ADVANCED AND INEXPENSIVE SEA LEVEL MEASUREMENT ACTIVITIES AT THE JOINT RESEARCH CENTRE OF THE EUROPEAN COMMISSION

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Joint Research Centre
European Commission
In the frame of the activities funded by DG-ECHO to support humanitarian efforts in live savings, two activities have been performed by JRC, related to Tsunami monitoring:

- Installation of a Sea Level Network of Inexpensive Device for Sea Level Measurement (IDSL) in close collaboration with UNESCO/IOC
  - Status and results of the first year campaign
- In-house development and testing of a new instrument based on a floating differential GPS
  - Concept development and results of the first sea experiment
Objective:
- To install 20 new IDSL devices in the NEAMTWS area

Funding:
- DG-ECHO, JRC

Conditions:
- Device and support by JRC
- Installation and Communication costs by hosting country
- Data transmission to JRC and made available to UNESCO

Timeline
- April 2015: 9 countries expressed their interest to test IDSL
- September 2016:
  - 14 (+1 prototype) devices have been installed and are all operational,
  - 3 the material has already been shipped, installation not yet performed (2 in Tunisia, 1 in Turkey)
  - 3 have been suspended because no suitable place was found for the installation (2 in Turkey, 1 in Morocco).
All data received through TAD_server method

- **Classical method:**
  - All stations scanned by a central system every $x$ min (i.e. 1 min)
  - In case of parallel scanning, the latency is given by the scanning interval

- **TAD_server method:** the stations transmit the data to the server as soon as it is available
  - It can be used also as backup method (transmission redundancy)
  - Latency is null or few seconds
  - IGN/PdE using for all Spanish stations and under testing by ISPRA for 10 stations (FAST Method)
The IDSL device

The requirements of the mareographs are:

- High quality of the data with an error of 0.5 cm maximum
- Short acquisition time interval, 15 s maximum
- Small transmission latency, smaller than 30 s
- Low overall cost, less than 1.5 kEuro
- Autonomy, at least 3 days without solar irradiation
Installation in Imperia 7th Nov 2014
**Switch on -> Data online**

**Sea Level Monitor**
Institute for Protection and Security of the Citizens
JRC Ispra Site

<table>
<thead>
<tr>
<th>General Data</th>
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**Last Measured values**
- Time(UTC): 11/6/2014 9:07:25 AM
- Time elapsed: 9 Seconds.
- Raw RSD (m): 0.38
- Error (m): 0.37
- RMS (m): 0.30
- Alert Signal (m): 0.02
- Alert (V): 0
- Battery (V): 12.44
- Panel (V): 13.08

- Get ASCII data (2 days)
- Last 1 day data
- Last 2 days data
- Last week data
- List all devices

**Measured Water Level**

**Forecast300 (blue) Forecast 30 (red)**

**Rms (blue) - Alert Signal (red) - Rms Limit (green)**

**Alert Level (0-10)**
With 5s time interval it is possible to describe completely the sea level oscillations in the port.
Visualization of port oscillations

14-01-2015 14:06 UTC

14-01-2015 14:13 UTC

Height (m) vs. Time (UTC)

-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
14:00 14:05 14:10 14:15 14:20 14:25 14:30

14:06 UTC

14:13 UTC
IDSL Status 10th Sept 2016

https://batchgeo.com/map/6c8f4603bb63045e725ca36f2708fce9
Splash screen with all the installations

Imperia, Italy, prototype
IDSL-01

Saidia Marina, Morocco
IDSL-02

Sagres, Portugal
IDSL-04

Albufeira, Portugal
IDSL-05

Cadiz, Spain
IDSL-06

Cartagena, Spain
IDSL-07

Pantelleria, Italy
IDSL-10

Portopalo di Capo Passero, Italy
IDSL-11

Le Castella, Italy
IDSL-12

Corinth, Greece
IDSL-13

Fethiye, Turkey
IDSL-15

Mangalia, Romania
IDSL-18

Costanta, Romania
IDSL-19

Sulina, Romania
IDSL-20

Batroun, Lebanon
IDSL-21

Devices to install:

Bozcaada, Turkey
Zarzis, Tunisia
Tabarka, Tunisia
Status of the installations

### Description

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<tr>
<th>Name</th>
<th>Location</th>
<th>Country</th>
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### Operation

- Last 1 days data
- Get ASCII data
- Device Details
- Device Statistics
- Devices List

Puerto Escombreras, Cartagena, Spain
Maritime commercial port
37.567146° -0.978958°

5 Oct 2015
Cadiz, Spain
Along the entrance of commercial port
37.54214° -6.280612°
Cadiz, Spain
Along the entrance of commercial port
37.54214° -6.280612°
7 Oct 2015
Albufeira, Algarve, Portugal
Albufeira Marina
37.082557° -8.260565°

8 Oct 2015
Albufeira, Algarve, Portugal
Albufeira Marina
37.082557° -8.260565°

8 Oct 2015
### Tide gauge list

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On the basis of the experience of the first 5 installations, an IDSL installation guide has been developed.

The objective is to have a sort of "IKEA" manual, i.e. a detailed and complete installation description.

The aim is to give the teams that will perform the next installations as much information as possible in order to conduct a successful installation.

In principle it could be possible to send the instruments without support from JRC.
Technical/Methodological issues

- Several technical issues have been resolved. Some were expected, other were unknown at the beginning
  - Software robustness and control scripts
  - Memory card degradation
  - Need for watch dog
  - Sensors life span
  - Batteries
  - Corrosion of marine salt
  - Solar Panel salt deposits
  - Construction technology (SICE)
- Now we have a device which appears quite robust, high quality data, reliable
- Construction license to SICE company for commercialization; JRC still keeps the data collection infrastructure
The great importance to have an off-shore measurement for Tsunami Monitoring is justified by two main reasons:

- Early Tsunami Detection
- Cleaner Tsunami Estimations

The measurement of Sea Level using differential GPS is not a new technique and is currently extensively adopted by Japan:

- The cost of these devices is however extremely high (about 2 million euro) and their dimensions so large that the installation becomes problematic for most countries.

The availability of more affordable GPS receivers, connected with the newly created GNSS constellation allows to explore the possibility to develop a low cost floating GPS device, that can be extremely useful for the monitoring of sea level around the Mediterranean Sea.
The Japanese approach

- 14 devices installed and operational
- About 2 M euro for each device
A first test was done last week in collaboration with MARS action, to use a differential GPS as level meter to install on buoys. The method is not new (Japan) but we were unable to have companies to offer the installation (2 call for tender without any participant !)

Very promising results in the comparison with the radar system: all small movements of the device were detected. The max error was less than 5 cm!
Galileo is the European global satellite positioning and timing system

- 14 satellites in orbit today (11 healthy)
- next launch of 4 on Nov 11th
  - 24 satellites by the end of next year
- Compatible and interoperable with the American GPS but
  - Property of the EU
  - Higher accuracy ranging signals
  - Native triple frequency constellation
  - Better atomic clocks
- Introduced this year in mass-market satnav receivers:
  - Broadcom, uBlox, STMicroelectronics, NVS, …
Standalone and differential accuracy

Standalone single frequency GNSS (GPS+Galileo+EGNOS) achieves sub-meter accuracy. Main error sources are:

- Multipath (signal reflections causing distortion in TOA estimation)
- Real-time satellite orbits and clock parameters
- Atmospheric introduced delays
  - Troposphere (frequency independent)
  - Ionosphere (frequency dependent)

Most cancel out in differential: accuracies of centimetres are possible.
In GNSS, code and phase measurements are possible

- GPS codes are 300 km long, with resolution of 100 metres
- Galileo codes are 1.2 Km long, with resolution of 30 metres
- Phase measurements are 19 cm long, with resolution of 1 cm

We want to use differential phase to achieve the best possible accuracy!
Differential phase Real Time Kinematic (RTK)

RTK provides cm accuracy in differential mode using carrier phase

- Need to use a GNSS receiver with carrier phase output
  - **uBlox NEO-M8T chosen**
  - Open source RTKLIB software does RTK for us
    - **runs on embedded PCs**
    - the devil is in the details, but it is good starting point
Rover design

- Based on the RaspberryPi running headless Linux OS
- Uses a uBlox M8T with GPS, Galileo and Egnos
- Rover gets corrections from base
  - using a 100 mW serial modem at 868 MHz
- Battery powered with a low-cost USB power bank
**Gateway software architecture**

- Abstracting RTK engine from actual hardware
- Multi-thread gateway to multiple instances of the RTK engine
- Solution combiner based on weighting and the likelihood

![Diagram showing Gateway software architecture with GNSS module, PHY gateway, and Solution combiner connected to Radio modem, Continuous AR, Fix-and-hold AR, and PPP through UART, SPI, I2C connections.](image)
The experiment in Marina di Ravenna (June 2016)

Base

Radio link (about 3 km)

GLONASS Antenna (Rover)

GLONASS Antenna (Base)

Data online in real time

Base Station
Experiment in Ravenna

Results of first day morning
• (08:30) buoy onshore, then going down to the water edge, then being lifted on the boat, then being carried off the coast
• (10:30) left for about 1 hour measuring sea level
• (11:50) then finally being lifted again on the boat to be brought back to the office for preliminary data analysis.
Experiment in Ravenna

Results of first day afternoon

• The device was brought offshore and kept on the boat for a couple of hours (from 13:15 to 15:00)
• then dropped into the sea at which point perfectly matches the reference again.
Experiment in Ravenna

- Boat reaching up to 3.3 km with a good RF link,
- Link lost when dropping the device in water and
- Link only regained steadily at 2.2 km distance: fresnel zone
Experiment in Ravenna

Overnight measurement of sea level

- At midnight base reboots
- Also the small peaks are very well estimated by the device
Experiment in Ravenna

Second day afternoon
• Measured sea level in open sea (2.5 km from the coast) on June 1st 2016. The device was retrieved and lifted on the boat at around 14:50.
The benefit of Galileo

- More satellites -> better performance
- Despite current level of maturity in Galileo processing from the chosen receiver

Galileo

GPS
Conclusions

- The **IDSL device** is a mature object that has been proved in more than 9 years of overall operational experience and an average of 8 months per device.

- The low cost, the easy installation, the turn-key-on-and-run and the excellent latency and interval capabilities makes this device as a good candidate to improve the existing Tsunami monitoring networks.

- The **floating GPS device** is still in a development phase but is quite interesting because again the low-cost and the excellent performance results let hope for a nice and valid instrument.

- The full engineering and the solution of several technological issues need to be analysed and solved over next year(s).
  - i.e. power of the rover: stored in batteries or solar panels?
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