TIDE TOOL: SOFTWARE TO ANALYZE GTS SEA-LEVEL DATA

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GTS – Global Telecommunications Service:

Maintained by the WMO and is comprised of a network of surface and satellite based telecommunications links and centers. It is a system for the global exchange of meteorological, climatic, seismic and other data to support multipurpose early warning and forecast systems*.

The TWCs (Tsunami Warning Centers) rely heavily on the GTS to supply sea-level data in near real time from ~600 sea-level stations world wide and to transmit Tsunami Bulletins.

*Source: http://www.wmo.ch/pages/prog/drr/events/humanitarian/Documents/HumanitarianBackground%20document.pdf

GOESW

CHANNEL 96

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

GTS Sea-Level Data is structured in a rich variety of formats. There are approximately 12 or so basic formats, with a number of variations.

UHSLC format (Hiva Oa, Marquesas) Readable ASCII (XMT 5min)

```
SEHI40 KWAL 260032
  9322451A 299003218 :PRS 1 #1 1879 1853 1832 1831 ……..
PR2 1 #1 1916 1920 1894 1878 1875 1839 1848 1900 ……...
:BAT 2 #15 13.0 :NAME 9322451A   38-0NN  96W  (GOESW Chan 96)
```

NOS "Tsunami Expert" Station (Nawiliwili, Hawaii USA)

```
SXXX03 KWAL 050000          Base 64 Encoding   (XMT 6min)
^^336015FC 186000041"P16114001@|]~[@@v0KwW1@il@WADWDM
@ij5DY<U`2@Rs@T@"@Rt kTWyJBQBeBcB^BqBo  41+0NN 148W
```

(one minute data)

GNS (New Zealand) Station (Auckland)

```
SZNZ01 NZKL 160521
CREX++
T000103 A001 D01021 D06025++
-3683144 17478654 AUCT  2017 08 16 05 13 //// 11 07 00 01
04879 3239 04872 3241 04863 3241 04855 3242 04846 3243 04840 324
```

As you can see, GTS Sea-Level Data does not come gift wrapped and easy to use.

For a TWC to use GTS Sea-Level Data, the TWC needs (at minimum):

1. **Access to GTS Data!**
   (Easier said than done in many cases)
2. **A Decoder to translate Sea-Level messages into sea-level data.**
3. **A MetaData Database (used by the decoder).**

Tide Tool

Was originally developed to give BMG (Jakarta) a nascent capability to decode GTS sea-level messages from Indian Ocean and nearby Pacific Ocean sea-level stations back in Nov. 2005.

Tide Tool has grown in sophistication and is now used as an operational sea-level processing system at PTWC and a number of other centers

Tide Tool

Tide Tool continuously decodes sea-level messages in real-time and displays the time series using the open source, platform independent, graphical scripting language Tcl/Tk.

Tide Tool consists of two main parts:

1. **Decoder which reads log files of GTS sea-level messages and a sea-level station metadata base.**
2. **Dynamic map based clients that allow the user to select a single station or a group of stations to display and analyze.**

Tide Tool Requirements

In order to decode GTS messages, run the dynamic map clients and display the time series, the following are required*:

- Computer running Tcl/Tk software with BLT extension.
- GTS Sea level messages that are continuously archived into a log file.
- Tide.tcl and client Tcl/Tk scripts.
  (contains decoder and creates marigram displays)
- Sea-level Station metadata.
- A link to GTS data via the country's Met Service.

Tide Tool

COMP_META metadata database*

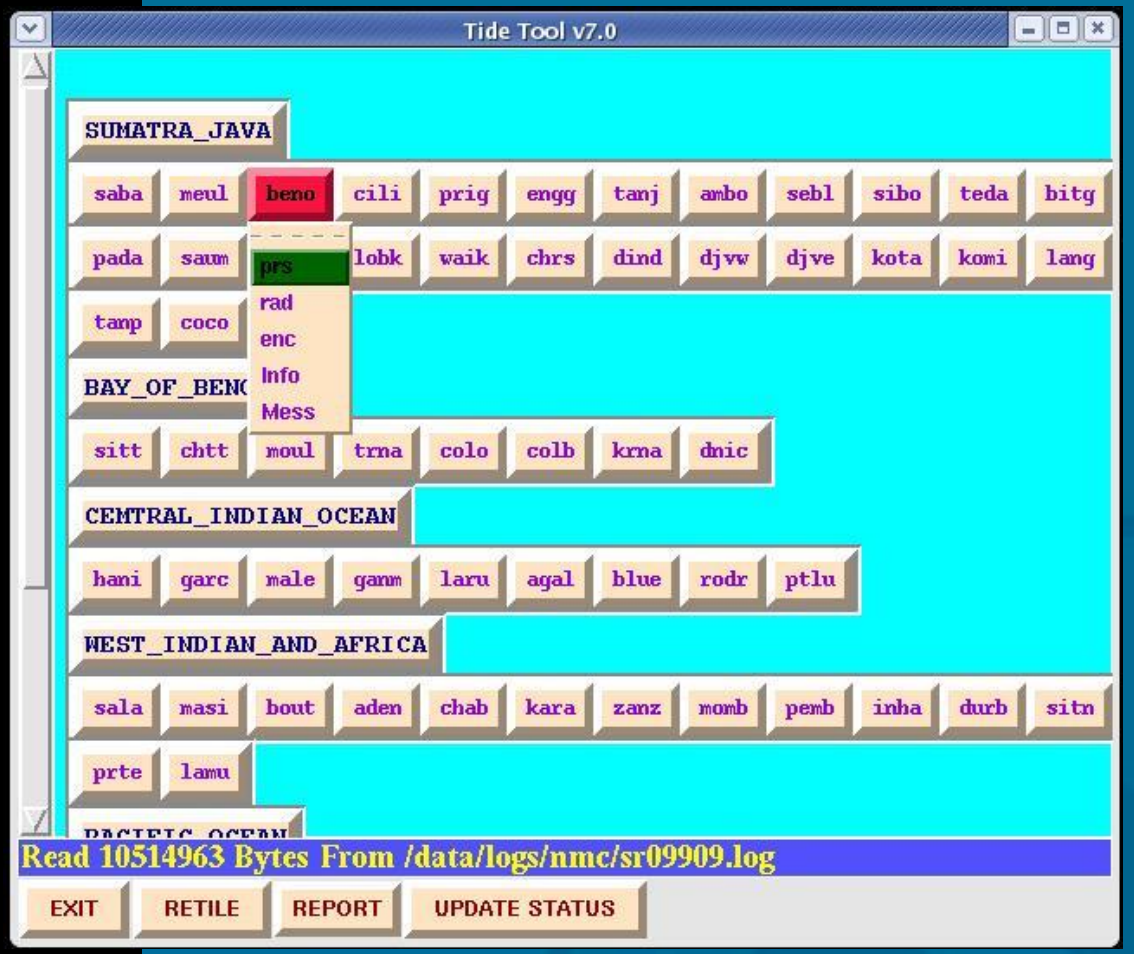
PTWC actively maintains a database (COMP_META) of all sea-level stations that transmit sea-level messages via the GTS. Tide Tool reads a *dump* of this database to understand how sea-level messages are structured for the various sea-level stations.

```
manz          Manzanillo_MX     3541502E  SEPA40  prs  1  10  M   3 -1  1.0000
  005 0000    19.0558  -104.3176     1      UHSLC  163  PARSE_GLOSS
manz          Manzanillo_MX     3541502E  SEPA40  rad  1  10  M   3 -1  1.0000
  005 0000    19.0558  -104.3176     1      UHSLC  163  PARSE_GLOSS
```

The COMP_META database has ~1800 entries

Tide Tool Decoder
(Tide.tcl script)

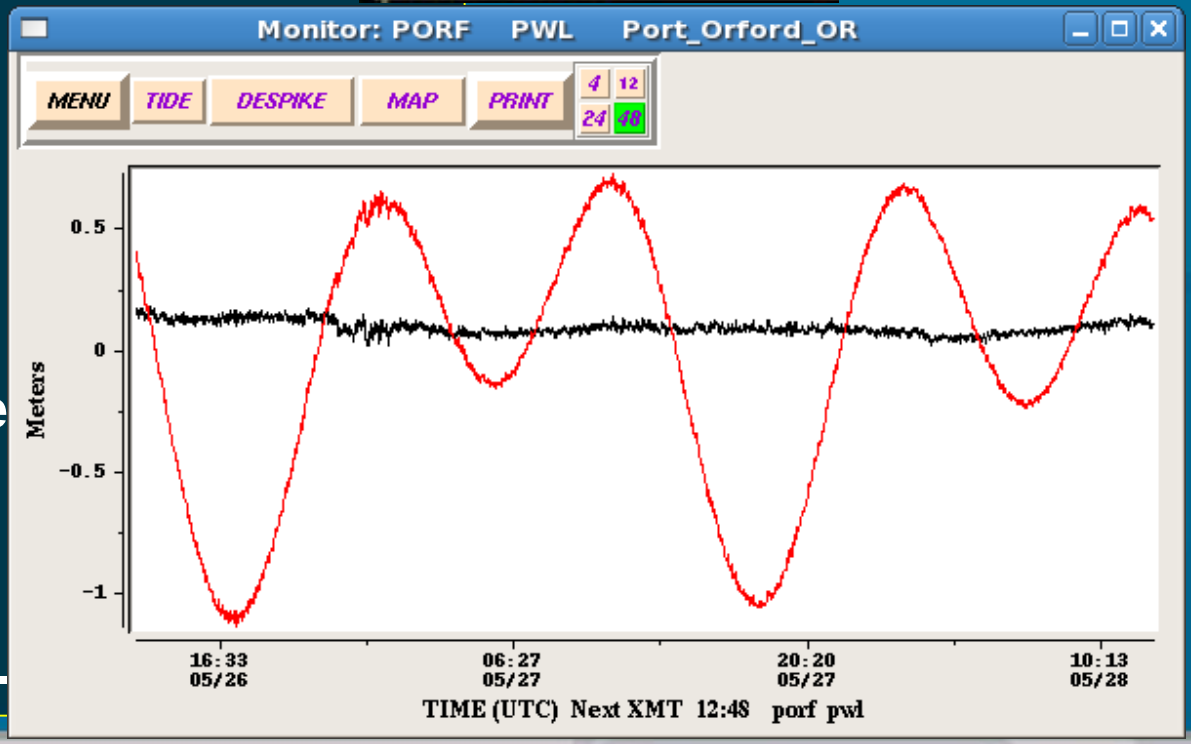
- Reads and decodes GTS sea-level messages from the logfile.
- Constructs the main GUI which responds to mouse clicks.
- Sends and services Instructions to and from clients respectively.
- Supports multiple clients via sockets.
- Creates transmission report and determines status of stations.
- Scrollable.



Tide Tool Monitor Widget

- Can display up to three different time series:
  - Red – Actual time series
  - Black – De-tided time series
  - Blue -- Predicted time series

- Two de-tiding options: permanent or on-the-fly coefficients.
- Despike option based on three point median.
- Station location map option showing reverse travel-time contours.
- Rubber banding zoom option to expand time series.



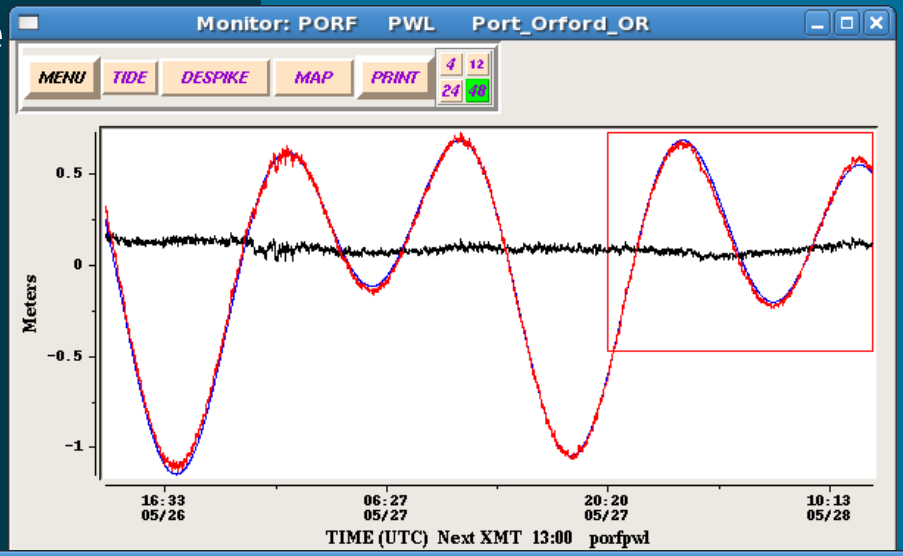
Tide Tool Zoom Widget

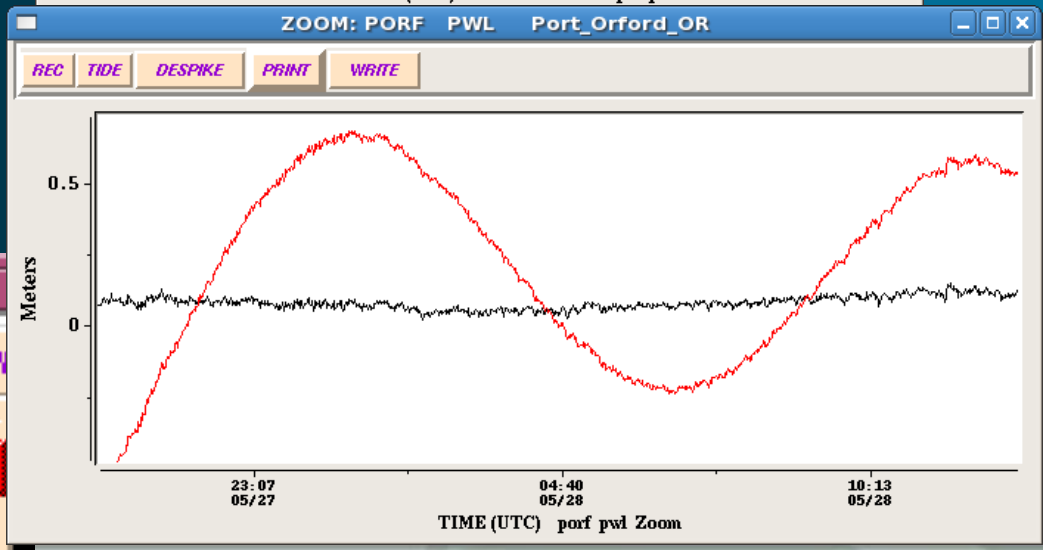
- Used to measure tsunami wave arrival time, amplitude, and period with mouse clicks and record measurements in a file. Can zoom recursively

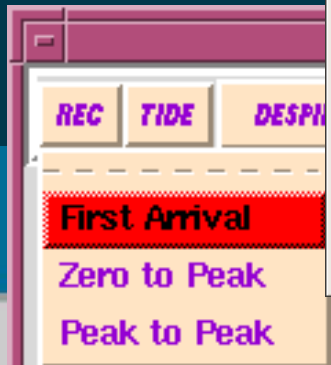
- Can display up to three different time series:
  - Red – Actual time series
  - Black – De-tided time series
  - Blue -- Predicted time series

- Two de-tiding options: permanent or on-the-fly coefficients.

- De-spike option based on three point median.







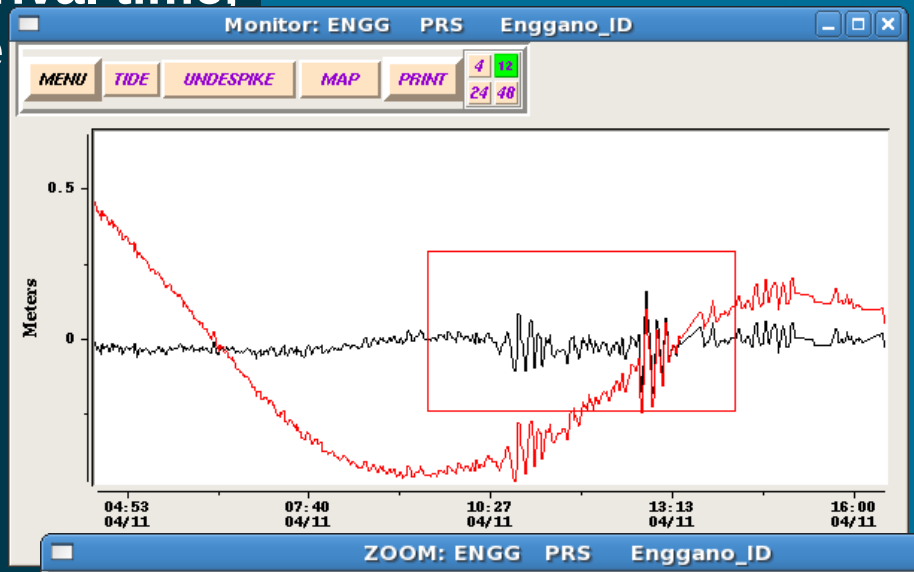
Tide Tool Zoom Widget

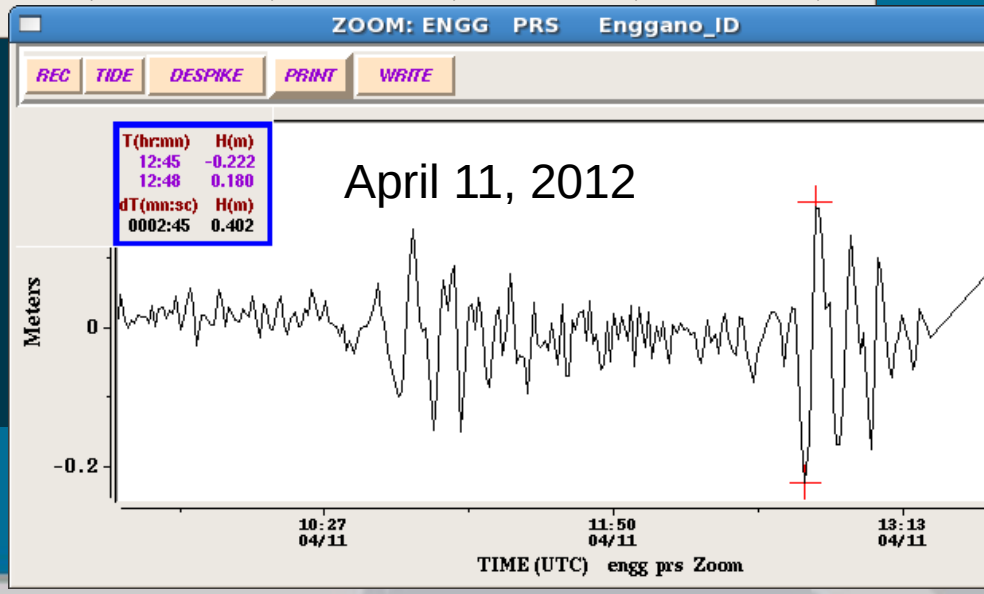
- Used to measure tsunami wave arrival time, amplitude, and period with mouse clicks and record measurements in a file. Can zoom recursively.

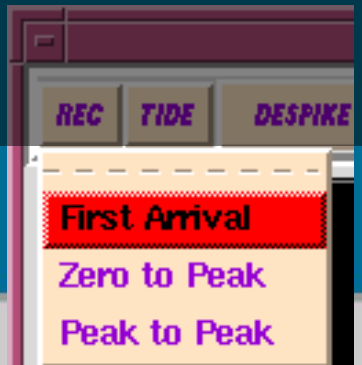
- Can display up to three different time series:
  - Green – Actual time series
  - White – De-tided time series
  - Blue -- Predicted time series

- Two de-tiding options: permanent or on-the-fly coefficients.

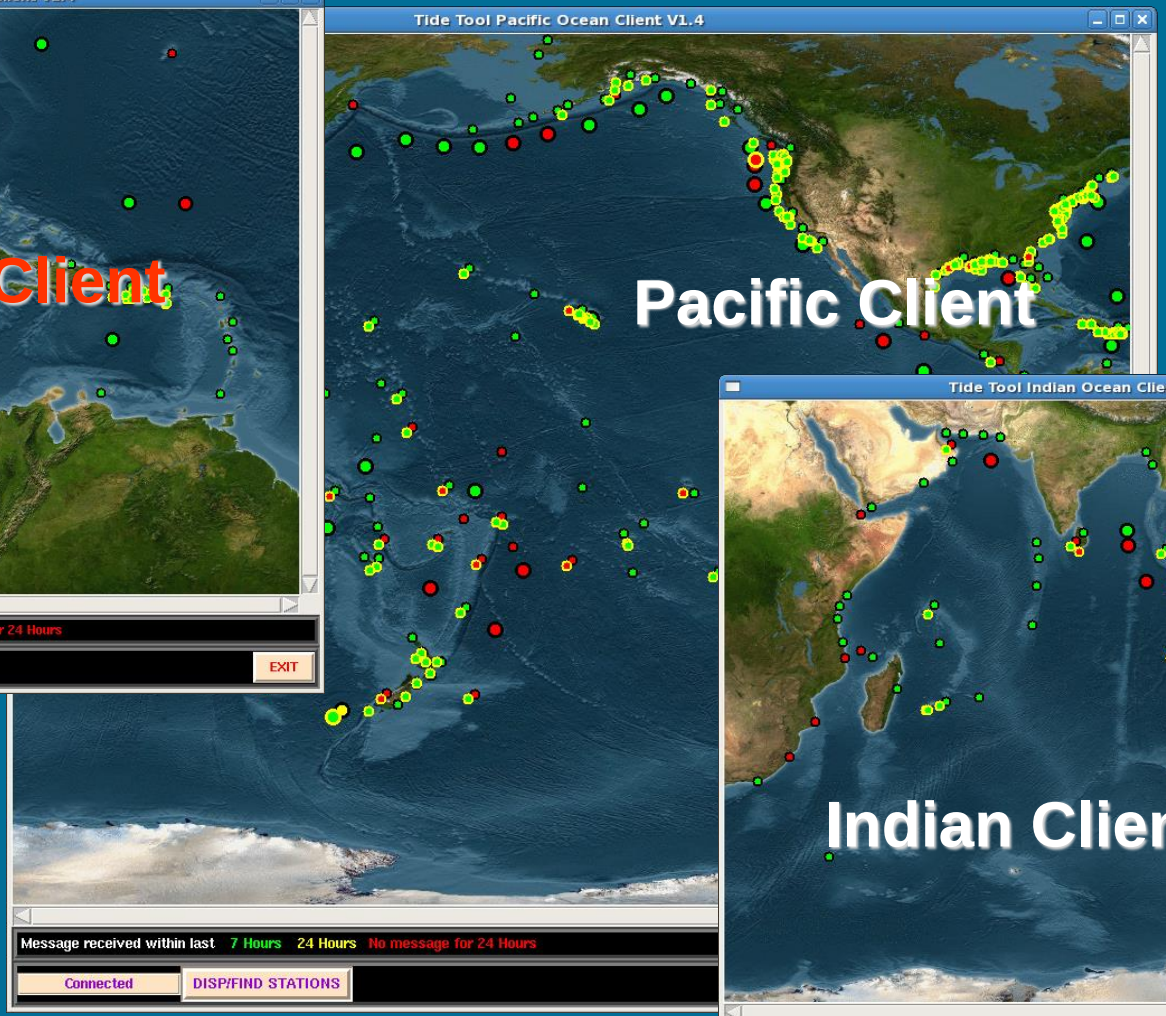
- De-spike option based on three point median.





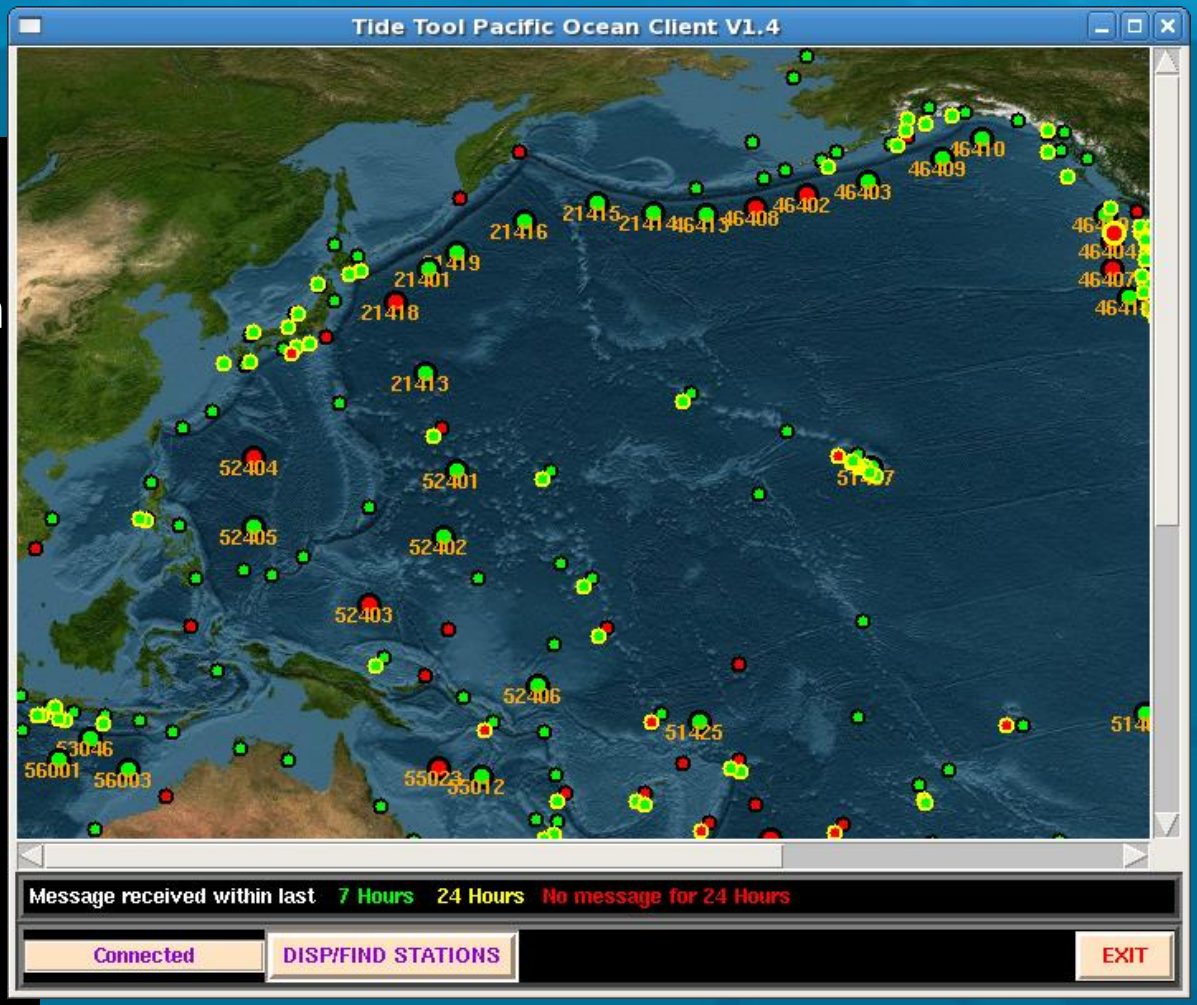


Tide Tool Clients



Clients are Interactive

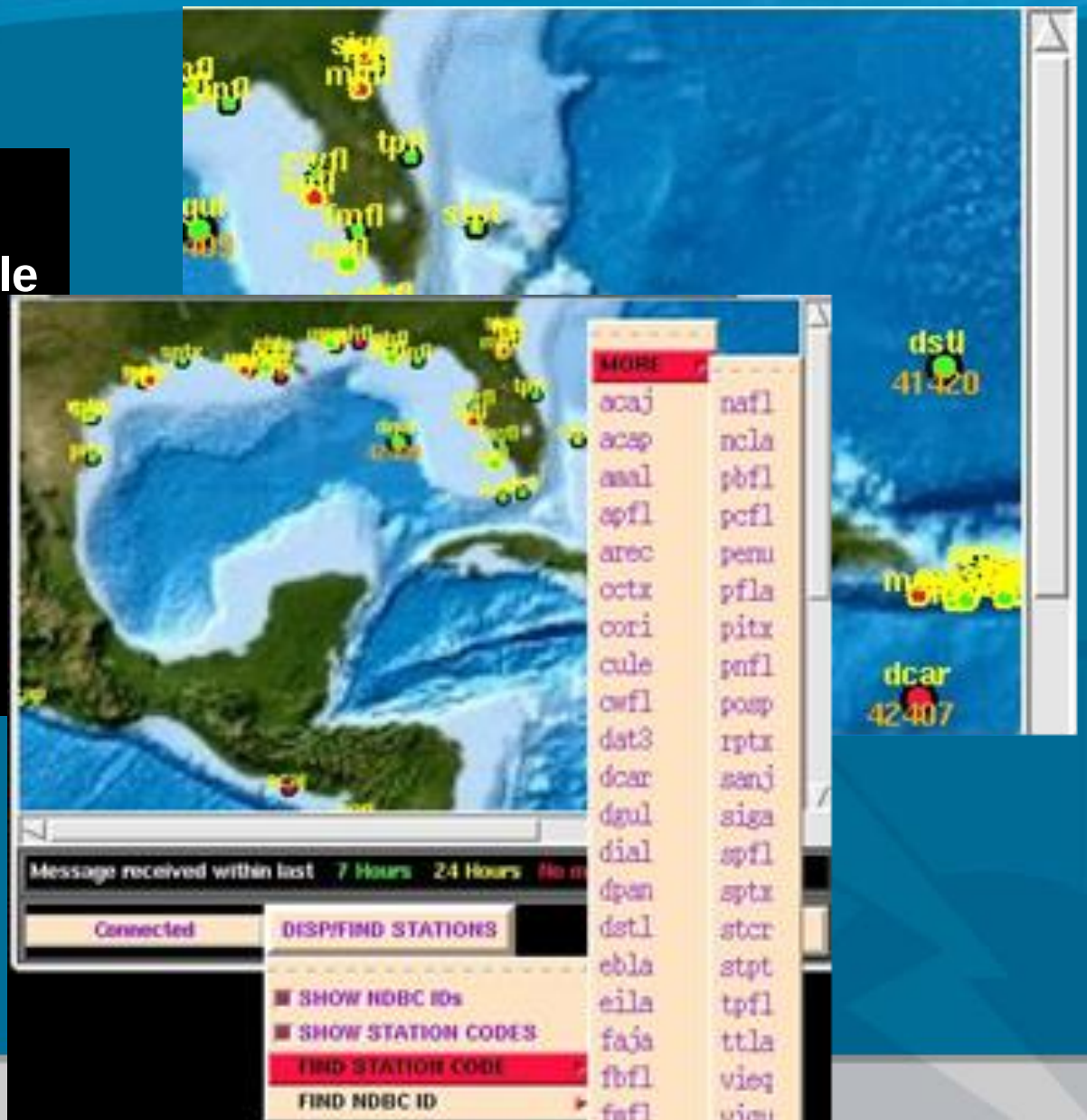
- **Send instructions to Decoder to display time series or other information**
- **Responds to mouse operations to display a single station or zoom in on a region and display multiple stations.**
- **Scrollable.**
- **Indicates station status (color).**



Tide Tool Clients

- Responds to mouse operations to display a single station or zoom in on a Region and display multiple stations.

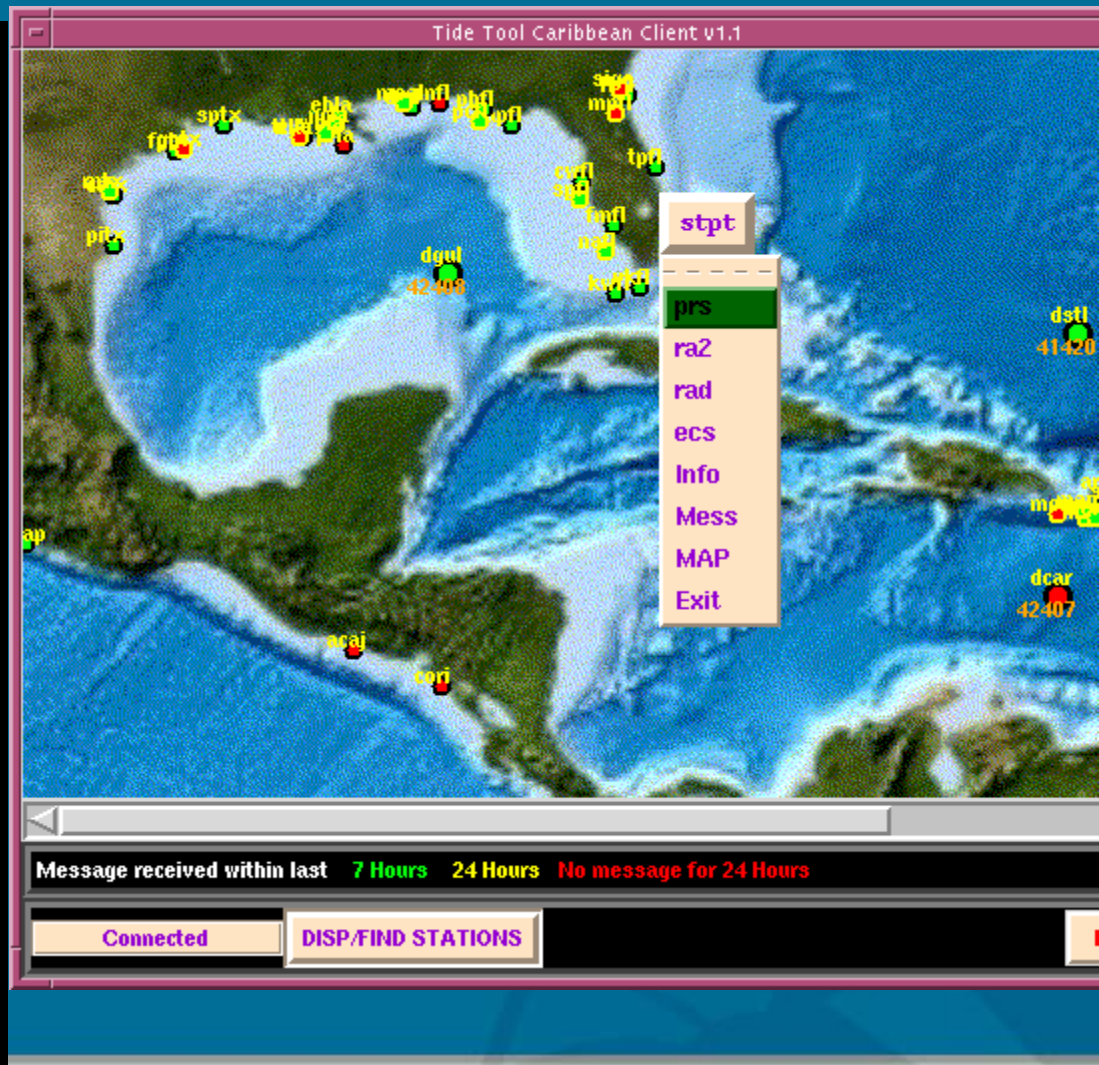
- Locates stations by code or NDBC number (DARTS).



Tide Tool Clients

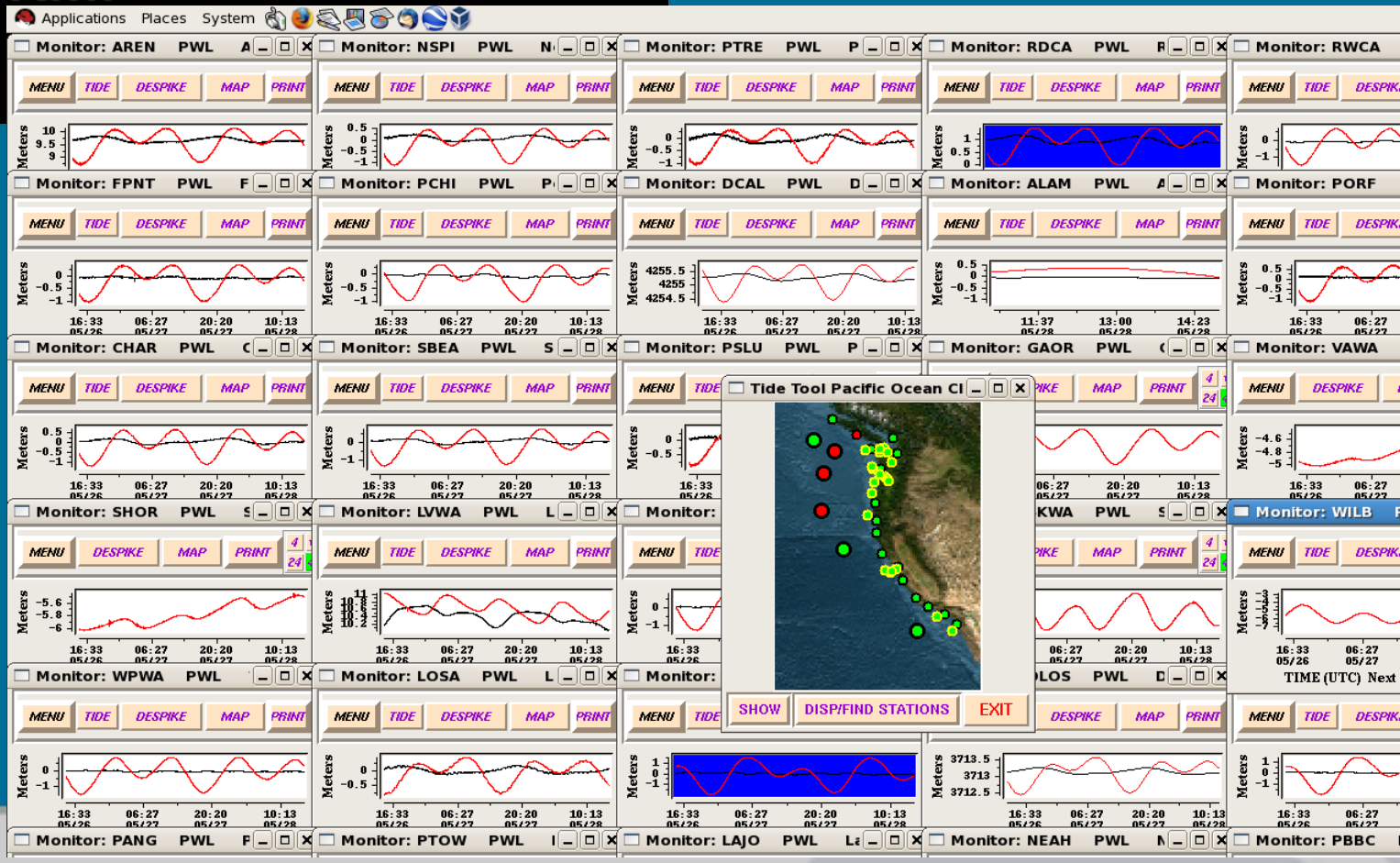
- Double click on a station Creates a button with a drop-down menu.
- Menu has selections to display time series for each sensor and widgets showing station info, recent GTS messages, and a geographic map of the nearby area with tsunami travel-times.

(Settlement Pt., Bahamas in this example.)



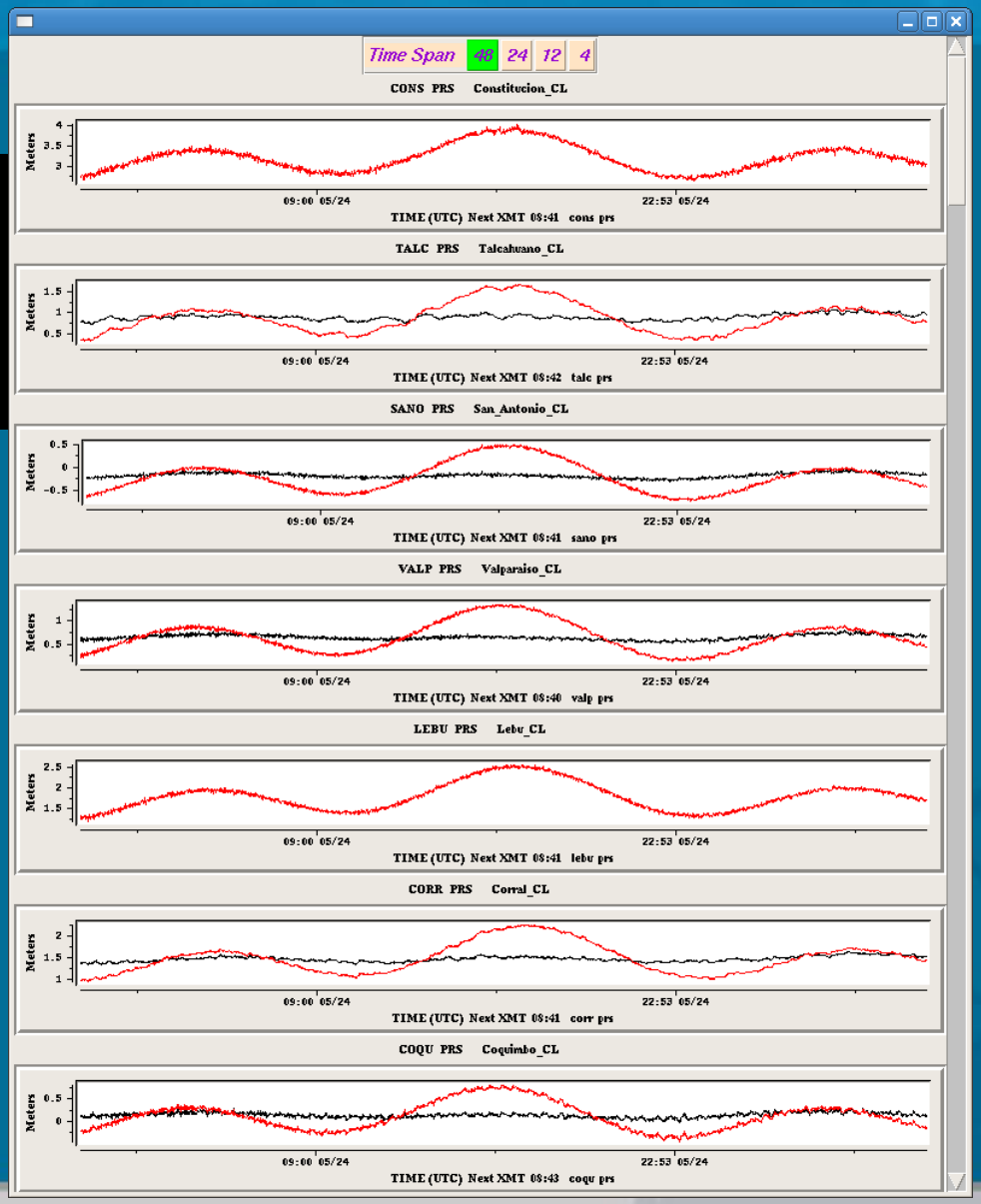
Tide Tool Clients

- Draw a rectangle (rubber banding) to zoom in on a region and tile the screen OR….

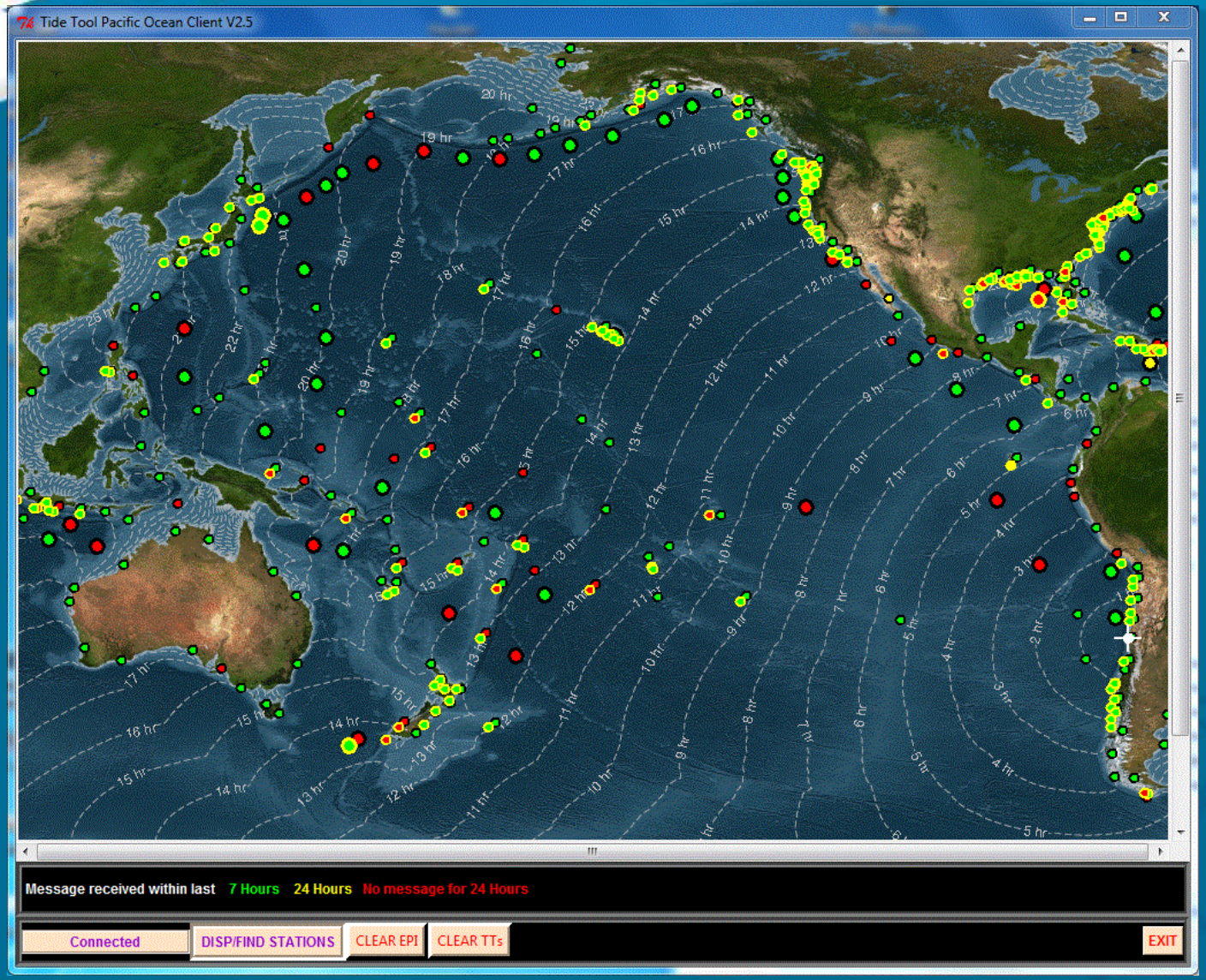


Tide Tool Clients

…. make a
"Strip Chart Widget"

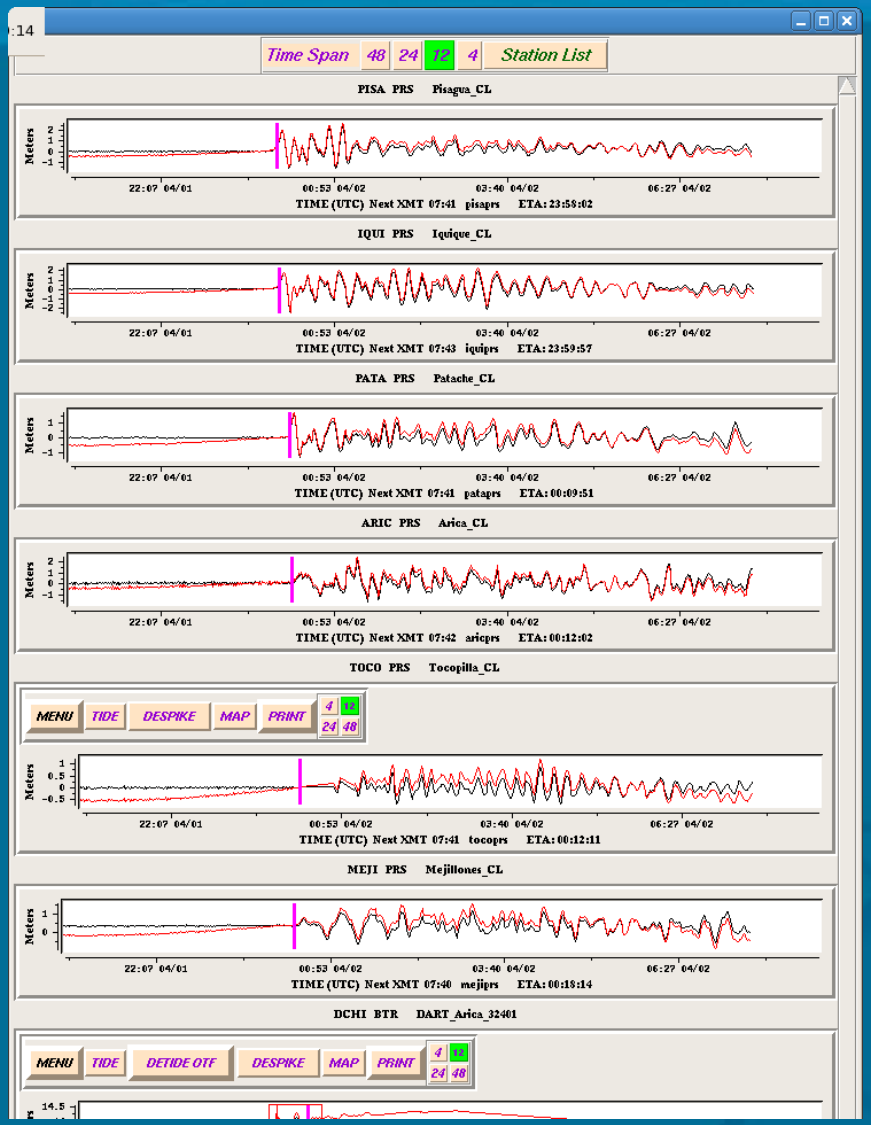


Tide Tool & ETA's



Created with the ttt_tidetool script

Tide Tool & ETA's

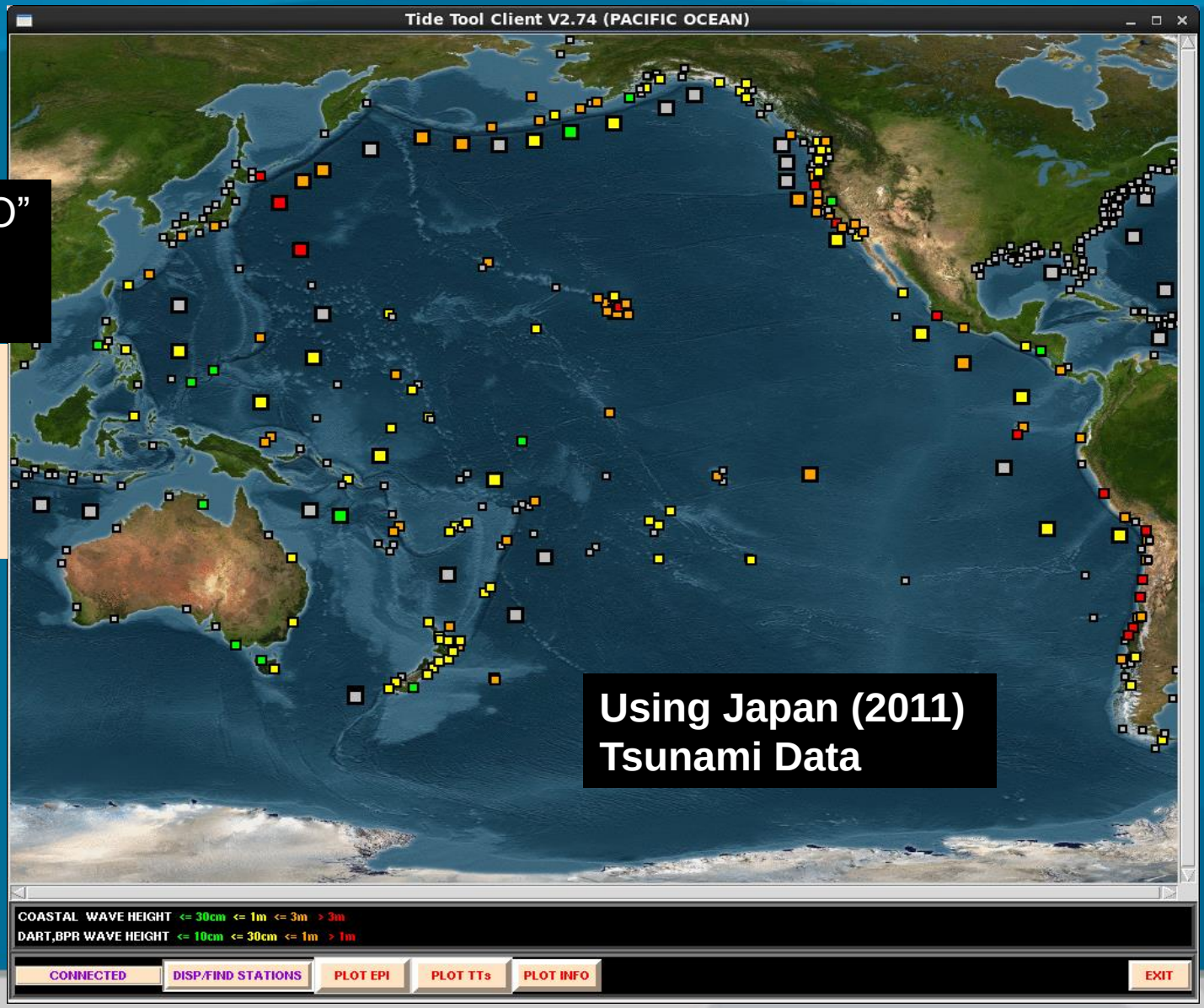


Stations arranged in ETA order..

Plotting Measurements

Clicking “PLOT INFO” Button creates this Menu:

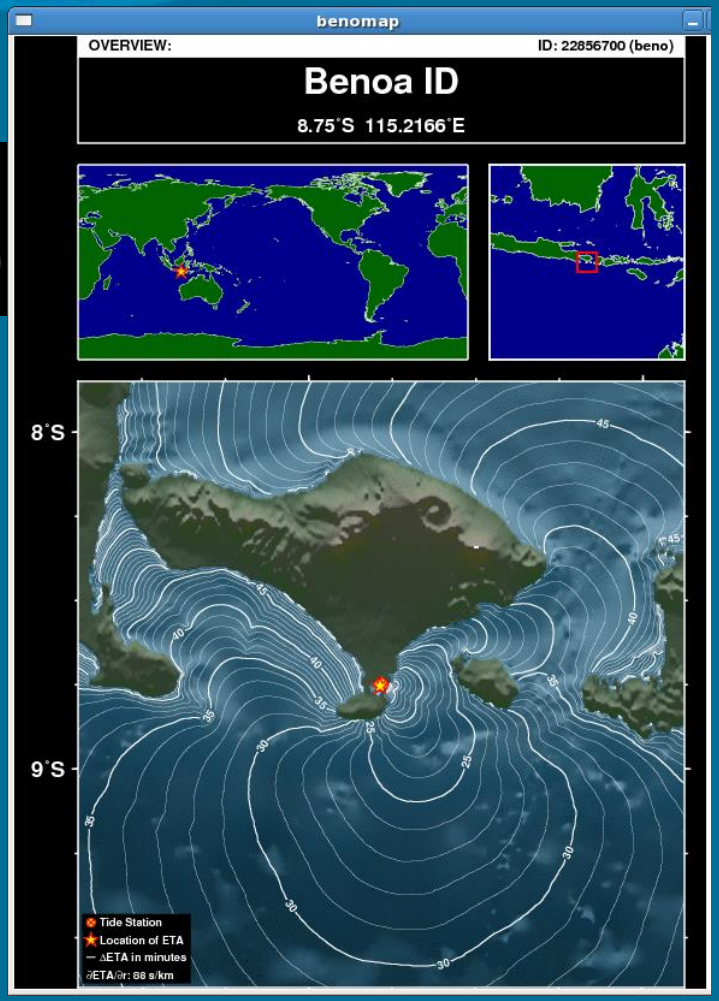
- ✔ SHOW LATENCY
- SHOW WAVE HEIGHT
- SHOW WAVE AMPLITUDE
- SHOW WAVE PERIOD
- ERASE OBS

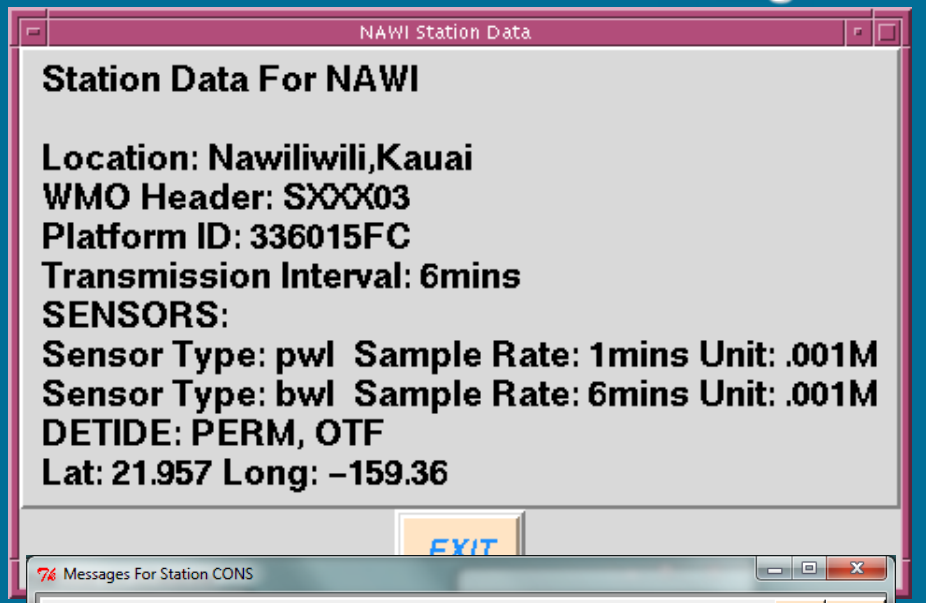


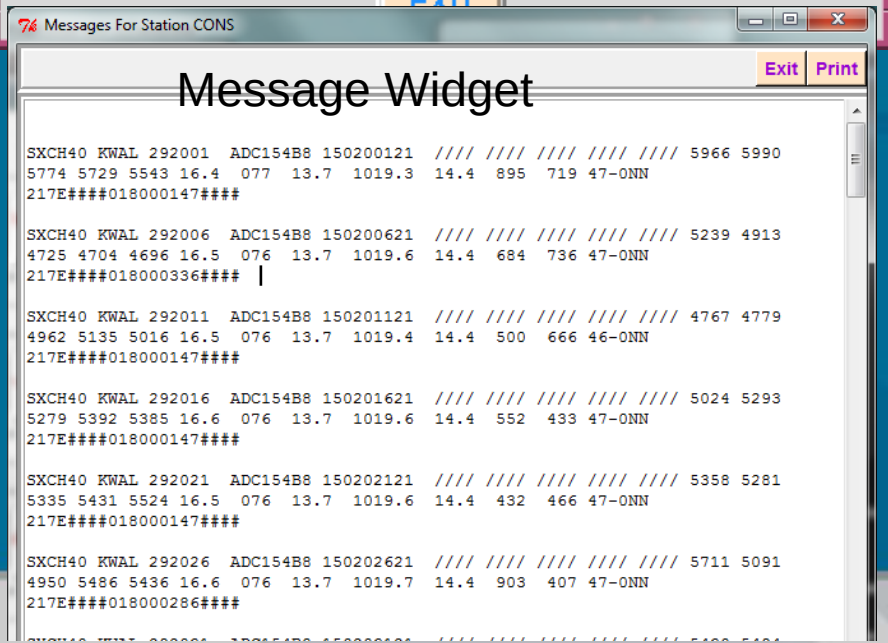
Other Features

Station Information Widget

Station MAP







Other Features

Tide Tool will decode historical GTS logfiles provided the correct Metadata is available.

Tide Tool will write files containing decoded data in a simple two column format:

102.48542 0001.300
102.48611 0001.324
102.48681 0001.333
102.48750 0001.290

Tide Tool records wave measurements:

engg prs Peak to Peak 102/12 12:45 H -0.222 102/12 12:48 H 00.180 Per 00:03 Amp 00.402 2012149 15:13

Tide Tool De-Tiding

For the purpose of accurate tsunami measurement it is important to remove the tide signal. Tsunamis have long enough periods that variations in sea-level can significantly affect the measurement of Tsunamis from marigrams. On the marigram, the tsunami will "ride the tide" affecting the precision of measurement.

Tide Tool uses two methods for de-tiding. One method is based on *permanent* coefficients* (long term prediction) determined (Foreman's method) from long time series (years). The other method, "on-the-fly" (short term prediction), uses non-static coefficients determined using recent (previous few days) data (Wang, 2009).

*PTWC maintains a set of permanent coefficients and these are available for distribution with Tide Tool

Tide Tool De-Tiding

Long Term Prediction (Permanent Coefficients)*

- Interactive (matlab) harmonic analysis of tide records of one year or longer (raw 3-6 min. or processed hourly data).
- Built-in de-spiking algorithm and quality control, and visual inspection.
- 67 of the Foreman's astronomical constituents are used in the analysis.

Short Term or On-The-Fly Prediction

- Using latest data (as short 2-3 hours and up to 5 days of data).
- Same method as above except fewer constituents are used: Depending on the length of records, 1 to 10 constituents (with increasing periods) can be used.
- Limited de-spiking but without interactive quality control
- Detiding one station takes about one sec of cpu or less.

*PTWC maintains a set of permanent coefficients and these are available for distribution with Tide Tool

Tide Tool De-Tiding

Long Term Prediction

Harmonic analysis: Least-square fit of 67 of Foreman's astronomical constituents to tide record of one year or longer (hourly means, or 3-6min data). If sampling interval is < 3min, it is resampled at 3-min or 4-6-min. In cases where quality of raw data is really poor, hourly mean data (NOS and UHSLC) are used.

Time series are despiked and smoothed if they appear noisy under visual inspection. After this formal harmonic analysis can be applied:

Least-square fit: minimization of L:

```
L = sum_k { (sum_i (Ai*cos(omega_i*Tk) + Bi*sin(omega(i)*Tk))
                                - tide_obs(Tk))**2}
```

where, Tk=time(k), Ai and Bi are harmonic coefficients, omega(i) are frequencies of constituents.

Tide Tool De-Tiding

Short Term Prediction

1. Use the latest data (up to 5 days). If there are multiple sensors at a given station, the sensor with the most data is used for de-tiding (unless that data is of poor quality, in which case another sensor is used.

2. De-spiking based on the distribution of data

3. Harmonic analysis of de-spiked data: depending on the length of data, one or more constituents with periods typically less or comparable to the length of data are used.

4. Number of harmonics considered depends on length of time series. The number of harmonics that gives the best fit in a least-squares sense is used.

Tide Tool De-Tiding

Both de-tiding methods have strengths and weaknesses:

Short Term Prediction*

Strengths: Does not require long time series and can therefore be used for new stations.

Will eliminate non-gravitational effects.

Weakness: Will not work well if data contains gaps or other defects.

Coefficients need to be computed every few hours.

*PTWC working on creating a pure Tcl script that computes the on-the-fly coefficients.

Tide Tool De-Tiding

Both de-tiding methods have strengths and weaknesses:

Long Term Prediction*

Strengths: De-tiding not affected by spikes or other defects in the data.

Weaknesses: Susceptible to non-gravitational effects.

Requires one or more years worth of data to compute coefficients that give correct phase well into the future.

*PTWC maintains a set of permanent coefficients and these are available for distribution with Tide Tool

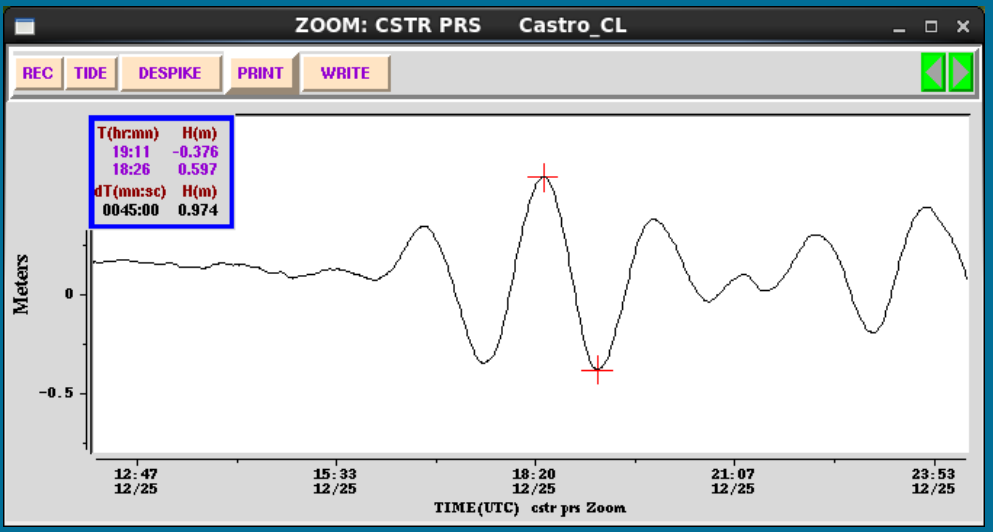
Future Directions

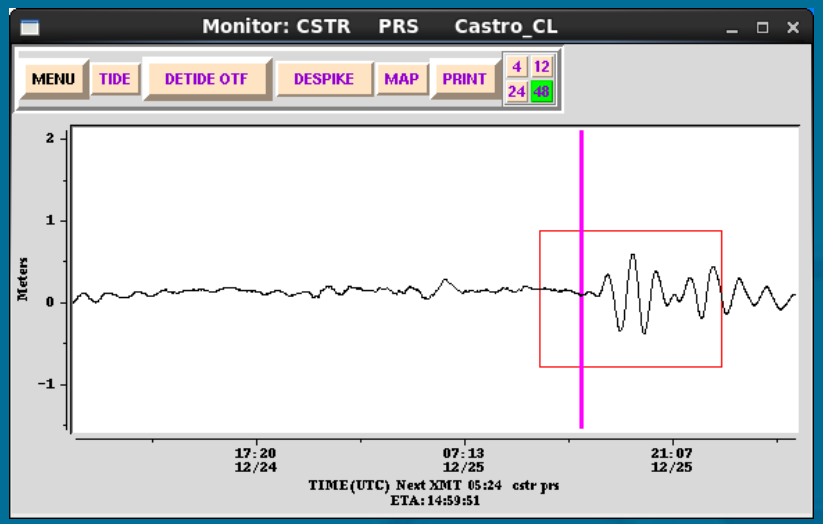
1. “On The Fly” Tide Modeling distributed with Tide Tool
2. Band-pass filtering

Sample Tsunamis…

Observations from Chile Dec. 25, 2016

Tsunami had unusually long period (60-90 minutes) at several stations. Largest at Castro T2P 97cm.

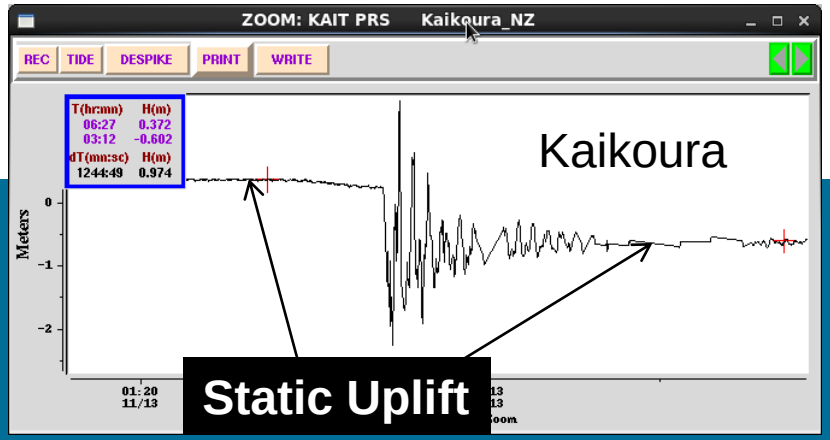


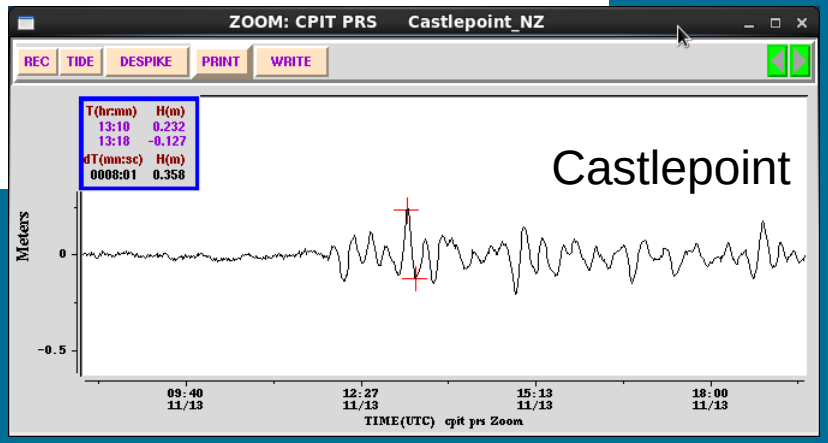


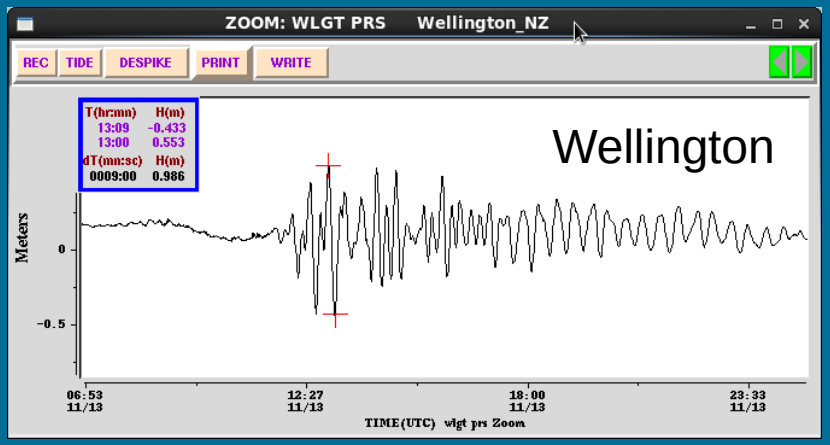
Sample Tsunamis…

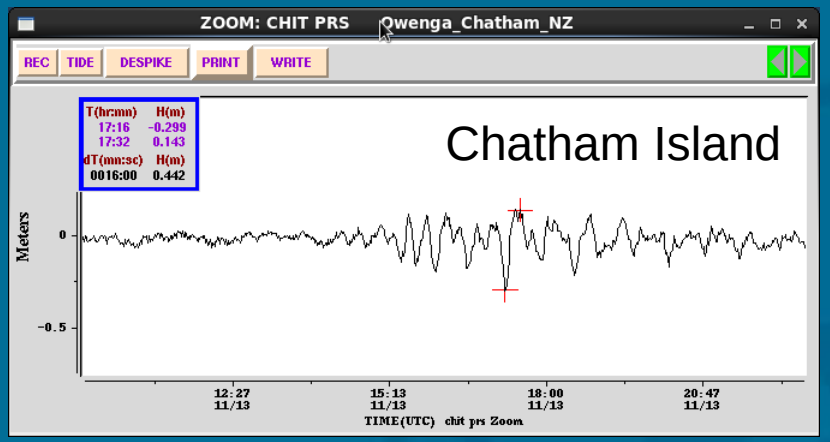
New Zealand Quake 11/13/2016

Kaikoura showed maximum amplitude. Also note the static uplift of Kaikoura due the earthquake.



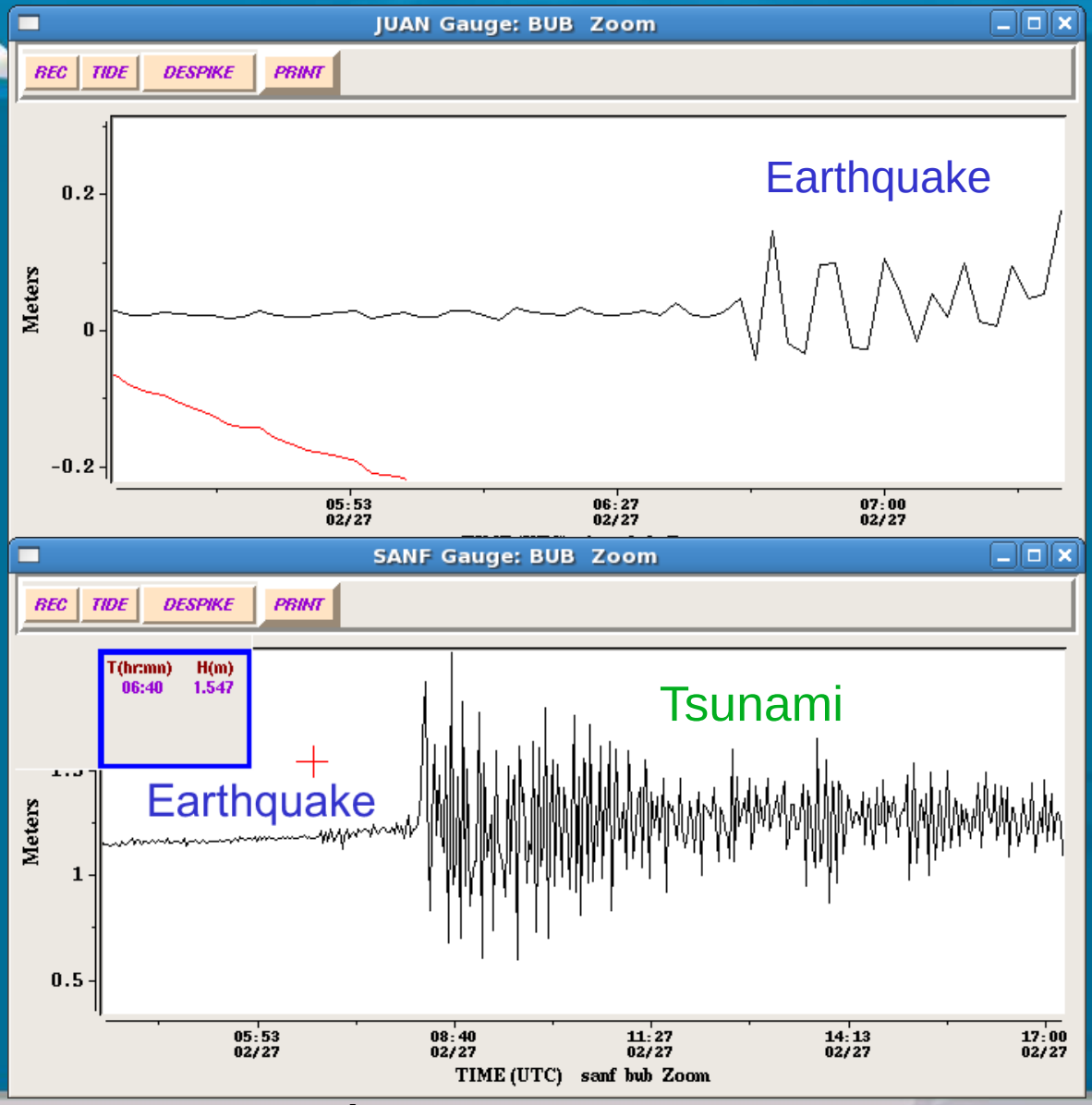






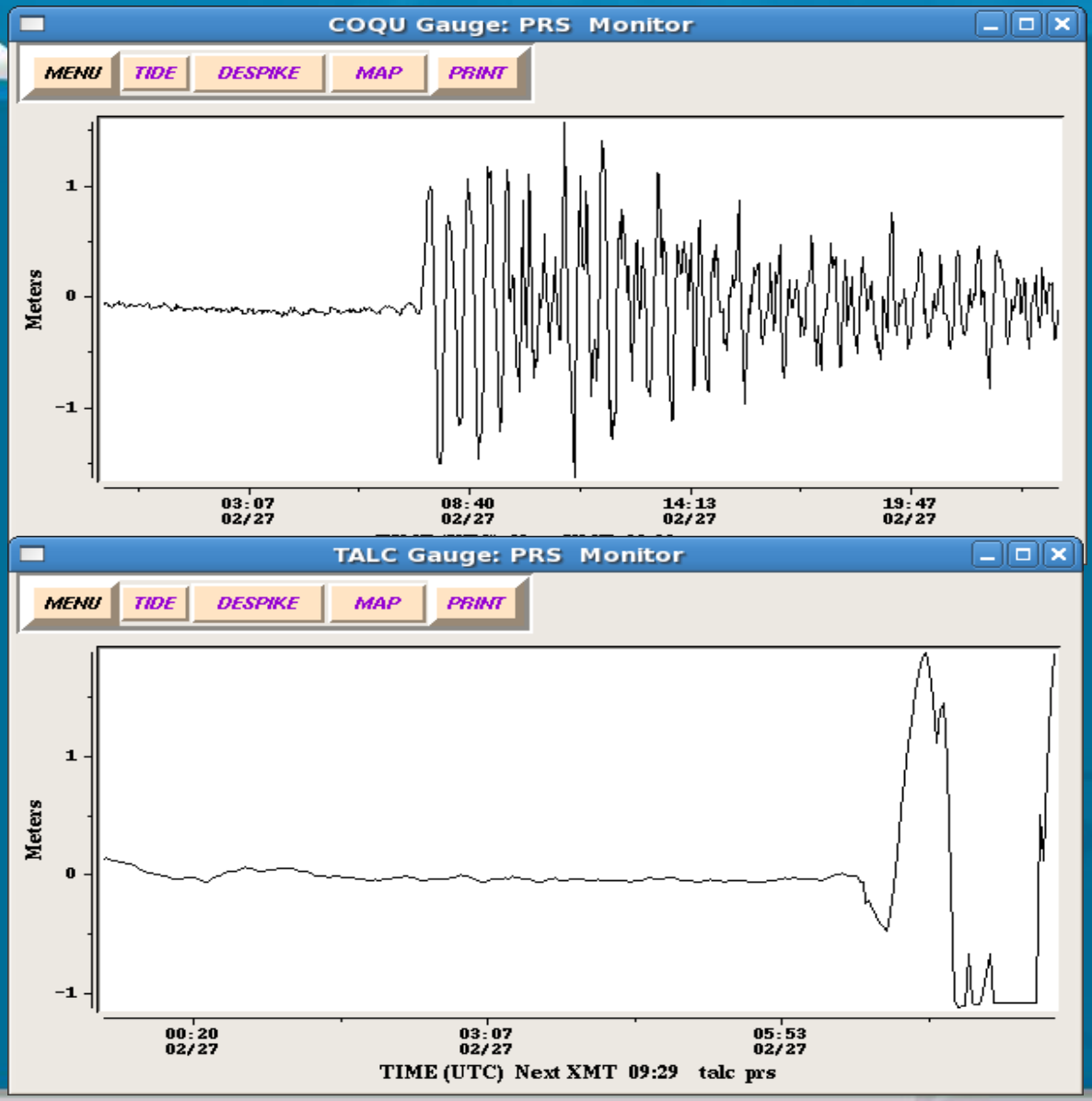
Chile 2010 Tsunami Marigrams

OT 6:34 UTC, Feb 27 2010 Mw = 8.8



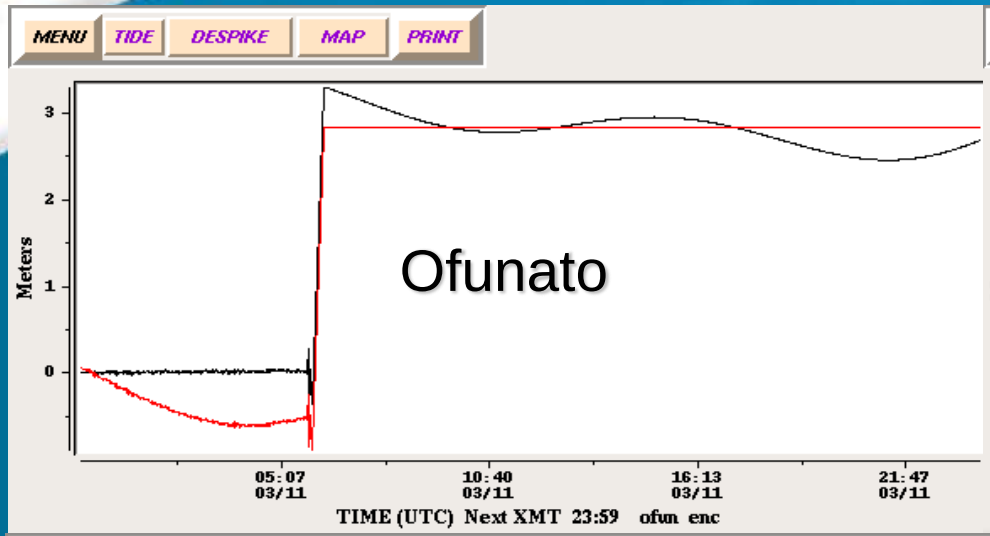
Chile 2010 Tsunami Marigrams

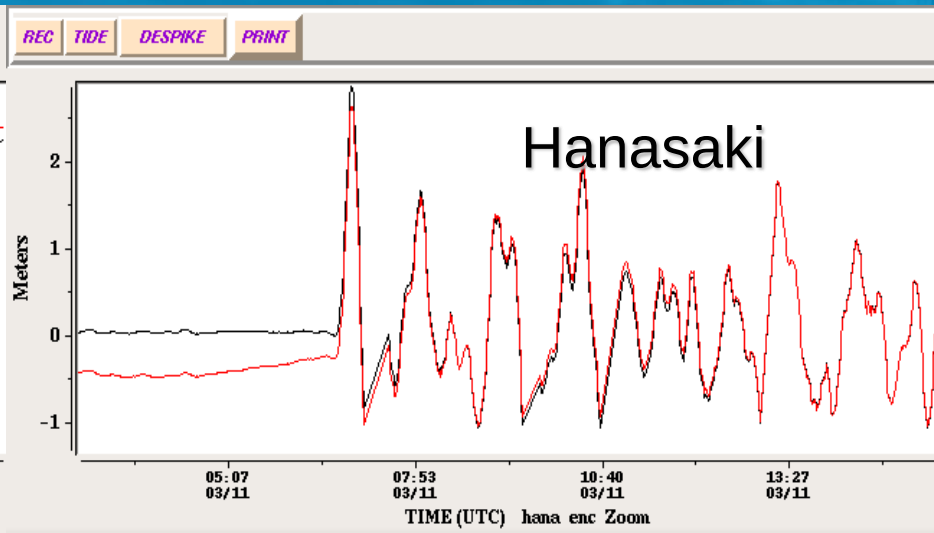
OT 6:34 UTC, Feb 27 2010

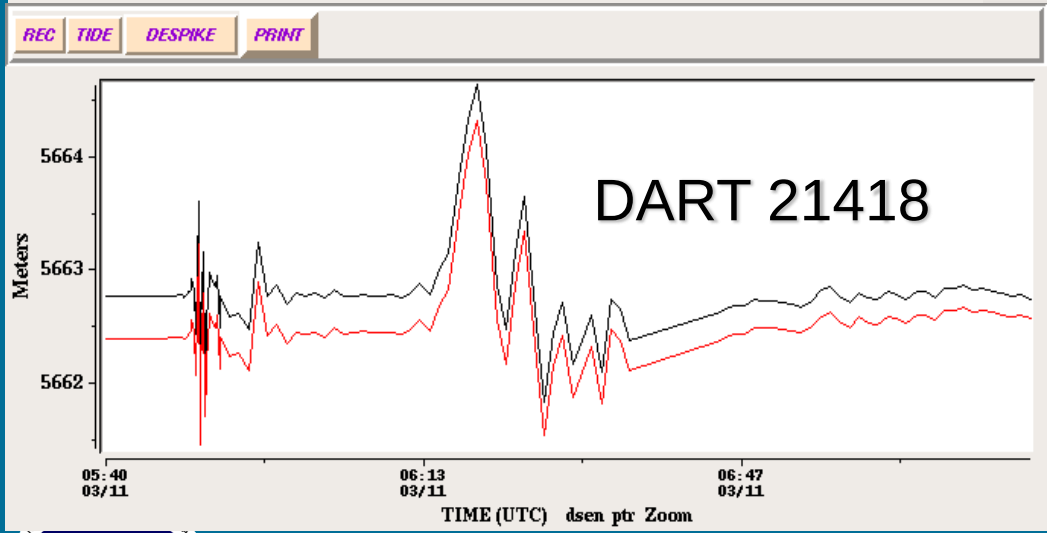


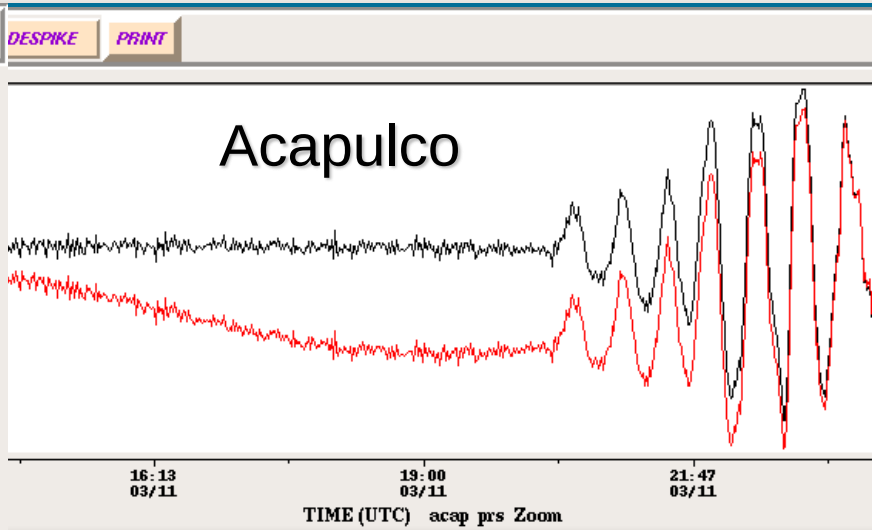
Tohoku Tsunami Marigrams

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

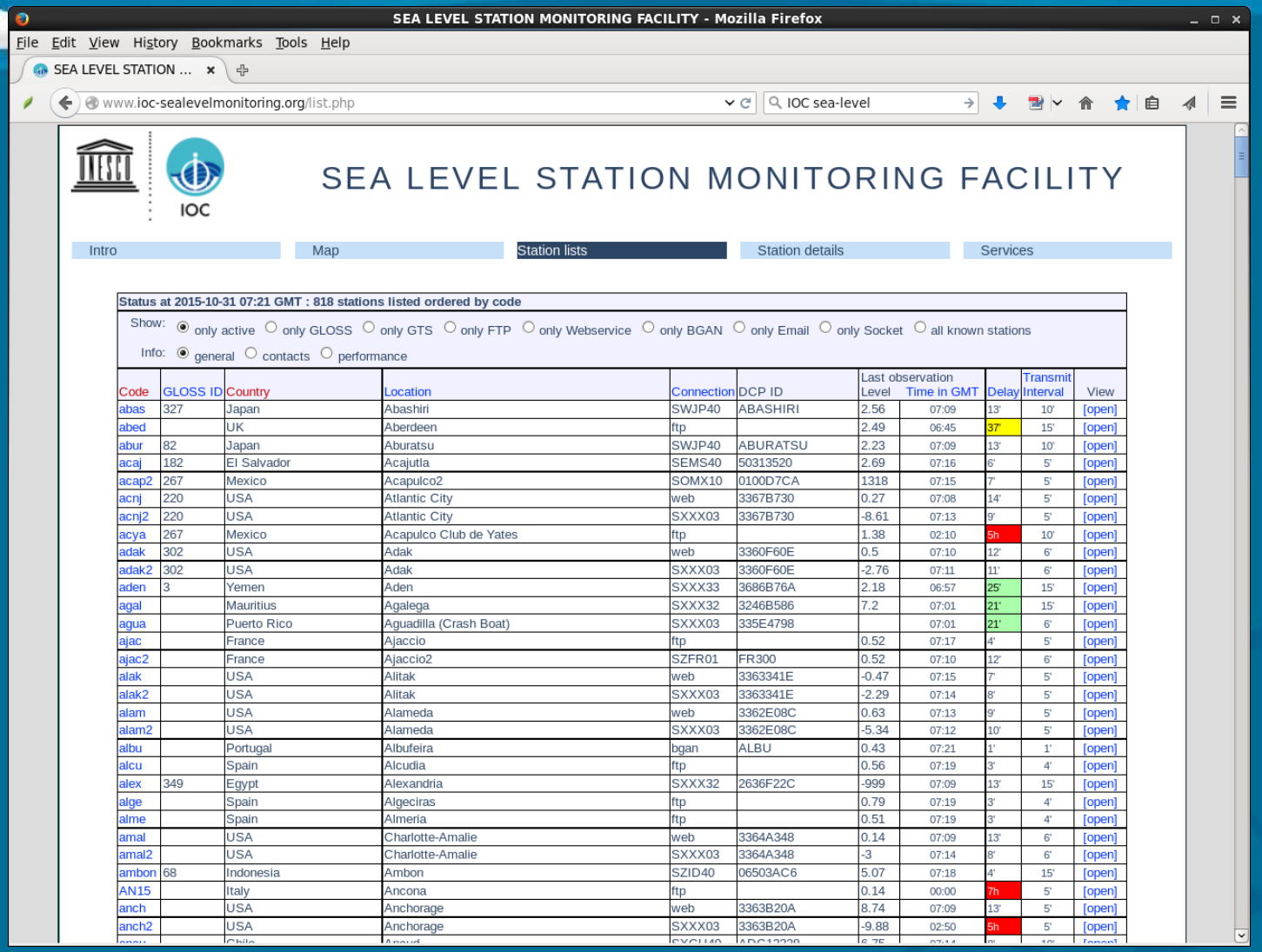








Historical and Live Data: IOC Sea-Level Website



Code	GLOSS ID	Country	Location	Connection	DCP ID	Last observation Level	Last observation Time in GMT	Delay	Transmit Interval	View
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abed		UK	Aberdeen	ftp		2.49	06:45	37'	15'	[open]
abur	82	Japan	Aburatsu	SWJP40	ABURATSU	2.23	07:09	13'	10'	[open]
acaj	182	El Salvador	Acajutla	SEMS40	50313520	2.69	07:16	6'	5'	[open]
acap2	267	Mexico	Acapulco2	SOMX10	0100D7CA	1318	07:15	7'	5'	[open]
acnj	220	USA	Atlantic City	web	3367B730	0.27	07:08	14'	5'	[open]
acnj2	220	USA	Atlantic City	SXXX03	3367B730	-8.61	07:13	9'	5'	[open]
acya	267	Mexico	Acapulco Club de Yates	ftp		1.38	02:10	5h	10'	[open]
adak	302	USA	Adak	web	3360F60E	0.5	07:10	12'	6'	[open]
adak2	302	USA	Adak	SXXX03	3360F60E	-2.76	07:11	11'	6'	[open]
aden	3	Yemen	Aden	SXXX33	3686B76A	2.18	06:57	25'	15'	[open]
agal		Mauritius	Agalega	SXXX32	3246B586	7.2	07:01	21'	15'	[open]
agua		Puerto Rico	Aguadilla (Crash Boat)	SXXX03	335E4798		07:01	21'	6'	[open]
ajac		France	Ajaccio	ftp		0.52	07:17	4'	5'	[open]
ajac2		France	Ajaccio2	SZFR01	FR300	0.52	07:10	12'	6'	[open]
alak		USA	Alitak	web	3363341E	-0.47	07:15	7'	5'	[open]
alak2		USA	Alitak	SXXX03	3363341E	-2.29	07:14	8'	5'	[open]
alam		USA	Alameda	web	3362E08C	0.63	07:13	9'	5'	[open]
alam2		USA	Alameda	SXXX03	3362E08C	-5.34	07:12	10'	5'	[open]
albu		Portugal	Albufeira	bgan	ALBU	0.43	07:21	1'	1'	[open]
alcu		Spain	Alcudia	ftp		0.56	07:19	3'	4'	[open]
alex	349	Egypt	Alexandria	SXXX32	2636F22C	-999	07:09	13'	15'	[open]
alge		Spain	Algeciras	ftp		0.79	07:19	3'	4'	[open]
almе		Spain	Almeria	ftp		0.51	07:19	3'	4'	[open]
amal		USA	Charlotte-Amalie	web	3364A348	0.14	07:09	13'	6'	[open]
amal2		USA	Charlotte-Amalie	SXXX03	3364A348	-3	07:14	8'	6'	[open]
ambon	68	Indonesia	Ambon	SZID40	06503AC6	5.07	07:18	4'	15'	[open]
AN15		Italy	Ancona	ftp		0.14	00:00	7h	5'	[open]
anch		USA	Anchorage	web	3363B20A	8.74	07:09	13'	5'	[open]
anch2		USA	Anchorage	SXXX03	3363B20A	-9.88	02:50	5h	5'	[open]

Updates (FTP site)

Updates will be posted to the UHSLC anonymous FTP server:

ilikai.soest.hawaii.edu

Login with anonymous FTP
cd ptwc

Or via the web:
http://www.ilikai.soest.hawaii.edu/ptwc


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Thank You!


NATIONAL WEATHER SERVICE

You may need to edit your Tide.tcl file in C:\Tcl\bin. Notepad or WordPad will work. Find the line: “set USE_LOG 0”

=> Change the 0 to a 1, “set USE_LOG 1”

Also the FTP site is now:
ftp.soest.hawaii.edu

NOT ilikai.soest.hawaii.edu