



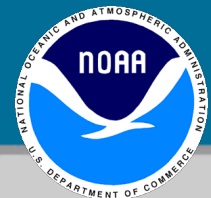
UNESCO/IOC – NOAA ITIC Training Program in Hawaii (ITP-Hawaii)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
7-18 August 2023, Honolulu, Hawaii USA

A Not Too Technical Introduction to PTWC Operations

Presented by Dr. Stuart A. Weinstein, Asst. Director
NOAA/NWS/PTWC

The Tsunami Early Warning Problem

- Most tsunamis are caused by great earthquakes
- Great earthquakes cannot be predicted
- Tsunamis can travel 800km/hr in the deep ocean
- Tsunamis strike within minutes to hours
- Tsunami warnings must be delivered in time to take action to save lives



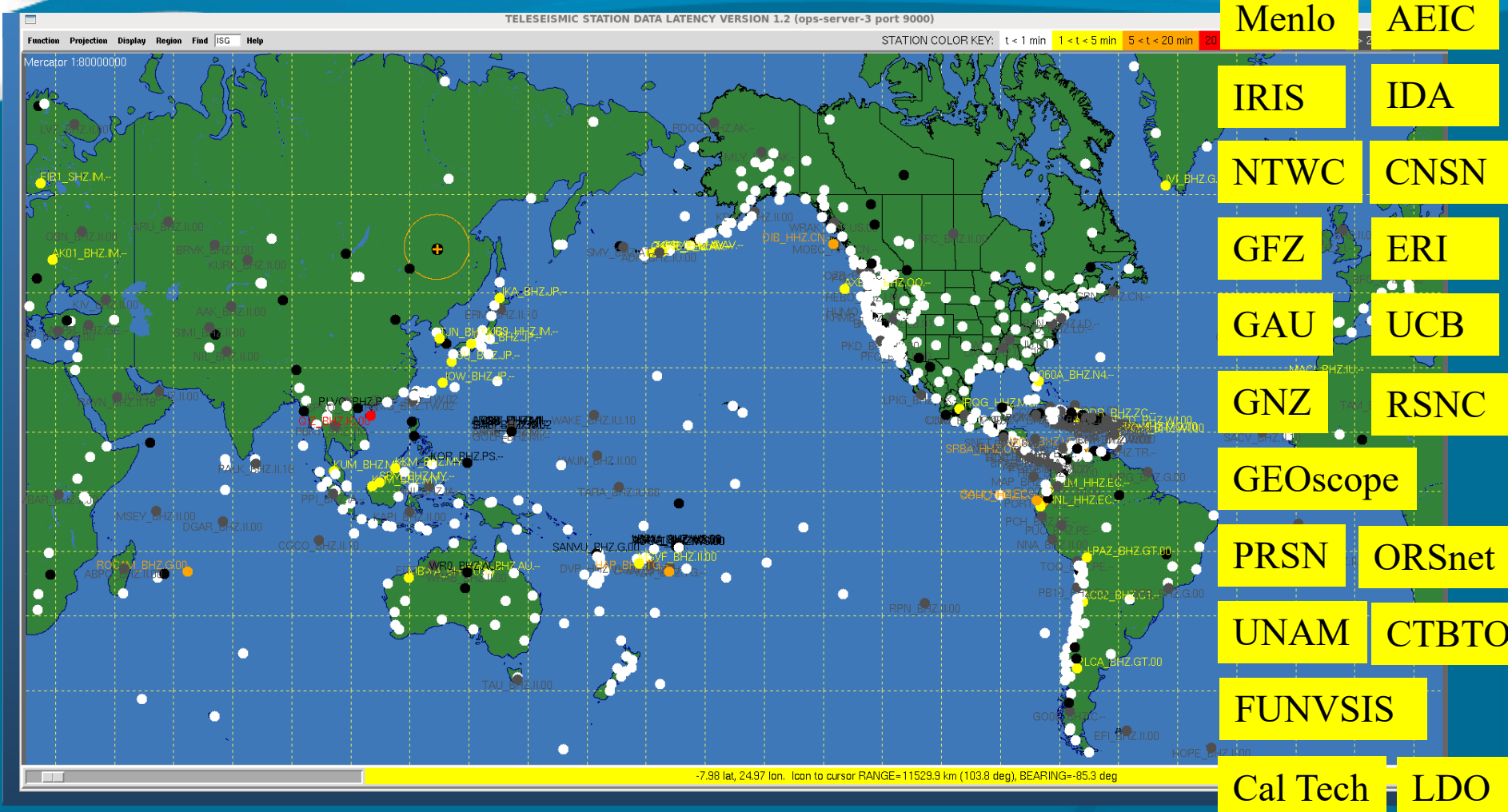
BASIC OPERATIONAL ACTIVITIES

- **SEISMIC DATA COLLECTION, MONITORING, PROCESSING & ANALYSES**
- **SEA-LEVEL DATA COLLECTION, MONITORING, PROCESSING & ANALYSES**
- **TSUNAMI FORECASTING**
- **MESSAGE CREATION & DISSEMINATION**

Global Seismic Processing

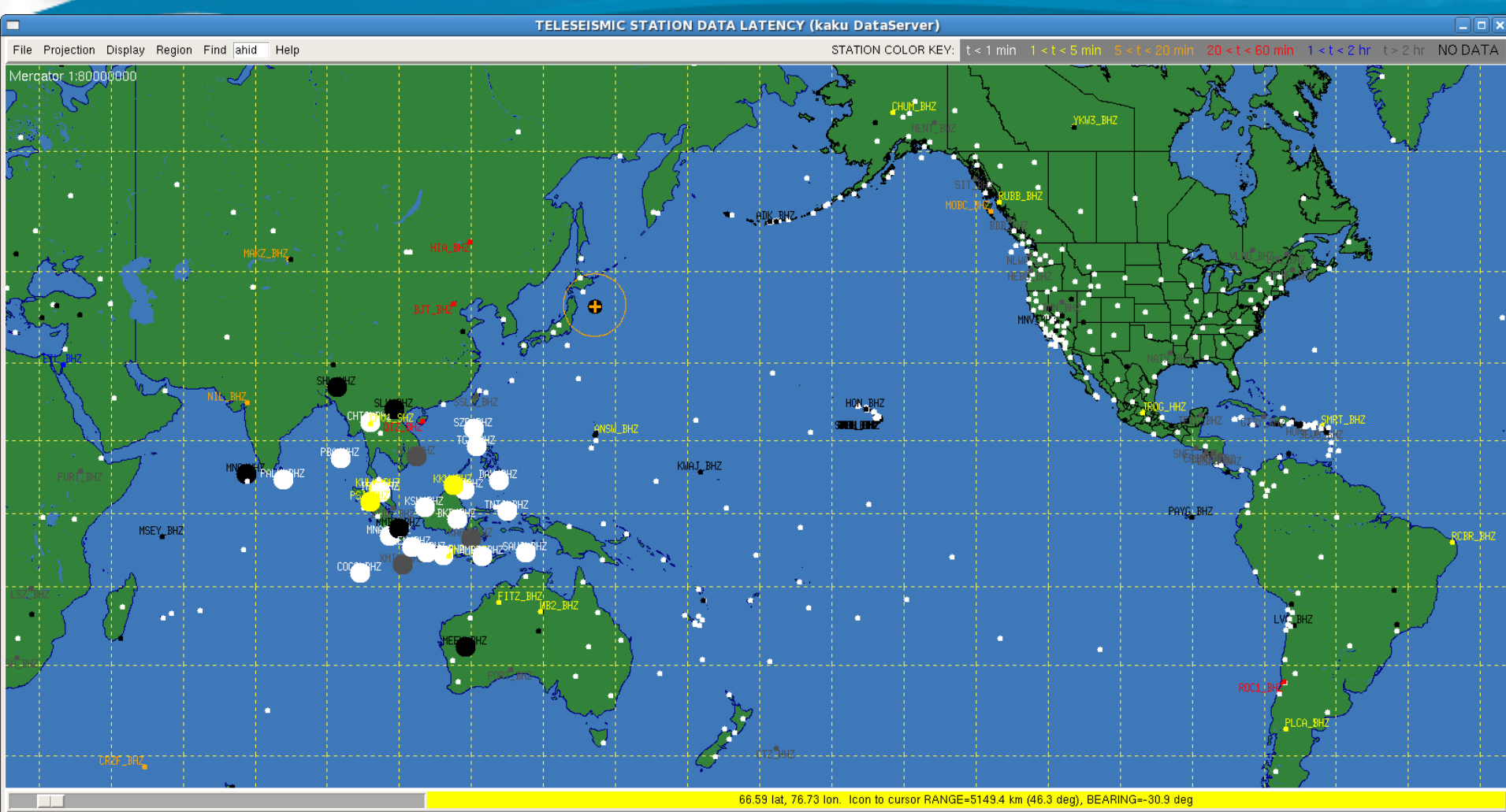


Broadband Seismometer Distribution



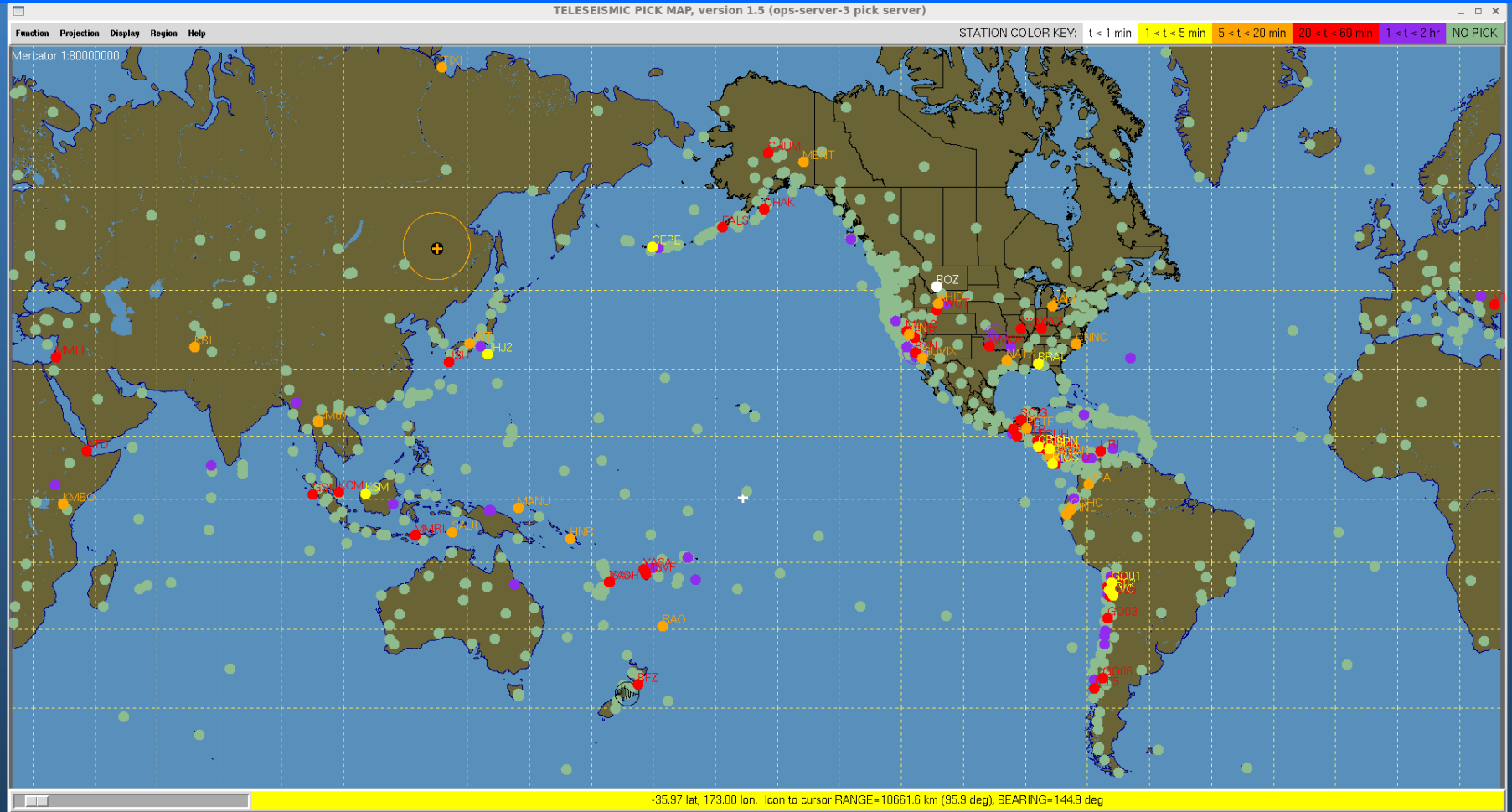
More than 630 Stations!

Broadband Seismometer Distribution



The large dots are the stations involved in the East Indian Ocean Alarm region. PTWC has 14 such alarm regions.

Seismic Detection



Earthquake Location

Function ETAs Obs Message
MASTER RESET

Search params

fix depth => Depth:

set start lat/lon => Lat: Lon:

Display params

display map images

Reset Locate write COMF

picks

load

reviewed auto

Compute ML

	LAT	Lon	DEPTH	ORIGIN TIME	GAP	RMS	PICKS	NEAREST	LOCATION
4	18.59	-68.67	135.5	2017/09/14 03:40:50	153.0	0.65	19	0.3	MONA PASSAGE
5	18.48	-68.71	140.4	2017/09/14 03:40:49	152.0	0.69	22	0.3	MONA PASSAGE
6	18.48	-68.71	140.4	2017/09/14 03:40:49	152.0	0.69	22	0.3	MONA PASSAGE
7	18.48	-68.71	140.4	2017/09/14 03:40:49	152.0	0.69	22	0.3	MONA PASSAGE
8	18.48	-68.71	140.4	2017/09/14 03:40:49	152.0	0.69	22	0.3	MONA PASSAGE

1 2 3 4 5 6 7 8

ARIV ID	STA	PHASE	TIME	RESID	DIST (DEG)	AZIM (DEG)	TYPE	WEIGHT
1	PCDR	P	03:41:09	-0.68	0.3	84.2	REV	0.48
2	SDD	P	03:41:14	-0.62	1.1	269.0	REV	0.26
3	LONA1	P	03:41:17	-0.13	1.4	309.5	REV	0.45
4	PRSN	P	03:41:19	0.77	1.5	99.8	REV	0.09
5	AGPR	P	03:41:20	1.12	1.5	90.3	REV	0.09
6	CRPR	P	03:41:20	0.64	1.6	107.0	REV	0.12
7	MLPR	P	03:41:21	0.56	1.7	107.6	REV	0.12
8	AOPR	P	03:41:23	0.65	1.9	93.8	REV	0.07

SOURCE	YMD	HMS	GAP	MAG	PICKS	NEAREST	RES	LAT	Lon	DEPTH
AT	2017/09/14	04:14:43	153	3.64 M1	22	0.70	0.83	37.25	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.64 M1	21	0.70	0.86	37.25	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.63 M1	20	0.70	0.86	37.24	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.60 M1	19	0.70	0.87	37.24	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.60 M1	20	0.70	1.25	37.28	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.58 M1	19	0.70	0.87	37.24	-97.94	20.00
AT	2017/09/14	04:14:43	152	3.55 M1	16	0.70	0.93	37.23	-97.93	20.00
AT	2017/09/14	04:14:43	156	3.55 M1	14	0.70	1.02	37.23	-97.94	20.00
AT	2017/09/14	04:14:43	156	3.51 M1	13	0.70	1.00	37.22	-97.94	20.00
AT	2017/09/14	04:14:43	155	3.45 M1	12	0.70	0.96	37.21	-97.94	20.00

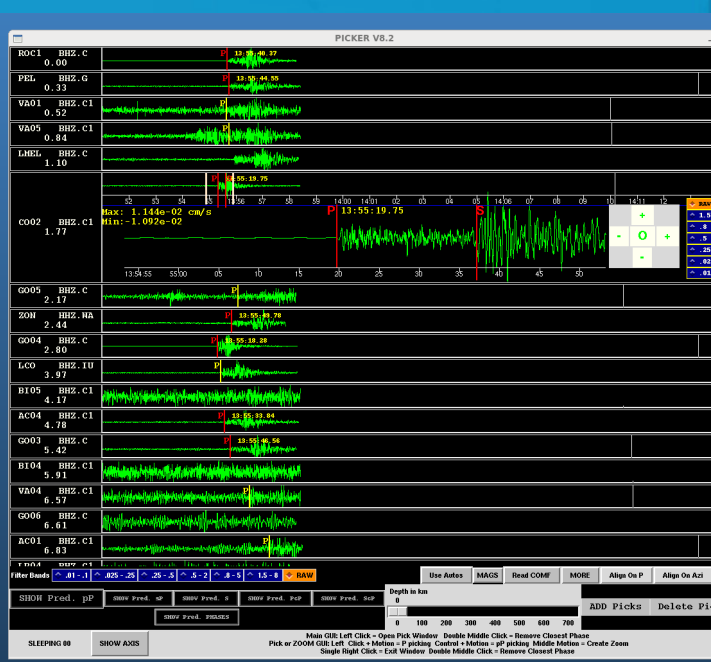
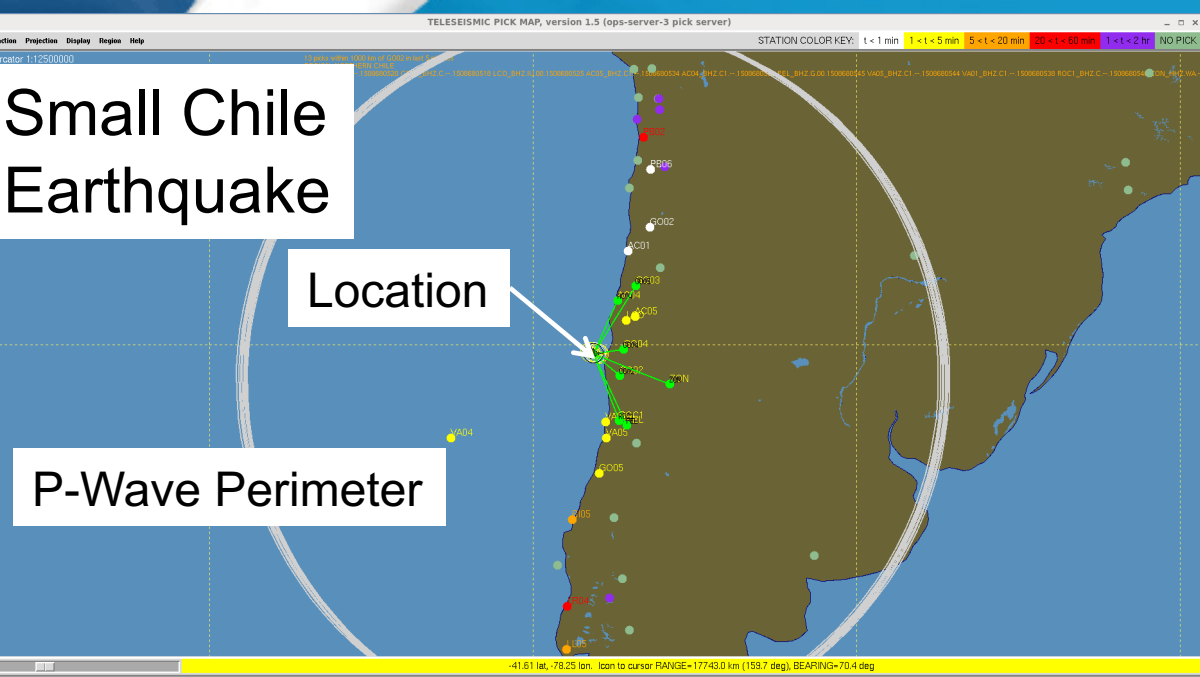
Hawaii Seismic Data Processing



Small Chile Earthquake

Location

P-Wave Perimeter



Function ETAs Obs Message

Search params: fix depth => Depth: 33

Display params: display map images

1	LAT	Lon	DEPTH	ORIGIN TIME	GAP	RMS	PICKS	NEAREST	LOCATION
1	-30.34	-72.23	33.0 (F)	2017/10/22 13:54:57	226.0	1.14	8	1.2	OFF THE COAST OF CENTRAL CHILE
2	-30.35	-72.21	10.0	2017/10/22 13:54:55	226.0	1.12	8	1.2	OFF THE COAST OF CENTRAL CHILE

ARIV ID	STA	PHASE	TIME	RESID	DIST (DEG)	AZIM (DEG)	TYPE	WEIGHT
1	GO04	P	13:55:18	-0.11	1.2	82.3	REV	0.32
2	CO02	P	13:55:19	-0.34	1.3	129.7	REV	0.16
4	CO02	S	13:55:37	-1.11	1.3	129.7	REV	0.67
3	AC04	P	13:55:33	-0.78	2.4	25.0	REV	0.44
5	ROC1	P	13:55:40	-0.41	2.8	159.1	REV	0.47
6	PEL	P	13:55:44	0.09	3.1	155.3	REV	0.41
7	GO03	P	13:55:46	-0.16	3.2	32.8	REV	0.39
8	ZON	P	13:55:49	2.82	3.3	112.4	REV	0.15

SOURCE	YMD	HMS	GAP	MAG	PICKS	NEAREST	RES	LAT	Lon	DEPTH
AT	2017/10/22	13:54:55	139	3.97 Ml	14	1.10	1.64	-30.38	-72.08	37.00
AT	2017/10/22	13:54:55	199	4.03 Ml	13	1.20	1.65	-30.35	-72.27	37.00
AT	2017/10/22	13:54:55	194	3.99 Ml	12	1.20	1.57	-30.30	-72.29	37.00
AT	2017/10/22	13:54:55	194	4.04 Ml	12	1.20	1.57	-30.31	-72.28	37.00
AT	2017/10/22	13:54:54	220	4.04 Ml	10	1.30	1.82	-30.32	-72.36	37.00
AT	2017/10/22	13:54:54	217	3.94 Ml	10	1.50	1.57	-30.31	-72.48	37.00
AT	2017/10/22	13:54:55	203	3.91 Ml	9	1.00	2.15	-30.36	-72.03	37.00
AT	2017/10/22	13:54:56	210	3.93 Ml	9	1.00	2.33	-30.38	-71.96	37.00
PT	2017/10/22	13:54:51	151	4.42 Ml	12	1.30	1.30	-30.30	-72.35	1.00
AT	2017/10/22	13:54:55	211	4.24 Ml	8	1.10	1.36	-30.34	-72.10	7.00

watchstander (v1.3) -

All
 Baton

Shift

- Barry
- Chip
- Cndi
- Dailin
- Dave
- Kanoa
- Nalhan
- Stan
- Stuart
- Victor

Text:



Interactive Phase Picker

The screenshot displays the Interactive Phase Picker interface. On the left, a list of stations is shown with their corresponding depth values in km:

- GSI 4.62
- PSI 5.87
- KULM 8.13
- IPM 8.27
- BTDF 10.75
- MNAI 11.93
- 14.93
- LEM 17.15
- KSM 17.26
- CHTO 17.43
- DLV 18.05
- UGM 20.18
- HMDM 20.30
- DGAR 22.73
- KKM 23.39
- JAGI 23.62

The main display area shows seismic waveforms for these stations. A red vertical line indicates a picked phase at 08:40:33.43. The IPM station plot includes a scale for velocity: Max: 1.545e-02 cm/s and Min: -1.567e-02. A control panel on the right features a 3x3 grid with a central '0' and '+' signs.

At the bottom, the control panel includes:

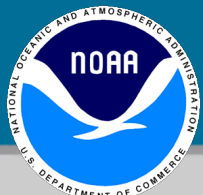
- Filter Bands: \wedge .01 - .1, \wedge .025 - .25, \wedge .25 - .5, \wedge .5 - 2, \blacktriangledown .8 - 5, \wedge RAW
- Buttons: Use Autos, MAGS, LOCATE, Read COMF, MORE, Align On P, EXIT
- Depth in km: 0 (with a slider from 0 to 700)
- Buttons: SHOW Pred. pP, SHOW Pred. sP, SHOW Pred. S, SHOW Pred. PcP, SHOW Pred. ScP, Delete Picks
- Buttons: GETTING DATA, SHOW AXIS, SHOW Pred. PHASES

Main GUI: Left Click = Open Pick Window Double Middle Click = Remove Closest Phase
 Pick or ZOOM GUI: Left Click + Motion = P picking Control + Motion = pP picking Middle Motion = Create Zoom
 Single Right Click = Exit Window Double Middle Click = Remove Closest Phase

OT +
270s

Sumatra 2012

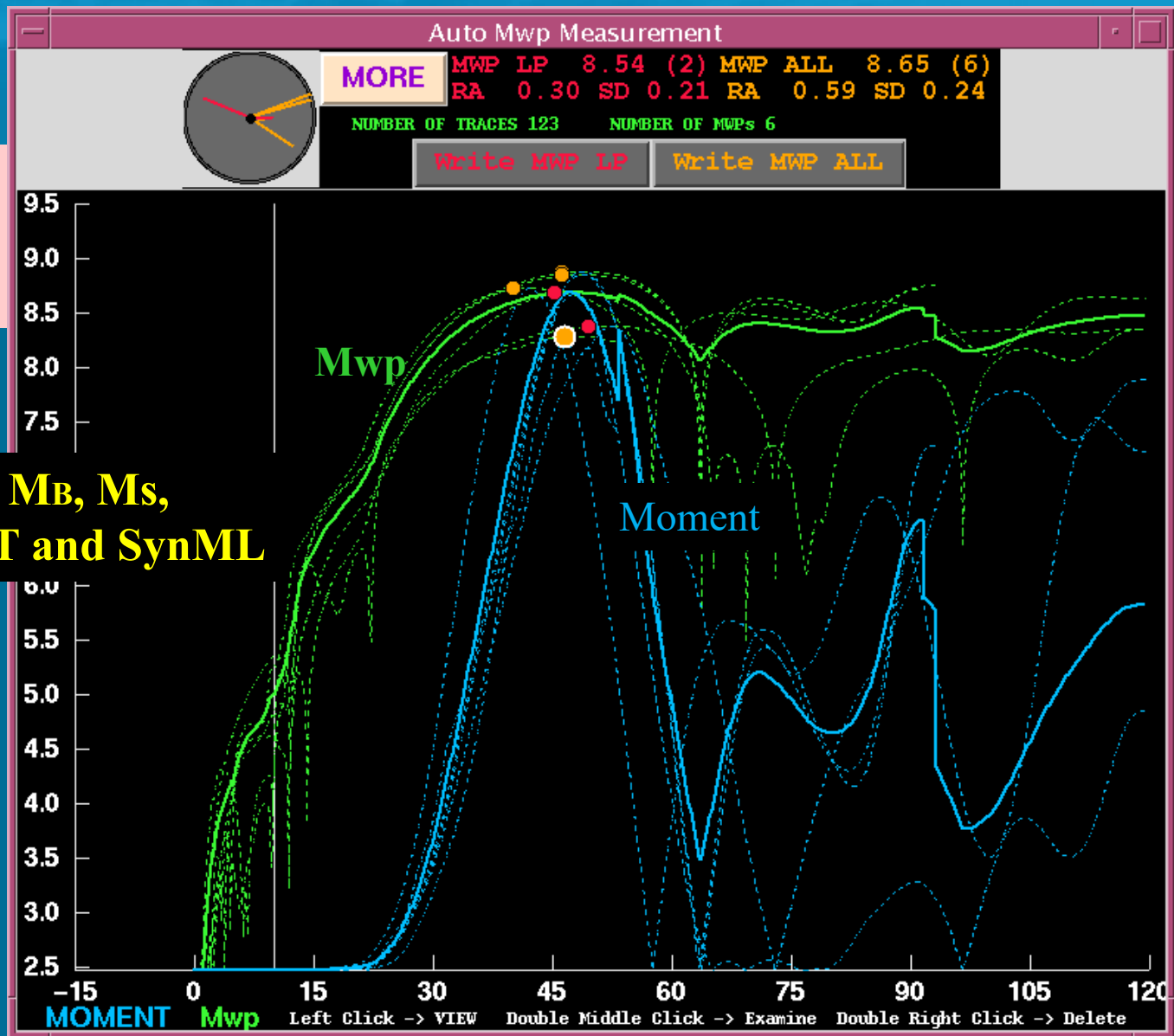
P, S, pP, sP, ScP, PcP
Align-on-P
Align-on-Azi



Compute Mwp This is the Mwp GUI Interface

We also compute MB, Ms,
Me, Mm, WCMT and SynML

Sumatra 2012



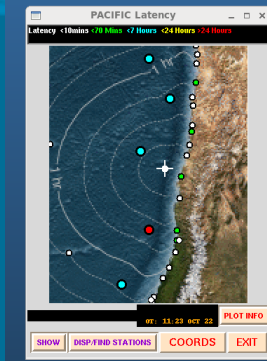
Mwp method developed by Tsuboi et al., 1995



BASIC OPERATIONAL ACTIVITIES

- SEISMIC DATA COLLECTION, MONITORING, PROCESSING & ANALYSES
- SEA-LEVEL DATA COLLECTION, MONITORING, PROCESSING & ANALYSES
- TSUNAMI FORECASTING
- MESSAGE CREATION & DISSEMINATION

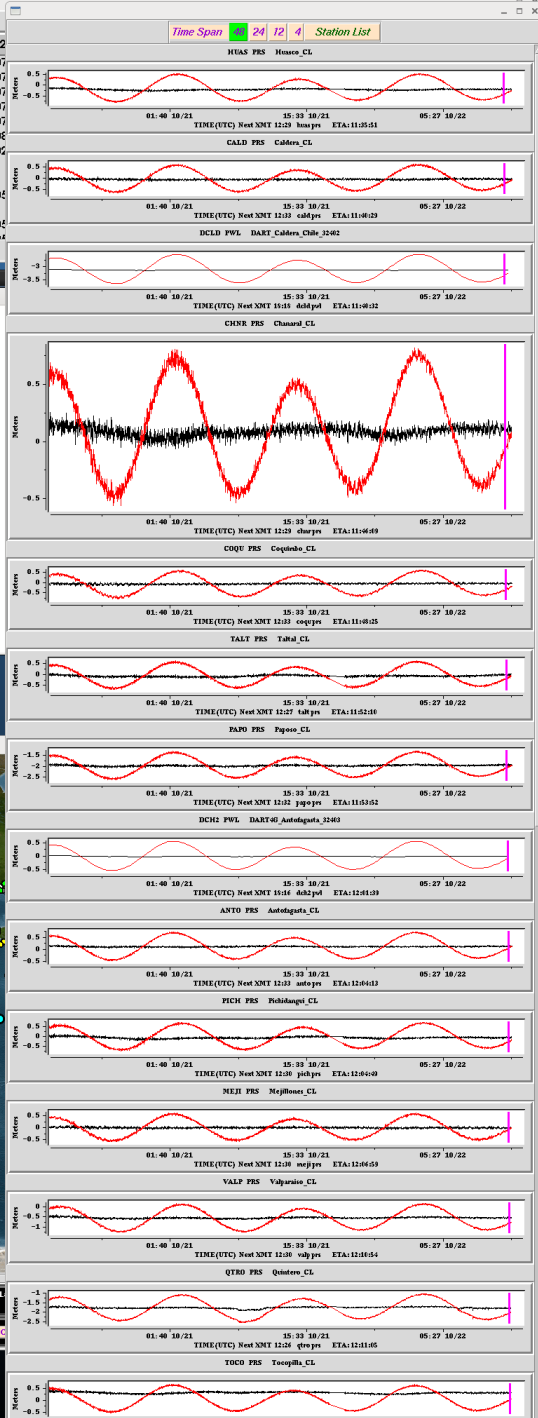
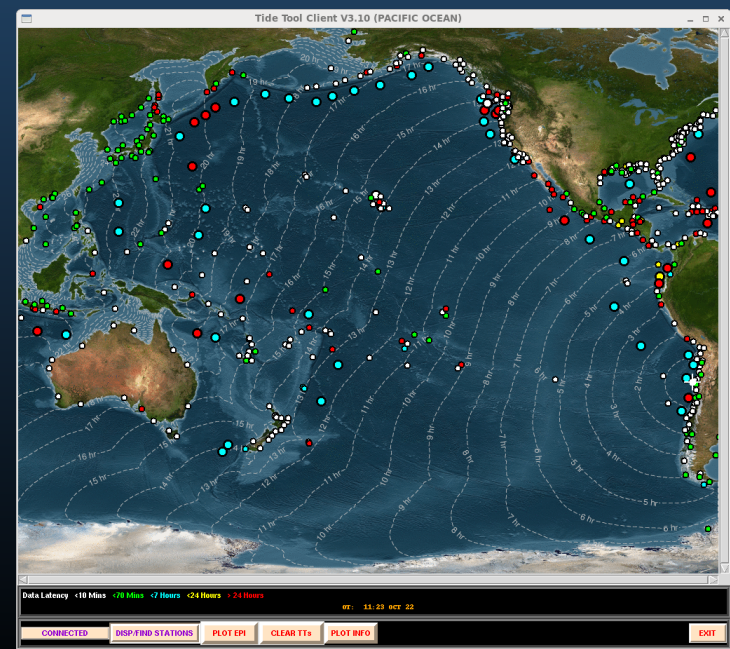
Function	TYPE	STATION	CHANNEL	LAT	LONG	REGION	COUNTRY	TIME 1	y1(m)	TIME 2
Peak to Peak	buve	rad		3.89060	-77.08080	Buenaventura	Colombia	2017-09-04 01:14:00	1.596	2017-09-04 07:00:00
Peak to Peak	lali	prs		-2.21770	-80.90630	La_Libertad_EC	Ecuador	2017-09-04 01:33:00	-0.841	2017-09-04 07:00:00
Peak to Peak	lali	prs		-2.21770	-80.90630	La_Libertad_EC	Ecuador	2017-09-04 01:33:00	-0.841	2017-09-04 07:00:00
Peak to Peak	sant	prs		-0.72160	-90.31330	SantaCruz_Galap	Ecuador	2017-09-04 01:38:00	-0.719	2017-09-04 07:00:00
Peak to Peak	tala	prs		-4.57780	-81.27990	Talara_PE	Peru	2017-09-04 13:56:00	-0.71	2017-09-04 07:00:00
Peak to Peak	lali	rad		-2.21770	-80.90630	La_Libertad_EC	Ecuador	2017-09-05 14:18:00	3.906	2017-09-05 06:00:00
Peak to Peak	xmas	prs		1.98400	-157.47300	Christmas_KI	Kiribati	2017-09-05 19:51:00	-0.321	2017-09-06 02:00:00
First Arrival	ptan	rad		15.86670	-96.49170	Puerto_Angel_M	Mexico	2017-09-08 04:57:00		
First Arrival	huat	rad		15.75310	-96.12940	Huatlaco_MX	Mexico	2017-09-08 05:01:00		
Peak to Peak	huat	rad		15.75310	-96.12940	Huatlaco_MX	Mexico	2017-09-08 05:14:00	-0.949	2017-09-08 05:00:00
First Arrival	sali	flt		16.16840	-95.19680	Salina_Cruz_MX	Mexico	2017-09-08 05:15:00		
Peak to Peak	ptan	rad		15.86670	-96.49170	Puerto_Angel_M	Mexico	2017-09-08 05:17:00	-0.342	2017-09-08 05:00:00
Peak to Peak	sal	flt		16.16840	-95.19680	Salina_Cruz_MX	Mexico	2017-09-08 05:18:00	0.666	2017-09-08 05:00:00

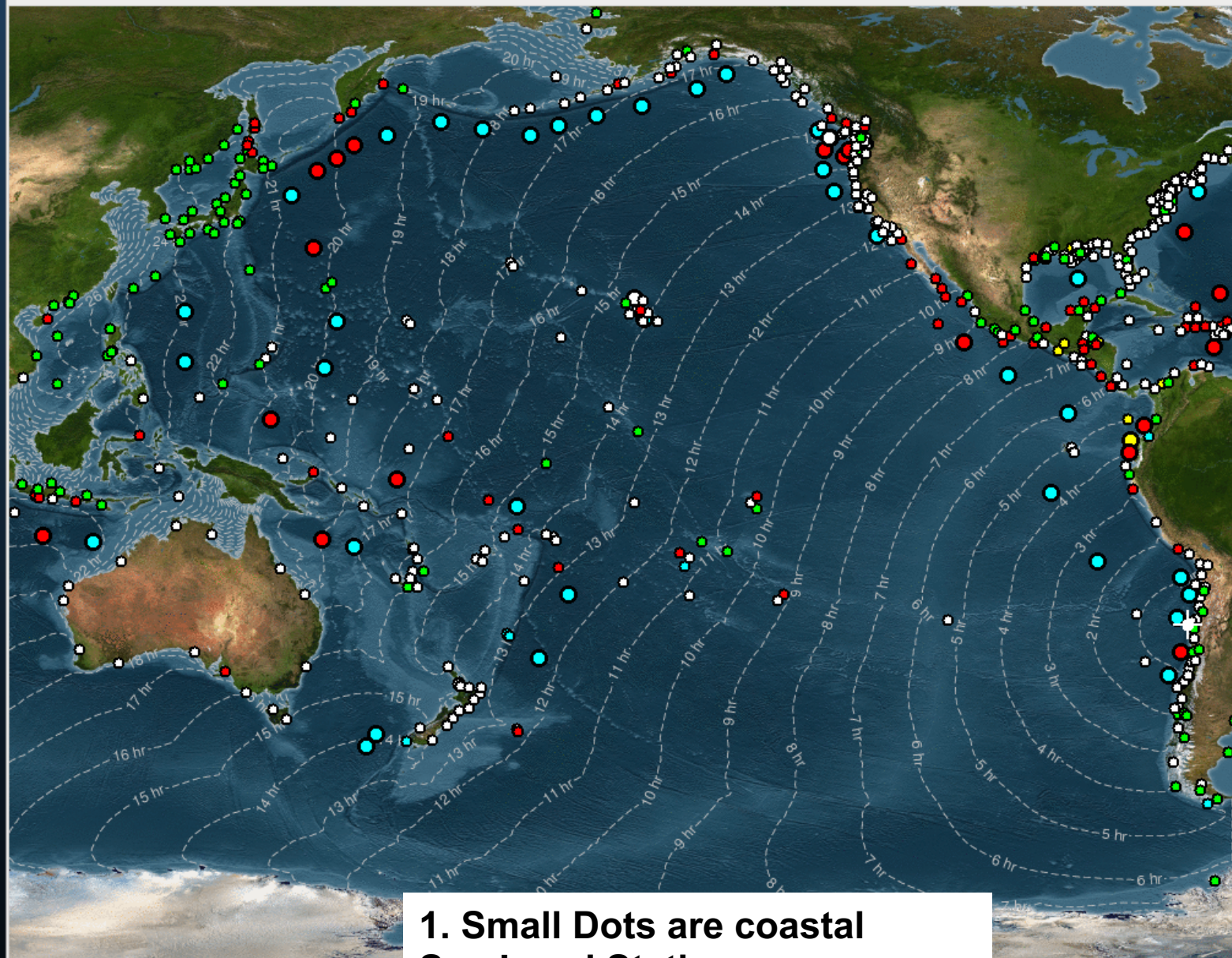


```

ptwc@holo:~$ df -k
Filesystem            1K-blocks    Used Available Use% Mounted on
/dev/mapper/vg_opsserver2-lv_root
51475068      7522572  41331056    16% /
tmpfs          32962824      33212  32929612    1% /dev/shm
/dev/sda1      487652      115886   346166    26% /boot
/dev/mapper/vg_opsserver2-lv_home
1056763060    87686120  915389852    9% /home
/dev/mapper/vg_opsserver2-lv_tmp
32380816      140460   30588852    1% /tmp
/dev/mapper/vg_opsserver2-lv_usrlocal
15350768      4946988   9617348    34% /usr/local
/dev/mapper/vg_opsserver2-lv_var
32380816      3514112  27215200    12% /var
/dev/mapper/vg_opsserver2-lv_audit
32380816      49808    30680232    1% /var/audit
/dev/mapper/vg_opsserver2-lv_varlog
32380816      264404   30464908    1% /var/log
/dev/mapper/vg_opsserver2-lv_data
619142920    161001008  426684632    28% /data
ptwc@holo ~$

```





1. Small Dots are coastal
Sea-Level Stations

2. Large Dots are DARTs, BPRs

Data Latency <10 Mins <70 Mins <7 Hours <24 Hours >24

CONNECTED

DISP/FIND STATIONS

PLOT EP

EXIT

Coastal Sea-Level Stations:

1. Situated in shallow water
2. Typically installed along piers.
3. Usually first to detect tsunami
4. Provide “facts on the ground”
5. Lots of them.



ning Program in Hawaii (ITP-Hawaii)
Y WARNING SYSTEMS
G CENTER (PTWC) ENHANCED PRODUCTS
UNESCO IOC TSUNAMI READY PROGRAMME
Honolulu, Hawaii USA

GOESW
Part of the GTS

CHANNEL 32

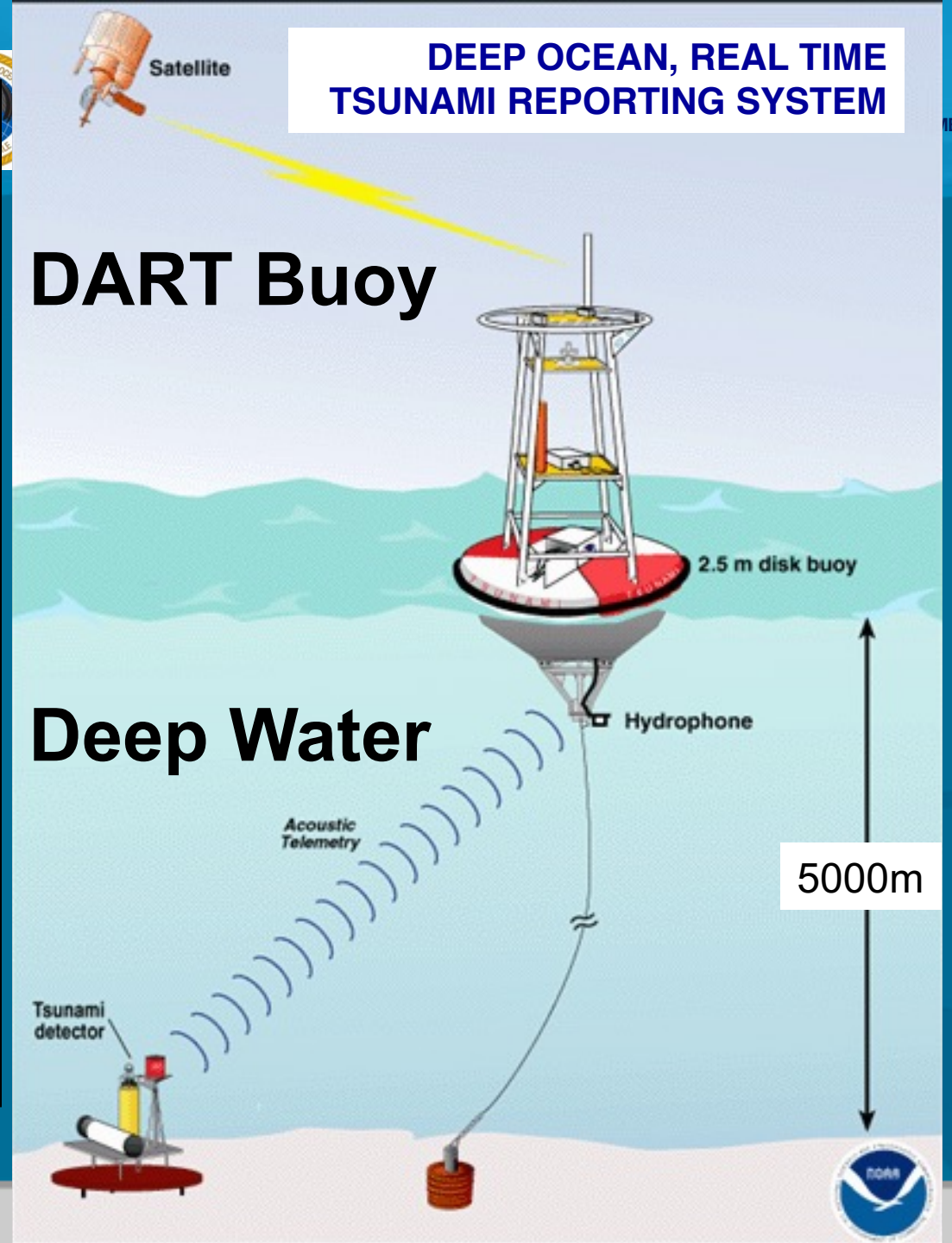
Hiva Oa



**Downloaded at Wallops Island
VA/USA and forwarded to the
US TWCs and Met. Offices.**

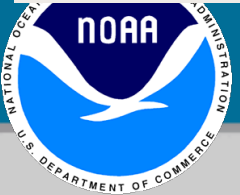
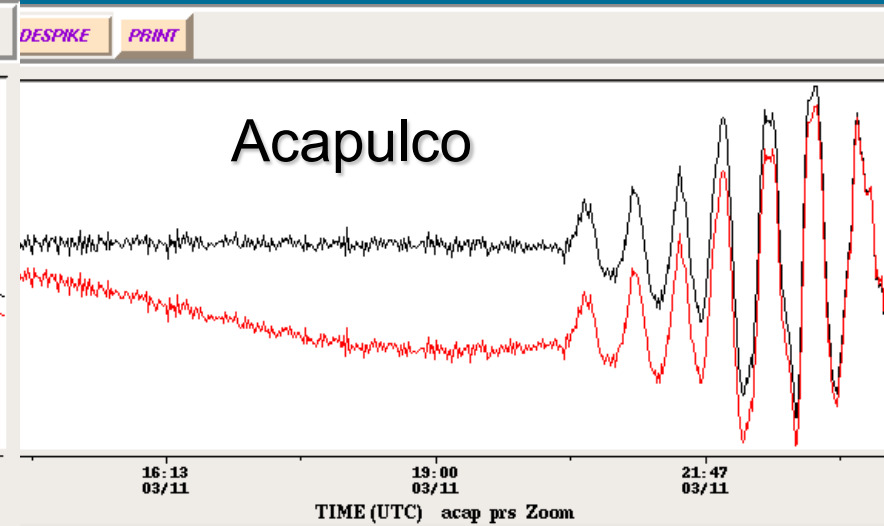
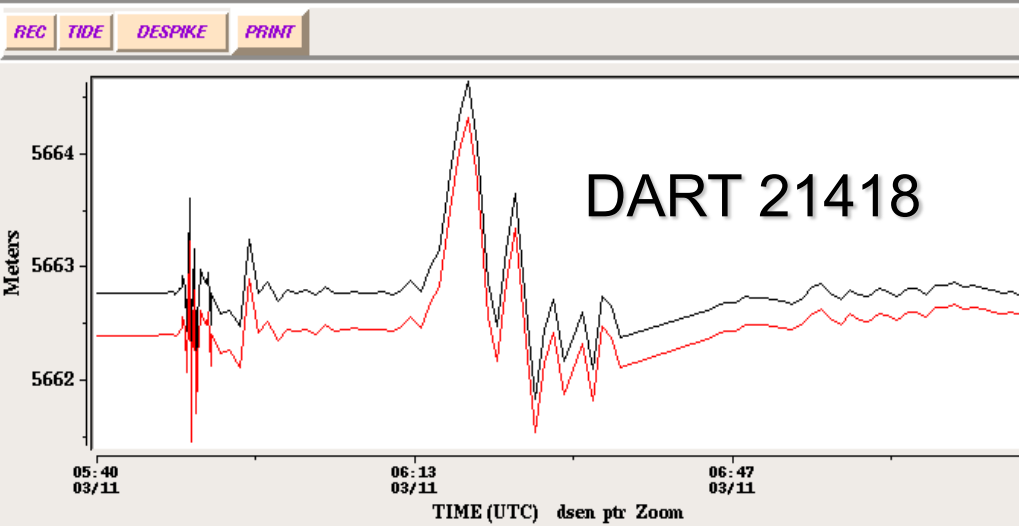
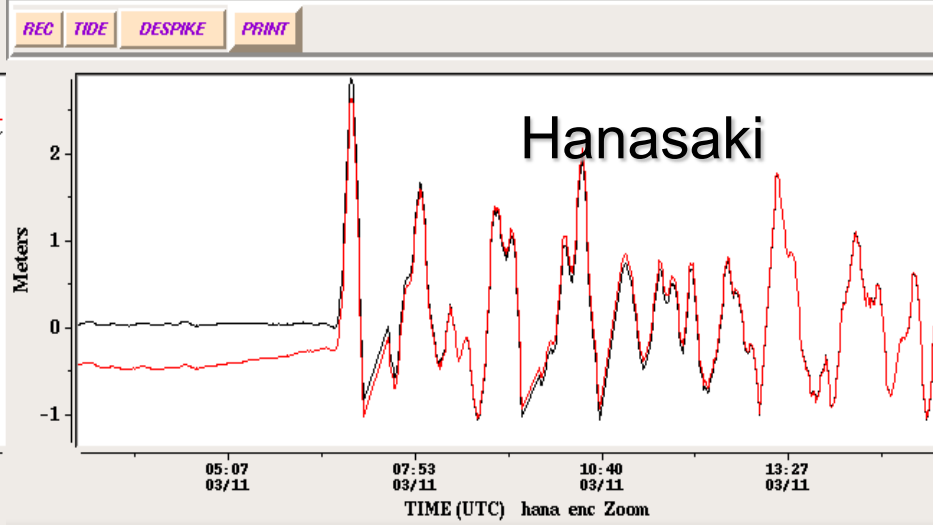
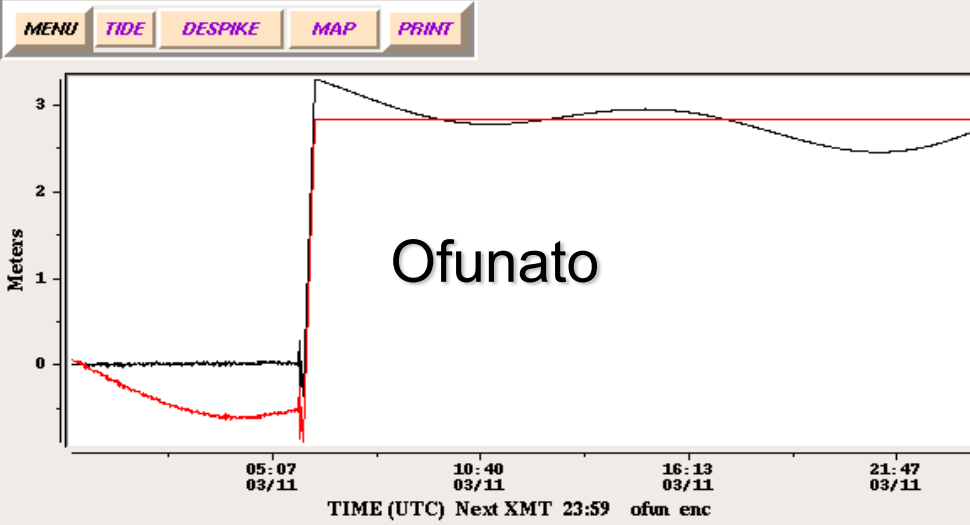
The tsunami signal is detected by a pressure sensor on the ocean floor. That signal is relayed by acoustic telemetry to the buoy. The buoy in turn transmits the signal via satellite back to the warning centers.

Can measure changes in sea-level as small as 1mm!



Tohoku Tsunami Marigrams

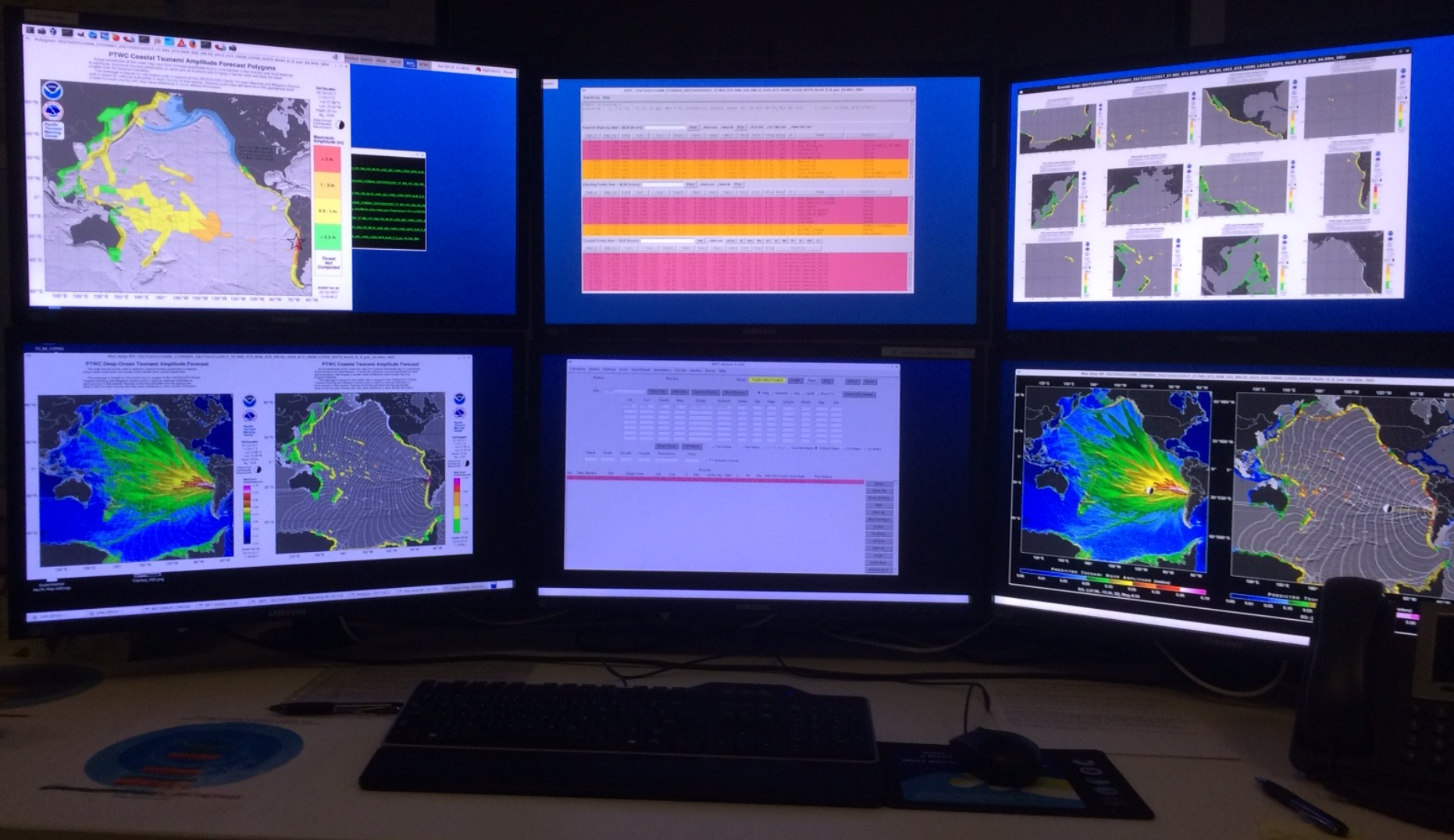
OT 5:46 UTC, Mar 11 2011 Mw = 9.1

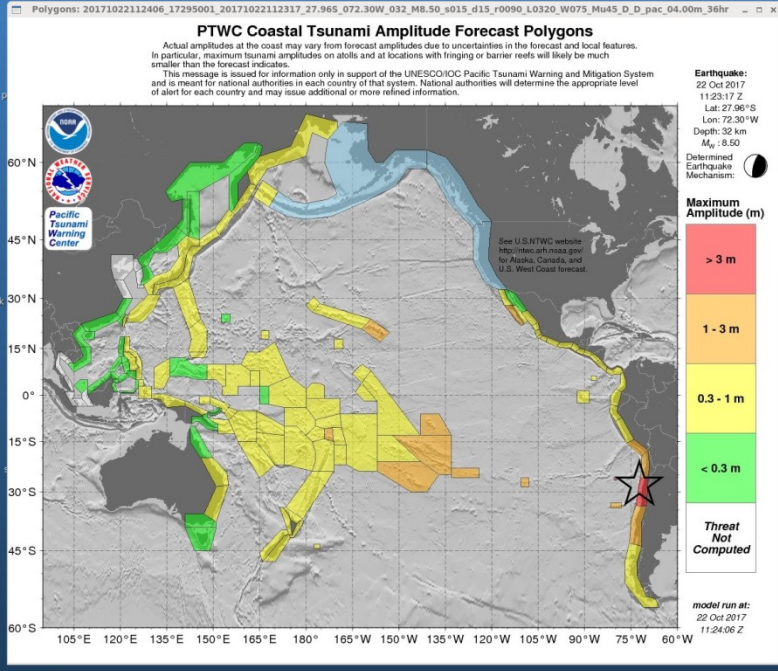


BASIC OPERATIONAL ACTIVITIES

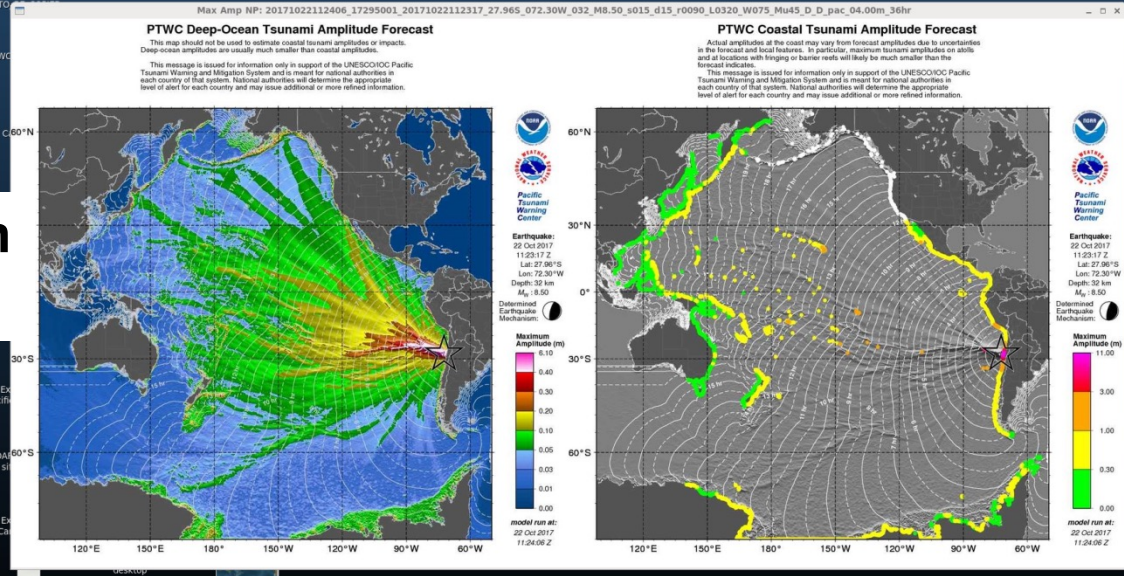
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- SEA-LEVEL DATA COLLECTION, MONITORING, PROCESSING & ANALYSES
- TSUNAMI FORECASTING
- MESSAGE CREATION & DISSEMINATION

RIFT TSUNAMI FORECASTING DESKTOP





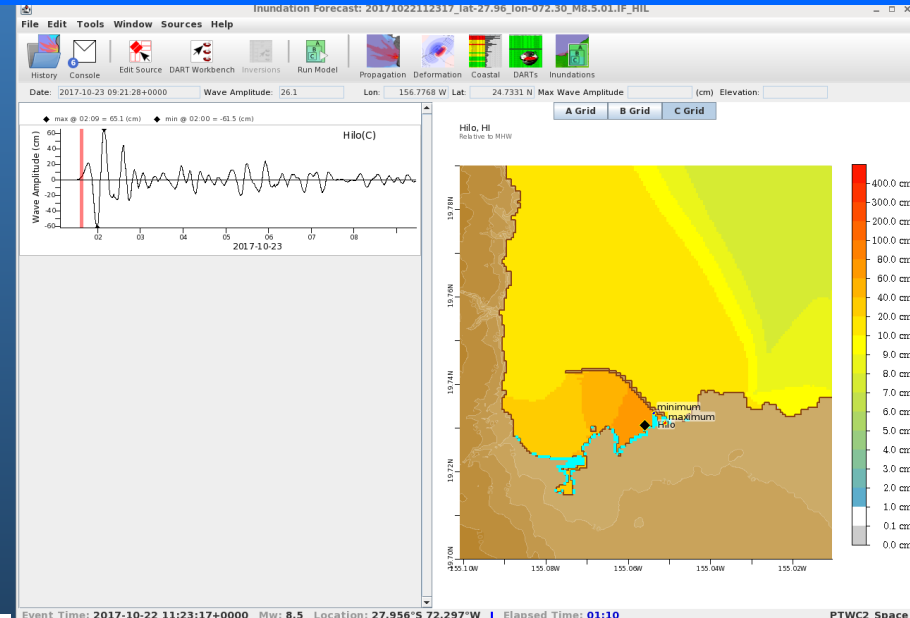
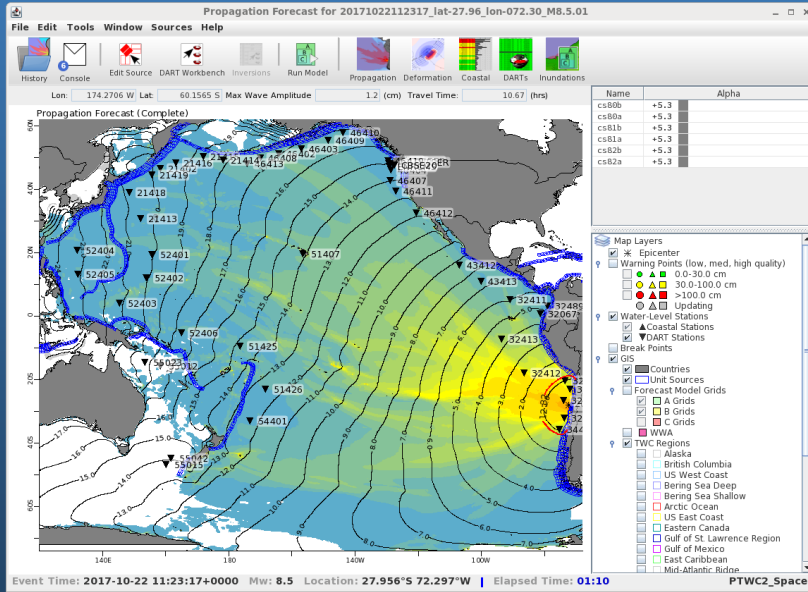
Polygon Map



Deep Ocean Forecast

Coastal Forecast

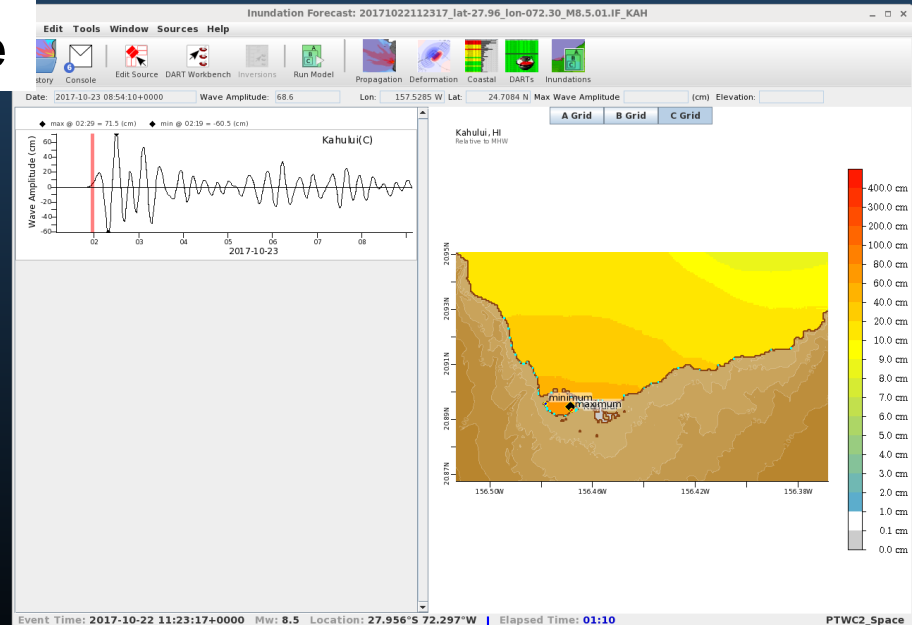
SIFT TSUNAMI FORECAST



Uses a more complicated algorithm
To model the effects along the shore

Model	Region	Arrival Time (UTC)	C Min (cm)	C Max (cm)	Gauge Min (cm)	Gauge Max (cm)	Flooding	Flooded Area	Model Ended
Hilo, HI	Hawaii	01:37 2017-10-23	-136.2	91.4	-61.5	65.1	Yes	0.500	12:03 2017-10-22
Kahului, HI	Hawaii	01:57 2017-10-23	-66.3	77.5	-60.5	71.5	Yes	0.157	12:03 2017-10-22
Haleiwa, HI	Hawaii	02:04 2017-10-23	-25.8	62.8	-15.3	13.1	Yes	0.013	12:21 2017-10-22
Honolulu, HI	Hawaii	02:06 2017-10-23	-21.9	48.7	-11.0	11.1	No	0.000	12:01 2017-10-22
Kihei, HI	Hawaii	01:35 2017-10-23	-25.8	75.3	-15.3	15.1	Yes	0.024	12:06 2017-10-22
Kaunakakai, HI	Hawaii	01:36 2017-10-23	-12.1	13.7	-7.0	5.4	No	0.000	12:05 2017-10-22
Nawiliwili, HI	Hawaii	02:09 2017-10-23	-9.7	11.2	-9.0	9.7	No	0.000	12:01 2017-10-22

Event Time: 2017-10-22 11:23:17+0000 Mw: 8.5 Location: 27.956°S 72.297°W | Elapsed Time: 01:10 PTWC2_Space



BASIC OPERATIONAL ACTIVITIES

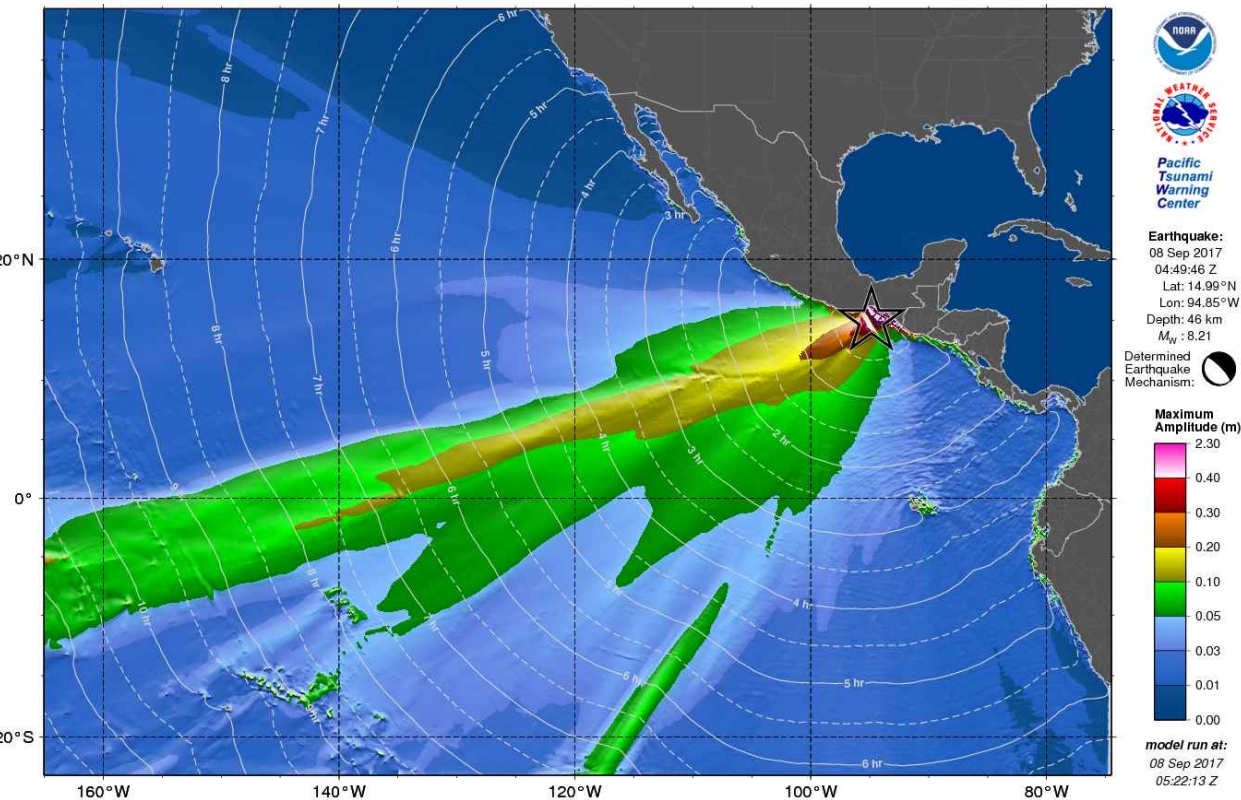
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Graphical Product: Deep-Ocean Forecast

PTWC Deep-Ocean Tsunami Amplitude Forecast

This map should not be used to estimate coastal tsunami amplitudes or impacts. Deep-ocean amplitudes are usually much smaller than coastal amplitudes.

This message is issued for information only in support of the UNESCO/IOC Pacific Tsunami Warning and Mitigation System and is meant for national authorities in each country of that system. National authorities will determine the appropriate level of alert for each country and may issue additional or more refined information.



- Tsunami Travel Time contours
- Color range scaled so red / white show maxima
- Shaded textures show energy distribution

Chiapas Mexico, Mw 8.2, Sept. 7, 2017

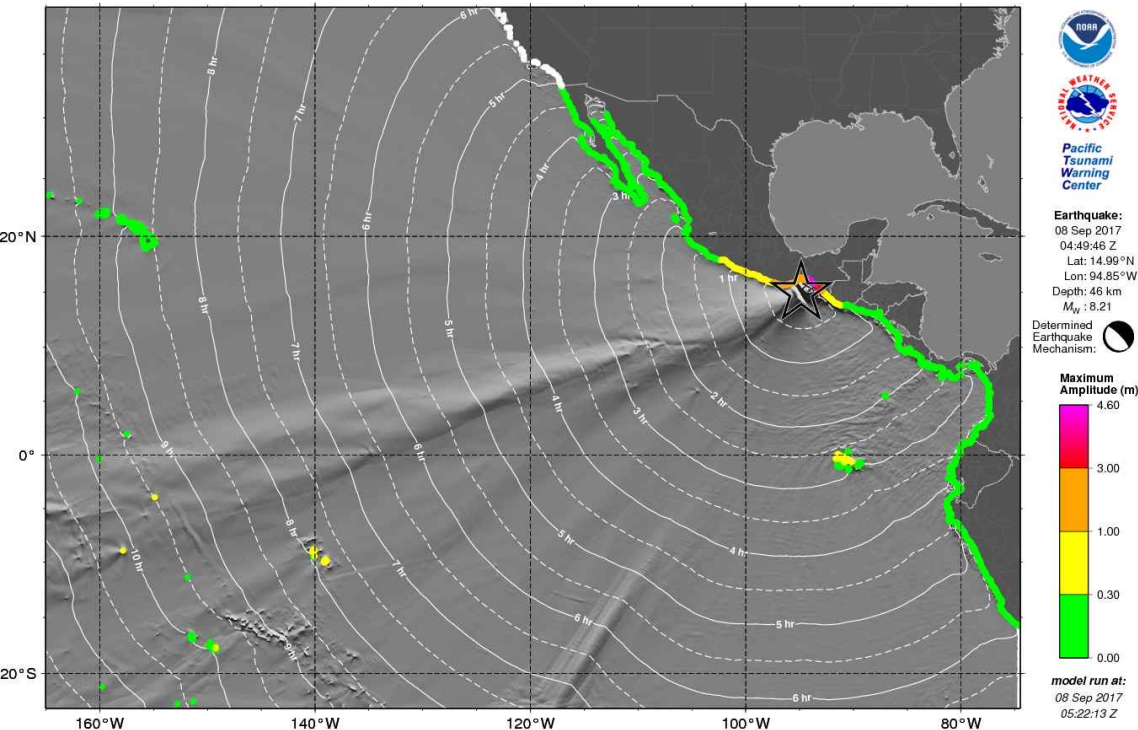
Graphical Product: Coastal Forecast



PTWC Coastal Tsunami Amplitude Forecast

Actual amplitudes at the coast may vary from forecast amplitudes due to uncertainties in the forecast and local features. In particular, maximum tsunami amplitudes on atolls and at locations with fringing or barrier reefs will likely be much smaller than the forecast indicates.

This message is issued for information only in support of the UNESCO/IOC Pacific Tsunami Warning and Mitigation System and is meant for national authorities in each country of that system. National authorities will determine the appropriate level of alert for each country and may issue additional or more refined information.



- Green's Law used to propagate off-shore, deep-ocean to coast
- Tsunami Travel Time contours
- Tsunami Wave Amplitudes at designated coastal forecast points (Green's Law)
- Shaded textures show energy distribution
- Pacific-wide, sub-region plots

Chiapas Mexico, Mw 8.2, Sept. 7, 2017

Graphical Product: Forecast Polygon

PTWC Coastal Tsunami Amplitude Forecast Polygons

Actual amplitudes at the coast may vary from forecast amplitudes due to uncertainties in the forecast and local features. In particular, maximum tsunami amplitudes on atolls and at locations with fringing or barrier reefs will likely be much smaller than the forecast indicates.

This message is issued for information only in support of the UNESCO/IOC Pacific Tsunami Warning and Mitigation System and is meant for national authorities in each country of that system. National authorities will determine the appropriate level of alert for each country and may issue additional or more refined information.

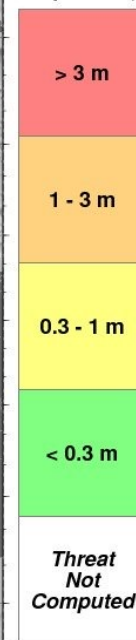
Earthquake:

08 Sep 2017
04:49:46 Z
Lat: 14.99°N
Lon: 94.85°W
Depth: 46 km
 M_w : 8.21

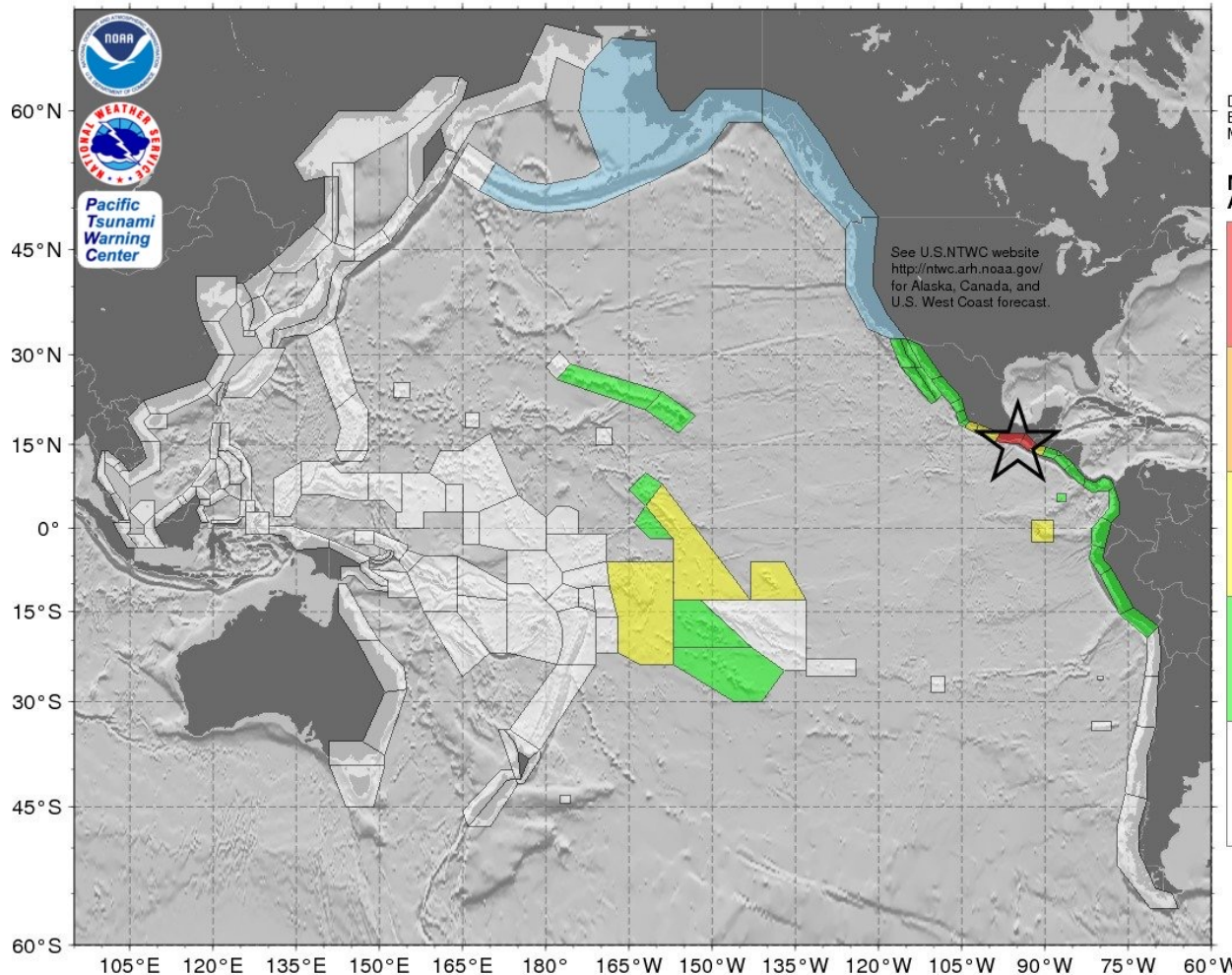
Determined Earthquake Mechanism:



Maximum Amplitude (m)



model run at:
08 Sep 2017
05:22:13 Z



- Threat level for designated forecast zones (based on geographical, geopolitical)
- Threat level for polygon based on largest coastal amplitude in polygon

Current Procedures, Products (As of Oct. 2014)

- **Base threat on forecast models, not on pre-determined magnitude threshold (can also apply to local tsunamis)**
- **Initial Products:**
 - Forecast based on preliminary earthquake parameters (hypocenter, magnitude)
 - Issued in < 7 min, so helpful for local threat
- **Later improved forecasts constrained by earthquake mechanism (WCMT) and sea level readings**
- **No Alert levels. Instead, 3 THREAT LEVELS based on maximum forecast wave amplitudes:**
 - 0.3 to less than 1 m
 - 1 to less than 3 m
 - 3 m or more
 - Other: Forecast not yet computed
 - No Threat - 0 to less than 0.3 m

Words like Warning/Watch no longer used



Public Text message – Threat Message

(Mw >= 7.1, Earthquake shallow)

1st Message

- Threat
- Take Action
- EQ-based

*PTWC guidance
information to
Country TWFP/NTWC*

First Product just based on
Earthquake Magnitude,
Location, Depth and
Distance

TSUNAMI MESSAGE NUMBER 1
NWS PACIFIC TSUNAMI WARNING CENTER EWA BEACH HI
0454 UTC FRI SEP 8 2017

..PTWC TSUNAMI THREAT MESSAGE...

**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE ****

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UNESCO/IOC PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM AND IS
MEANT FOR NATIONAL AUTHORITIES IN EACH COUNTRY OF THAT SYSTEM.

NATIONAL AUTHORITIES WILL DETERMINE THE APPROPRIATE LEVEL OF
ALERT FOR EACH COUNTRY AND MAY ISSUE ADDITIONAL OR MORE REFINED
INFORMATION.

**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE ****

PRELIMINARY EARTHQUAKE PARAMETERS

* MAGNITUDE 8.0
* ORIGIN TIME 0449 UTC SEP 8 2017
* COORDINATES 14.9 NORTH 94.0 WEST
* DEPTH 33 KM / 20 MILES
* LOCATION OFF THE COAST OF CHIAPAS MEXICO

EVALUATION

* AN EARTHQUAKE WITH A PRELIMINARY MAGNITUDE OF 8.0 OCCURRED
OFF THE COAST OF CHIAPAS, MEXICO AT 0449 UTC ON FRIDAY
SEPTEMBER 8 2017.

* BASED ON THE PRELIMINARY EARTHQUAKE PARAMETERS... WIDESPREAD
HAZARDOUS TSUNAMI WAVES ARE POSSIBLE.

TSUNAMI THREAT FORECAST

* HAZARDOUS TSUNAMI WAVES FROM THIS EARTHQUAKE ARE POSSIBLE

Public Text message – Threat Message

2nd-3rd Message

- Threat
- Take Action
- Wave Forecast

*PTWC guidance
information to
Country TWFP/NTWC*

These Products based
on Tsunami Forecast
and/or Sea-Level info.

TSUNAMI MESSAGE NUMBER 2
NWS PACIFIC TSUNAMI WARNING CENTER EWA BEACH HI
0524 UTC FRI SEP 8 2017

...PTWC TSUNAMI THREAT MESSAGE...

**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE ****

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**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE ****

THE TSUNAMI FORECAST IS UPDATED IN THIS MESSAGE.

PRELIMINARY EARTHQUAKE PARAMETERS

* MAGNITUDE 8.2
* ORIGIN TIME 0449 UTC SEP 8 2017
* COORDINATES 14.9 NORTH 94.0 WEST
* DEPTH 33 KM / 20 MILES
* LOCATION OFF THE COAST OF CHIAPAS MEXICO

EVALUATION

* AN EARTHQUAKE WITH A PRELIMINARY MAGNITUDE OF 8.2 OCCURRED OFF THE COAST OF CHIAPAS, MEXICO AT 0449 UTC ON FRIDAY SEPTEMBER 8 2017.

* BASED ON ALL AVAILABLE DATA... HAZARDOUS TSUNAMI WAVES ARE FORECAST FOR SOME COASTS.

TSUNAMI THREAT FORECAST...UPDATED

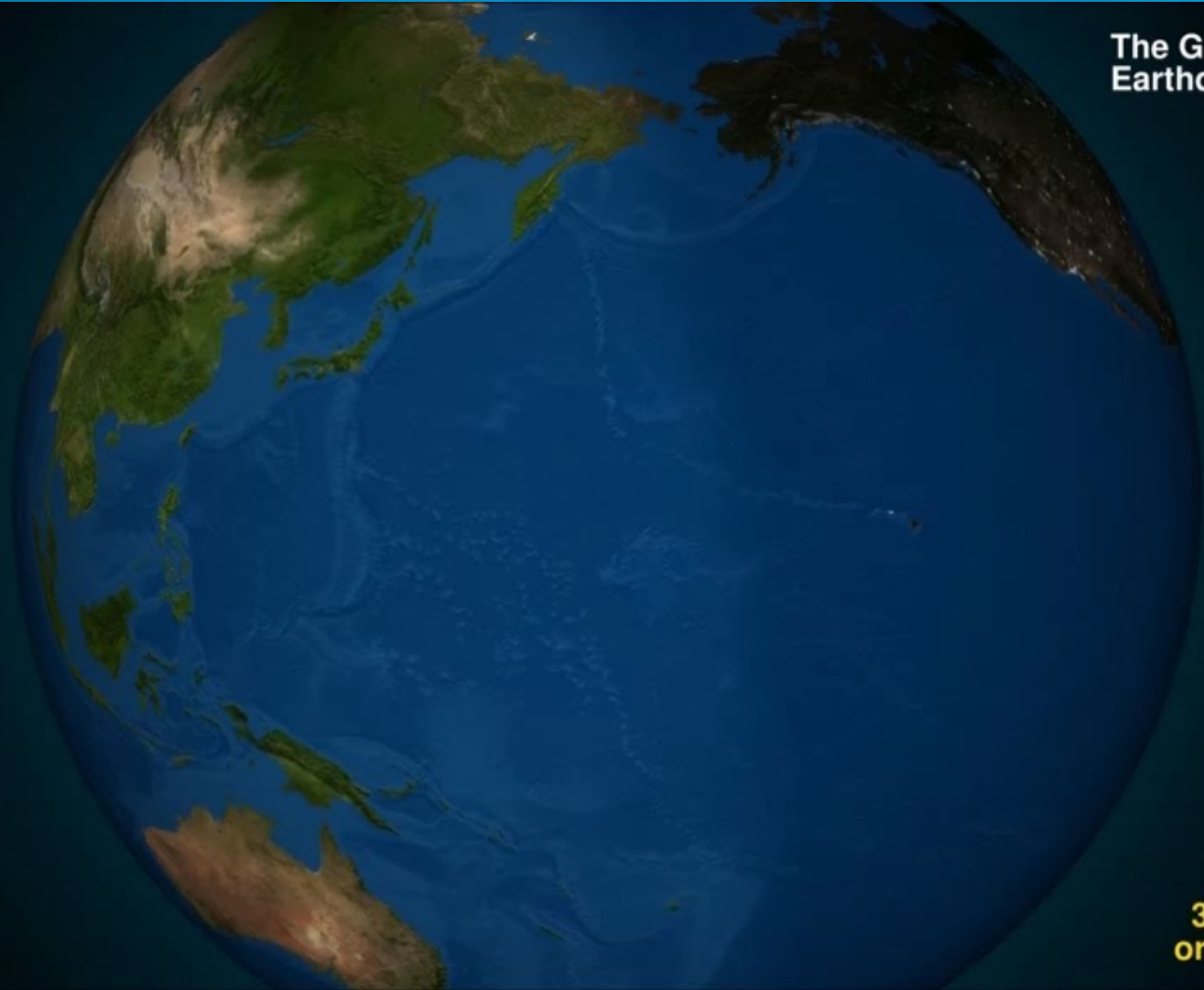
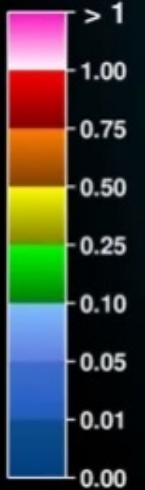
Tohoku Timeline Video

The Great Tōhoku-Oki Earthquake ($M_W = 9.1$)

Elapsed Time:
00 hr
00 min

UTC:
2011
11 Mar
05:45 Z

Tsunami Wave Amplitude (\pm meters)



30x actual speed
or 1 sec. = 30 sec.



UNESCO/IOC – NOAA ITIC Training Program in Hawaii (ITP-Hawaii)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
3-13 September 2019, Honolulu, Hawaii USA

Thank You!