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"Environmental Monitoring & Disaster Mitigation"

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Modeling scenarios of earthquake-generated tsunamis for the Vietnam coasts

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Direct and inverse problems in seismology

- A wide set of direct and inverse problems in seismology may significantly benefit from advanced e-infrastructures and improved computational capability.

- Aim: allow for a physically sound and reliable assessment of seismic and tsunami hazard, and, in conjunction with geophysical data assimilation, improve the current understanding of the Earth structure and dynamics.

Top Eleven Deadliest earthquakes since 2000

All of them are “surprises” with respect to traditional probabilistic ground shaking estimates (GSHAP). Some of them also generated tsunamis. => Need for a new scenario-based approach to seismic and tsunami hazard assessment.

Sendai (Japan, 11.03.2011, M9.0), $\Delta I = 3.3$	> 20,000
Port-au-Prince (Haiti, 12.01.2010, M7.3), $\Delta I_0 = 2.2$	222,570
Padang (Southern Sumatra, Indonesia, 30.09.2009, M7.5), $\Delta I_0 = 1.8$	1,117
Wenchuan (Sichuan, China, 12.05.2008, M8.1), $\Delta I_0 = 3.2$	87,587
Yogyakarta (Java, Indonesia, 26.05.2006, M6.3), $\Delta I_0 = 0.3$	5,749
Kashmir (North India and Pakistan border region, 08.10.2005, M7.7), $\Delta I_0 = 2.3$	86,000
Nias (Sumatra, Indonesia, 28.03.2005, M8.6), $\Delta I_0 = 3.3$	1,313
Sumatra-Andaman (“Indian Ocean Disaster”, 26.12.2004, M9.0), $\Delta I_0 = 4.0$	227,898
Bam (Iran, 26.12.2003, M6.6), $\Delta I_0 = 0.2$	31,000
Boumerdes (Algeria, 21.05.2003, M6.8), $\Delta I_0 = 2.1$	2,266
Bhuj (Gujarat, India, 26.01.2001, M8.0), $\Delta I_0 = 2.9$	20,085

Courtesy V. Kossobokov - AGU Fall Meeting 2010, U13A-0020

Possible approaches to tsunami modeling

- Classical hydrodynamic approach: numerical solution of Navier-Stokes equations with bottom lift condition. Partial liquid-solid coupling.

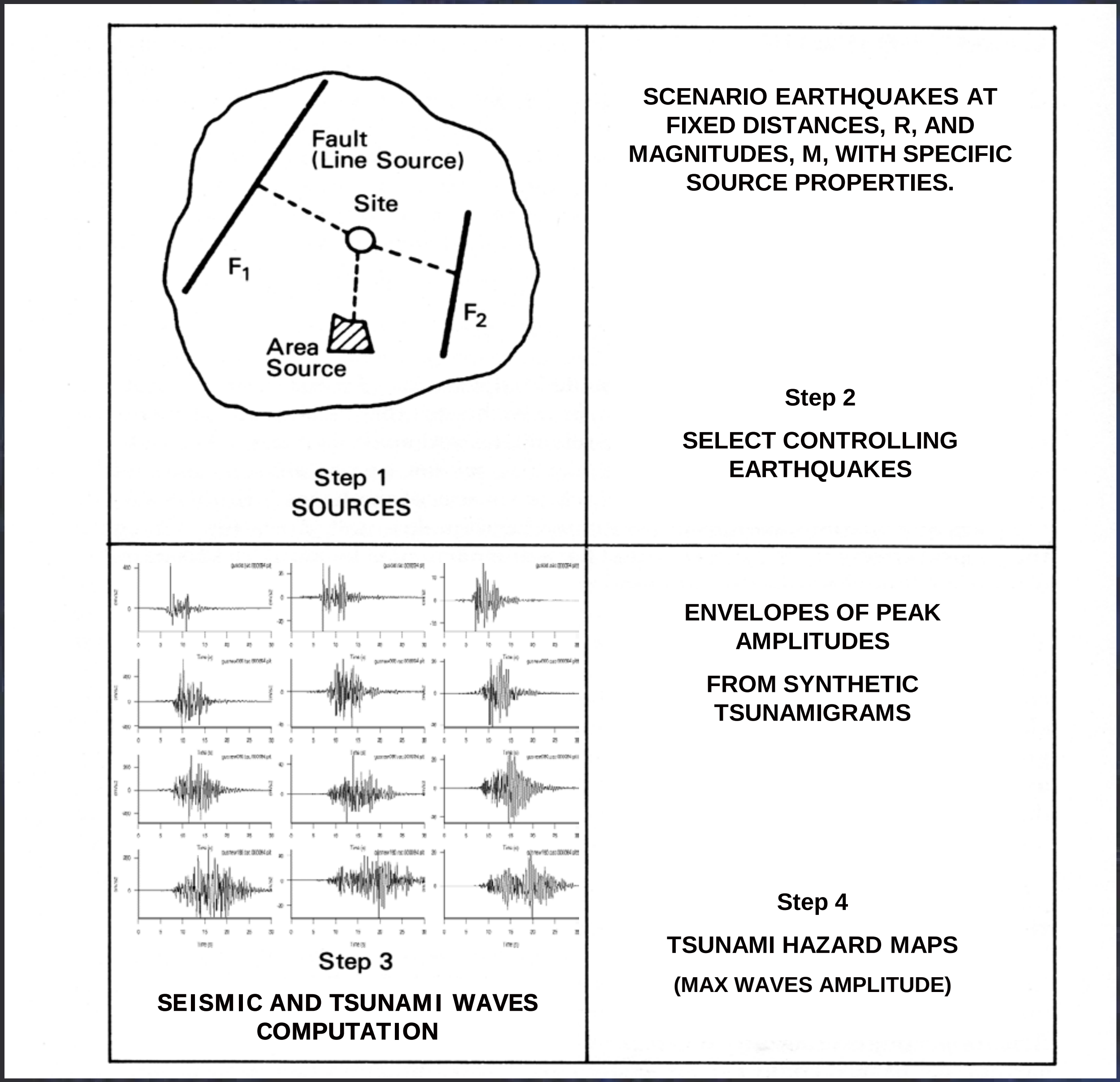
- Modal approach: tsunami as a low frequency gravity mode generated in a liquid layer over a solid structure *(Ward, 1980; Okal, 1982; Comer, 1984; Panza et al., 2000)*

Modal approach

- Considering tsunami as a gravity mode allows us to use the modal technique to compute complete signals; this permits very fast calculations.

- Seismic source is naturally included in computation, directly as a force, and not treated as an external condition.

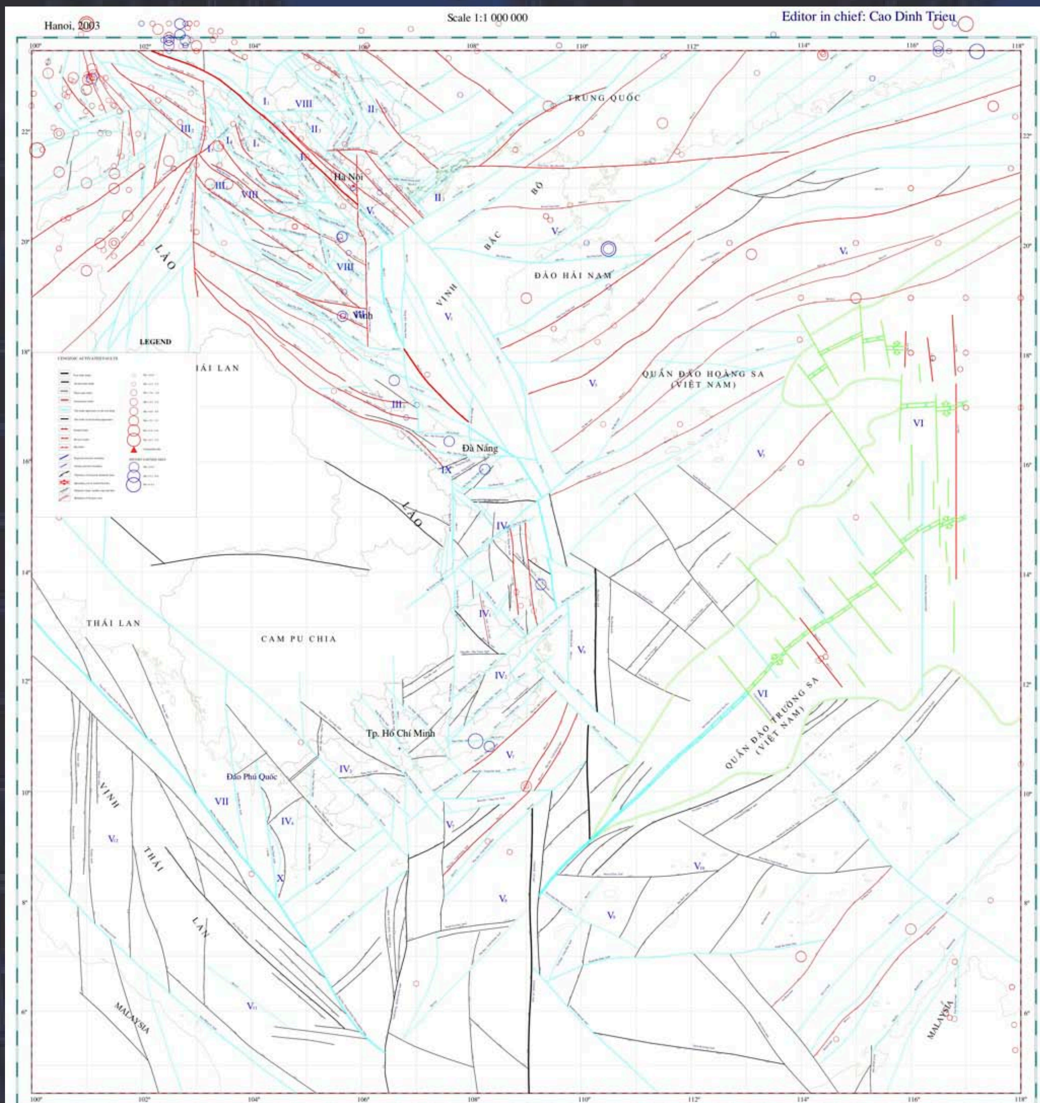
- The low computational costs and the efficiency in including the source mechanism can be very helpful in fast computation of tsunami hazard scenarios.

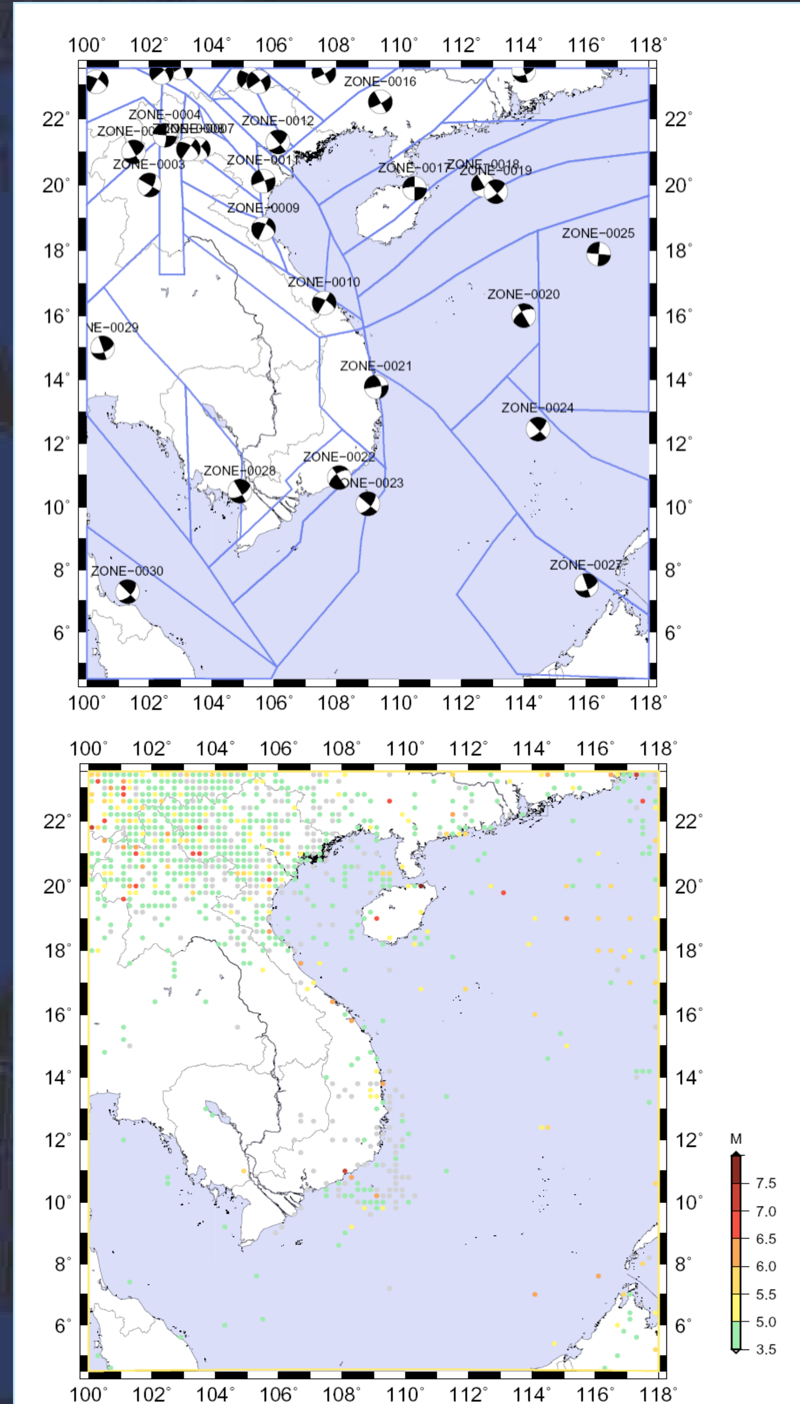


Tsunami hazard assessment

- New approach based on the **possibility to compute synthetic tsunamigrams** by the modal technique.
- Starting from the available information about seismic sources and bathymetry, the off-shore expected tsunami wave is **modeled**, considering a **wide set of scenario events**.
- Possibility to use extended sources
- Fast computation!!

Seismotectonic map of Vietnam

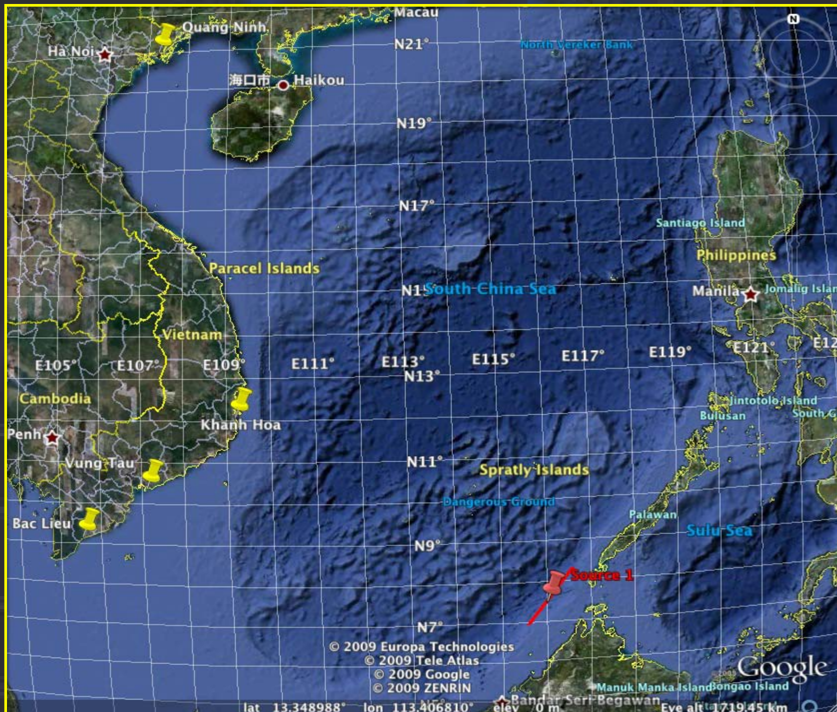


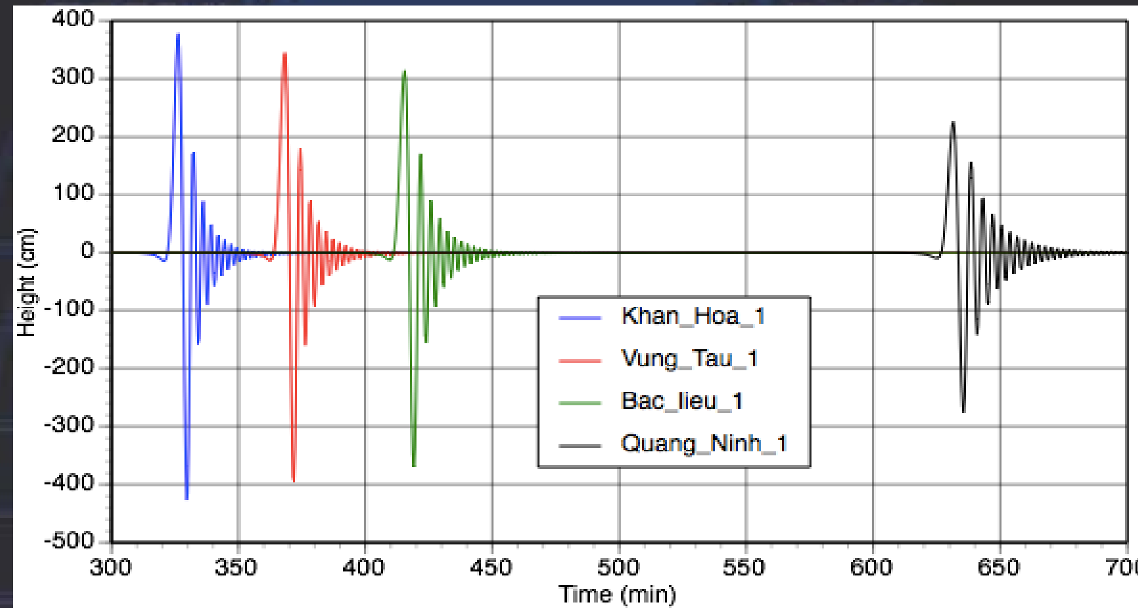


Tsunami scenarios for the Vietnam's coasts

Map of the Southern Chinese Sea, with the locations of the six selected **tsunamigenic seismic sources** (the red pins correspond to the epicenters), and of the seven selected **receiver sites** (yellow pins) along the Vietnam coasts.

Tsunami scenarios - Source 1

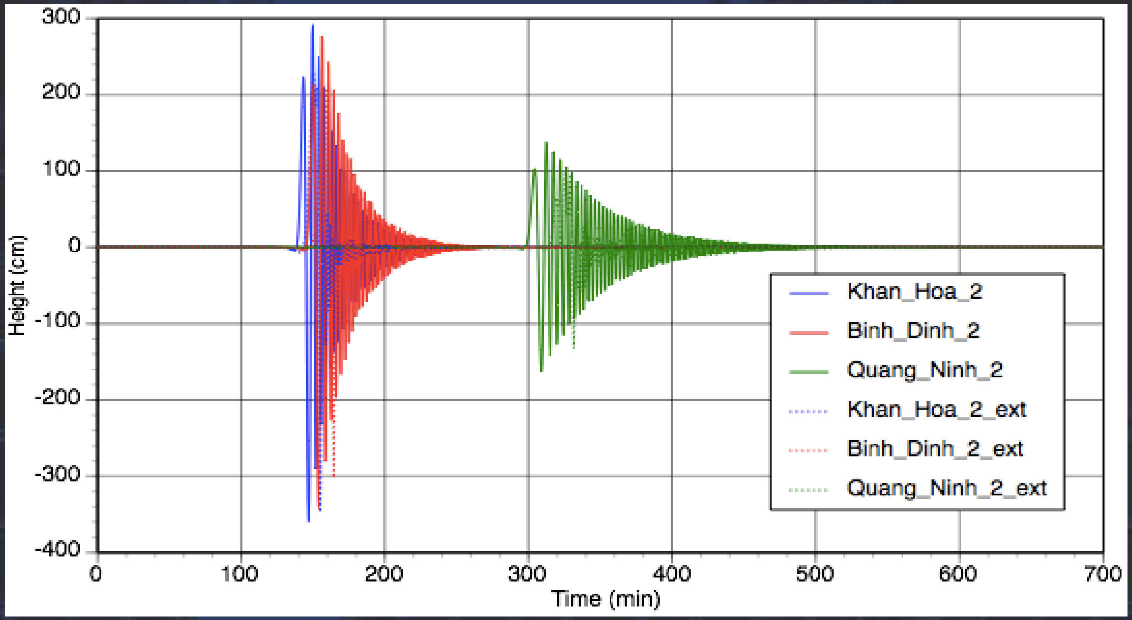




Synthetic tsunamigrams computed at the different sites for Source 1 scenario

Site	Khan Hoa	Vung Tau	Bac Lieu	Quang Ninh
Distance (km)	911	1028	1160	1736
Tmax (min)	205	229	261	397
Tmax – Tmin(min)	6	6	6	7
Strike max (°)	30	15	7.5	60
Max(cm) M=7	16	14	13	10
Max(cm) M=7.5	93	84	76	56
Max(cm) M=8	378	345	314	225

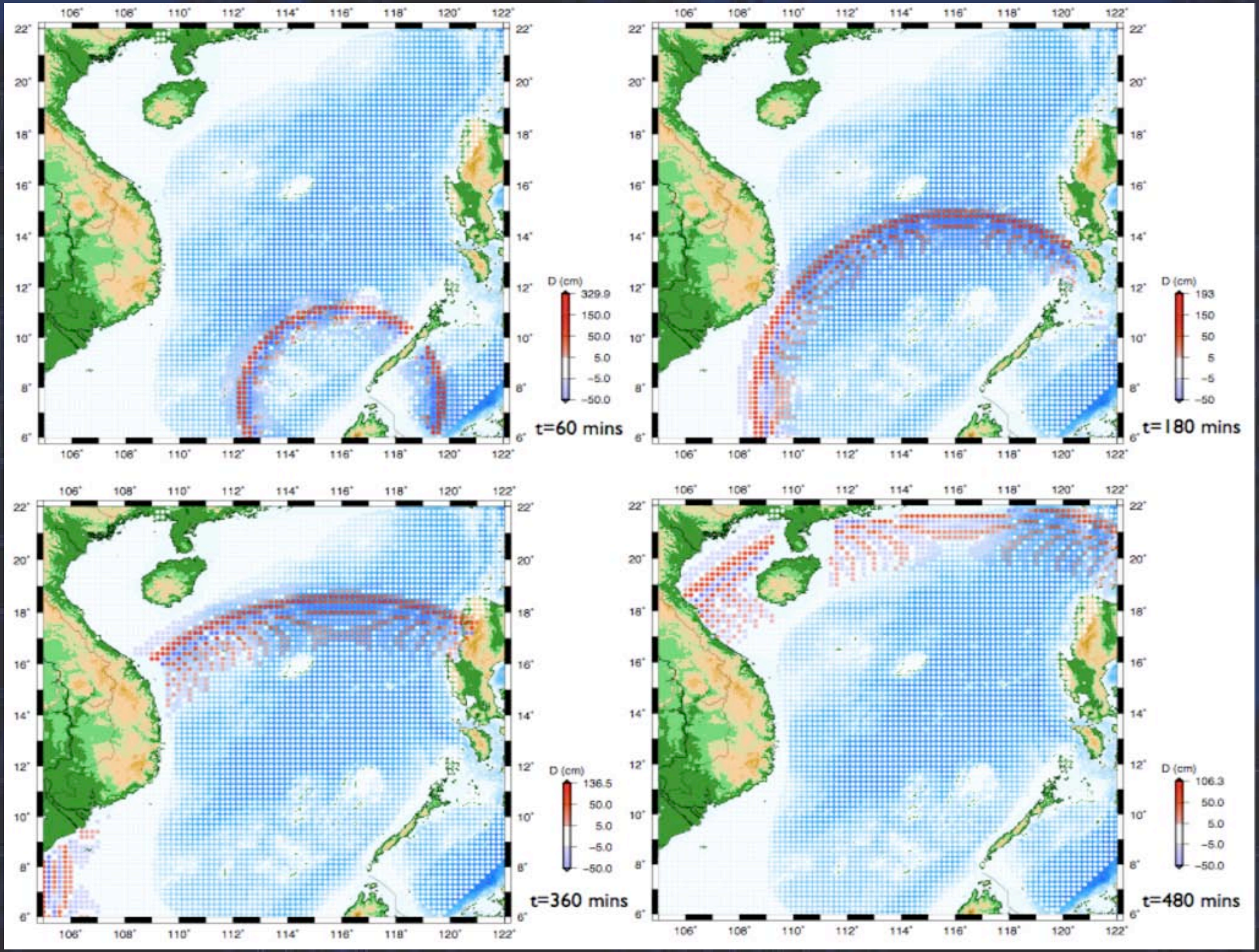
Tsunami scenarios - Source 2



Site	Khan Hoa	Bin Dinh	Quang Ninh
Distance (km)	571	598	1214
Tmax (min)	150	156	312
Tmax – Tmin(min)	3	3	4
Strike max (°)	0	15	52.5
Max(cm) M=7	11	11	5
Max(cm) M=7.5	64	60	30
Max(cm) M=8	290	276	150

Synthetic tsunamigrams computed at the different sites for Source 2 scenario

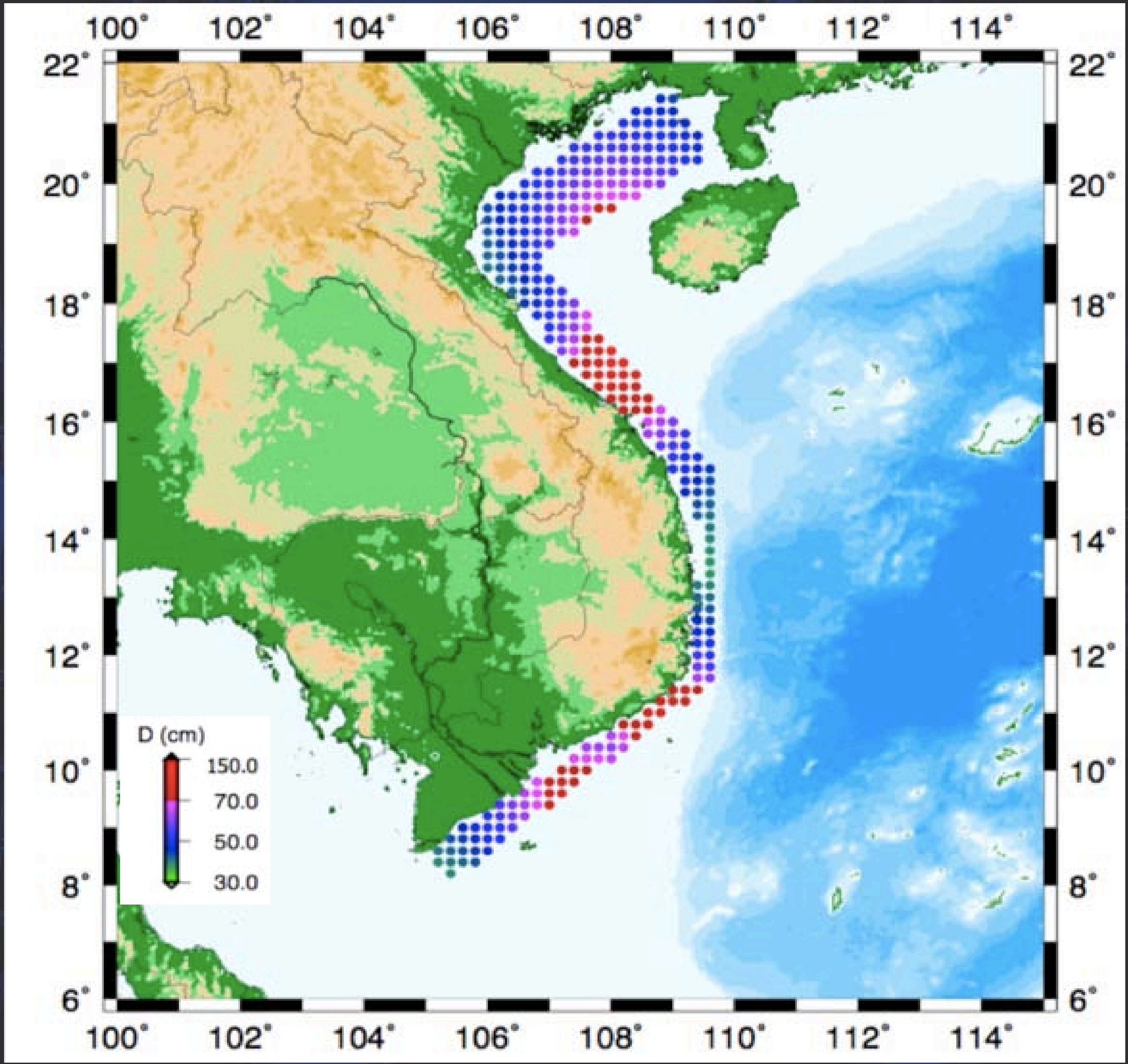
Tsunami scenarios - Snapshots for Source 1



Snapshots of the tsunami wave heights for a Mw=8.0 earthquake at Source 1 location

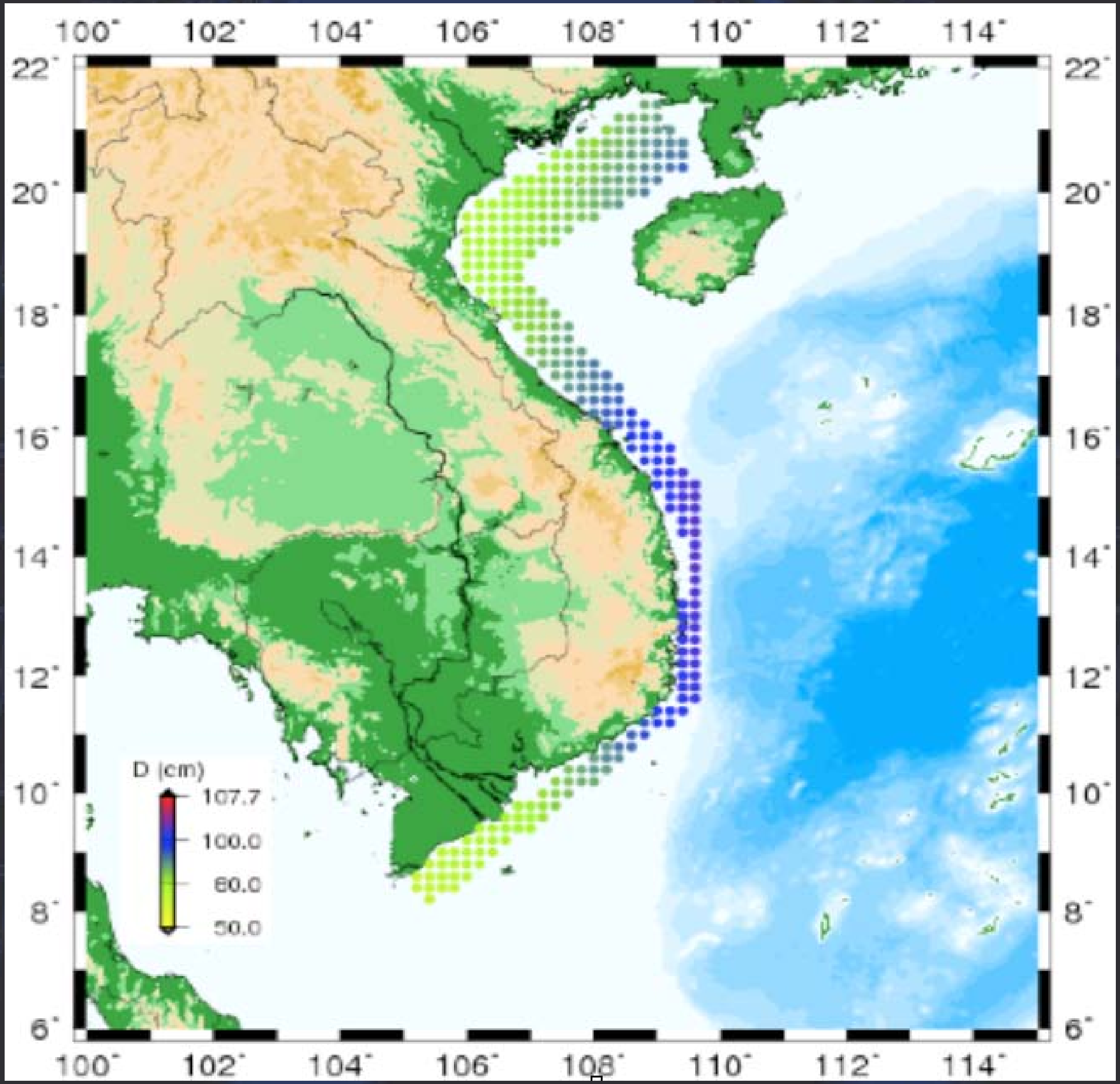
Tsunami hazard for the Vietnam's coasts

Distribution of the maximum positive tsunami wave heights along the Vietnam coasts computed considering the six sources with Mw=7.0



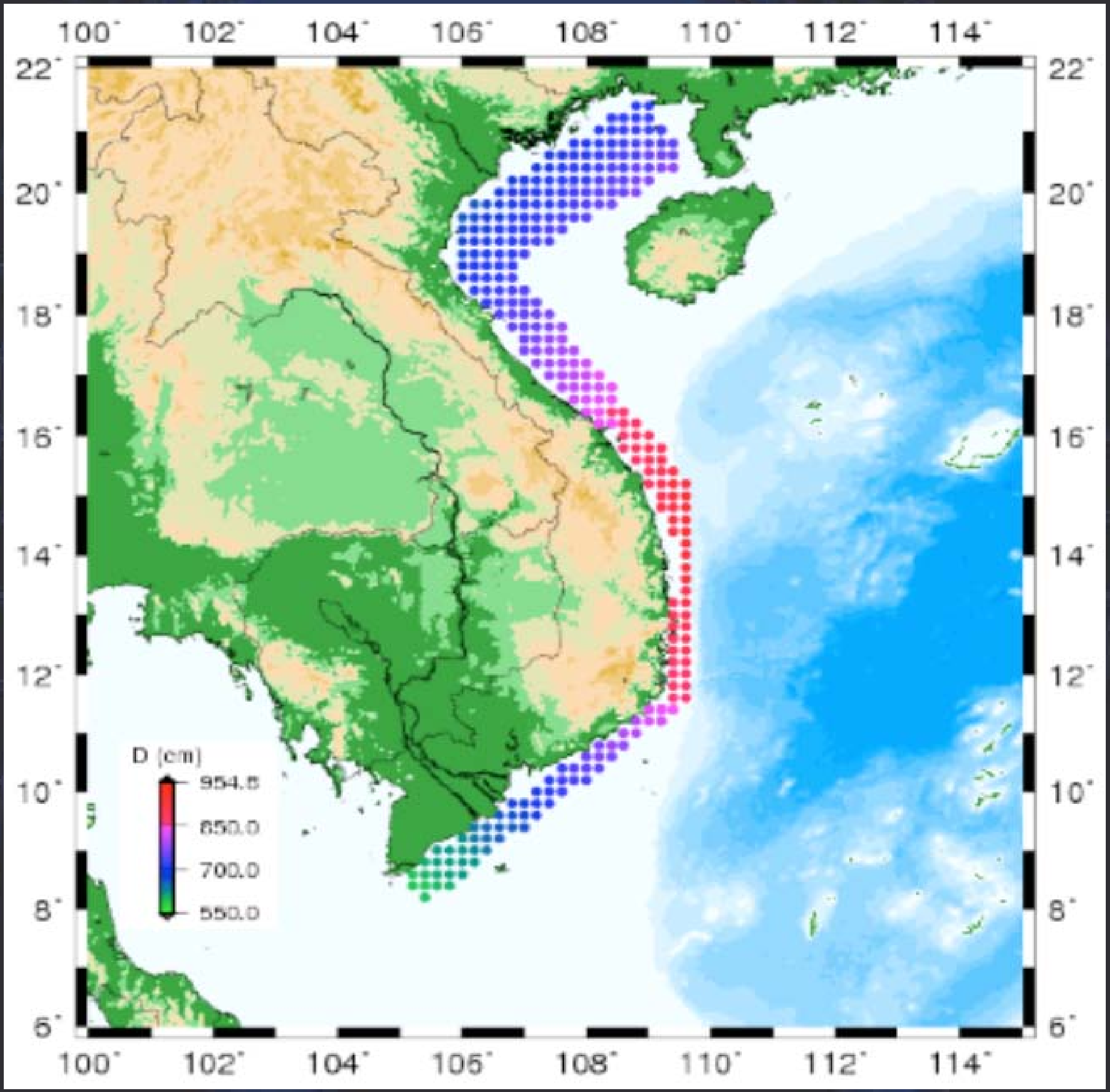
Tsunami hazard for the Vietnam's coasts

Distribution of the maximum positive tsunami wave heights along the Vietnam coasts computed considering the seven sources defined according to historical seismicity

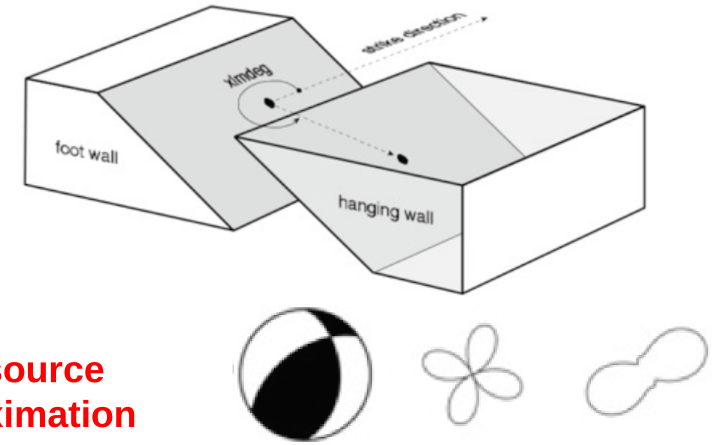


Tsunami hazard for the Vietnam's coasts

Distribution of the maximum positive tsunami wave heights along the Vietnam coasts computed considering the seven sources defined based on maximum credible earthquake, including the extreme scenario of M=9.0 at Manila Trench



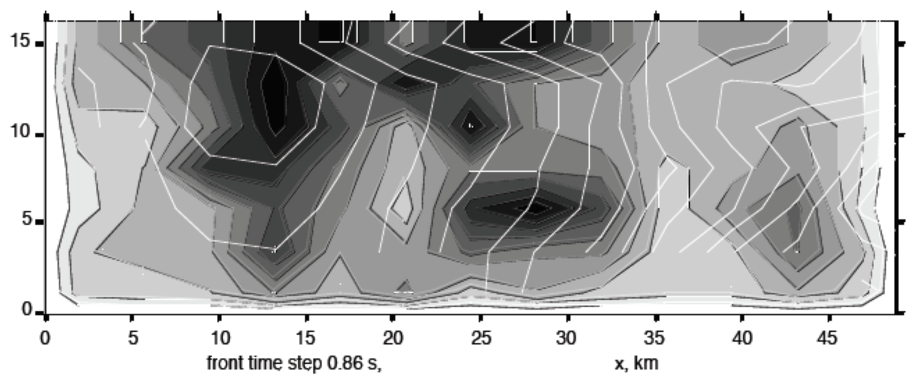
Extended seismic source models



Point source approximation

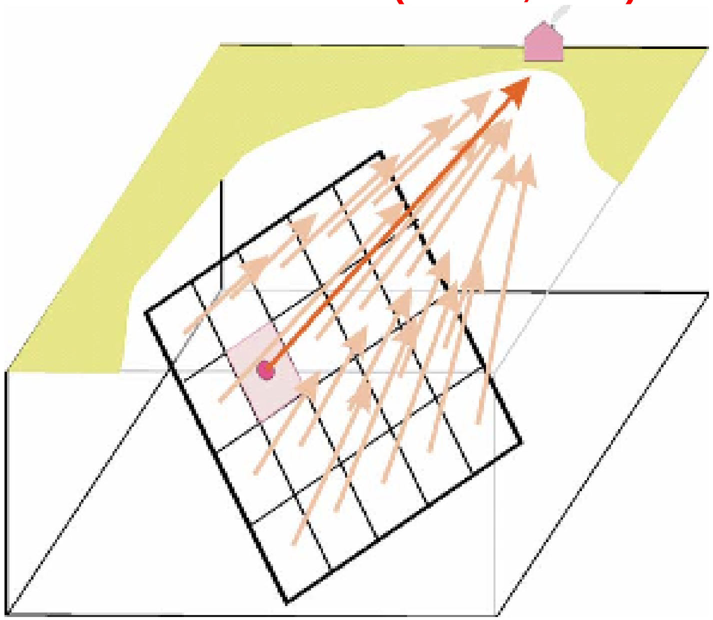
FPS and radiation pattern

Extendend source kinematic model

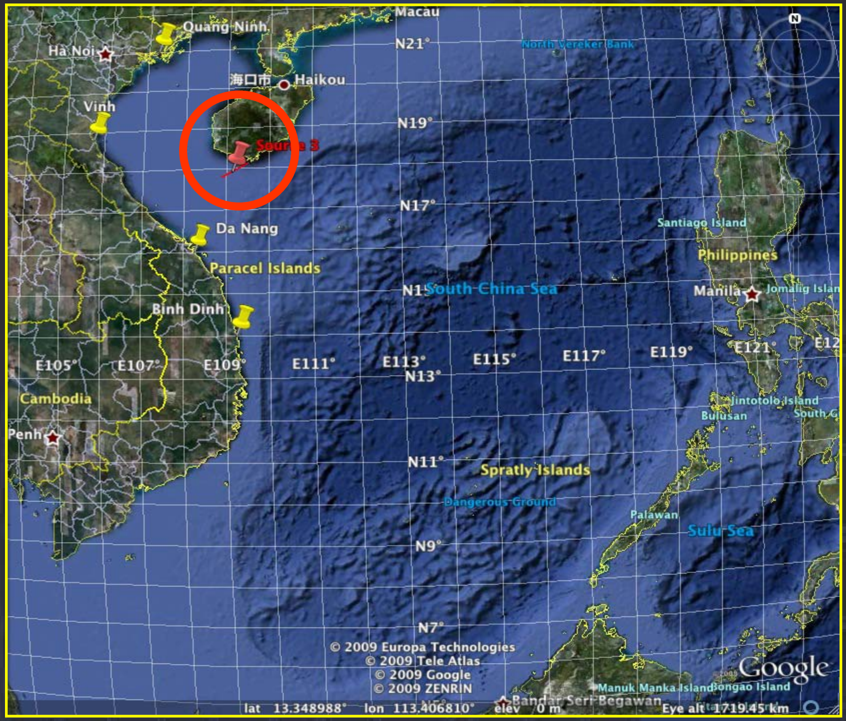


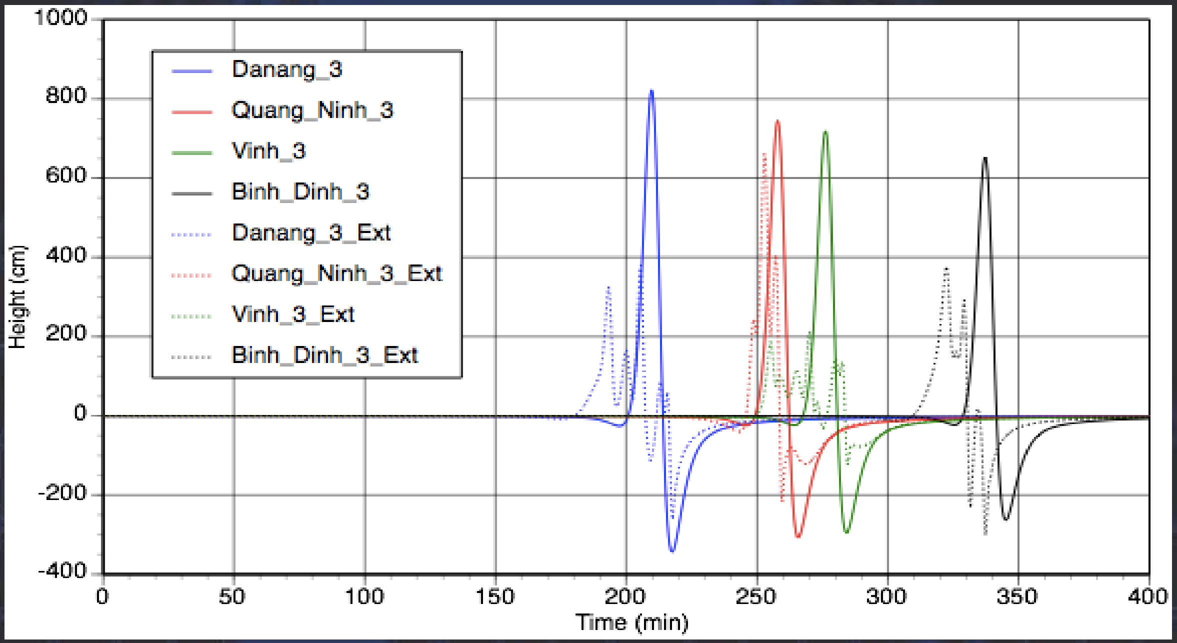
2-dimensional final slip distribution over a source rectangle. Rupture front evolution is simulated kinematically from random rupture velocity field.

Method DWN (Pavlov, 2002)



Tsunami scenarios – Extended Source 3

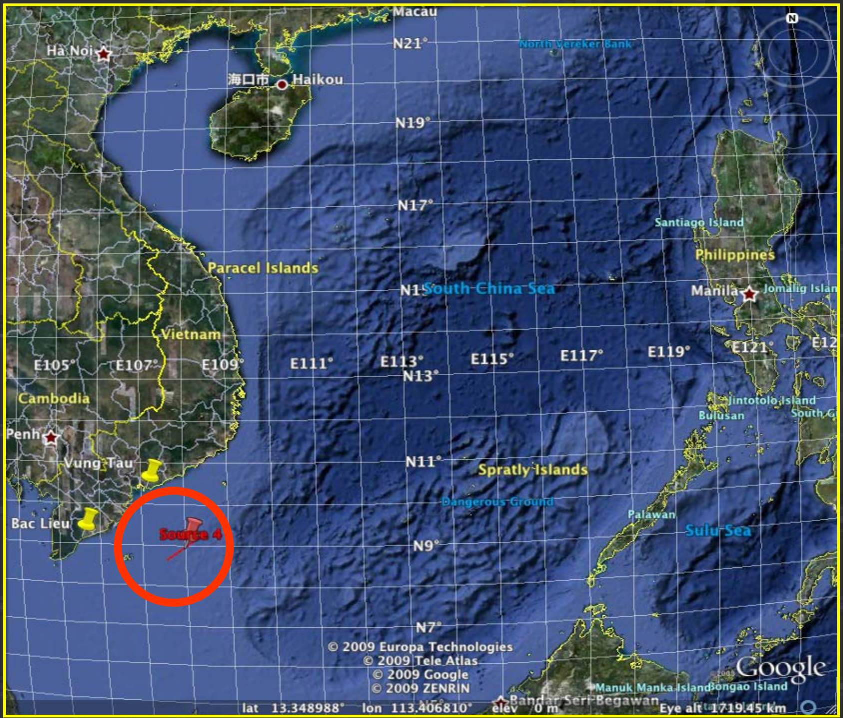


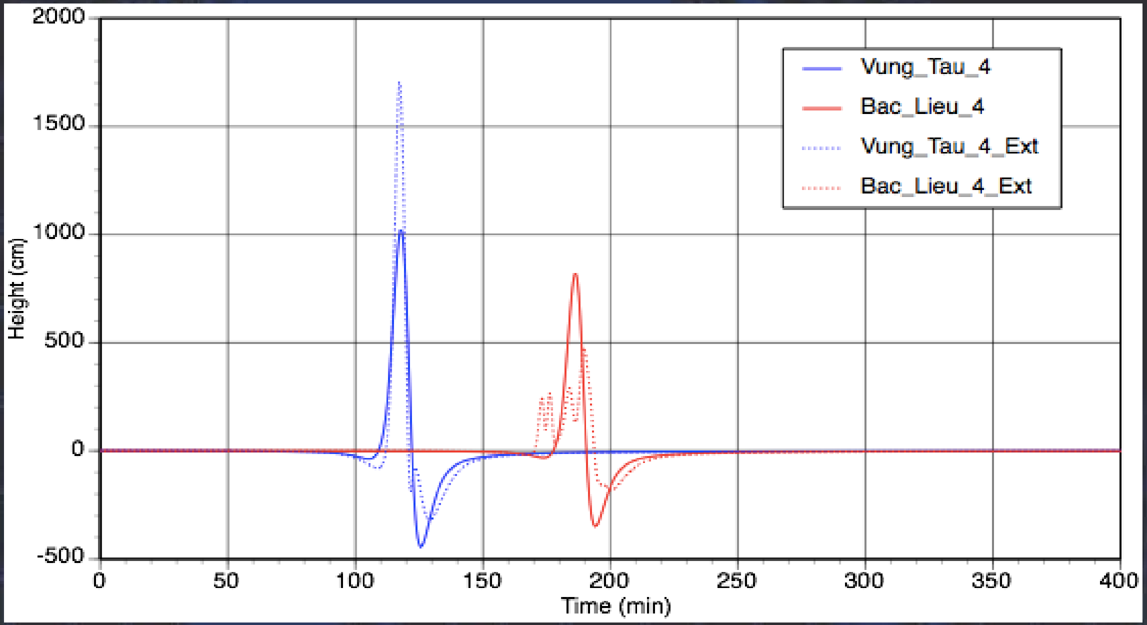


Synthetic tsunamigrams computed at the different sites for Source 3 scenario, considering point source approximation (continuous line) and **extended source** (dashed line)

Site	Da Nang	Quang Ninh	Vinh	Bin Dinh
Distance (km)	268	366	392	478
Tmax (min)	210	258	277	338
Tmax – Tmin(min)	12	13	12	12
Strike max (°)	120	52.5	0	90
Max(cm) M=7	56	50	49	44
Max(cm) M=7.5	314	285	276	250
Max(cm) M=8	823	744	720	654

Tsunami scenarios – Extended Source 4





Site	Vung Tau	Bac Lieu
Distance (km)	169	275
Tmax (min)	118	187
Tmax − Tmin(min)	13	13
Strike max (°)	60	0
Max(cm) M=7	68	54
Max(cm) M=7.5	384	308
Max(cm) M=8	1022	820

Synthetic tsunamigrams computed at the different sites for Source 4 scenario, considering point source approximation (continuous line) and **extended source** (dashed line)

Tsunami hazard for the Vietnam's coasts

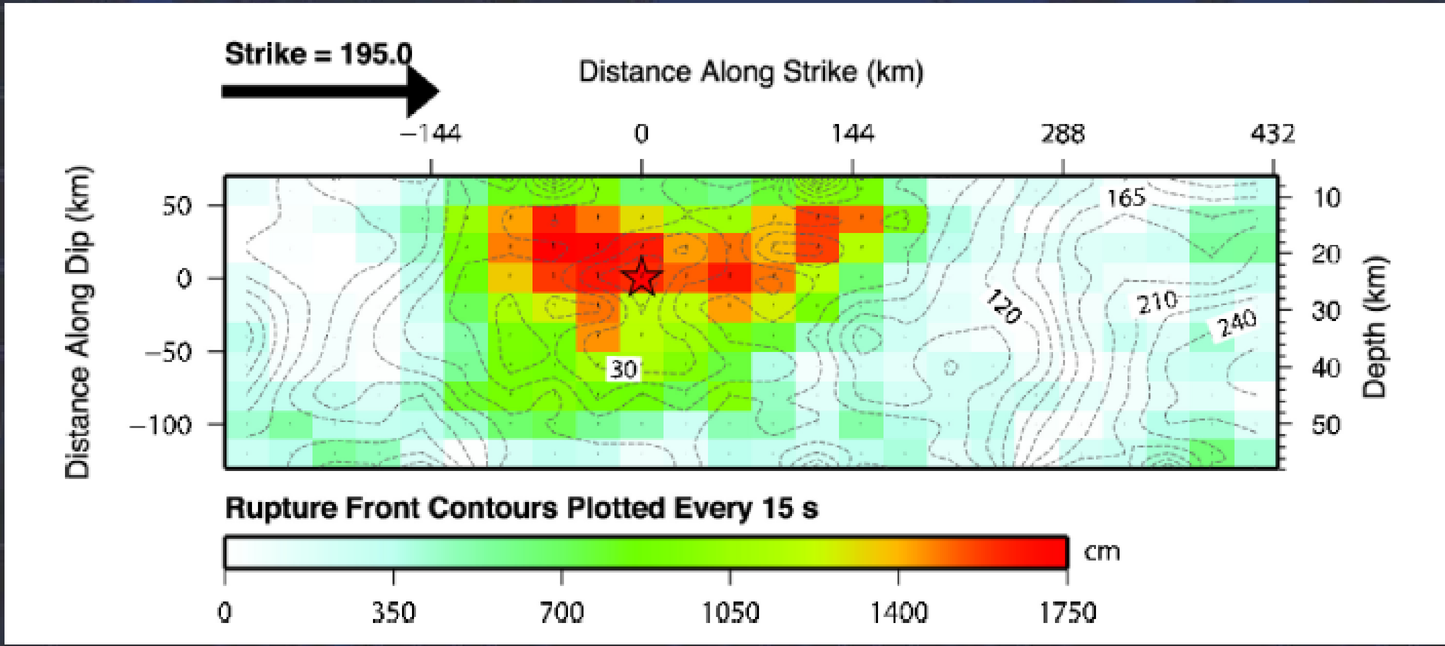
- Events with magnitude M=8.0 (which is nearly the maximum magnitude expected in many regions of the South China domain) could generate tsunamis with amplitudes up to a few meters, in agreement with a number of historical events reported in the catalogues.
- The shoaling and other amplification phenomena due to the local morphology, could increase that amplitude, enough to cause some damages and inundations, specially if coinciding with the high tide or a sea storm.
- The low level of monitoring of the South China Sea and the high degree of anthropization of the Vietnam coasts (and their high level of vulnerability) could make the risk quite high.

Japan earthquake March 11, 2011

Extended earthquake source information

Finite Fault Model: Preliminary result of the Mar 11, 2011 Mw 8.9 Earthquake Offshore Honshu, Japan (*Gavin Hayes, USGS*):

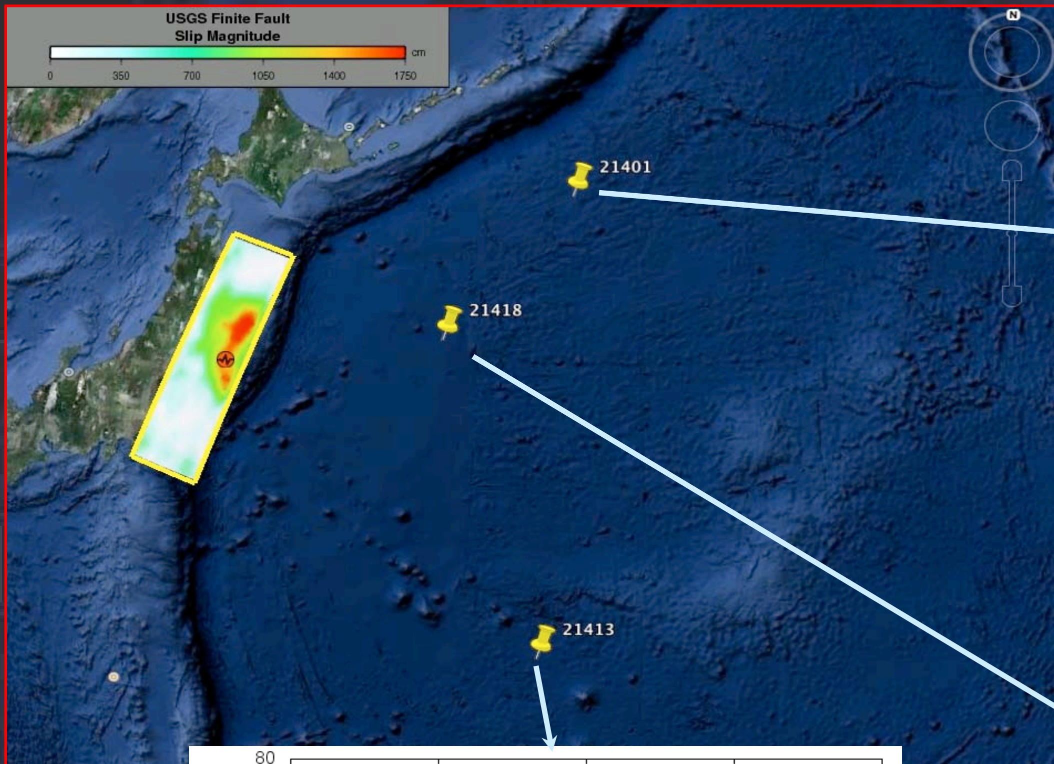
http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usc0001xgp/finite_fault.php



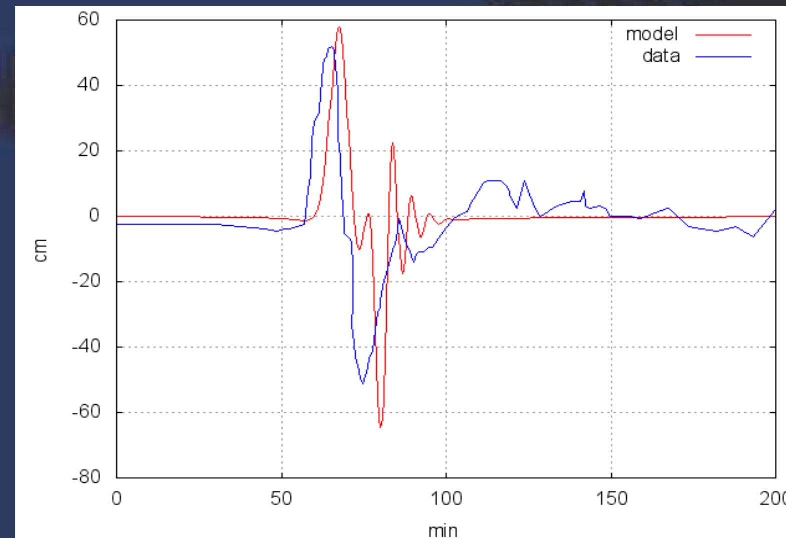
Cross-section of slip distribution. The strike direction of the fault plane is indicated by the black arrow and the hypocenter location is denoted by the red star. The slip amplitude are showed in color and motion direction of the hanging wall relative to the footwall is indicated by black arrows. Contours show the rupture initiation time in seconds.

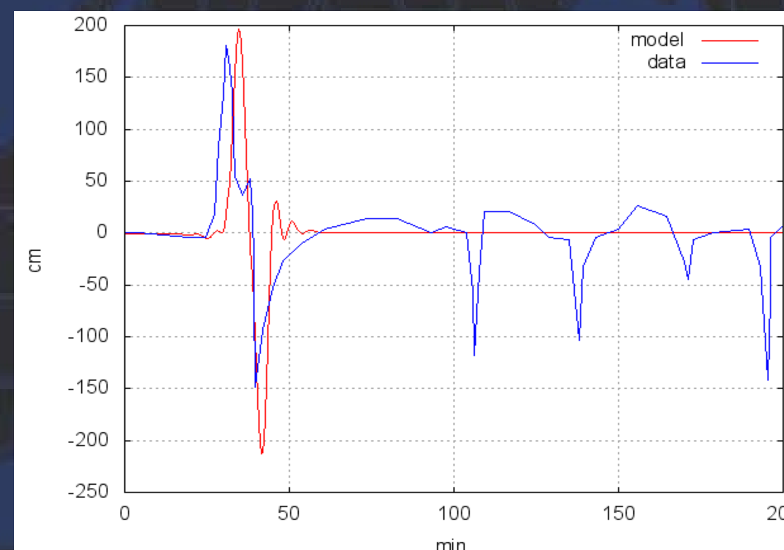
Japan earthquake March 11, 2011

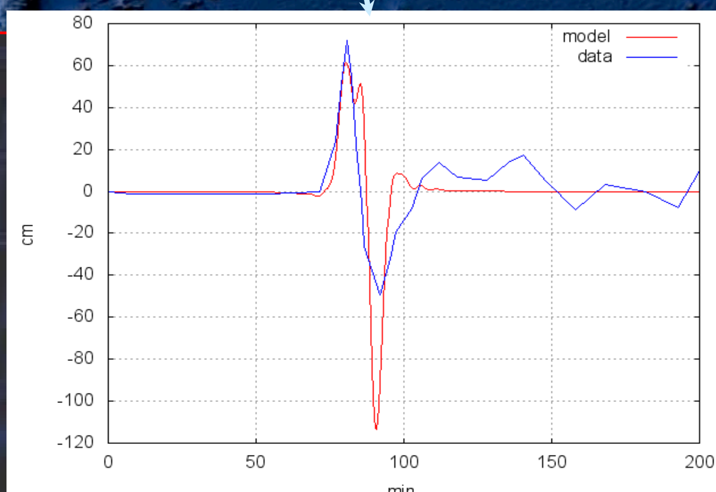
(few seconds of computations...)



Modeled vs Observed tsunamigrams





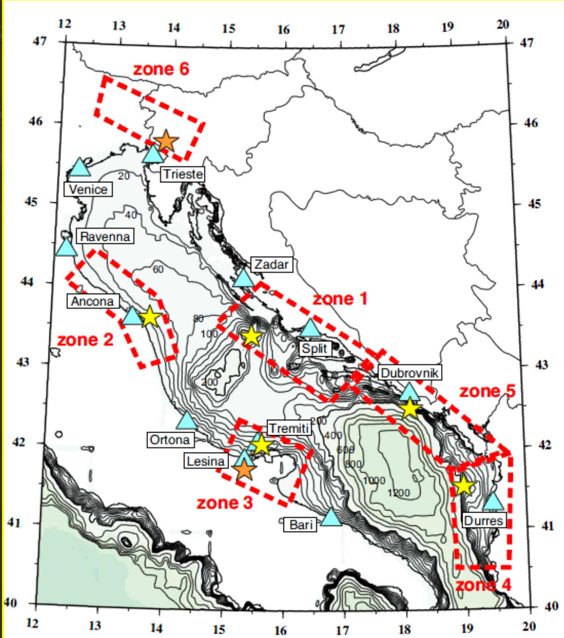


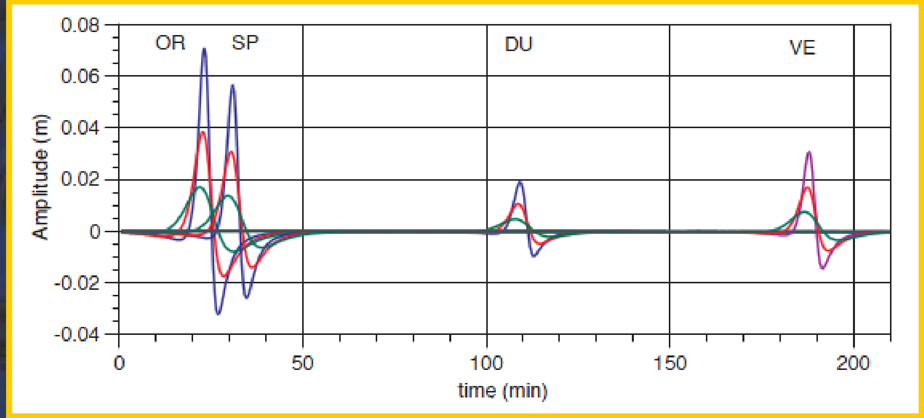
Tsunami hazard: inland sources

The tsunamis are computed for different scenarios, compatible with seismic history and seismotectonics

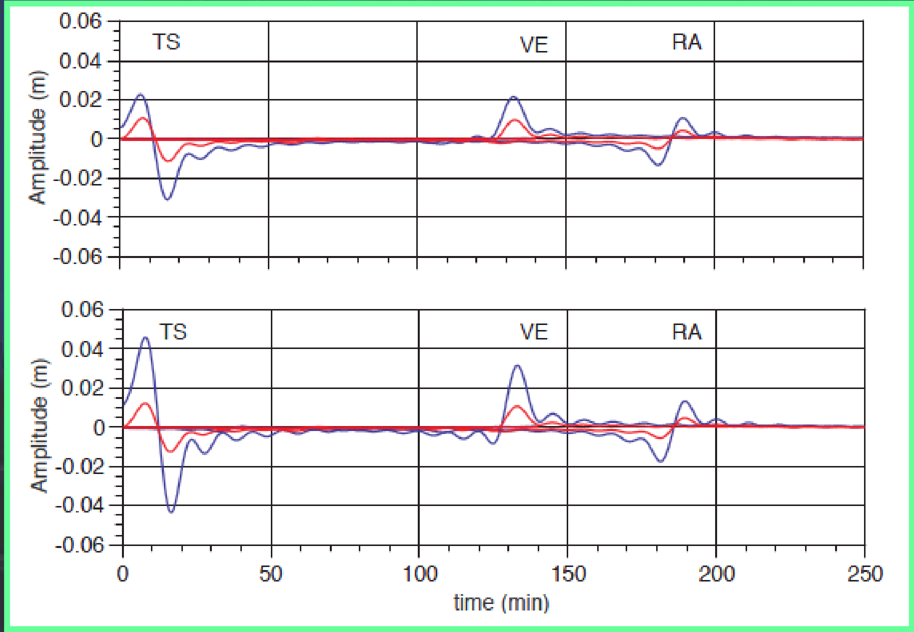
Two possible source localizations adopted for the tsunami modeling :
1) **offshore**, in front of the Croatian coastlines, where many historical tsunamis occurred
2) **inland**, associated to the historical event of 26/3/1511

Area:
Adriatic Basin



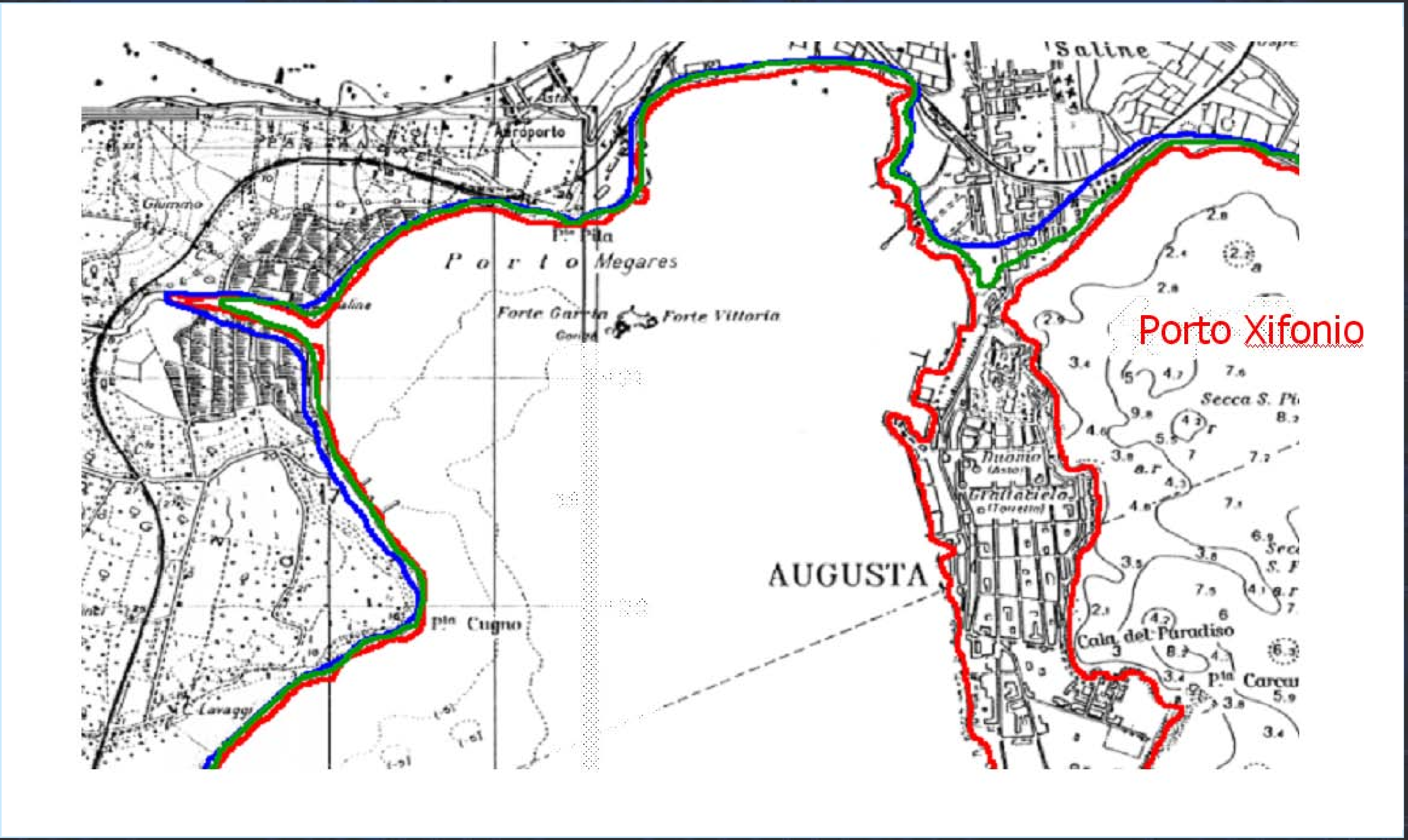


Synthetic mareograms for Zone 1, H =10 km (blue), 15 km (red), 25 km (green). Magnitude: M =6.5.



Synthetic mareograms for Zone 6, magnitude, M=7.0. Above: dip angle=45˚; below: dip angle=30˚. Blue line, d=20 km; red line, d=40 km.

Tsunami hazard: expected waves ingression



Comparison of the coast line in quiet conditions and maximun ingression of two scenario tsunami A and B

Conclusions

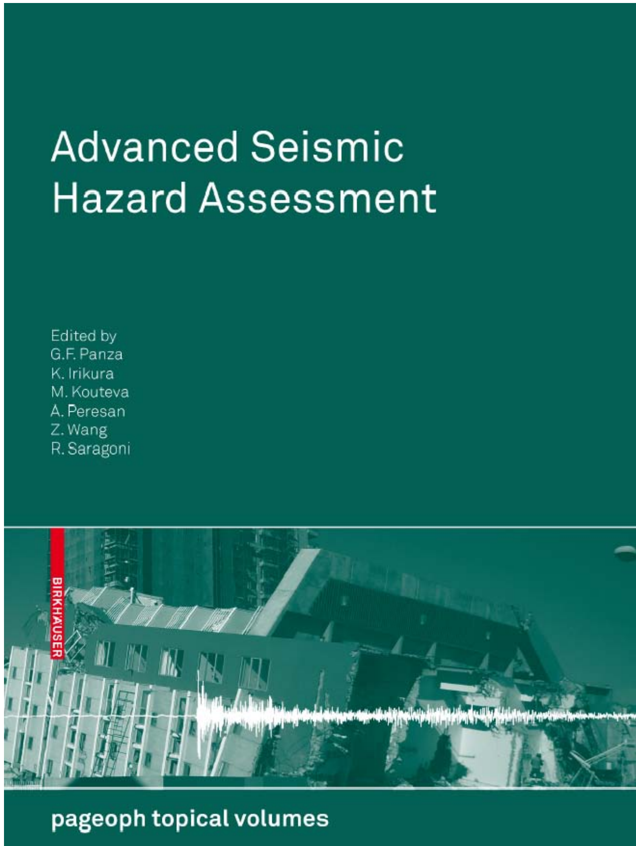
- The considered method, based on modal technique, makes it possible to define a set of earthquake-generated tsunamis scenarios for the Vietnam coasts, using the current knowledge of the physical process of earthquake generation and wave propagation.
- An improved computational capability would enable us the fast computation of increasingly realistic tsunamigrams, dealing efficiently with the complexity of the seismic sources, and to carry out parametric studies that may permit accounting for the related uncertainties.

International Collaborations

Long-term international collaborations on seismic and tsunami hazard assessment are ongoing, based at the DiGeo - University of Trieste and at the ICTP-SAND Group, in the framework of various projects and scientific networks:

- **Europe**: Switzerland, Germany, Spain, Russia,
CEI Countries network: Bulgaria, Croatia, Czech Republic, Hungary, Romania, Albania, Macedonia, Republic of Moldova
- **Asia**: China, India, Iran, Pakistan, Vietnam, Nepal
("Seismic hazard in Asia" Scientific Network)
- **Africa**: Morocco, Algeria, Tunisia, Libya, Egypt, Ghana
(NASG – North Africa Seismological Group)
- **America**: Cuba, Chile, Argentina, Ecuador, USA

Activities: ICTP advanced schools and workshops (on a yearly basis); fellowships, scholarships and visits exchange; sharing of software and computing resources.



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Part I: Seismic Hazard Assessment, ISBN 978-3-0348-0039-6
Part II: Regional Seismic Hazard and Seismic Microzonation Case Studies, ISBN: 978-3-0348-0091-4

Advanced Seismic Hazard Assessment

Editors: G.F. Panza (Italy), K. Irikura (Japan), M. Kouteva (Bulgaria), A. Peresan (Italy), Z. Wang (USA), R. Saragoni (Chile)

ICTP Advanced Conference on *"Seismic Risk Mitigation and Sustainable Development"*

(Trieste, 10-14 May 2010)

Main outcomes:

- Current methods for seismic hazard assessment are moving towards physical modelling of earthquake ground motions, mainly due to the lack of statistically representative and complete data.
- Both probabilistic and deterministic methods are essentially coming to a scenario-based approach, aiming to include a wide range of possible seismic sources into their analysis.

The Abdus Salam International Centre for Theoretical Physics

Advanced Conference on "Seismic Risk Mitigation & Sustainable Development"

10 – 14 May 2010

(Miramare - Trieste, Italy)

The Abdus Salam International Centre for Theoretical Physics (ICTP), in the framework of the PCFVG-ICTP Agreement, funded by the Civil Defence of the Friuli Venezia Giulia Region, and the ASI-SISMA Project, funded by the Italian Space Agency, is organizing under the auspices of the Italian Ministry for Environment and Land and Sea (Ministero dell'Ambiente e della Tutela del Mare e del Territorio) an Advanced Conference on "Seismic Risk Mitigation and Sustainable Development". The Conference, co-sponsored by UNESCO-IPRED, GLIS (Working Group on Seismic Isolation), ASSISI (Anti-Seismic Systems International Society) and ENEA, will take place from 10 to 14 May 2010.

The Conference will span from theoretical issues to practical engineering and decision-making problems, recognizing the societal need for a critical and realistic view to earthquake hazard assessment, which should be attained by advanced independent approaches and exploiting of available seismological, geological and geophysical knowledge, to the maximum possible extent.

Top scientists/experts in the field and participants from developing countries (seismologists, engineers, decision makers) are foreseen to attend the Conference. The Conference will facilitate and accelerate interaction of science - practice and exploitation of scientific achievements in the decision-making process. Lectures will cover the following topics:

- *The concept of sustainable development related to Earthquake Preparedness, Hazard and Risk mitigation;*
- *General issues of Seismic Hazard Assessment (SHA). Classical (deterministic and probabilistic) and innovative (neo-deterministic and scenario-based) SHA approaches: advantages and disadvantages. SHA concerns related to seismic regulations;*
- *Advanced SHA tools. Definition of scenario earthquakes. Earthquake lesson and preparedness experience with respect to recent strong earthquakes;*
- *Seismic wave propagation modeling and modeling validation. Strong ground motion data bases and strong motion processing related to the necessity of seismic input modeling;*
- *Seismic zonation at regional, national and metropolitan scale: case studies in Europe, Asia and North Africa;*
- *Educational aspects and problems concerning SHA.*

An open panel discussion will be promoted to debate the limits of current methodologies and available advanced alternatives, taking into account comments and specific requirements from end-users (engineers and stakeholders). The latter will have the possibility of exposure with the most advanced techniques especially useful in countries which need to start from the very beginning and will be able to discuss their own situation/problems. The Conference will thus provide a unique opportunity to establish contacts and receive hints for future implementation of the most advanced techniques in developing countries.

Participants are encouraged to make poster presentations illustrating their own recent research and practical problems, related to the Conference issues.

PARTICIPATION

Scientists and students from all countries that are members of the United Nations, UNESCO or IAEA may attend the Conference that will be conducted in English, therefore participants should have an adequate working knowledge of that language.

As a rule, travel and subsistence expenses of the participants should be borne by the home institution. Every effort should be made by candidates to secure support for their fare (or at least half-fare). However, limited funds are available for some participants who are nationals of, and working in, a developing country, and who are not more than 45 years old. Such support is available only for those who attend the entire activity. There is no registration fee.

REQUEST FOR PARTICIPATION

The application form can be accessed at the activity website http://agenda.ictp.it/smr.php?2142
Once in the website, comprehensive instructions will guide you step-by-step, on how to fill out and submit the application form.

ACTIVITY SECRETARIAT: Telephone: +39-040-2240-355 Telefax: +39-040-2240-585

E-mail: smr2142@ictp.it ICTP Home Page: http://www.ictp.it/

October 2009

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Deadline for: requesting participation:

10 January 2010

Agenda and Summary report:

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