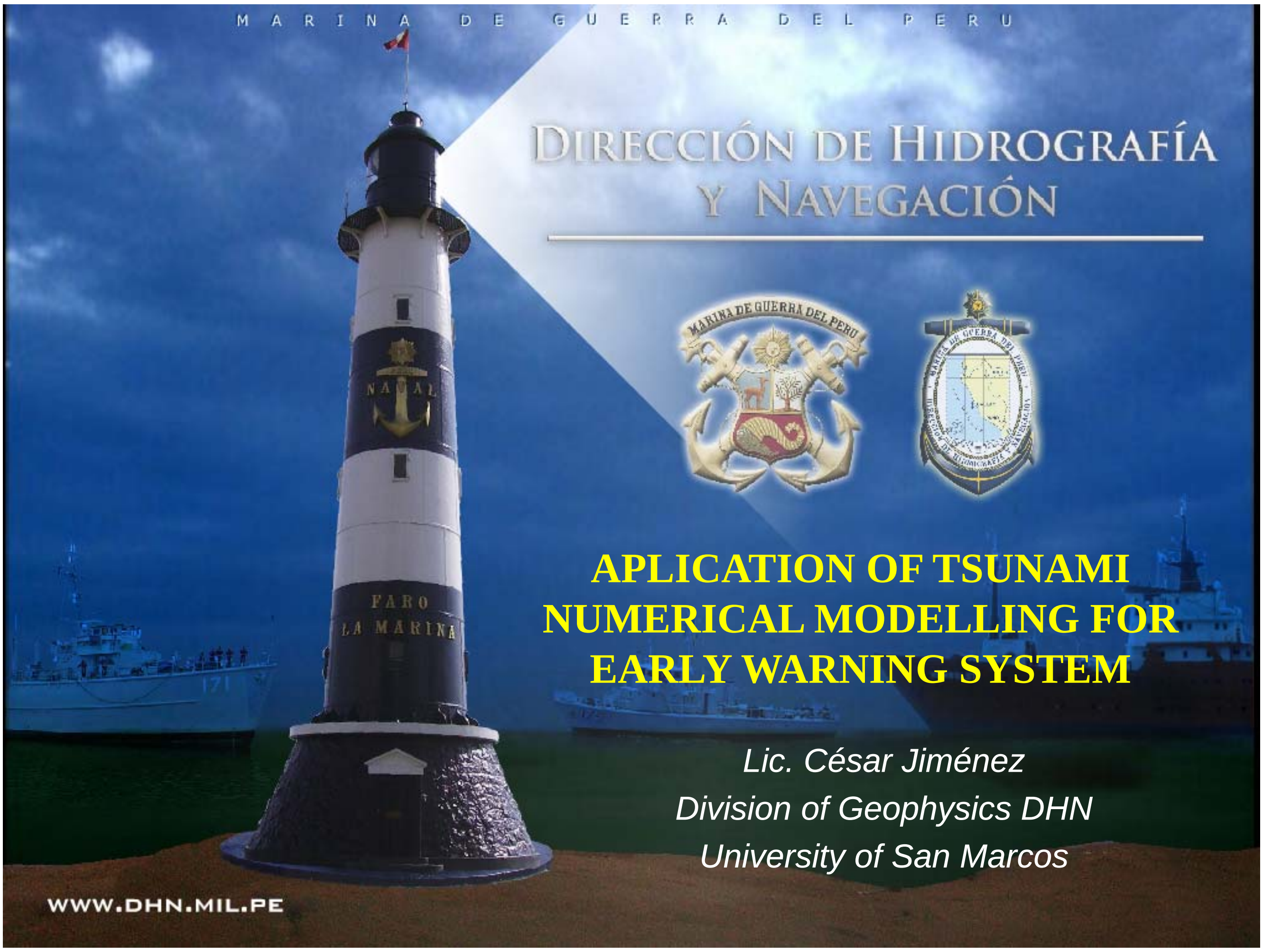
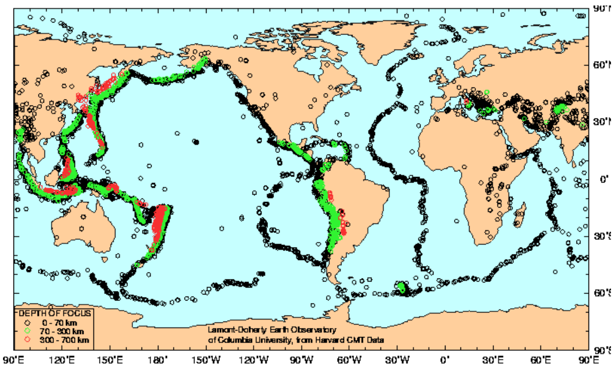
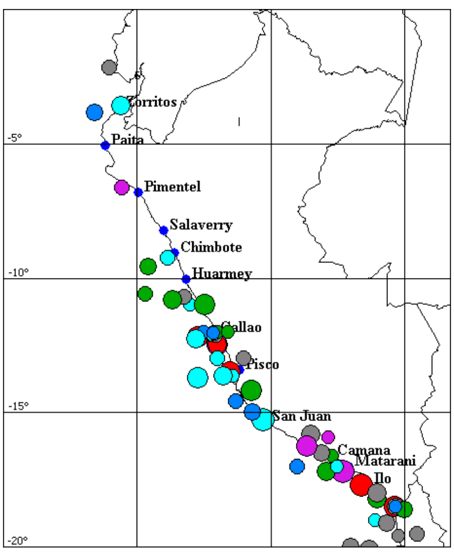
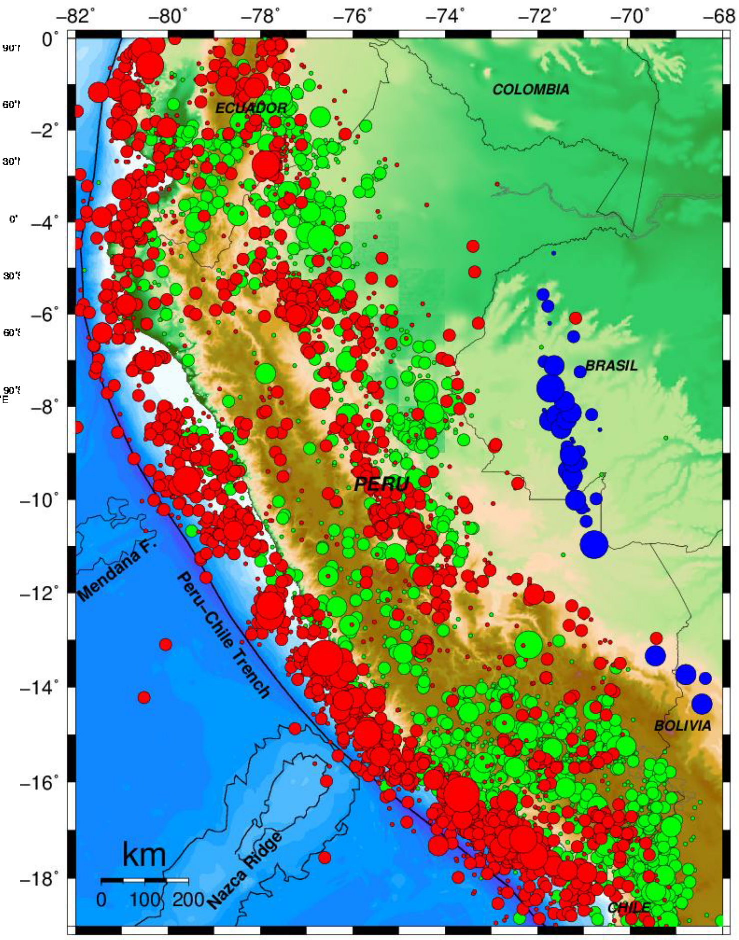


Seismicity of Perú







Seismic gaps

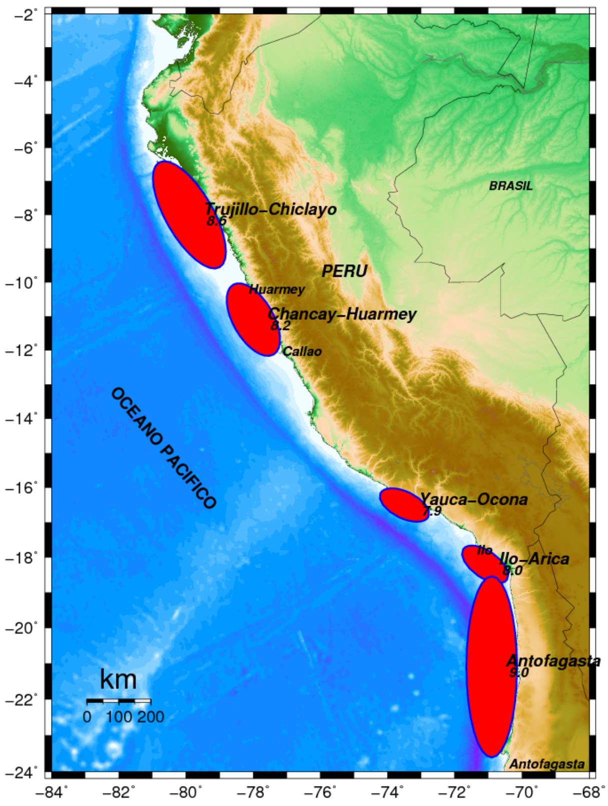
a) Seismic gap of Trujillo-Chiclayo.- Size of the fault 350 km in northern Perú. The potencial magnitude would be at least 8.6 Mw.

b) Seismic gap of Chancay-Huarmey.- Size of fault 200 km (aprox). The potencial magnitude would be at least 8.2 Mw. If the rupture would be from Cañete to Huarmey, the size would be 390 km, magnitude at least 8.7 Mw.

c) Seismic gap of Yauca-Ocoña.- Located in Arequipa. Size of the fault 140 km, The potencial magnitude would be at least 7.9 Mw.

d) Seismic gap of Ilo-Arica.- Size of fault 150 km, located between Moquegua and Tacna. The potencial magnitude would be at least 8.0 Mw.

e) Seismic gap of Arica-Antofagasta: Size of fault greater than 500 km and potencial magnitude 9.0 Mw. The last earthquake took place in 1877.



Remarkable Tsunamis in Peru (*something in spanish, sorry!*)

28 OCTOBER 1746

El Callao fue destruido. Olas más de 10 m. Causó la muerte de 5 á 7 mil habitantes. También hubo destrucción especialmente en Chancay y Huacho.

13 AUGUST 1868

Daños desde Trujillo (Perú) hasta Concepción (Chile); Hawai, Australia y Japón. Terremoto 9.0 Mw, epicentro se localizó en el mar a 70 km de Arica. Olas aproximadamente 14 metros

22 MAY 1960

Originado frente a las costas de Chile, magnitud 9.5 Mw. En la Punta (Callao) el mareógrafo registro 2.2 m de altura. Los daños más grandes fueron en Chile, Hawai y Japón

23 JUNE 2001

Tsunami en Camaná, epicentro en el mar al NW de Ocoña, Magnitud 8.4 Mw. Generó tres olas, la mayor alcanzó una altura de 8m. Causando la muerte de 23 personas, 63 desaparecidos y cuantiosos daños materiales.

15 AUGUST 2007

Originado frente a las costas de Pisco (Ica), magnitud 8.0 Mw. En Lagunillas la altura maxima fue de 10m. En la Punta (Callao) el mareógrafo registro 70 cm de altura.

03 OCTOBER 1974

Originado frente a las costas del Callao, el Tsunami inundo varias fábricas frente a las bahías de Chimú y Tortugas (norte de Lima) destruyendo muelles y cultivos.

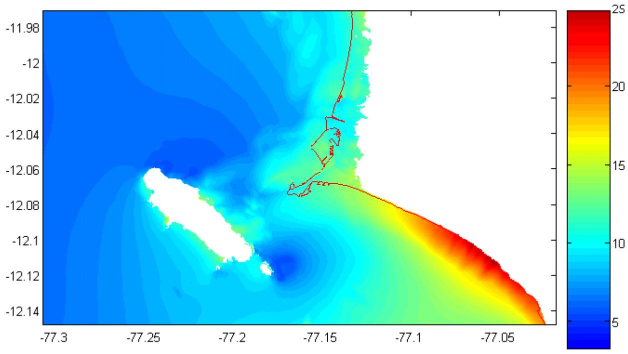
21 FEBRUARY 1996

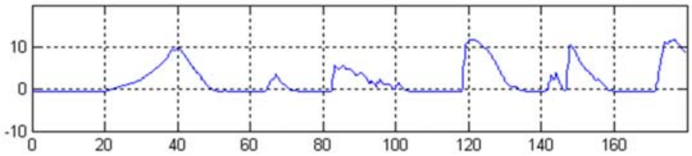
Originado a 210 Km. al SW de Chimbote, Magnitud 6.9. La ola causó daños materiales y pérdidas de 15 vidas humanas en Chimbote, en Salaverry causó daños materiales de poca consideración

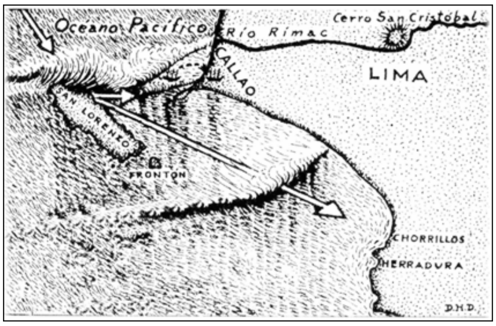
12 NOVEMBER 1996

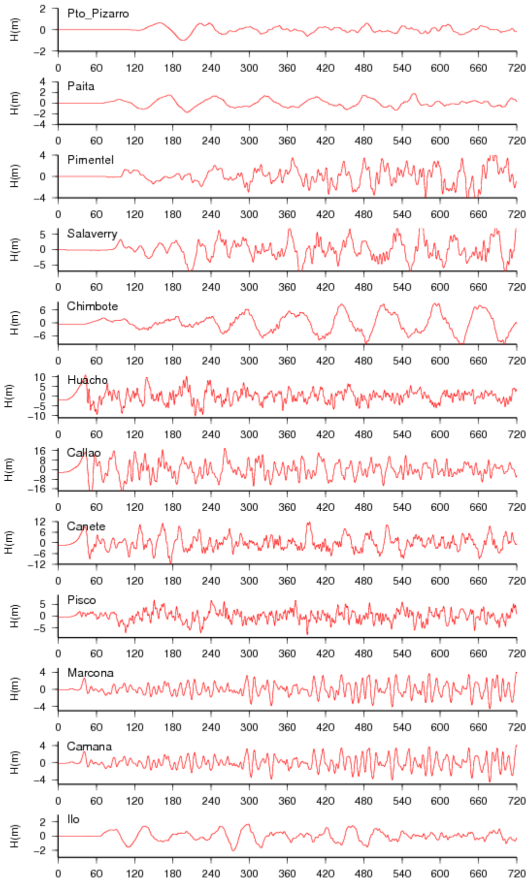
Originado a 93 Km. SW de San Juan de Marcona. Magnitud 6.4 profundidad 46 Km. Causó grandes daños materiales y pérdidas de vidas humanas.

1746 Tsunami of Callao Mw9.0





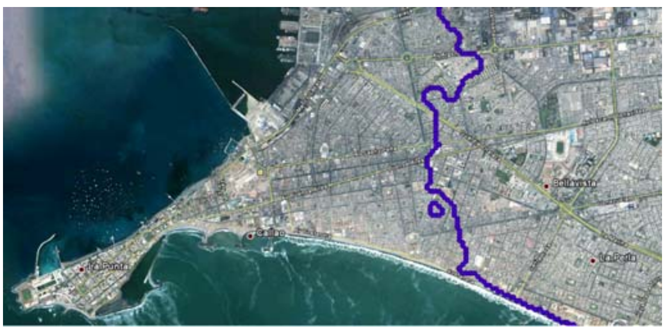




Inundation line for 1746 Callao Tsunami Mw9.0

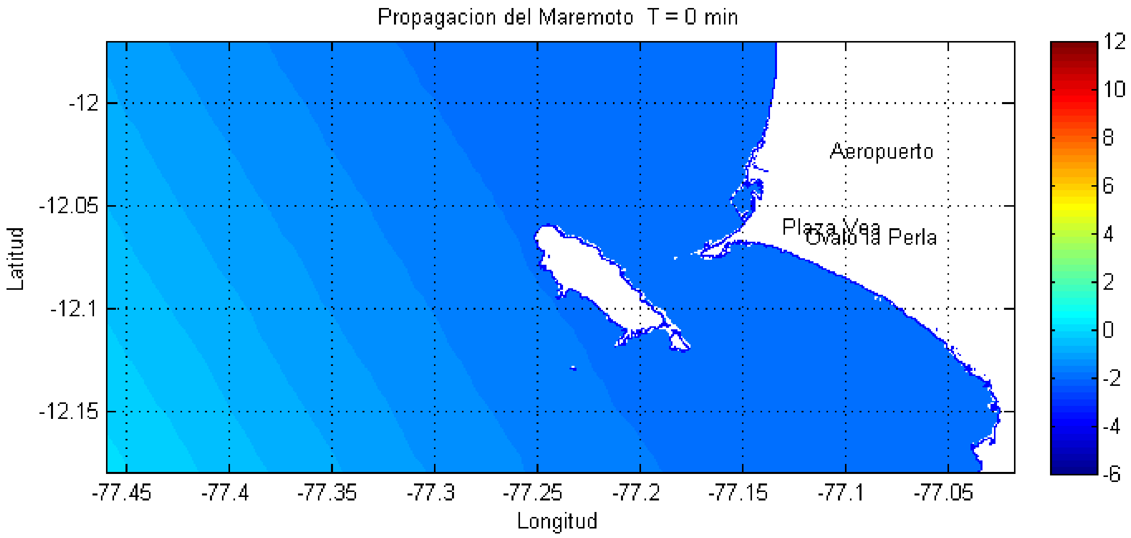
Ventanilla

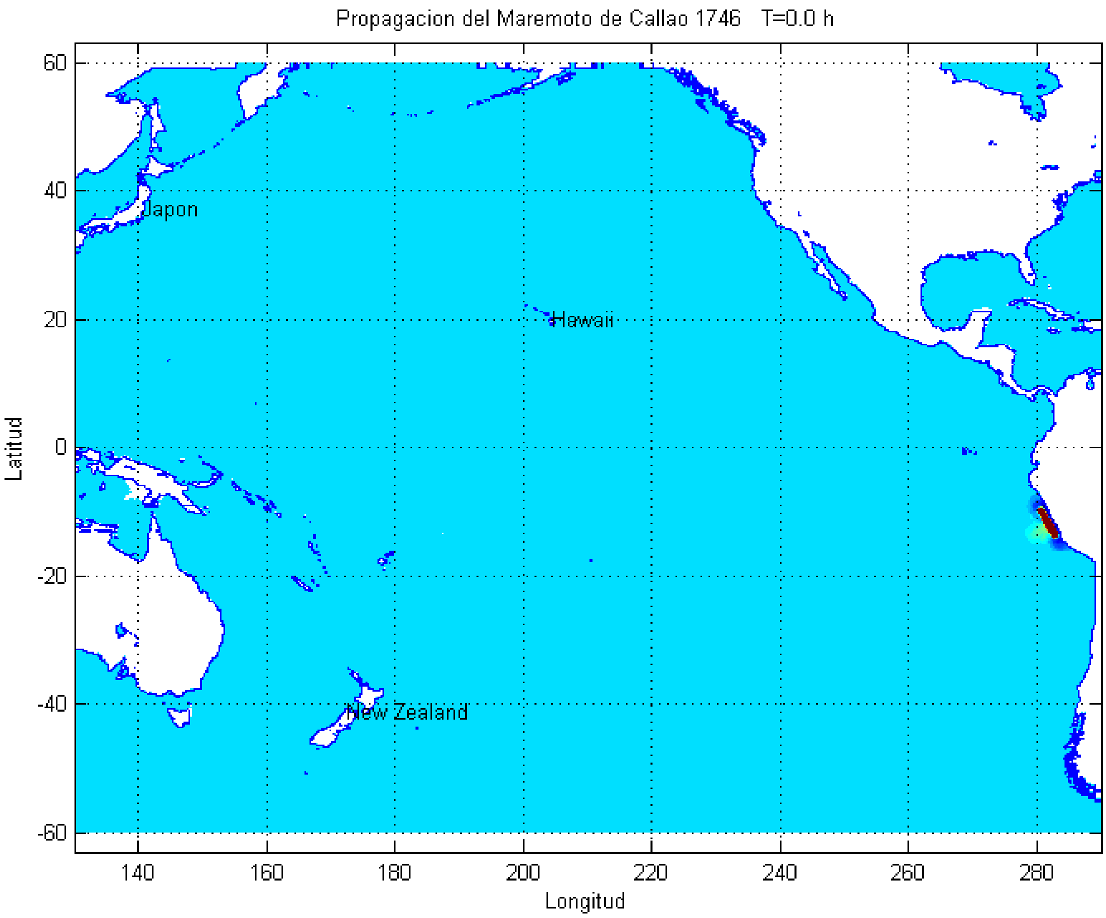
Villa Chorrillos



Callao

Lurín


Propagacion del Maremoto T = 0 min
Aeropuerto
Plaza Vea
Ovalo la Perla
Latitud
Longitud
-12
-12.05
-12.1
-12.15
-77.45
-77.4
-77.35
-77.3
-77.25
-77.2
-77.15
-77.1
-77.05
12
10
8
6
4
2
0
-2
-4
-6


Propagacion del Maremoto de Callao 1746 T=0.0 h
Japon
Hawaii
New Zealand
Latitud
Longitud
60
40
20
0
-20
-40
-60
140
160
180
200
220
240
260
280

TSUNAMI OF CAMANA (AREQUIPA) 2001

EPICENTER
16.15°S; 74.4°W

MAGNITUDE
8.4 Mw

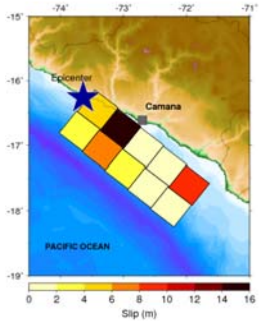
DATE
Saturday, Jun 23, 2001

ORIGIN TIME
15:33:13 (LOCAL)

ARRIVAL TIME
20 minutes

MAXIMUM HEIGHT
8 m

EFFECTS
24 victims due to the tsunami and great material damages.



TSUNAMI OF PISCO (ICA) 2007

EPICENTER
16.15°S; 74.4°W

MAGNITUDE
8.0 Mw

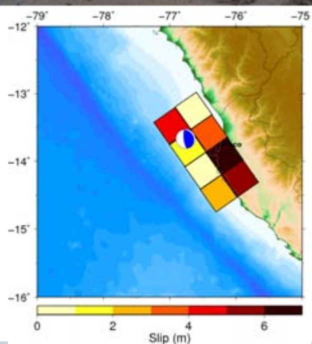
DATE
Wednesday, Aug. 15, 2007

ORIGIN TIME
18:40 (LOCAL)

ARRIVAL TIME
15 min

MAXIMUM HEIGHT
9.5 m (Lagunillas)

EFFECTS
500 victims due to the earthquake and 3 victims due to the tsunami. Great material damages.



TSUNAMI OF CHILE 2010

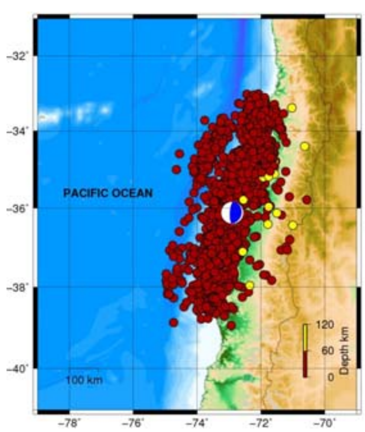
EPICENTER:
Lat: 36.1 S
Lon: 72.6 W

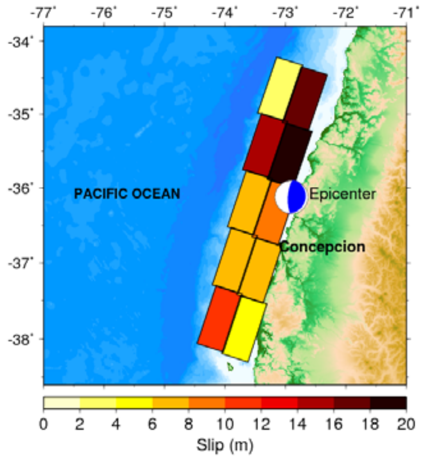
MAGNITUDE
8.8 Mw

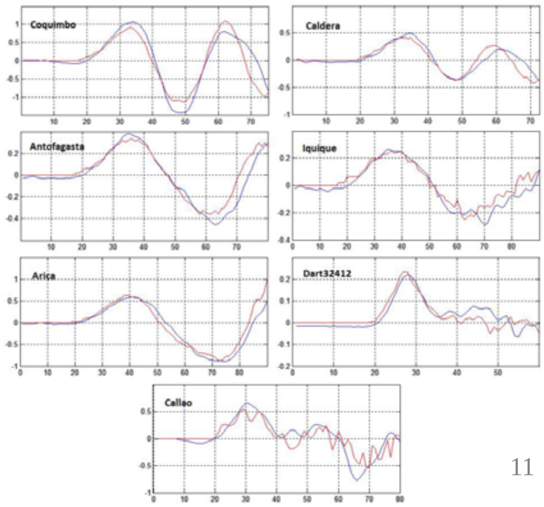
DATE
Saturday, Feb 27, 2010

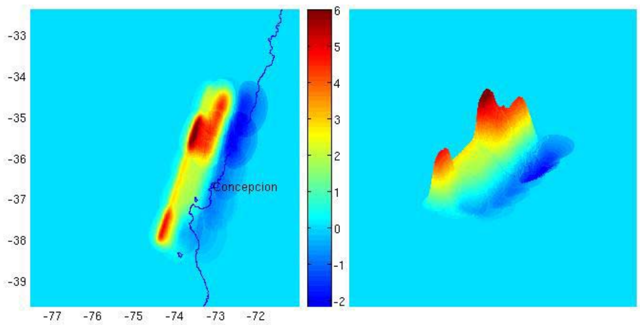
ORIGIN TIME
01:34 (LOCAL)

VICTIMS: near 600



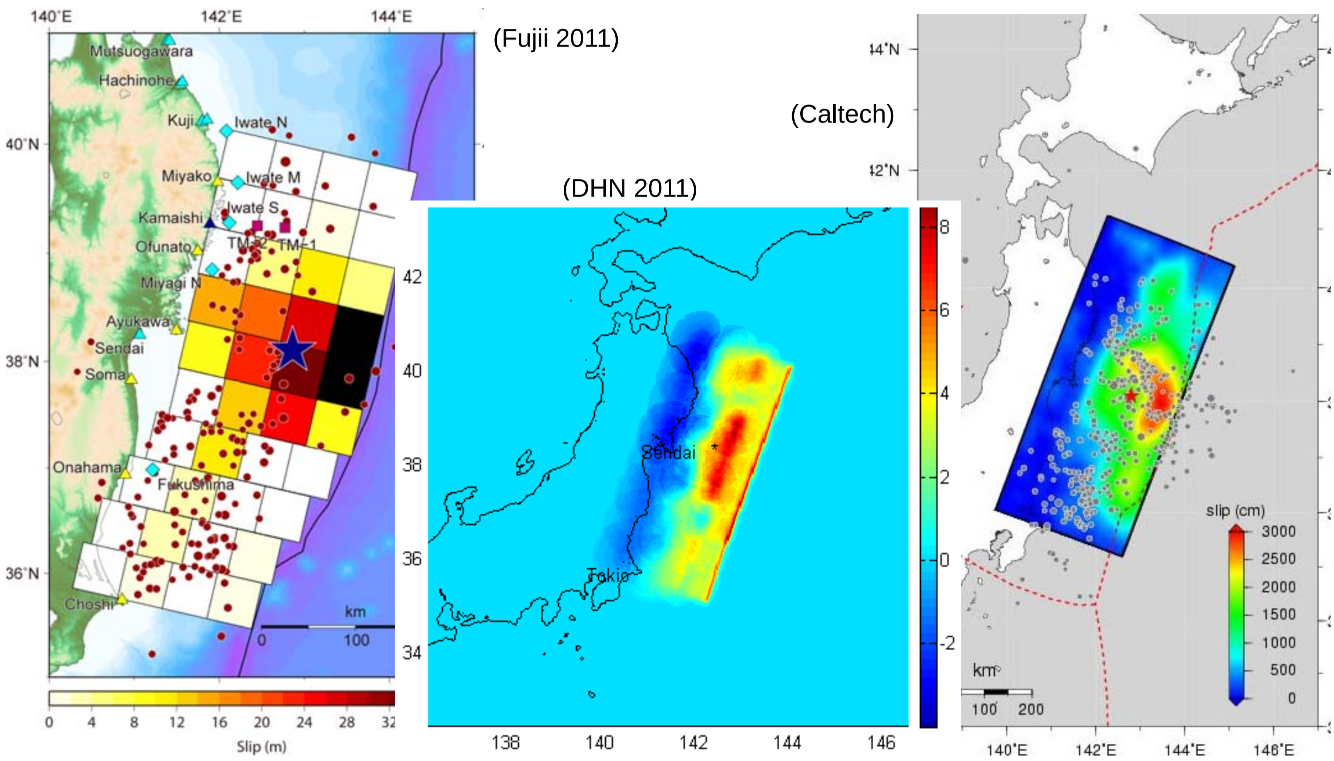






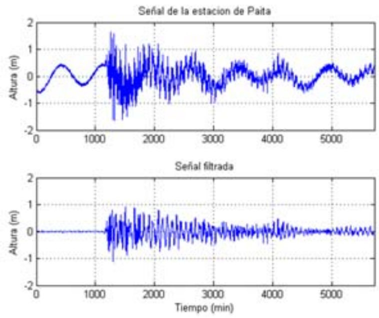
Earthquake and Tsunami in Japan 2011 (Mw=9.0)

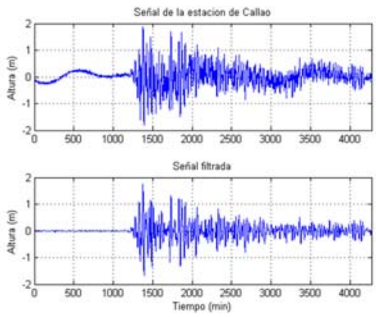
The seismic source model can be obtained from seismic data, geodetic data or tsunami data through inversión method. In this case, the greatest asperity is located just between Sendai and Ofunato, what expains the great destruction caused by the tsunami in this zone.

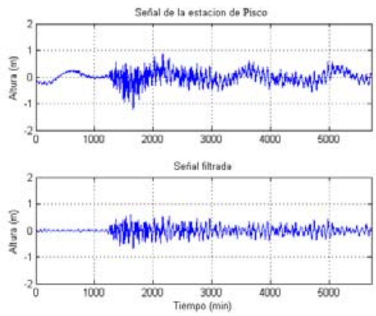


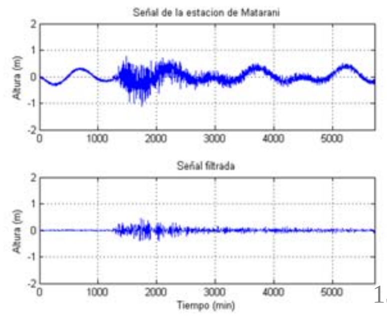
Tsunami 2011: impact on Perú

Station	Max. (m)	Mín. (m)	Per. (min)	Travel time
Paita	0.91	-1.11	78	19h 18min
Callao	1.75	-1.65	45	20h 20min
Pisco	0.58	-0.69	80	20h 30min
Matarani	0.44	-0.40	45	20h 50min









PERUVIAN TSUNAMI WARNING SYSTEM

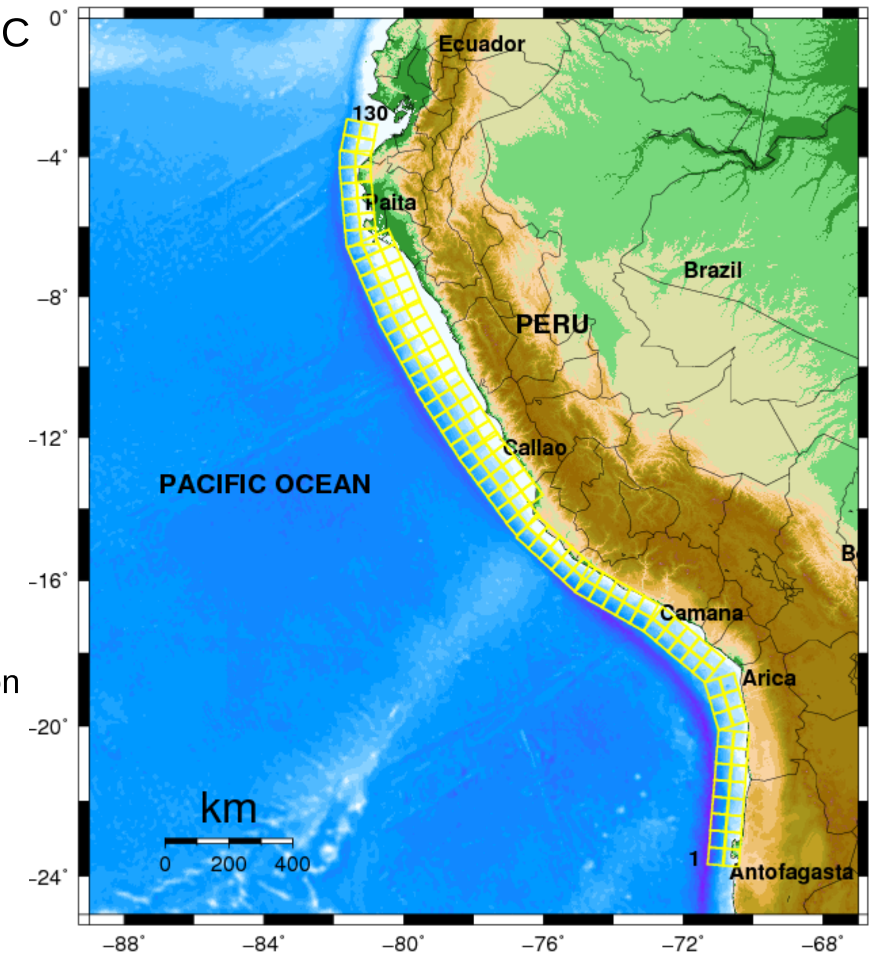
The Direction of Hidrography and Navigation conduct the management of the Peruvian Tsunami Warning System.

We will talk about the advances of numerical tsunami simulation applied for improvement of early warning.

We need a system for to get quickly the tsunami parameters, such as: arrival time and maximun height of the wave for near field tsunamis.

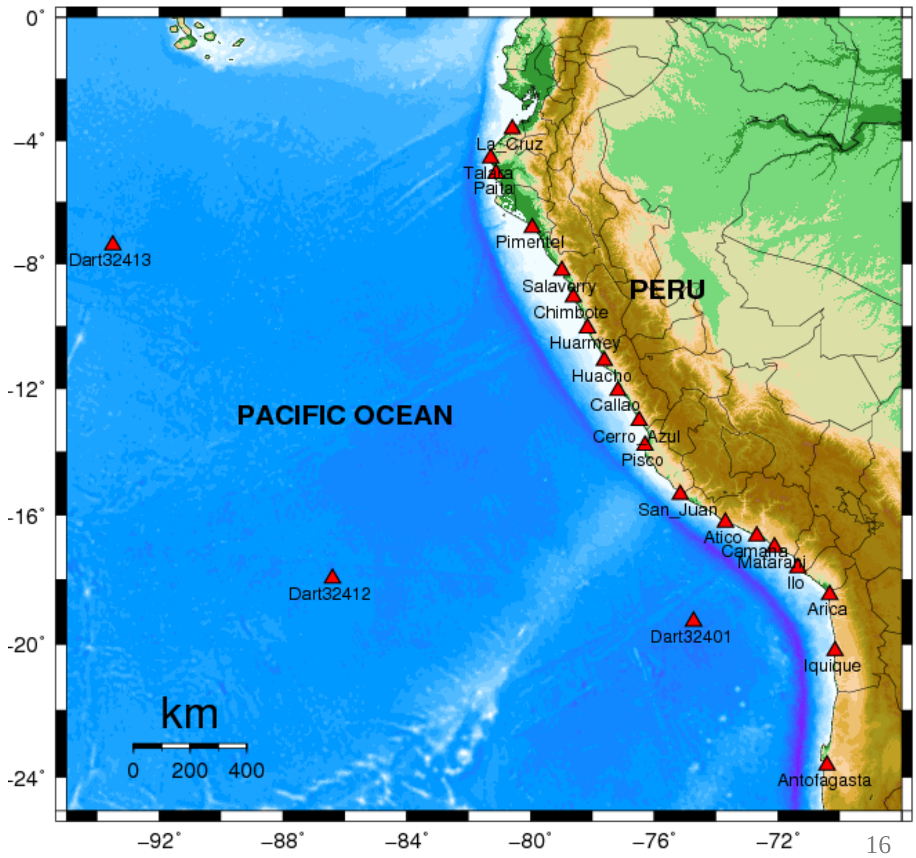
DATABASE OF SEISMIC UNIT SOURCES

- Taking into account the seismicity and seismic gaps of peruvian coast, we have choosen the area from Antofagasta to Ecuador.
- This area was divided in 130 “unit sources” of 50x50 km.
- The idea is to conduct the simulation of tsunami propagation for each unit source and calculate the Green functions or virtual mareograms in some location (see next slide).



Location of virtual Tidal Stations

- We have put 22 virtual stations, most of them coincide with locations of real tidal gauges and 3 DART buoys.
- These virtual gauges belongs to principal cities and harbors along the peruvian coast.
- In some future, we will conduct the post-tsunami waveform inversion for to get the slip distribution.



Database Governing Equations

All the relations are strongly dependent of the magnitude Mw.
The tsunami output is the linear combination of Green Functions
An amplification factor (slip D) is needed.

$$\log(L) = 0.55M - 2.19$$

$$\log(W) = 0.31M - 0.63$$

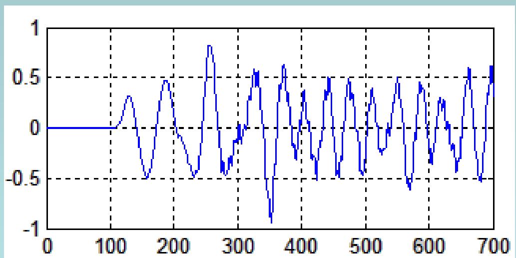
$$\log(M_0) = 1.5M + 9.1$$

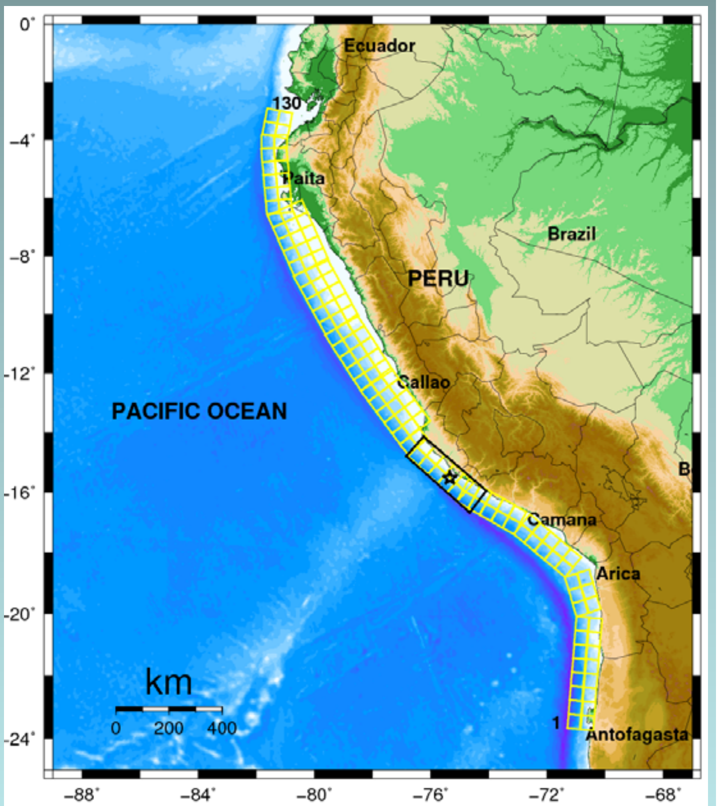
$$M_0 = \mu LWD$$

$$N = \frac{LW}{50*50}$$

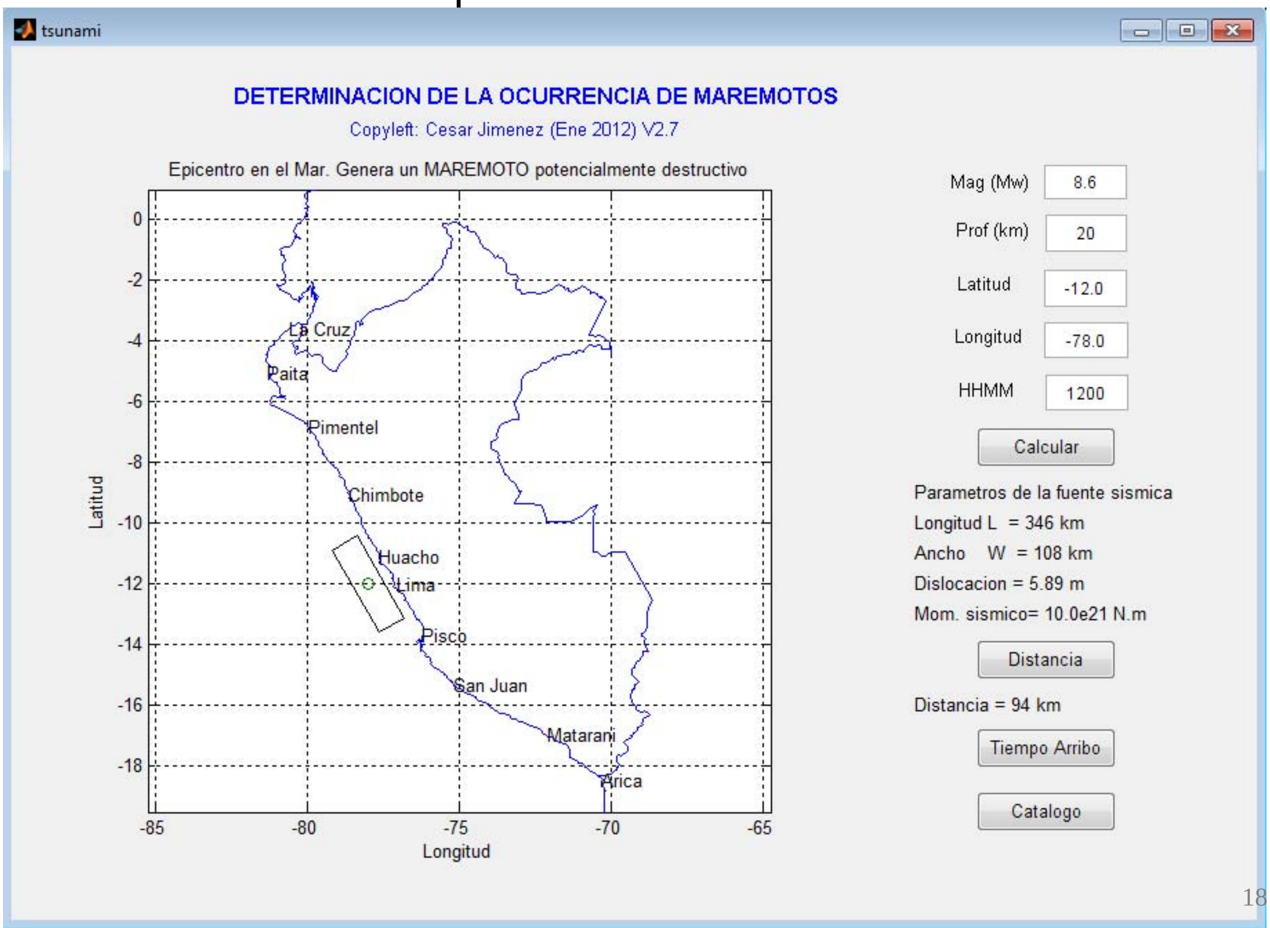
Mw	*N*
7.0	1
7.5	2
8.0	5
8.5	12
9.0	33

$$Tsunami = D\sum_{k=1}^{N}(Green\_Function_k)$$

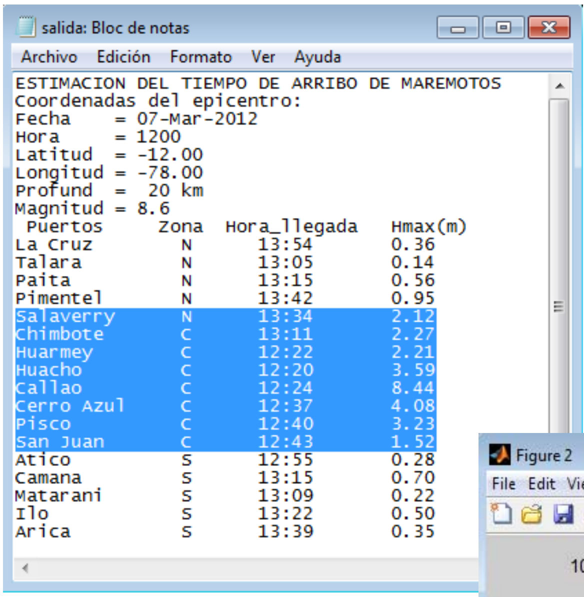




Graphics User Interface



Output of the software from Database



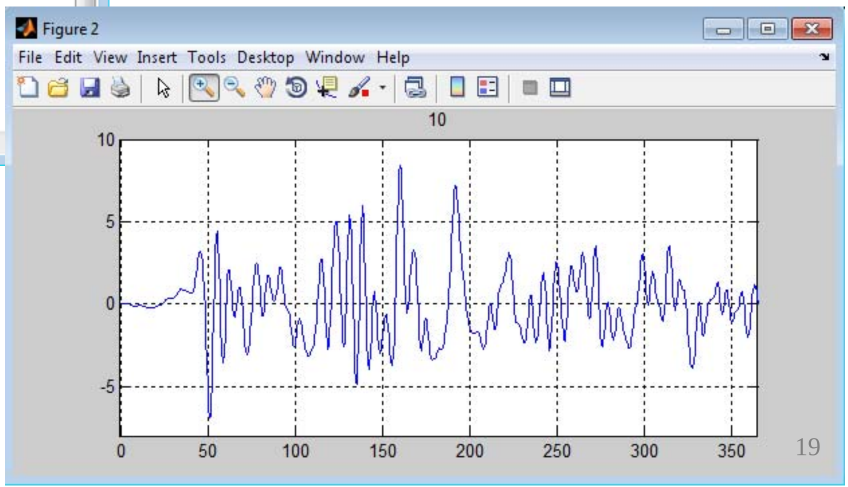
salida: Bloc de notas

Archivo Edición Formato Ver Ayuda

ESTIMACION DEL TIEMPO DE ARRIBO DE MAREMOTOS
Coordenadas del epicentro:
Fecha = 07-Mar-2012
Hora = 1200
Latitud = -12.00
Longitud = -78.00
Profund = 20 km
Magnitud = 8.6

Puertos	Zona	Hora_llegada	Hmax(m)
La Cruz	N	13:54	0.36
Talara	N	13:05	0.14
Paita	N	13:15	0.56
Pimentel	N	13:42	0.95
Salaverry	N	13:34	2.12
Chimbote	C	13:11	2.27
Huarmey	C	12:22	2.21
Huacho	C	12:20	3.59
Callao	C	12:24	8.44
Cerro Azul	C	12:37	4.08
Pisco	C	12:40	3.23
San Juan	C	12:43	1.52
Atico	S	12:55	0.28
Camana	S	13:15	0.70
Matarani	S	13:09	0.22
Ilo	S	13:22	0.50
Arica	S	13:39	0.35

- The output result will be useful only for near field tsunamis.
- The output results are a) the arrival time of the first wave and b) the maximum heigth of the tsunami wave.
- This output will be useful for to give the tsunami warning (or evacuation) only for some cities.



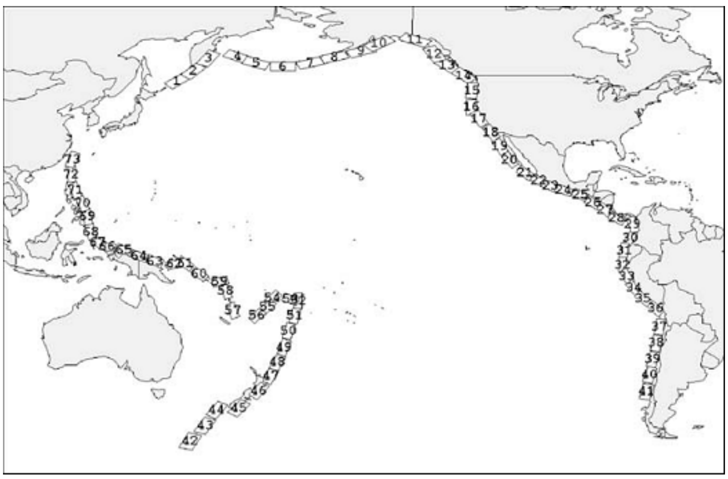
Applications and future research

In the Pacific Ring of Fire there are several seismic "gaps" to be monitored (Cascadia gap, southern Japan gap, etc), so it will be of interest:

1) Development of a catalogue of tsunami simulated or "unit sources" and Green functions for all the Pacific Ring of Fire.

2) Implementation of a quasi real-time tsunami warning system from waveform inversion for near-field tsunamis for Peruvian coasts (a denser tidal network is needed).

3) Implementation of a real-time tsunami warning system for far-field tsunamis from DART buoys inversion.



Picture taken from Koike & Imamura 2003