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ANAK KRAKATAU VOLCANO EMERGENCY TSUNAMI EARLY WARNING SYSTEM

A. Annunziato[1], G. Prasetya[2], S. Husrin[3]

[1]European Commission Joint Research Centre - [2]Tsunami Society Indonesia (IATsI) - [3]Ministry of Marine Affairs and Fisheries of the Republic of Indonesia

ABSTRACT

On 22 Dec 2018 13:56 UTC a tsunami was generated from the area of the Anak Krakatau Volcano, with waves propagating in all directions inside the Sunda Strait - the sea portion between the islands of Java and Sumatra. The cause of this event seems to have a correlation with the ongoing volcanic eruption, which was particularly active since June 2018 [4].

At the time of the event, the Tsunami Early Warning System currently implemented in Indonesia, could not be used because there was no mechanism to activate the system on the basis of sea levels measurements or other information from the volcano activities. Given the situation, the Indonesian authorities decided to implement an Emergency Early Warning System that can timely inform if any sea level disturbance represents a tsunami from volcano activities and therefore be able to activate the warning sirens.

The Joint Research Centre (JRC), in collaboration with the Indonesian Tsunami Society, the Marine Research Centre of the Ministry of Marine Affairs and Fisheries and the Meteorological, Climatological and Geophysical Agency of Indonesia (BMKG) worked together since the event in December in order to design and implement the new Emergency System. The new system will adopt the real time fast Tsunami instruments (Inexpensive Device for Sea Level Monitoring or IDSL), developed by JRC [1], to monitor in real time on a 24/7 the sea level and provide email, SMS alerts, CCTV images and inform about a potential event. The activation of the sirens in the area can be performed after human verification of the signals. The first two devices were

installed at the end of January 2018; other devices will be provided and installed in the near future. The present report illustrates the basic principle of the Early Warning System and reports about the first two months of operational activity since the new devices were installed.

1 THE KRAKATOA TSUNAMI OF 22 DECEMBER 2018

On 22 December 2018 a large tsunami was generated from the collapse of the Krakatau volcano's structure inside the Anak Krakatau Volcanic Complex. The tsunami hit the coasts of Sumatra and Java in the Sunda Strait, with waves up to 6-8 m, causing a huge number of fatalities, currently estimated to be more than four hundred. The tsunami arrived at about 21:30 local time (14:30 UTC) on 22 December, completely unexpected, and caused fatalities and extensive damage along the coastal areas of the Sunda Strait. As of 14 January 2019, there were at least 430 casualties, mostly along the southeast coast of West Java in the Pandeglang Regency (Banten province, Java), 23 people were missing, 7200 were injured, more than 1000 structures were damaged and 430 boats damaged [2]).

At the time of the event, the Early Warning System that had been implemented in Indonesia to protect the people from tsunamis was operational; however, this system had been designed to warn only about tsunamis of seismic origin (which are the majority in the world)[3]. The generation of the tsunami of 22 December 2018 was detected by the tide gauges that had been installed on the coast, but not in sufficient time to provide any warning to the population, about any larger seismic event or the relevant increase in volcanic activity of the Krakatau volcano. In any case the distance from the volcano to coastal areas is rather large to prevent a detailed visual or acoustic alerting. In principle, the availability of the tide gauges datum in real time, connected with an analysis and change detection software, could have allowed to identify the first impulse in Marina Jambu.[1]

Tide Gauge	**Arrival Time on 22 Dec (UTC)**	**Time Difference (min)**	**Max Height (above tide, m)**
Estimated Time of the event	13:58	0	-
Marina Jambu	14:27	29	0.90
Ciwabdan	14:33	35	0.35
Kota Agung	14:35	37	0.36
Panjang	14:53	55	0.28
Bengkunat	16:20	142	0.20
Krui	Not detected		
Binuangen	Not detected		

Tab I – Arrival time at tide gauges and max height

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[1] http://tides.big.go.id:8888/dash/prov/Banten.html

Taking into account that 5-8 min of latency are present in the data, there are still many locations not yet reached after 29+8 (latency) = 37 min

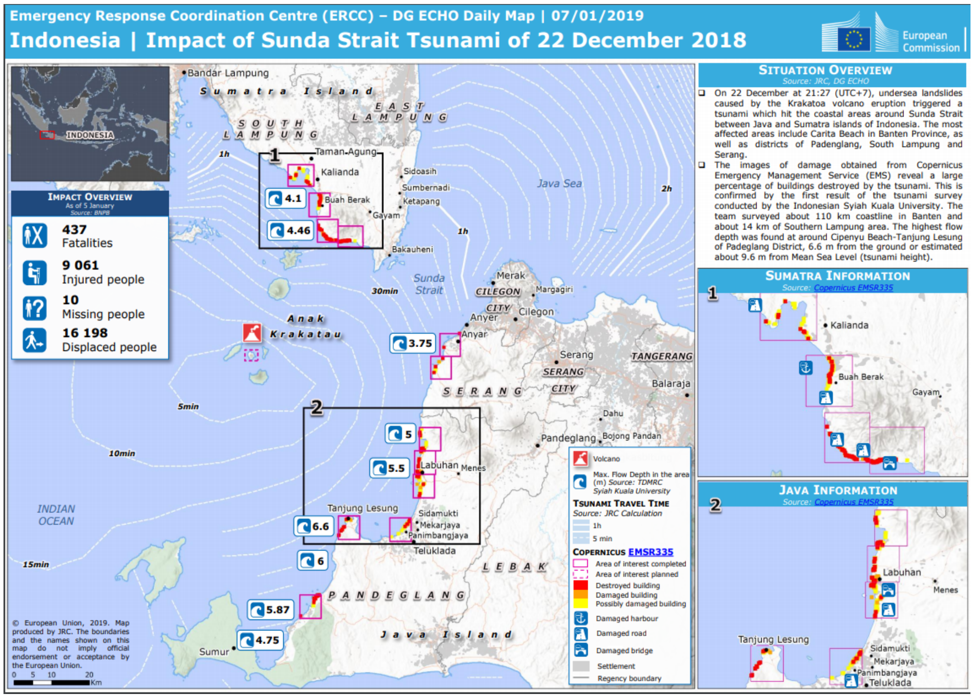
In order to have an alert from the sea level change several intermediate steps are necessary:

1. Accurate sea level measurement, as close as possible to the tsunami source
2. Fast data transmission from the measurement location
3. Software to analyse in real time and detect level changes, providing an alert
4. A double check of the data (i.e. CCTV images)
5. Decision to issue an alert to coastal locations
6. Activation of siren systems

Any time delay from 1 to 6 min will reduce the effectiveness of the alerting because when the wave arrives nothing can be done any more.

Given the fact that the Krakatau volcano eruption is still ongoing and at any time a further tsunami event is possible, an emergency implementation of an Early Warning System is of paramount importance in terms of timeliness. A more stable solution can be identified in the next months but something to correct the situation is necessary as a matter of urgency.

The objective of this report, jointly elaborated by the Joint Research Center and Tsunami Research Center Indonesia, is to outline an Emergency System that can help the Indonesian Government to face the immediate situation; future improvements and stable infrastructure can be designed in the future.


Emergency Response Coordination Centre (ERCC) – DG ECHO Daily Map | 07/01/2019

Indonesia | Impact of Sunda Strait Tsunami of 22 December 2018

SITUATION OVERVIEW
Source: JRC, DG ECHO

☐ On 22 December at 21:27 (UTC+7), undersea landslides caused by the Krakatoa volcano eruption triggered a tsunami which hit the coastal areas around Sunda Strait between Java and Sumatra islands of Indonesia. The most affected areas include Carita Beach in Banten Province, as well as districts of Padenglang, South Lampung and Serang.

☐ The images of damage obtained from Copernicus Emergency Management Service (EMS) reveal a large percentage of buildings destroyed by the tsunami. This is confirmed by the first result of the tsunami survey conducted by the Indonesian Syiah Kuala University. The team surveyed about 110 km coastline in Banten and about 14 km of Southern Lampung area. The highest flow depth was found at around Cipenyu Beach-Tanjung Lesung of Padeglang District, 6.6 m from the ground or estimated about 9.6 m from Mean Sea Level (tsunami height).

IMPACT OVERVIEW
As of 5 January
Source: BNPB

437	Fatalities
9 061	Injured people
10	Missing people
16 198	Displaced people

© European Union, 2019. Map produced by JRC. The boundaries and the names shown on this map do not imply official endorsement or acceptance by the European Union.

Figure 1 - Impact from the Tsunami caused by the collapse of Krakatoa Volcano

2 TSUNAMI PROPAGATION CALCULATIONS

Taking into account the worse case scenario of the potential tsunami generation by Anak Krakatau with diameter of the Volcano being 2km x 2km, the computation of tsunami propagation and the resulting wave height along the coast is illustrated in Figure 2.

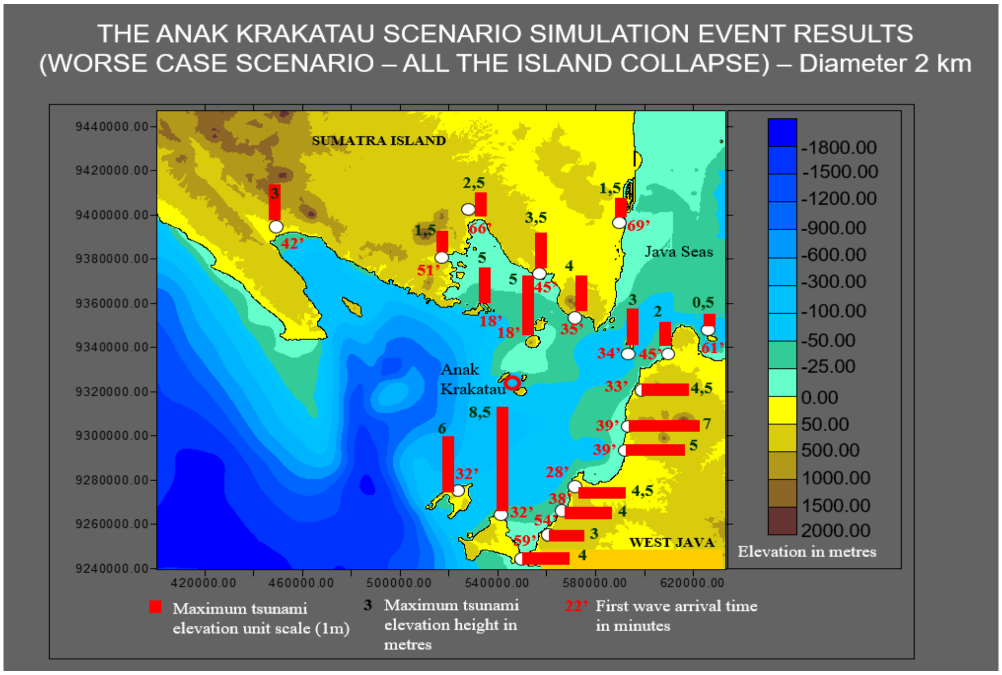
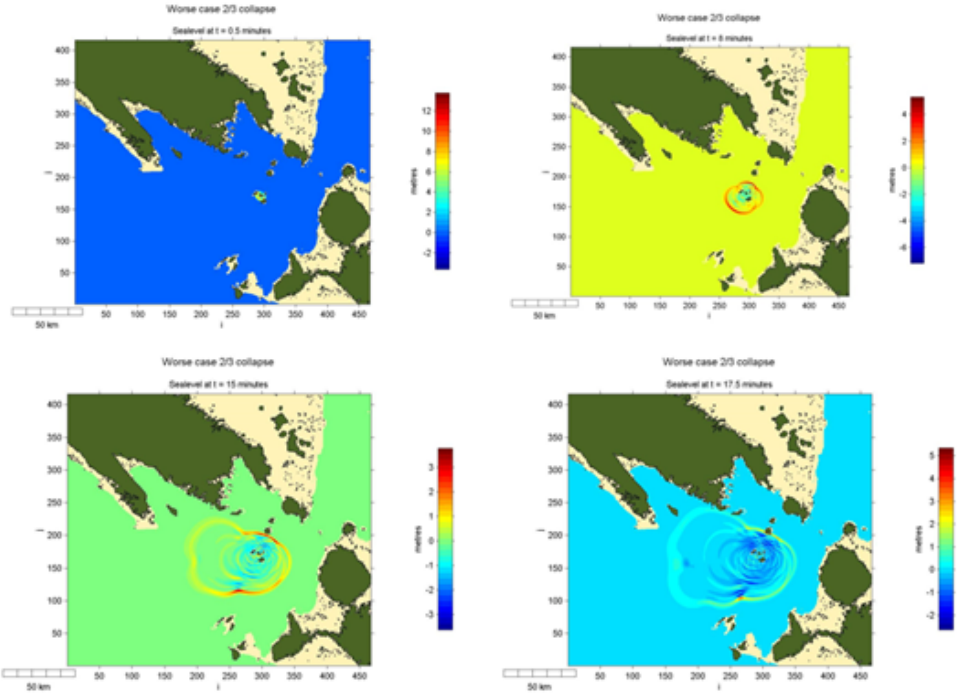


Figure 2 - Travel time (red numbers) and maximum Tsunami height in m (black numbers)



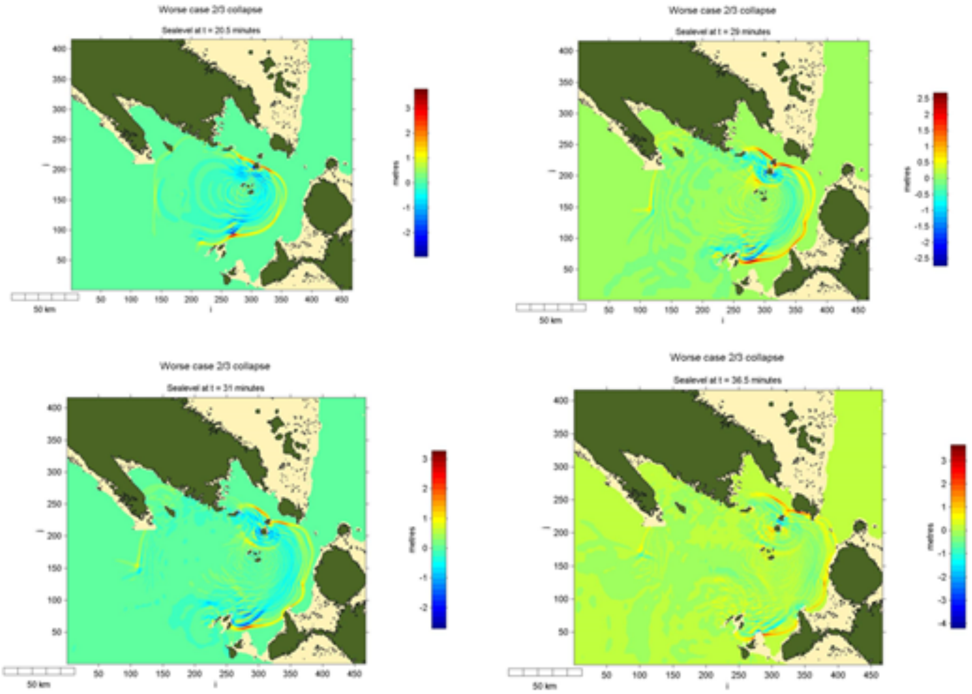


Figure 3 - Wave propagation in the Sunda Strait

3 EARLY WARNING SYSTEM DESIGN

In this section, the current Tsunami Warning System implemented in Indonesia is briefly described. Then an emergency TWS, specifically designed to protect the people from another tsunami generated by the Anak Krakatau volcano is outlined. The definite final system is subsequently described briefly.

3.1 Definition of the new Emergency EWS for the Sunda Strait

The objective is the implementation, in very short time (1 month), of an additional system that can support the operation of the National System until a final dedicated Warning System for the Krakatau volcano is implemented.

The working mode of the emergency system is based on a number of fast response tide gauges, transmitting the sea level in 'almost real time' and having a software on board (or with an analysis system in the collection server), that analyses the sea level and determines if an alert is needed. The coincidence of two or three sea level alerts can be considered as a reliable alert and

- can automatically activate the sirens in the Sunda Strait or
- can issue email/SMS to a list of addresses and someone should then decide to activate the sirens

The second case is the most conservative to avoid false alerts but some time is then lost in order to understand what is happening. Therefore the availability of tide gauges as close as possible (in terms of travel time) to the origin of the waves, is necessary.

Taking into account the travel time determined above, the following solution is proposed:

- Management of the data from the existing instrumentation with the implementation of wave detection and alerting routines.
- Installation of IDSL devices[2] in port areas around the volcano, as much as possible at shortest travel time, with minimum data latency of few seconds.
- Installation of tide gauges on the three islands close to the Anak Krakatau volcano: Sertung, Panjang and Rakata islands, travel time <2 min, alert time 3 min from the event

It is clear that the last set of tide gauges is certainly more useful for the purpose of quick alerting. The remote installation site and the absence of coastal protection for those devices, makes them rather fragile and possibly not always available in case of need. The IDSL devices, designed to provide fast data collection and dissemination, as well as identification of anomalous waves, can constitute a reliable backup or confirmation solution.

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[2] Inexpensive Device for Sea Level measurements – IDSL

4 PROPOSED IMPLEMENTATION

The implementation proposed foresees analytical intervention to the existing instrumentation and installation of new fast reacting and fast transmitting instruments (IDSLs)

4.1 Existing instrumentation

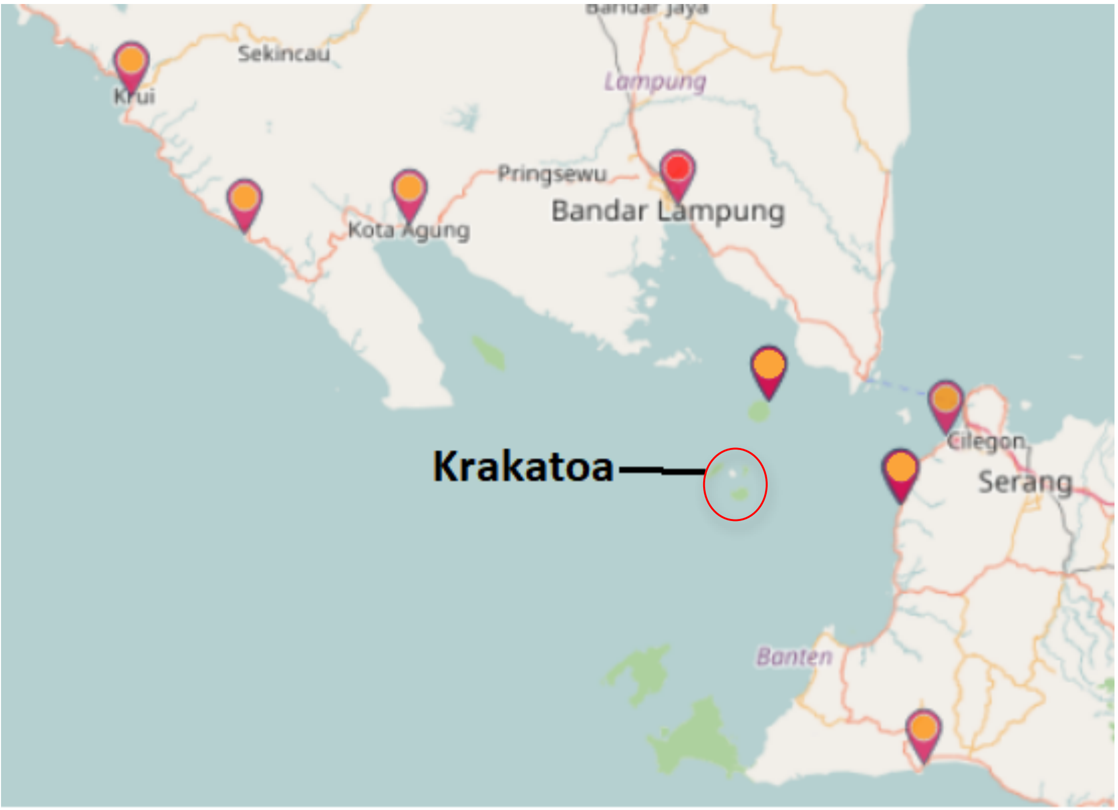


Figure 4 - Existing tide gauges in the Sunda Strait

The existing tide gauges in the Sunda strait are shown in the above figure. The gauges are operated by the Badan Informasi Geospasial (BIG) Institute. The data are collected every 2 or 3 minutes and are made available on the BIG web site. Those data are acquired and included in the TAD server for further processing and formulation of the alert signals (see Appendix A). Unfortunately the latency is rather long (about 10 min) and therefore the signal can take up to 12-14 minutes between measurement and processing, which makes the alerting too delayed. For this reason it is necessary to adopt faster instrumentation (IDSLs). It should be noted that the BIG tide gauge in Sebesi Island was installed on 26 Jan 2019 and therefore was not available at the time of the event.

4.2 Medium Distance Instruments

4.2.1 Possible installation sites

A proper installation site for the IDSL requires a port structure where to fix the pole. Locations close to the port entrance are preferable. In normal conditions it is better to perform a survey onsite in order to define the right position of the instrument, verify the GSM connection and take contacts with local authorities. In this case there is no time to perform all these steps and therefore we will identify the possible installation places from satellite images (Google Earth) and preliminary contacts should be taken with local authorities to be sure that when the installation has to be performed all goes smoothly. The list below is a not exhaustive list of possible locations. A more detailed analysis in collaboration with Indonesia authorities is necessary in order to check whether the locations are possible and if not, if some locations could not be improved with necessary infrastructure to install a tide gauge. We concentrated more on Sumatra, respect to Java as the arrival times here are shorter; also however because in Sumatra many more potential locations are available.

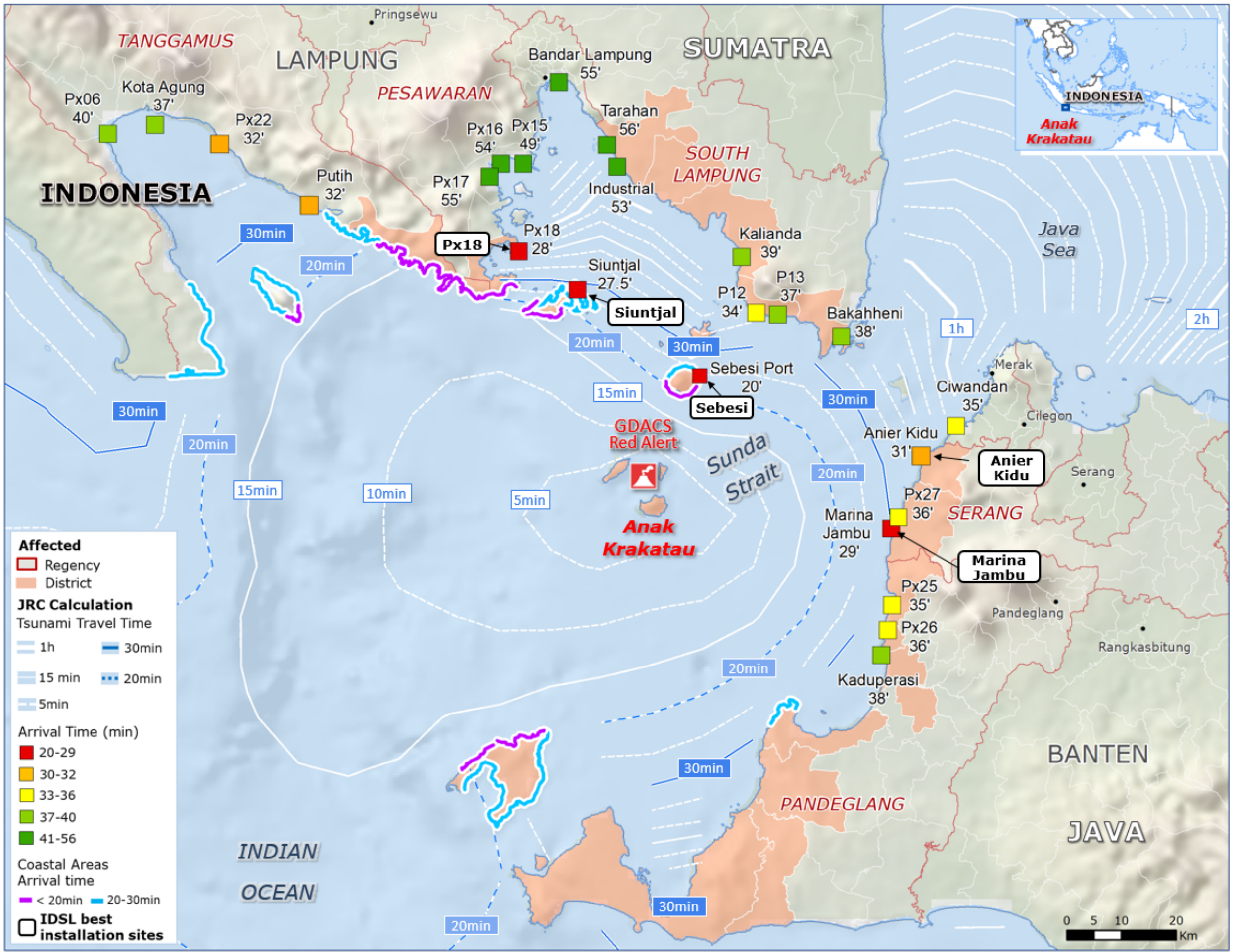
	Location	Lat	Lon	Travel Time (min)	Device present	Notes
Lampung (SUMATRA)						
	Kota Agung	104.621	-5.52338	37	YES	
	Bandar Lampung	105.2865	-5.45358	55	YES	
	Px06	104.5426402	-5.538199375	40		
	Tarahan	105.3654596	-5.557232192	56		Small fisherman port
	Industrial	105.3827018	-5.59305023	53		Industrial dock
	Kalianda	105.5883822	-5.741851675	39		Large Marina **
	P12	105.6122501	-5.833707747	34		Small dock
	P13	105.6472288	-5.836579004	37		Small fisherman port
	Bakahheni	105.7524992	-5.872764	38		Large industrial port
	Px15	105.2278809	-5.587868168	49		Small marina
	Px16	105.1906576	-5.588327294	54		Small dock
	Px17	105.17204	-5.609379404	55		Small dock
2	Px18	105.2205098	-5.732823134	28		Small dock
	Legundi	105.292515	-5.80172512	n.a.		Small dock
1	Siuntjal	105.317415	-5.795647179	27.5		Small dock
	Putih	104.8752156	-5.655967117	32		Long dock, not sure if

						floating
	Px22	104.7268941	-5.554785442	32		small dock
Banten (JAVA)						
	Marina Jambu (O)	105.8346	-6.18963	29		
4	Marina Jambu	105.8395384	-6.189708674	32	YES	
	Ciwandan	105.9437	-6.01444	35	YES	
3	Anier Kidu	105.884252	-6.069176	31		
	Px25	105.8359229	-6.315025722	35		
	Px26	105.819007	-6.359434186	36		
	Kaduperasi (?)	105.8181349	-6.398484035	38		Dock ?
	Px27	105.846862	-6.170636673	36		
	Sebesi2	105.507854	-5.962299	18		Wood dock, suitable ?
	Sebesi Port	105.512787	-5.935818	20	YES	Installed 26 Jan 2019

In the list of locations, considering the arrival time, the 4 best installation sites are

- **Sebesi Port** (at the time of the design of the system no tide gauge was present. A tide gauge was installed on 26 Jan 2019)
- Siuncal
- Px18
- Anyer Kidul
- **Marina Jambu** (device exists at this location)

As it can be seen from the map below, even if 27 min is rather short, leaving short evacuation time, several locations are not yet reached by the wave and will be reached several minutes after. In the figure below in red the coastal locations reached by the wave before 30 minutes. Which means that **a large portion of the coast is not reached yet by the wave.**



Copyright, European Union, 2019. Map created by EC-JRC. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union.

Figure 5 - Arrival Time in minutes in the selected locations for IDSL installation. The coastal locations in violet are reached by the wave within 20 min, the locations in cyan between 20 and 30 min. All the other locations are reached after 30 minutes

If the short term instrumentation is available, practically the whole coastal areas can be alerted if proper siren system is actuated.

However it is important to note that, in case the short distance instrumentation is not available:

- The detection of the alert may occur at about 27 min plus 2-3 min to give the operators the time to verify that it is not a false alert
- It is important to verify the alerting conditions in at least 2 devices, in order to avoid a spike from one device
- That given 30 min as alerting limit, there are still several locations that are reached after 30 min and that, with proper siren alerting can be informed of the incoming wave
- That very strict Standard Operating Procedures (SOPs) are necessary to avoid to lose vital time

4.2.2 Performed Installations

Two installations have been performed at end of January 2019: Sebesi and Marina Jambu; other will be performed in the near future.

4.2.2.1 Sebesi Island

Figure 6 - Location of the Jetty on Sebesi island

The Sebesi island is located about 18 km (center to center) from the Anak Krakatau volcano, and is NNE respect to the volcano. In the opposite site of the volcano, a 130 m long jetty is present that allows medium ferry boats to serve the island needs (tourists and residents). The island has been evacuated after the Tsunami but at the time of the IDSL installation all appeared returned to its original status.

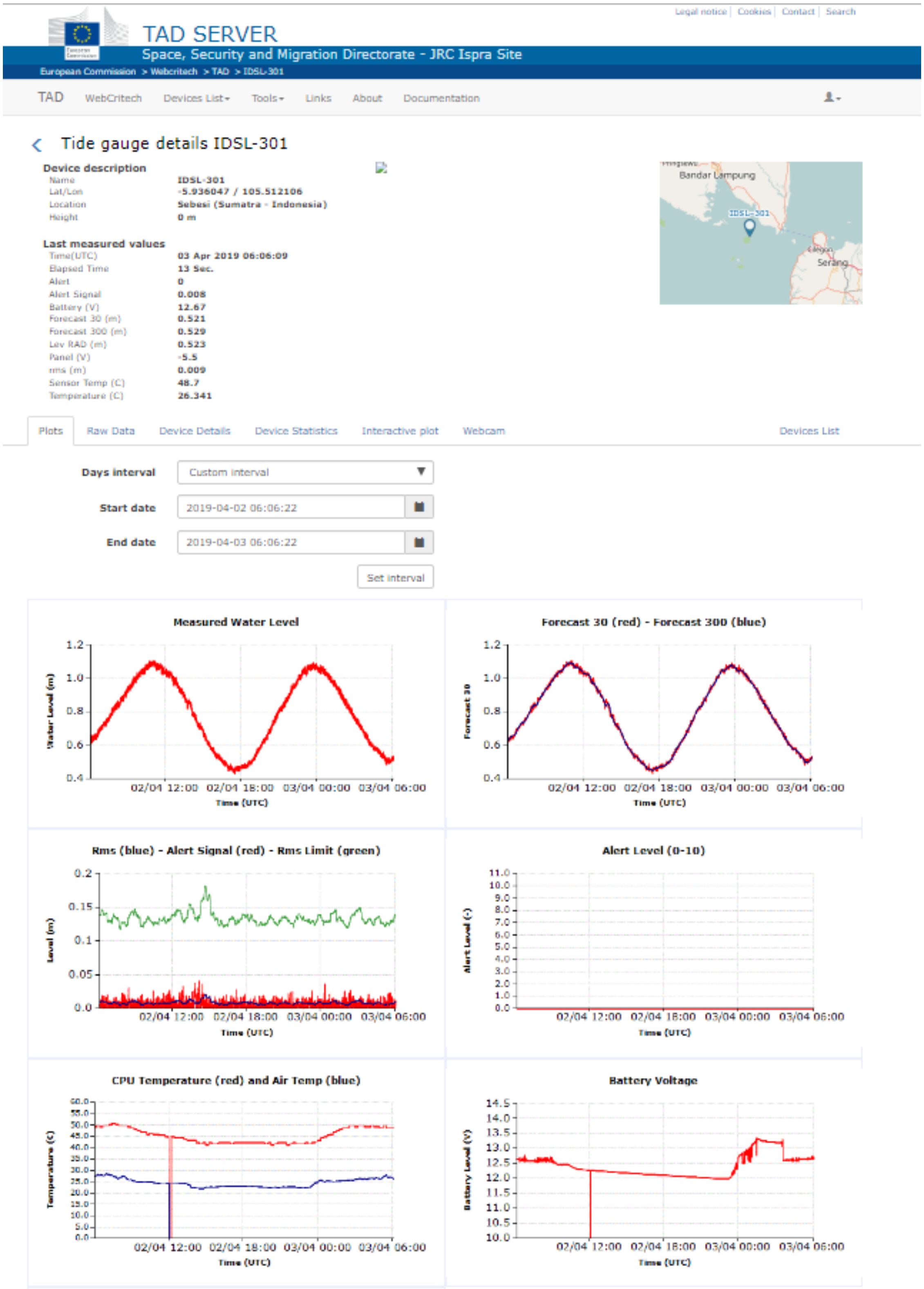
From Wikipedia:

***Sebesi** (also Sebeezee, or 'Bleezie') is an Indonesian island in the Sunda Strait, between Java and Sumatra, and part of the province of Lampung. It rises to a height of 844 metres (2,769 ft) and lies about 12 kilometres (7.5 mi) north of the Krakatoa Archipelago; it is the closest large island to Krakatoa, about the same area and height as the remmant of Rakata. Like Krakatoa, it too is volcanic, although there are no dated eruptions known. (A single report of an eruption in*

1680 seems to be a confusion with the Krakatoa eruption reported from that year.) Unlike the Krakatoa Archipelago, Sebesi has permanent streams and is inhabited. Sebesi was devastated during the 1883 volcanic eruption of Krakatoa. Official records give approximately 3,000 people killed, with 1,000 of these being 'non-residents'. By 1890, Sebesi was being re-cleared. It is believed that since it lies closer to Sumatra, it has served as a 'stepping stone' for much of the flora and fauna which was re-established at Krakatoa. By the 1920s, settlers had returned, and today Sebesi is virtually completely cultivated, with only a small area at the peak and some mangrove swamps still natural.

Figure 7 - The preparation of the installation of the IDSL in Sebesi island, followed by several local people

Figure 8 – On the left the BIG tide gauge installation and on the right the IDSL one, both on the Sebesi Port.



Tide gauge details IDSL-301

Device description

Name	IDSL-301
Lat/Lon	-5.936047 / 105.512106
Location	Sebesi (Sumatra - Indonesia)
Height	0 m

Last measured values

Time(UTC)	03 Apr 2019 06:06:09
Elapsed Time	13 Sec.
Alert	0
Alert Signal	0.008
Battery (V)	12.67
Forecast 30 (m)	0.521
Forecast 300 (m)	0.529
Lev RAD (m)	0.523
Panel (V)	-5.5
rms (m)	0.009
Sensor Temp (C)	48.7
Temperature (C)	26.341

Days interval Custom interval

Start date 2019-04-02 06:06:22

End date 2019-04-03 06:06:22

Figure 9 –The web page in the TAD server with the data from Sebesi, http://webcritech.jrc.ec.europa.eu/TAD_server/Device/206

The installation in Sebesi was performed on 30th Jan 2019 and since then is transmitting 1 point every 6 seconds, with 5-10 s of latency. There was a period (3-15 March) of data missing due to a problem in the GSM Telecom contract, then solved. Unfortunately the webcam installed on the IDSL does not work, probably damaged during the transport on site; it will be replaced soon.

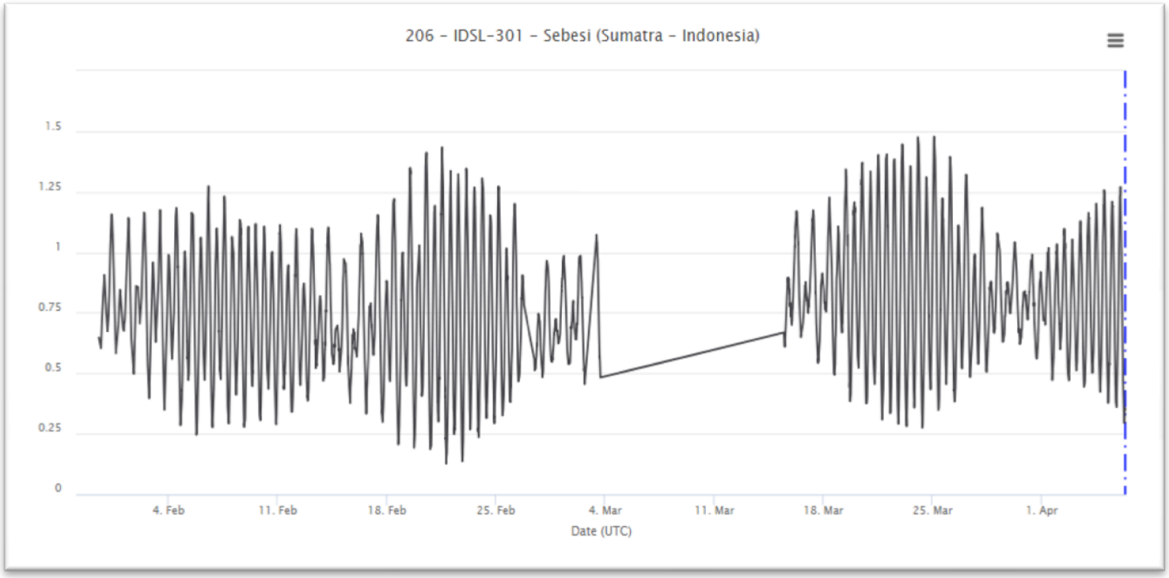


Figure 10 –The whole dataset for Sebesi Island. It is possible to note the data missing between 3 and 15 March, after which the telecom contract has been restored.

4.2.2.2 Marina Jambu

The installation in Marina Jambu was performed on 29th Jan 2019 at a location close to the existing tide gauge from BIG. In this way it is possible to compare the two instrument behaviour. Marina Jambu is one of the main ports in the Sunda Strait and it contains the tide gauge of BIG that detected as first the Tsunami of 22nd Dec 2018.

The IDSL device was positioned close to the existing BIG device, and also at this device the webcam was installed, working correctly since the time of the installation. The webcam provides very clear image of the state of the sea every 15 min; in case of a detected wave, the time interval reduces to 2 min.

The installation in Sebesi was performed on 29th Jan 2019 and since then is transmitting 1 point every 6 seconds, with 5-10 s of latency.

Figure 11 - The Marina Jambu tide gauge is in the center, the red building, before the installation of the IDSL.

Figure 12 – On the left the BIG installation, on the right the IDSL device in Marina Jambu.

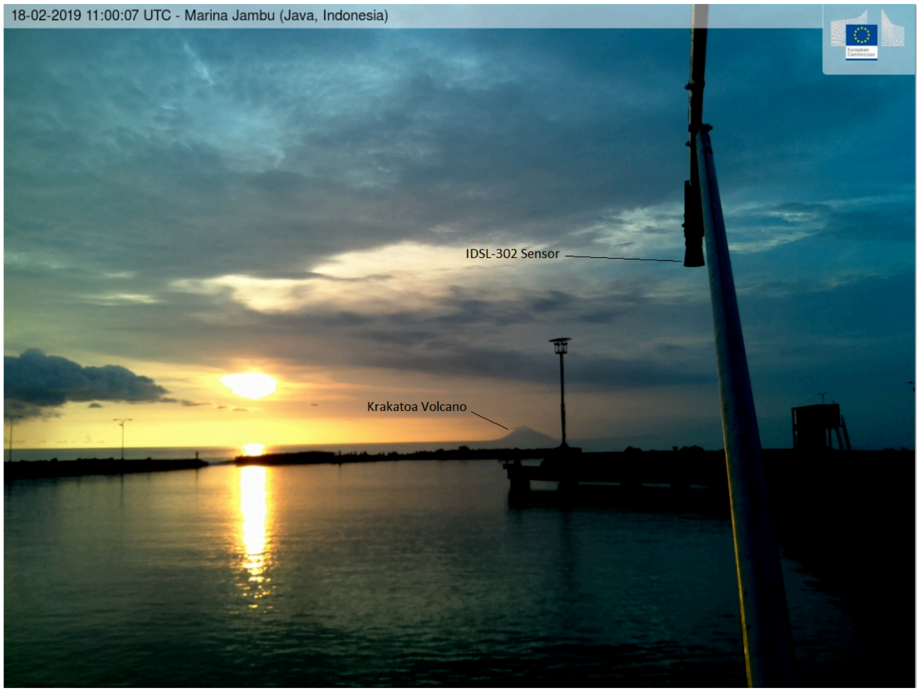


Figure 13 – The image from the webcam shows the IDSL sensor and on the back the Krakatoa complex. The webcam collects one image every 15 min and during detected events, every 2 min.

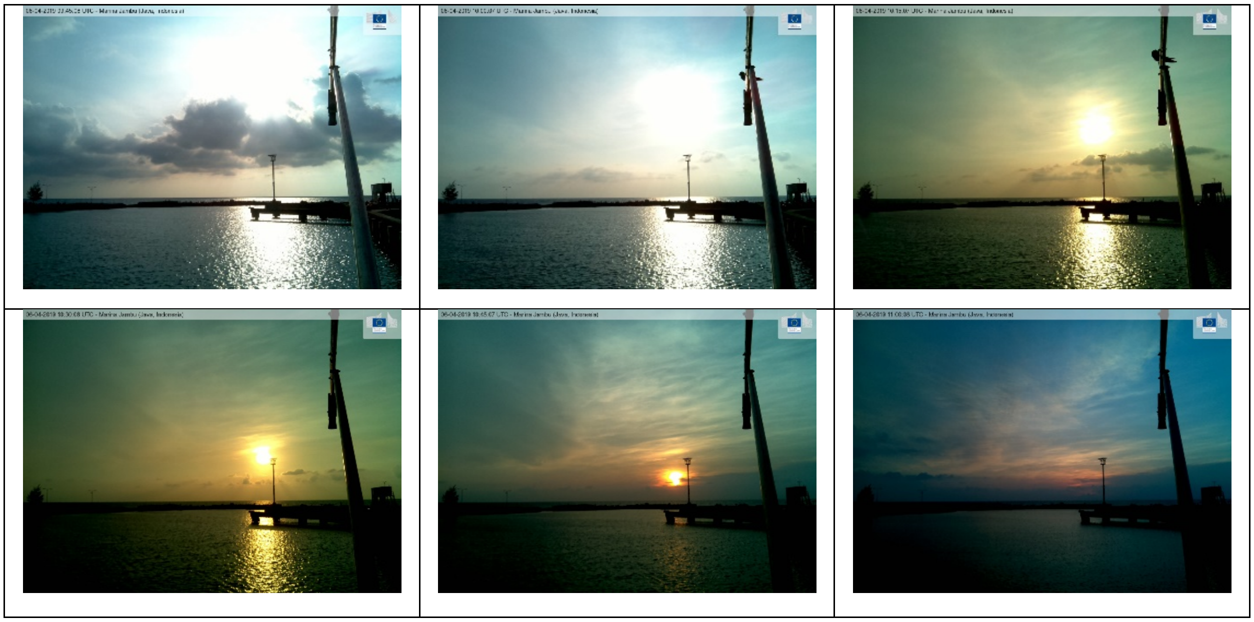
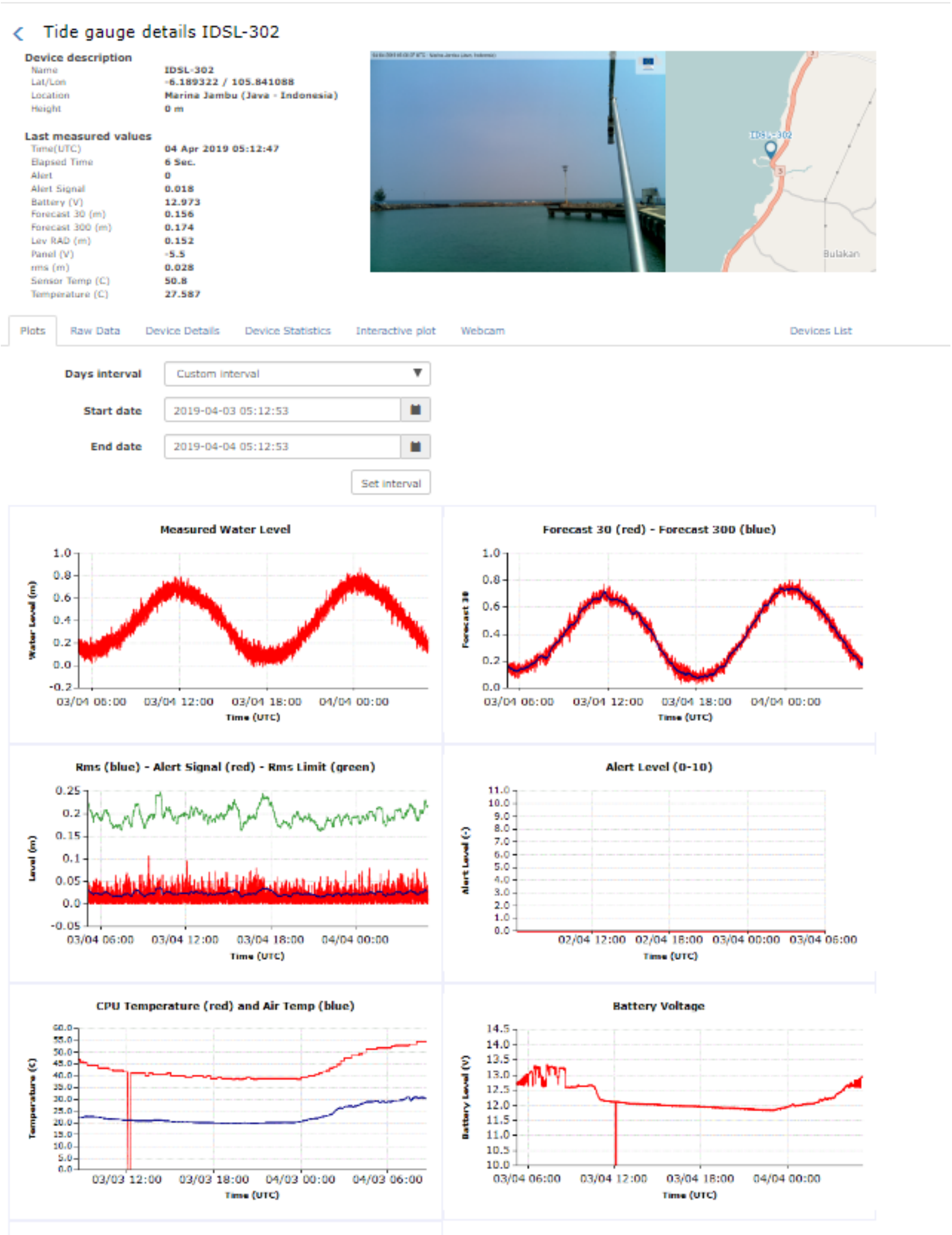


Figure 14 – A sequence of images every 15 min (6 April 2019). All the images are accessible from the TAD_server web site and can be seen as a sequence.



Tide gauge details IDSL-302

Device description

Name	IDSL-302
Lat/Lon	-6.189322 / 105.841088
Location	Marina Jambu (Java - Indonesia)
Height	0 m

Last measured values

Time(UTC)	04 Apr 2019 05:12:47
Elapsed Time	6 Sec.
Alert	0
Alert Signal	0.018
Battery (V)	12.973
Forecast 30 (m)	0.156
Forecast 300 (m)	0.174
Lev RAD (m)	0.152
Panel (V)	-5.5
rms (m)	0.028
Sensor Temp (C)	50.8
Temperature (C)	27.587

Days interval: Custom interval

Start date: 2019-04-03 05:12:53

End date: 2019-04-04 05:12:53

Figure 15 – The web page in the TAD server with the data from Marina Jambu, http://webcritech.jrc.ec.europa.eu/TAD_server/Device/207

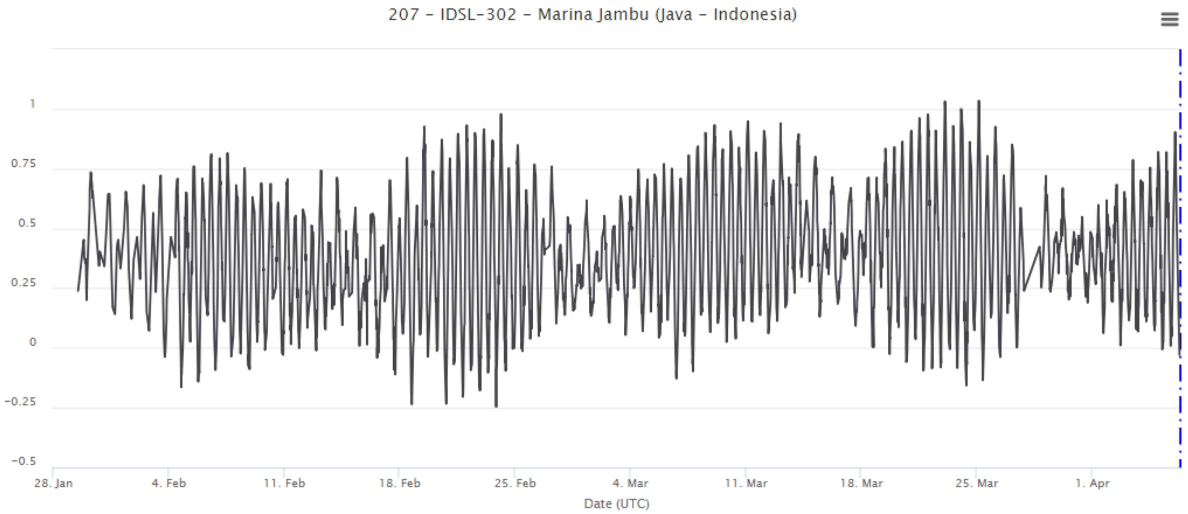


Figure 16 - The whole dataset from the installation to current date

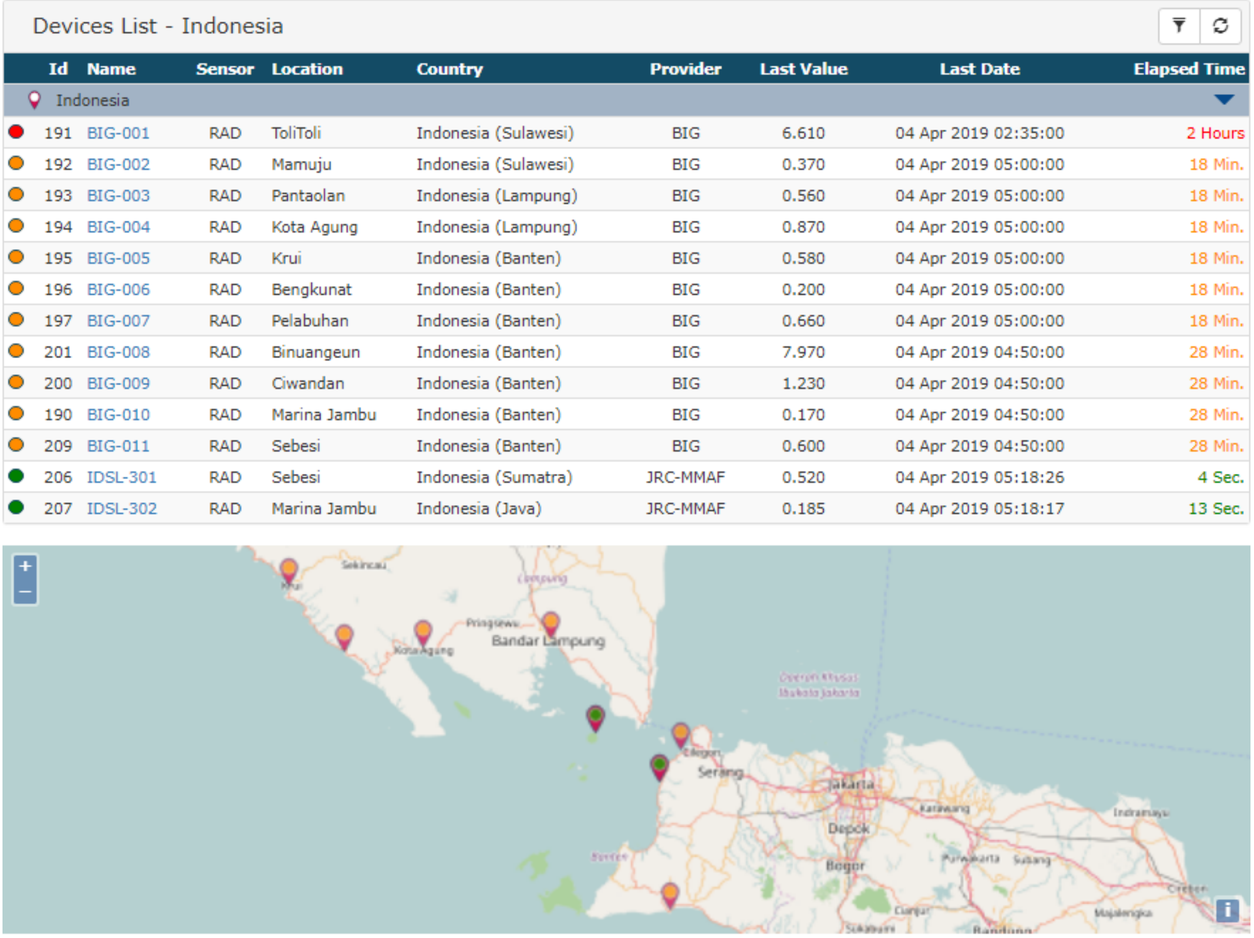
4.3 Short Distance instruments

Figure 17 - the 3 islands around the Anak Krakatau volcano; the arrow indicates the possible installation site, once the communication problems are solved

The installation of instruments on the three islands around the Anak Krakatau volcano would guarantee a minimum time for the arrival time and therefore would leave more time for the alerting. A survey around the island allowed to identify a possible platform for installation south of Krakatua island. However there is not GSM coverage on the islands (17 km from the closest inhabited island) and therefore UHF or satellite communication is necessary in order to have online data availability. Discussion are under way with Governmental authorities and Telecommunication company to install communication system on one of the 3 islands and thus facilitating the installation of instruments.

5 DATA PROCESSING AND ALERT MECHANISMS

All the data from the existing and the new instrumentation reach a common hub where to store the acquired data and made available to whoever wants to use them: http://webcritech.jrc.ec.europa.eu/TAD_server?group=Indonesia .



Devices List - Indonesia

	Id	Name	Sensor	Location	Country	Provider	Last Value	Last Date	Elapsed Time
	Indonesia								
🔴	191	BIG-001	RAD	ToliToli	Indonesia (Sulawesi)	BIG	6.610	04 Apr 2019 02:35:00	2 Hours
🟠	192	BIG-002	RAD	Mamuju	Indonesia (Sulawesi)	BIG	0.370	04 Apr 2019 05:00:00	18 Min.
🟠	193	BIG-003	RAD	Pantaolan	Indonesia (Lampung)	BIG	0.560	04 Apr 2019 05:00:00	18 Min.
🟠	194	BIG-004	RAD	Kota Agung	Indonesia (Lampung)	BIG	0.870	04 Apr 2019 05:00:00	18 Min.
🟠	195	BIG-005	RAD	Krui	Indonesia (Banten)	BIG	0.580	04 Apr 2019 05:00:00	18 Min.
🟠	196	BIG-006	RAD	Bengkunat	Indonesia (Banten)	BIG	0.200	04 Apr 2019 05:00:00	18 Min.
🟠	197	BIG-007	RAD	Pelabuhan	Indonesia (Banten)	BIG	0.660	04 Apr 2019 05:00:00	18 Min.
🟠	201	BIG-008	RAD	Binuangeun	Indonesia (Banten)	BIG	7.970	04 Apr 2019 04:50:00	28 Min.
🟠	200	BIG-009	RAD	Ciwandan	Indonesia (Banten)	BIG	1.230	04 Apr 2019 04:50:00	28 Min.
🟠	190	BIG-010	RAD	Marina Jambu	Indonesia (Banten)	BIG	0.170	04 Apr 2019 04:50:00	28 Min.
🟠	209	BIG-011	RAD	Sebesi	Indonesia (Banten)	BIG	0.600	04 Apr 2019 04:50:00	28 Min.
🟢	206	IDSL-301	RAD	Sebesi	Indonesia (Sumatra)	JRC-MMAF	0.520	04 Apr 2019 05:18:26	4 Sec.
🟢	207	IDSL-302	RAD	Marina Jambu	Indonesia (Java)	JRC-MMAF	0.185	04 Apr 2019 05:18:17	13 Sec.

Figure 18 – TAD Server list of acquired locations.

In all the instrument data an alert value is computed (on the data logger in the case of IDSL, on the JRC server for the BIG data) using a methodology that computes the difference between the signal and the tide that is estimated with a modified Kalman filter type. When this difference exceeds a number of times the standard deviation of the signal the alert level is incremented of one unit (10 units is the maximum alert level).

When the alert level exceeds 5 units an email and SMS is issued to a list of specified subscribers, including at the moment BMKG and also the Australian Bureau of Meteorology (BOM). The Indonesia BMKG, once getting the alert can eventually activate the downstream alerting component (sirens, messages etc) to inform the population of the ongoing event, after a verification that at least another instrument provided the same response.

When the alert level exceeds 1 unit the webcam is requested to perform an image every 2 min. Detail about the system are included in Appendix B.

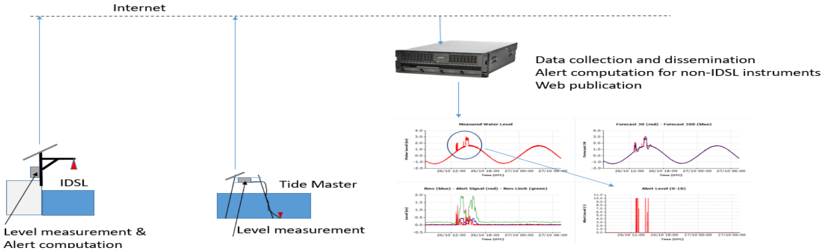


Figure 19 - Data Flow and Processing

An example can be visualized for Ciwandan for the case of 22nd Dec 2018:

http://webcritech.jrc.ec.europa.eu/TAD_server/Device/188?tmin=21%20Dec%202018&tmax=24%20Dec%202018

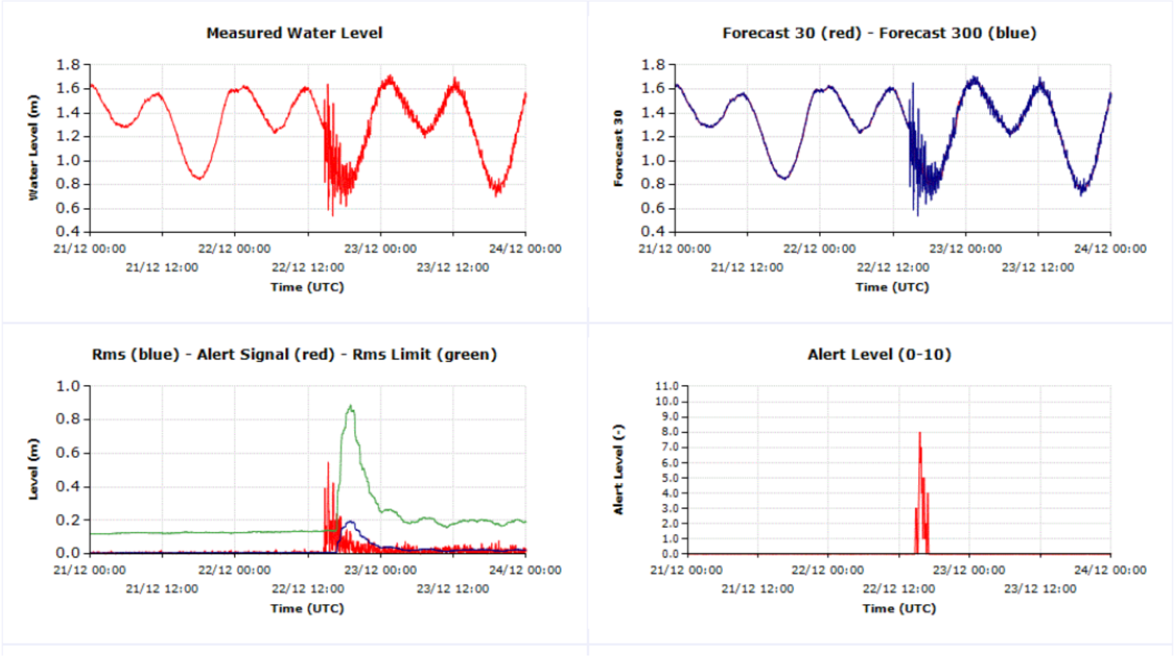


Figure 20 - Algorithm response to the tide gauge signal in Ciwandan on 22 Dec 2018.

From the figure above it is possible to note that the presence of the large oscillation is detected by the system providing an alert of level 8 or 9.

An overview of the current status of the various gauges is also available here:

http://webcritech.jrc.ec.europa.eu/TAD_server/Tools/SensorMonitor/Show/932e3105f5144258abd363f76aac8a01

An example of the comparison between the BIG and IDSL data in Sebesi island in the figure below. It is possible to note the highest acquisition frequency of the IDSL and the shortest latency. The vertical dotted line represents the current time and the last IDSL point is practically coincident with the current time while in the case of BIG data a delay exists.

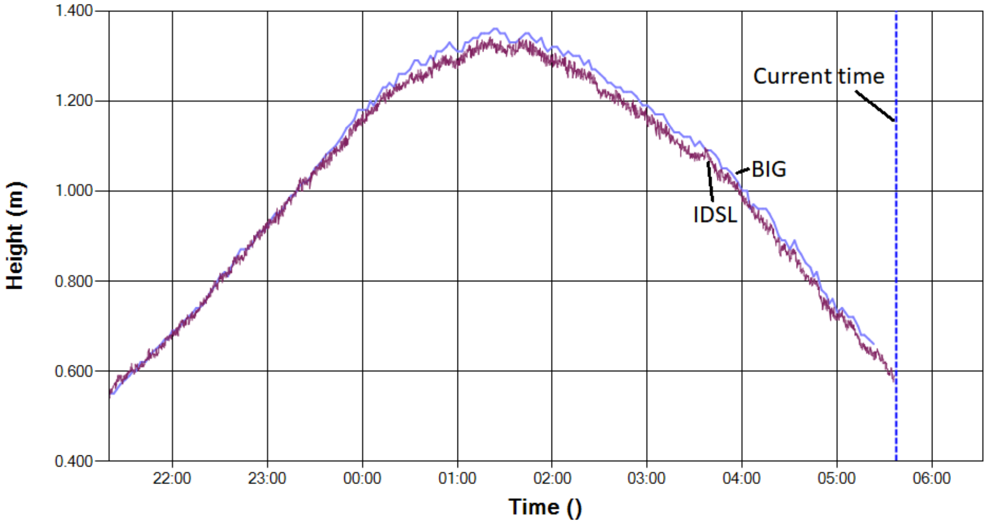


Figure 21 – An example of the comparison between the BIG and IDSL data in Sebesi island. It is possible to note the highest acquisition frequency of the IDSL and the shortest latency

6 CONCLUSIONS

The Sunda Strait Tsunami of 22 Dec 2018, caused by the Anak Krakatau volcano eruption, which struck the Indonesia coasts causing hundreds of fatalities demands for a dedicated effort to setup a proper alerting mechanism for the coastal population.

The report describe a possible solution with the installation of a sea level realtime alerting mechanism based on existing and new tide gauges which are continuously monitored to detect anomalous signals.

The best position for the installation of the new tide gauges has been identified. If realized and the data properly processed, those instruments could provide a long time for alerting, up to 30 minutes. However for the short arrival time locations (within 1-2 min) some concerns for the installation mode are identified. Two IDSL devices have been installed in January 2019; other six devices will be deployed to Indonesia before summer 2019.

For the medium arrival time locations (20 min to 30 min) the IDSL system will allow to alert a large coastal portion if the alerting signal is taken into consideration and if the siren alerting system is available and provide for most of the coast 10-20 minutes of available time to

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[4] ESDM – AKTIVITAS GUNUNG ANAK KRAKATAU 28 DESEMBER 2018 – A press release by Pusat Vulkanologi dan Mitigasi Bencana Geologi ESDM, 29 Desember 2018, Jakarta (2018)

6 APPENDIX A – DESCRIPTION OF IDSL

A new mareograph device has been designed at the Joint Research Centre (JRC) of the European Commission (EC) in order improve the sea level network in use for the Tsunami Hazard monitoring in the Mediterranean Sea and in the North Atlantic area (NEAMTWS area of UNESCO). The instrument has the characteristic to be cheap and very effective but its reliability, duration and quality need to be determined and qualified. For this reason a number of experimental campaigns are being conducted, whose first results are presented here. In collaboration with the UNESCO/IOC (Intergovernmental Oceanographic Commission), responsible of the definition of the Tsunami Warning System of this geographical area, a set of 30 devices have been installed by JRC.

Based on the experience of other similar devices and the need during a Tsunami analysis, the requirements that we have fixed for the mareographs are the following:

- High quality of the data with an error of **0.5 cm** maximum (sensitivity justified by the expected error in the sea level calculations)
- Short acquisition time interval, **5 s** maximum (to have a well-defined sea level wave description over time)
- Small transmission latency, smaller than **15 s** (this is particular important for small basins with low travel time)
- Low overall cost, less than **2.5 k€**
- Autonomy, at least **3 days** without solar irradiation (the autonomy can be increased to 7 days with an over cost and weight on the battery)

The heart of this device is the Raspberry Pi, which is a powerful electronic board that contains a Linux operating system with several standard components (USB, HDMI, Ethernet port, Video card, and sound card) and other busses that can easily be connected with external devices. The device therefore has a computer on which software can be installed and that can be reached remotely for debugging or software change. The other important component is the radar sensor: we have identified a relatively low cost rugged component that could be used as sea level sensor. Additional components are necessary in order to have an autonomous system (electrical power feed and communication). The communication is through the GSM line, which imposes the installation in areas reached by this cellular network. In principle satellite images could also be possible but has not yet tested.

The whole list of IDSL devices can be consulted and the data downloaded at this web site:
http://webcritech.jrc.ec.europa.eu/TAD_server/Home?group=IDSL

Figure A.1 - Typical installation of an IDSL device (Portopalo di Capo Passero, Italy)

APPENDIX B - DESCRIPTION OF TAD SERVER METHODOLOGY

The TAD (Tsunami Alerting Device ®) server has been developed in order to analyse and serve the Tsunami Alerting Panel for which JRC has a patent ongoing. The same system is however used for collecting all the IDSLs and to provide calculations of the alerting parameters to other retrieved data from Internet.

In this case the TAD server will be used both for the IDSLs that will be installed as well as for all the other instruments.

The system is composed of 3 components:

- The data collection and analysis (IDSL software or GaugListener software)
- The data ingestion programme
- The web component for data presentation

Data Collection and Analysis

The method is based on the composition of a URL basic string that is filled with the proper parameters; when the analysis programme is running.

http://webcritech.jrc.ec.europa.eu/TAD_server/EnterData.aspx?idDevice=$IDdevice&log=$S$IDdevice,$DATE,$TIME,$TEMP,$PRESS,$LEV,$FORE30,$FORE300,$RMS,$ALERT_LEVEL,$ALERT_SIGNAL,$V1,$V2,$E

In the case of IDSL the level is read from the sensor. In the GaugeListener the level is acquired via internet from an open data source. In both cases the level is used in order to apply the Change Detection Algorithm (CDA) described below. The CDA provides FORE30, FORE300, RMS, ALERT LEVEL and ALERT SIGNAL parameters that are also composing the storage URL.

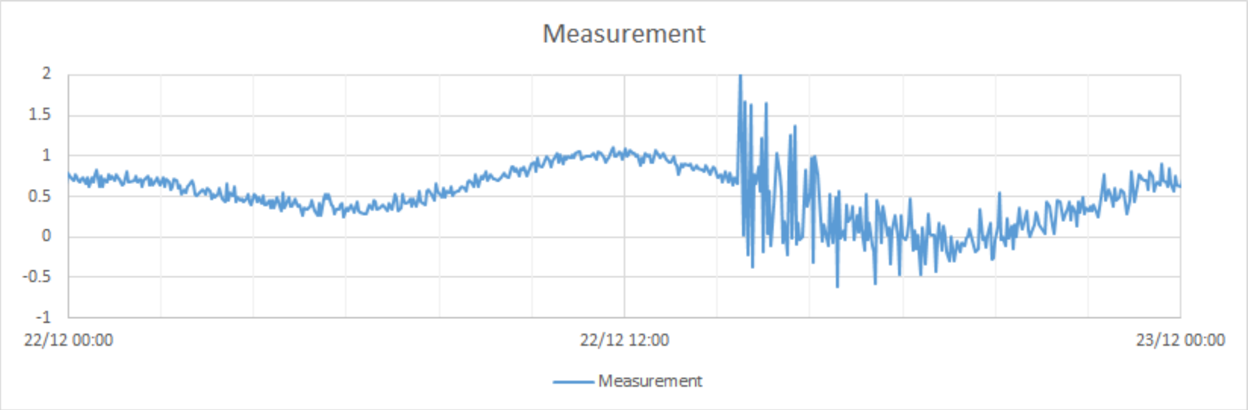
The change detection algorithm is based on the estimation at each new data acquisition of the absolute difference between the long term forecast (FORECAST300) and the short term forecast (FORECAST30). The FORECAST300 is the estimation of the value of the current point, performed by calculating the least square 2nd order polynomial related to a long period (1.5-3h of data); the FORECAST30 is the same quantity, estimated using a shorter time (10-20 min). The difference tends therefore to identify sudden changes of the sea level. However for very noisy signals the change could be due to an increase of the noise. Therefore we compare the difference with a number of times the root mean square of the signal in the period of estimation of the FORECAST300. When the difference is positive, the alert level increases of 1 unit; when it comes back below the threshold, the alert level decreases of 1 unit. The maximum value of the alert level is 10.

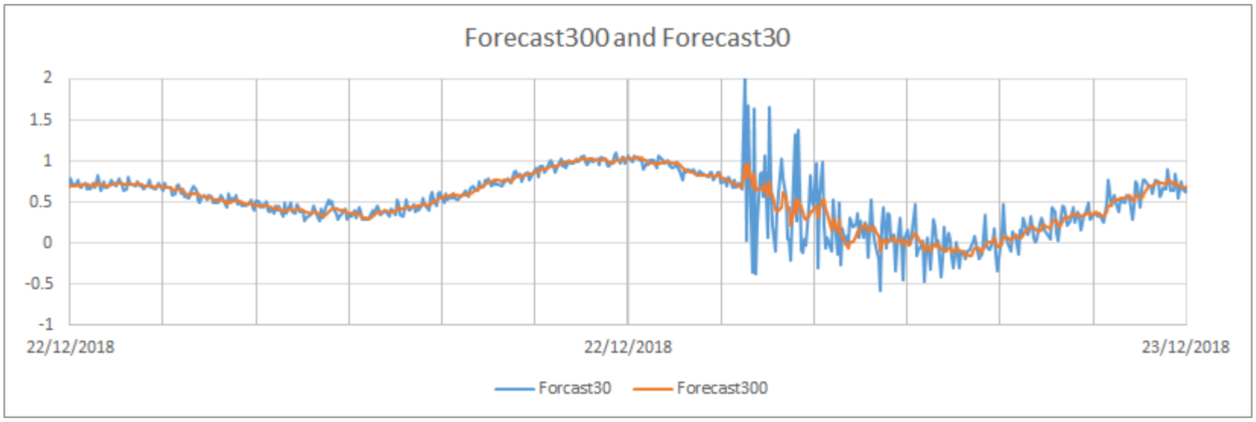
IF abs(Fore30-Fore300)> rms(time300) then AL=AL+1

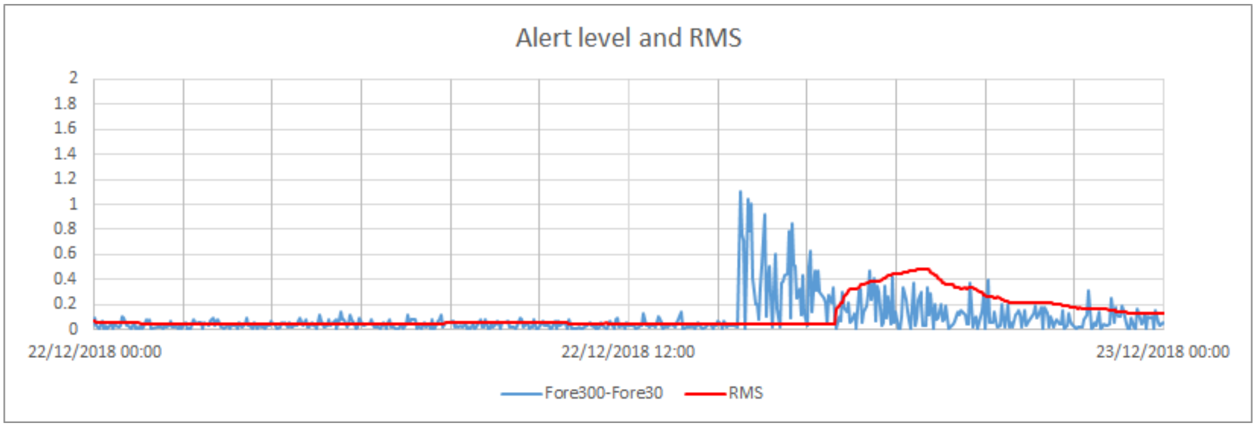
In order to avoid that for very smooth and with very small RMS a single spike creates an alert we also introduce a minimum value of the difference; so instead of the rms we use the maximum between rms and a threshold. All these parameters are defined in the configuration file of the devices. Below is an example of the Mamuju device

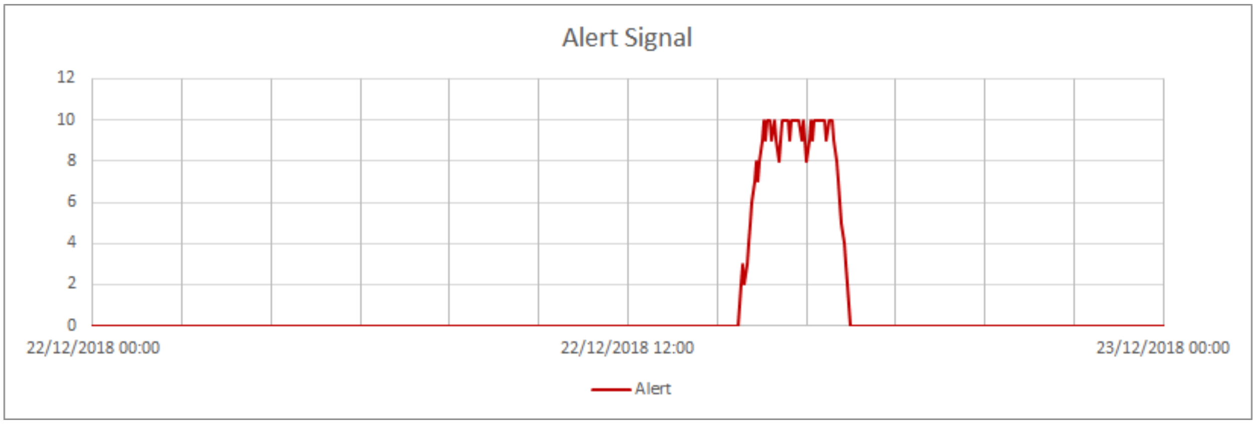
```
   Example of configuration file for Mamuju device
   title         = Mamuju
   IDdevice      = BIG-002
   serverAddress                                                    =
http://tides.big.go.id:8888/kacrut/0009MMJU02/temp.csv
   ServerPort    = 0
   OutFolder     = .\logs\
   SaveURL=
http://webcritech.jrc.ec.europa.eu/TAD_server/xxxx.aspx?idDevice=
$IDdevice&log=$S$IDdevice,$DATE,$TIME,$TEMP,$PRESS,$LEV,$FORE30,$FORE300,$RMS
,$ALERT_LEVEL,$ALERT_SIGNAL,$V1,$V2,$E
   AlertURL      = none
   DataFile      = logs\Data_yyyyMMdd.txt
   #errLog       = logs\errLog_yyyyMMdd.txt
   Datalog       = logs\dataLog_yyyyMMdd.txt
   Interval      = -1
   n300          =  100
   n30           =  10
   threshold     = 0.05
   ratioRMS      = 2
   AddRMS        = 0.1
   backFactor    = 0
   vmin          = -2
   vmax          = 10.
   remAndInvert  = 0.
   mode          = DOWNLOAD
   type          = BIG
```

As an example the plots below show the various signals for the Sunda Tsunami case and the measurement in Marina Jambu. It is possible to note that at 14:27 the alert level starts to rise and at 14:45 surpasses the level 5, that is considered an alert level suitable for alerting. *It should be* *noted that the data from those measurements have a very large interval (2-3 min) and since the alert level rises of 1 unit every time that a new estimation is done, with such a large interval it takes "at least" 30 min to go from 0 to 10. In the case of IDSL, with an interval of 5 s between two successive points, the interval is much shorter , 50 seconds.*









Data Ingestion

Once the data are pushed into the web server with the URL shown above, another programme, continuously running on the server, introduce the data in the SQL server database. The reason for this choice was done in order to prevent an overload of the database. At the beginning it was decided to store immediately the data but we realized that with a huge amount of data the database was not working properly and was slowing down the reply to the IDSLs that therefore were penalized. So we decided to have a separate task that takes the data, stored by the web server in dedicated accumulation files and process them for introduction into the database.

The web component for data presentation

The web site for data presentation is rather standard, showing all the measured and derived quantities and offering the export of all the quantities in various formats for the users.

The web site address URL is: http://webcritech.jrc.ec.europa.eu/TAD_server