UNESCO-IOC / NOAA ITIC Training Program in Hawaii (ITP-TEWS Hawaii)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
15-26 September 2025, Honolulu, Hawaii

Crises Events SOPs: Earthquake and Sea-Level Monitoring, Earthquake Analysis Methods, Threat Analysis, Forecasting, Products, Dissemination

Stuart A. Weinstein
NOAA/NWS/PTWC

General TWC SOP during an Event

0. EQ!!! - Digital Alarm - Duty Staff paged

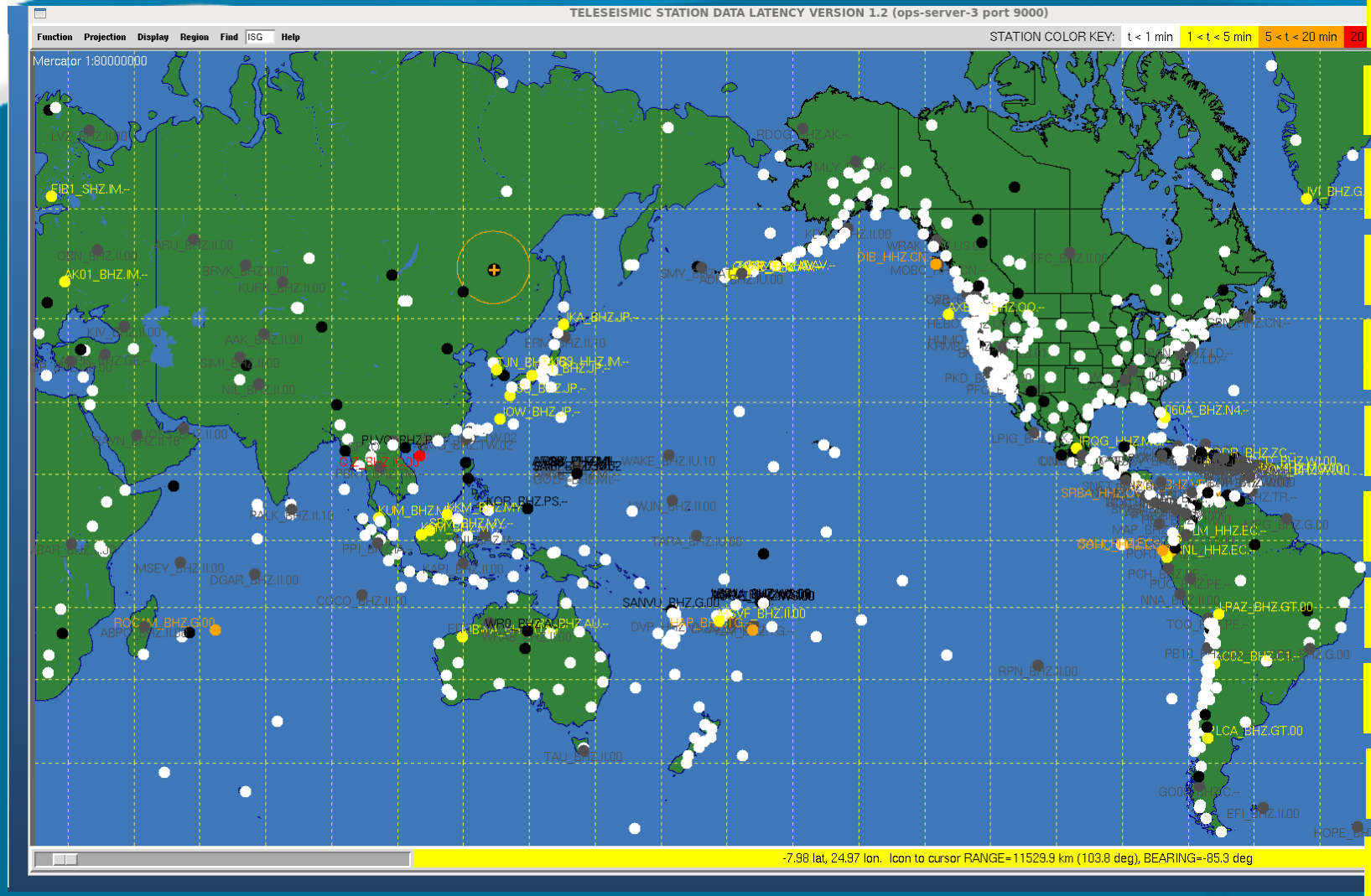
1. Detect and Analyze Large Earthquake
2. Determine Tsunami Hazard based on Pre-Determined Criteria
3. Issue Initial Message
4. Further Seismic Analyses
5. Detect and Analyze Tsunami Signals
6. Re-evaluate Tsunami Hazard
7. Issue Additional Message
8. Repeat Steps 4-7 until Threat Passed
9. Cancellation or Final Message

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



NEIC

HVO

Menlo

AEIC

IRIS

IDA

NTWC

CNSN

GFZ

ERI

GAU

UCB

GNZ

RSNC

GEOscope

PRSN

ORSnet

UNAM

CTBTO

FUNVSIS

Cal Tech

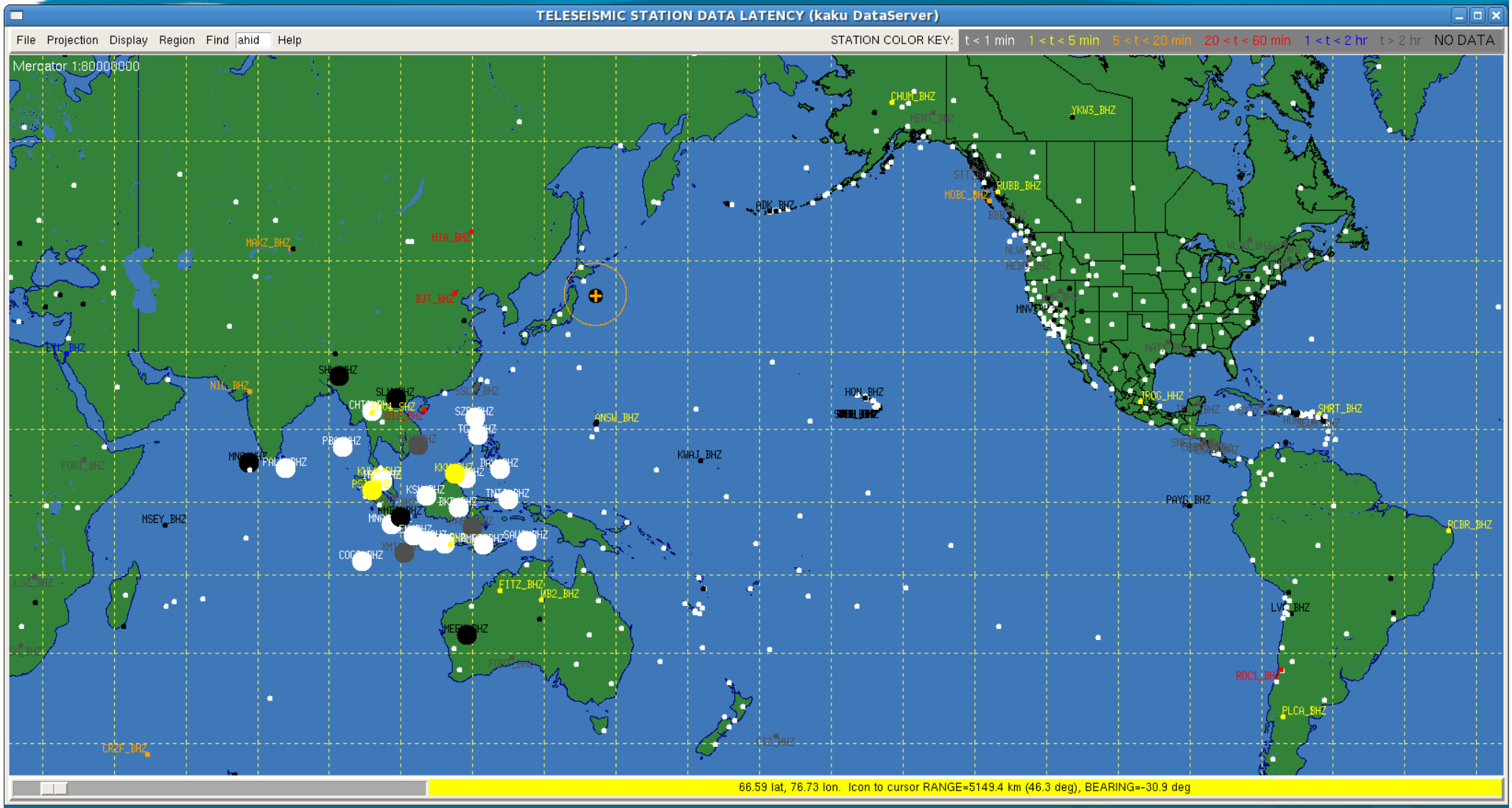
LDO

UWash

UCHILE

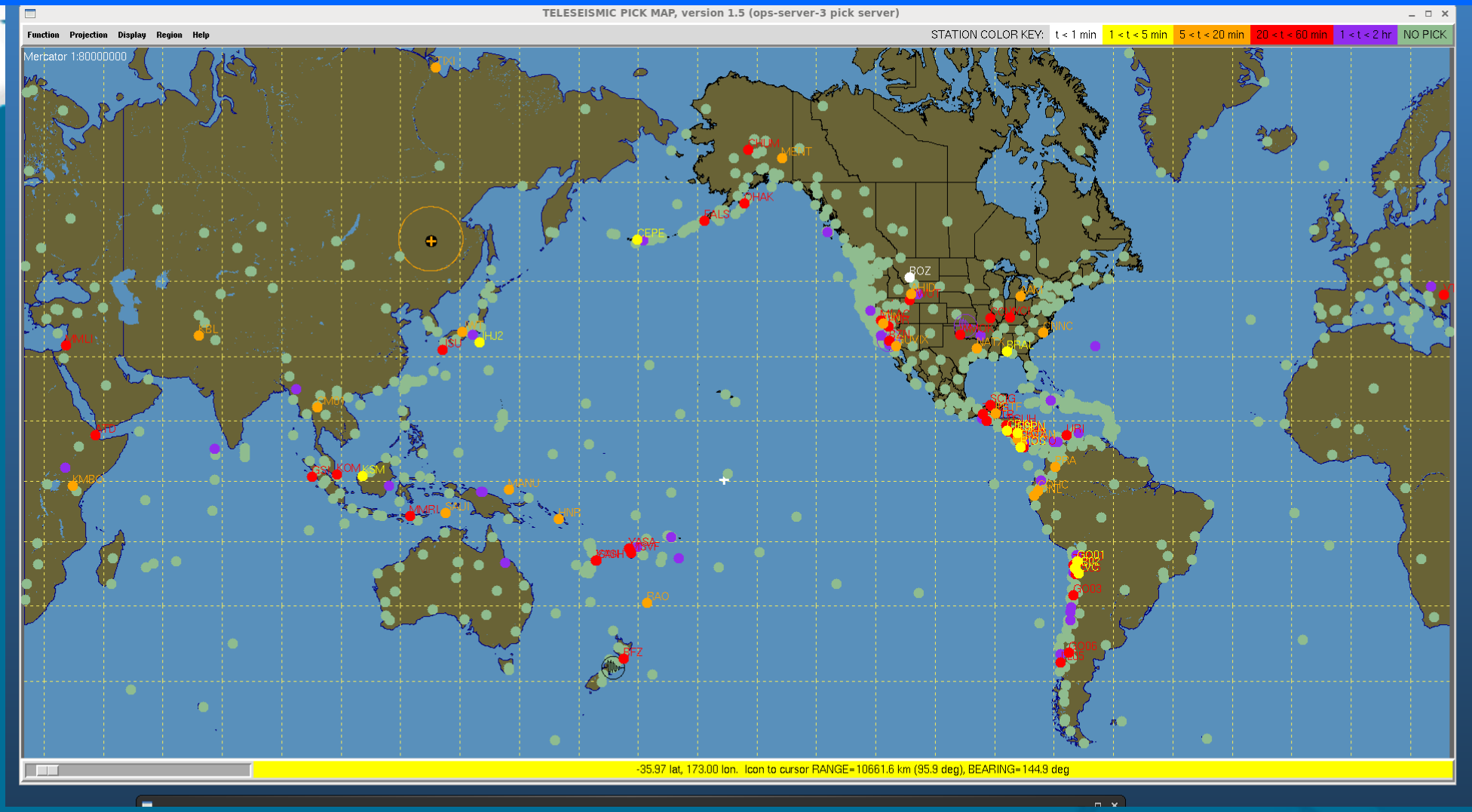
More than 630 Stations!

Broadband Seismometer Distribution

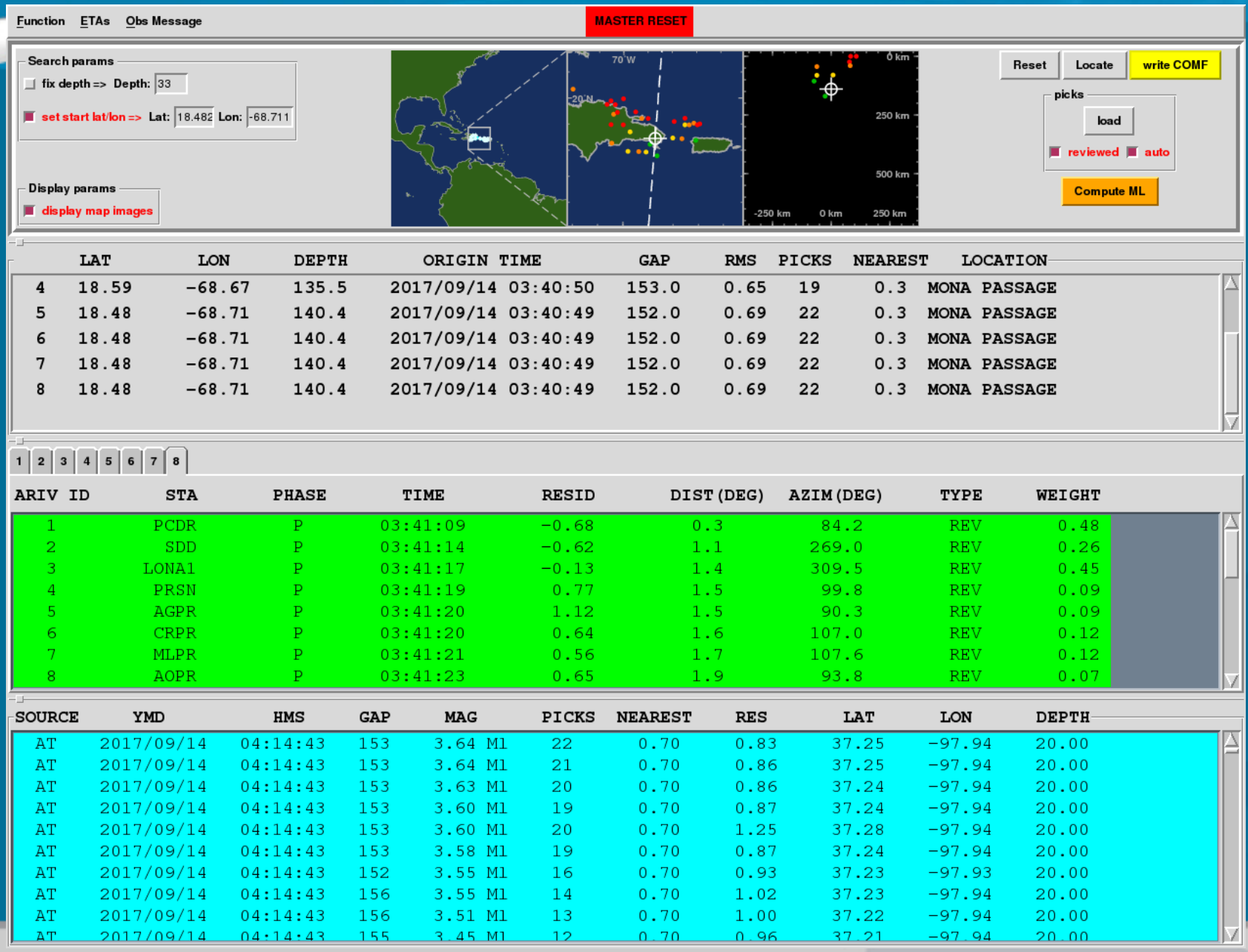


The large dots are the stations involved in the East Indian Ocean Alarm region. PTWC has 14 such alarm regions.

Seismic Detection



Earthquake Location

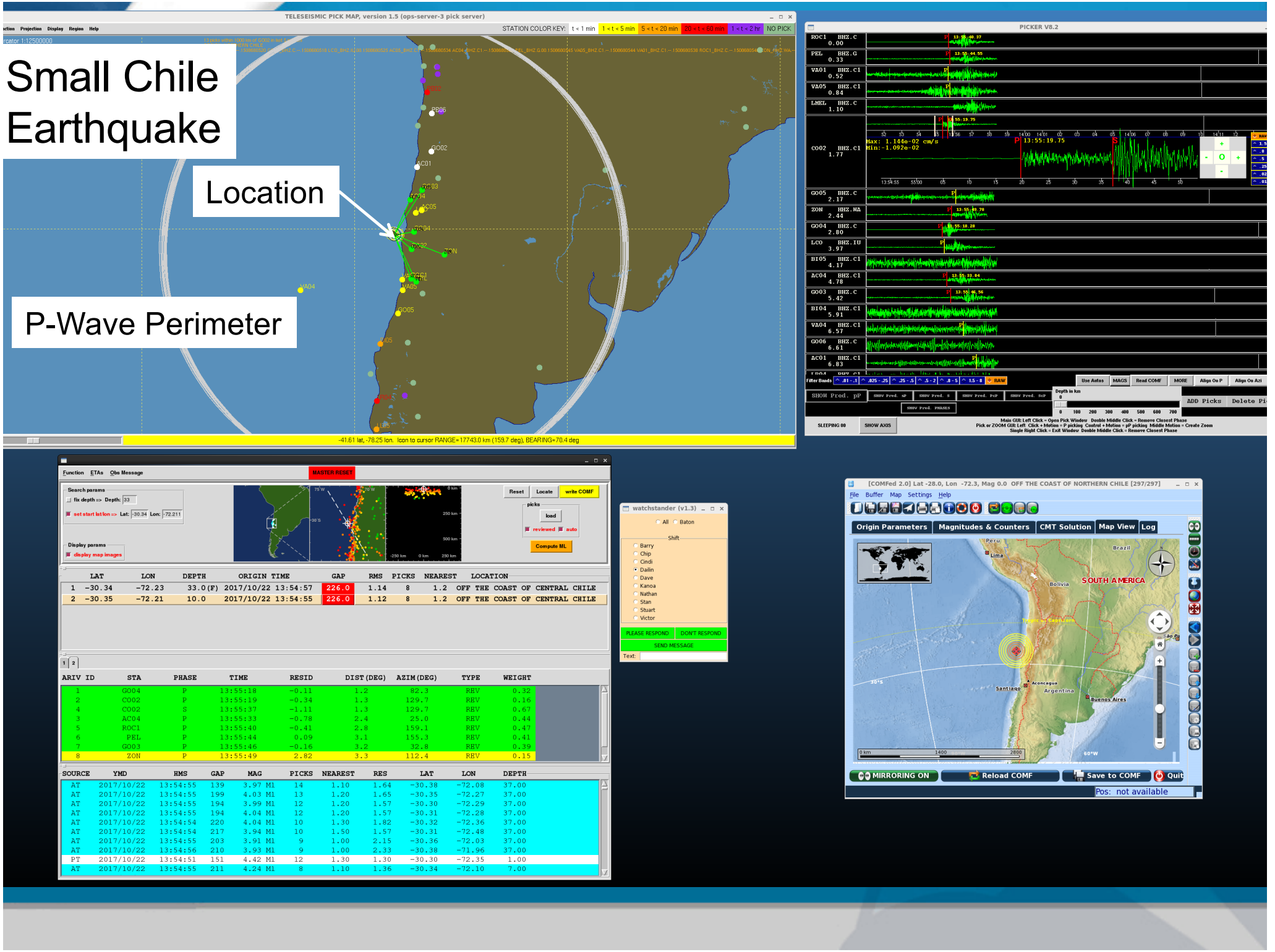


	LAT	LON	DEPTH	ORIGIN TIME	GAP	RMS	PICKS	NEAREST	LOCATION
4	18.59	-68.67	135.5	2017/09/14 03:40:50	153.0	0.65	19	0.3	MONA PASSAGE
5	18.48	-68.71	140.4	2017/09/14 03:40:49	152.0	0.69	22	0.3	MONA PASSAGE
6	18.48	-68.71	140.4	2017/09/14 03:40:49	152.0	0.69	22	0.3	MONA PASSAGE
7	18.48	-68.71	140.4	2017/09/14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

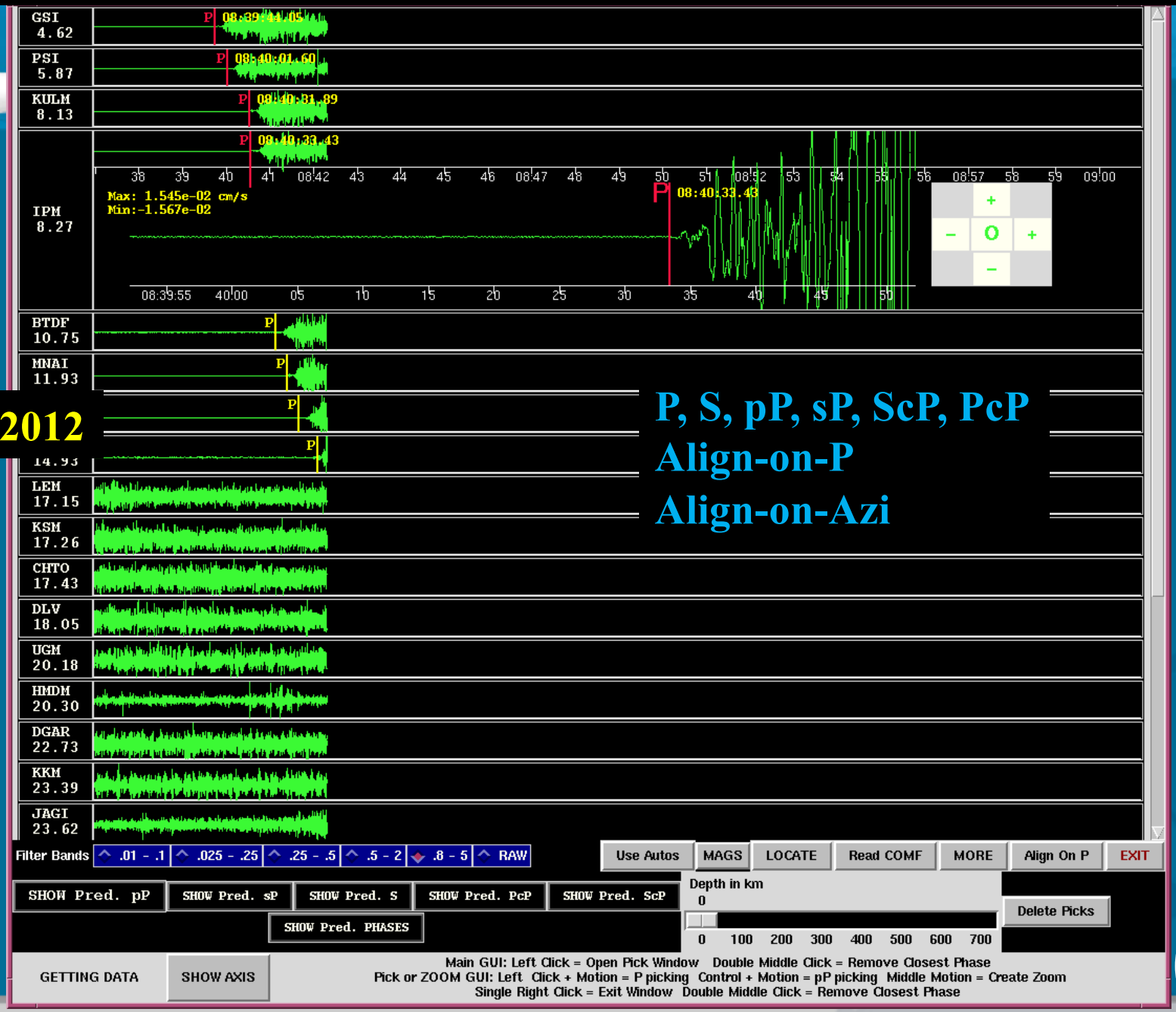
SOURCE	YMD	HMS	GAP	MAG	PICKS	NEAREST	RES	LAT	LON	DEPTH
AT	2017/09/14	04:14:43	153	3.64 Ml	22	0.70	0.83	37.25	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.64 Ml	21	0.70	0.86	37.25	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.63 Ml	20	0.70	0.86	37.24	-97.94	20.00
AT	2017/09/14	04:14:43	153	3.60 Ml	19	0.70	0.87	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


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
-41.61 lat, -78.25 lon. Icon to cursor RANGE=17743.0 km (159.7 deg), BEARING=70.4 deg
PICKER V8.2
Function
ETAs
Obs Message
MASTER RESET
Search params
Display params
Reset
Locate
write COMF
picks
load
reviewed
auto
Compute ML
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 M1 14 1.10 1.64 -30.38 -72.08 37.00
AT 2017/10/22 13:54:55 199 4.03 M1 13 1.20 1.65 -30.35 -72.27 37.00
AT 2017/10/22 13:54:55 194 3.99 M1 12 1.20 1.57 -30.30 -72.29 37.00
AT 2017/10/22 13:54:55 194 4.04 M1 12 1.20 1.57 -30.31 -72.28 37.00
AT 2017/10/22 13:54:54 220 4.04 M1 10 1.30 1.82 -30.32 -72.36 37.00
AT 2017/10/22 13:54:54 217 3.94 M1 10 1.50 1.57 -30.31 -72.48 37.00
AT 2017/10/22 13:54:55 203 3.91 M1 9 1.00 2.15 -30.36 -72.03 37.00
AT 2017/10/22 13:54:56 210 3.93 M1 9 1.00 2.33 -30.38 -71.96 37.00
PT 2017/10/22 13:54:51 151 4.42 M1 12 1.30 1.30 -30.30 -72.35 1.00
AT 2017/10/22 13:54:55 211 4.24 M1 8 1.10 1.36 -30.34 -72.10 7.00
watchstander (v1.3)
All
Baton
Shift
Barry
Chip
Cindi
Dailin
Dave
Kanoa
Nathan
Stan
Stuart
Victor
PLEASE RESPOND
DON'T RESPOND
SEND MESSAGE
Text:
[COMFed 2.0] Lat -28.0, Lon -72.3, Mag 0.0 OFF THE COAST OF NORTHERN CHILE [297/297]
File
Buffer
Map
Settings
Help
Origin Parameters
Magnitudes & Counters
CMT Solution
Map View
Log
SOUTH AMERICA
MIRRORING ON
Reload COMF
Save to COMF
Quit
Pos: not available

Interactive Phase Picker

OT +
270s

Sumatra 2012

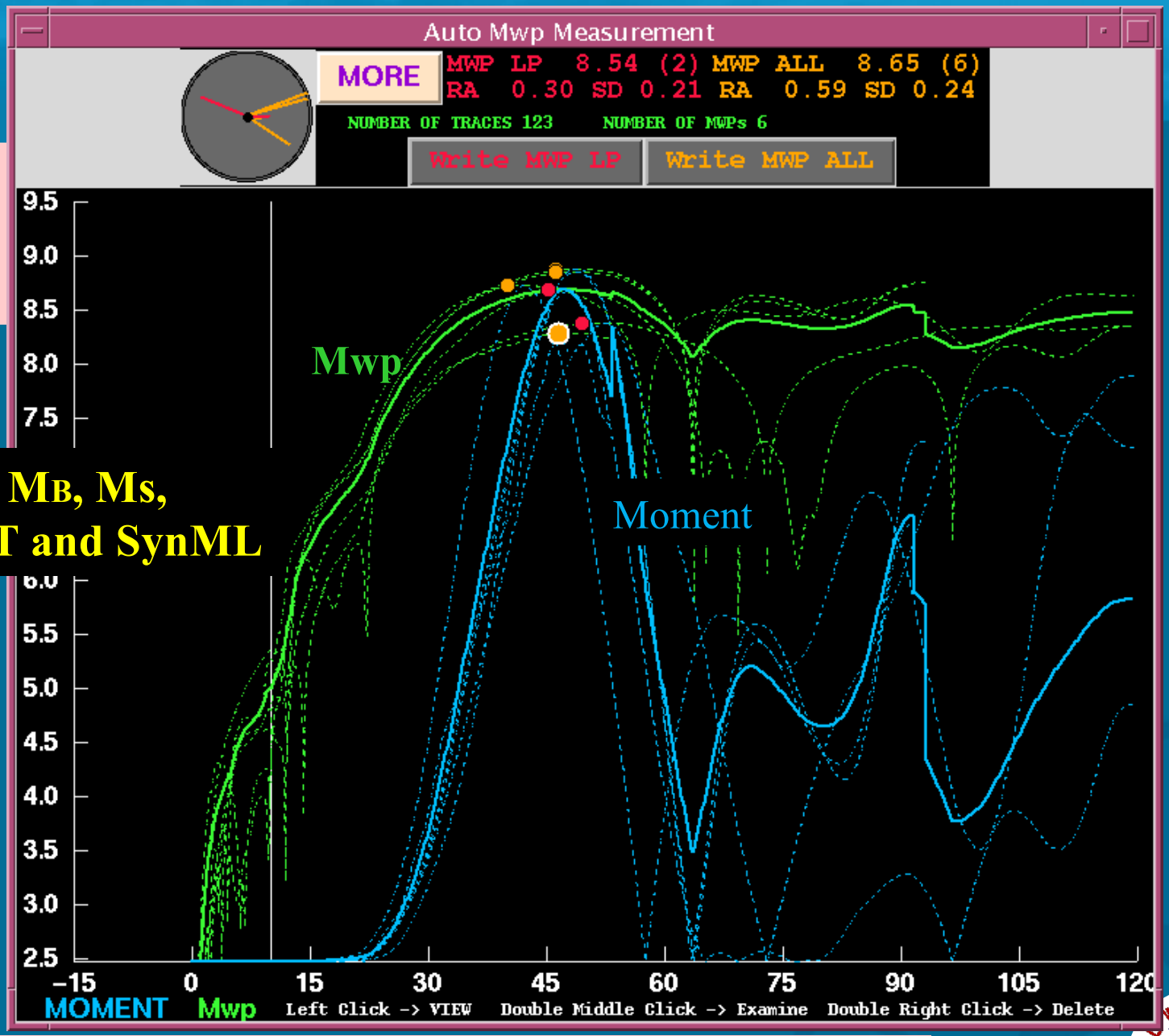


P, S, pP, sP, ScP, PcP
Align-on-P
Align-on-Azi

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

Wphase listener version 2.0

Function | Write COMF

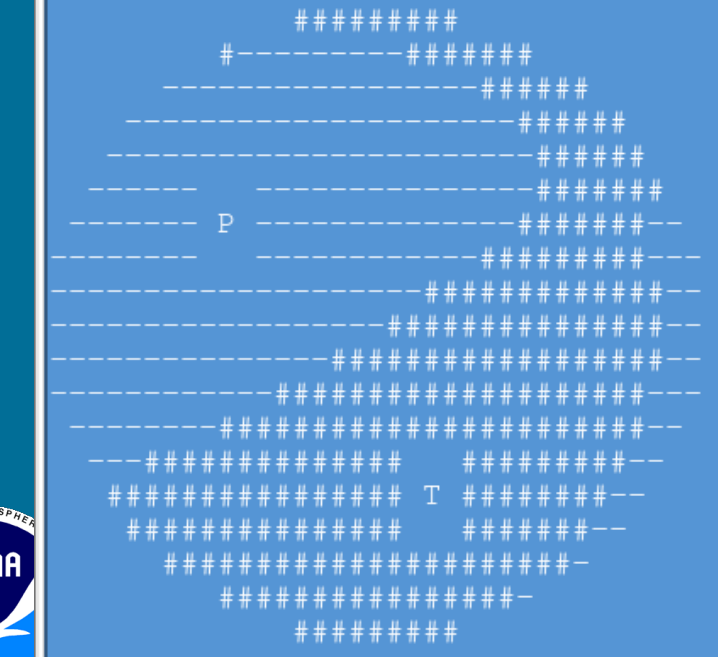
GLOBAL | REGIONAL

```
PDE location : Lat= 47.20N; Lon= 144.70E; Dep=415.2 km
Centroid loc.: Lat= 47.30N; Lon= 144.41E; Dep=410.5 km
Origin time  : 2024/08/10 03:28:33.00
Time delay   : 2.0   sec
Half duration: 2.0   sec

Moment tensor: scale= 1.0E+26 dyn.cm
rr=-0.013 ; tt= 0.184 ; pp=-0.171
rt=-0.555 ; rp=-0.398 ; tp=-0.126

Principal Axes:
1.(T) Val= 0.684 ; Plg=  43 ; Azm=163
2.(N)      0.062 ;       17 ;      56
3.(P)     -0.745 ;       42 ;     310

Best Double Couple: M0=7.15E+25 dyn.cm Mw =  6.50
NP1: Strike=327.7 ; Dip=17.3 ; Slip=   1.3
NP2: Strike=236.4 ; Dip=89.6 ; Slip= 107.3
```



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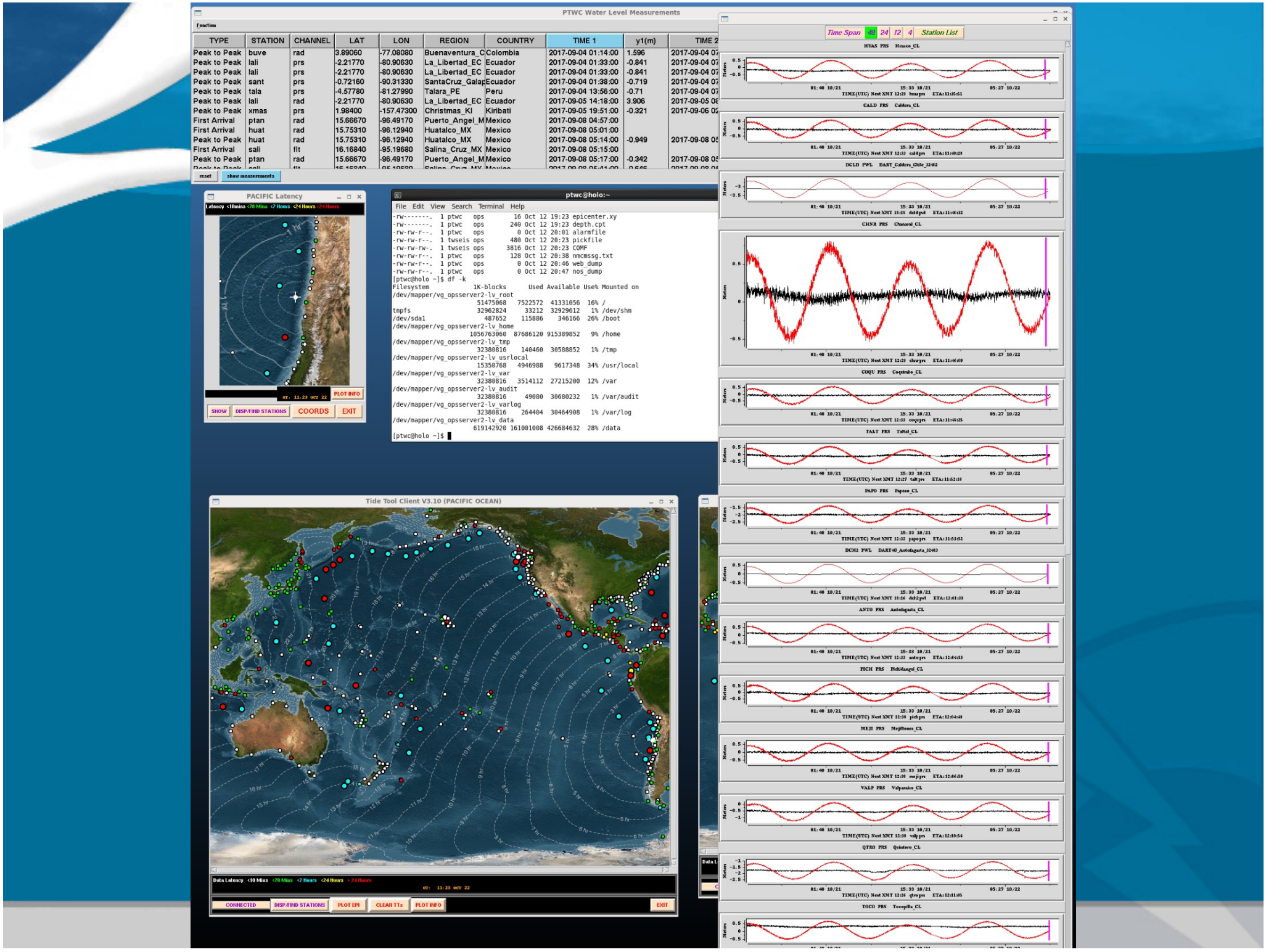
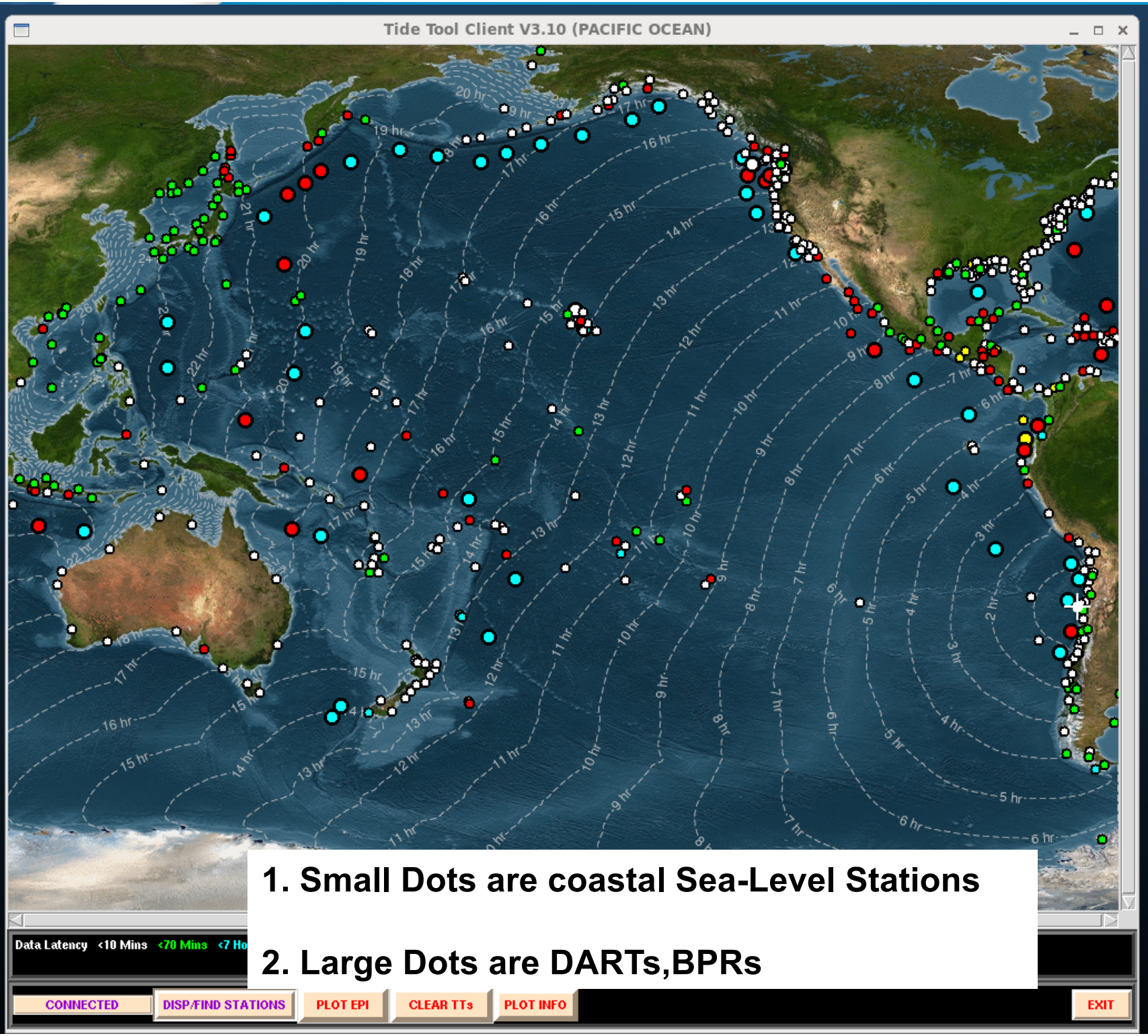
- MESSAGE CREATION & DISSEMINATION

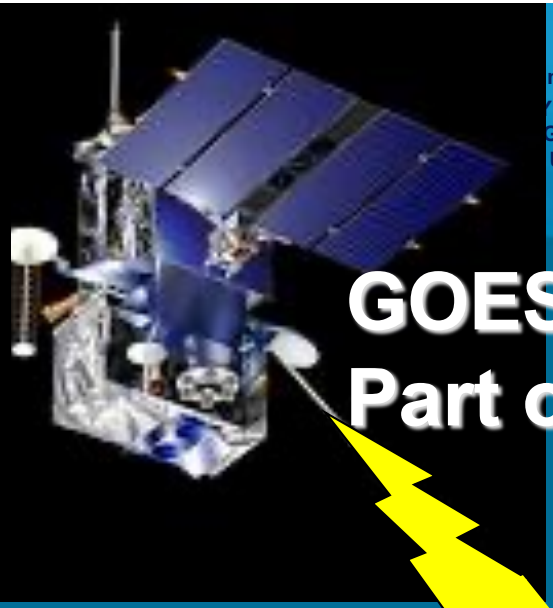
Global Sea-Level Processing Desktop


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
Peak to Peak lali prs -2.21770 -80.90630 La_Libertad_EC Ecuador 2017-09-04 01:33:00 -0.841
Peak to Peak lali prs -2.21770 -80.90630 La_Libertad_EC Ecuador 2017-09-04 01:33:00 -0.841
Peak to Peak sant prs -0.72160 -90.31330 SantaCruz_Galap Ecuador 2017-09-04 01:38:00 -0.719
Peak to Peak tala prs -4.57780 -81.27990 Talara_PE Peru 2017-09-04 13:56:00 -0.71
Peak to Peak lali rad -2.21770 -80.90630 La_Libertad_EC Ecuador 2017-09-05 14:18:00 3.906
Peak to Peak xmas prs 1.98400 -157.47300 Christmas_KI Kiribati 2017-09-05 19:51:00 -0.321
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
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
reset
show measurements
PACIFIC Latency
Latency <10mins <70 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 ~]$
Tide Tool Client V3.10 (PACIFIC OCEAN)
Data Latency <10 Mins <70 Mins <2 Hours <24 Hours >24 Hours
CONNECTED
DISP/FIND STATIONS
PLOT EPI
CLEAR TTs
PLOT INFO
EXIT
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 Papoose_CL
DCM2 PWL DART40_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 <70 Mins
CONNECTED
DISP/FIND STATIONS
PLOT EPI
CLEAR TTs
PLOT INFO
EXIT
1. Small Dots are coastal Sea-Level Stations
2. Large Dots are DARTs,BPRs

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

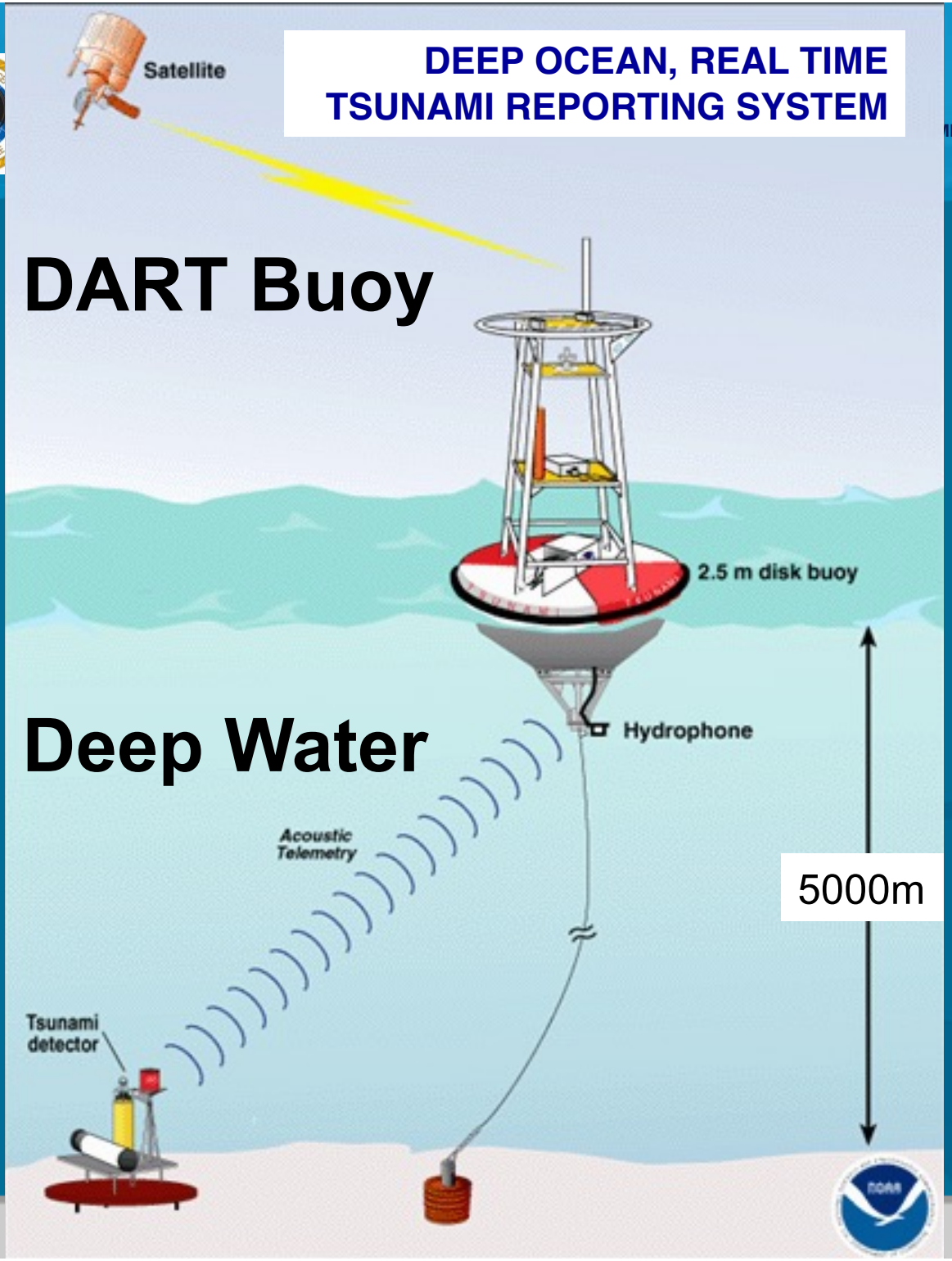
CHANNEL 32

Hiva Oa

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

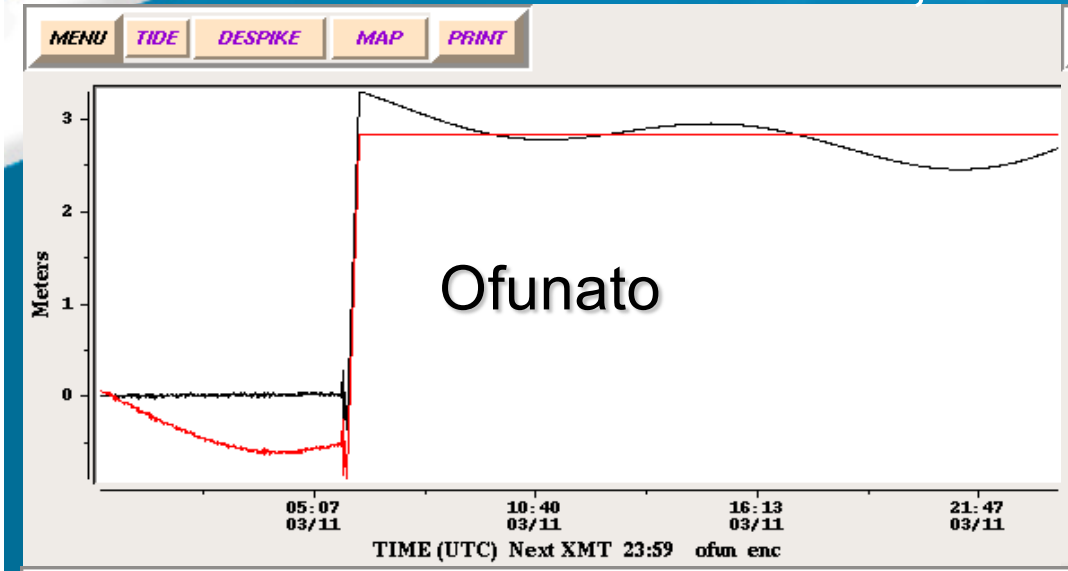
The tsunami signal is detected by a pressure sensor on the ocean floor. That signal is relayed by acoustic telemetry to the buoy. The buoy in turn transmits the signal via satellite back to the warning centers.

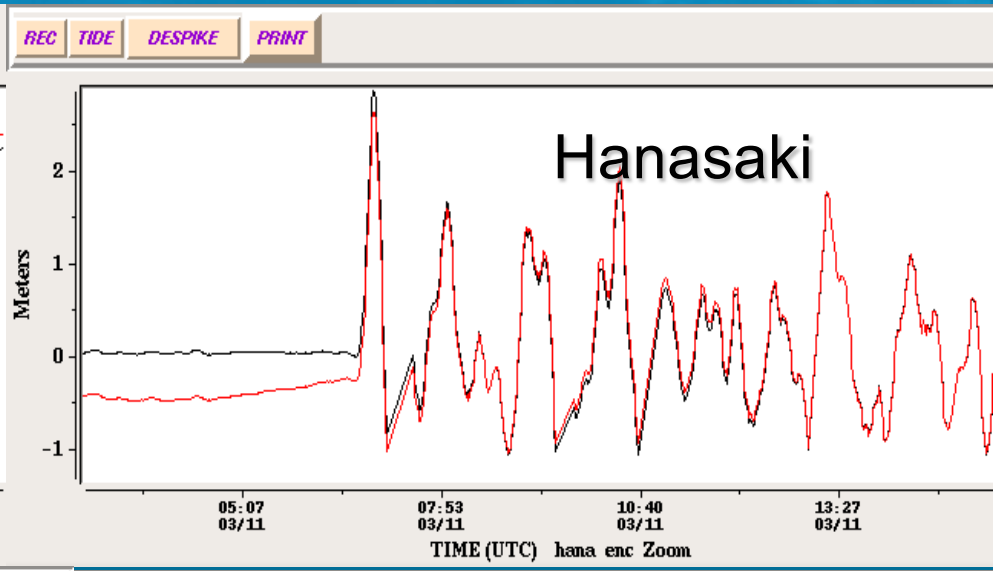
Can measure changes in sea-level as small as 1mm!

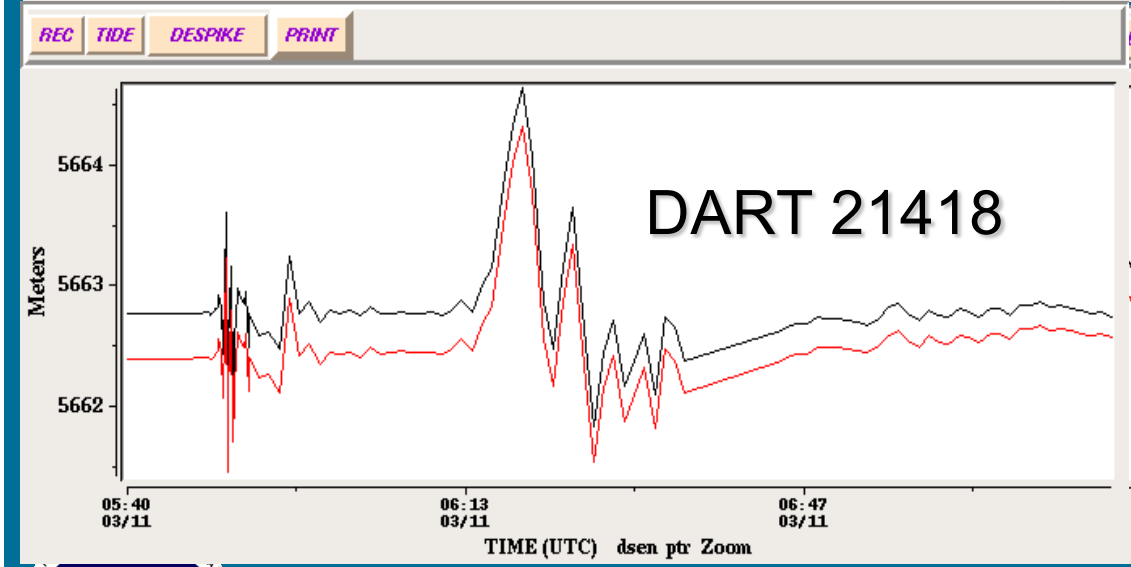


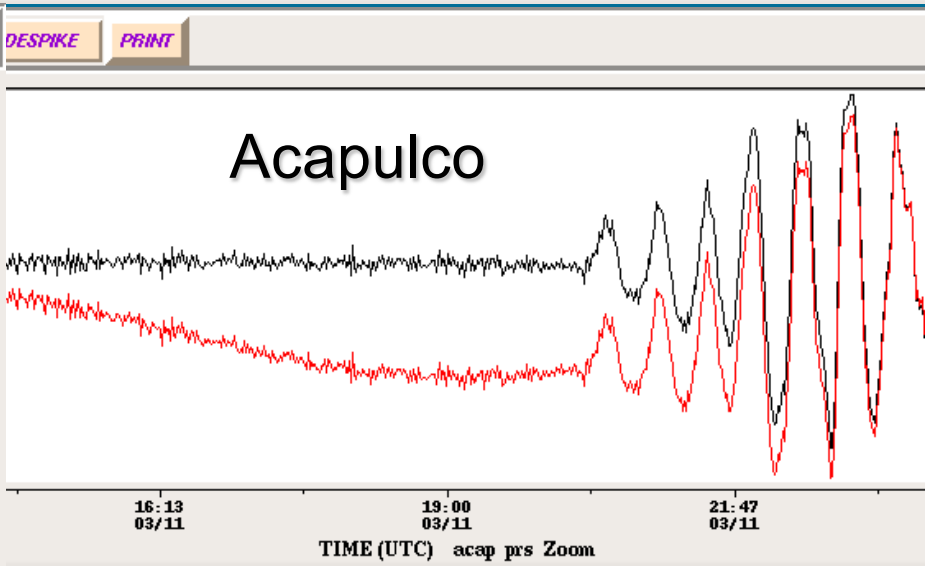
Tohoku Tsunami Marigrams

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









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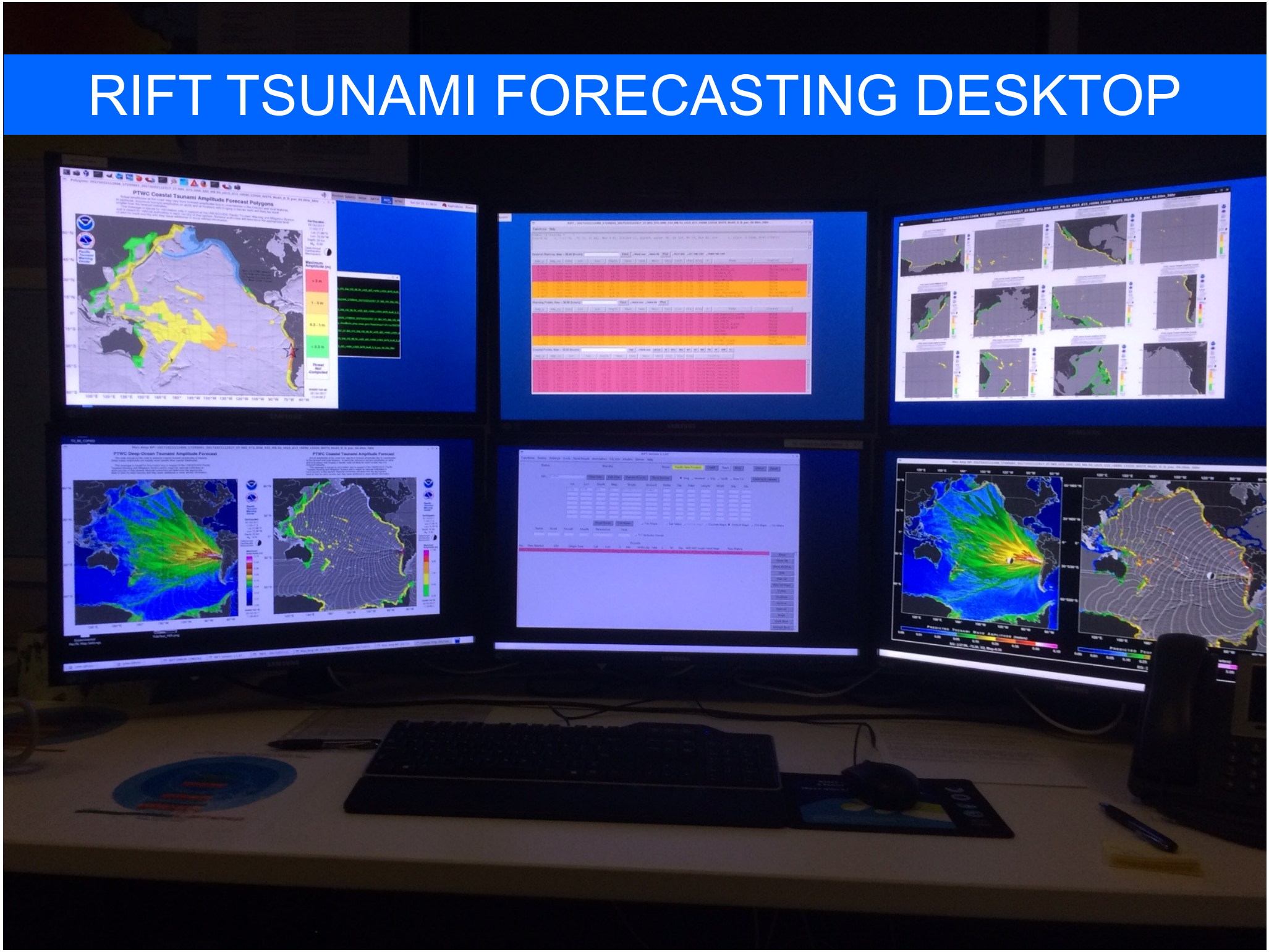
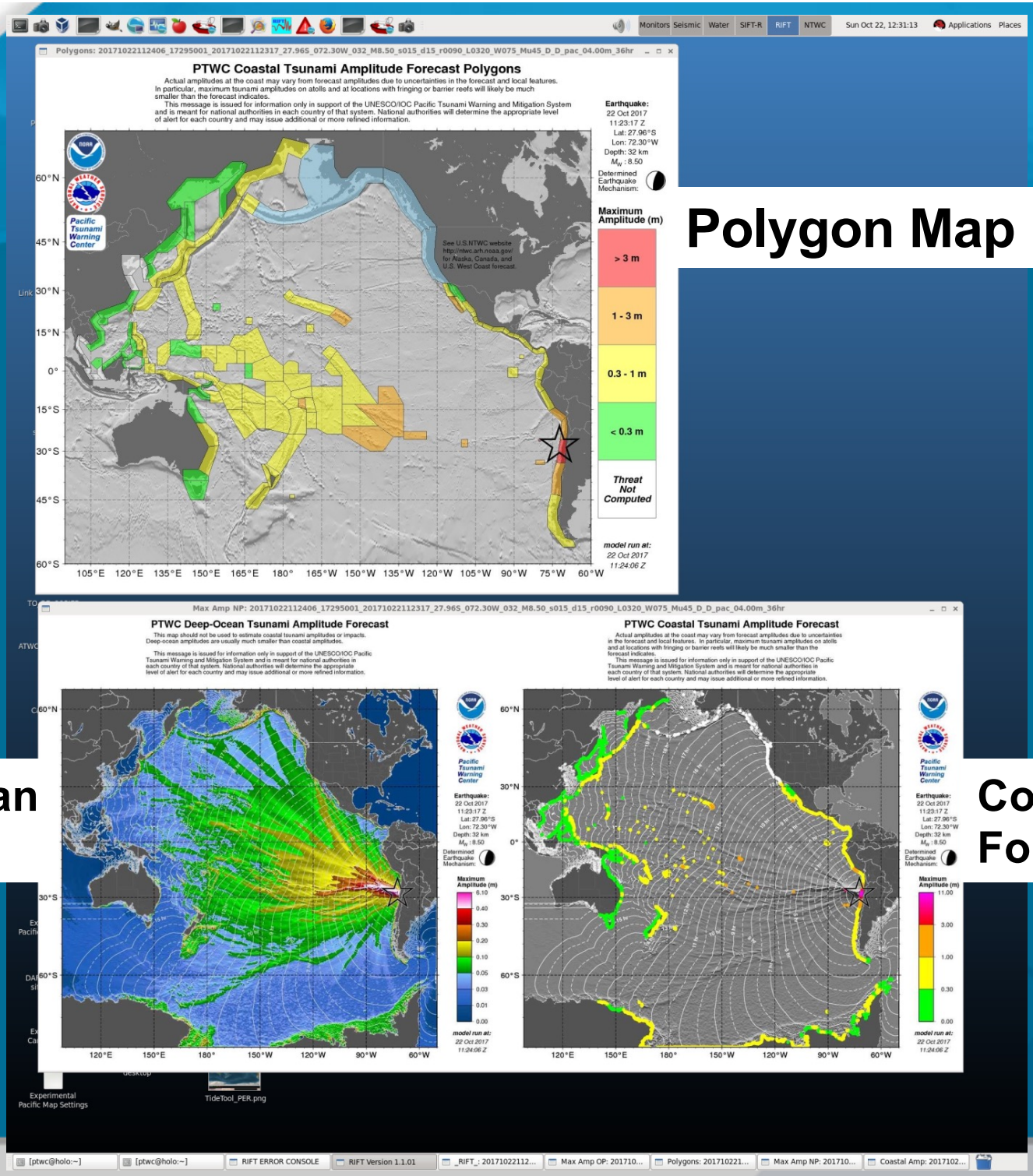
RIFT TSUNAMI FORECASTING DESKTOP



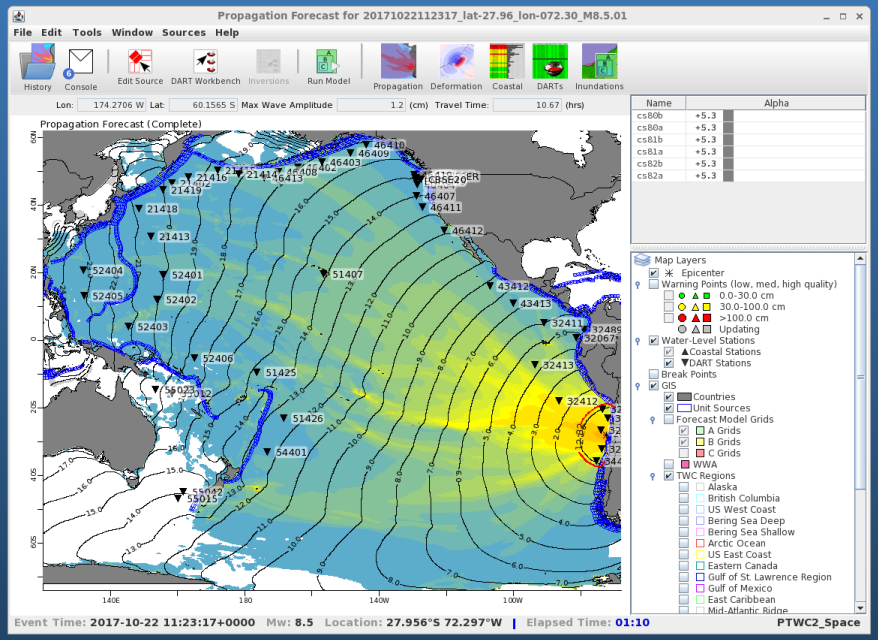


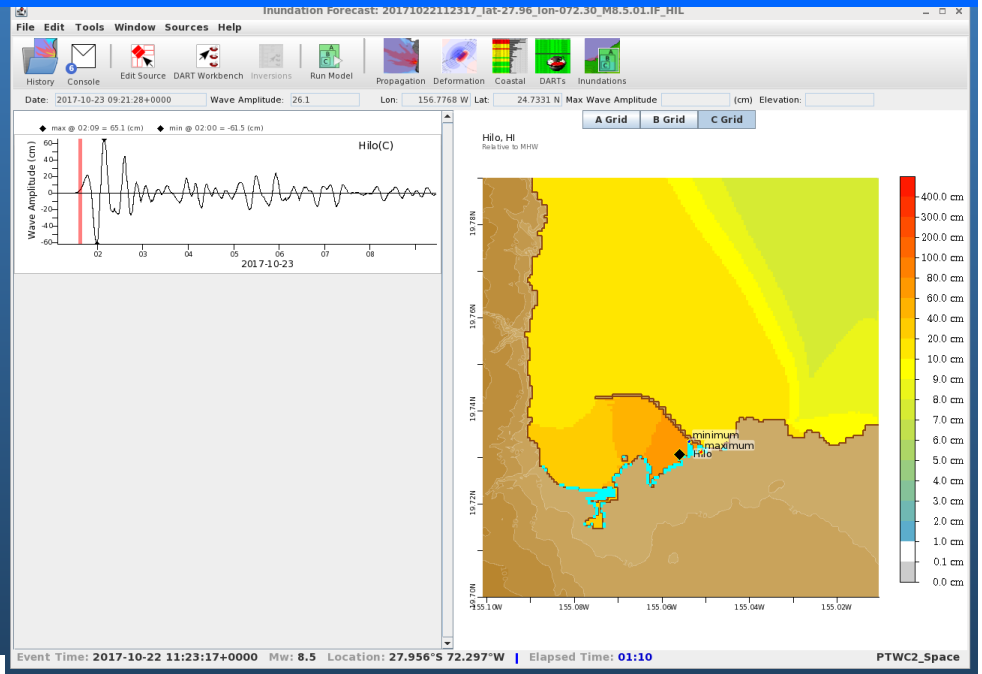
Polygon Map

Deep Ocean Forecast

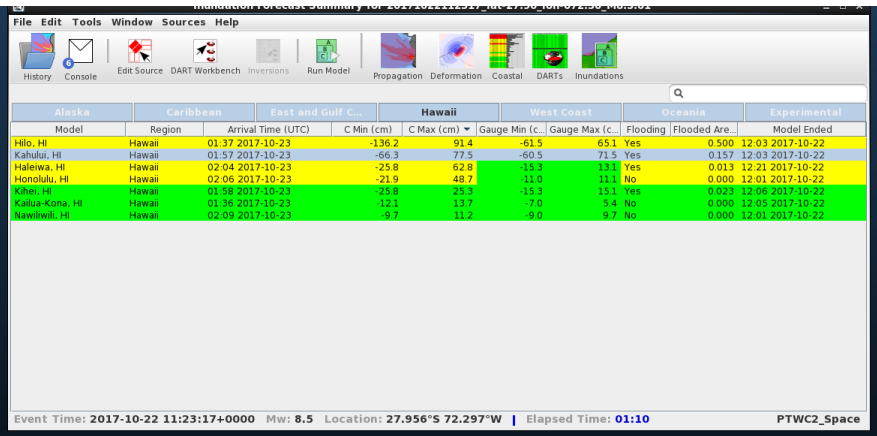
Coastal Forecast

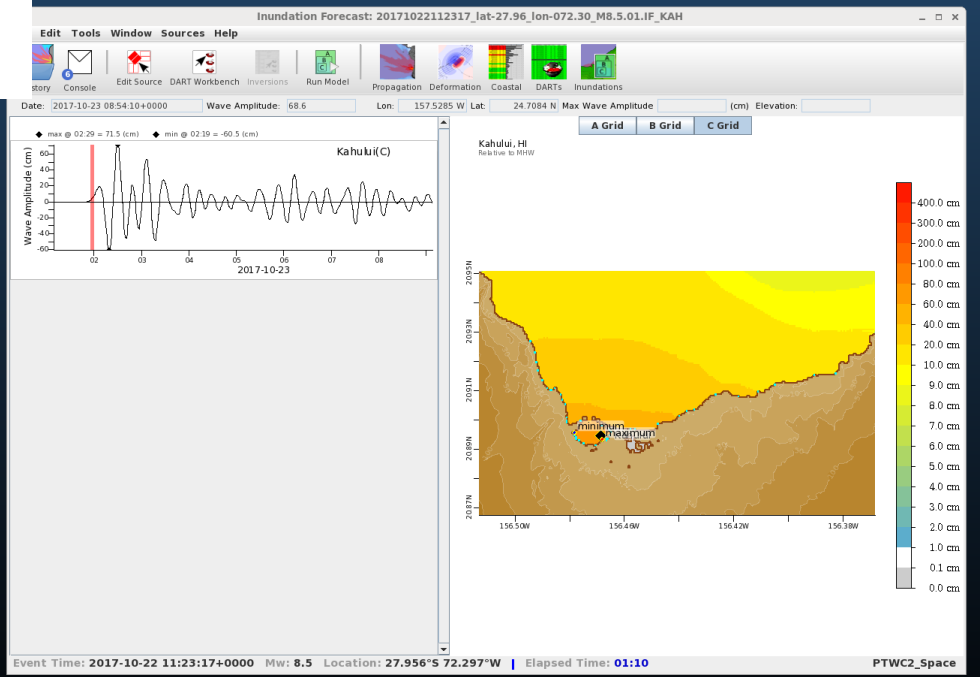
SIFT TSUNAMI FORECAST





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





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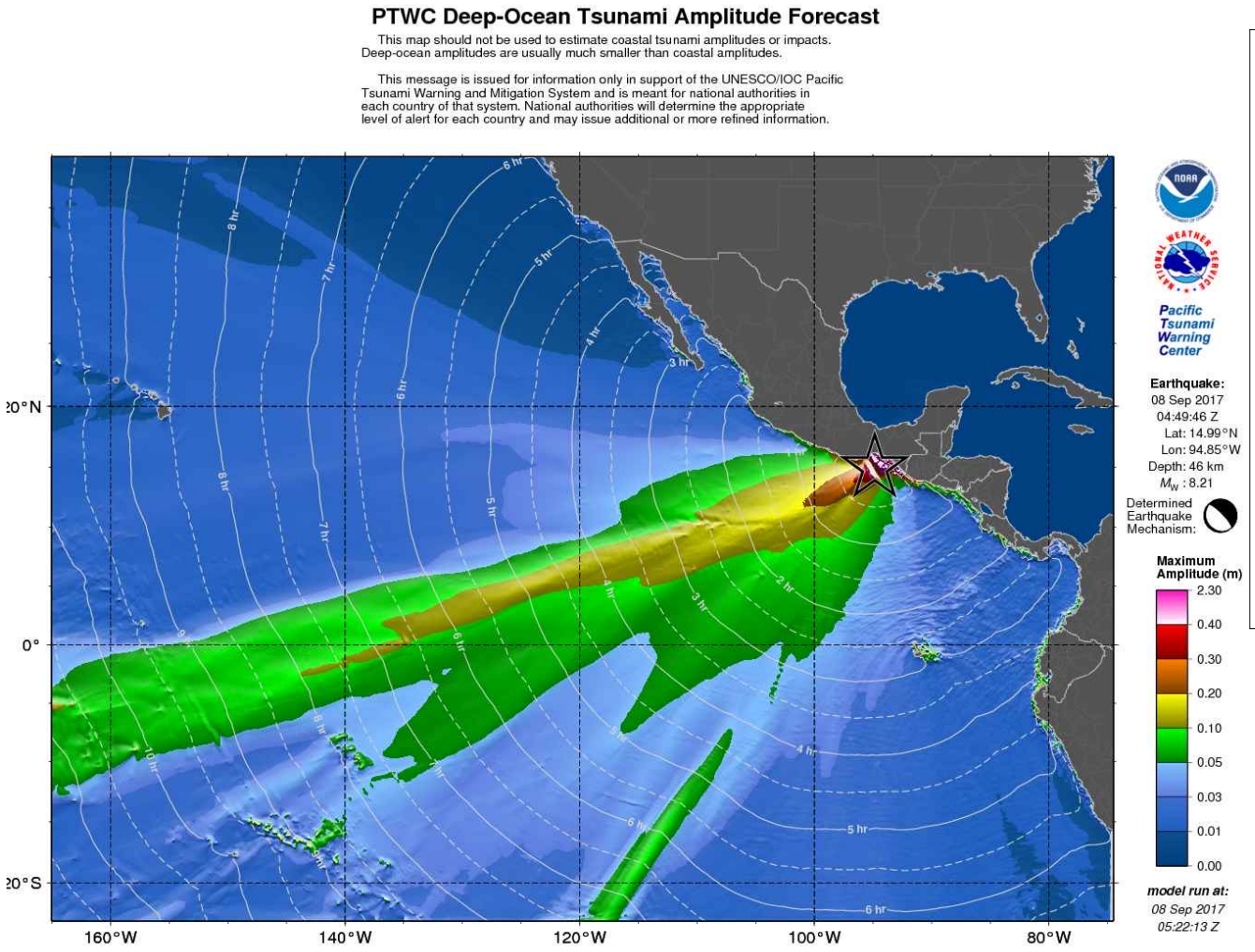
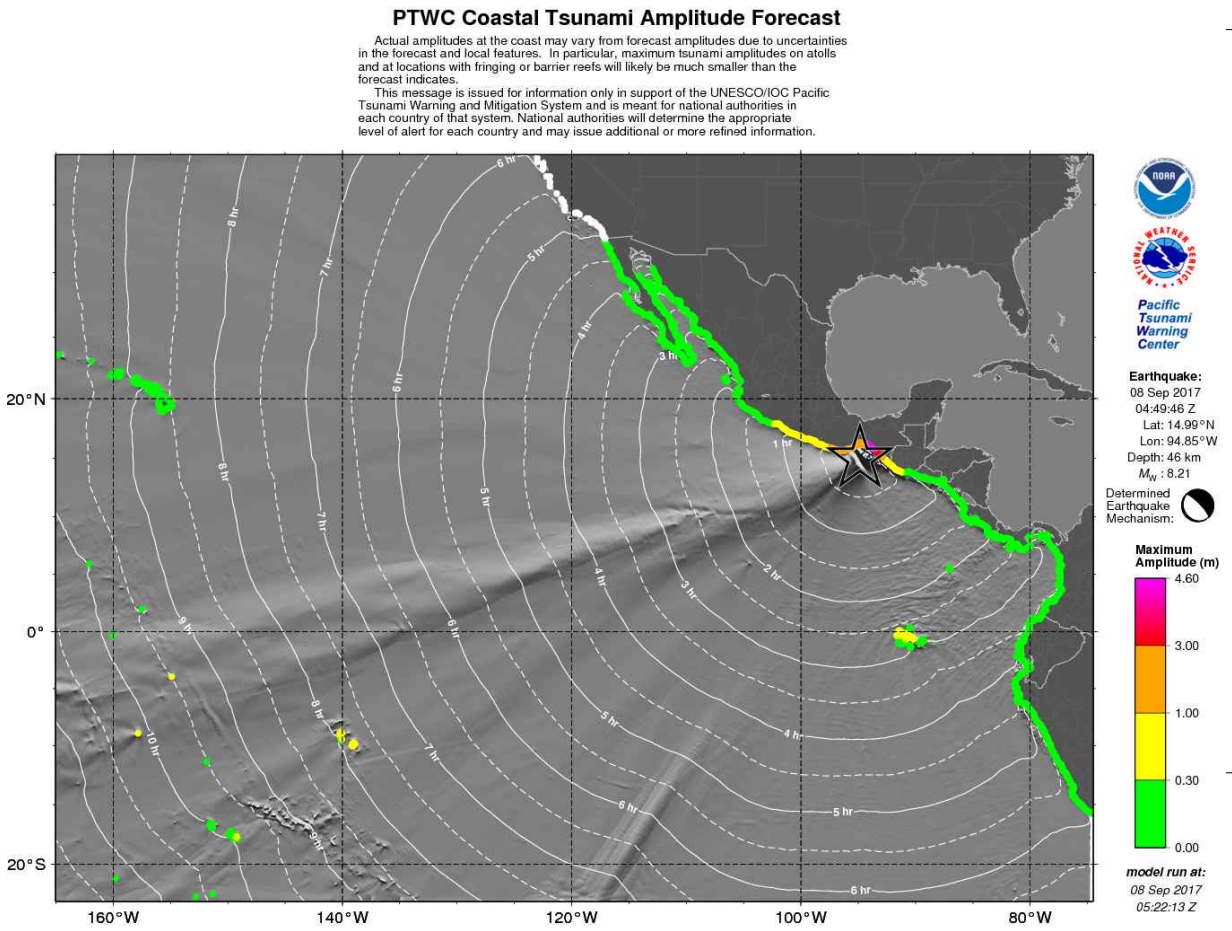
Graphical Product: Deep-Ocean Forecast



- 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

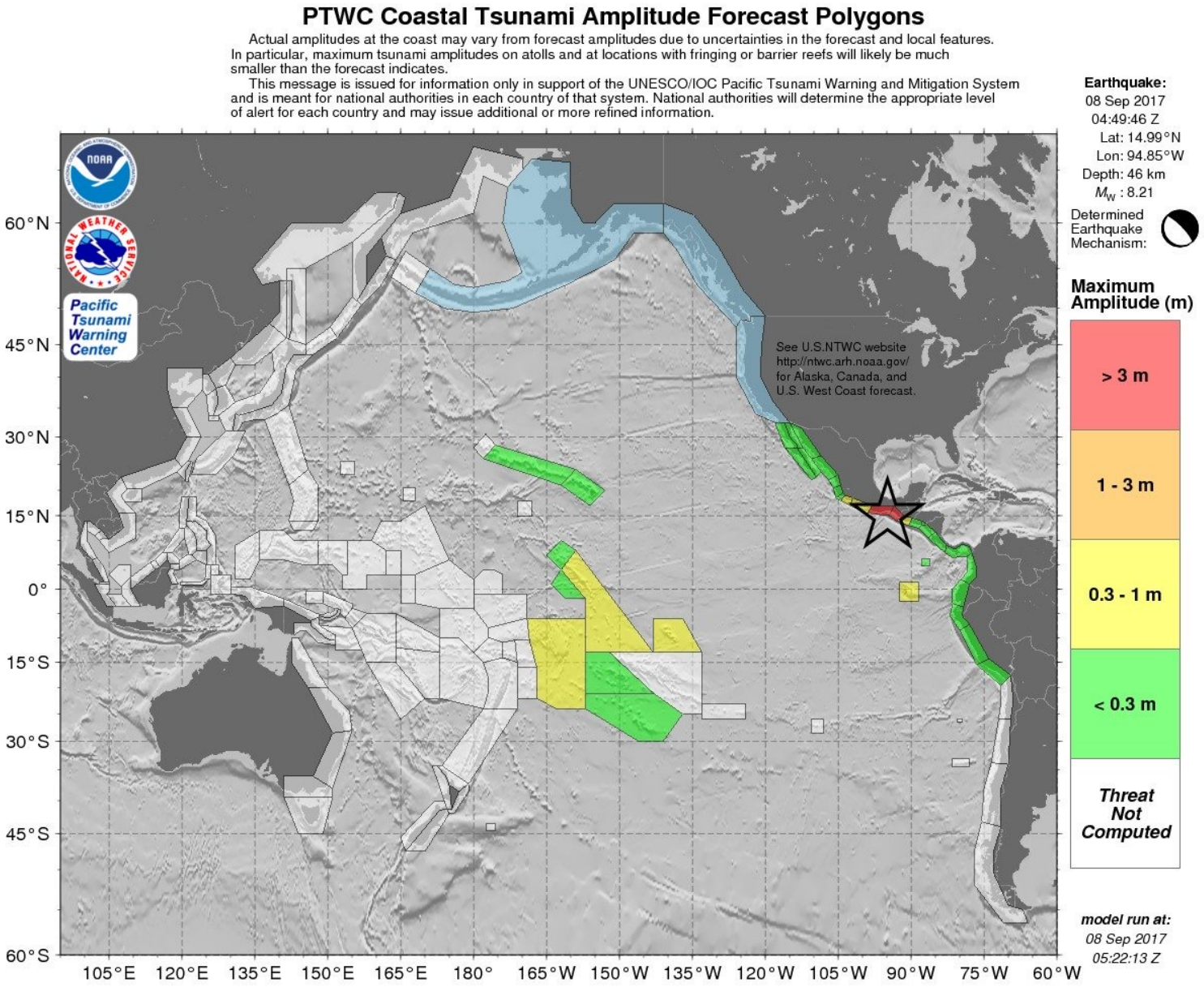
Graphical Product: Coastal Forecast



- 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
----

* 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

unesco
Intergovernmental
Oceanographic
Commission

Thank You

Stuart A. Weinstein
NOAA/NWS/PTWC

Pacific Community
Communauté du Pacifique