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

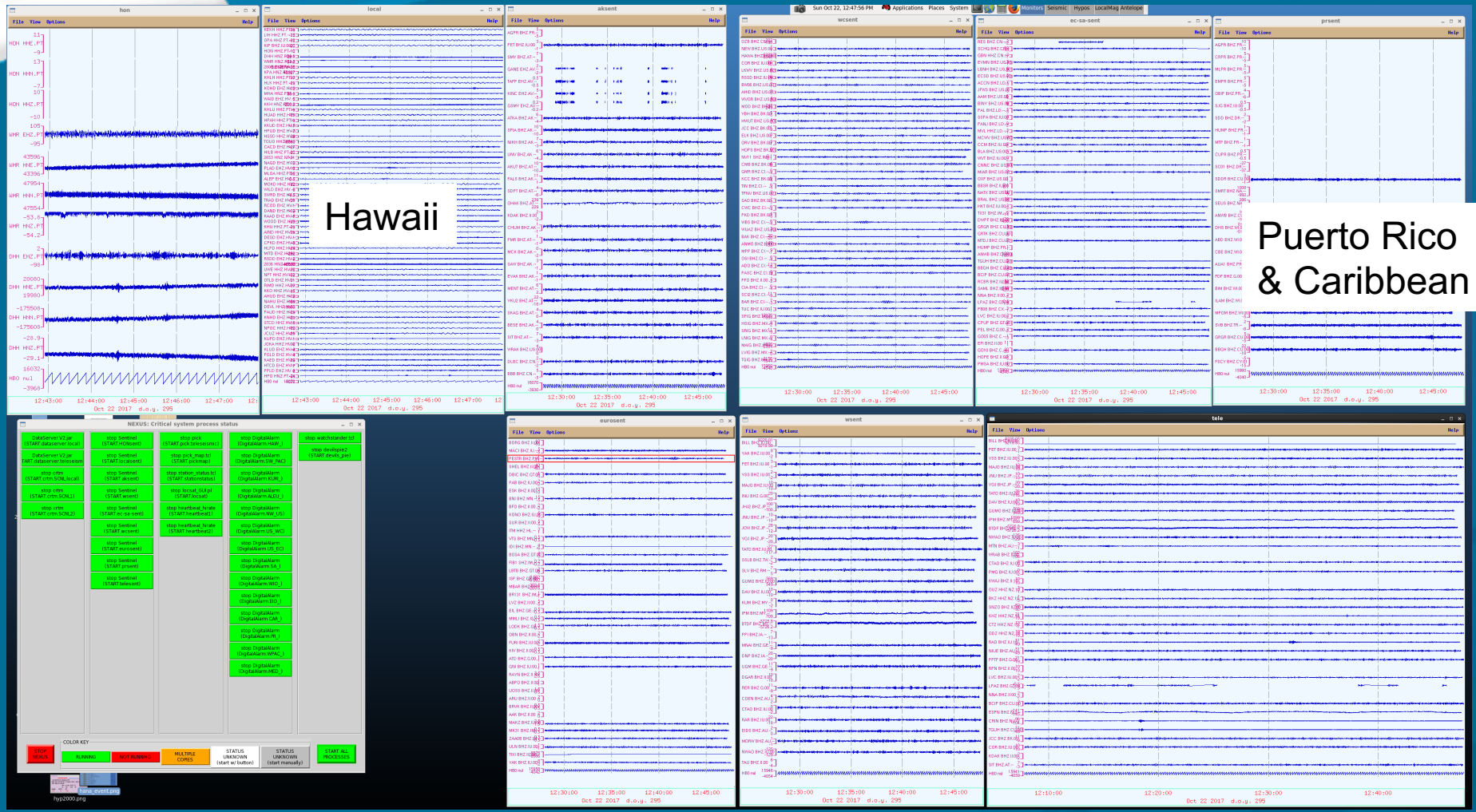
- Most tsunamis are caused by great earthquakes
- Great earthquakes cannot be predicted
- Tsunamis can travel 800km/hr in the deep ocean
- Tsunamis strike within minutes to hours
- Tsunami warnings must be delivered in time to take action to save lives

BASIC OPERATIONAL ACTIVITIES

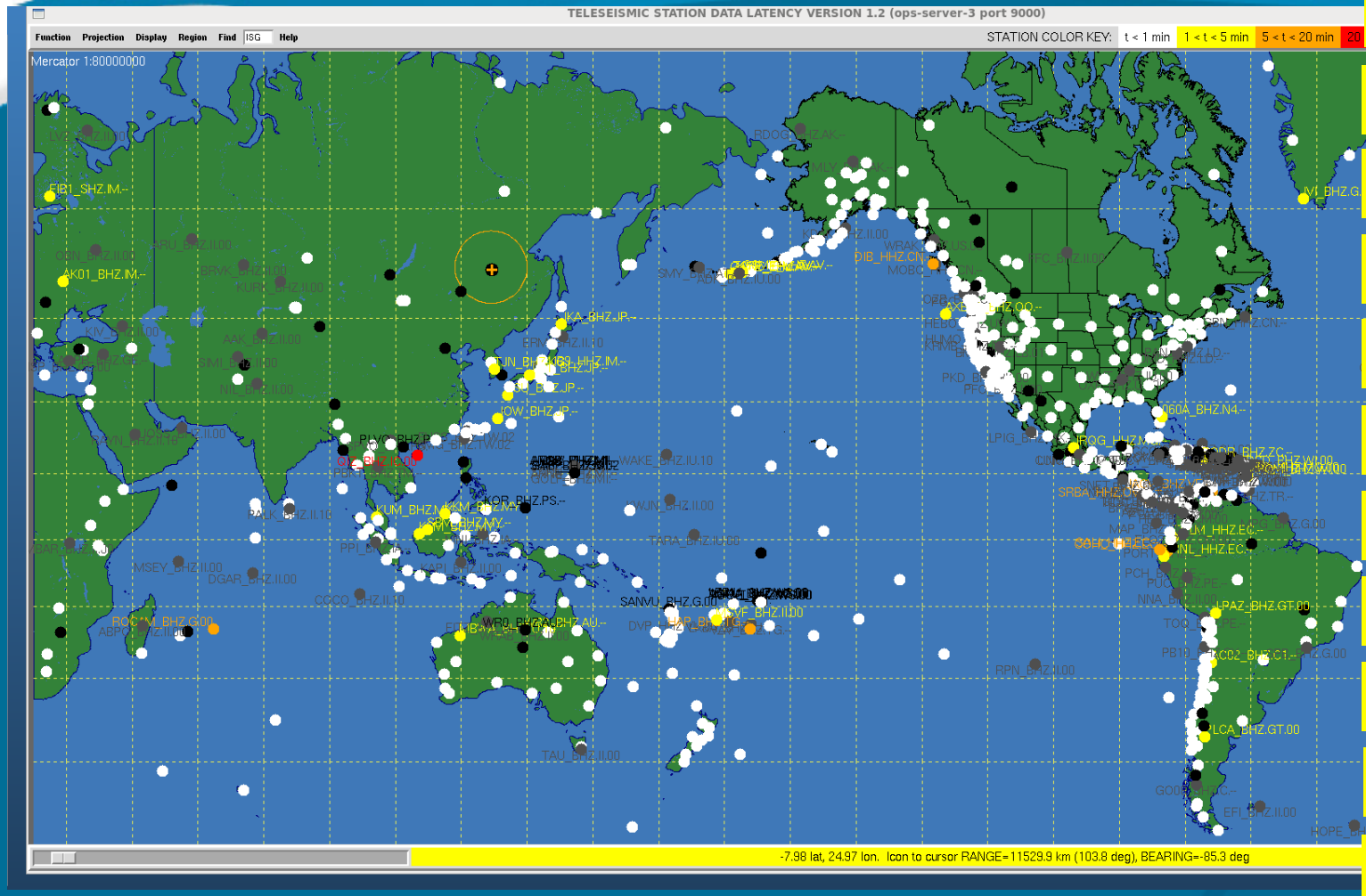
- SEISMIC DATA COLLECTION, MONITORING, PROCESSING & ANALYSES
- SEA-LEVEL DATA COLLECTION, MONITORING, PROCESSING & ANALYSES
- TSUNAMI FORECASTING
- MESSAGE CREATION & DISSEMINATION

Global Seismic Processing

Select Seismograms from Different Regions



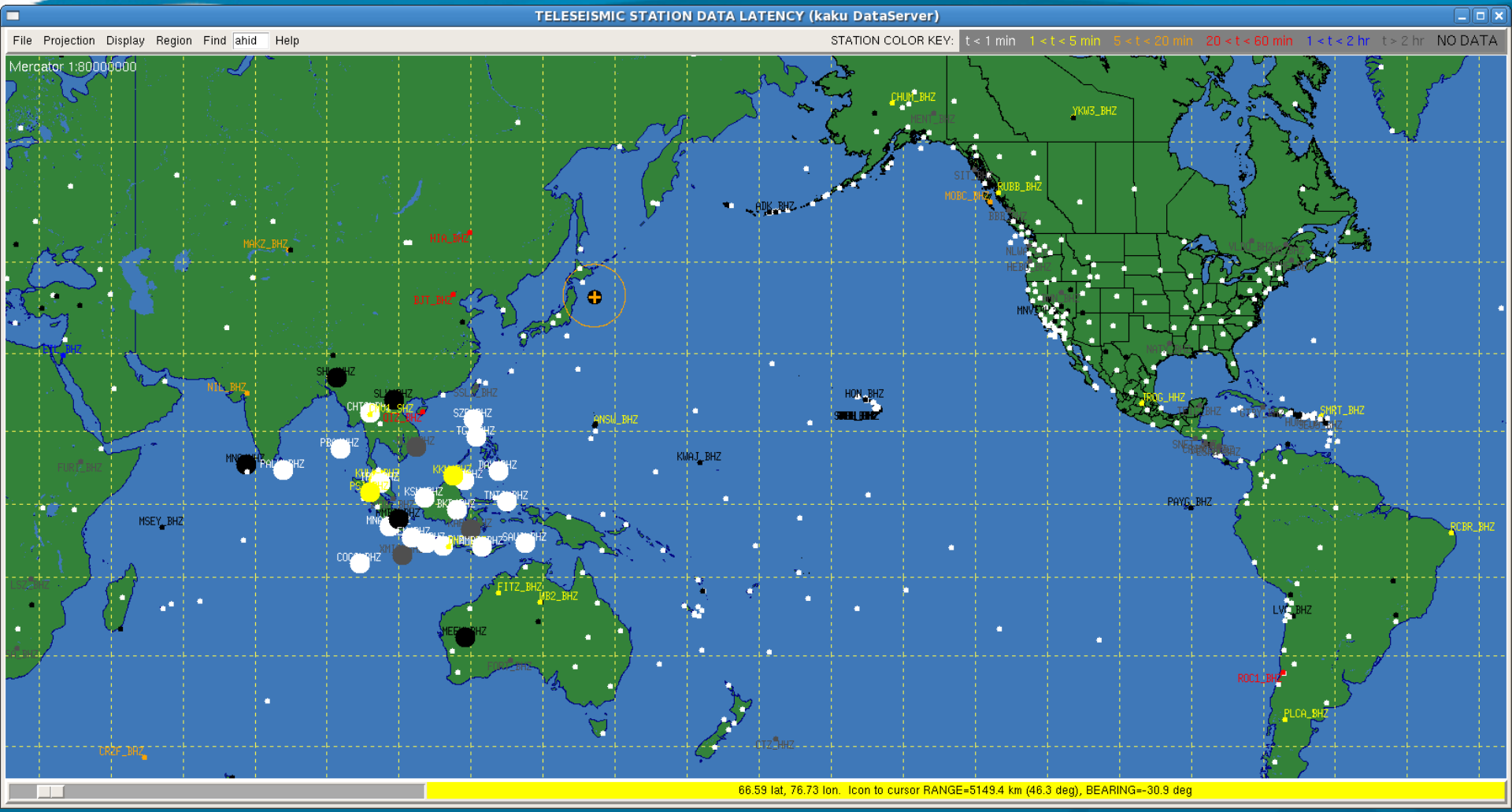
Broadband Seismometer Distribution



More than 630 Stations!

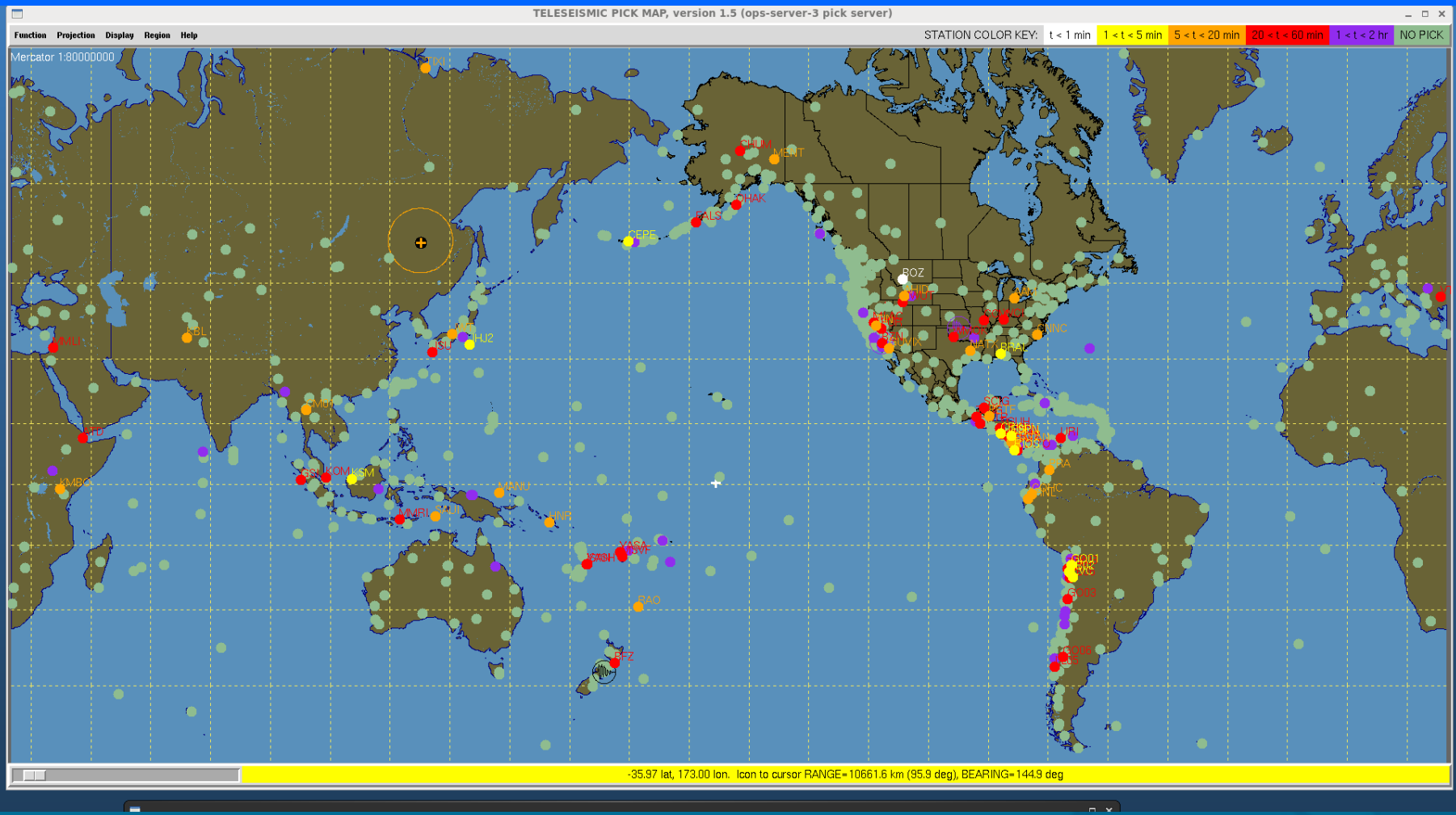
NEIC
HVO
Menlo
AEIC
IRIS
IDA
NTWC
CNSN
GFZ
ERI
GAU
UCB
GNZ
RSNC
GEOscope
PRSN
ORSnet
UNAM
CTBTO
FUNVSIS
Cal Tech
LDO
UWash
UCHILE

Broadband Seismometer Distribution

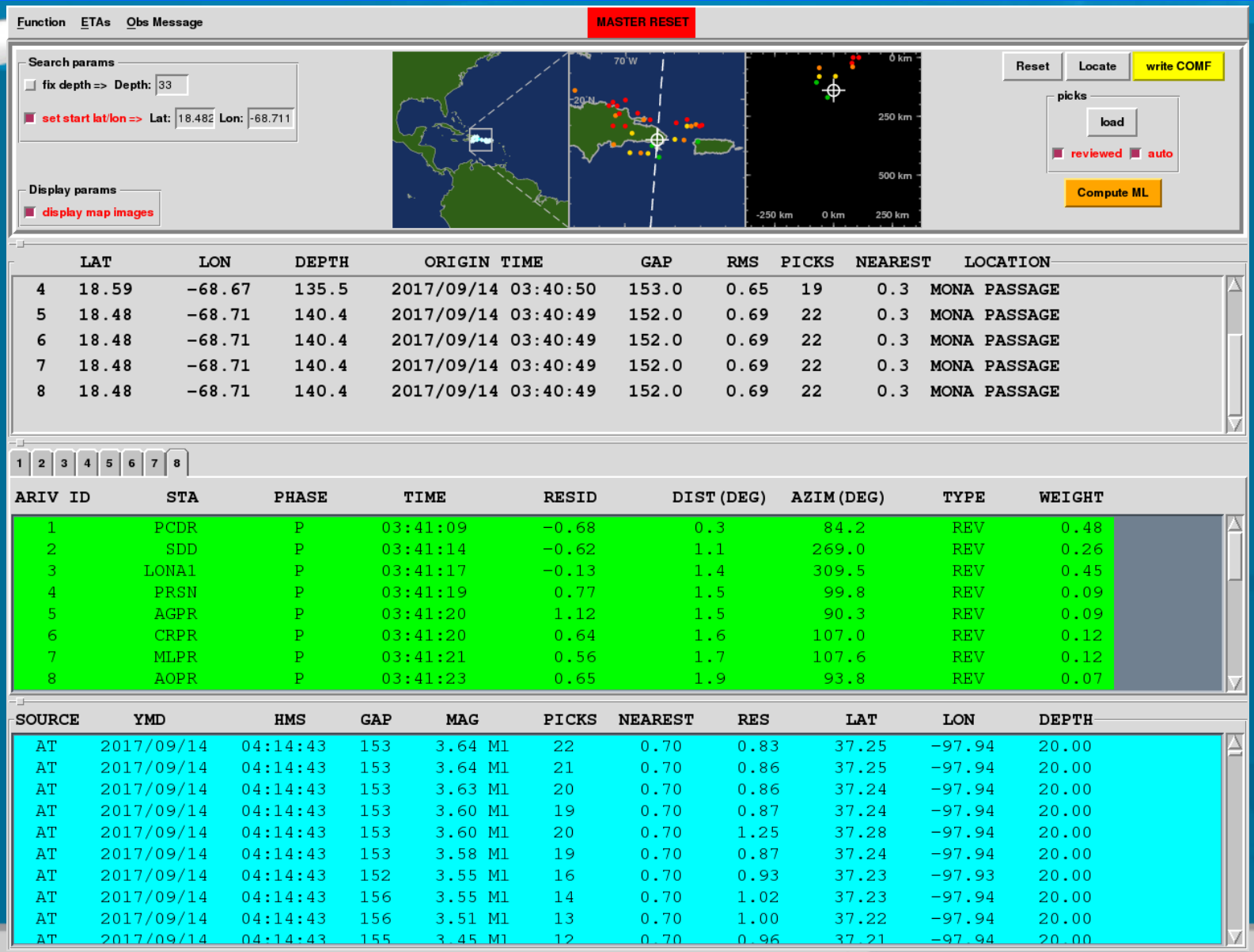


The large dots are the stations involved in the East Indian Ocean Alarm region. PTWC has 14 such alarm regions.

Seismic Detection



Earthquake Location



	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

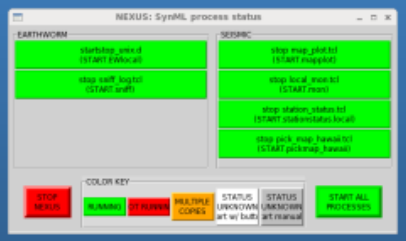
1 2 3 4 5 6 7 8

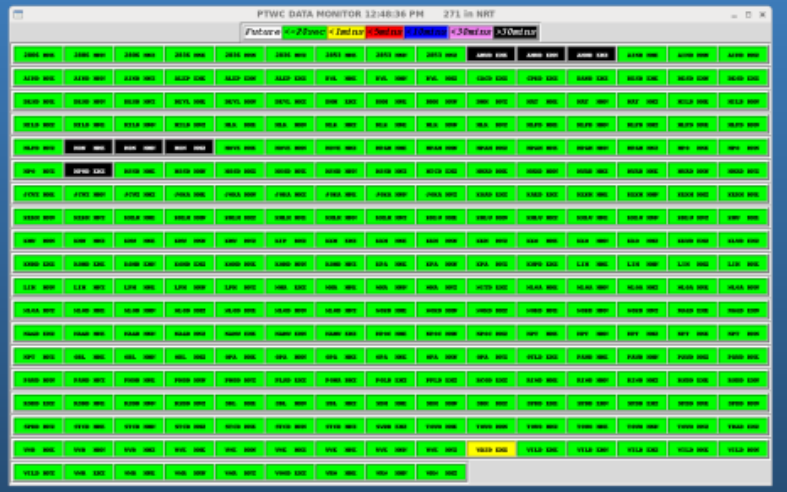
ARIV ID	STA	PHASE	TIME	RESID	DIST(DEG)	AZIM(DEG)	TYPE	WEIGHT
1	PCDR	P	03:41:09	-0.68	0.3	84.2	REV	0.48
2	SDD	P	03:41:14	-0.62	1.1	269.0	REV	0.26
3	LONA1	P	03:41:17	-0.13	1.4	309.5	REV	0.45
4	PRSN	P	03:41:19	0.77	1.5	99.8	REV	0.09
5	AGPR	P	03:41:20	1.12	1.5	90.3	REV	0.09
6	CRPR	P	03:41:20	0.64	1.6	107.0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

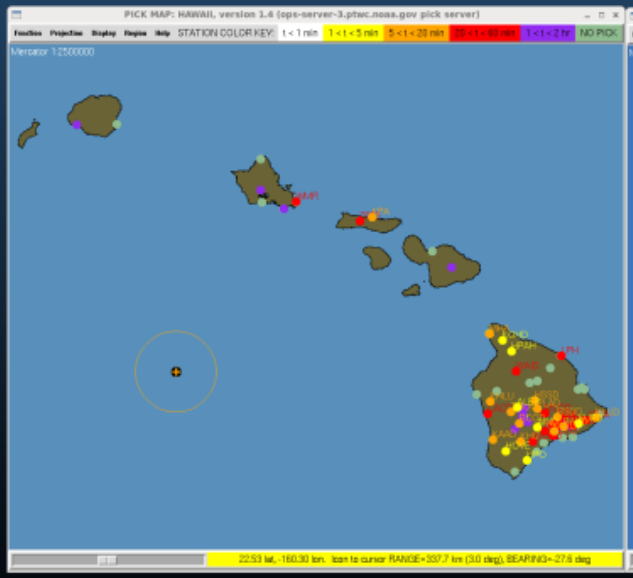
SOURCE	YMD	HMS	GAP	MAG	PICKS	NEAREST	RES	LAT	LON	DEPTH
AT	2017/09/14	04:14:43	153	3.64 Ml	22	0.70	0.83	37.25	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.64 Ml	21	0.70	0.86	37.25	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.63 Ml	20	0.70	0.86	37.24	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.60 Ml	19	0.70	0.87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

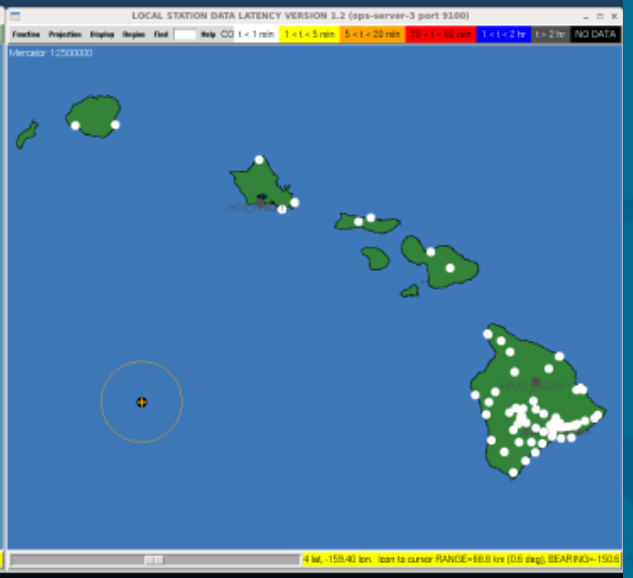
Hawaii Seismic Data Processing

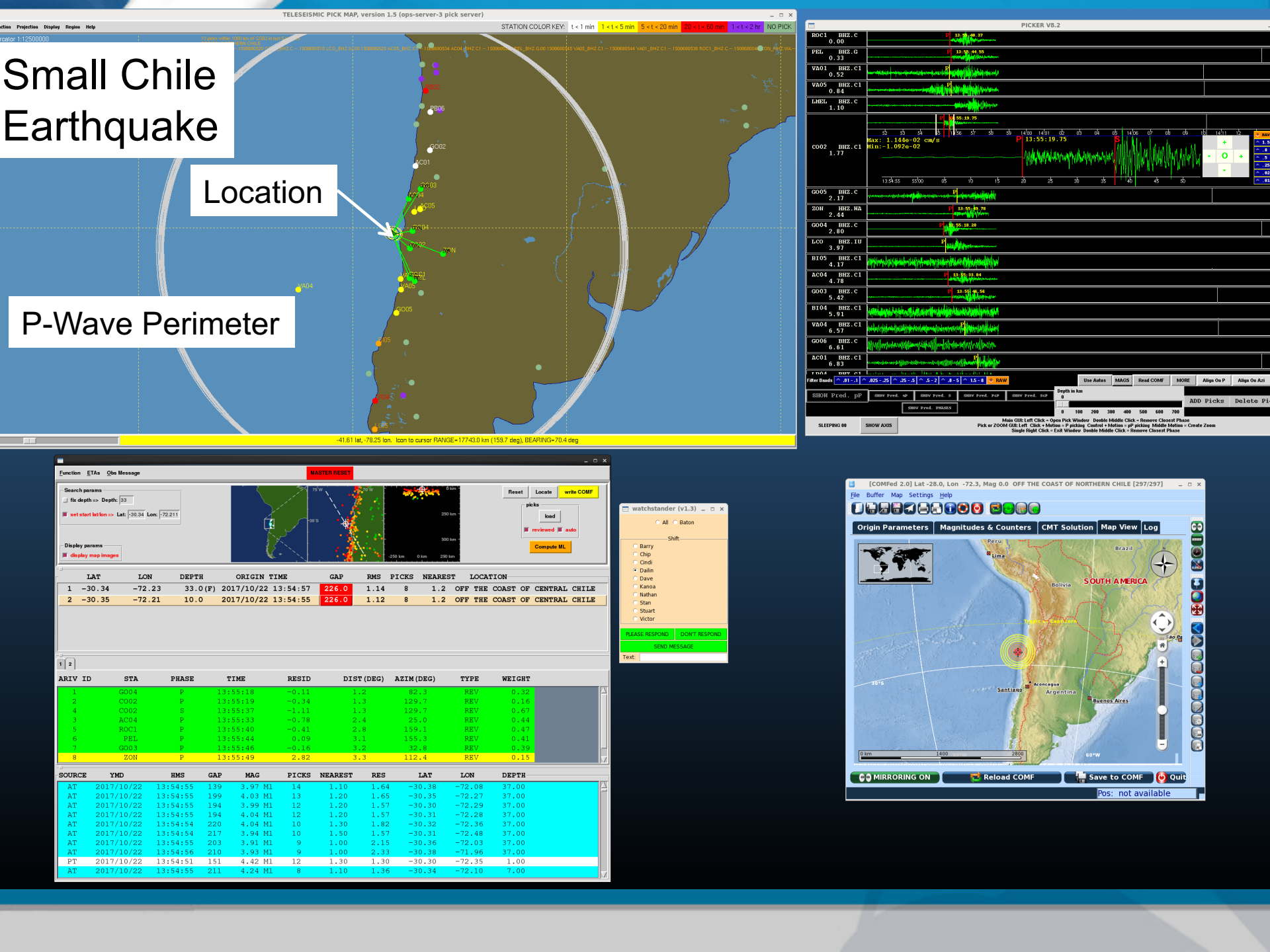
Hawaii Seismic Data Processing







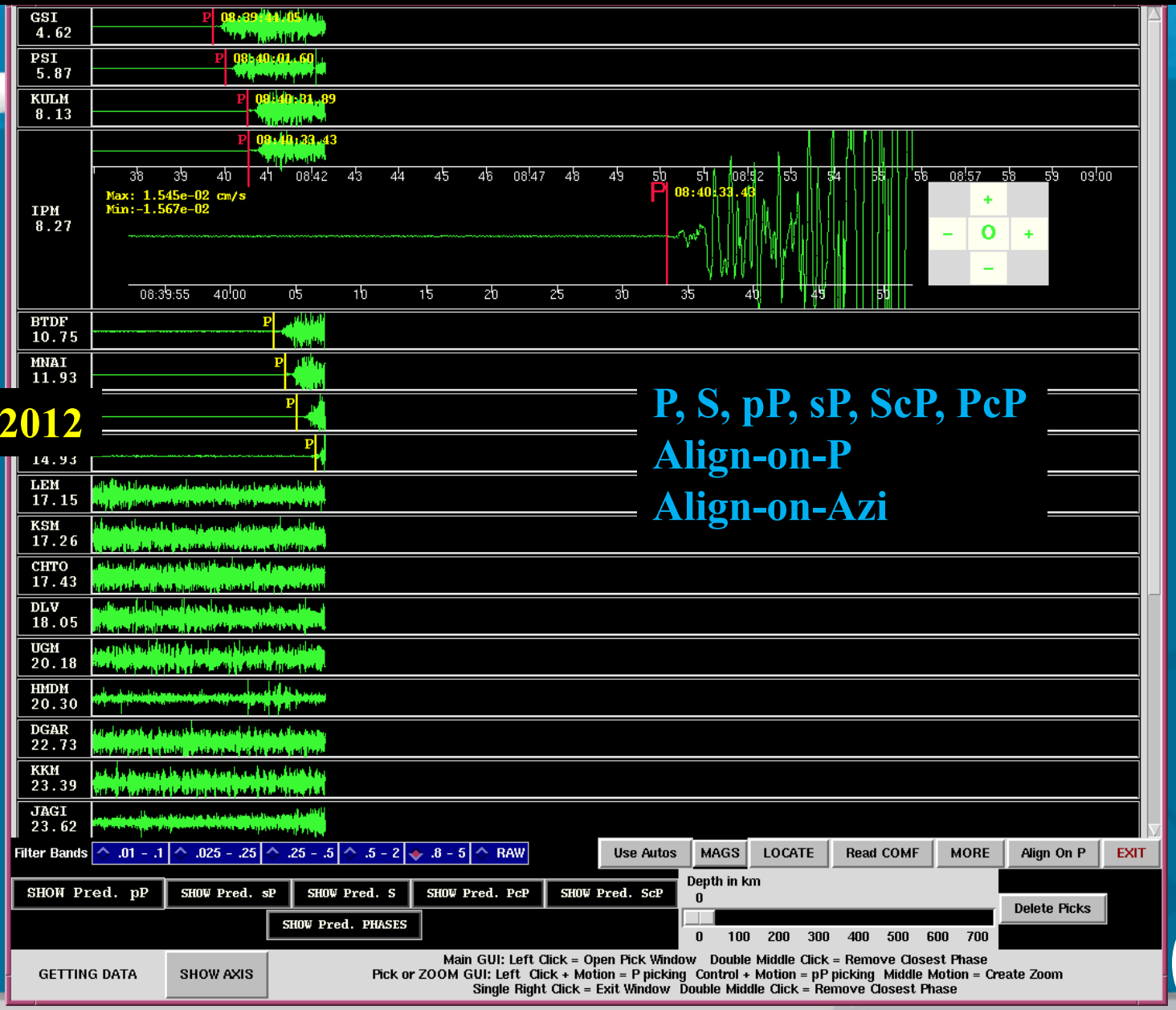



Small Chile Earthquake
Location
P-Wave Perimeter
TELESEISMIC PICK MAP, version 1.5 (ops-server-3 pick server)
STATION COLOR KEY:
t < 1 min
1 < t < 5 min
5 < t < 20 min
20 < t < 60 min
1 < t < 2 hr
NO PICK
PICKER V8.2
watchstander (v1.3)
[COMFed 2.0] Lat -28.0, Lon -72.3, Mag 0.0 OFF THE COAST OF NORTHERN CHILE [297/297]
Origin Parameters
Magnitudes & Counters
CMT Solution
Map View
Log
MIRRORING ON
Reload COMF
Save to COMF
Quit

Interactive Phase Picker

OT +
270s

Sumatra 2012



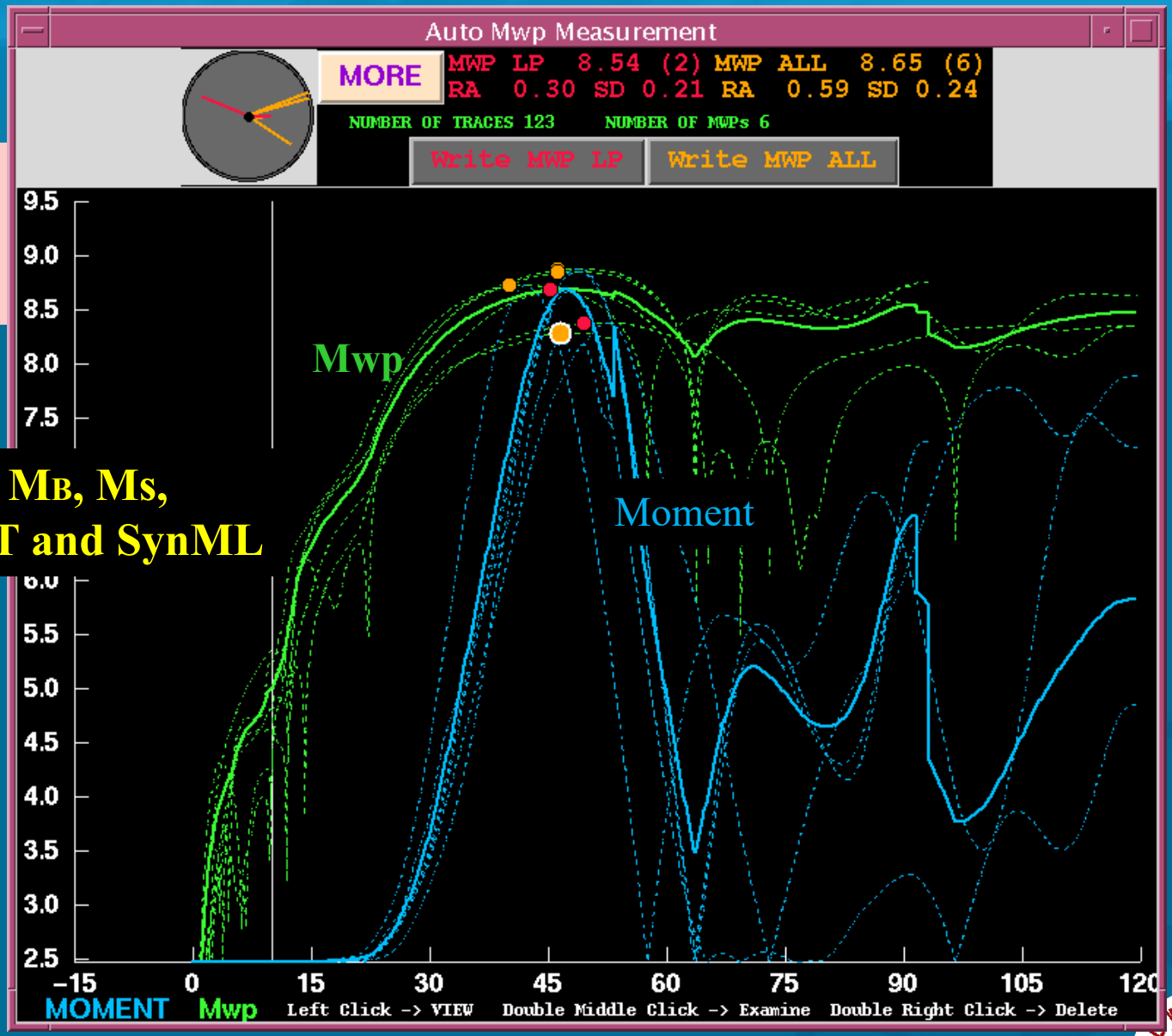
P, S, pP, sP, ScP, PcP
Align-on-P
Align-on-Azi

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

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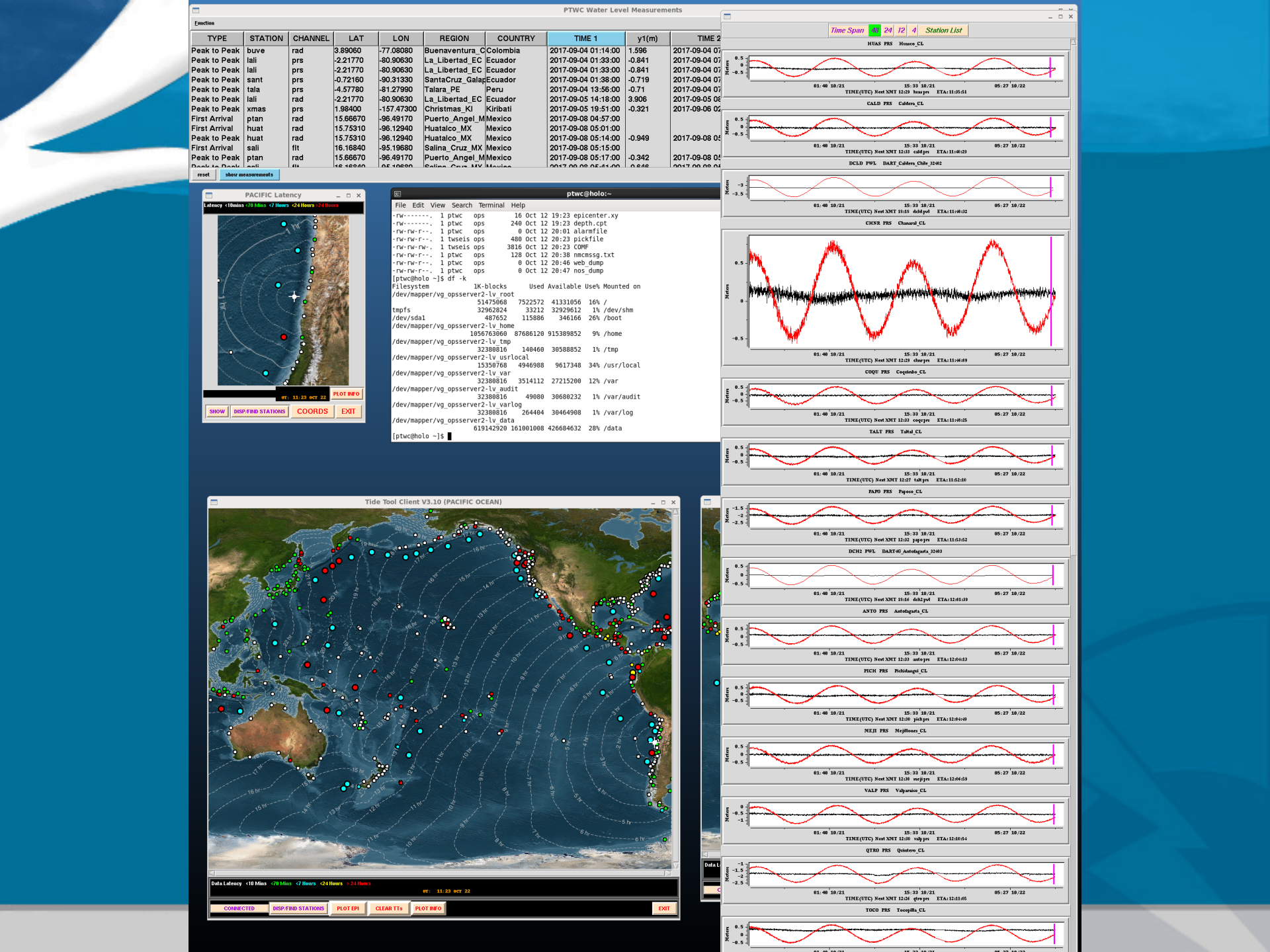
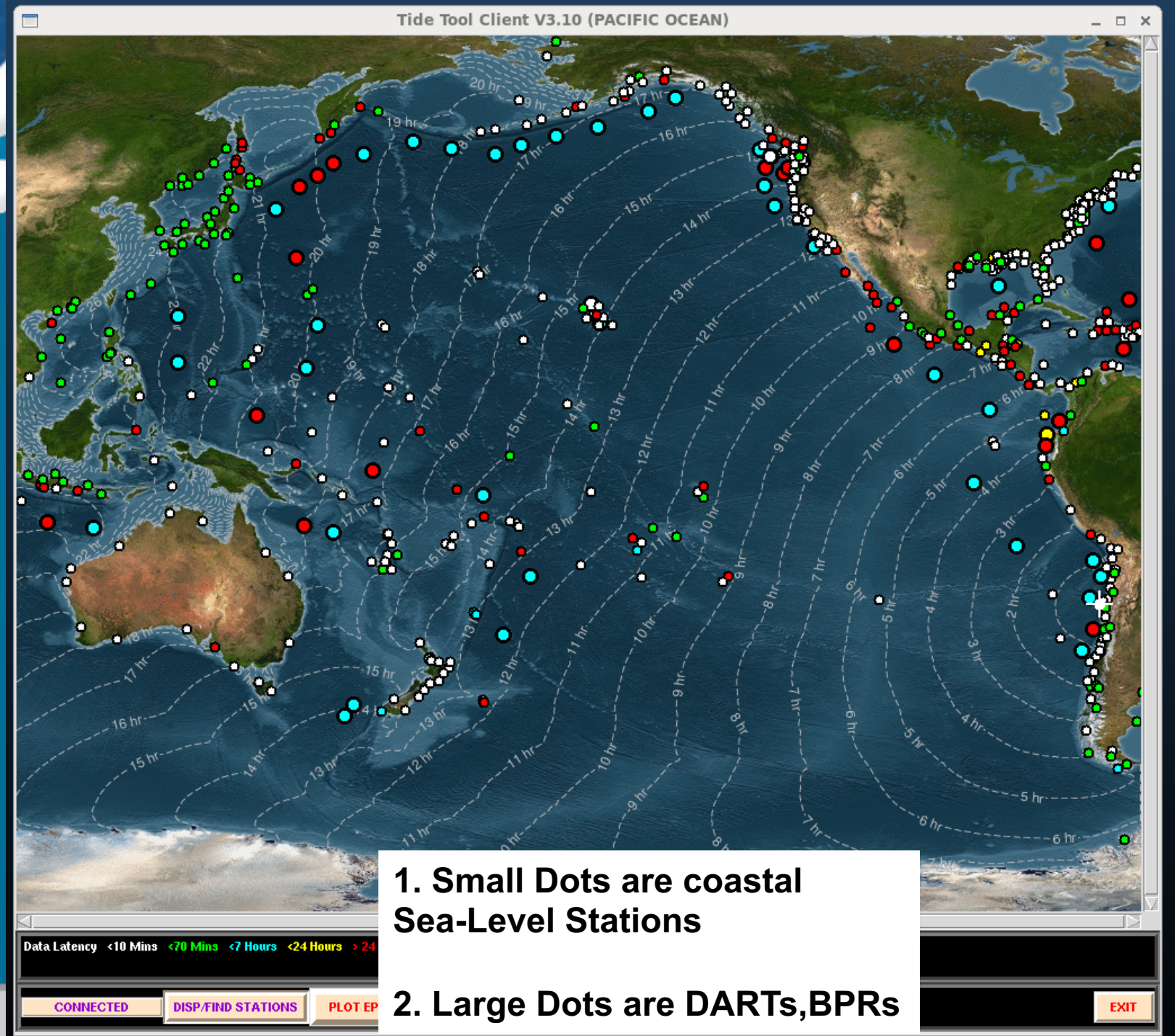
Global Sea-Level Processing Desktop

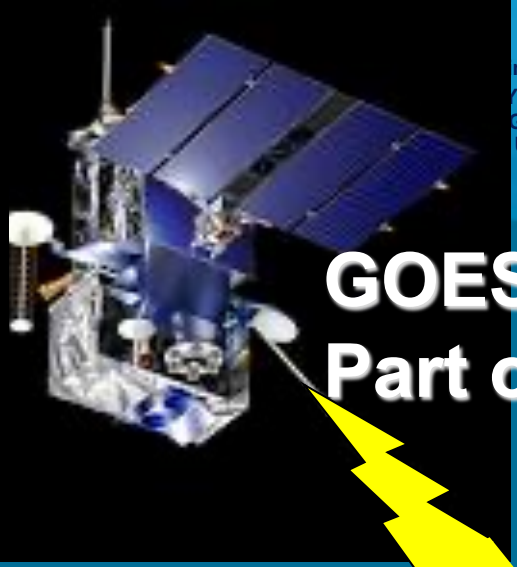

PTWC Water Level Measurements
Function
TYPE STATION CHANNEL LAT LON REGION COUNTRY TIME 1 y1(m) TIME 2
Peak to Peak buve rad 3.89060 -77.08080 Buenaventura_C Colombia 2017-09-04 01:14:00 1.596 2017-09-04 07
Peak to Peak lali prs -2.21770 -80.90630 La_Libertad_EC Ecuador 2017-09-04 01:33:00 -0.841 2017-09-04 07
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
Peak to Peak sant prs -0.72160 -90.31330 SantaCruz_Galap Ecuador 2017-09-04 01:38:00 -0.719 2017-09-04 07
Peak to Peak tala prs -4.57780 -81.27990 Talara_PE Peru 2017-09-04 13:56:00 -0.71 2017-09-04 07
Peak to Peak lali rad -2.21770 -80.90630 La_Libertad_EC Ecuador 2017-09-05 14:18:00 3.906 2017-09-05 08
Peak to Peak xmas prs 1.98400 -157.47300 Christmas_KI Kiribati 2017-09-05 19:51:00 -0.321 2017-09-06 02
First Arrival ptan rad 15.66670 -96.49170 Puerto_Angel_M Mexico 2017-09-08 04:57:00
First Arrival huat rad 15.75310 -96.12940 Huatalco_MX Mexico 2017-09-08 05:01:00
Peak to Peak huat rad 15.75310 -96.12940 Huatalco_MX Mexico 2017-09-08 05:14:00 -0.949 2017-09-08 05
First Arrival sali flt 16.16840 -95.19680 Salina_Cruz_MX Mexico 2017-09-08 05:15:00
Peak to Peak ptan rad 15.66670 -96.49170 Puerto_Angel_M Mexico 2017-09-08 05:17:00 -0.342 2017-09-08 05
reset
show measurements
PACIFIC Latency
Latency <10mins <78 Mins <7 Hours <24 Hours >24 Hours
PLOT INFO
SHOW
DISP/FIND STATIONS
COORDS
EXIT
ptwc@holo:~
File Edit View Search Terminal Help
-rw-------. 1 ptwc ops 16 Oct 12 19:23 epicenter.xy
-rw-------. 1 ptwc ops 240 Oct 12 19:23 depth.cpt
-rw-rw-r--. 1 ptwc ops 0 Oct 12 20:01 alarmfile
-rw-rw-r--. 1 twseis ops 480 Oct 12 20:23 pickfile
-rw-rw-rw-. 1 twseis ops 3816 Oct 12 20:23 COMF
-rw-rw-r--. 1 ptwc ops 128 Oct 12 20:38 nmcmssg.txt
-rw-rw-r--. 1 ptwc ops 0 Oct 12 20:46 web_dump
-rw-rw-r--. 1 ptwc ops 0 Oct 12 20:47 nos_dump
[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 49080 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 ~]$
Time Span 48 24 12 4 Station List
HUAS PRS Huasco_CL
CALD PRS Caldera_CL
DCLD PWL DART_Caldera_Chile_32402
CHNR PRS Chanaral_CL
COQU PRS Coquimbo_CL
TALT PRS Taltal_CL
PAPO PRS Paposo_CL
DCH2 PWL DART-2G_Antofagasta_32403
ANTO PRS Antofagasta_CL
PICH PRS Pichidangui_CL
MEJI PRS Mejillones_CL
VALP PRS Valparaiso_CL
QTRO PRS Quintero_CL
TOCO PRS Tocopilla_CL
Tide Tool Client V3.10 (PACIFIC OCEAN)
Data Latency <10 Mins <78 Mins <7 Hours <24 Hours >24 Hours
CONNECTED
DISP/FIND STATIONS
PLOT EPI
CLEAR TTs
PLOT INFO
EXIT


Tide Tool Client V3.10 (PACIFIC OCEAN)
Data Latency <10 Mins <70 Mins <7 Hours <24 Hours > 24
CONNECTED
DISP/FIND STATIONS
PLOT EP
EXIT
1. Small Dots are coastal Sea-Level Stations
2. Large Dots are DARTs,BPRs

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

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.



GOESW
Part of the GTS

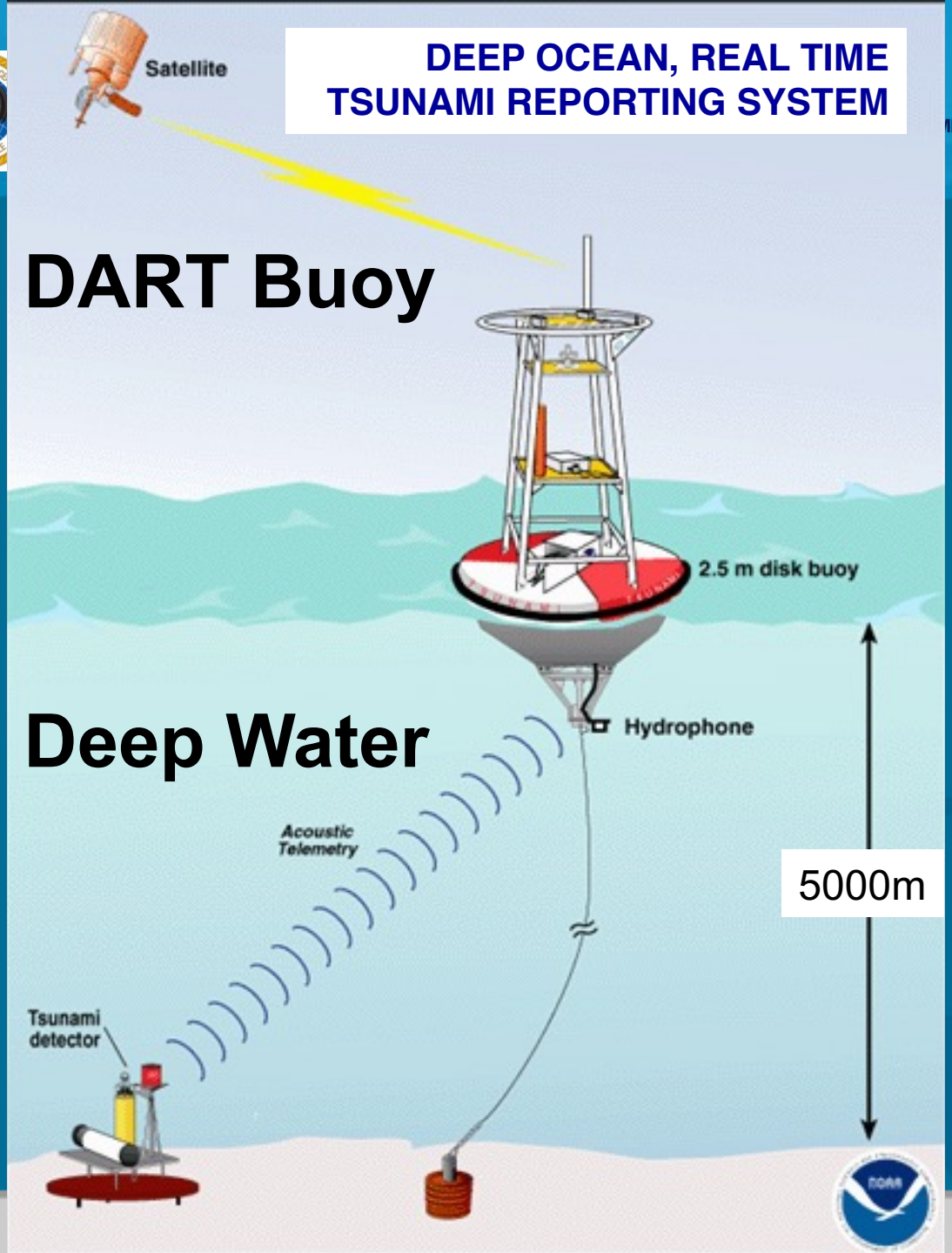
CHANNEL 32

Hiva Oa

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

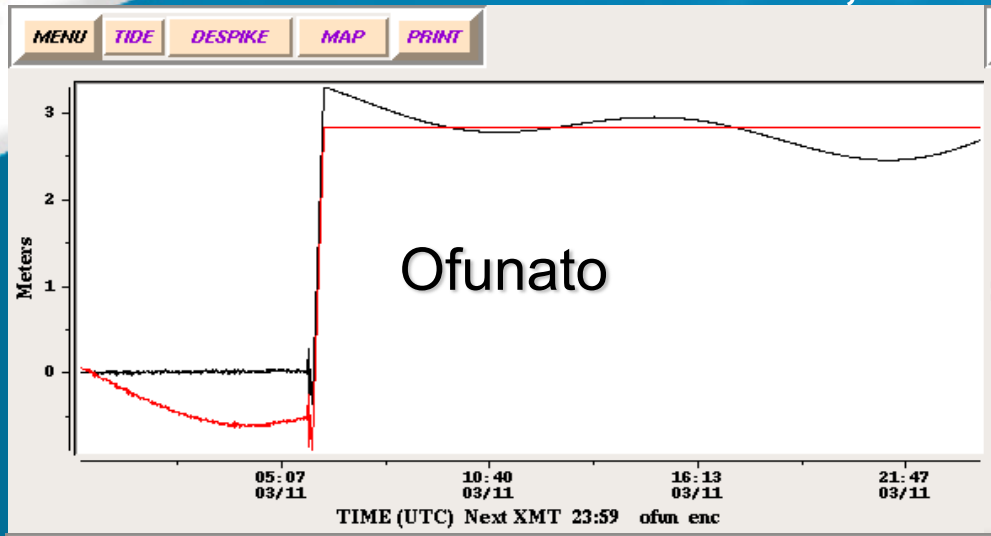
The tsunami signal is detected by a pressure sensor on the ocean floor. That signal is relayed by acoustic telemetry to the buoy. The buoy in turn transmits the signal via satellite back to the warning centers.

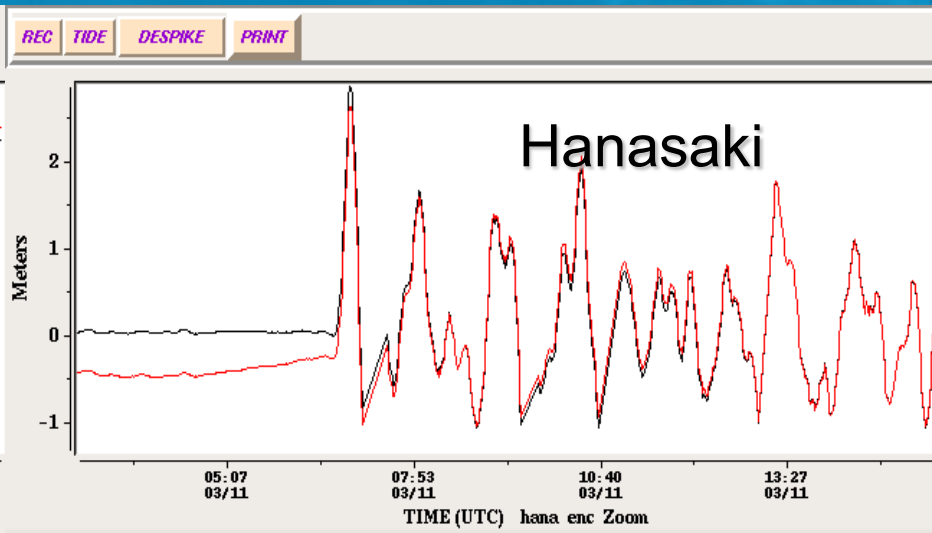
Can measure changes in sea-level as small as 1mm!

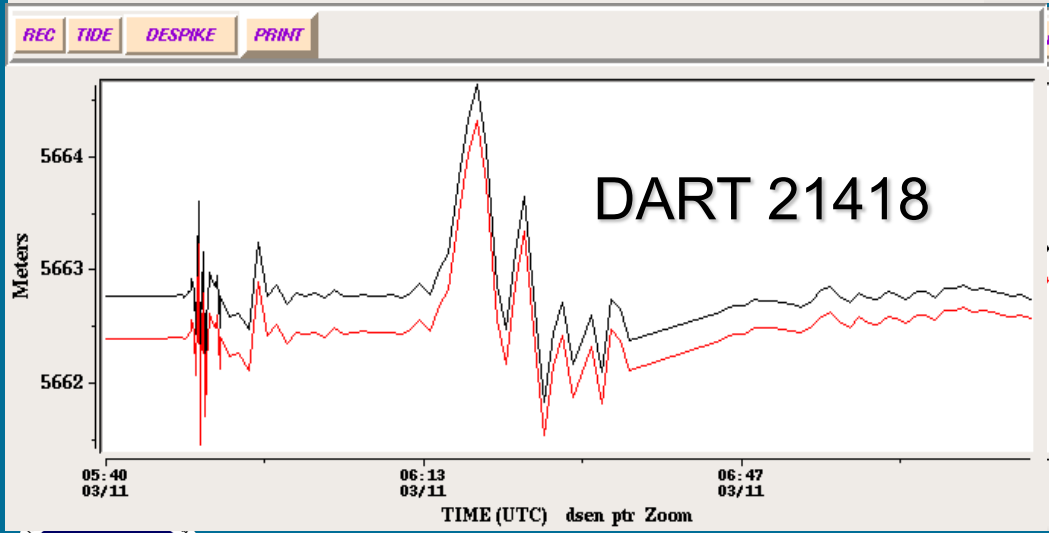


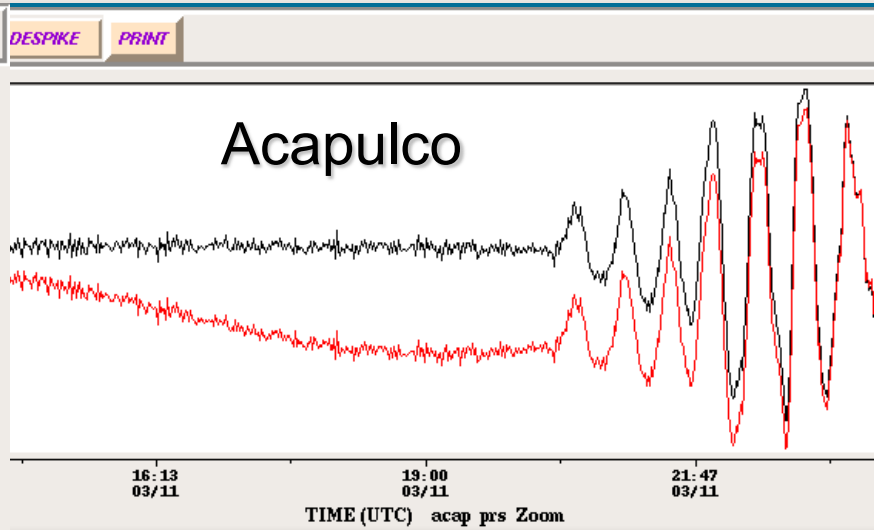
Tohoku Tsunami Marigrams

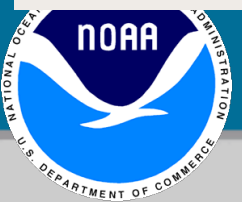
OT 5:46 UTC, Mar 11 2011 Mw = 9.1











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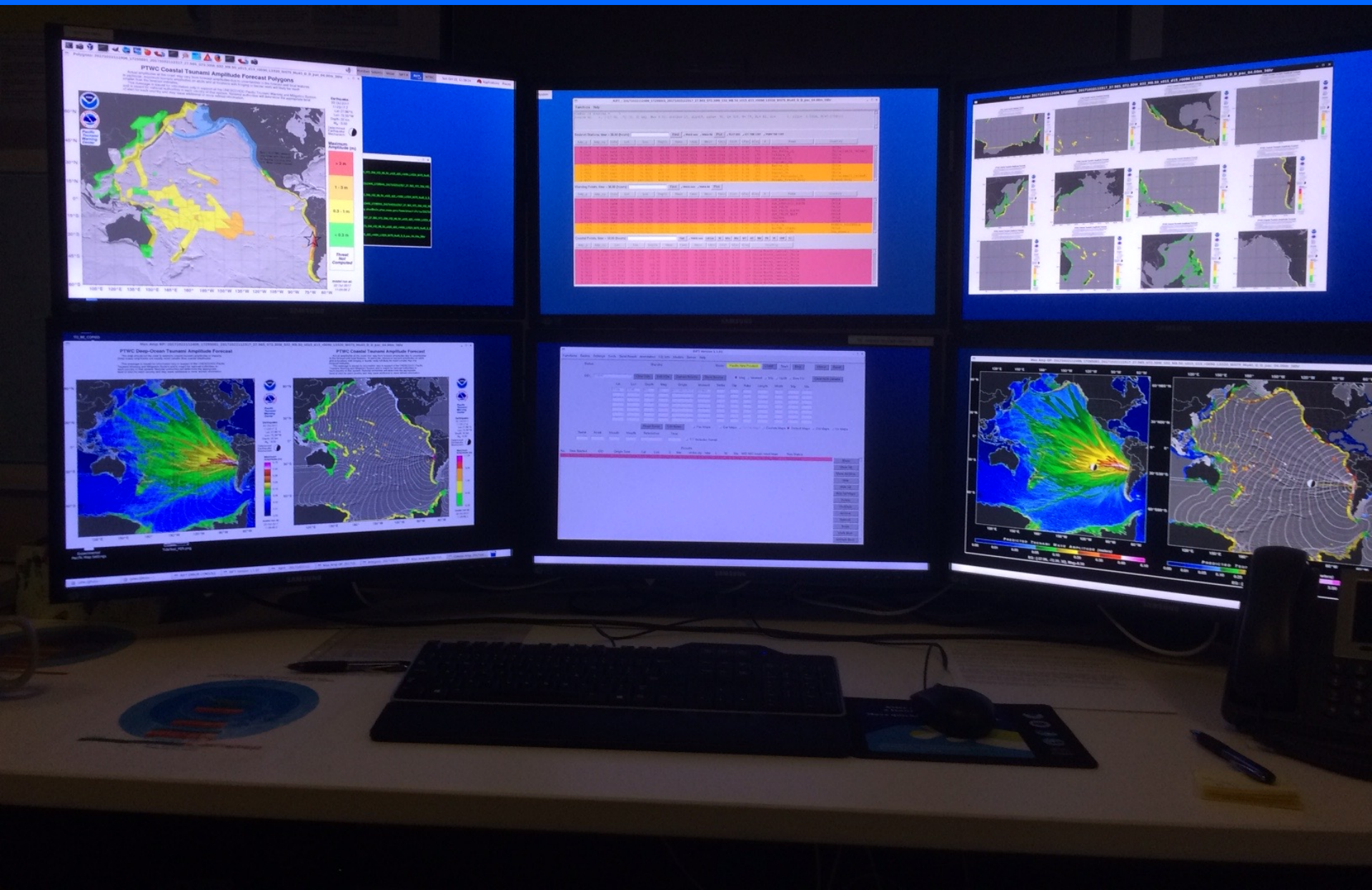
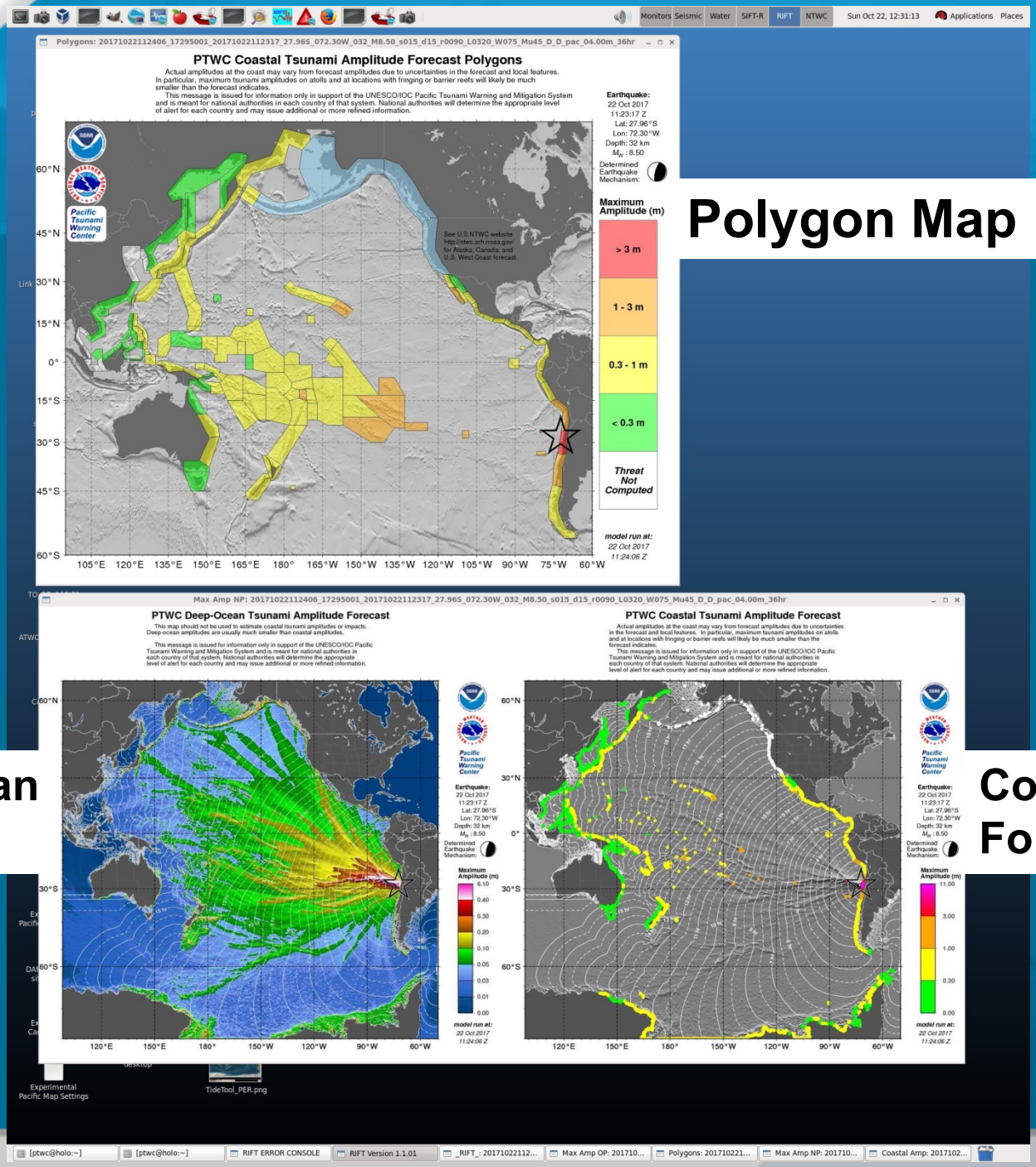
RIFT TSUNAMI FORECASTING DESKTOP



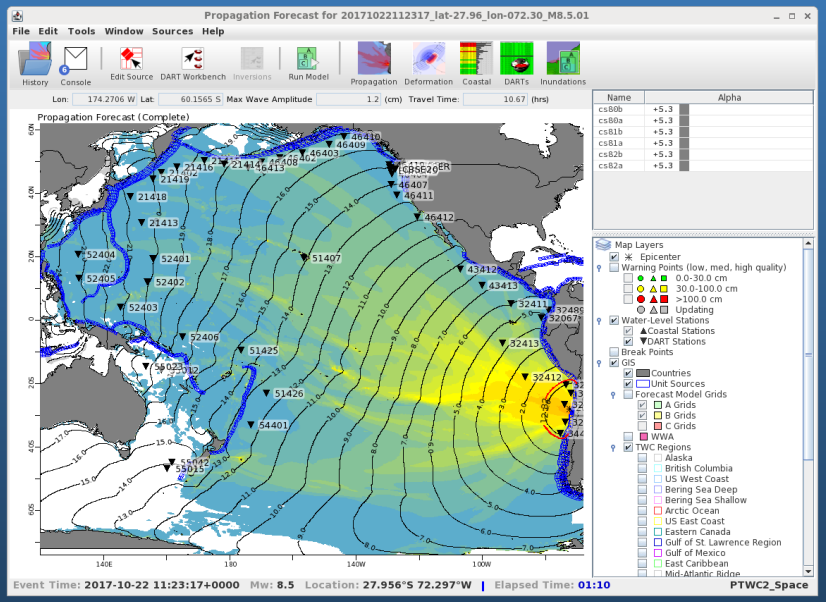


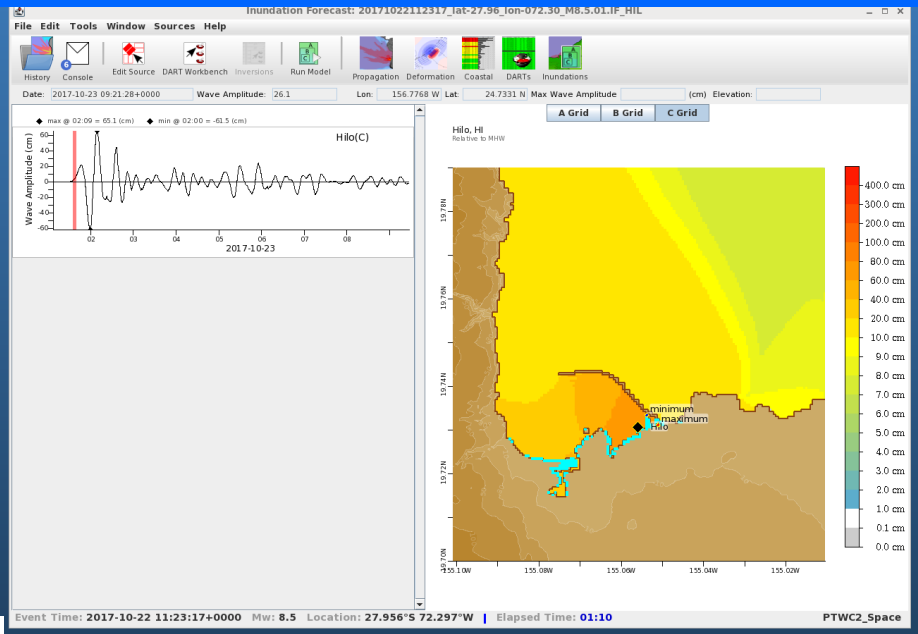
Polygon Map

Deep Ocean Forecast

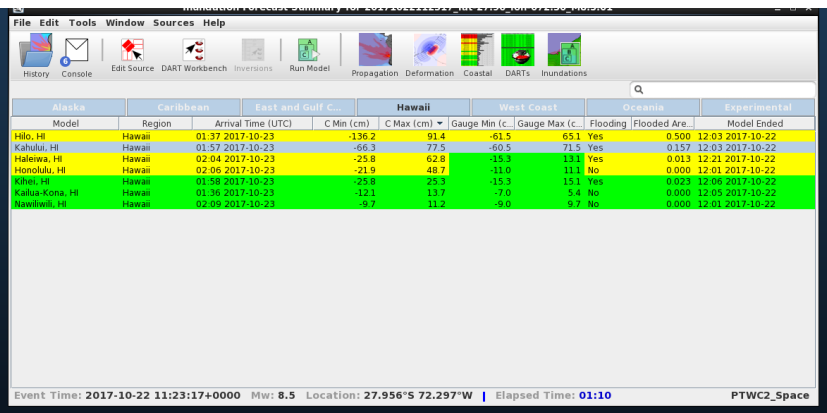
Coastal Forecast

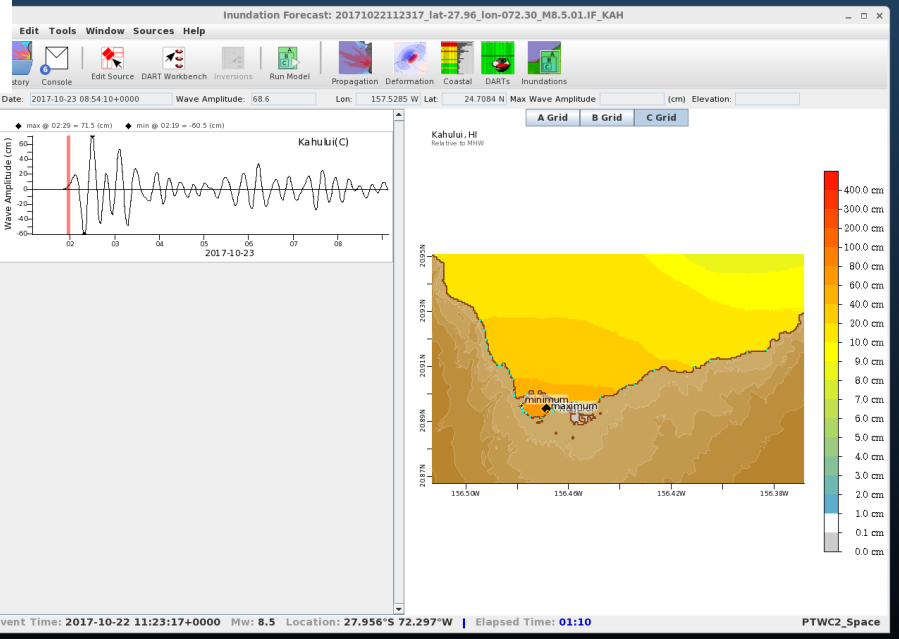
SIFT TSUNAMI FORECAST





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





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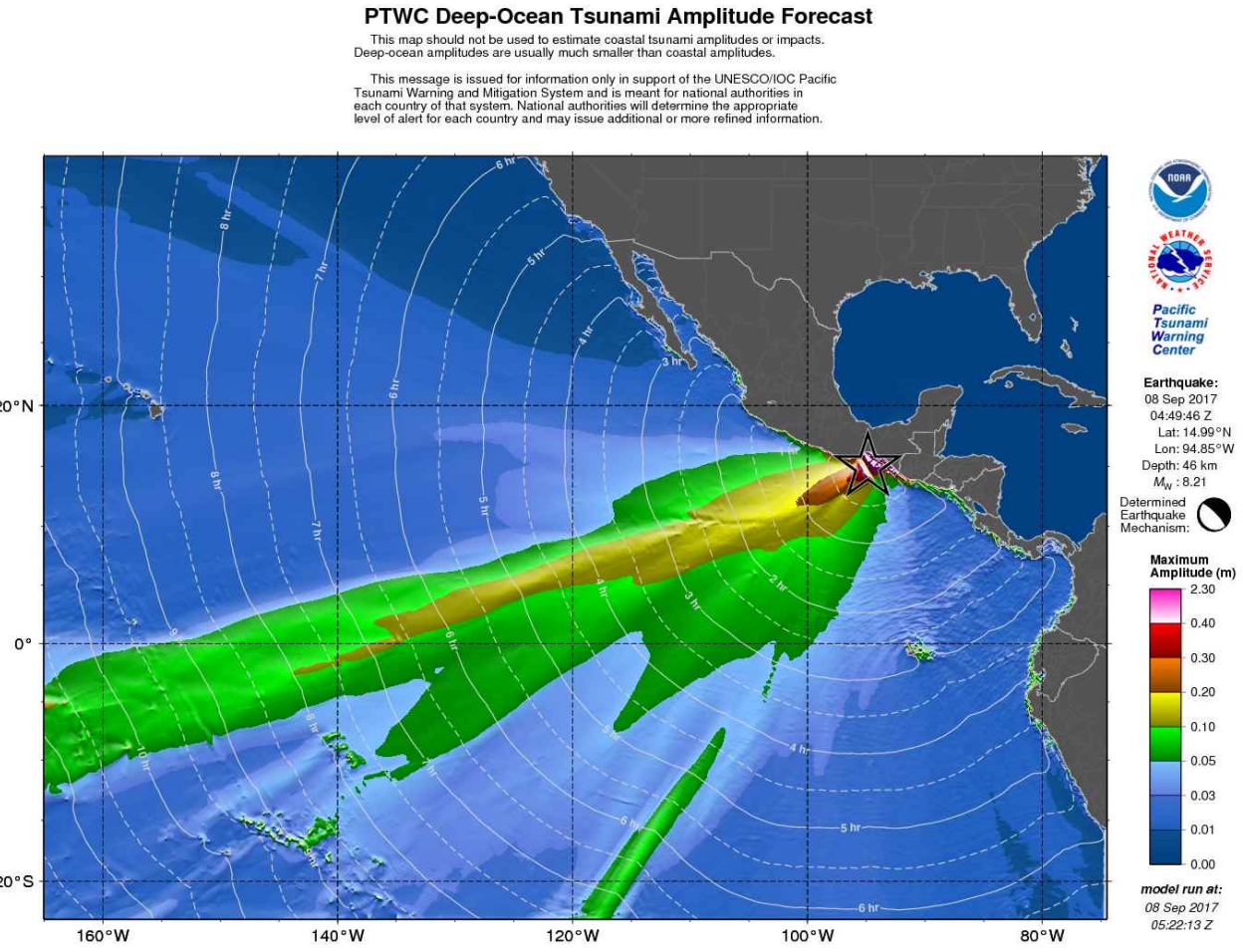
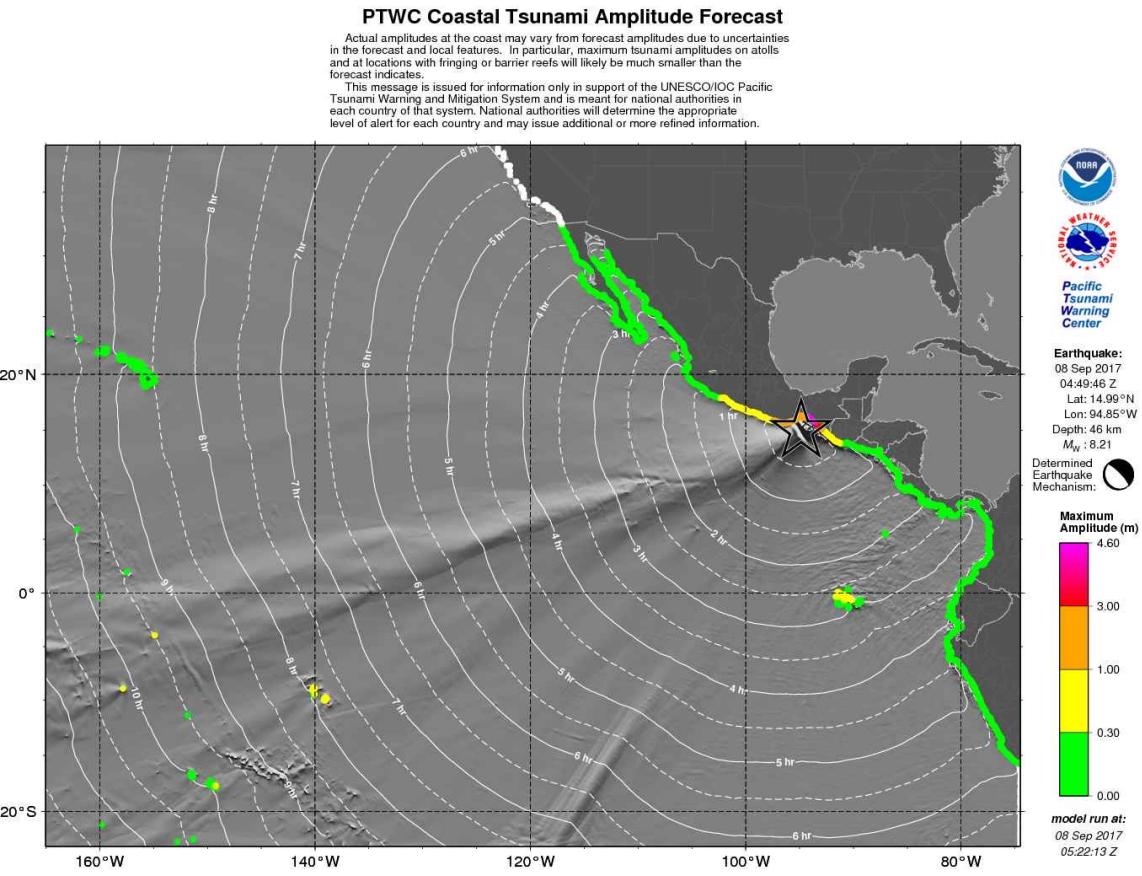
Graphical Product: Deep-Ocean Forecast



- 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

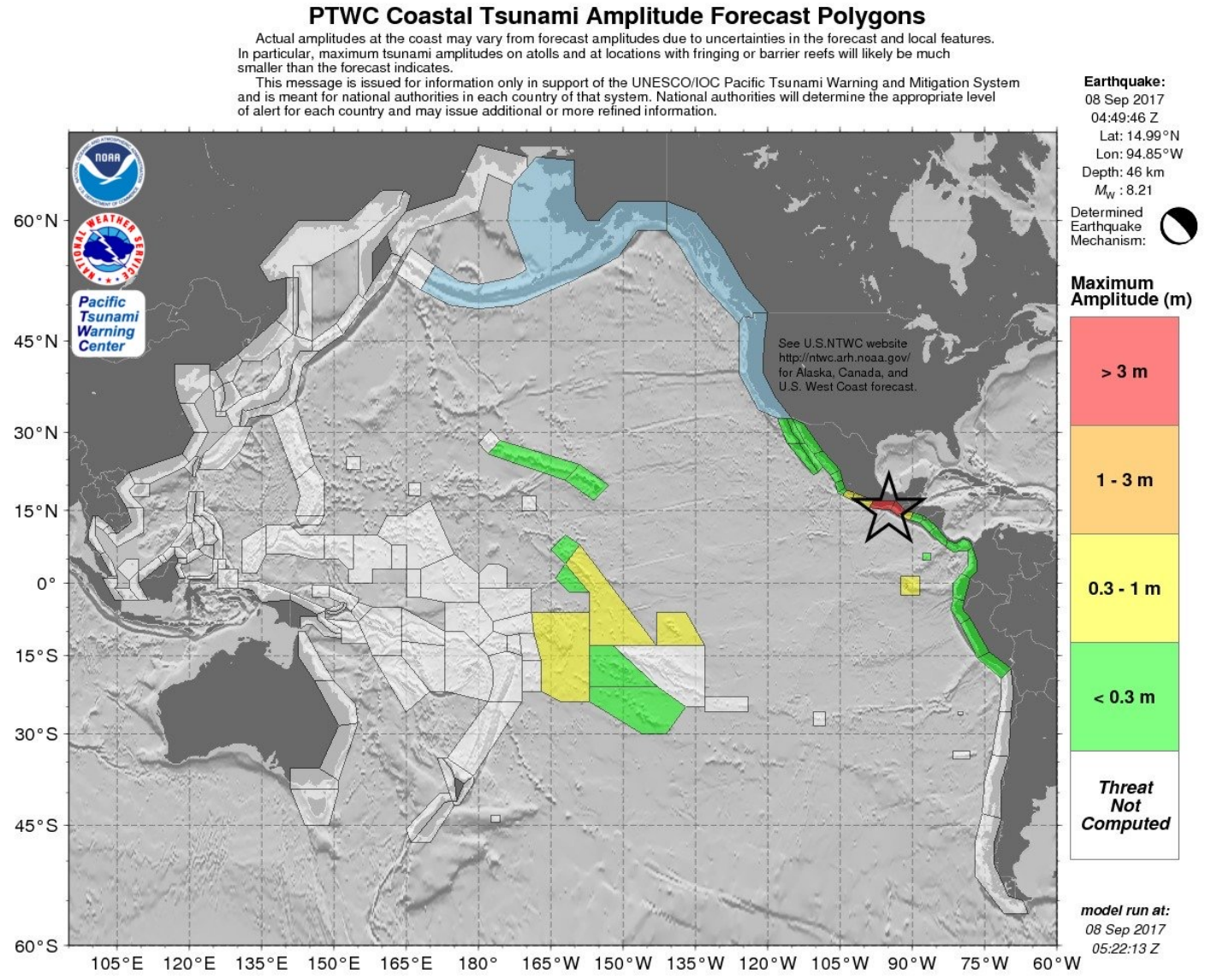
Graphical Product: Coastal Forecast



- 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



- **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 *******

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.

****** 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
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* 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 *******

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.

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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

Thank You!