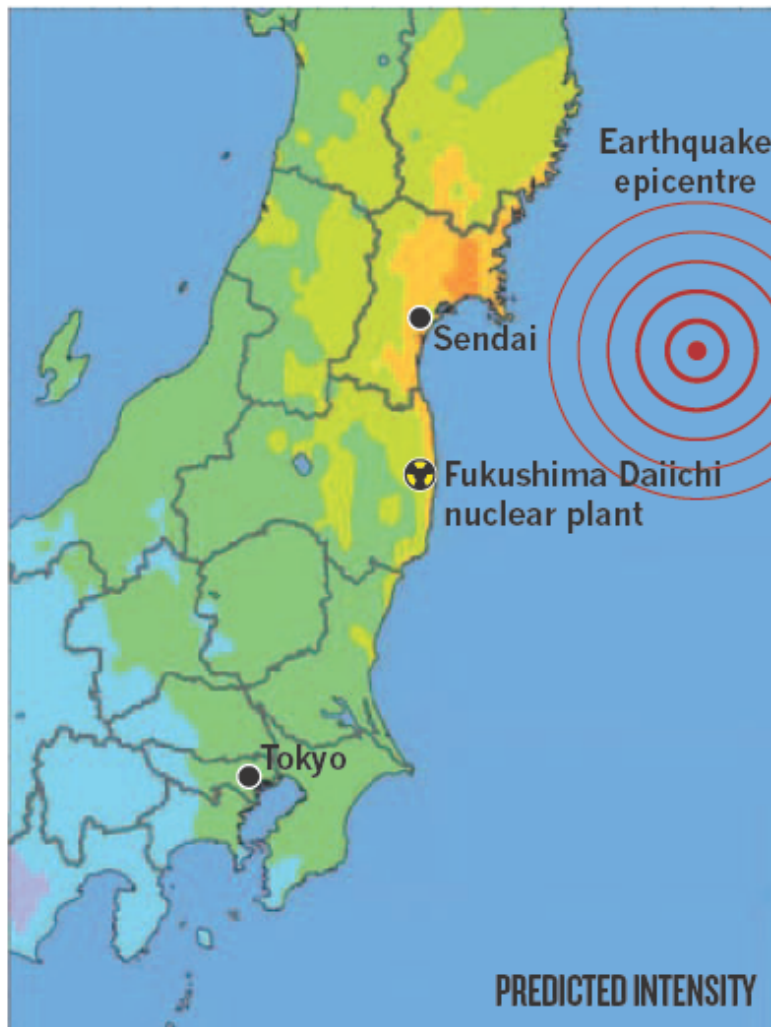
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FALSE COMFORT

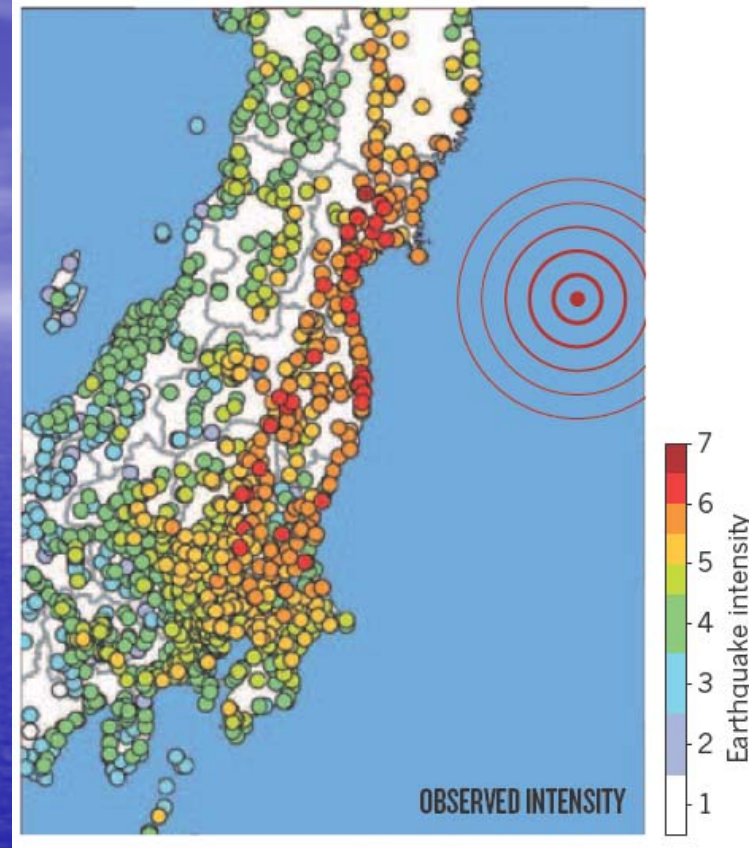
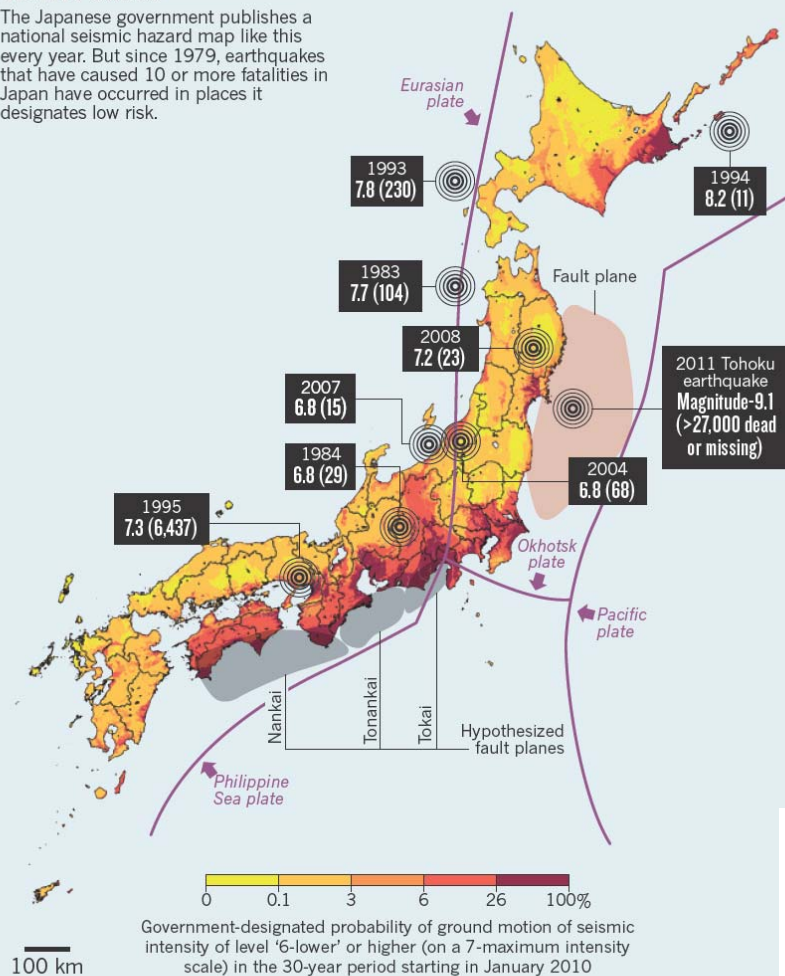
A warning system based on initial seismic signals predicted a limited region of intense shaking. The actual shaking was far more severe and widespread.

SOURCE: M. YAMADA & JAPAN MET. AGENCY



REALITY CHECK

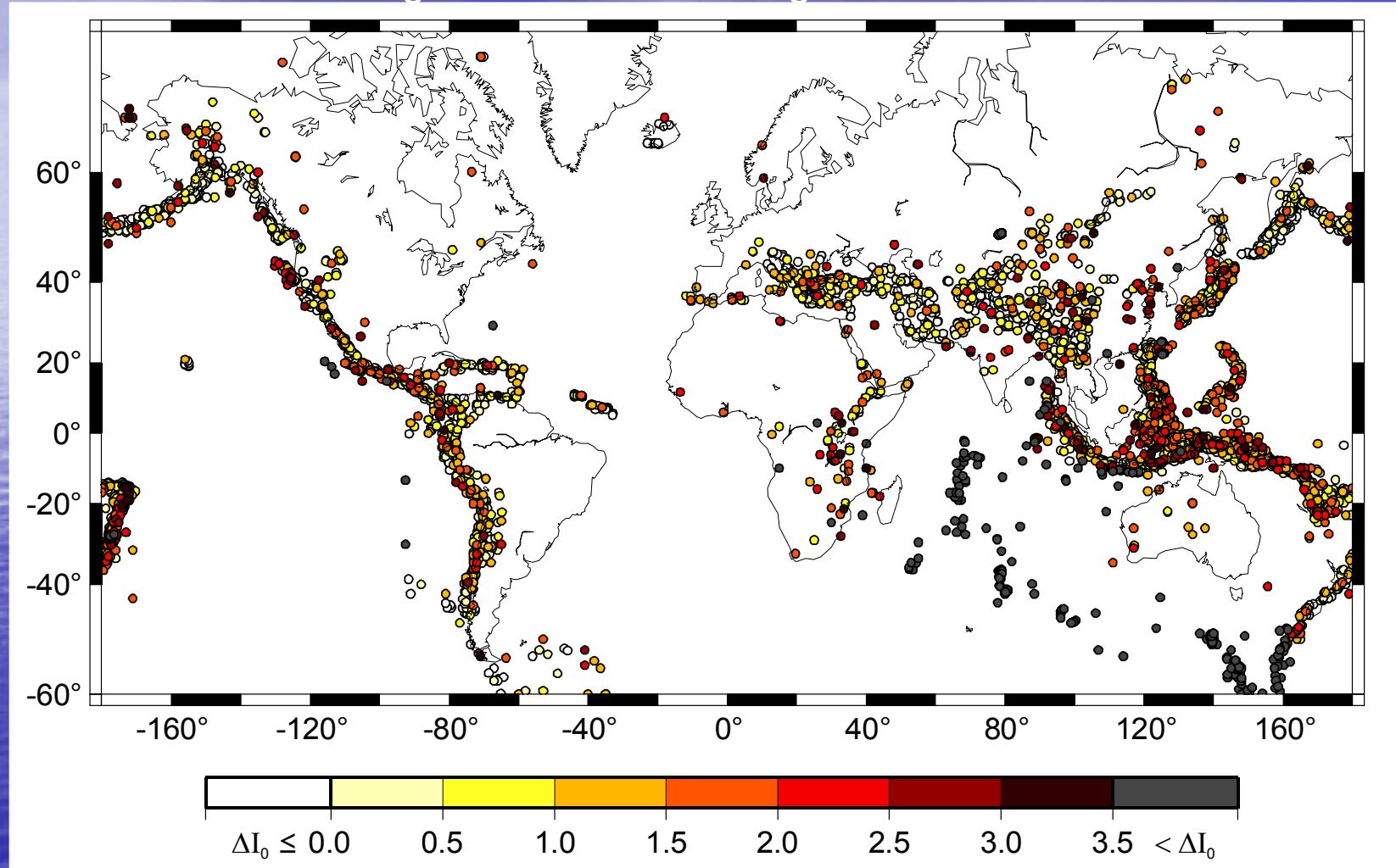
The Japanese government publishes a national seismic hazard map like this every year. But since 1979, earthquakes that have caused 10 or more fatalities in Japan have occurred in places it designates low risk.



Shake-up time for Japanese seismology

Robert J. Geller calls on Japan to stop using flawed methods for long-term forecasts and to scrap its system for trying to predict the 'Tokai earthquake'.

The color coded discrepancy, ΔI_0 , between actual and GSHAP predicted effect at epicenters of strong shallow earthquakes in 1900-2009. "Surprises" dominate, while "big surprises" (i.e., $\Delta I_0 > 1$) are widespread throughout all seismic regions worldwide.



Conclusion:

Thus, a systematic and quantitative comparison of the GSHAP peak ground acceleration estimates (a 10% chance of exceedance in 50 years) with those related to actual strong earthquakes, unfortunately, discloses gross inadequacy of this “probabilistic” product; which, in common sense, is evidently UNACCEPTABLE FOR ANY KIND OF RESPONSIBLE SEISMIC RISK EVALUATION AND KNOWLEDGEABLE DISASTER PREVENTION.

The self-evident shortcomings and failures of GSHAP appeals to all earthquake scientists and engineers for an urgent revision of the global seismic hazard maps from the first principles including the background methodologies involved, such that there becomes:

- (1) a demonstrated and sufficient justification of hazard assessment protocols;**
- (2) a more complete learning of the actual range of earthquake hazards to local communities and populations, and**
- (3) a more ethically responsible control over how seismic hazard and seismic risk is implemented to protect the public safety.**



“Men han har jo ikke noget paa,” sagde et lille Barn. “Herre Gud, hør den Uskyldiges Røst,” sagde Faderen; og den Ene hvidskede til den Anden, hvad Barnet sagde.

“Men han har jo ikke noget paa,” raabte tilsidst hele Folket. Det krøb i Keiseren, thi han syntes, de havde Ret, men han tænkte som saa: “nu maa jeg holde Processionen ud”. Og Kammerherrerne gik og bar paa Slæbet, som der slet ikke var.

Hans Christian Andersen, 1837. *Keiserens nye Klæder*



Thank you!

"When sorrows come, they come not single spies, but in battalions"
(William Shakespeare, 1564-1616)