CariCOOS's Buoy detects an Air Pressure Disturbance before Meteotsunami hits Puerto Rico

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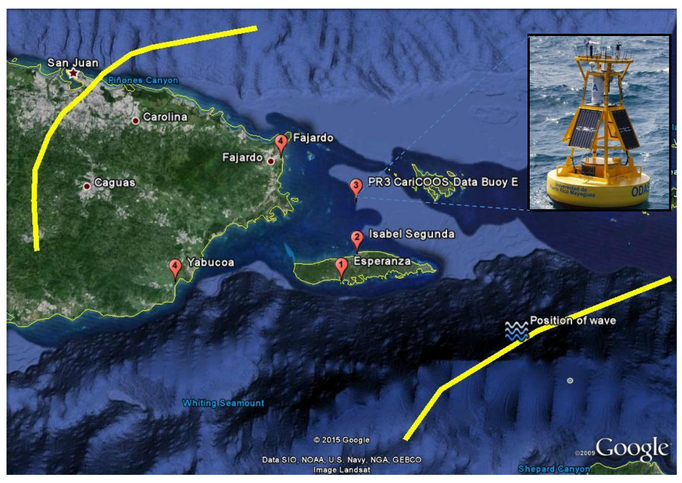
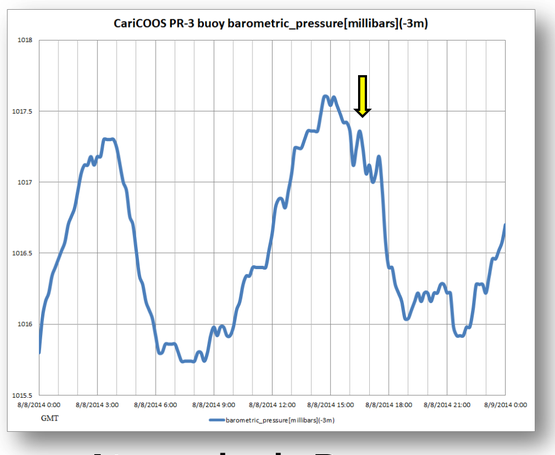
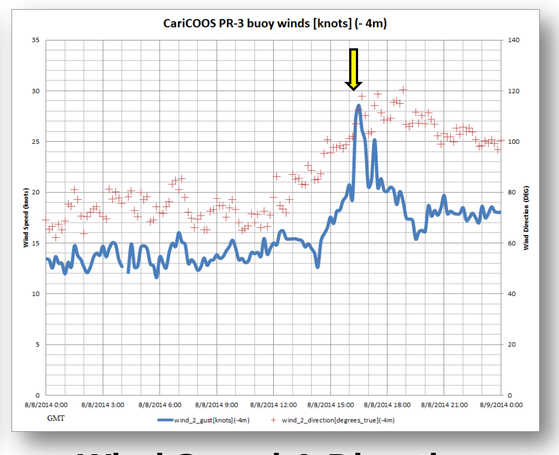
OVERVIEW

On August 8th 2014 1630 GMT, CariCOOS's PR-3 buoy detects an atmospheric pressure jump (0.2 mb) and a strong ESE wind gust (28 kn) (yellow arrows). Both associated with the passage of a squall line (yellow lines). The disturbance was detected by 4 NOS coastal stations. Exactly, **23 minutes** later, at 1653 GMT, occurred a 15 cm amplitude oscillation of the water level at Puerto de Fajardo (red arrow). Followed by a smaller one 52 minutes later.

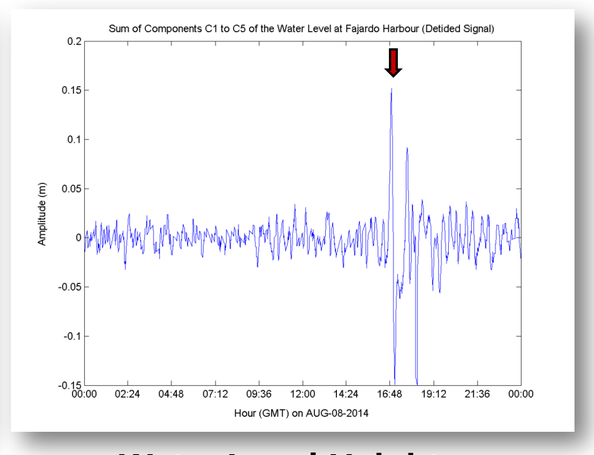




Atmospheric Pressure



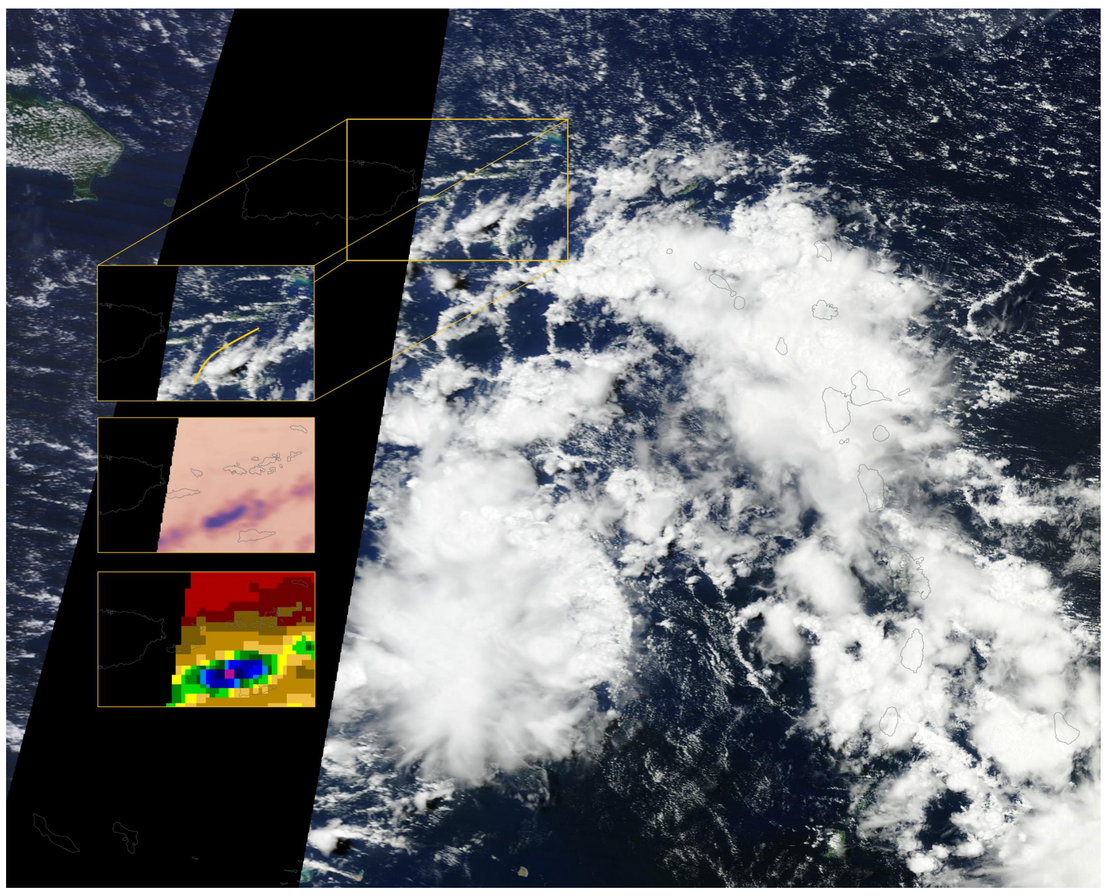
Wind Speed & Direction

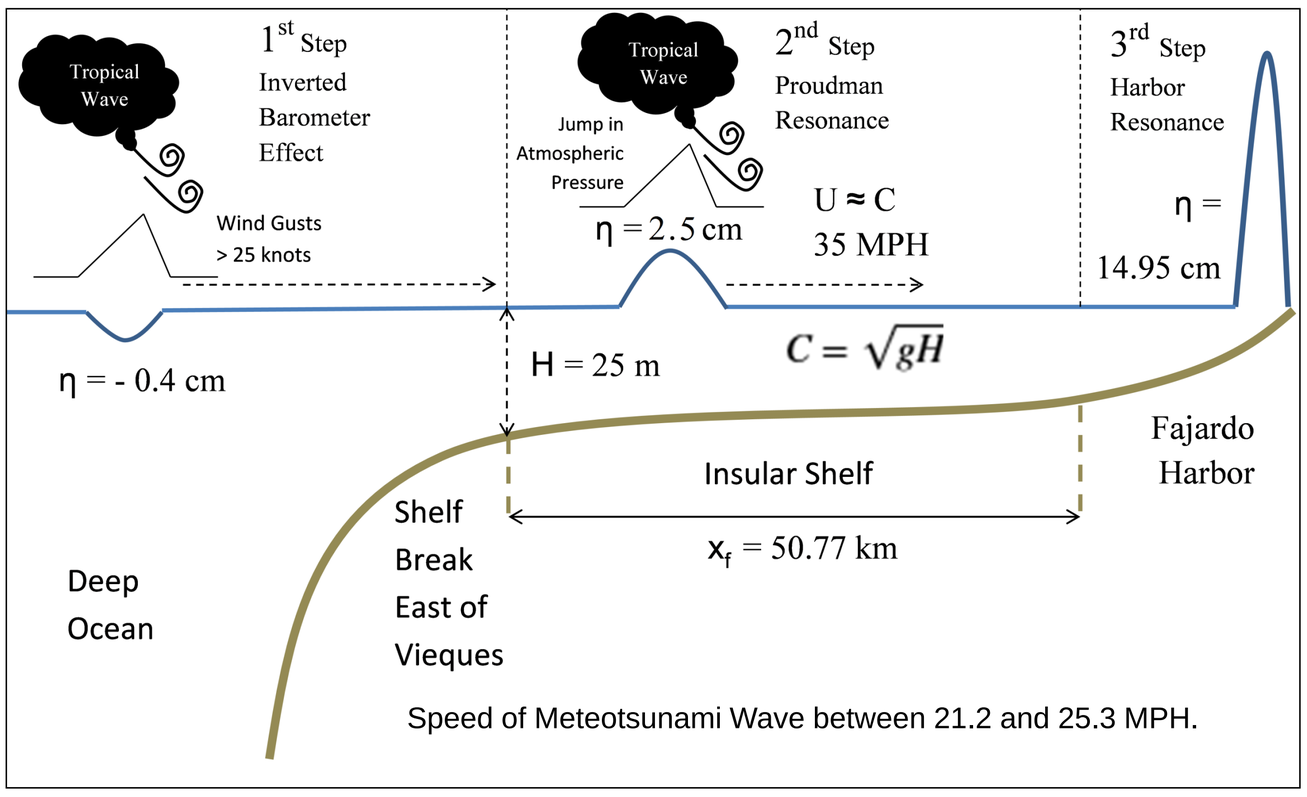


Water Level Height

UNDERSTANDING THE SOURCE OF A METEOTSUNAMI

The source of the meteotsunami was a squall line generated during a tropical wave crossing the Caribbean Sea. See video at http://youtu.be/bAF39ppjAn0. The traveling atmospheric pressure disturbance characterized by an air pressure jump and sudden strong winds resonantly generates a barotropic gravity wave in the insular shelf waters. The speed of the air disturbance equals the speed of a shallow water wave, this coupling increases its amplitude. Harbor resonance amplifies the wave a second time. The diagram below explains in three steps the generation of a meteotsunami.



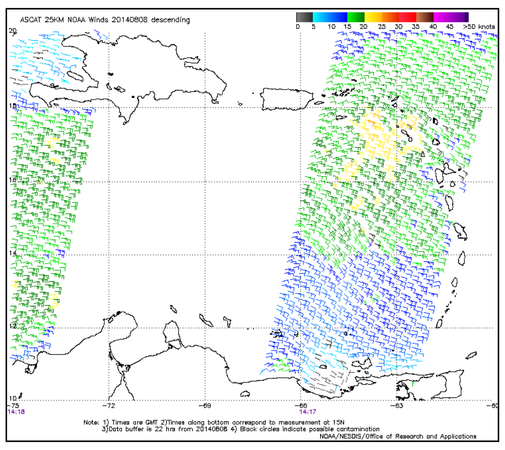


Air Pressure Disturbance Speed & Direction (Meteotsunami 8-AUG-2014) Determined by Isochronal Analysis Method, Orlić (1980)										
From	To	Measured difference between arrival times of pressure disturbances at various stations Δti bar (hours)	Distance between two stations (statute miles) δi	Angle between stations measured CW from North	CCW Angle between the line δi and the parallel of latitude γi	Speed of Wave (MPH)	CCW Angle between wave and the parallel of latitude γ	Estimated difference between arrival times of pressure disturbances at stations whose distance is δi Δti = (δi*cos(γi-γ))/v (hours)	(Δti - Δti bar)^2	Speed of Wave (m/s)
						25.3	140			11.3
Isabel Segunda	Fajardo	0.5	17.4	136.1	133.89			0.685	0.034	
Esperanza	Fajardo	0.8	19.3	148.1	121.91			0.726	0.005	
Esperanza	Yabucoa H.	0.8	23.86	83.38	186.62			0.648	0.023	
PR3 Buoy	Fajardo	0.3	12.4	115.48	154.52			0.474	0.030	
Esperanza	PR3 Buoy	0.5	11.56	184.54	85.46			0.265	0.055	
Isabel Segunda	PR3 Buoy	0.2	7.56	173.27	96.73			0.218	0.000	
								sum (Δti - Δti bar)^2 =	0.1488	

Orlić, M. (1980), About the possible occurrence of the Proudman resonance in the Adriatic, Thalassia Jugosl., 16(1), 79-88

Air Pressure Disturbance Speed & Direction Determined by Analysis of MODIS Images

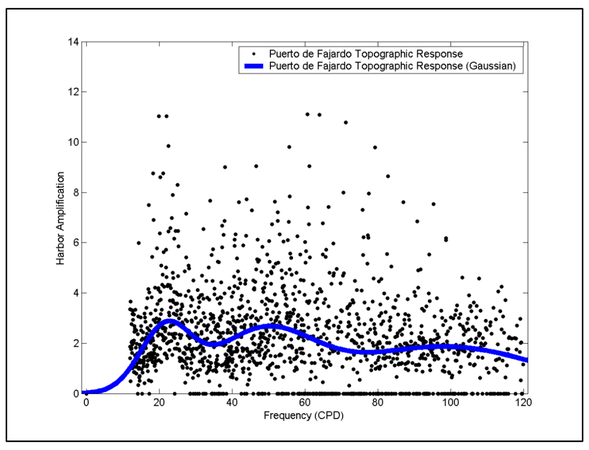
Location	Date (GMT)	Start Pressure Jump*	Barometric Pressure*	Time of Maximum Barometric Pressure*	Barometric Pressure*	Atm. pressure Jump at the sea surface Δp (mb, hPa)*	Travel Time of Pressure Jump (hours)	Travel Distance (miles)	Atm. Pressure Jump Speed (MPH)
Esperanza, Puerto Rico		8/8/14 15:54	1017.7	8/8/14 16:00	1018.1	0.4			
PR3 Buoy		8/8/2014 16:10	1017.12	8/8/2014 16:30	1017.36	0.2	0.5	11.56	23.1
MODIS IMAGES									
LesserAntilles.2014220.terra.250m		8/8/14 14:15							
LesserAntilles.2014220.aqua.250m		8/8/14 17:25							
Time difference (hours)		3.17							
Travel Distance (miles)		67							
Speed		21.2							
Coming From Direction	CW from N	123							
Going Away Direction	CCW from E	147							



$$\Delta t_i = \frac{\delta_i \cdot \cos(\gamma_i - \gamma)}{v}$$

$$f(v,\gamma) = \sum_{i=1}^{n} (\Delta t_i - \overline{\Delta t_i})^2 = \sum_{i=1}^{n} \left(\frac{\delta_i \cdot \cos(\gamma_i - \gamma)}{v} - \overline{\Delta t_i} \right)^2$$

Isochronal Analysis Equations



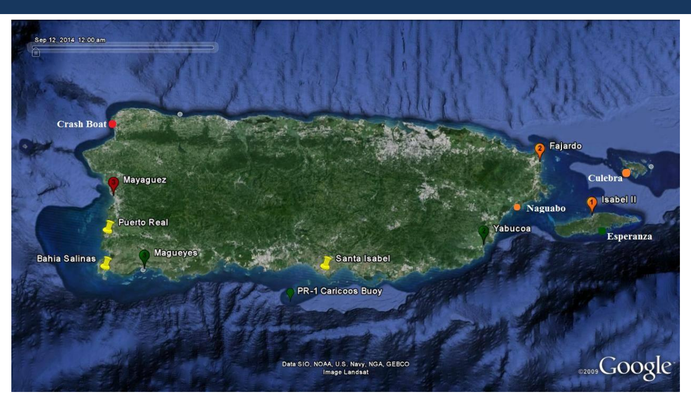
Harbor Amplification: Puerto de Fajardo amplified the wave six times at a frequency of 28 CPD.

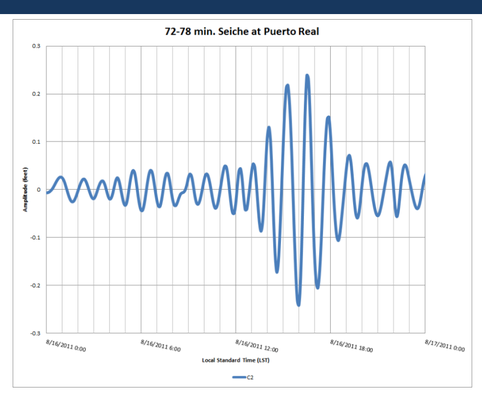
The isochronal analysis method for determining the speed and direction of air pressure disturbances was developed by Orlić (1980). This method assumes that the pressure disturbance is a plain wave, propagating over the given area with constant speed and direction. Let **v** be the speed of the wave and **γ** its direction, measured CCW from the eastward direction. Let $\boldsymbol{\delta_i}$ be the distance between two meteorological stations and $\boldsymbol{\gamma_i}$ is the angle between the line δ_i and the parallel of latitude. $\boldsymbol{\Delta t_i}$ stand for the **estimated** difference between arrival times of pressure disturbances at stations whose distance is δ_i. The $\boldsymbol{\Delta t_i}$ **bar** denote the **measured** difference of arrival times of disturbances at stations.

TIME INTERVAL BETWEEN AIR PRESSURE DISTURBANCE AT CariCOOS PR-1 BUOY AND METEOTSUNAMI HIT THE SW COAST OF PR

Time interval between detection of air pressure disturbance at PR1 Buoy and the meteotsunami ocurrence at each locality

Localidad	Air pressure jump detected at PR-1 Buoy (LST)	Start Time of Coastal Seiche (LST)	Time Interval (minutes)
PR-1 Buoy- SE Caja de Muertos	8/16/2011 12:10		
Magueyes Island, La Parguera		8/16/2011 12:24	14
Bahia Salinas, Cabo Rojo		8/16/2011 13:24	74
Puerto Real, Cabo Rojo (C1)		8/16/2011 13:42	92
Puerto Real, Cabo Rojo (C2)		8/16/2011 13:36	86





REFERENCES

- Orlić, M. (1980), About the possible ocurrence of the Proudman resonance in the Adriatic, Thalassia Jugosl, 16(1), 79-88.
- Alfonso-Sosa, E. (2012), Primer Reporte de un meteotsunami en la costa caribeña de Puerto Rico. Ocean Physics Education, Inc., 24 pp.