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JRC storm surge system for Europe

JRC SSCS bulletins and the new GDACS system

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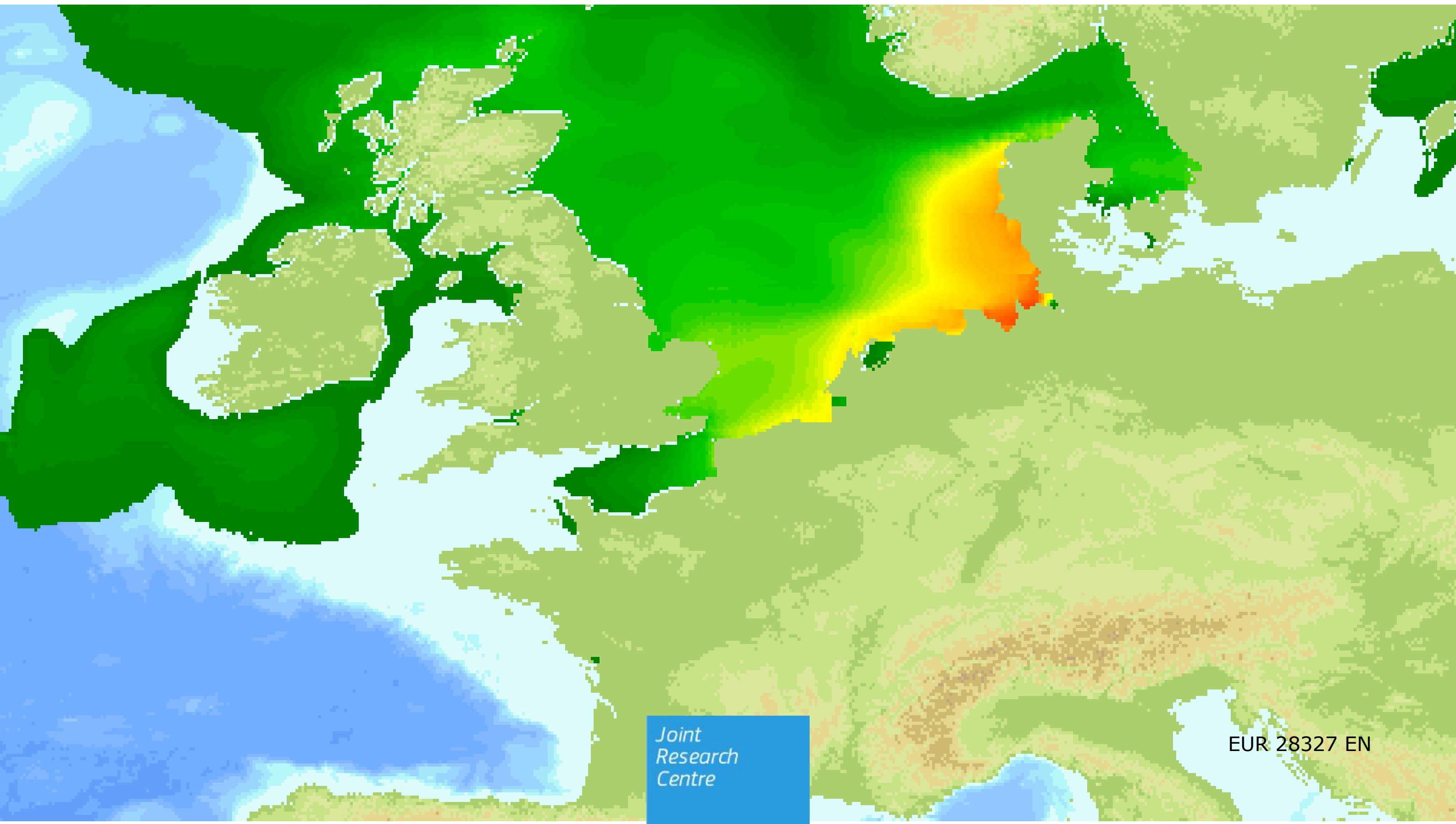

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Contents

Abstract

The storm surge is an abnormal rise of water above the astronomical tides, generated by strong winds and a drop in the atmospheric pressure, due to the passage of a Tropical Cyclone (TC) or an intense low pressure system in general.

The JRC has developed the first storm surge calculation system for the TCs in 2011, including the results in the Global Disasters Alert and Coordination System (GDACS). The TCs are not the only weather system that can generate a storm surge event, therefore the JRC has developed a new Storm Surge Calculation System (SSCS) in 2013, to simulate the storm surge also in Europe.

The SSCS system has been established at the JRC in the frame of GDACS and it is intended as a series of procedures that use meteorological forecasts forcing conditions produced by several meteorological centers to obtain the expected sea level rise along the coasts. Every day several SSCS bulletins are created for different areas of Europe. The JRC is currently implementing this system also in GDACS.

This report describes the procedures of this new storm surge system developed by the JRC and the SSCS bulletins produced every day, as well as the implementation of this system in GDACS.

1 Introduction

The Joint Research Centre (JRC) of the European Commission has developed the Global Disasters Alert and Coordination System (GDACS, www.gdacs.org), an early warning system created to alert the humanitarian community about the potential disasters which are under development. The system automatically invokes ad hoc numerical models in order to analyse the level of the hazard of natural disasters like earthquakes, tsunamis, tropical cyclones, floods and volcanoes.

The storm surge is an abnormal rise of water above the astronomical tides, generated by strong winds and a drop in the atmospheric pressure, due to the passage of a Tropical Cyclone (TC) or an intense low pressure system in general. In 2011, the JRC has developed a storm surge calculation system for the TCs, including the results in the Global Disasters Alert and Coordination System (GDACS).

The TCs are not the only weather system that can generate a storm surge event, also the intense low pressure systems that affect northern Europe in winter (e.g. Storm Xaver in 2013) could produce storm surge. Therefore the JRC has developed a new system in 2013 - the JRC Storm Surge Calculation System - SSCS[1] - to simulate the storm surge also in several areas of Europe on a daily basis.

This new system has been established at the JRC in the frame of the GDACS and it is intended as a series of procedures that use meteorological forecasts forcing conditions produced by several meteorological centers (European Centre for Medium Weather Forecast - ECMWF, Italian Air Force Meteorological Weather Service – AM, Hellenic National Meteorological Service - HNMS) in order to estimate the sea level rise along the coasts.

Every day several SSCS bulletins are created for different areas of Europe, published on the SSCS website and sent by email to different subscribed users. In case of particularly important events, a special alert is raised to inform the Emergency Response and Coordination Center (ERCC) of the European Commission, as well the other counterpart Meteorological Services with which JRC has collaboration Agreements.

An overview of the Storm Surge Calculation System- SSCS is presented in Section 2. The description of the atmospheric forcing used in this system is in Section 3, while the one of the solvers in Section 4. An overview of all the SSCS bulletins is created presented in Section 5, while the SSCS website and mail service are shown in Section 6 and 7. The implementation of this new system in GDACS is shown in Section 8, while two applications of the SSCS system are shown in Section 9. Concluding remarks are in Section 10.

[1] JRC Storm Surge Calculation System - SSCS
http://webcritech.jrc.ec.europa.eu/StormSurgeWeb/loginPage.aspx

2 JRC Storm Surge Calculation System (SSCS)

In this Section, an overview of the JRC SSCS is presented, while the atmospheric forcing and the model solvers used are described in Section 3 and 4.

2.1 Basin coverage

The SSCS cover the whole Europe and in particular there are three different domains of calculations:

- **North Atlantic**
- **North Sea**
- **Mediterranean Sea**

For each of these areas several different SSCS bulletins are prepared, in order to create a bulletin more focused on a specific area, like Italy, Greece and UK. All these SSCS are listed and described in Section 5, while a brief description of the procedure used is shown in the next section.

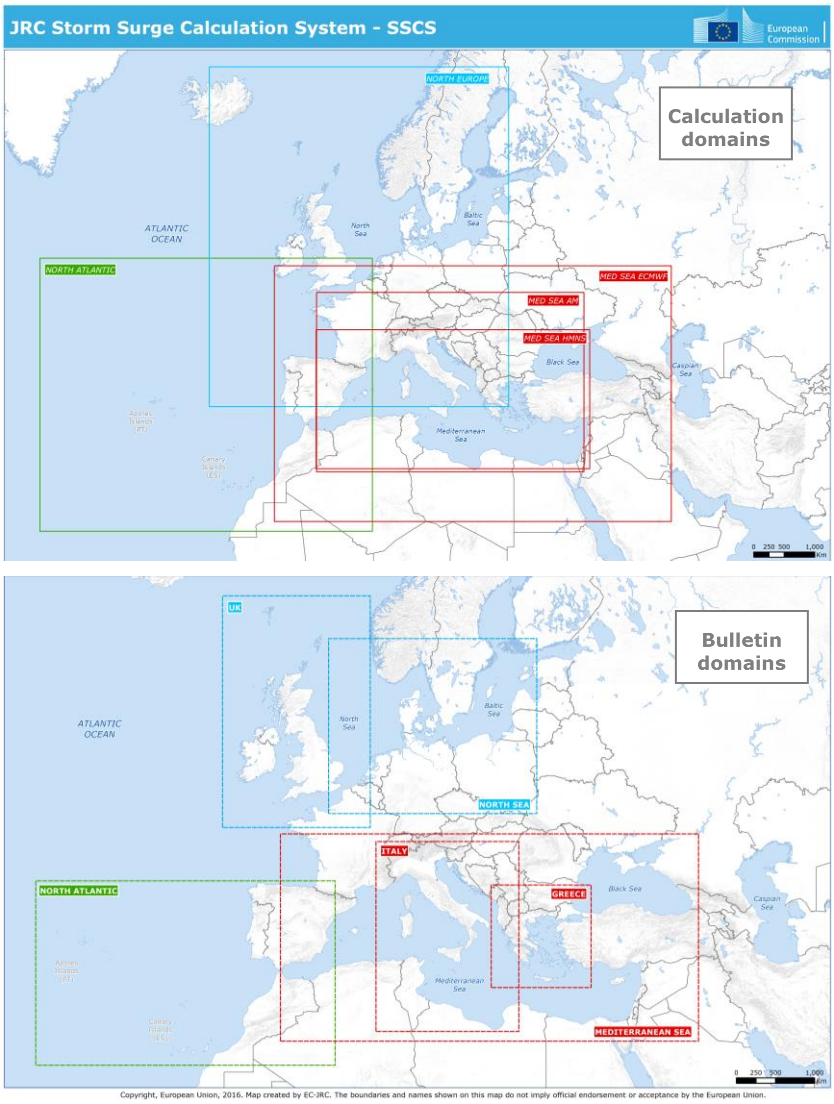


Figure 1 - *SSCS calculations domains (above) and SSCS bulletin domains(below).*

2.2 Procedure

In order to create the SSCS bulletins, the JRC has set up the following automatic procedure:

1) **Input data**: Download the input data files (GRIB data) two times per day, as soon as the files become available (see *Table 1*).
2) **Pre-Processing**: Extract a portion of the grib file and convert it into a netcdf file for a number of windows of interest (see *Figure 1*) and prepares the input file needed by the storm surge calculations (GeoTiff raster maps for each time interval for pressure and wind speed components).
3) **Calculations**: Launch the calculations using HyFlux2 and Delft3D (see Section 4).
4) **Post processing** of the results
    - Create the files needed to analyse, using TAT (JRC Tsunami Analysis Tool).
    - Create the bulletins for fixed windows.
    - Publish the results on the website (see Section 6).
    - Send the e-mail with the bulletin (see Section 7).

A brief description of these steps is presented over the next pages, while a scheme of these procedures is shown in *Figure 2*.

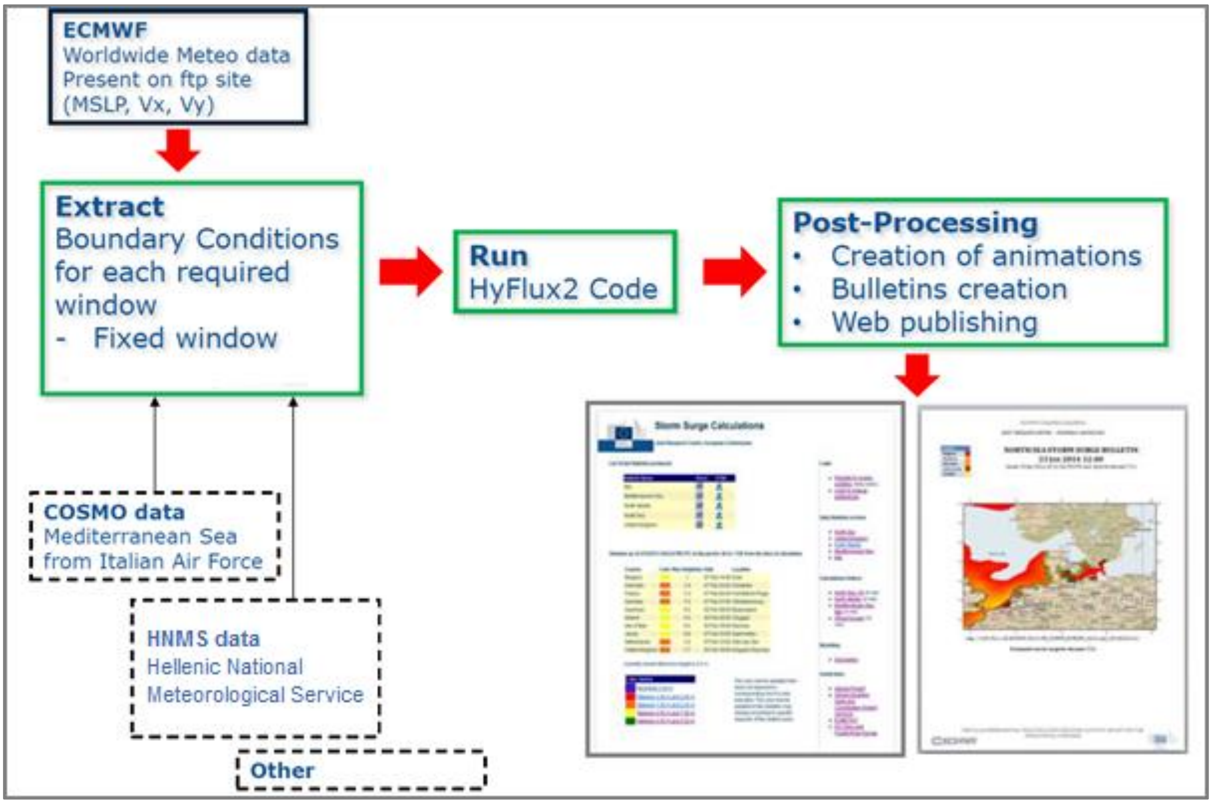


Figure 2 - *SSCS Procedure.*

1) **Input data:** *Download of the atmospheric forcing*

ECMWF, AM, HNMS produce every 12 hours a forecast for several parameters, including Mean Sea Level Pressure (MSLP) and 10m wind speed of the two components (u10, v10), for a 72h forecast period. The characteristics of each file and the domain of the data provided are shown in *Table 1*, while the descriptions of the models are in Section 3.

	FORMAT	DOMAIN	PARAMETERS	FORECASTING TIME (UTC)	RESOLUTION	SIZE FILES
ECMWF	Grib, single file	World	MSLP, u10,v10	00:00, 12:00	16 km *(before 03/2016)* 9 km *(after 03/2016)*	900 MB *(before 03/2016)* 5.6 GB[2] *(after 03/2016)*
AM	Grib, several files	Mediterranean Sea	MSLP, u10,v10	00:00, 12:00	7 km	1.5 MB each file
HNMS	Grib, several files	Mediterranean Sea	MSLP, u10,v10	00:00, 12:00	7 km	1.5 MB each file

Table 1- *Data sources.*

2) **Pre-processing of the data**

All the input files are in GRIB format, therefore, after having extract the area of interest (in case of ECMWF), the data are converted into a netCDF file. Then another routine prepares the input needed by the storm surge model, creating a GeoTIFF raster map for each times interval for the pressure and wind speed components, as requested by the HyFlux2 code as boundary condition.

3) **Calculations:** *Storm surge calculations for several basins*

Currently the HyFlux2 model (see Section 4.1) is used as default model, however JRC has recently implemented a new solver: Deltares - Delft3D (see Section 4.2).
Several windows have been defined for each calculation every day (*Figure 1*) and these calculations are performed using the previous forecast at -6 h and the forecasted values of the next 72 h (after the time 0 of the forecast).
At the moment the calculations are performed using a 24 cores Linux workstation; however for each case only 6 cores are used in order to perform several domain calculations at the same time. The current computational time is of the order of 2 h.

ECMWF - *Resolution*	
Mediterranean Sea	4 min
North Sea	4 min
Atlantic Ocean	4 min

AM COSMO-ME *Resolution*	
Mediterranean Sea	4 min

HNMS COSMO *Resolution*	
Mediterranean Sea	4 min

Table 2 - *Resolutions of the calculations using the ECMWF, AM and HNMS data.*

2 Before 03/2016: Reduced Gaussian grid. After 03/2016: Octahedral Gaussian grid.

4) **<u>Post processing:</u>** *<u>Creation of map, animations, bulletins</u>*

After having calculated the storm surge for all the basins, there are several post processing steps described below:

- Creation of the final calculation set
    - All the calculations performed contains forecast section of 72 h. The "final calculation" is composed collating all the calculation results between -10 days and + 72 h respect to the nominal time of the analysis. The results of the previous days contain the individual forecasts between two successive calculations. Example:

        If the analysis is related to 16 March 2016 at 12:00, the final data set contains data from 6 March 12:00 to 19 March 12:00 as follows:

        - From 6 March 12:00 to 7 March 00:00, using the results of the 6 March 12:00 run
        - From 7 March 00:00 to 7 March 12:00, using the results of the 7 March 00:00 run
        - ..
        - From 16 March 00:00 to 16 March 12:00 using the results of the 16 March 00:00 run
        - From 16 March 12:00 to 19 March 12:00 using the results of the current 16 March 12:00 run
- Create the animations and maps
- Create the bulletins for fixed windows (see Section 5) using the Tsunami Analysis Tool software
- Publish the results on the website (see Section 6)
- Send the e-mail with the SSCS bulletin (see Section 7)

2.3 Schedule tasks

For all the procedures described in the previous Section, three different schedule tasks have been created:

Name	Description	Time
CheckSync	Check if new Forcing data are available	Every 5 min
CheckRun	Check if there is a new calculation to be performed	Every 5 min
DailySummary	Send the e-mail: SSCS Daily summary	Every day at 07:00

Table 3 - *Schedule task description.*

3 Atmospheric forcing used in the SSCS

The SSCS uses meteorological forecasts produced by several meteorological centers in order to have the atmospheric input for the storm surge model and estimate the effect caused by the passage of an intense low pressure system.

The following fields are used as atmospheric input for the JRC Storm surge model and included in the JRC Storm Surge Calculation System:

- U component of wind (**10U**) at 10 meters in m/s
- V component of wind (**10V**) at 10 meters in m/s
- Mean Sea Level Pressure (**MSLP**) in Pa

The numerical weather forecasts of the following centers are used in the SSCS and are described below:

3.1. European Centre for Medium-Range Forecasts (ECMWF)

3.2. Italian Air Force Meteorological Weather Service (AM)

3.3. Hellenic National Meteorological Service (HNMS)

3.1 ECMWF Weather Deterministic Forecast

In the JRC SSCS, the numerical weather forecasts provided at a global scale by the European Centre for Medium-Range Forecasts (ECMWF) model are used to infer pressure and wind fields for the storm surge calculations (see *Table 7*). Most of the ECMWF applications required are available through the Integrated Forecasting System (IFS). The IFS runs both in "deterministic forecast" and "ensemble" mode. The IFS operational high-resolution (HRES) with its deterministic single-model configuration runs every 12 hours and forecasts up to 10 days on a global scale. The HRES data are used in the JRC SSCS.

Before March 2016

Before March 2016, the HRES horizontal resolution corresponded to a grid of 0.125° x 0.125° lat / long (≈16 km), while its vertical resolution was equal to 137 levels. More information can be found in Hortal and Simmons (1991) and Untch et al. (1999).

After March 2016

In March 2016, the ECMWF has started using a new grid, with up to 904 million prediction points. The new cycle has reduced the horizontal grid spacing for high-resolution from 16 km to 9 km, while the vertical grid is unchanged.

More information can be found at: http://www.ecmwf.int/en/about/media-centre/news/2016/new-forecast-model-cycle-brings-highest-ever-resolution or at http://www.ecmwf.int/sites/default/files/ECMWF_41r2_PressRelease.pdf.

ECMWF Atmospheric Model high resolution	Before March 2016	After March 2016
Domain	World	World
Horizontal Grid Size	≈ 16 km	≈ 9 km
Vertical Levels	137 levels	137 levels
Forecast range	10 days (72 hours used in the SSCS)	10 days (72 hours used in the SSCS)
Initial Time of Model runs	00, 12 UTC	00, 12 UTC
Data Format	Grib	Grib

Table 4 *- Main features of the ECMWF model.*

3.2 AM COSMO-ME

The **COSMO-ME** model outputs are used as atmospheric input in the bulletin of Italy (see Section 5.2.5). This atmospheric input is provided by the Italian Air Force Meteorological Weather Service (AM). Two different configurations are available for deterministic forecast for Local Area Modelling: **COSMO-ME** and **COSMO-IT**. A probabilistic version (**COSMO-ME EPS**) is also available, with a grid size of 10 km.

The main features of COSMO-ME and COSMO-IT and their domains are shown in *Table 5* and in *Figure 3*, while more information can be found at: http://www.meteoam.it/modelli-di-previsione-numerica and at http://www.cosmo-model.org/content/tasks/operational/remet/default.htm.

ITALIAN MET SERVICE ***Local Area Modelling***	**COSMO-ME**	**COSMO-IT**
Domain	Central-southern Europe, Mediterranean Sea and Black Sea	Italy
Horizontal Grid Size	≈ 7 km	≈ 2.8 km
Vertical Levels	40 levels	65 levels
Forecast range	72 hours	30 hours
Initial Time of Model runs	00, 06, 12, 18 UTC	00, 06, 12, 18 UTC

Table 5 - *Overview of the main features of COSMO-ME and COSMO-IT.*

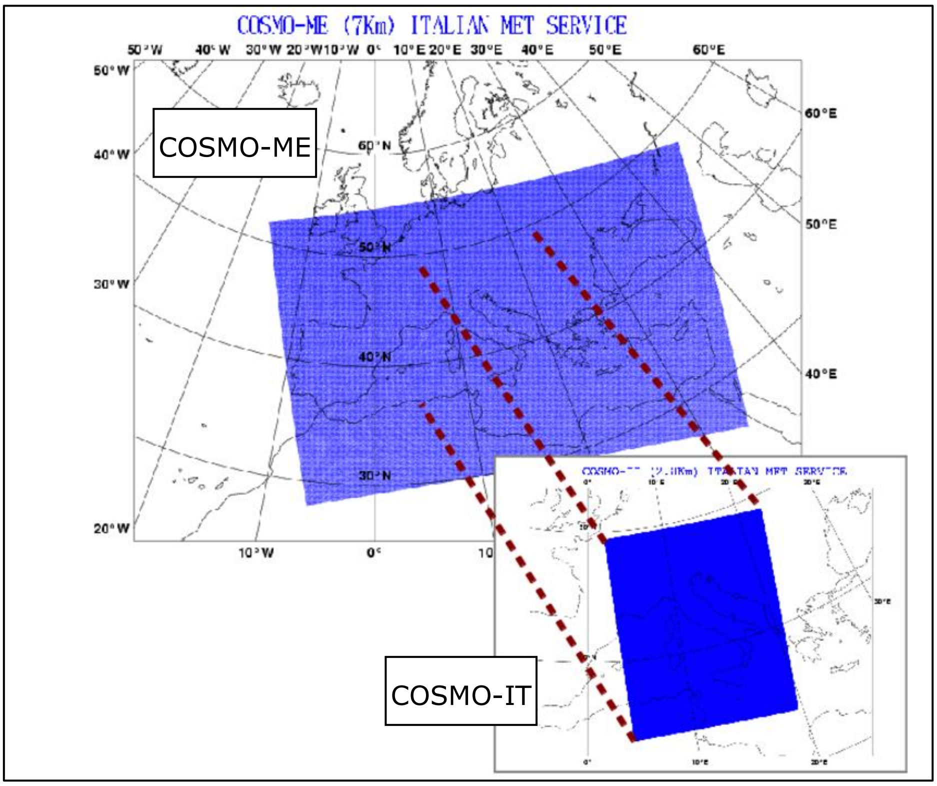


Figure 3 - *COSMO-ME and COSMO-IT domain used at the Italian Met Service. (source: http://www.cosmo-model.org/content/default.htm)*

3.3 HNMS COSMO-GR

The HNMS COSMO model outputs are used as atmospheric input in the SSCS of Greece (see Section 5.2.7). The Hellenic National Meteorological Service (HNMS) uses this model in operational mode. A brief overview of the main features of the COSMO-GR model used at HNMS is shown in *Table 6*, while its domain is shown in *Figure 4*.

HELLENIC NAT. MET. SERVICE HNMS	COSMO-GR
Domain	Southern Europe, Mediterranean Sea, Black Sea
Horizontal Grid Size	≈ 7 km
Vertical Levels	60 levels
Forecast range	72 hours
Initial Time of Model runs	00, 12 UTC

Table 6 *- Overview of the main features of COSMO HNMS data.*

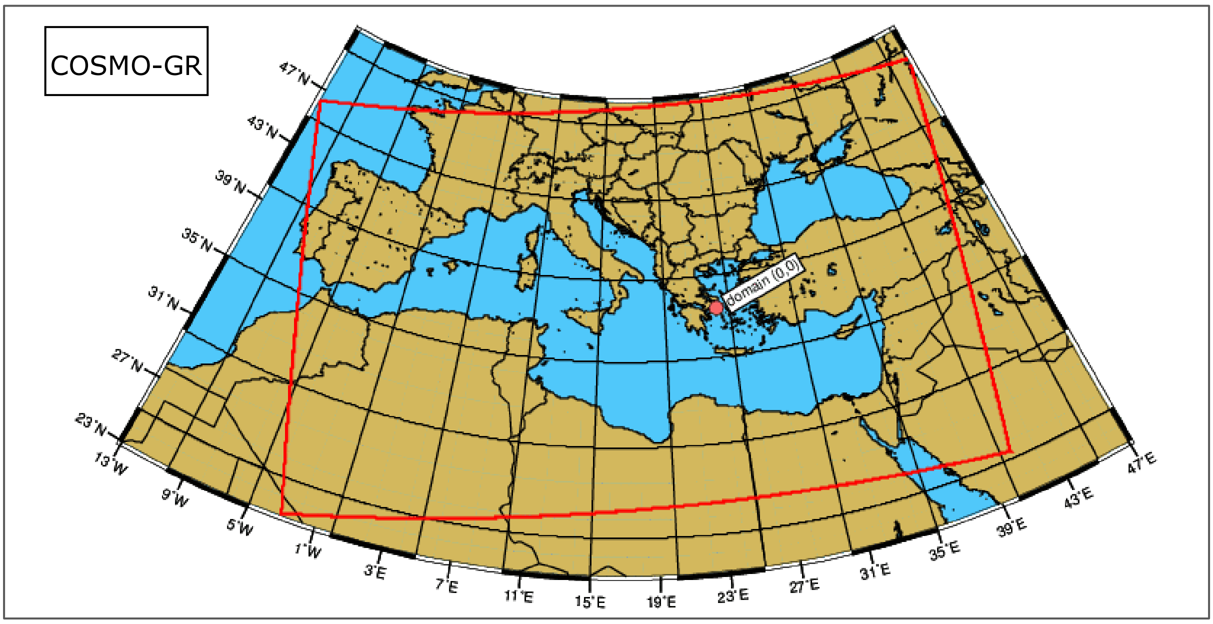


Figure 4 – *COSMO-GR domain used at HNMS.*
(source: http://www.cosmo-model.org/content/default.htm)

4 Model Solvers used in the SSCS

4.1 HyFlux2

JRC has developed extensive experience in tsunami early warning systems, using the JRC-SWAN finite difference code for wave propagation modeling and the JRC finite-volume HyFlux2 code for wave propagation and inundation modeling over the last years and in 2011 the atmospheric forcing has been included in the HyFlux2 code in order to use it also for storm surge modeling.

HyFlux2 model solves the shallow water equations using a finite volume method. The interface flux is computed by a Flux Vector Splitting method for shallow water equations based on a Godunov-type approach. A second-order scheme is applied to the water surface level and velocity, providing results with high accuracy and assuring the balance between fluxes and sources also for complex bathymetry and topography. Physical models are included to deal with bottom steps and shorelines. The second-order scheme together with the shorelinetracking method and the implicit source term treatment makes the model well balanced in respect to mass and momentum conservation laws, providing reliable and robust results.

HyFlux2 model uses uniform Cartesian grid and more detailed inundation simulations are performed by a nested grid approach. In the nest grid approach the boundary conditions of the simulations performed at finer grid size are taken from the simulation results at coarser grid size. A brief description of this model is shown below, while more information can be found in Franchello (2008, 2010).

HyFlux solves the 2D shallow water equation:

$$\frac{\partial U}{\partial t} + \Delta \cdot \vec{F} = C$$

, where

- U is the conservative vector,
- F is the flux vector {Fx, Fy},
- C is the source vector.

$$U = \begin{Bmatrix} h \\ hv_x \\ hv_y \end{Bmatrix} \quad F_x = \begin{Bmatrix} hv_x \\ hv_x{}^2 + gh^2/2 \\ hv_x v_y \end{Bmatrix} \quad F_y = \begin{Bmatrix} hv_y \\ hv_y v_x \\ hv_y{}^2 + gh^2/2 \end{Bmatrix}$$

$$C = \begin{Bmatrix} q \\ fv_y - gh\left(\partial z/\partial x + S_{fx} + S_{px} - S_{ux} - S_{rx}\right) \\ -fv_x - gh\left(\partial z/\partial y + S_{fy} + S_{py} - S_{uy} - S_{ry}\right) \end{Bmatrix}$$

The scheme of the shallow water model is shown in *Figure 5*, where *h* signifies the water depth, $v = \{v_x, v_y\}$ is the velocity of the fluid in the $\{x, y\}$ plane, *z* is the vertical coordinate of the bottom (or bed), η is the elevation of the free surface, *g* is the gravitational acceleration (opposite to the *z* direction).

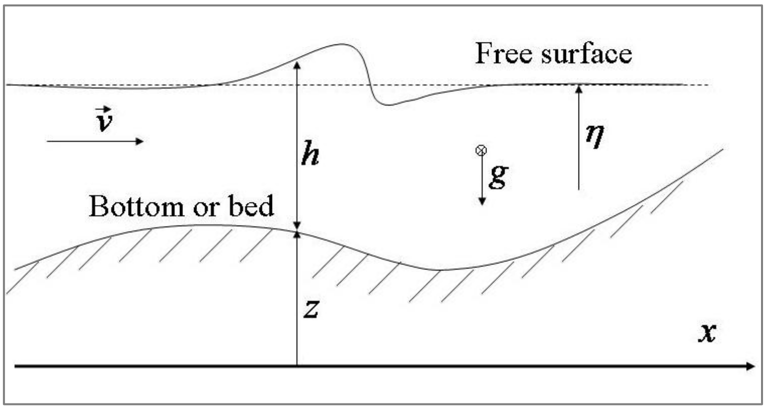


***Figure 5 -** Scheme of coordinate and variables of the shallow water model.*

The source parameters are the following:

- Bottom slope: $\{\partial z/\partial x \ , \partial z/\partial y\}$
- Coriolis forces: $f = 2\omega \sin\theta$ (ω = rotation rate of the Earth, θ = latitude)
- Bottom friction: $S_f = \{S_{fx}, S_{fy}\} = \frac{n^2\sqrt{v_x^2 + v_y^2}}{h^{4/3}}\{v_x, v_y\}$ (see Manning formula)
- Pressure Surge: $S_p = \{S_{px}, S_{py}\} = \frac{1}{\rho_{water} g}\left\{\frac{\partial p}{\partial x}, \frac{\partial p}{\partial y}\right\}$ (ρ = water density)
- Wind Friction: $\{S_{ux}, S_{uy}\} = \frac{\rho_{air} C_D}{\rho_{water} g}\frac{\sqrt{U_{10x}^2 + U_{10y}^2}}{h}\{U_{10x}, U_{10y}\}$

  where
  - $U_{10} = \{U_{10x}, U_{10y}\}$ is the horizontal components of the wind velocity 10m above the sea surface;
  - C_D is the drag coefficient (see Powell et al. 2003).

4.2 Delft3D

Delft3D of DELTARES is a flexible integrated 3D modelling suite to investigate hydrodynamics, sediment transport and morphology and water quality for fluvial, estuarine and coastal environments.
The Delft3D suite has many modules that can be run independently or in coupled mode. The Delft3D-FLOW module can be used to evaluate the hydrodynamic response of a mass of water to various forcing components such as tides and winds. It can run on a rectilinear or curvilinear, boundary fitted grid in 2D or 3D mode. The 2D mode solves the depth-averaged hydrodynamic equations most applicable to storm surge computations while the 3D mode is required in dealing with transport processes.
The model solves the Navier Stokes equations for an incompressible fluid, under the shallow water and Boussinesq assumptions. This is coupled with a hydrostatic equation for pressure. The grid is staggered with the velocity computed on the vertices and the height of the water (pressure points) in the center of the grid cell. The numerical method is based on finite differences. The time integration is implicit, utilizing a variation of the ADI-method providing 2nd order accuracy both in space and time. The code is written in fortran and is using Mpich to run in parallel mode. More information is available within the extensive collection of manuals provided by Deltares (http://oss.deltares.nl/web/delft3d/manuals).

5 SSCS bulletins

5.1 Main characteristics

The JRC SSCS creates every day several bulletins for different areas, as shown in *Figure 1* and in *Table 7*. These bulletin are created using TAT and are based on a WORD dotx template. A general description of the template used in order to create these bulletins is presented in this Section, while the detailed descriptions of the bulletins are in the next sections.

5.1.1 Colour scheme used in the SSCS bulletins

The colour scheme used in the SSCS bulletins (e.g. tables of the locations affected and maps) does not represent a corresponding risk and is only indicative.

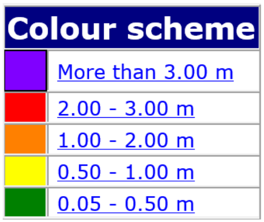


Figure 6 *- Colour scheme used in the SSCS bulletins*

5.1.2 List of the SSCS bulletins

Al the SSCS bulletins created are listed in *Table 7* , where the atmospheric inputs and the codes used are also shown.

SSCS BULLETINS *(see Section 4)*		**ECMWF**			**AM**	**HNMS**
HYFLUX 2 CODE		**NORTH SEA**	**MED SEA**	**ATLANTIC**	**MED SEA**	**MED SEA**
UK & Ireland	*5.2.1*	●				
UK Harmonics	*5.2.1*	●				
NORTH SEA	*5.2.2*	●				
NSEA Harmonics	*5.2.2*	●				
MEDSEA	*5.2.3*		●			
IT	*5.2.4*		●			
IT AM	*5.2.5*				●	
IT ENSEMBLE	*5.2.6*		●		●	
GREECE	*5.2.7*					●
N ATLANTIC	*5.2.8*			●		
DELFT3D CODE		**NORTH SEA**	**MED SEA**	**ATLANTIC**	**MED SEA**	**MED SEA**
MEDSEA Delft3D	*5.2.9*		●			

Table 7 – *List of the SSCS bulletins available.*

5.1.3 Word dotx template of the SSCS bulletins

Every SSCS bulletin is created using TAT that processes a specific "Word dotx template". The main characteristics of this template are presented below, while the description of the SSCS bulletins produced are in Section 5.2.

1 - Main Page

- *Title*:
  - type of bulletin (see list in *Table 7*)
  - time of the input data
  - time when the bulletin is issued

- *Table*:
  - list of the countries affected
  - alert level colour

- *Map*: the map includes the storm surge max height and the locations affected

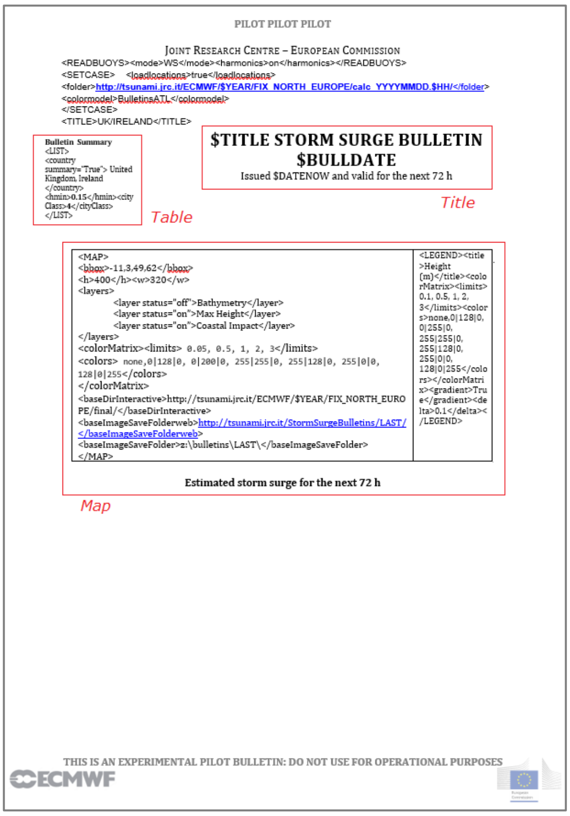
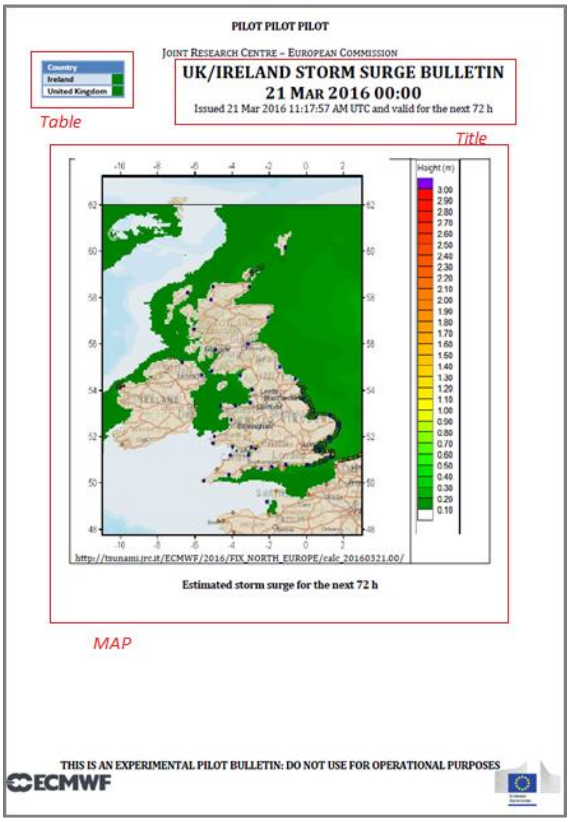
TEMPLATE (word dotx file)	OUTPUT (pdf file)
	

Figure 7 - *Example of the main page of the SSCS bulletin ok UK/Ireland.*

2 - List of Locations

List of the locations affected by a storm surge greater than 0.5 m (North Sea, UK, Med Sea, North Atlantic), 0.3 m (Greece) and 0.25 m (Italy).
For each location affected:

- Max storm calculated
- Time of the max. storm surge
- Colour code (see Section 5.1.1)

TEMPLATE (word dotx file)

LIST OF LOCATIONS

<LIST>
<country>Belgium, Netherlands, Germany, Denmark, Sweden, Poland</country>
<hmin>**0.5**</hmin><cityClass>**4**</cityClass>
</LIST>

<LEGEND><title>Height (m)</title><colorMatrix><limits>0.05, 0.5, 1, 2, 3</limits><colors>none,0|128|0, 0|128|0, 255|255|0, 255|128|0, 255|0|0, 255|0|0</colors></colorMatrix><gradient>False</gradient><delta>-1</delta></LEGEND>

OUTPUT (pdf file)

LIST OF LOCATIONS

Actual Time	Country	Location	Height		ID	
08 Feb 2016 23:00	Belgium	De Panne	0.8		51.10	2.59
08 Feb 2016 20:00	Belgium	Koksijde	0.8		51.11	2.65
08 Feb 2016 20:00	Belgium	Nieuwpoort	0.8		51.13	2.75
08 Feb 2016 20:00	Belgium	Middelkerke	0.8		51.19	2.82
08 Feb 2016 20:00	Belgium	Oostende	0.8		51.23	2.91
08 Feb 2016 20:00	Belgium	Bredene	0.8		51.25	2.97
08 Feb 2016 20:00	Belgium	De Haan	0.8		51.27	3.04
08 Feb 2016 23:00	Belgium	Blankenberge	0.9		51.32	3.13
08 Feb 2016 21:00	Belgium	Knokke-Heist	1.0		51.35	3.29
08 Feb 2016 21:00	Netherlands	Domburg	1.0		51.57	3.50
08 Feb 2016 22:00	Netherlands	Ouddorp	1.2		51.81	3.93
08 Feb 2016 23:00	Netherlands	Europoort	1.3		51.96	4.11
08 Feb 2016 23:00	Netherlands	Hoek van Holland	1.3		51.98	4.13
09 Feb 2016 00:00	Netherlands	Monster	1.3		52.03	4.18
09 Feb 2016 00:00	Netherlands	Poeldijk	1.3		52.02	4.21
08 Feb 2016 22:00	Netherlands	Den Haag	1.2		52.08	4.31
09 Feb 2016 04:00	Germany	Carolinensiel	1.3		53.69	7.80
09 Feb 2016 06:00	Germany	Helgoland	1.2		54.18	7.88
09 Feb 2016 05:00	Germany	Hooksiel	1.2		53.63	8.03
09 Feb 2016 02:00	Germany	Wilhelmshaven	1.2		53.52	8.11
09 Feb 2016 10:00	Denmark	Hvide Sande	1.3		56.00	8.13
09 Feb 2016 11:00	Denmark	Ferring	1.2		56.53	8.13
09 Feb 2016 05:00	Germany	Alte Weser LT	1.3		53.87	8.13
09 Feb 2016 10:00	Denmark	Blavand	1.6		55.54	8.19
09 Feb 2016 10:00	Denmark	Nymindegab	1.3		55.82	8.20
09 Feb 2016 11:00	Denmark	Thyboron	1.2		56.70	8.22
09 Feb 2016 10:00	Denmark	Ringkobing	1.3		56.08	8.25
09 Feb 2016 08:00	Germany	Westerland	1.5		54.92	8.27
09 Feb 2016 08:00	Germany	Hornum	1.5		54.76	8.29
09 Feb 2016 05:00	Germany	Langwarden	1.3		53.60	8.31
09 Feb 2016 08:00	Germany	Sylt	1.5		54.92	8.31
09 Feb 2016 09:00	Germany	Kampen	1.6		54.95	8.34
09 Feb 2016 07:00	Germany	Nebel	1.5		54.65	8.35
09 Feb 2016 11:00	Denmark	Norre Vorupor	1.2		56.95	8.38
09 Feb 2016 09:00	Denmark	Fano	1.7		55.40	8.39

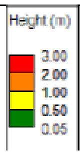


Figure 8 – *Example of the table of the list of the locations affected.*

3 – Meteorological section

- **Meteosat Images** (source: EUMETSAT)
  Two Meteosat images (IR 10.8 Channels and EGB composite Natural Colours) are included in the SSCS bulletins (see *Figure 9*). Based on the area covered by the bulletin, three different images are included in the SSCS bulletin (see *Table 8*). More information are available at http://oiswww.eumetsat.org/IPPS/html/MSG/ .

Area	SSCS Bulletins
WESTERN EUROPE	North Atlantic
CENTRAL EUROPE	UK, North Sea, Med Sea, Italy
EASTERN EUROPE	Greece

Table 8 *- Meteosat areas.*

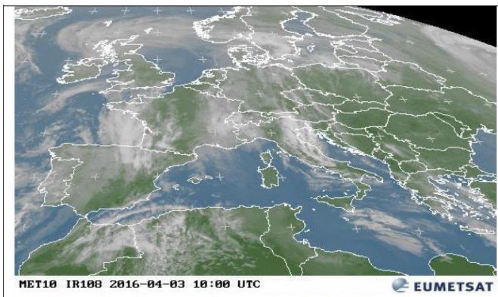
TEMPLATE (word dotx file)

METEOSAT (EUMETSAT)

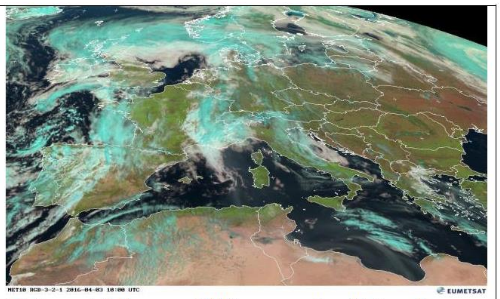
<IMAGE> <url>http://oiswww.eumetsat.org/IPPS/html/latestImages/EUMETSAT_MSG_IR108EColor-westernEurope.jpg </url> *<h>138</h><w>230</w>* *<label>Meteosat 0 degree, Channels, IR 10.8</label>* </IMAGE>	<IMAGE> <url>http://oiswww.eumetsat.org/IPPS/html/latestImages/EUMETSAT_MSG_RGB-naturalcolor-westernEurope.jpg </url> *<h>138</h><w>230</w>* *<label>Meteosat 0 Degree, RGB composite, Natural Colors</label>* </IMAGE>

OUTPUT (pdf file)

METEOSAT (EUMETSAT)



Meteosat 0 degree, Channels, IR 10.8



Meteosat 0 Degree, RGB composite, Natural Colors

Figure 9 - *Meteosat images included in the SSCS bulletins.*

- **Meteorological analysis** (source: ECMWF)

  The ECMWF charts of the Mean Sea Level Pressure and Wind speed at 850hPa from the ECMWF high resolution forecast model at time: *t0h, t+24h, t+48h, t+72h* are included in the page no. 3 of the SSCS bulletin (see *Figure 10)*. More information are available at http://www.ecmwf.int/en/forecasts/charts/catalogue.

TEMPLATE (word dotx file)

METEOROLOGIC ANALYSIS (ECMWF)

The wind speed indicated is the 850hPa isobaric surface, which is around 1.5km above sea level

<IMAGE> *<url>* <![CDATA[*http://old.ecmwf.int/products/forecasts/d/getchart/catalog/products/forecasts/medium/deterministic/msl_uv850_z500!Wind%20850%20and%20mslp!0!Europe!pop!od!oper!public_plots! YYYYMMDD$HH!!chart.gif*]]> *</url>* *<h>138</h><w>230</w>* *<label> Analysis time 0</label>* *</IMAGE>*	<IMAGE> *<url>* <![CDATA[*http://old.ecmwf.int/products/forecasts/d/getchart/catalog/products/forecasts/medium/deterministic/msl_uv850_z500!Wind%20850%20and%20mslp!24!Europe!pop!od!oper!public_plots! YYYYMMDD$HH!!chart.gif*]]> *</url>* *<h>138</h><w>230</w>* *<label> Forecast 24 h</label>* *</IMAGE>*
<IMAGE> *<url>* <![CDATA[*http://old.ecmwf.int/products/forecasts/d/getchart/catalog/products/forecasts/medium/deterministic/msl_uv850_z500!Wind%20850%20and%20mslp!48!Europe!pop!od!oper!public_plots!YYYYMMDD$HH!!chart.gif*]]> *</url>* *<h>138</h><w>230</w>* *<label> Forecast 48 h</label>* *</IMAGE>*	<IMAGE> *<url>* <![CDATA[*http://old.ecmwf.int/products/forecasts/d/getchart/catalog/products/forecasts/medium/deterministic/msl_uv850_z500!Wind%20850%20and%20mslp!72!Europe!pop!od!oper!public_plots!YYYYMMDD$HH!!chart.gif*]]> *</url>* *<h>138</h><w>230</w>* *<label> Forecast 72 h</label>* *</IMAGE>*

OUTPUT (pdf file)

METEOROLOGIC ANALYSIS (ECMWF)

The wind speed indicated is the 850hPa isobaric surface, which is around 1.5km above sea level

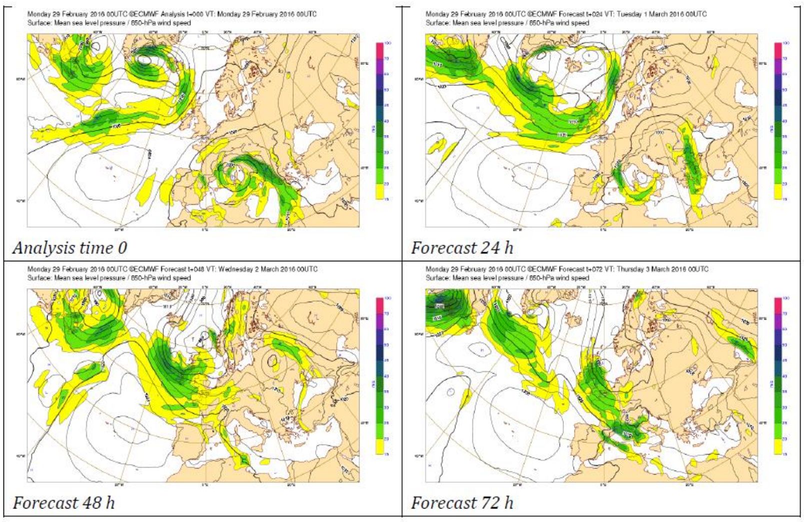


Figure 10 - *ECMWF charts for Mean Sea Level Pressure and Wind Speed at 850hPa for time t 0h, t+24 h, t+48h, t+72h*

4 – JRC calculations: 10m Wind Speed and Sea Level Height

The maps of the Wind Speed at 10 m (data source: ECMWF) and the Sea Level Evolution obtained from the JRC calculations (see Section 2) for the time: *t 0, t +24h, t + 48 h, t + 72 h* are included in this page of the SSCS bulletin.

TEMPLATE (word dotx file)

WIND IMPOSED

The wind speed here is 10 m height wind and is the quantity imposed to the sea surface

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255|255|0,255|255|0, 115|220|0, 0|186|0,
0|151|0, 0|115|25,
0|115|25</colors></colorMatrix>
<v1>u10x00</v1><v2>u10y00</v2>
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<showVectors>True</showVectors>
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<h>120</h><w>200</w><label>Wind Speed at sea level at time 0 h</label>
</CREATEMAP>
```

```
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</baseTif>
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0|151|0, 0|115|25,
0|115|25</colors></colorMatrix>
<v1>u10x00</v1><v2>u10y00</v2>
<idCalc>YYYYMMDD.$HH"</idCalc>
<showVectors>True</showVectors>
<url><![CDATA[http://tsunami.jrc.it/ECMWF//FIX_MED_SEA/calc_YYYYMMDD.$HH]]></url>
<h>120</h><w>200</w><label> Wind Speed at sea level at time 24 h</label>
</CREATEMAP>
```

```
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```

```
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<idCalc>YYYYMMDD.$HH"</idCalc>
<showVectors>True</showVectors>
<url>
<![CDATA[http://tsunami.jrc.it/ECMWF/$YEAR/FIX_MED_SEA/calc_YYYYMMDD.$HH]]></url>
<h>120</h><w>200</w><label>Wind Speed at sea level at time 48 h</label>
</CREATEMAP>
```

```
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</baseTif>
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255|255|0,255|255|0, 115|220|0, 0|186|0,
0|151|0, 0|115|25,
0|115|25</colors></colorMatrix>
<v1>u10x00</v1><v2>u10y00</v2>
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<showVectors>True</showVectors>
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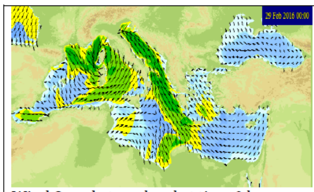
<![CDATA[http://tsunami.jrc.it/ECMWF/$YEAR/FIX_MED_SEA/calc_YYYYMMDD.$HH]]></url>
<h>120</h><w>200</w><label>Wind Speed at sea level at time 72 h</label>
</CREATEMAP>
```

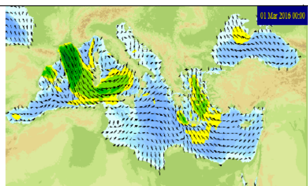
OUTPUT (pdf file)

WIND IMPOSED

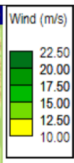
The wind speed here is 10 m height wind and is the quantity imposed to the sea surface

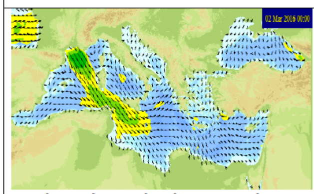


Wind Speed at sea level at time 0 h

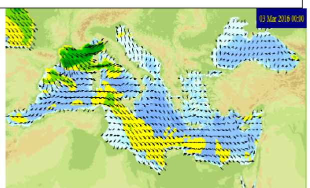


Wind Speed at sea level at time 24 h





Wind Speed at sea level at time 48 h



Wind Speed at sea level at time 72 h

Figure 11 - *Maps of the Wind Speed*

TEMPLATE (word dotx file)

SEA LEVEL EVOLUTION

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</colorMatrix>
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<h>120</h><w>200</w><label>Sea Level Height at time 0</label>
</CREATEMAP></td>
<td><CREATEMAP><baseTif><![CDATA[Z:\processed\$YEAR\FIX_MED_SEA\calc_YYYYMMDD.$HH]]>
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</CREATEMAP></td>
<td rowspan="2"><LEGEND><title>Height (m)</title><colorMatrix><limits>0.2, 0.5, 1, 2, 3</limits><colors>none,0|150|0, 0|200|0, 255|255|0, 255|128|0, 255|0|0, 128|0|255</colors></colorMatrix><gradient>True</gradient><delta>0.2</delta></LEGEND></td>
</tr>
<tr>
<td><CREATEMAP><baseTif><![CDATA[Z:\processed\$YEAR\FIX_MED_SEA\calc_YYYYMMDD.$HH]]>
</baseTif >
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<colorMatrix>
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<![CDATA[http://tsunami.jrc.it/ECMWF/$YEAR/FIX_MED_SEA/calc_YYYYMMDD.$HH]]></url>
<h>120</h><w>200</w><label>Sea Level Height at time 48 h</label>
</CREATEMAP></td>
<td><CREATEMAP><baseTif><![CDATA[Z:\processed\$YEAR\FIX_MED_SEA\calc_YYYYMMDD.$HH]]>
</baseTif >
<hour>72</hour>
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<colorMatrix>
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</tr>
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OUTPUT (pdf file)

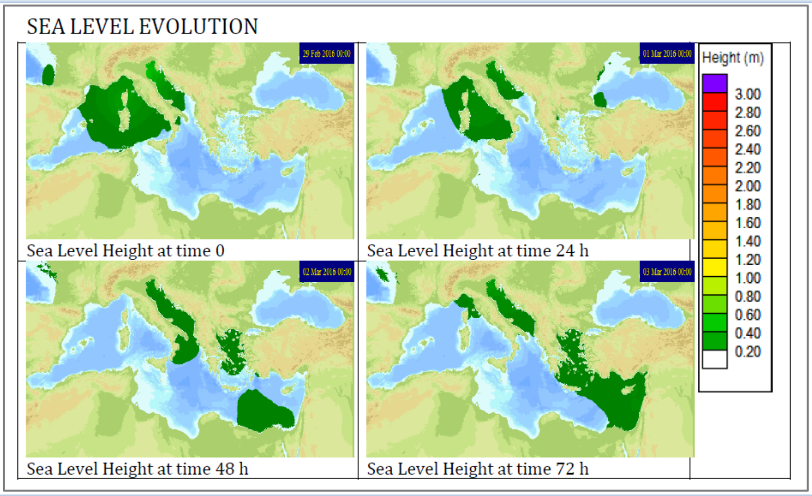


Figure 12 *- Maps of the Sea Level Evolution.*

5 - Sea level comparisons between JRC calculations and observations

In this section of the SSCS bulletin the JRC storm surge calculations are compared with the storm surge measured, obtained as:

Storm Surge (SS)	=	Sea level measured (TWL)	-	Tide level simulated (TD)

For each location, the sea level measured minus the tide level simulated and the storm surge calculated by the JRC are shown in the plot (see *Figure 13*), where the blue line represents the storm surge measured, while the purple line represents the JRC storm surge calculations.

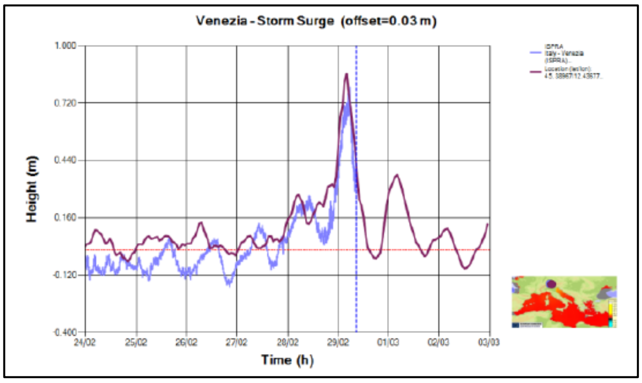
TEMPLATE (word dotx file)	OUTPUT (pdf file)
<PLOT> <id>1870</id> <sensor> 45.38967 , 12.43677</sensor> <h>200</h><w>250</w> <tmin>$NOW-10</tmin> <tmax>$NOW+4</tmax> <title>Venezia</title> <removeOffset>2 1</removeOffset> </PLOT>	

Figure 13 - *Example of the comparison between the storm surge measured (blue line) and the storm surge calculated (purple line), where the values of the measured ones are obtained as: sea level measured (TWL) - tide level simulated (TD).*

The images of several webcams are also include in the SSCS bulletin (see *Figure 14*).

TEMPLATE (word dotx file)	OUTPUT (pdf file)
<IMAGE> <url>http://93.62.201.235/maree/WEBCAM/smarcoweb2.jpg </url> <h>144</h><w>240</w> <label>*Webcam in Venezia, Piazza San Marco, by Istituzione Centro Previsione e Segnalazione Maree*</label> </IMAGE>	

Figure 14 - *Example of the webcam in Venice included in the bulletin of Italy. The storm surge event of 28-29 February 2016 is visible in the figure.*

*In the **TWL version**[3] of the SSCS*

In the TWL version of the SSCS bulletins of North Sea and UK (see ***Error! Reference source not found.***), as well as in the COSMO-ME AM bulletin of Italy (see ***Error! Reference source not found.***), this section is slightly different.

For each location analysed there are two figures:

- LEFT Figure: Sea levels (**TWL**): Storm Surge (SS) plus tide (TD)
  → the max. yearly tide (red line) and the time of the max is also included in the figures (see left figure in ***Error! Reference source not found.***).
- RIGHT Figure: Storm Surge (**SS**): Sea level measured (TWL) minus tide (TD)
  ➔ This figure is like the ones included in the other SSCS bulletins described previously.

<table>
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<ylab>Actual Sea Level (m)</ylab>
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<tmax>$NOW+2</tmax>
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</PLOT></td><td><PLOT>
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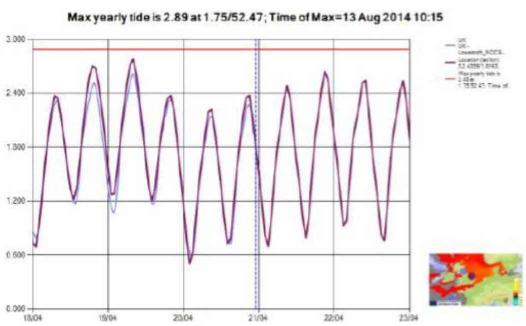
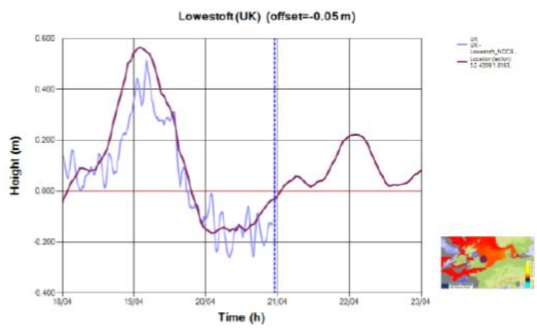
</PLOT></td></tr>
<tr><td colspan="2">OUTPUT (pdf file)</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Figure 15 - *Sea level (left figure), storm surge (right figure) for Lowestoft (UK bulletin).*

[3] Version of the bulletin that includes also the tides.

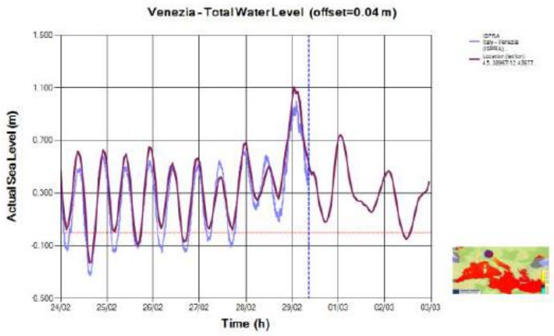
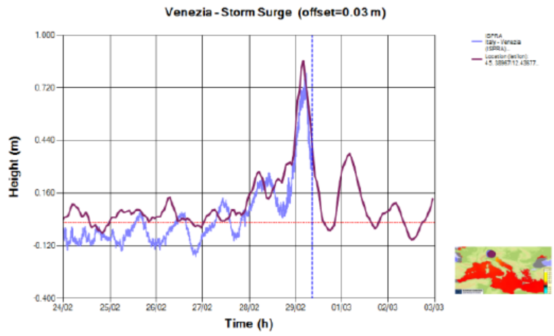
TWL= SS+TD	SS=TWL-TD
TEMPLATE (word dotx file)	
<PLOT> <id harmonics="off" TideMax="off">1870</id> <sensor getHarmonicsFrom="1870"> 45.38967 , 12.43677</sensor> <h>200</h><w>250</w> <ylab>Actual Sea Level (m)</ylab> <tmin>$NOW-5</tmin> <tmax>$NOW+3</tmax> <ymin>-0.5</ymin> <ymax delta="0.5">1.5</ymax> <title>**Venezia – Total Water Level** </title> <removeOffset>2 1</removeOffset> </PLOT>	<PLOT> <id>1870</id> <sensor>45.38967 , 12.43677</sensor> <h>200</h><w>250</w> <tmin>$NOW-5</tmin> <tmax>$NOW+3</tmax> <title>**Venezia – Storm Surge** </title> <removeOffset>2 1</removeOffset> </PLOT>
OUTPUT (pdf file)	
	

Figure 16 –*Sea level (left figure), storm surge (right figure) for Venice (Italy, COSMO-ME AM).*

*<u>In the **“Italy – ENSEMBLE”** version of the SSCS</u>*

In the Ensemble bulletin for ITALY, the storm surge calculated by **KASSANDRA ISAC-CNR** is also included for several locations

> *KASSANDRA is a storm surge operational forecast system for the Mediterranean and the Black seas. It is a 3D finite element hydrodynamic model (SHYFEM) and includes a tidal model, in a third generation finite element spectral wave model (WWMII), fully coupled to the hydrodynamic model and uses as input the surface data (wind and pressure) obtained from a suite of meteorological models provided by ISAC-CNR.*

More information are available at:

http://kassandra.ve.ismar.cnr.it:8080/kassandra

TEMPLATE (word dotx file)	OUTPUT (pdf file)

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12.43677</sensor1>
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</PLOT>
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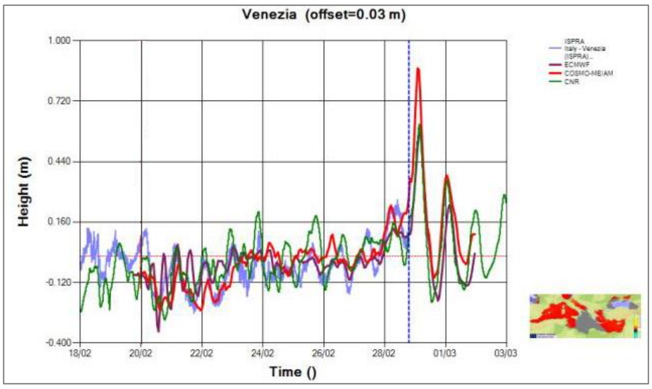


Figure 17 - *Storm Surge for Venice in the Italy (ENSEMBLE) bulletins, using as atmospheric input the data of ECMWF (blue line), AM COSMO-ME (red line), KASSANDRA ISAC-CNR (green line).*

5.2 Description of the SSCS bulletins

5.2.1 United Kingdom & Ireland

The "***UK / Ireland Storm surge bulletin***" covers the UK and Ireland.

The sea level data of UK NOC (National Oceanography Centre) and GLOSS (Global Sea Level Observing System) are used in this bulletin.

JRC has prepared also a second version of this bulletin, that includes the total water level (tides + storm surge) in order to identify the most dangerous storm surge case, i.e. when a storm surge event occurs during a period of high tide.

Atmospheric input: ECMWF. Code: HyFlux2.

UK & Ireland SSCS bulletin: General Info	
Total nr. Buoys	22
Areas analysed	5
Area 1	*IR, N Ireland (UK)*
Area 2	*Scotland (UK)*
Area 3	*England, Wales, E UK*
Nr. Webcams	0

Table 9 - *General information on the UK/ Ireland SSCS bulletin.*

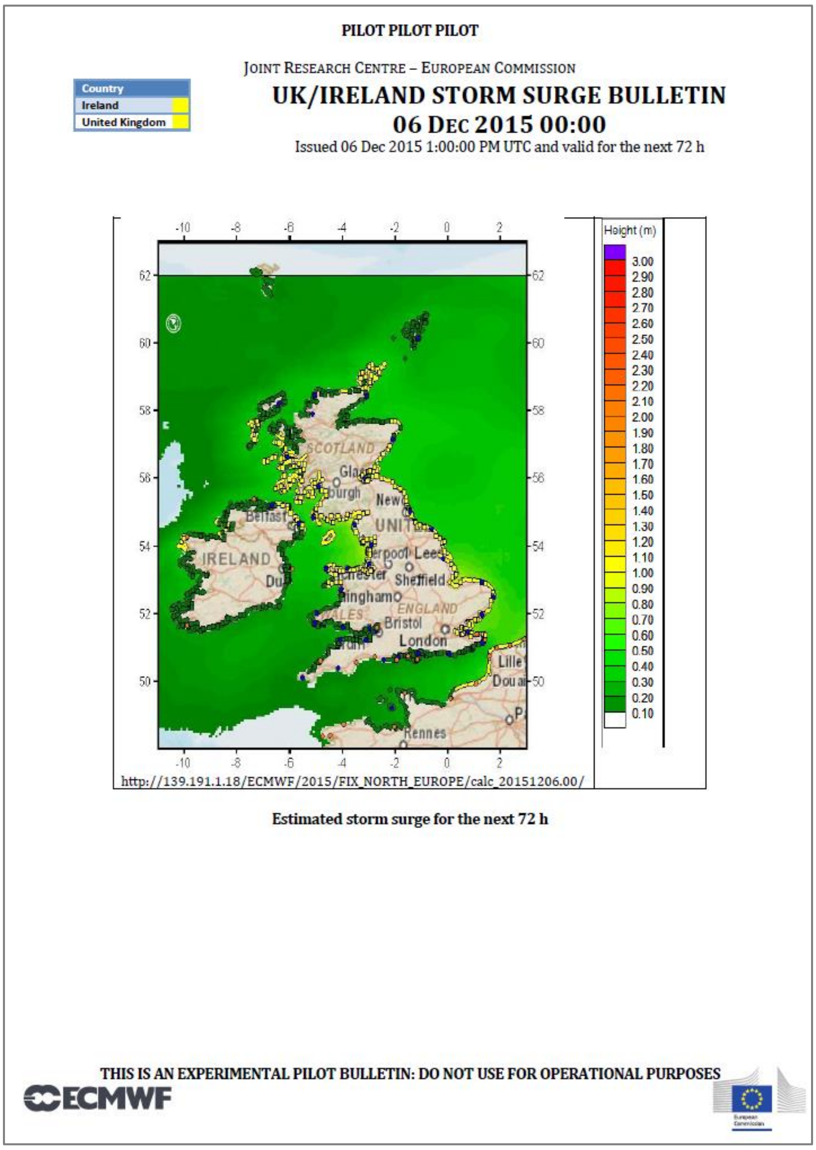


Figure 18 - *Example of the SSCS bulletin for the UK and Ireland.*

UK & Ireland SSCS bulletin								
ID	**Name**	**Country**	**Area**	**Source**	**buoy location**		**sensor location**	
					lat	lon	lat	lon
832	**Castletownbere**	IR	IR, N Ireland (UK)	GLOSS	51.6496	-9.9034	51.5590	-10.0558
816	**Ballyglass pier**	IR	IR, N Ireland (UK)	GLOSS	54.2530	-9.8900	54.3361	-10.0025
1975	**Portrush**	UK	IR, N Ireland (UK)	UK NOC	55.2100	-6.6600	55.2723	-6.6540
913	**Kish Bank Lighthouse**	IR	IR, N Ireland (UK)	GLOSS	53.3117	-5.9217	53.3120	-5.9220
1974	**Port Patrick**	UK	Scotland (UK)	UK NOC	54.8400	-5.1200	54.7663	-5.1785
1968	**Millport**	UK	Scotland (UK)	UK NOC	55.7500	-4.9100	55.7105	-4.9680
1987	**Stornoway**	UK	Scotland (UK)	UK NOC	58.2100	-6.3900	58.1378	-6.2930
1983	**Wic**	UK	Scotland (UK)	UK NOC	58.4400	-3.0900	58.4402	-3.0327
1985	**Lerwick**	UK	Scotland (UK)	UK NOC	60.1500	-1.1400	60.1469	-1.0774
1963	**Leith**	UK	Scotland (UK)	UK NOC	55.9900	-3.1800	56.0644	-3.0204
1982	**Whitby**	UK	England, Wales, E UK	UK NOC	54.4900	-0.6100	54.5462	-0.5445
1966	**Lowestoft**	UK	England, Wales, E UK	UK NOC	52.4700	1.7500	52.4359	1.8163
1977	**Sheerness**	UK	England, Wales, E UK	UK NOC	51.4500	0.7400	51.4668	0.7401
1970	**Newhaven**	UK	England, Wales, E UK	UK NOC	50.7800	0.0600	50.6803	0.0117
1973	**Plymouth**	UK	England, Wales, E UK	UK NOC	50.3700	-4.1900	50.2940	-4.2085
1958	**Holyhead**	UK	England, Wales, E UK	UK NOC	53.3100	-4.6200	53.4000	-4.6670
1984	**Workington**	UK	England, Wales, E UK	UK NOC	54.6500	-3.5700	54.6670	-3.6395
1964	**Liverpool**	UK	England, Wales, E UK	UK NOC	53.4500	-3.0200	53.5026	-3.1829
1967	**Milford Haven**	UK	England, Wales, E UK	UK NOC	51.7100	-5.0500	51.6068	-5.1123
1971	**Newport**	UK	England, Wales, E UK	UK NOC	51.5500	-2.9900	51.4989	-2.9042
1986	**Newlyn**	UK	England, Wales, E UK	UK NOC	50.1000	-5.5400	50.0243	-5.5078
1959	**Ilfracombe**	UK	England, Wales, E UK	UK NOC	51.2100	-4.1100	51.3034	-4.1691

Table 10 - *Buoy and sensor locations included in the SSCS UK & Irleand bulletin.*

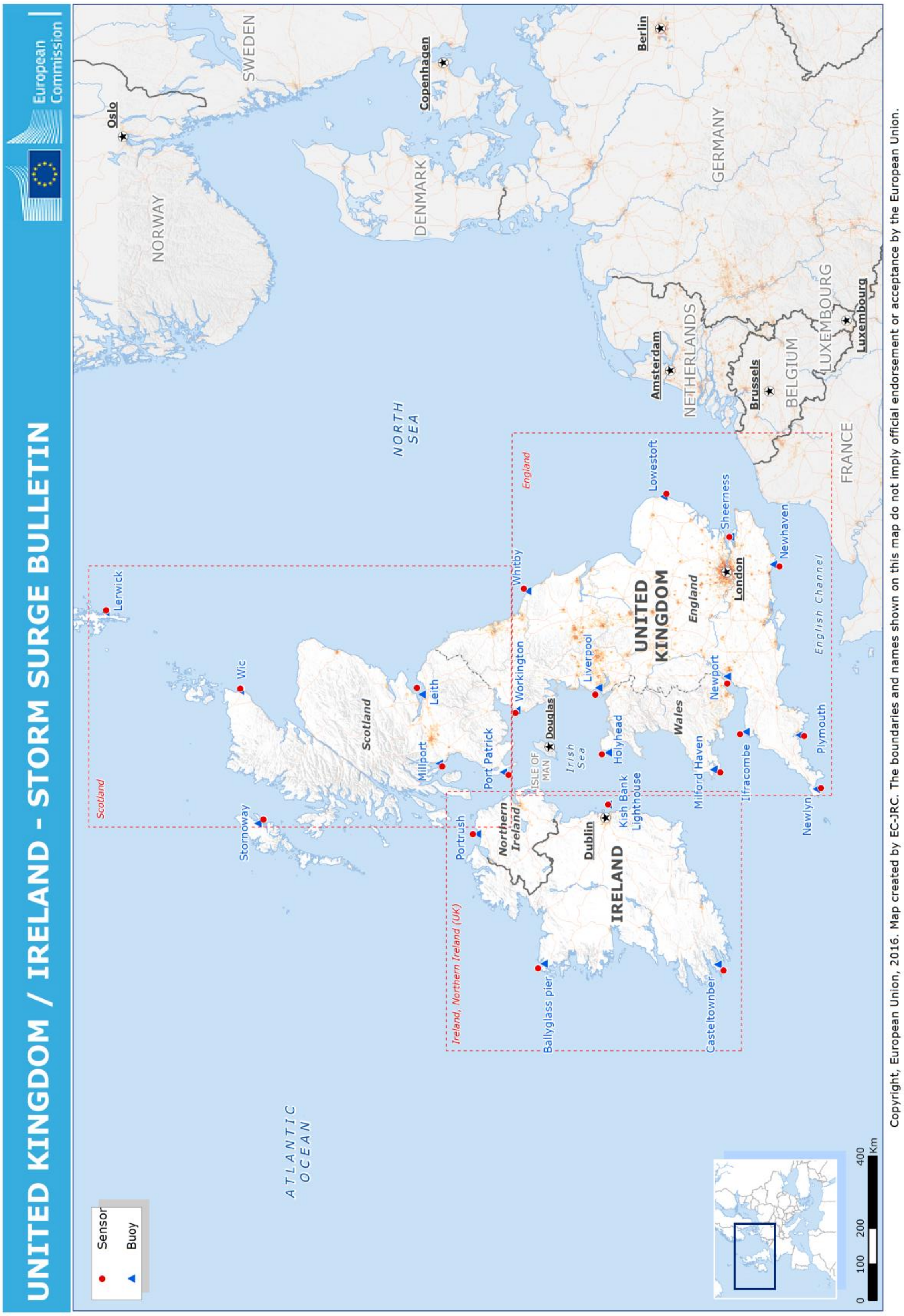


Figure 19 - *Locations of the sensors and buoys of the UK -SSCS bulletin.*

5.2.2 North Sea

The ***"North Sea storm surge bulletin"*** covers the North Sea and provides the storm surge for several countries (UK, FR, NL, DE, DK, NO and SE).

The sea level data of UK NOC, GLOSS, RWS-NL (Rijkswaterstaat - Ministry of Infrastructure and the Environment of the Netherland) are used in this bulletin.

For this bulletin, JRC has prepared also a second version, that includes the total water levels (tides + storm surge) in order to identify the most dangerous storm surge case, i.e. when a storm surge event occurs during a period of high tide.

Atmospheric input: ECMWF. Code: HyFlux2.

NORTH SEA SSCS Bulletin: General Info	
Total nr. Buoys	**18**
Areas analysed	3
Area 1	UK, FR, NL
Area 2	DE, DK
Area 3	NO, SE
Nr. Webcams	2

Table 11 - *As in Table 9, but for the North Sea SSCS bulletin.*

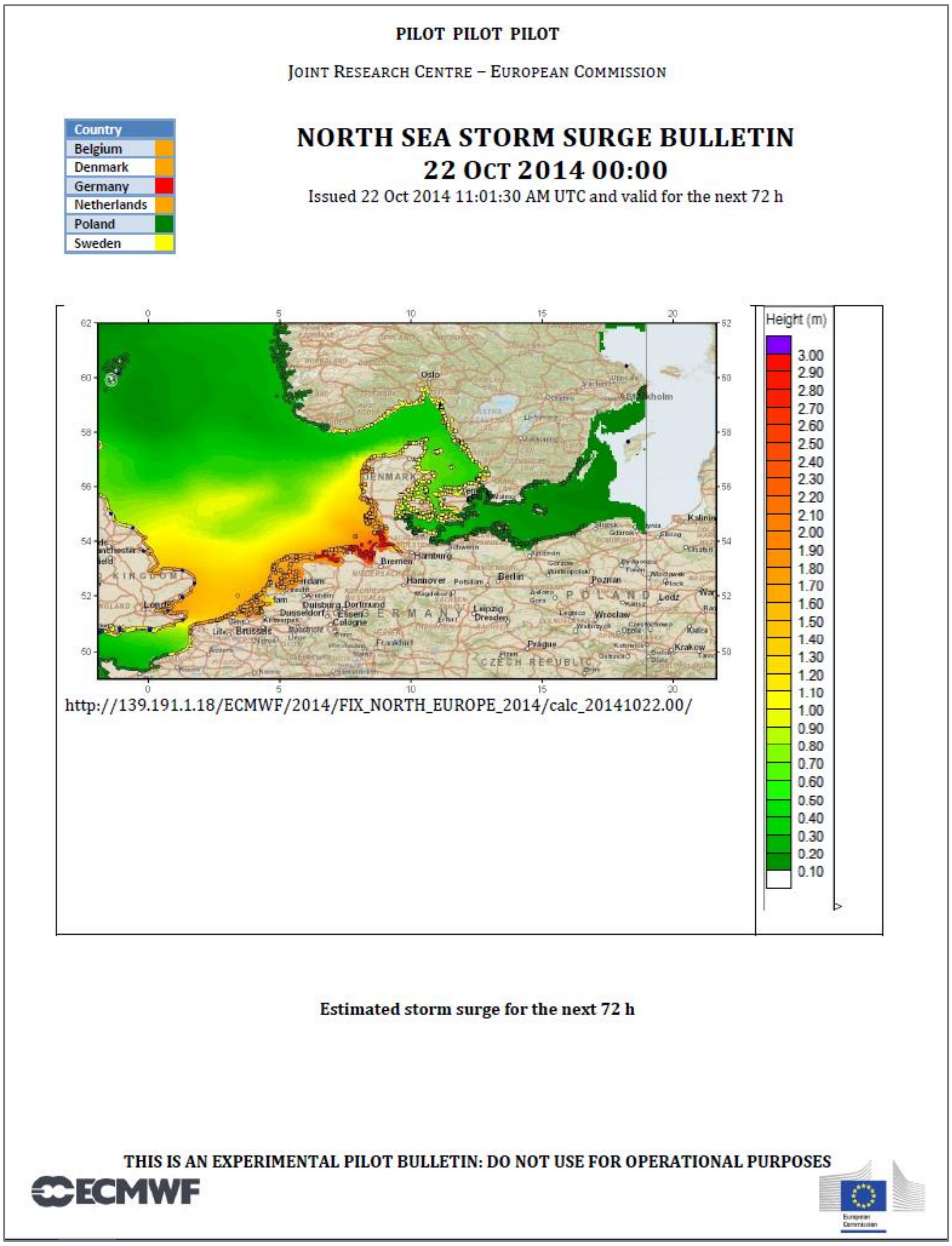


Figure 20 - *As in Figure 18, but for the North Sea.*

NORTH SEA – SSCS BULLETIN								
ID	**Name**	**Country**	**Area**	**Source**	**buoy location**		**sensor location**	
					lat	lon	lat	lon
1966	**Lowestoft**	UK	UK, FR, NL	UK NOC	52.4700	1.7500	52.4359	1.8163
1444	**Calais**	FR	UK, FR, NL	GLOSS	50.9690	1.8680	51.0133	1.8936
1877	**Dunquerque**	FR	UK, FR, NL	GLOSS	51.0481	2.3667	51.0481	2.3667
2028	**Europlatform**	NL	UK, FR, NL	RWS/NL	52.0073	3.4032	52.0073	3.4032
2027	**Scheveningen**	NL	UK, FR, NL	RWS/NL	52.0991	4.2630	52.1741	4.1633
2030	**Terchellinh Nordzee**	NL	UK, FR, NL	RWS/NL	53.4738	5.3967	53.4738	5.3967
1494	**Borkum**	DE	DE, DK	GLOSS	53.5570	6.7490	53.5570	6.7490
1511	**Helgoland Binnenhafen**	DE	DE, DK	GLOSS	54.1760	7.8910	54.1760	7.8910
1512	**Hörnum**	DE	DE, DK	GLOSS	54.7580	8.2970	54.7580	8.2970
853	**Cuxhaven**	DE	DE, DK	GLOSS	53.8678	8.7175	53.8678	8.7175
894	**Hitrschal**	DK	DE, DK	GLOSS	57.6000	9.9700	57.6528	9.9282
1517	**LT Kiel**	DE	DE, DK	GLOSS	54.5000	10.2750	54.5000	10.2750
1708	**Warnemünde**	DE	DE, DK	GLOSS	54.1697	12.1033	54.2039	12.0735
1582	**Sassnitz**	DE	DE, DK	GLOSS	54.5110	13.6430	54.5120	13.7671
1703	**Tregde**	NO	NO, SE	GLOSS	58.0000	7.5667	57.8670	7.5455
1005	**Smogen**	SE	NO, SE	GLOSS	58.3500	11.2160	58.3669	11.1455
886	**Goteborg**	SE	NO, SE	GLOSS	57.6830	11.7830	57.5583	11.7048
1011	**Stockholm**	SE	NO, SE	GLOSS	59.3160	18.0830	58.9640	18.2269

Table 12 *- As in Table 10, but for the North Sea.*

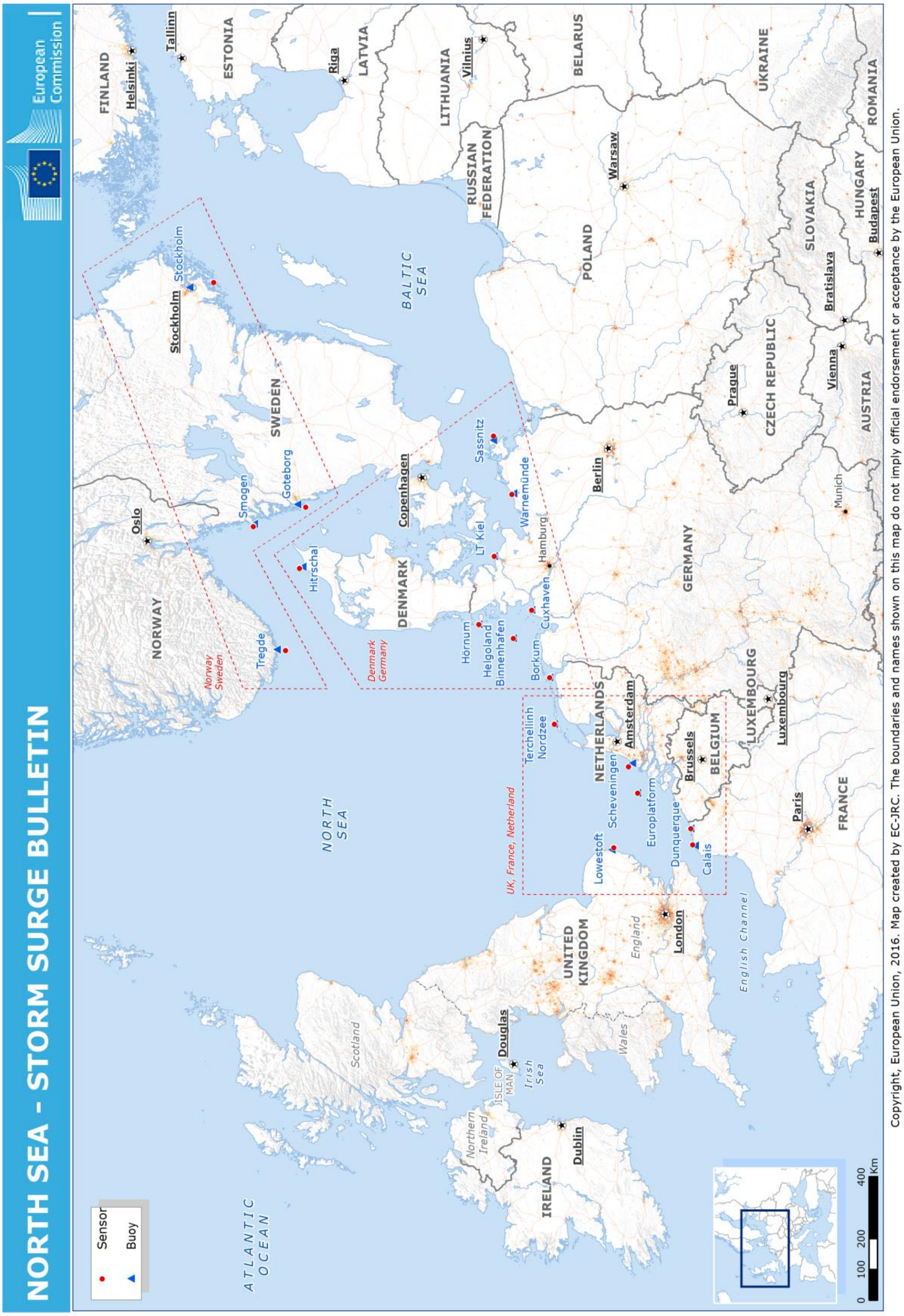


Figure 21 - *As in Figure 19, but for the North Sea.*

5.2.3 Mediterranean Sea

The ***"Mediterranean Sea Storm Surge bulletin"*** covers the Mediterranean Sea and the Black Sea. This bulletin provides the storm surge for several countries:

ES, FR, IT, SI, HR, BA, ME, AL, GR, BG, RO, TR, RU, SY, LB, IL, MA, PS, LY, TN, DZ, GI.

The sea level data of GLOSS, ISPRA, JRC, NOA (National Observatory of Athens) and KOERI (Kandilli Observatory and Earthquake Research Institute) are included in this bulletin.

Atmospheric input: ECMWF. Code: HyFlux2.

Mediterranean Sea SSCS Bulletin General Info	
Total nr. Buoys	38
Areas analysed	5
Area 1	West Med
Area 2	Central Med
Area 3	East Med
Area 4	Middle East
Area 5	Black Sea
Nr. Webcams	6

Table 13 - *As in Table 9, but for the Mediterranean Sea SSCS bulletin.*

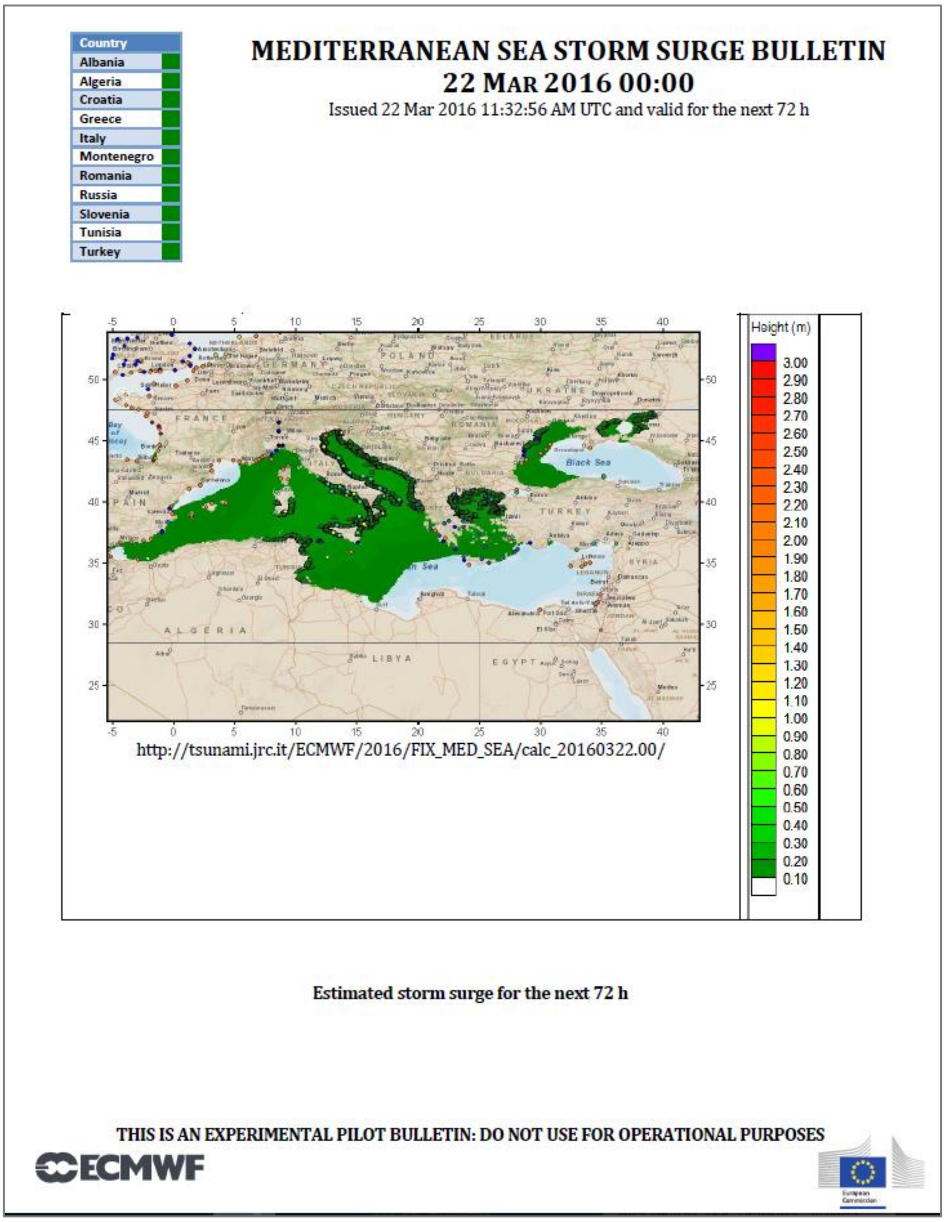


Figure 22 - *As in Figure 18, but for the Mediterranean Sea bulletin.*

MEDITERRANEAN SEA – SSCS BULLETIN								
ID	**NAME**	**Country**	**Area**	**Source**	**buoy location**		**sensor location**	
					lat	lon	lat	lon
1630	**Almeira**	ES	West Med	GLOSS	36.8300	-2.4783	36.7251	-2.4684
1706	**Valencia**	ES	West Med	GLOSS	39.4400	-0.3100	39.4404	-0.2990
819	**Barcelona**	ES	West Med	GLOSS	41.3400	2.1600	41.2775	2.2139
1449	**Ibiza**	ES	West Med	GLOSS	38.9170	1.4500	38.7903	1.4510
1461	**Palma de Mallorca**	ES	West Med	GLOSS	39.5600	2.6380	39.3946	2.6146
100080	**Cartagena**	ES	West Med	JRC	37.5671	-0.9790	37.4528	-0.9823
1741	**Sète**	FR	West Med	GLOSS	43.3976	3.6991	43.3186	3.7612
1721	**Cannes**	FR	West Med	GLOSS	43.4835	6.9338	43.4424	6.9713
1500	**Corsica, Centuri**	FR	Central Med	GLOSS	42.9670	9.3500	43.0953	9.2670
1862	**Porto Torres**	IT	Central Med	ISPRA	40.8422	8.4039	40.9625	8.4032
1841	**Carloforte**	IT	Central Med	ISPRA	39.1480	8.3095	39.2260	8.2312
1848	**Imperia**	IT	Central Med	ISPRA	43.8783	8.0189	43.8306	8.1495
1846	**Genova**	IT	Central Med	ISPRA	44.4101	8.9255	44.3226	8.9194
1843	**Civitavecchia**	IT	Central Med	ISPRA	42.0940	11.7896	41.9992	11.6773
1855	**Napoli**	IT	Central Med	ISPRA	40.8414	14.2692	40.6634	14.2085
1847	**Ginostra**	IT	Central Med	ISPRA	38.7852	15.1908	38.7852	15.2018
1858	**Palermo**	IT	Central Med	ISPRA	38.1214	13.3713	38.1696	13.4596
1851	**Lampedusa**	IT	Central Med	ISPRA	35.4998	12.6044	35.4804	12.6074
100083	**Pantelleria**	IT	Central Med	JRC	36.8348	11.9366	36.8557	11.9248
100084	**Portopalo**	IT	Central Med	JRC	36.6691	15.1228	36.6643	15.1286
1844	**Crotone**	IT	Central Med	ISPRA	39.0836	17.1371	39.0581	17.2090
1866	**S. Benedetto del Tronto**	IT	Central Med	ISPRA	42.9551	13.8898	42.9652	13.9770
1870	**Venezia**	IT	Central Med	ISPRA	45.4182	12.4265	45.3897	12.4368
1452	**Katakolo**	GR	East Med	GLOSS	37.6400	21.3190	37.5958	21.3268
2003	**Paleochora**	GR	East Med	JRC/NOA	35.2240	23.6786	35.2000	23.6747
2001	**Kapsali** *(Kythira)*	GR	East Med	JRC/NOA	36.1418	23.0037	36.0658	23.0076
2005	**Koroni**	GR	East Med	JRC/NOA	36.7975	21.9628	36.7933	22.0114
1463	**Peiraias**	GR	East Med	GLOSS	37.9350	23.6210	37.8187	23.5523
2361	**Kalathos**	GR	Central Med	NOA	36.1139	28.0696	36.1120	28.1456
100086	**Corinth**	GR	East Med	JRC	37.9452	22.9365	38.1271	22.8793
100088	**Fethiye**	TR	East Med	JRC	36.6207	29.0922	36.4501	28.9677
1889	**Iskenderum**	TR	East Med	KOERI	36.5942	36.1768	36.6606	36.0586
2031	**Gokceada**	TR	East Med	KOERI	40.2330	25.8940	40.2462	25.9877
2367	**Ashkelon**	IL	Middle East	GLOSS	31.6349	34.4938	31.6782	34.4268
1440	**Alexandria**	EG	Middle East	GLOSS	31.2110	29.9240	31.3138	29.8762
100091	**Mangalia**	RO	Black Sea	JRC	43.8014	28.5952	43.7998	28.6778
100092	**Constanta**	RO	Black Sea	JRC	44.1475	28.6720	44.2063	28.6843
100093	**Sulina**	RO	Black Sea	JRC	45.1622	29.7272	45.1468	29.7419

Table 14 - *As in Table 10, but for the Mediterranean Sea SSCS bulletin.*

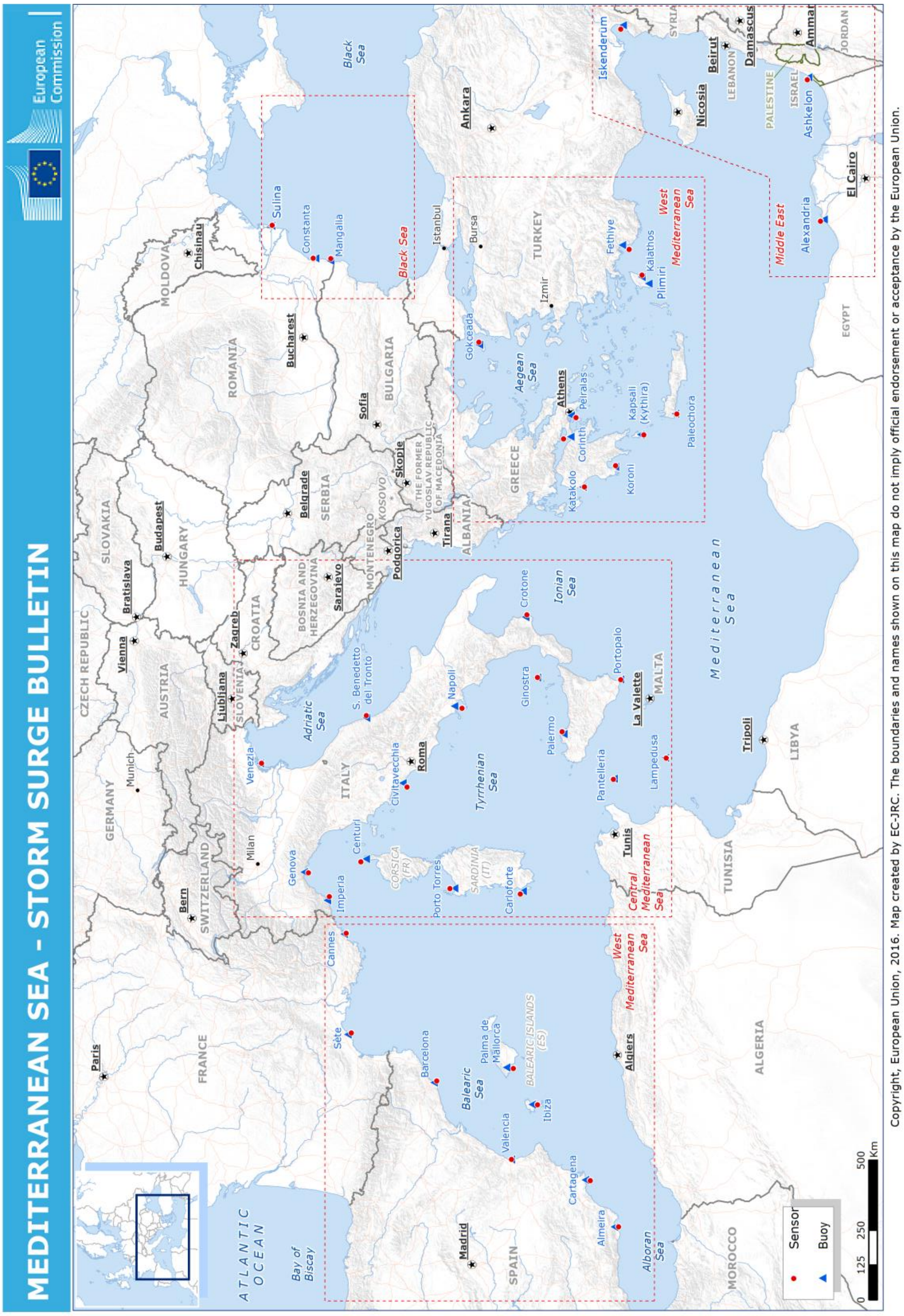


Figure 23 - *As in Figure 19, but for the Mediterranean Sea SSCS bulletin.*

5.2.4 Italy (ECMWF)

The ***"Italy (ECMWF) Storm Surge bulletin"*** covers the Italian coasts of the Mediterranean Sea, as well as the coast of other countries along the Tyrrhenian and Adriatic Sea like: FR, IT, SI, HR, BA, ME, AL, GR. However only the locations of Italy and south-east France and Corsica are included in the bulletin.

The sea level data of ISPRA (*"Istituto Superiore per la Protezione e la Ricerca Ambientale"*), GLOSS and JRC are included in this bulletin.

Atmospheric input: ECMWF. Code: HyFlux2.

Italy SSCS Bulletin: General Info	
Total nr. Buoys	24
Areas analysed	2
Area 1	France
Area 2	Italy
Nr. Webcams	6

Table 15 - *As in Table 9, but for the Italy (ECMWF) SSCS bulletin.*

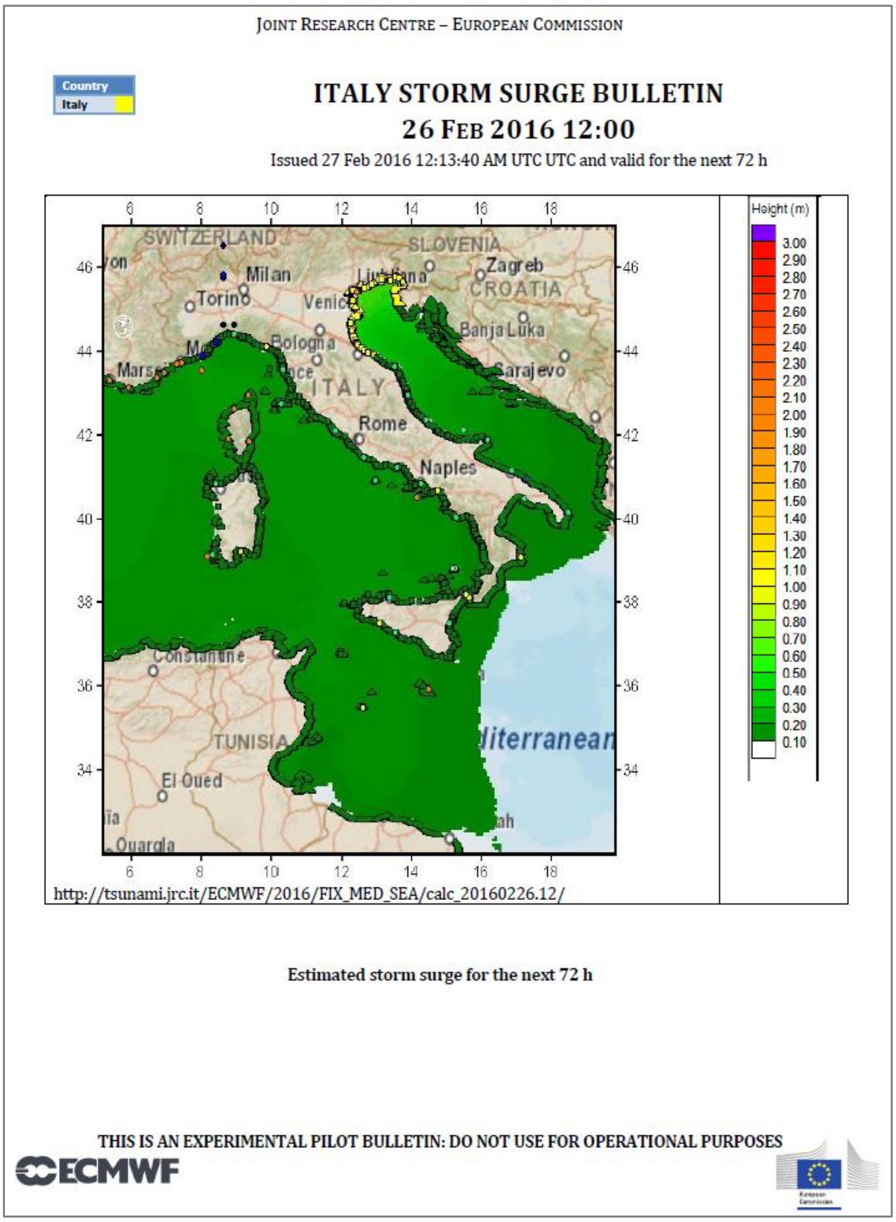


Figure 24 - *As in Figure 18, but for the Italy (ECMWF) SSCS bulletin.*

ITALY – SSCS BULLETIN								
ID	**NAME**	**Country**	**Area**	**Source**	**buoy location**		**sensor location**	
					lat	lon	lat	lon
1721	**Cannes**	FR	France	GLOSS	43.4835	6.9338	43.4424	6.9713
1500	**Corsica, Centuri**	FR	France	GLOSS	42.9670	9.3500	43.0953	9.2670
1846	**Genova**	IT	Italy	ISPRA	44.4101	8.9255	44.3226	8.9194
1848	**Imperia**	IT	Italy	ISPRA	43.8783	8.0189	43.8306	8.1495
1852	**Livorno**	IT	Italy	ISPRA	43.5463	10.2993	43.5130	10.1925
1843	**Civitavecchia**	IT	Italy	ISPRA	42.0940	11.7896	41.9992	11.6773
1841	**Carloforte**	IT	Italy	ISPRA	39.1480	8.3095	39.2260	8.2312
1862	**Porto Torres**	IT	Italy	ISPRA	40.8422	8.4039	40.9625	8.4032
1855	**Napoli**	IT	Italy	ISPRA	40.8414	14.2692	40.6634	14.2085
1858	**Palermo**	IT	Italy	ISPRA	38.1214	13.3713	38.1696	13.4596
1847	**Ginostra**	IT	Italy	ISPRA	38.7852	15.1908	38.7852	15.2018
2026	**Strombolicchio**	IT	Italy	ISPRA	38.8173	15.2518	38.8118	15.2770
100083	**Pantelleria**	IT	Italy	JRC	36.8348	11.9366	36.8557	11.9248
100084	**Portopalo**	IT	Italy	JRC	36.6691	15.1228	36.6643	15.1286
1851	**Lampedusa**	IT	Italy	ISPRA	35.4998	12.6044	35.4804	12.6074
1842	**Catania**	IT	Italy	ISPRA	37.4981	15.0938	37.4466	15.1500
1844	**Crotone**	IT	Italy	ISPRA	39.0836	17.1371	39.0581	17.2090
1857	**Otranto**	IT	Italy	ISPRA	40.1471	18.4971	40.1252	18.5338
1871	**Vieste**	IT	Italy	ISPRA	41.8881	16.1770	41.9250	16.2855
1866	**S. Benedetto del Tronto**	IT	Italy	ISPRA	42.9551	13.8898	42.9652	13.9770
1837	**Ancona**	IT	Italy	ISPRA	43.6248	13.5065	43.7244	13.5411
1870	**Venice**	IT	Italy	ISPRA	45.4182	12.4265	45.3897	12.4368
1869	**Trieste**	IT	Italy	ISPRA	45.6494	13.7579	45.6293	13.5527
1863	**Ravenna**	IT	Italy	ISPRA	44.4921	12.2827	44.4955	12.3868

Table 16 - *As in Table 10, but for the Italy (ECMWF) SSCS bulletin.*

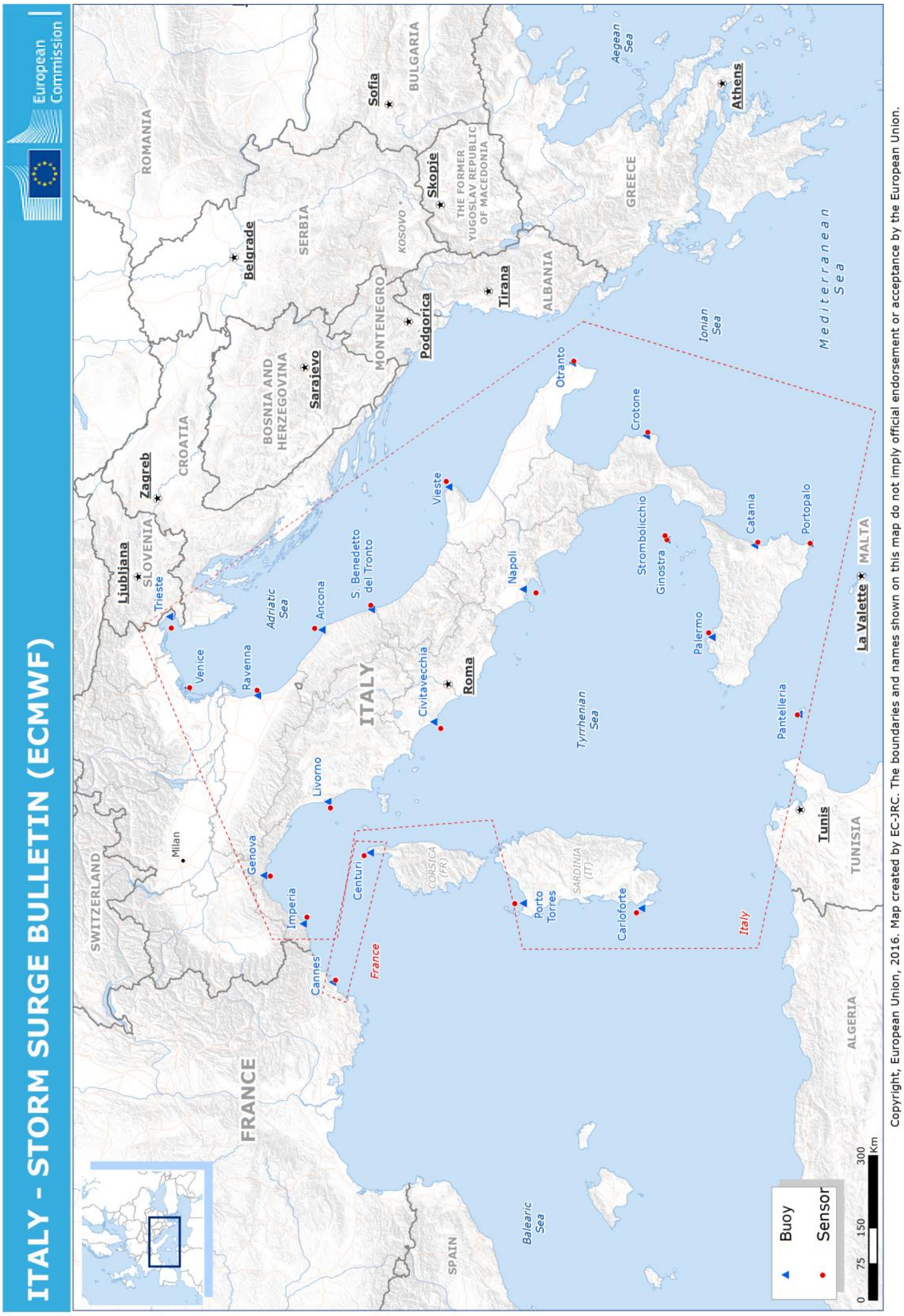


Figure 25 - *As in Figure 19, but for the Italy (ECMWF) SSCS bulletin.*

5.2.5 Italy (AM COSMO-ME)

The **"Italy (AM COSMO-ME) storm surge bulletin"** is similar to the bulletin described in the previous Section, but a different source for the atmospheric forcing is used: COSMO-ME AM instead of ECMWF (see Section 3). The runs used are: 00 and 12 UTC. This bulletin covers the Italian coasts of the Mediterranean Sea. The south-east France and Corsica are also included in the bulletin.

The sea level date of ISPRA and JRC are included.

In this bulletin, two different graphics are included:
- LEFT: Sea levels (TWL), that is the real sea level measured: Storm Surge (SS) plus tide (TD): TWL= SS+TD
- RIGHT: Storm Surge (SS), that is the Sea Level (TWL) minus tide (TD): SS=TWL-TD

Atmospheric input: AM COSMO-ME. Code: HyFlux2.

Italy AM COSMO-ME SSCS Bulletin: General Info	
Total nr. Buoys	24
Areas analysed	2
Area 1	France
Area 2	Italy
Nr. Webcams	6

Table 17 - *As in Table 10, but for ITALY AM COSMO-ME*

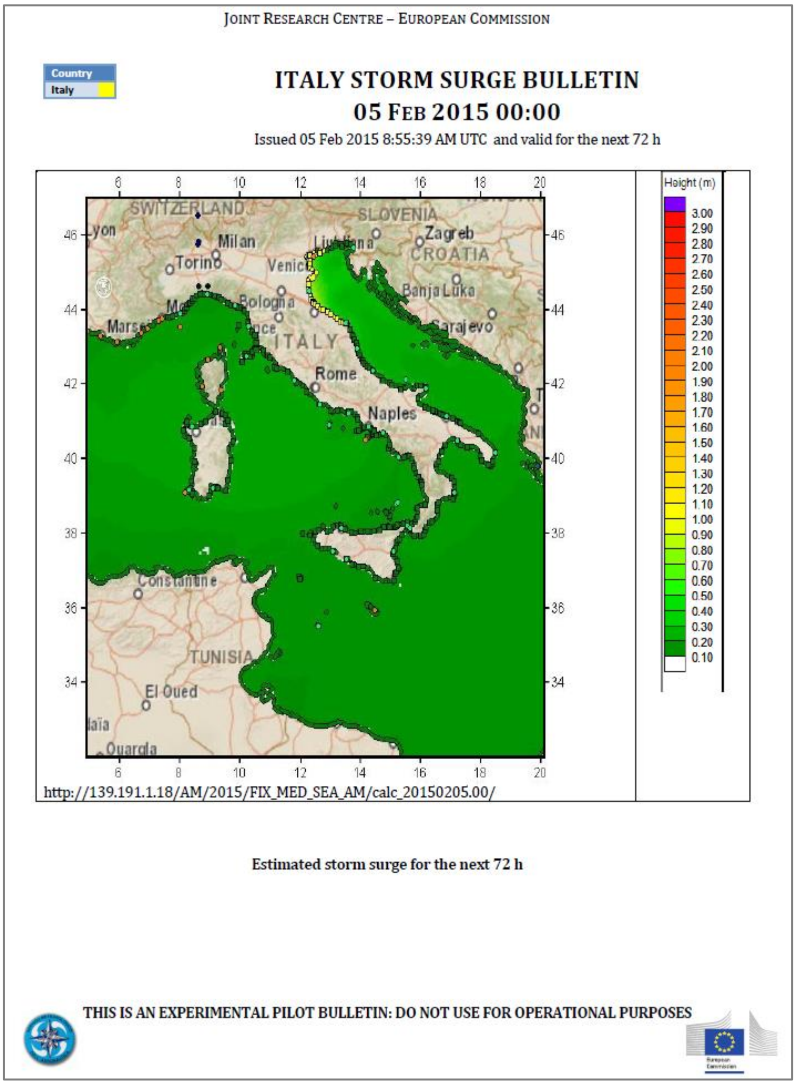


Figure 26 - *As in Figure 18, but for the ITALY AM SSCS bulletin.*

ITALY AM COSMO-ME– SSCS BULLETIN								
ID	NAME	Country	Area	Source	buoy location		sensor location	
					lat	lon	lat	lon
1721	**Cannes**	FR	France	GLOSS	43.4835	6.9338	43.4424	6.9713
1500	**Corsica, Centuri**	FR	France	GLOSS	42.9670	9.3500	43.0953	9.2670
1846	**Genova**	IT	Italy	ISPRA	44.4101	8.9255	44.3226	8.9194
1848	**Imperia**	IT	Italy	ISPRA	43.8783	8.0189	43.8306	8.1495
1852	**Livorno**	IT	Italy	ISPRA	43.5463	10.2993	43.5130	10.1925
1843	**Civitavecchia**	IT	Italy	ISPRA	42.0940	11.7896	41.9992	11.6773
1841	**Carloforte**	IT	Italy	ISPRA	39.1480	8.3095	39.2260	8.2312
1862	**Porto Torres**	IT	Italy	ISPRA	40.8422	8.4039	40.9625	8.4032
1855	**Napoli**	IT	Italy	ISPRA	40.8414	14.2692	40.6634	14.2085
1858	**Palermo**	IT	Italy	ISPRA	38.1214	13.3713	38.1696	13.4596
1847	**Ginostra**	IT	Italy	ISPRA	38.7852	15.1908	38.7852	15.2018
100083	**Pantelleria**	IT	Italy	JRC	36.83483	11.9366	36.8557	11.9248
100084	**Portopalo**	IT	Italy	JRC	36.66912	15.1228	36.6643	15.1286
1851	**Lampedusa**	IT	Italy	ISPRA	35.4998	12.6044	35.4804	12.6074
1842	**Catania**	IT	Italy	ISPRA	37.4981	15.0938	37.4466	15.1500
1844	**Crotone**	IT	Italy	ISPRA	39.0836	17.1371	39.0581	17.2090
1857	**Otranto**	IT	Italy	ISPRA	40.1471	18.4971	40.1252	18.5338
1871	**Vieste**	IT	Italy	ISPRA	41.8881	16.1770	41.9250	16.2855
1866	**S. Benedetto del Tronto**	IT	Italy	ISPRA	42.9551	13.8898	42.9652	13.9770
1856	**Ortona**	IT	Italy	ISPRA	42.3559	14.4149	42.4455	14.5586
1837	**Ancona**	IT	Italy	ISPRA	43.6248	13.5065	43.7244	13.5411
1863	**Ravenna**	IT	Italy	ISPRA	44.4921	12.2827	44.4955	12.3868
1870	**Venezia**	IT	Italy	ISPRA	45.4182	12.4265	45.3897	12.4368
1869	**Trieste**	IT	Italy	ISPRA	45.6494	13.7579	45.6293	13.5527

Table 18 - *As in Table 10, but for Italy AM COSMO-ME SSCS bulletin.*

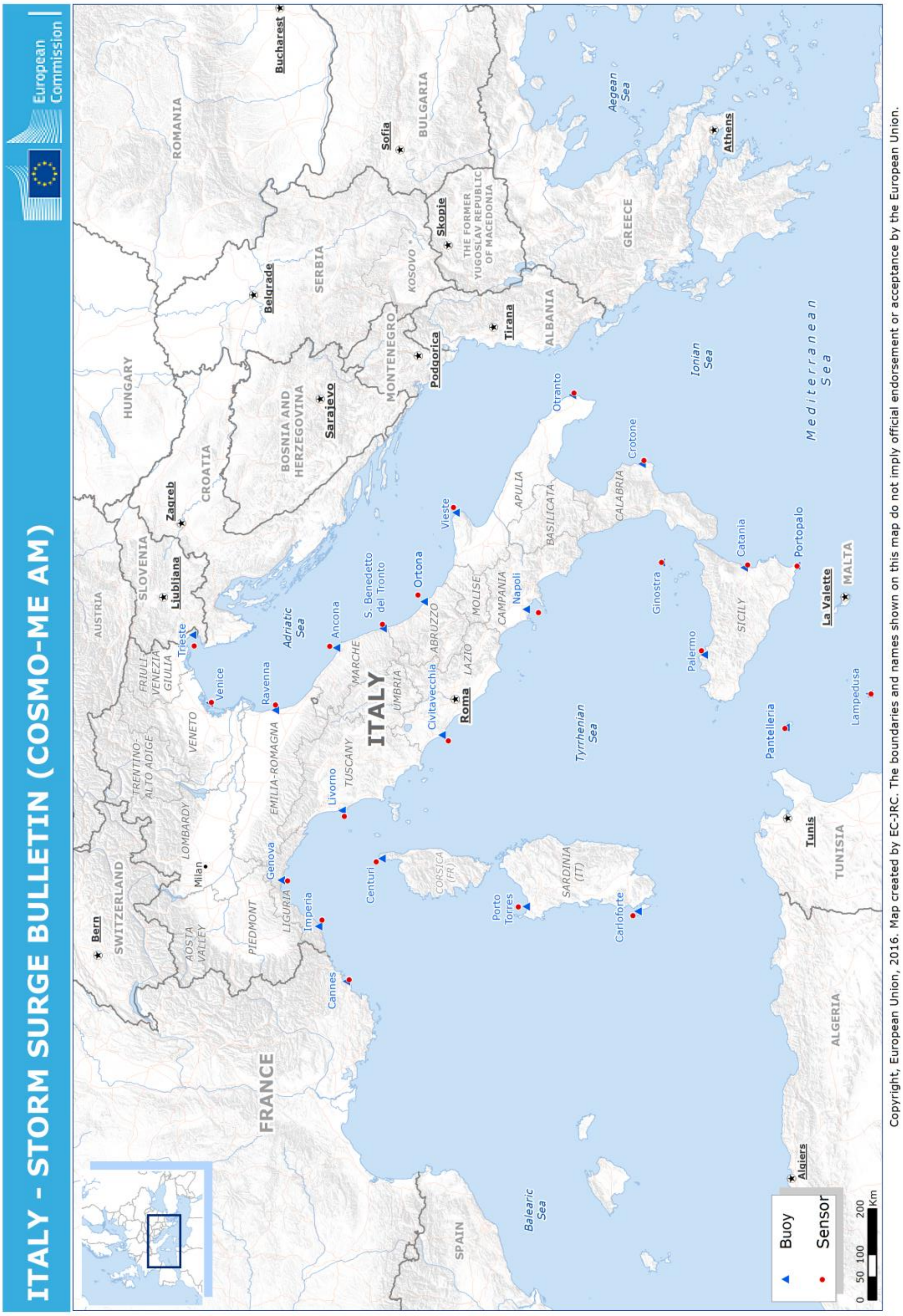


Figure 27 - *As in Figure 19, but for the ITALY COSMO-ME SSCS bulletin.*

5.2.6 Italy (Ensemble)

In the **"Italy (ENSEMBLE) Storm Surge bulletin"** the results of the JRC calculations that use as input as input the ECMWF (see Section 5.2.4) and AM COSMO-ME (see Section 5.2.5) are included. For a number of locations these calculations are also compared with the results of KASSANDRA model (see description in Section 5.1).

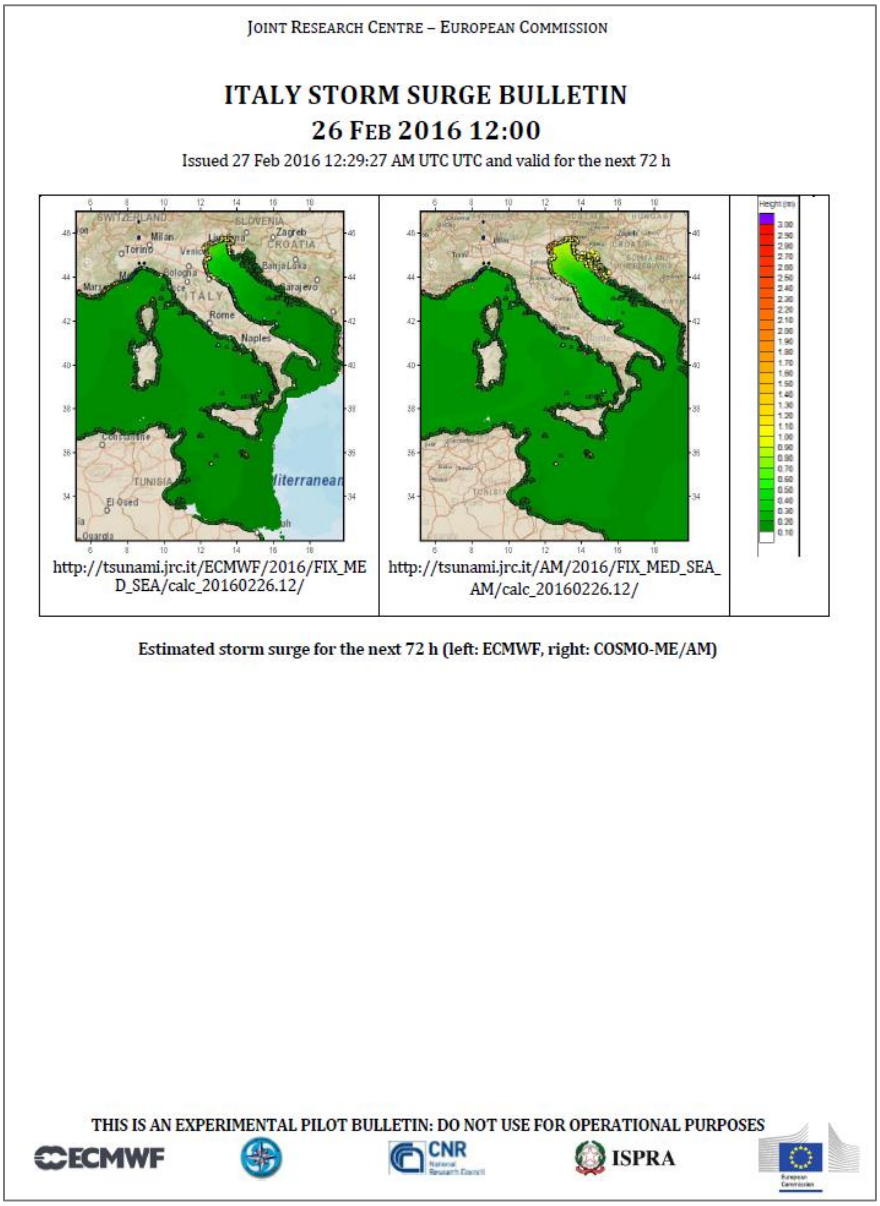
The sea level date of ISPRA and JRC are included.

Atmospheric inputs: ECMWF, AM COSMO-ME.

Codes: HyFlux2 and recently also the results obtained using Delft3D (atmospheric source: ECMWF).

Italy ENSEMBLE SSCS Bulletin General Info	
Total nr. Buoys	22
Areas analysed	2
Area 1	France
Area 2	Italy
Nr. Webcams	6

Table 19 *- As in Table 9, but for the ITALY ENSEMBLE SSCS bulletin.*



JOINT RESEARCH CENTRE – EUROPEAN COMMISSION

ITALY STORM SURGE BULLETIN

26 FEB 2016 12:00

Issued 27 Feb 2016 12:29:27 AM UTC UTC and valid for the next 72 h

http://tsunami.jrc.it/ECMWF/2016/FIX_MED_SEA/calc_20160226.12/

http://tsunami.jrc.it/AM/2016/FIX_MED_SEA_AM/calc_20160226.12/

Estimated storm surge for the next 72 h (left: ECMWF, right: COSMO-ME/AM)

THIS IS AN EXPERIMENTAL PILOT BULLETIN: DO NOT USE FOR OPERATIONAL PURPOSES

Figure 28 - *As in Figure 18, but for the ITALY ENSEMBLE SSCS bulletin.*

ITALY ENSEMBLE SSCS BULLETIN								
ID	**NAME**	**Country**	**Area**	**Source**	**buoy location**		**sensor location ECMWF/AM**	
					lat	lon	lat	lon
1846	**Genova**	IT	Italy	ISPRA	44.4101	8.9255	44.3226	8.9194
1848	**Imperia**	IT	Italy	ISPRA	43.8783	8.0189	43.8306	8.1495
1852	**Livorno**	IT	Italy	ISPRA	43.5463	10.2993	43.5130	10.1925
1843	**Civitavecchia**	IT	Italy	ISPRA	42.0940	11.7896	41.9992	11.6773
1841	**Carloforte**	IT	Italy	ISPRA	39.1480	8.3095	39.2260	8.2312
1862	**Porto Torres**	IT	Italy	ISPRA	40.8422	8.4039	40.9625	8.4032
1855	**Napoli**	IT	Italy	ISPRA	40.8414	14.2692	40.6634	14.2085
1858	**Palermo**	IT	Italy	ISPRA	38.1214	13.3713	38.1696	13.4596
1847	**Ginostra**	IT	Italy	ISPRA	38.7852	15.1908	38.7852	15.2018
2026	**Strombolicchio**	IT	Italy	ISPRA	38.8173	15.2518	38.8118	15.2770
100083	**Pantelleria**	IT	Italy	JRC	36.83483	11.9366	36.8557	11.9248
100084	**Portopalo**	IT	Italy	JRC	36.66912	15.1228	36.6643	15.1286
1851	**Lampedusa**	IT	Italy	ISPRA	35.4998	12.6044	35.4804	12.6074
1842	**Catania**	IT	Italy	ISPRA	37.4981	15.0938	37.4466	15.1500
1844	**Crotone**	IT	Italy	ISPRA	39.0836	17.1371	39.0581	17.2090
1857	**Otranto**	IT	Italy	ISPRA	40.1471	18.4971	40.1252	18.5338
1871	**Vieste**	IT	Italy	ISPRA	41.8881	16.1770	41.9250	16.2855
1856	**Ortona**	IT	Italy	ISPRA	42.3559	14.4149	42.4455	14.5586
1837	**Ancona**	IT	Italy	ISPRA	43.6248	13.5065	43.7244	13.5411
1870	**Venezia**	IT	Italy	ISPRA	45.4182	12.4265	45.3897	12.4368
1869	**Trieste**	IT	Italy	ISPRA	45.6494	13.7579	45.6293	13.55267
1863	**Ravenna**	IT	Italy	ISPRA	44.4921	12.2827	44.4955	12.3868

Table 20 - *As in Table 10, but for the Italy Ensemble SSCS bulletin.*

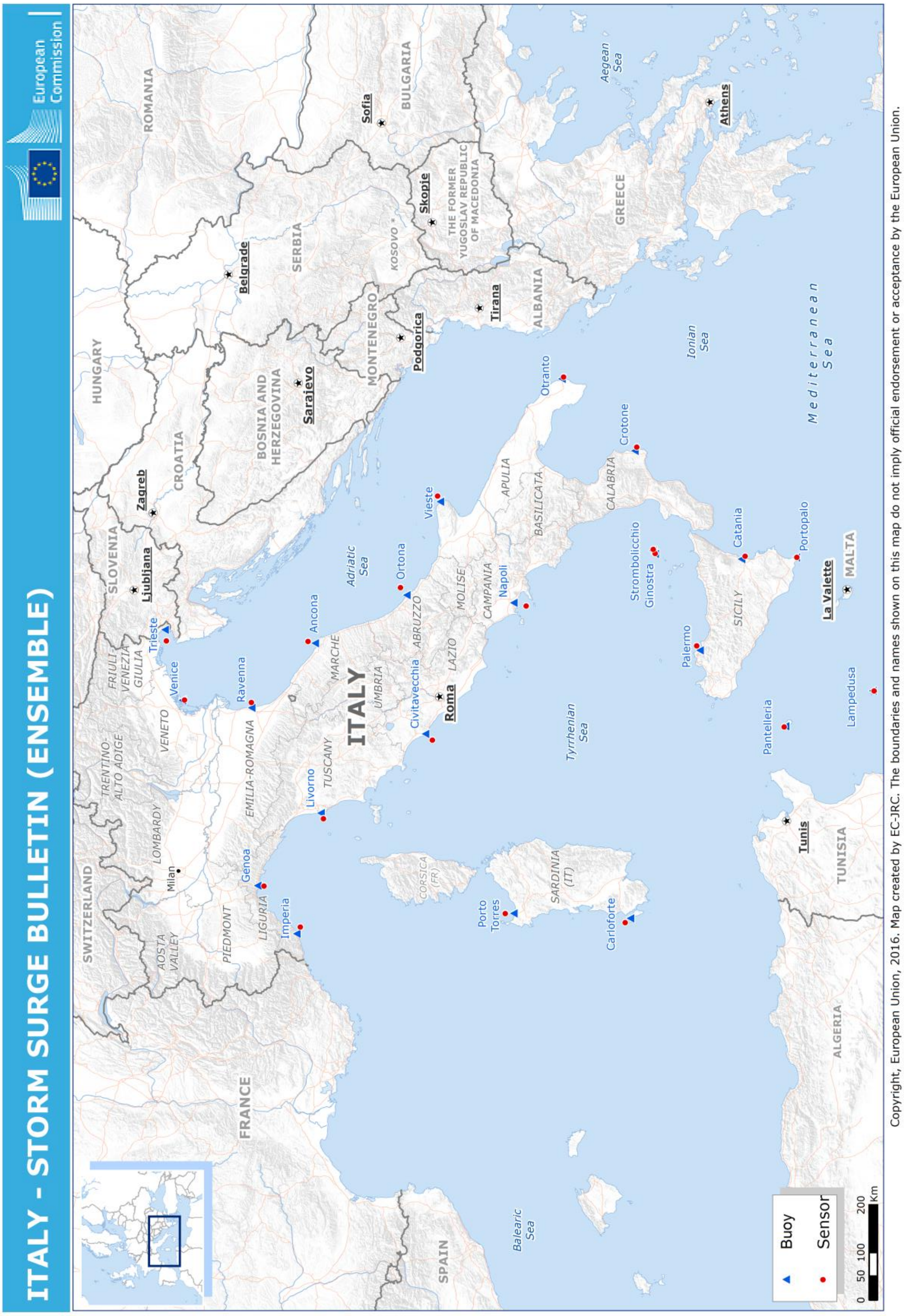


Figure 29 - *As in Figure 19, but for the Italy - ENSEMBLE SSCS bulletin.*

5.2.7 Greece (HNMS)

The ***"Greece (HNMS) Storm Surge bulletin"*** covers the Aegean Sea. This bulletin provides the storm surge for Greece. Two different versions of this bulletins are available: one in English and another one in Greek. The sea level date of GLOSS, ISPRA, KOERI, NOA, JRC are used in this bulletin.

Atmospheric input: HNMS

Greece SSCS Bulletin: General Info	
Total nr. Buoys	18
Areas analysed	5
Area 1	Italy
Area 2	Greece
Area 3	Turkey

Table 21 - *As in Table 9, but for the Greece SSCS Bulletin.*

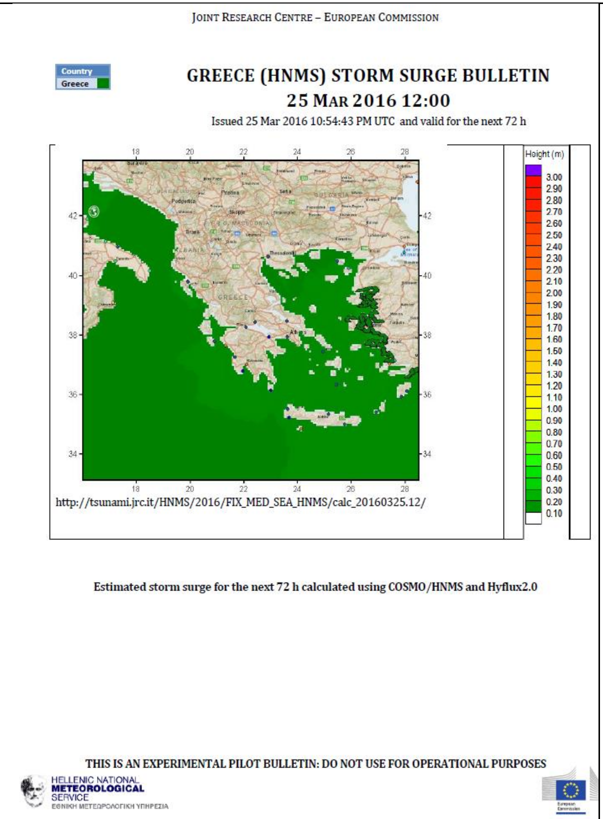


Figure 30 - *As in Figure 18, but for the Greece SSCS bulletin (English version).*

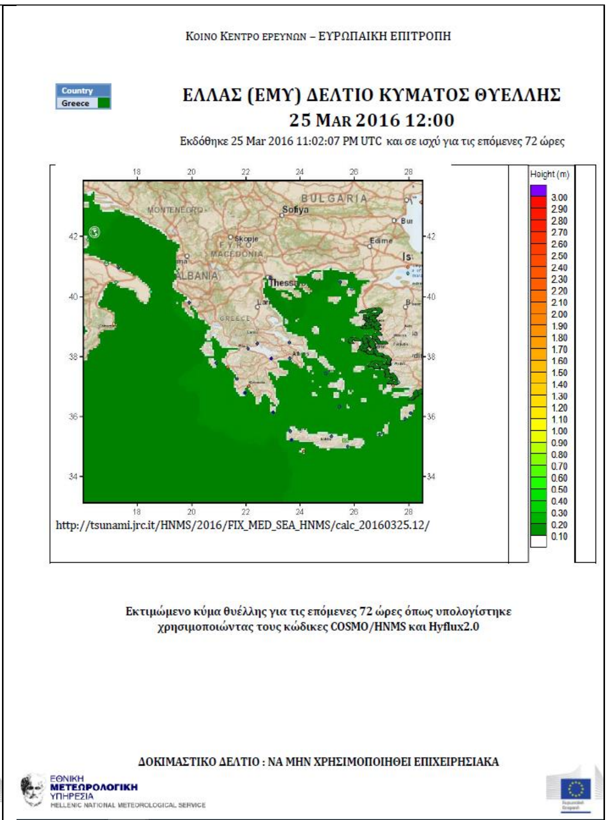


Figure 31 - *As in Figure 30, but in Greek. Greece SSCS bulletin (Greek version).*

GREECE SSCS BULLETIN								
ID	NAME	Country	Area	Source	buoy location		sensor location	
					lat	lon	lat	lon
1839	Bari	IT	Italy	ISPRA	41.1402	16.866	41.1966	16.8832
1868	Taranto	IT	Italy	ISPRA	40.4756	17.2238	40.2945	17.1107
1857	Otranto	IT	Italy	ISPRA	40.1471	18.4971	40.1252	18.5338
2037	Kerkira	GR	Greece	NOA	39.7902	19.9099	39.4231	20.1551
1452	Katakolo	GR	Greece	GLOSS	37.64	21.319	37.5594	21.2704
1451	Kalamata	GR	Greece	GLOSS	37.022	22.11	36.8837	22.0346
2005	Koroni	GR	Greece	JRC/NOA	36.7975	21.9628	36.7933	22.0114
2001	Kapsali (Kythira)	GR	Greece	JRC/NOA	36.1418	23.0037	36.1151	23.0618
2003	Paleochora	GR	Greece	JRC/NOA	35.224	23.6786	35.1629	23.6475
1463	Peiraias	GR	Greece	NOA	37.9347	23.6212	37.7781	23.6063
1477	Syros	GR	Greece	GLOSS	37.438	24.941	37.3641	24.9380
2562	Hrakleio	GR	Greece	NOA	35.349	25.153	35.3960	25.1325
2560	Ierapetra	GR	Greece	NOA	35.004	25.739	34.8914	25.7292
2361	Kalathos	GR	Greece	NOA	36.1139	28.0696	36.1120	28.1456
2567	Samothraki	GR	Greece	NOA	40.475	25.468	40.4748	25.3793
100086	Corinth	GR	Turkey	JRC	37.9452	22.9365	38.2274	22.5238
2031	Gokceada	TR	Turkey	KOERI	40.233	25.894	40.2462	25.9877
100088	Fethiye	TR	Turkey	JRC	36.6207	29.0922	36.4501	28.9677

Table 22 - *As in Table 10, but for the Greece SSCS bulletin.*

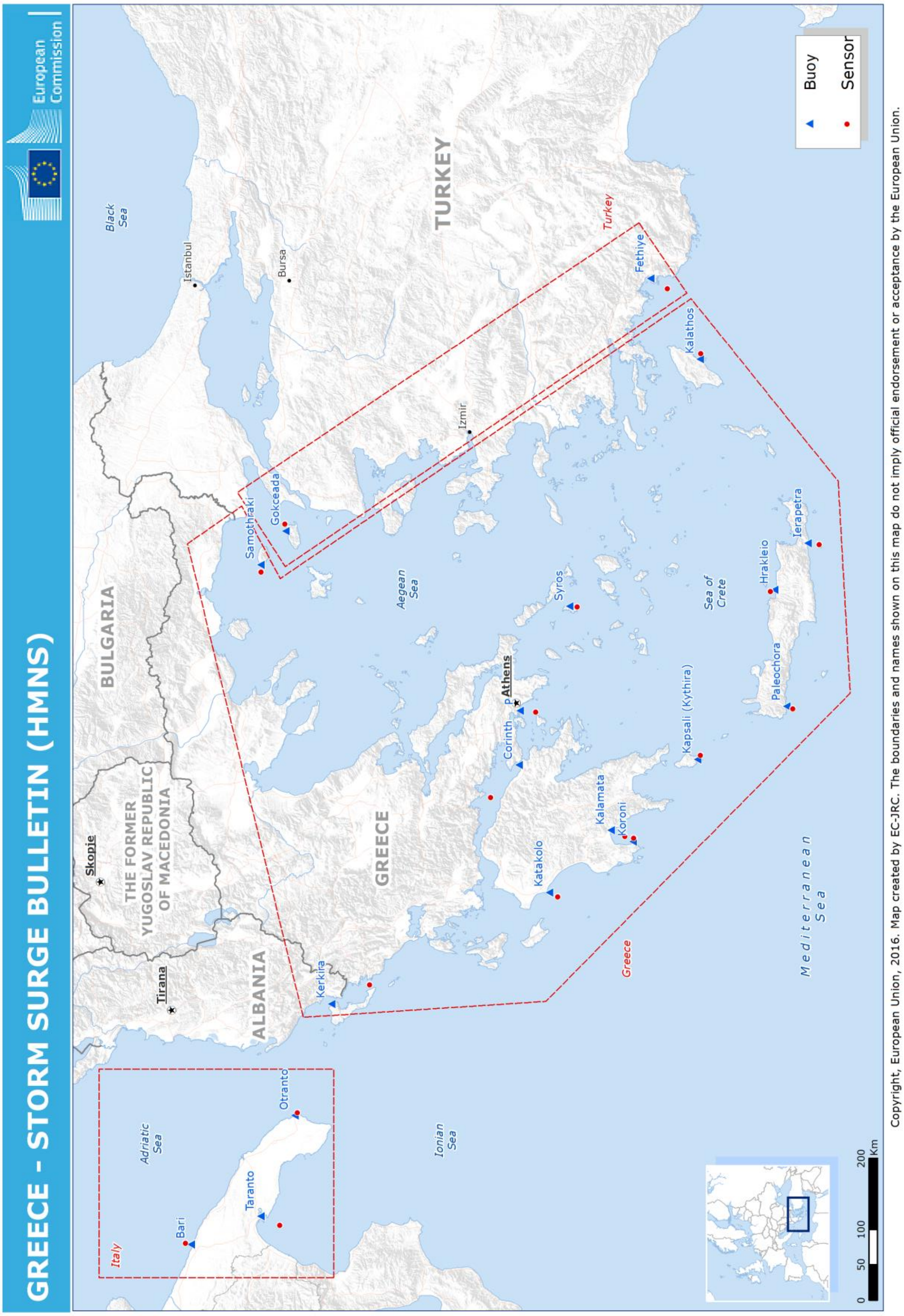


Figure 32 - *As in Figure 19, but for the Greece SSCS bulletin.*

5.2.8 North Atlantic

The ***"North Atlantic Storm Surge bulletin"*** covers the North-eastern Atlantic Ocean. This bulletin provides the storm surge for several countries (ES, PT, MA, GI) and includes also the Azores and Canary Islands.

The sea level date of GLOSS, JRC, IPMA (*"Instituto portugues do mar e da atmosphere"*), are used in this bulletin.

Atmospheric input: ECMWF

NORTH ATLANTIC SSCS Bulletin General Info	
Total nr. Buoys	**17**
Areas analysed	2
Area 1	Azores, Canary Is.
Area 2	PT, ES, FR
Nr. Webcams	1
webcam 1	Setubal

Table 23 - *As in Table 9, but for the North Atlantic SSCS bulletin.*

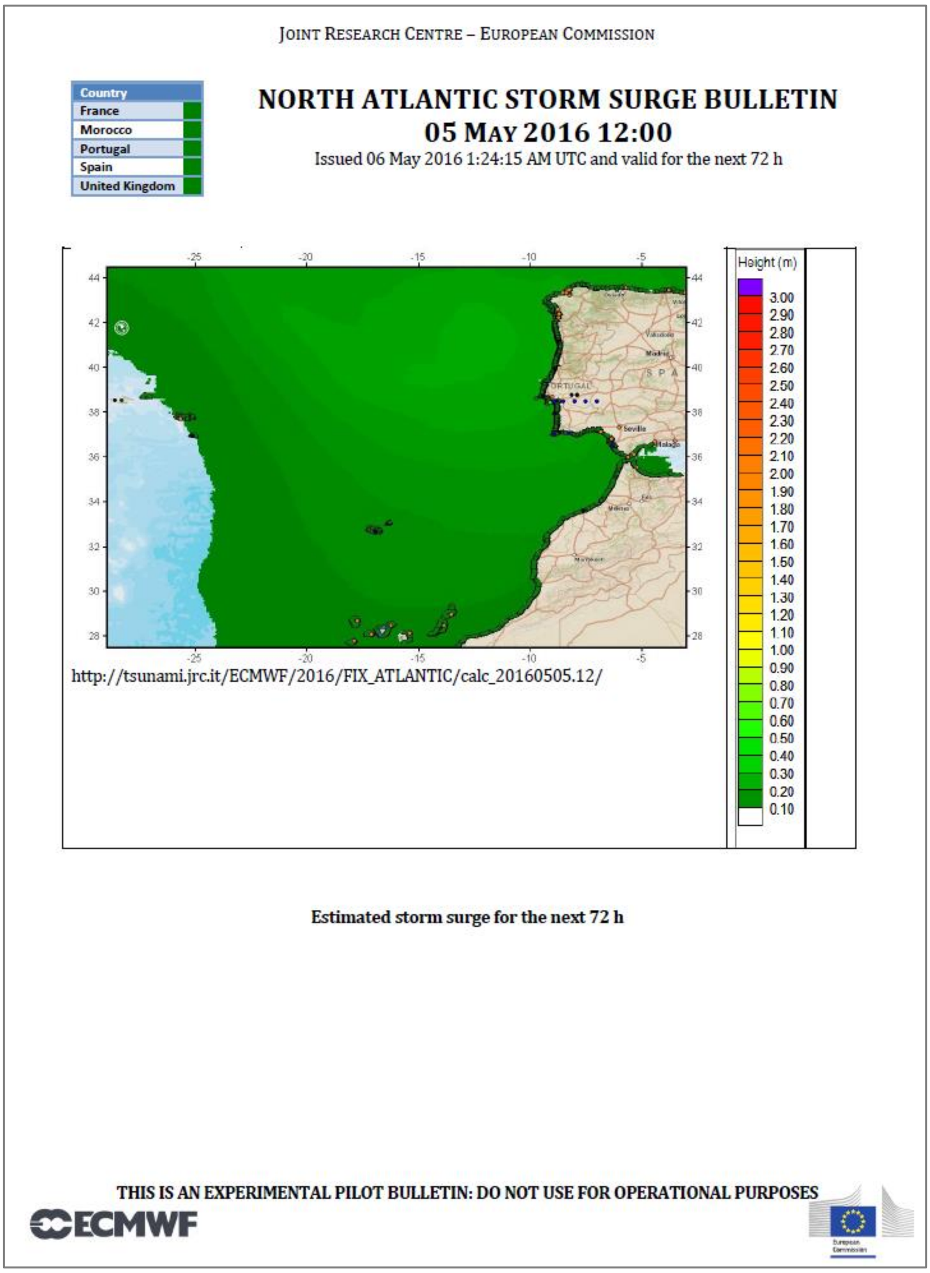


Figure 33 *- As in Figure 18, but for the North Atlantic SSCS bulletin.*

NORTH ATLANTIC OCEAN SSCS BULLETIN								
ID	**Name**	**Country**	**Area**	**Source**	**buoy location**		**sensor location**	
					lat	lon	lat	lon
2016	**Ponta Delgada**	PT	Azores, Canary Is.	IPMA	37.7376	-25.6617	37.69427	-25.69003
2018	**Santa Maria**	PT	Azores, Canary Is.	IPMA	36.9450	-25.1483	36.89137	-25.16985
1479	**Tenerife**	ES	Azores, Canary Is.	GLOSS	28.4770	-16.2410	28.38963	-16.07254
1638	**Arrecife**	ES	Azores, Canary Is.	GLOSS	28.9716	-13.5303	28.92998	-13.37081
1455	**Las Palmas**	ES	Azores, Canary Is.	GLOSS	28.1410	-15.4120	28.09244	-15.26202
2015	**Leixos**	PT	PT, ES, FR	IPMA	41.1850	-8.7033	41.15956	-8.78564
2017	**Peniche**	PT	PT, ES, FR	IPMA	39.9510	-8.8920	40.03938	-8.97234
2021	**Cascais**	PT	PT, ES, FR	IPMA	38.6932	-9.4154	38.90142	-9.57641
2020	**Sines**	PT	PT, ES, FR	IPMA	37.9450	-8.8920	37.93528	-9.01257
2033	**Setubal**	PT	PT, ES, FR	JRC	38.4942	-8.9310	38.27498	-8.97361
100077	**Sagres**	PT	PT, ES, FR	JRC	37.0103	-8.9285	36.94564	-8.89738
100078	**Albufeira**	PT	PT, ES, FR	JRC	37.0826	-8.2604	36.96629	-8.25714
898	**Huelva**	ES	PT, ES, FR	GLOSS	37.1300	-6.8300	36.96870	-6.86229
100079	**Cadiz**	ES	PT, ES, FR	JRC	36.5421	-6.2806	36.48783	-6.36739
1478	**Tarifa**	ES	PT, ES, FR	GLOSS	36.0060	-5.6040	35.95660	-5.61205
833	**Ceuta**	ES	PT, ES, FR	GLOSS	35.5400	-5.1900	35.69598	-5.08618
1739	**Socoa**	FR	PT, ES, FR	GLOSS	43.3952	-1.6816	43.47160	-1.66640

Table 24 – *As in Table 10, but for the North Atlantic SSCS bulletin.*

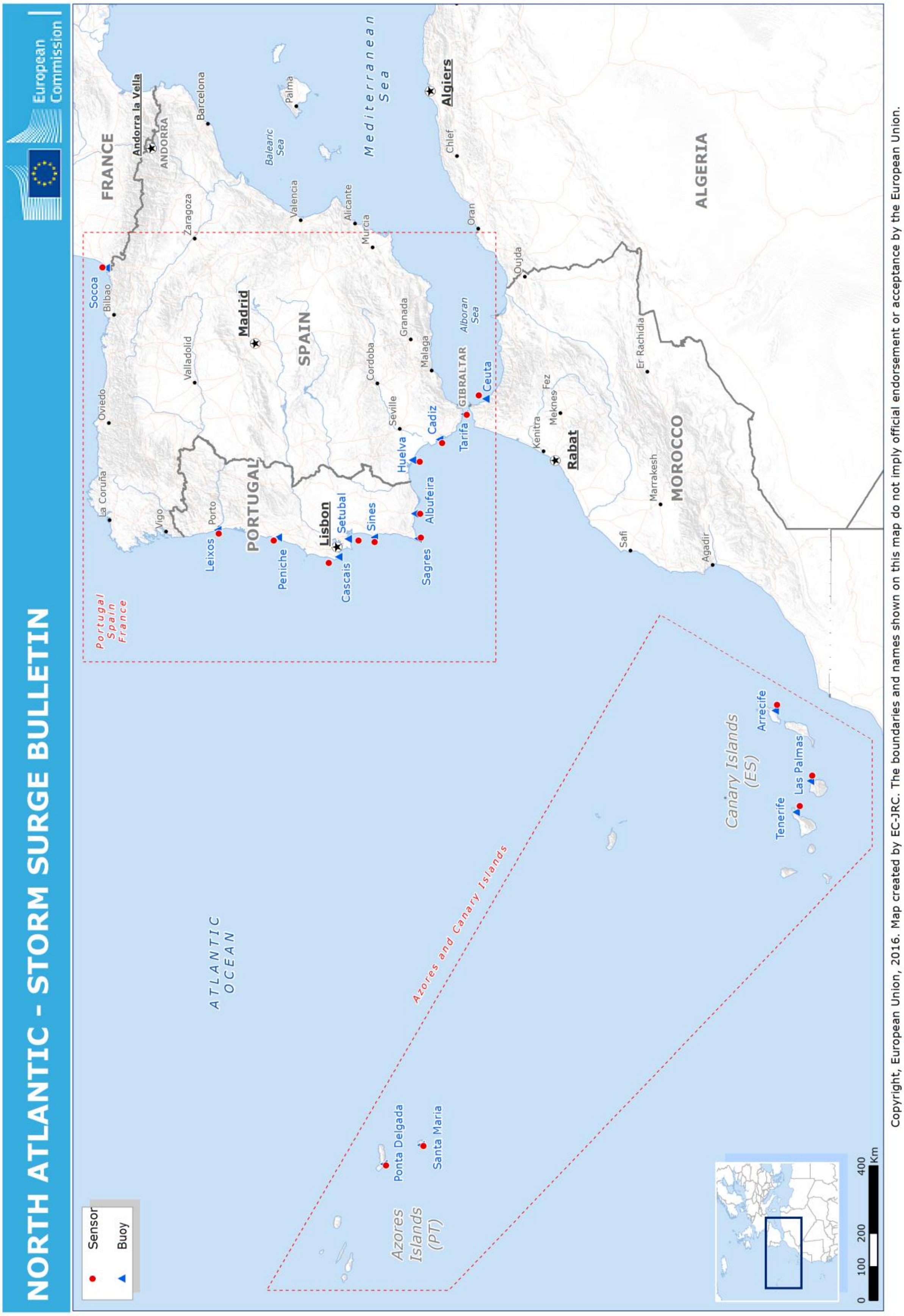


Figure 34 - *As in Figure 19, but for the North Atlantic SSCS bulletin.*

5.2.9 Mediterranean Sea using Delf3D

This SSCS bulleting is like the one described in Section 5.2.3, but the solver used is Delft3D, instead of using HyFlux2.

The ***"Mediterranean Sea -Delft3D Storm Surge bulletin"*** covers the Mediterranean Sea and the Black Sea. This bulletin provides the storm surge for several countries:

ES, FR, IT, SI, HR, BA, ME, AL, GR, BG, RO, TR, RU, SY, LB, IL, MA, PS, LY, TN, DZ, GI.

The sea level data of GLOSS, ISPRA, JRC, NOA (National Observatory of Athens) and KOERI (Kandilli Observatory and Earthquake Research Institute) are included in this bulletin.

Atmospheric input: ECMWF. Code: Delft 3D.

Mediterranean Sea -Delft3D SSCS Bulletin General Info	
Total nr. Buoys	38
Areas analysed	5
Area 1	West Med
Area 2	Central Med
Area 3	East Med
Area 4	Middle East
Area 5	Black Sea
Nr. Webcams	6

Table 25 - *As in Table 9, but for the Mediterranean Sea SSCS bulletin, using Delft3D instead of HyFlux2.*

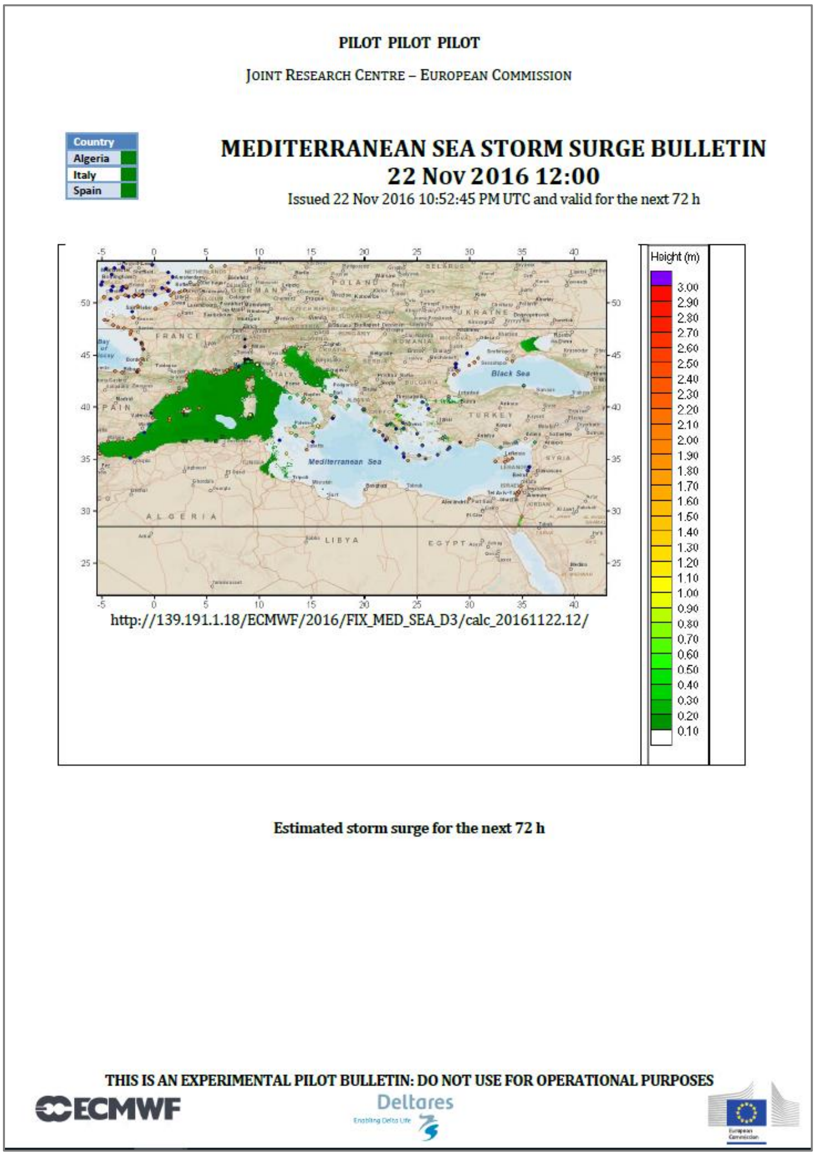


Figure 35 - *As in Figure 18, but for the Mediterranean Sea bulletin using Delft3D.*

MEDITERRANEAN SEA – Delft3D – SSCS BULLETIN								
ID	**NAME**	**Country**	**Area**	**Source**	**buoy location**		**sensor location**	
					lat	lon	lat	lon
1630	**Almeira**	ES	West Med	GLOSS	36.8300	-2.4783	36.7251	-2.4684
1706	**Valencia**	ES	West Med	GLOSS	39.4400	-0.3100	39.4404	-0.2990
819	**Barcelona**	ES	West Med	GLOSS	41.3400	2.1600	41.2775	2.2139
1449	**Ibiza**	ES	West Med	GLOSS	38.9170	1.4500	38.7903	1.4510
1461	**Palma de Mallorca**	ES	West Med	GLOSS	39.5600	2.6380	39.3946	2.6146
100080	**Cartagena**	ES	West Med	JRC	37.5671	-0.9790	37.4528	-0.9823
1741	**Sète**	FR	West Med	GLOSS	43.3976	3.6991	43.3186	3.7612
1721	**Cannes**	FR	West Med	GLOSS	43.4835	6.9338	43.4424	6.9713
1500	**Corsica, Centuri**	FR	Central Med	GLOSS	42.9670	9.3500	43.0953	9.2670
1862	**Porto Torres**	IT	Central Med	ISPRA	40.8422	8.4039	40.9625	8.4032
1841	**Carloforte**	IT	Central Med	ISPRA	39.1480	8.3095	39.2260	8.2312
1848	**Imperia**	IT	Central Med	ISPRA	43.8783	8.0189	43.8306	8.1495
1846	**Genova**	IT	Central Med	ISPRA	44.4101	8.9255	44.3226	8.9194
1843	**Civitavecchia**	IT	Central Med	ISPRA	42.0940	11.7896	41.9992	11.6773
1855	**Napoli**	IT	Central Med	ISPRA	40.8414	14.2692	40.6634	14.2085
1847	**Ginostra**	IT	Central Med	ISPRA	38.7852	15.1908	38.7852	15.2018
1858	**Palermo**	IT	Central Med	ISPRA	38.1214	13.3713	38.1696	13.4596
1851	**Lampedusa**	IT	Central Med	ISPRA	35.4998	12.6044	35.4804	12.6074
100083	**Pantelleria**	IT	Central Med	JRC	36.8348	11.9366	36.8557	11.9248
100084	**Portopalo**	IT	Central Med	JRC	36.6691	15.1228	36.6643	15.1286
1844	**Crotone**	IT	Central Med	ISPRA	39.0836	17.1371	39.0581	17.2090
1866	**S. Benedetto del Tronto**	IT	Central Med	ISPRA	42.9551	13.8898	42.9652	13.9770
1870	**Venezia**	IT	Central Med	ISPRA	45.4182	12.4265	45.3897	12.4368
1452	**Katakolo**	GR	East Med	GLOSS	37.6400	21.3190	37.5958	21.3268
2003	**Paleochora**	GR	East Med	JRC/NOA	35.2240	23.6786	35.2000	23.6747
2001	**Kapsali** *(Kythira)*	GR	East Med	JRC/NOA	36.1418	23.0037	36.0658	23.0076
2005	**Koroni**	GR	East Med	JRC/NOA	36.7975	21.9628	36.7933	22.0114
1463	**Peiraias**	GR	East Med	GLOSS	37.9350	23.6210	37.8187	23.5523
2361	**Kalathos**	GR	Central Med	NOA	36.1139	28.0696	36.1120	28.1456
100086	**Corinth**	GR	East Med	JRC	37.9452	22.9365	38.1271	22.8793
100088	**Fethiye**	TR	East Med	JRC	36.6207	29.0922	36.4501	28.9677
1889	**Iskenderum**	TR	East Med	KOERI	36.5942	36.1768	36.6606	36.0586
2031	**Gokceada**	TR	East Med	KOERI	40.2330	25.8940	40.2462	25.9877
2367	**Ashkelon**	IL	Middle East	GLOSS	31.6349	34.4938	31.6782	34.4268
1440	**Alexandria**	EG	Middle East	GLOSS	31.2110	29.9240	31.3138	29.8762
100091	**Mangalia**	RO	Black Sea	JRC	43.8014	28.5952	43.7998	28.6778
100092	**Constanta**	RO	Black Sea	JRC	44.1475	28.6720	44.2063	28.6843
100093	**Sulina**	RO	Black Sea	JRC	45.1622	29.7272	45.1468	29.7419

Table 26 - *As in Table 10, but for the Mediterranean Sea SSCS bulletin, using Delft3D.*

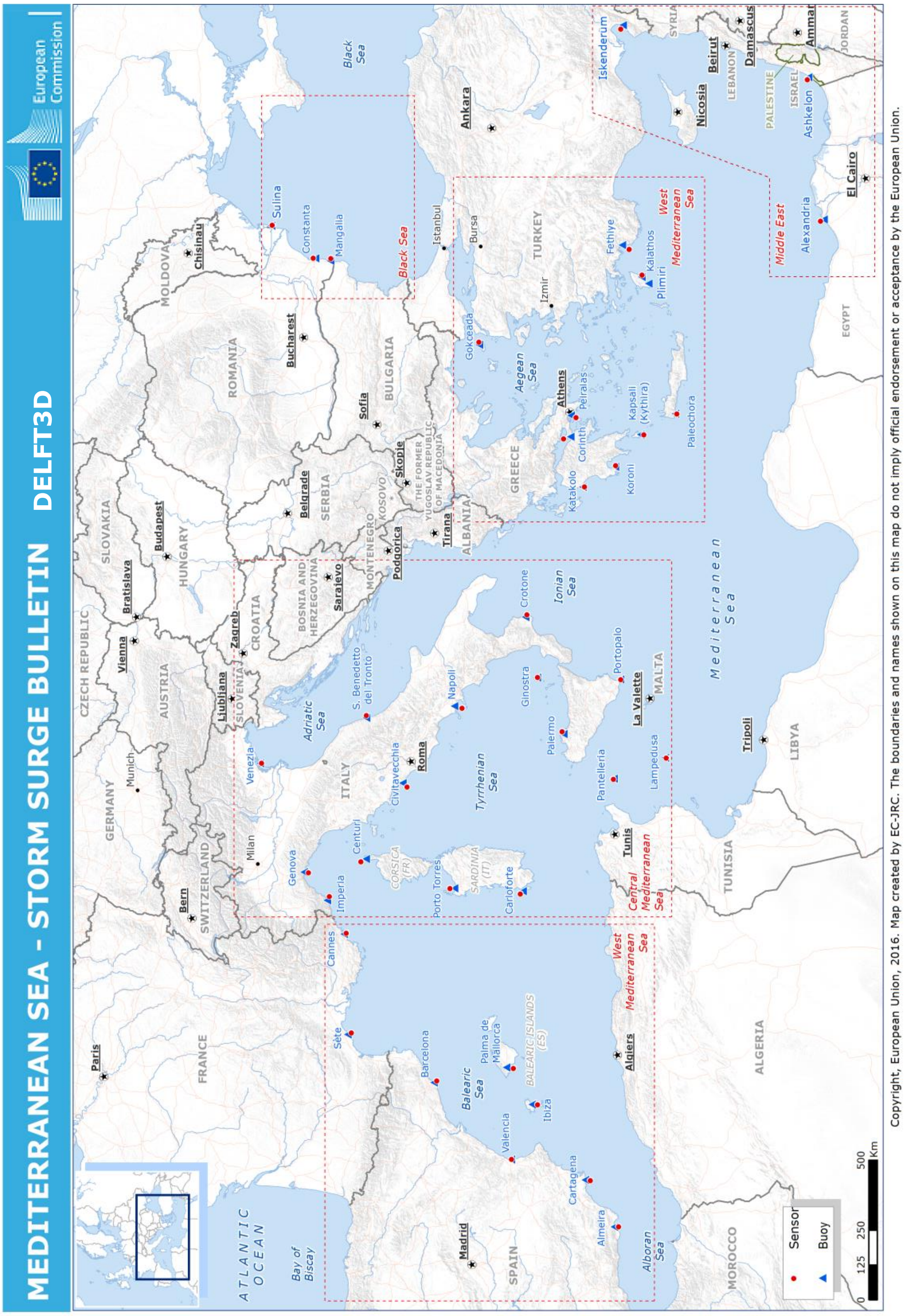


***Figure 36 -** As in Figure 19, but for the Mediterranean Sea SSCS bulletin, using Delft3D.*

6 SSCS website

All the bulletins are available at the SSCS website, after log in. In *Figure 37*, the home page of the SSCS website is shown.

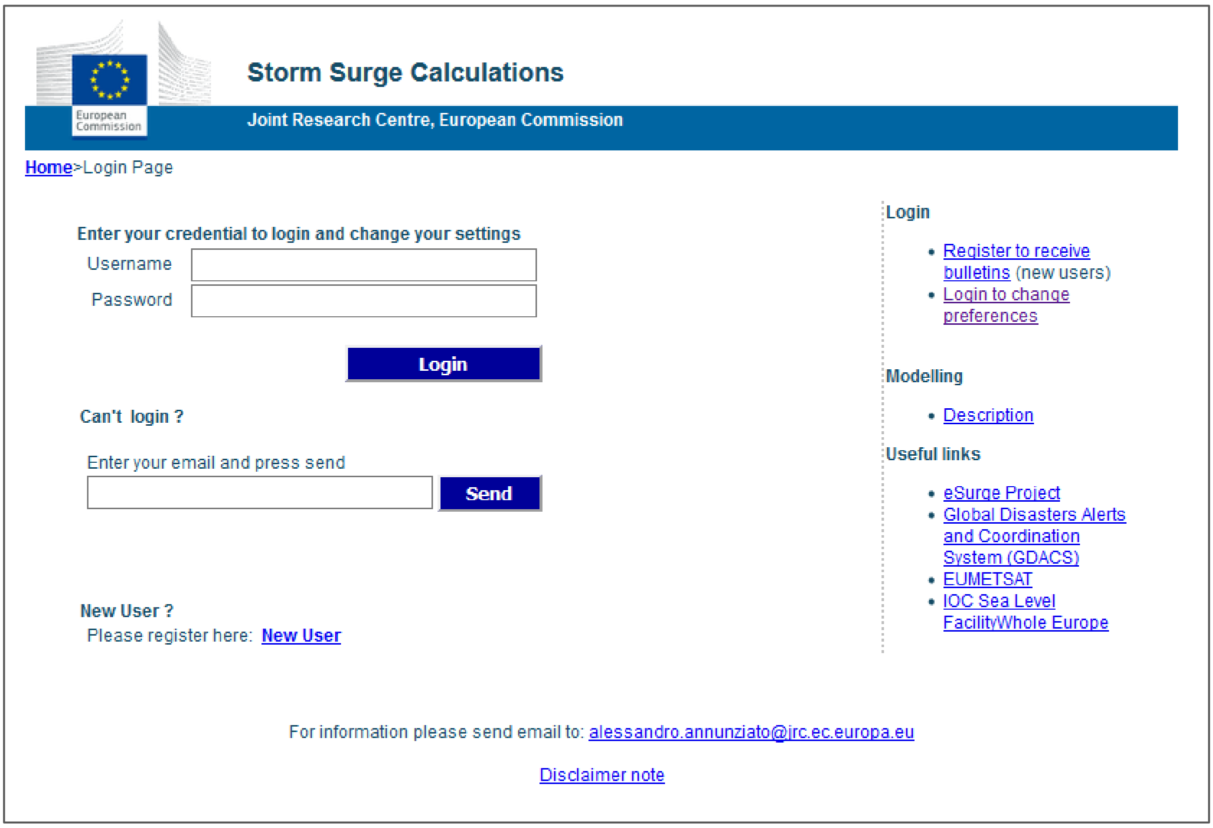


Figure 37 - *SSCS website - Home page.*

The SSCS bulletins are available in three different formats:

1) PDF: see description in Section 5.
2) WORD: like the PDF version.
3) HTML: one specific webpage for each bulletin, including interactive maps and figures, showing the calculations and the sea level measurements in real time.

The JRC is currently working on a new SSCS website that will be ready next year. Ths new website will include several new tools: e.g. download of the SSCS data in different formats (kmz, kml, shp, txt), new figures, new interactive maps, … .

European Commission

Storm Surge Calculations

Joint Research Centre, European Commission

List of last Bulletins produced

Bulletin Name	Pdf	Word	HTML
Greece - en (HNMS)*			
Greece - gr (HNMS)*			
Italy ensemble*			
Italy with COSMO*			
Mediterranean Sea			
North Atlantic			
North Sea			
North Sea (TWL)*			
United Kingdom			
United Kingdom (TWL)*			

* Restricted bulletin

Situation as of 4/27/2016 7:33:38 AM UTC in the period -6h to +72h from the time of calculation

Country	Color	Max Height(m)	Date	Location
Albania		0.16	25 Apr 22:00	Fusha
Algeria		0.08	28 Apr 13:00	La Calle
Belgium		0.81	26 Apr 08:00	Doel
Croatia		0.38	26 Apr 16:00	Savudrija
Cyprus		0.16	26 Apr 14:00	Kyrenia
Denmark		0.62	26 Apr 09:00	Norremolle
Egypt		0.25	26 Apr 13:00	'Ezbet 'Abd el-Rahman el-Qawatihl
France		0.43	26 Apr 07:00	Zuydcoote
Gaza Strip		0.15	26 Apr 13:00	Khan Yunis
Germany		0.74	26 Apr 07:00	Hillgroven
Greece		0.26	26 Apr 06:00	Loutra Termis
Guernsey		0.12	29 Apr 02:00	Saint Anne
Ireland		0.21	28 Apr 17:00	The Bush
Isle of Man		0.27	28 Apr 19:00	Maughold
Israel		0.15	26 Apr 15:00	Herzliyya
Italy		0.44	26 Apr 16:00	Aprilia Marittima
Jersey		0.12	29 Apr 02:00	Saint Martin
Lebanon		0.15	26 Apr 14:00	Al Knaysah
Libya		0.19	29 Apr 09:00	Ra's Ajdir
Malta		0.07	29 Apr 09:00	Zurrieq
Monaco		0.11	27 Apr 00:00	Monte-Carlo
Montenegro		0.10	25 Apr 23:00	Ulcinj
Morocco		0.06	27 Apr 13:00	Kariat Arekmam
Netherlands		0.81	26 Apr 08:00	Rilland
Norway		0.15	26 Apr 13:00	Vestre Amoy
Poland		0.13	26 Apr 16:00	Bagicz
Romania		0.09	26 Apr 14:00	Sfintu-Gheorghe
Russia		0.77	28 Apr 00:00	Taganrog
Slovenia		0.39	26 Apr 16:00	Piran
Spain		0.07	27 Apr 19:00	Velez-Malaga
Sweden		0.44	26 Apr 10:00	Domsten
Syria		0.16	26 Apr 17:00	Aakrak
Tunisia		0.24	29 Apr 10:00	Al Jurf
Turkey		0.26	26 Apr 06:00	Kucukkuyu
Ukraine		0.27	27 Apr 10:00	Chernyshove
United Kingdom		0.66	26 Apr 08:00	Beltinge

Color skeme	
	More than 3.00 m
	Between 2.00 m and 3.00 m
	Between 1.00 m and 2.00 m
	Between 0.50 m and 1.00 m
	Between 0.05 m and 0.50 m

The colour scheme adopted here does not represent a corresponding risk and it is only indicative. The colour scheme adopted in the bulletins may change according to specific requests of the related users.

Login

- Change your preferences
- Logout

Modelling

- Description

Useful links

- eSurge Project
- Global Disasters Alerts and Coordination System (GDACS)
- EUMETSAT
- IOC Sea Level FacilityWhole Europe

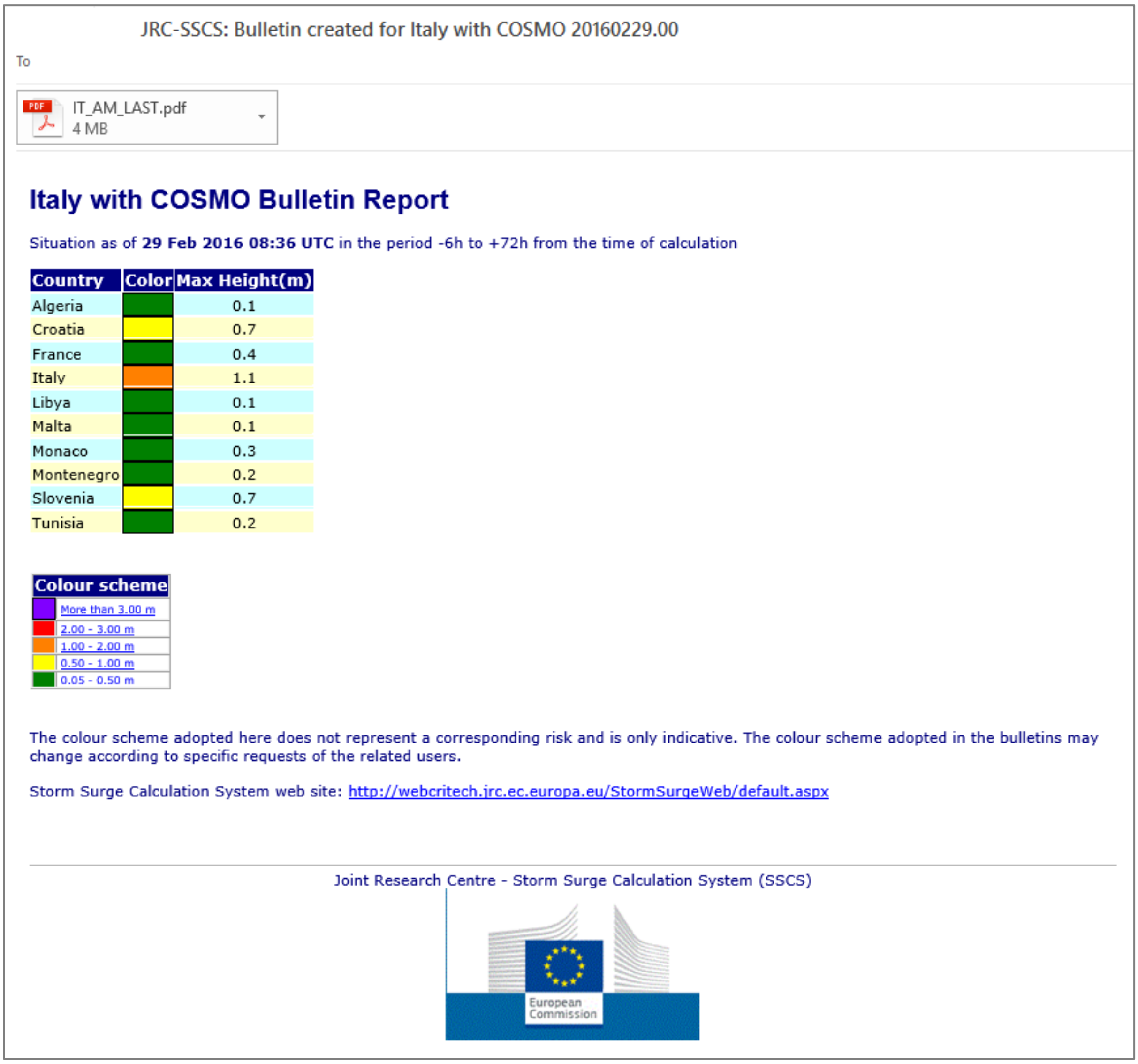
Figure 38 - *SSCS website (after login).*

7 SSCS e-mails

The PDF versions of SSCS bulletins produced are sent by e-mail to the SSCS users, after their registration, when the bulletin is ready.

The e-mail includes the pdf version of the bulletin and an overview table with:

- Affected countries
- Max height of storm surge calculated
- Time of the max. storm surge
- Location of the max. storm surge



JRC-SSCS: Bulletin created for Italy with COSMO 20160229.00

To

IT_AM_LAST.pdf
4 MB

Italy with COSMO Bulletin Report

Situation as of **29 Feb 2016 08:36 UTC** in the period -6h to +72h from the time of calculation

Country	Color	Max Height(m)
Algeria		0.1
Croatia		0.7
France		0.4
Italy		1.1
Libya		0.1
Malta		0.1
Monaco		0.3
Montenegro		0.2
Slovenia		0.7
Tunisia		0.2

Colour scheme	
	More than 3.00 m
	2.00 - 3.00 m
	1.00 - 2.00 m
	0.50 - 1.00 m
	0.05 - 0.50 m

The colour scheme adopted here does not represent a corresponding risk and is only indicative. The colour scheme adopted in the bulletins may change according to specific requests of the related users.

Storm Surge Calculation System web site: http://webcritech.jrc.ec.europa.eu/StormSurgeWeb/default.aspx

Joint Research Centre - Storm Surge Calculation System (SSCS)

European Commission

Figure 39 - *Example of the e-mail of the SSCS for Italy (COSMO-ME AM).*

Moreover, the **Daily Report on Storm Surge Calculation** (see *Figure 40*) is sent to all users once a day (at 7:00 CET). This e-mail includes an overview table with the max storm surge calculated in all the SSCS bulletins and also the hyperlink for each bulletin.

Storm Surge Calculations

List of last Bulletins produced

- Baltic Sea
- Italy
- Mediterranean Sea
- North Atlantic
- North Sea
- United Kingdom

Situation as of **04 Feb 2016 06:00 UTC** in the period -6h to +72h from the time of calculation

Country	Color	Max Height(m)	Date	Location
Belgium		0.7	03 Feb 07:00	Zandvliet
Denmark		**1.4**	**03 Feb 07:00**	Vester Vedsted
Germany		**1.4**	**03 Feb 07:00**	Kating
Netherlands		**1.1**	**03 Feb 08:00**	Spijk
Norway		0.6	03 Feb 09:00	Viker
Russia		**1.2**	**03 Feb 20:00**	Taganrog
Sweden		0.6	03 Feb 08:00	Smogen
Ukraine		0.6	05 Feb 23:00	Kalynivka
United Kingdom		0.7	03 Feb 13:00	Wingland

Currently shown Minimum height is 0.5 m

Colour scheme
More than 3.00 m
2.00 - 3.00 m
1.00 - 2.00 m
0.50 - 1.00 m
0.05 - 0.50 m

The colour scheme adopted here does not represent a corresponding risk and it is only indicative. The colour scheme adopted in the bulletins may change according to specific requests of the related users.

Storm Surge Calculation System web site: http://webcritech.jrc.ec.europa.eu/StormSurgeWeb/default.aspx

Figure 40 - *JRC-SSCS: Daily Report on Storm Surge Calculation (e-mail).*

8 Implementation of the SSCS in GDACS

8.1 Introduction

The JRC has developed the Storm Surge Calculation System (SSCS) in 2013, in order to simulate the storm surge events also in Europe (see Sections 2-7 of this report). This system has been established at the JRC in the frame of **GDACS** and it is intended as a series of procedures that use the meteorological forecasts produced by several meteorological centers as atmospheric input in the JRC HyFlux2 code, in order to simulate the storm surge along the coasts. Every day several SSCS bulletins are created for several areas of Europe. The JRC SSCS calculations domains are shown in the map below:

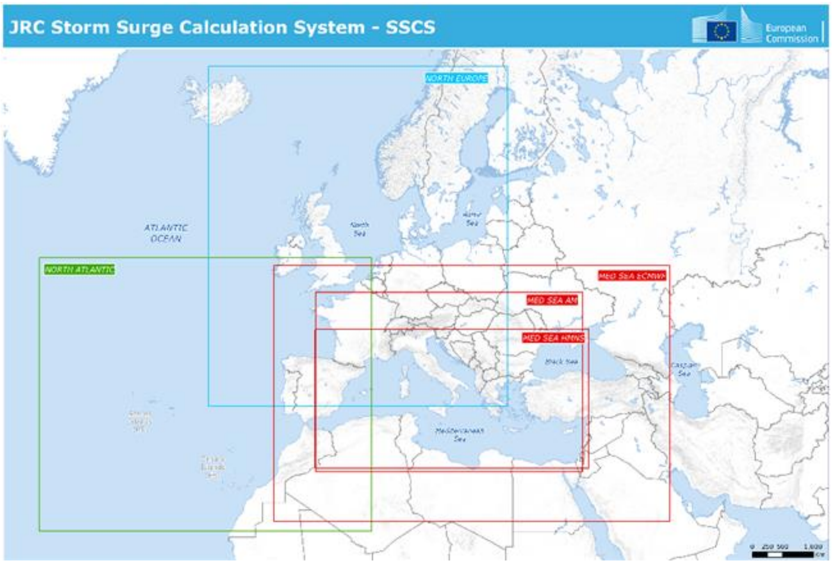


Figure 41- *JRC Storm Surge Calculation domains*

The **JRC is currently including the results of the SSCS system also in GDACS** and a new specific event type - "STORM SURGE" - has been created. The main aims of this work are:

- identify the storm surge events, using the SSCS.
- create the "storm surge pages" in GDACS for the events identified, including the results of the SSCS.
- Classify the storm surge events.
- Send out an alert in case of major events.

This new system identifies the "storm surge events" in Europe, calculated by the SSCS, due to the passage of a specific storm, like the Storm Xavier in 2013, and includes the results in GDACS, creating several specific pages for the possible impact, like for the Tropical Cyclones. Moreover for each event identified by the system a specific code or name (see Met FU-Berlin[4], UK Met Office and Met Eiran[5]) will be also included in GDACS.

The preliminary results of this pilot activity are included only in the GDACS development website for the moment and are presented below. Over the next few months the JRC will test this new system for the 2014-2016 events.

---

[4] Met FU-Berlin : http://www.met.fu-berlin.de/adopt-a-vortex/

5 UK MetOffice: http://www.metoffice.gov.uk/uk-storm-centre/2015-16,

Met Eiran: http://www.met.ie/news/display.asp?ID=338

8.2 Procedure

In order to implement the SSCS in GDACS, the following procedure has been created.

1) Identify and classify the most important storm surge events calculated by the SSCS.
2) Create the "storm surge pages" in GDACS for the events identified
   ➔ including the results of the SSCS, maps, reports, … .
3) Classify the alert level of the event and send out an alert in case of major events.

A brief description of the steps of this procedure is presented below, while the description of the new pages created in GDACS are presented in the next Section.

1) Identify and Classify the storm surge events calculated by the SSCS

The results of all the SSCS calculations described in Section 2 are analysed by this system in order to identify a storm surge event.

For each specific calculation, the following steps have been set up:

- ***Identify the locations possibly "affected"***

All the results of the SSCS for every calculation are analysed and only the locations having a storm surge higher than the values shown in the table below are analysed and considered as: "location affected by a storm surge event".

Basins	Storm surge
North Sea	> 0.5 m
Atlantic	> 0.5 m
Mediterranean Sea	> 0.3 m
Black Sea	> 0.3 m

Table 27 - *Thresholds used for the "locations affected"*

Every SSCS location identified as "location affected by a storm surge event" is included into a database as a record, including the following information:

- Location (lat/lon) of max. height
- Date/ time of max. height
- Date of the bulletin (calculations)
- Basin
- Countries
- Sources

For each location, the following specific analysis has been implemented.

- ***Classify the records as: new event or new episode***

Every single record (location affected) stored in the database is analysed in order to identify if it is a new event or a new episode of an event already included in GDACS.

One event could start in one basin and move to another basin. For example, if there is a storm that moves over the Atlantic and then over the North Sea, generating storm surge along the coast of several countries (like Storm Xaver in 2013), it is important to create one single event in GDACS for this storm and link all the locations possibly affected to this event. Therefore it's important to identify if it is a NEW STORM SURGE EVENT or a NEW EPISODE of an event already identified and stored in GDACS.

All the records previously stored are analysed, comparing the location (lat/lon) and the time of the max. height with the same values of the previous events and episodes already classified and stored in GDACS. Comparing these values, the record is classified as:

New EVENT

If one of these conditions is verified, the record is classified as a new event

- Located outside an area of a radius of **600 km** from an event already recorded.
- Difference between the time of max height of this event and the events already stored in GDACS is greater than **36 h**.

An example of one single event is shown in *Figure 42* while another example for two different events is shown in *Figure 43*.

New EPISODE of an event already recorded

If all the following conditions are verified, the record is classified as a new episode of an event already identified, classified and stored in GDACS.

- Located within an area of a radius of 600 km of an event already recorded.
- Difference between the time of max height of this event and the events already stored in GDACS is lower than 36 h.
- Date of the calculation of the record (bulletin time) is different from the date of the latest episode already recorded for the same event.

CLASSIFICATION *Based on the comparison between the record not yet classified and the previous events/episodes already classified and stored in GDACS*		
	NEW EVENT *At least one condition verified*	**NEW EPISODE** *All the conditions verified*
Position (lat/lon)	Outside an area of 600 km radius	Within an area of 600 km radius
Time of max. storm surge	time difference > 36 h	time difference < 36 h
Time of the calculation	-	Different from the latest episode recorded

Table 28 - *Thresholds used for the classification of a storm surge event*

After having analysed all the new records, the system allocates the proper classification ("New Event" or "New Episode") to each location previously stored in the database.

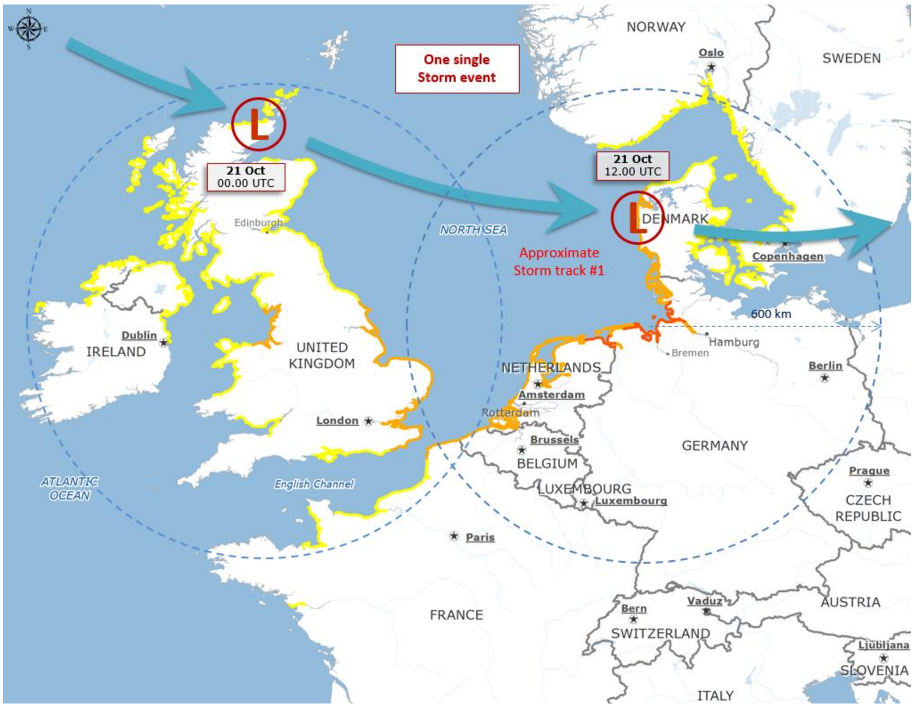


Figure 42 - *Example of one single storm event*

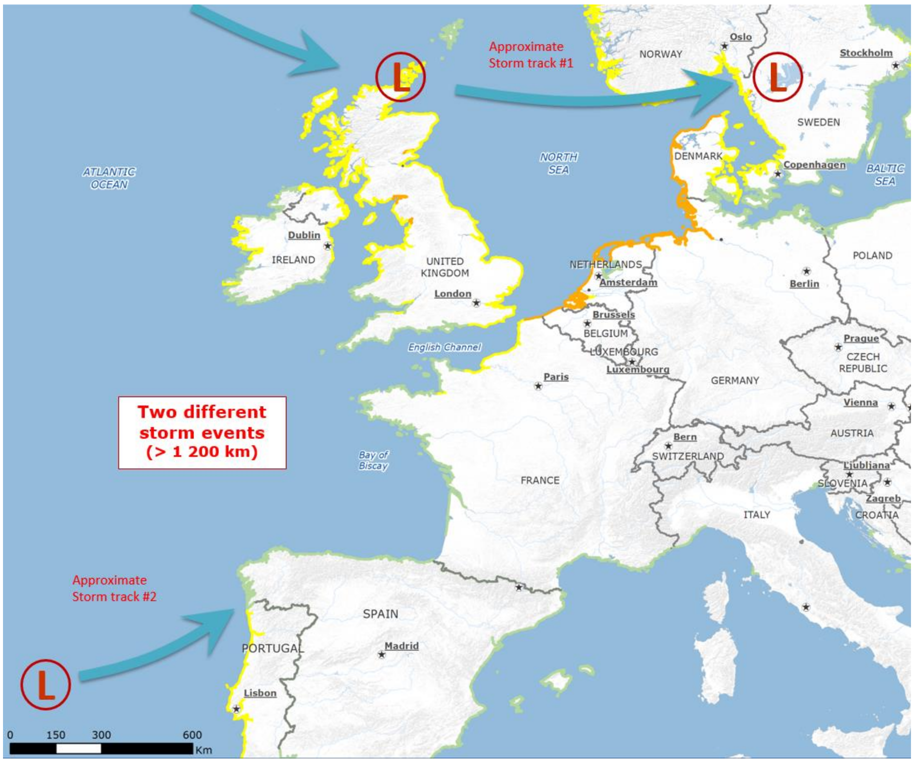


Figure 43 - *Example of two different events*

- ***Different atmospheric sources and/or solvers for the same episode***

All the calculations described in the previous Section are included in the new GDACS system. Therefore for the same event and episode identified, different results are available. For example for a Storm surge event in the Adriatic Sea, the system could have for the same episode, several different forecasts:

EVENT ID	EPISODE ID	ATM. SOURCE	CODE
104	5	ECMWF	JRC-HyFlux2
104	5	AM	JRC-HyFlux2
104	5	HMNS	JRC-HyFlux2
104	5	ECMWF	Delft3D

Table 29 - *Example of the classification of one event, using different sources/solvers*

- ***Classify the events/episodes:***

All the events/episodes are classified as:

- "CALC": only forecast calculations available (DEFAUL)
- "MEAS": if the sea level confirms that there is a storm surge event
- "ANALYST": if the event is analysed and confirmed by an analyst

- ***Assign a NAME or an ID to the new Events identified by the system***

STORM NAME

The intense low pressure systems that affect Europe could have a name. Two examples of the projects/centers that assign a name to these weather systems are:

- The National Meteorological Services of Ireland and the UK, Met Éireann and the Met Office, in 2015 released a list of names for the winter storms. This was a joint initiative to bring greater public awareness of warnings for medium and high-impact windstorms affecting Ireland and/or the UK. More information and the list for 2016/17 could be find at: http://www.met.ie/news/display.asp?ID=338 and at http://www.metoffice.gov.uk/uk-storm-centre/

Storm Names 2016/17 *(UK MetOffice - Met Éireann)*		
Angus	Holly	Oisín
Barbara	Ivor	Penelope
Conor	Jacqui	Robert
Doris	Kamil	Susan
Ewan	Louise	Thomas
Fleur	Malcolm	Valerie
Gabriel	Natalie	Wilbert

Table 30 - *A-Z of UK storm names 2016/17 (source: UK MetOffice - Met Éireann)*

- Another project that assign name to the low pressure system is "Adopt a Vortex" of the Institute of Meteorology of the University of Berlin (see Met FU-Berlin : http://www.met.fu-berlin.de/adopt-a-vortex/).

If one of the storm surge event identify by the system has a corresponding "name" in the projects described above, the JRC will assign this name to the event (not yet automatic).

JRC STORM ID

The JRC is currently using a proper classification for these weather systems, that is based on the **"Event ID"** and the **"Basin code".**

<Basin code> <Event ID>

However, a new The JRC is developing a new code based on the date of the max. storm surge height and the location of the maximum, subdividing the basing in several sub-basins. For example the Mediterranean Sea (MED_SEA) will be subdivided in:

- Alboran Sea (ALB_SEA)
- Balearic Sea (BAL_SEA)
- Ligurian Sea (LIG_SEA)
- Tyrrhenian Sea (TYR_SEA)
- Ionian Sea (ION_SEA)
- Adriatic Sea (ADR_SEA)
- Aegean Sea (AEG_SEA)
- Sea of Crete (CRE_SEA)

After all the steps described above, the results are published in GDACS, see description below. Moreover all the events/episodes detected are stored the GDACS archive, where the new event type "Storm Surge" has been also included.

2) CREATE THE GDACS STORM SURGE PAGES FOR THE EVENTS IDENTIFIED

After having analysed all the records, several new specific pages have been created in GDACS for the events identified (as descripted in the next Section).

"STORM SURGE OVERVIEW - ALL EVENTS IN ALL BASINS"

This page includes all the events identified by the system in all the basins over the last 4 days (only the last episode of each event identified by the system is shown in this page).

This page provides a general overview on the current situation in all the following basins:

- North Sea
- Atlantic
- Med Sea
- Black Sea

For each event identified by the system, one specific "Storm Analysis" is created.

"STORM ANALYSIS (ONE EVENT)"

For each event identified by the system, several pages are automatically created. In particular, the following information are included: storm surge, sea level measurements, winds, maps, reports, media analysis, … .

A detailed description of these pages is provided in the next Section.

3) Classify the alert level of the event and send out alerts in case of major events

Alert Level Classification

The events identified by the system are classified using the same colour scheme of the SSCS bulletins (see table below). However the SSCS system uses 5 classifications, while GDACS uses only three alert levels: Green, Orange and Red. Therefore, these new alert levels will be included in GDACS only for the "storm surge events".

The thresholds used are shown in *Table 31*. The JRC is currently working on a new classification, more realistic for each basin, using specific thresholds for each basin. This is very important because typically the storm surge events along the coast of the North Sea are higher than the events along the coast of the Mediterranean Sea. For example, if 1 m of storm surge occurs along the coast of North Sea could produce only minor damage, while if 1.5 m of storm surge occurs along the coast of Adriatic Sea could make serious damage. Therefore it is important to use a different scale for the alerts. Different thresholds are also used for the identification of the locations possibly most affected (see Table 27).

The colour scheme that is currently used in in the SSCS (and for the Storm Surge events in GDACS) is shown in the Table below:

	STORM SURGE ALERT LEVEL – COLOUR SCHEME (*)				
	Green	**Yellow**	**Orange**	**Red**	**Violet**
North Sea	0.5 – 1.0 m	1.0 – 1.5 m	1.5 – 2.0 m	2.0 – 3.0 m	> 3.0 m
Atlantic Ocean	0.5 – 1.0 m	1.0 – 1.5 m	1.5 – 2.0 m	2.0 – 3.0 m	> 3.0 m
Med Sea	0.3 – 0.5 m	0.5 – 1.0 m	1.0 – 2.0 m	2.0 – 3.0 m	> 3.0 m
Black Sea	0.3 – 0.5 m	0.5 – 1.0 m	1.0 – 2.0 m	2.0 – 3.0 m	> 3.0 m

Table 31 - *Colour scheme used for the classification of the event*

Note: (*) For the moment, the colour scheme adopted for the alert in this analysis does not represent a corresponding risk and is only indicative. More accurate alert thresholds for each basin will be included soon.

Alerts in case of major events

The JRC is currently preparing a new "e-mail for the storm surge alert". Therefore when a major event is identified (Red/Violet Alerts), a "storm surge alert" will be sent out and This alert will include the corresponding SSCS bulletin.

8.3 Description of the GDACS – Storm Surge pages

In this Section a brief description of the new GDACS pages developed for the storm surge events in Europe is presented.

First of all, as described above, a new event type - "STORM SURGE" - has been created in GDACS. This new event type will be included also in:

- GDACS alerts archive
- GDACS "register" page

A brief description of this new method will be also included in the GDACS Models page.

Regarding the storm surge events analysis, the following pages have been created:

STORM SURGE OVERVIEW *ALL EVENTS IN ALL BASINS*	STORM ANALYSIS (ONE EVENT)						
	SUMMARY	STORM SURGE IMPACT	WIND IMPACT	METEO SITUATION	MAPS & REPORTS	MEDIA ANALYSIS	DATA SOURCES
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 32 - *List of the new pages included in GDACS*

(1) STORM SURGE OVERVIEW – ALL EVENTS AND ALL BASINS

This page provides a general overview on the current situation in all the basins (North Sea, Atlantic, Mediterranean Sea and Black Sea) and includes all the events identified over the last 4 days in all these basins.

Title: "Storm surge events – Overview (Pilot Activity)"

Map: Overview map for all the SSCS calculations. The map includes the following layers for all the basins:

- Coastal impact
- Storm surge max. height
- Locations most affected in each basin (max. storm surge calculated in each basin)
- Alert level (see Table 31)

Current Situation: The table shows the list of the events identified in all the basins (not all the episodes, only the last episode) and the following information for each event:

- Event ID: GDACS number of the event identified by the system
- Storm name: ID created by the JRC for the event identified or "name" assigned to this event by Met FU-Berlin or MetOffice-MetEiran (see pag 4)
- Alert Colour: Alert level of this event (see pag. 6)
- Event Date: time of the bulletin
- Storm surge height: max of the storm surge in each basin
- Time of max. storm surge: time of the max of the storm surge in each basin
- Affected Countries: country where the max. of storm surge is located
- Event Classification
    - "CALC": only forecast calculations
    - "MEAS": sea level confirms that there is an event
    - "ANALYST": Event analysed and confirmed by an analyst
- Atmospheric source: source of the atmospheric input for the SSCS calculation
- Code: solver used for the calculations (HyFlux2 or Delft3D)

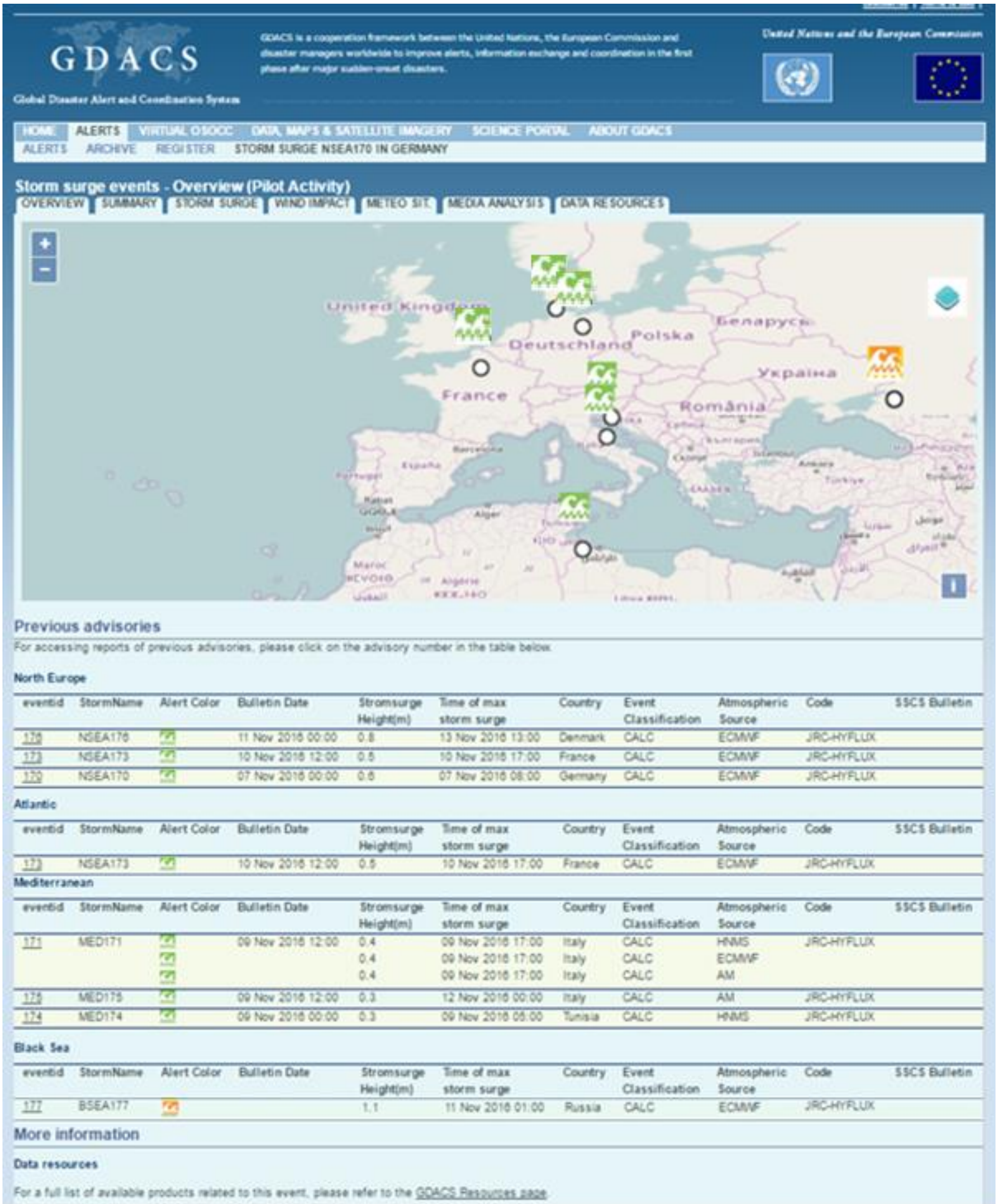


Figure 44 *- Storm surge overview - all basins*

(2) SUMMARY: "STORM ANALYSIS"

Summary of the situation for one single event identified by the system. This page is similar to the GDACS page: Tropical Cyclone – Summary.

Title: "<*Alert level*> - Storm surge alert for <*storm name*> in <*basin*>"

Summary

Brief description of the current situation for this event, including the following information:

- Name of the storm
- Basin
- Countries affected
- Max storm surge height and location of the max storm surge.
- Time of max. storm surge
- Max. winds
- Bulletin date

Overview – Storm surge table

A storm surge overview table that includes the max storm surge calculated and the time of the max. for each country affected.

Map: storm surge map of this event. The map will include the following layers:

- Coastal impact
- Storm surge max. height
- Locations most affected in each basin (max. storm surge calculated in each basin)

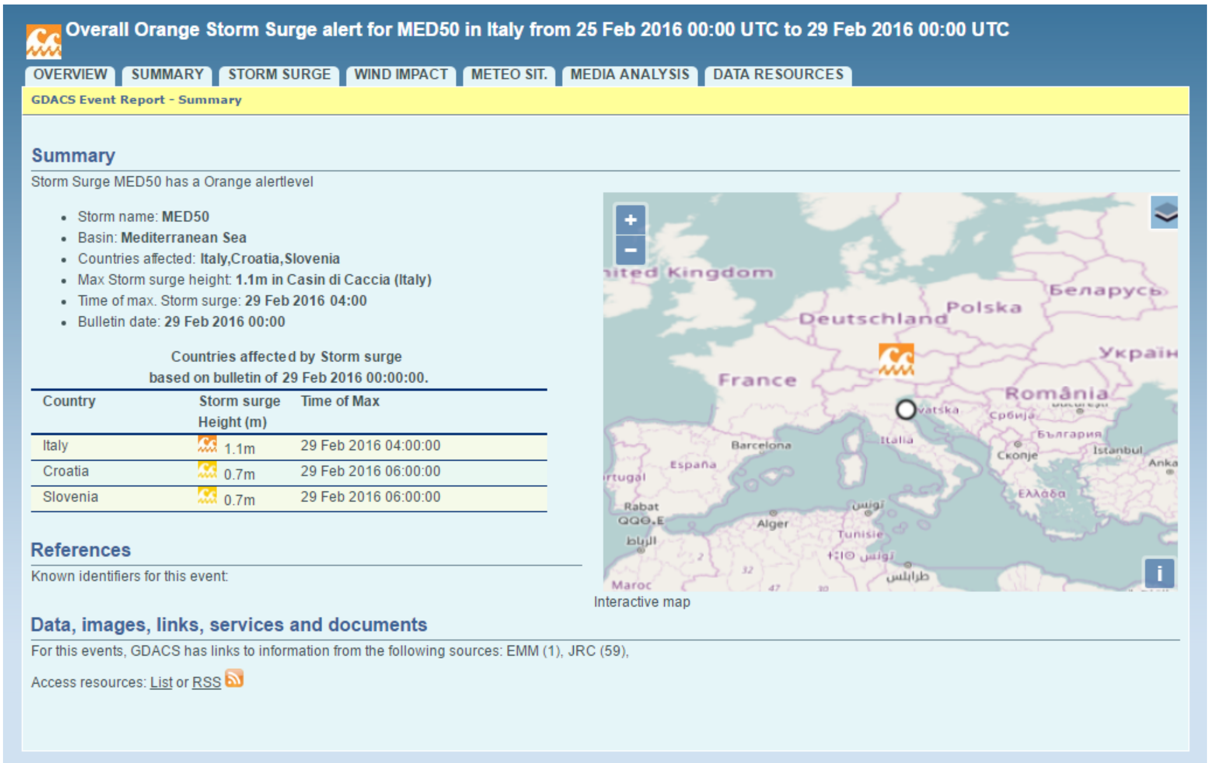


Figure 45- Summary of the storm surge event.

(3) STORM SURGE IMPACT

Storm surge impact for one specific event identified by the system.

This page is similar to the GDACS page: Tropical Cyclone – Storm Surge

Title: "*<Alert level>* - Storm surge alert for *<storm name>* in *<basin>*"

Description

This report is for the event <event ID> in the basin <basin name> based on the calculation <calculation date> (episode: <episode number>).

<u>Current impact:</u>

- Max storm surge height
- Time of the max. storm surge

➔ For all atmospheric sources and solvers

Storm surge map

Map for this event. The following layers are included:

- Coastal impact max
- Locations affected
- Max. height
- Sea levels

***Figure 46 -** Map of Storm Surge impact*

Tab: Locations affected

Tab showing the locations possibly affected by storm surge according to the latest calculation available.

- Country
- Name of the location
- Max. storm surge height
- Date of the max height

Country/Locations affected by Storm surge
Calculation based on bulletin of 29 Feb 2016 00:00:00,
(AM, JRC-HYFLUX) .

Country	Storm surge Height (m)	Time of Max
Italy	1.1m	29 Feb 2016 04:00:00
Alberoni	1.1m	29 Feb 2016 04:00:00
Mestre	1.1m	29 Feb 2016 04:00:00
Venezia	1.1m	29 Feb 2016 04:00:00
Tessera	1.1m	29 Feb 2016 04:00:00
Lido	1.0m	29 Feb 2016 04:00:00
Torcello	1.0m	29 Feb 2016 04:00:00
Le Vignole	1.0m	29 Feb 2016 04:00:00
Azienda le Trezze	1.0m	29 Feb 2016 04:00:00
Lio Piccolo	1.0m	29 Feb 2016 04:00:00
Lanzoni	0.9m	29 Feb 2016 04:00:00
Cavallino	0.9m	29 Feb 2016 04:00:00
Piave Vecchia	0.9m	29 Feb 2016 04:00:00
Lido di Jesolo	0.9m	29 Feb 2016 04:00:00
Cortellazzo	0.8m	29 Feb 2016 04:00:00
Eraclea Mare	0.8m	29 Feb 2016 04:00:00
Duna Verde	0.8m	29 Feb 2016 04:00:00
Caorle	0.8m	29 Feb 2016 04:00:00

***Table 33 -** Locations possibly affected by storm surge*

Sea level evolution

The maps of the Sea Level Evolution obtained from the JRC calculations (see Section 2) for the time: t 0, t +24h, t + 48 h, t + 72 h are included in this page.

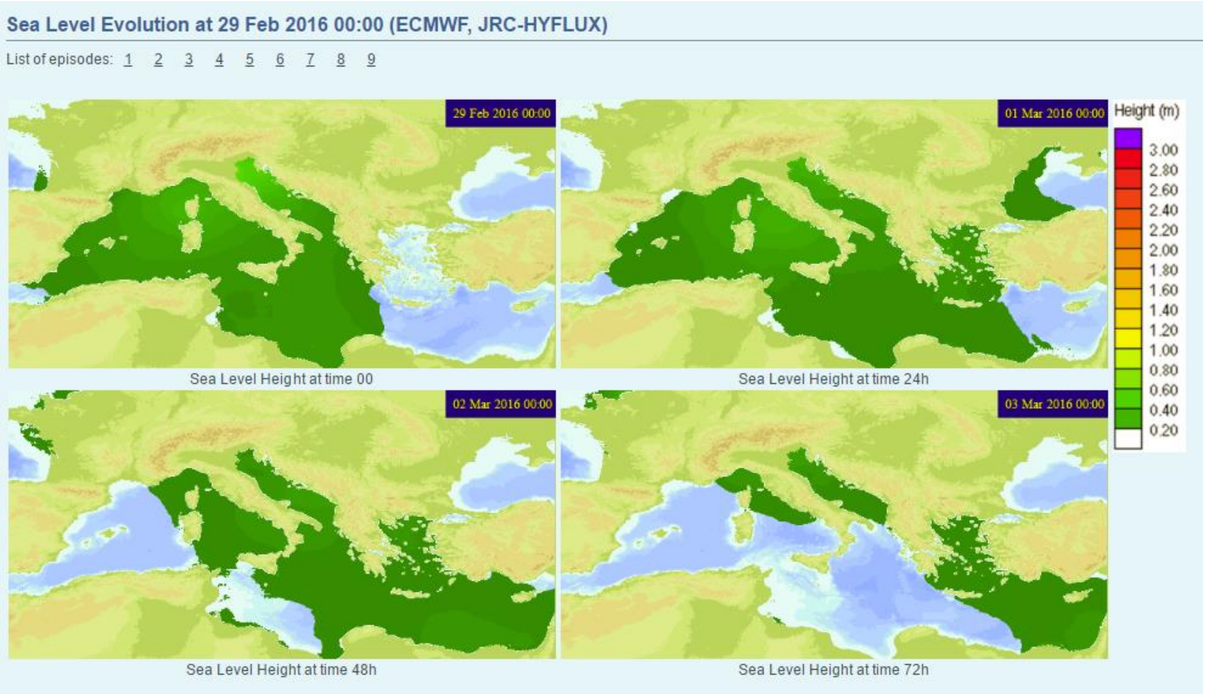


Figure 47 - *Sea level evolution*

Previous episodes

In this table the following information from the previous events are shown.

- Episode ID: number of the episode for the event identified
- Storm name: ID created by the JRC for the event identified or the "storm name" assigned to this event by Met FU-Berlin, MetOffice-MetEiran (see pag xx)
- Alert Colour: Alert level of this event (see pag. xx)
- Bulletin Date: time of the calculation
- Storm surge height: max of the storm surge
- Time of max. storm surge: time of the max of the storm surge
- Affected Countries: country where the max. of storm surge is located
- Event Classification
    - "CALC": only forecast calculations
    - "MEAS": sea level confirms that there is an event
    - "ANALYST": Event analysed and confirmed by an analyst
- Atmospheric Sources: source of the atmospheric input for the SSCS calculation
- Solvers: Code used for the SSCS calculations (Hyflux2, Delft3D)
- SSCS bulletin: link to the pdf of the SSCS bulletin created for that specific event

Bulletins of MED50

For accessing reports of previous episodes, please click on the bulletin number in the table below.

episode	StormName	Alert Color	Bulletin Date	Stromsurge Height(m)	Time of max storm surge	Country	Event Classification	Atmospheric Source	Code Source	SSCS Bulletin
9	MED50		29 Feb 2016 00:00	0.7	29 Feb 2016 04:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				1.1	29 Feb 2016 04:00	Italy	CALC	AM	JRC-HYFLUX	
8	MED50		28 Feb 2016 12:00	0.8	29 Feb 2016 04:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.9	29 Feb 2016 04:00	Italy	CALC	AM	JRC-HYFLUX	
7	MED50		28 Feb 2016 00:00	0.8	29 Feb 2016 03:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				1.0	29 Feb 2016 03:00	Italy	CALC	AM	JRC-HYFLUX	
6	MED50		27 Feb 2016 12:00	0.8	29 Feb 2016 02:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.6	29 Feb 2016 02:00	Croatia	CALC	AM	JRC-HYFLUX	
5	MED50		27 Feb 2016 00:00	0.8	28 Feb 2016 20:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.9	28 Feb 2016 20:00	Italy	CALC	AM	JRC-HYFLUX	
4	MED50		26 Feb 2016 12:00	0.8	29 Feb 2016 02:00	Italy	CALC	ECMWF	JRC-HYFLUX	
3	MED50		26 Feb 2016 00:00	0.7	29 Feb 2016 00:00	Italy	CALC	ECMWF	JRC-HYFLUX	
2	MED50		25 Feb 2016 12:00	0.4	28 Feb 2016 03:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.5	28 Feb 2016 03:00	Italy	CALC	AM	JRC-HYFLUX	
1	MED50		25 Feb 2016 00:00	0.3	27 Feb 2016 23:00	Italy	CALC	AM	JRC-HYFLUX	

Table 34 - *Previous SSCS bulletins*

Event time line of Max storm surge

In this figure the height of the max storm surge for each SSCS calculations is shown.

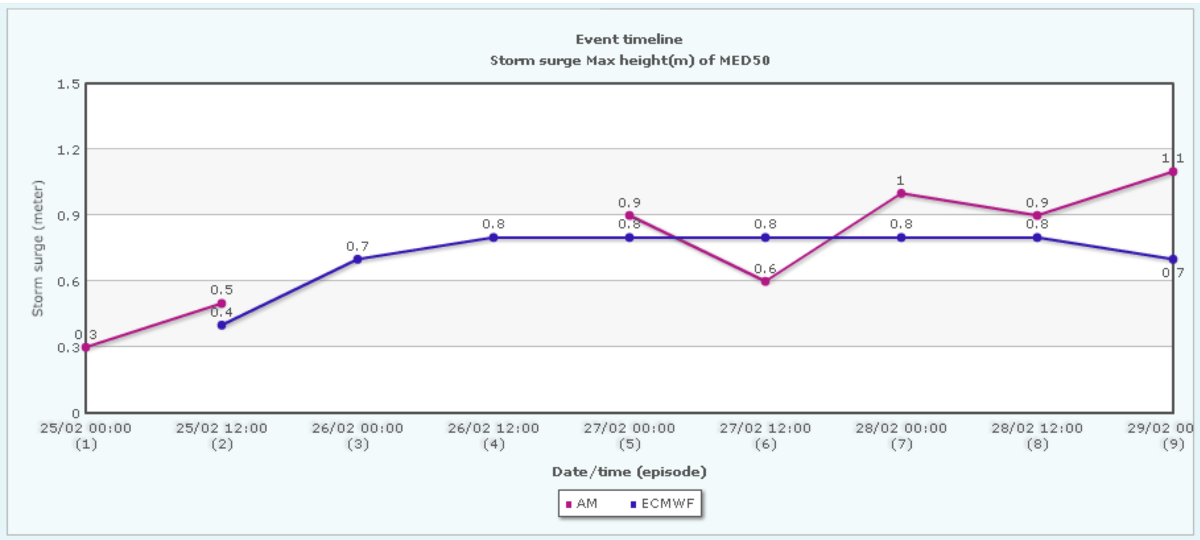


Figure 48 - *Event time line of max. storm surge*

Sea Level Comparisons

The JRC is currently implementing, the comparisons between the sea level observations for the locations that are in the SSCS bulletin (see SSCS bulletin in Section 5).

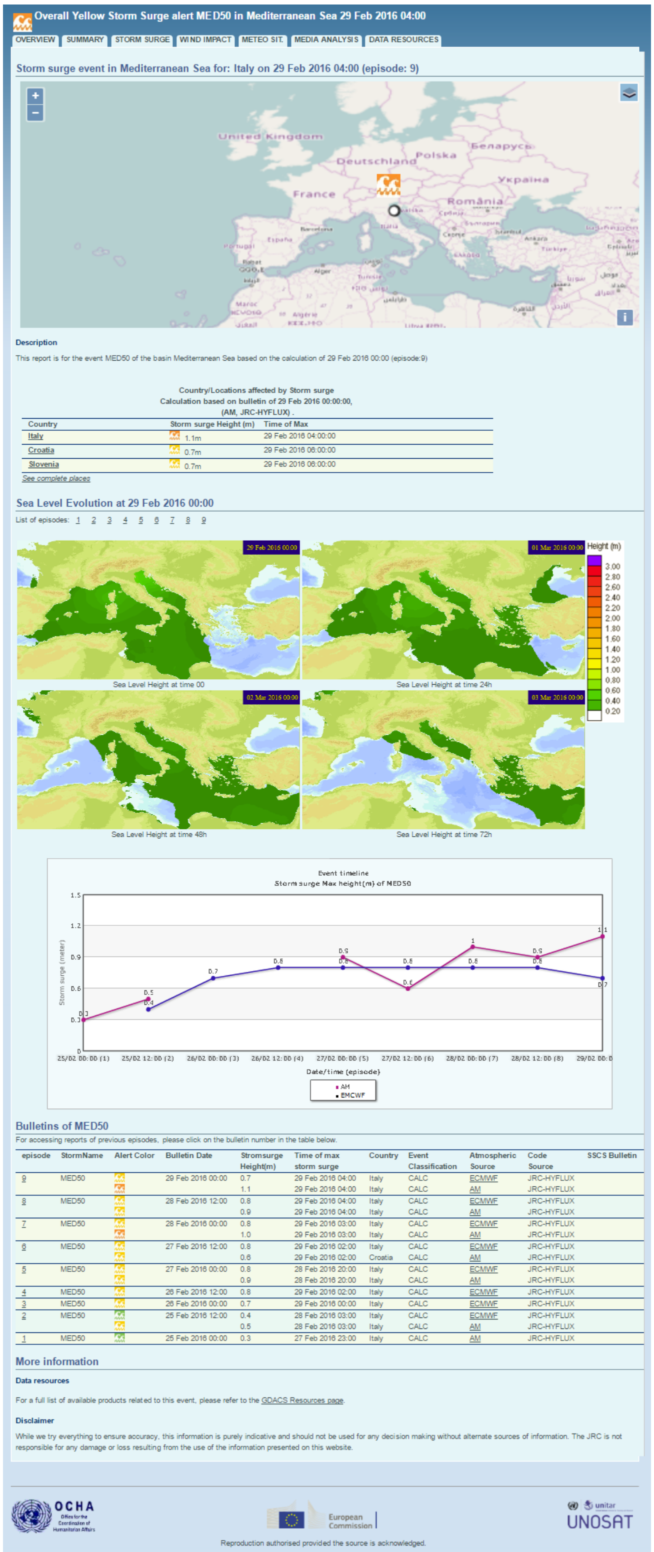


Figure 49 - *GDACS storm surge impact*

(4) WIND IMPACT

Wind impact for one specific event identified by the system

Title: "<*Alert level*> - Storm surge alert for <*storm name*> in <*basin*>"

Description

This report is for the event <event ID> in the basin <basin name> based on the calculation <calculation date> (episode: <episode number>).

Current impact:

- Max winds
- Time of max winds

Wind maps

The maps of the max winds used as input for the JRC calculations (see Sections 2-3) for the time: t 0, t +24h, t + 48 h, t + 72 h are included in this page.

The JRC is also evaluating the possibility to include an interactive map that includes also the **METAR data**.

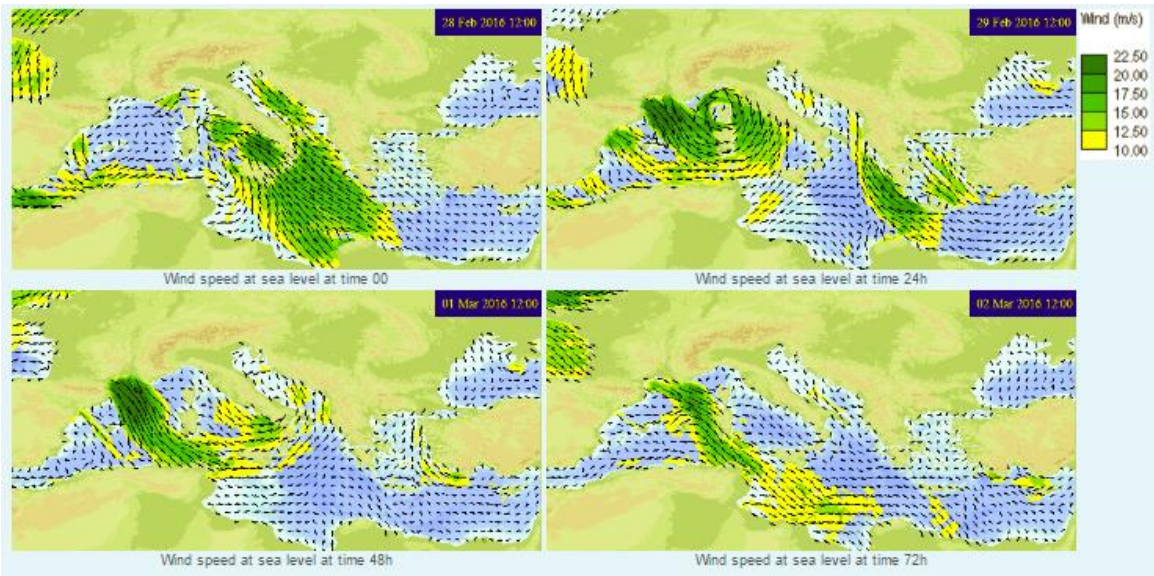


Figure 50 - *Wind maps*

Overall Yellow Storm Surge alert MED50 in Mediterranean Sea 29 Feb 2016 04:00

OVERVIEW | SUMMARY | STORM SURGE | WIND IMPACT | METEO SIT. | MEDIA ANALYSIS | DATA RESOURCES

Wind for the storm surge event in Mediterranean Sea for: Italy on 29 Feb 2016 04:00 (episode: 8), (AM, JRC-HYFLUX)

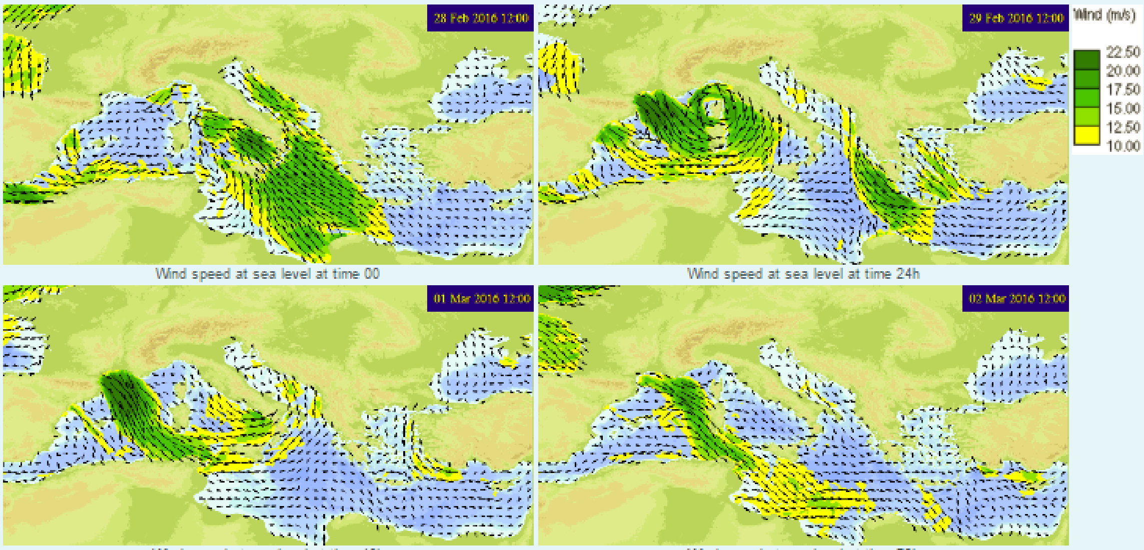
Description

This report is for the storm MED50 in the basin of Mediterranean Sea based on the calculation of 28 Feb 2016 12:00 (episode:8)

The maps of the max winds used as input from JRC calculations for the time t 0, t + 24h, t + 48h, t + 72h are included in this page

Wind maps

List of episodes: 1 2 3 4 5 6 7 8 9



Wind speed at sea level at time 00 | Wind speed at sea level at time 24h

Wind speed at sea level at time 48h | Wind speed at sea level at time 72h

Bulletins of MED50

For accessing reports of previous episodes, please click on the bulletin number in the table below

episode	StormName	Alert Color	Bulletin Date	Stromsurge Height(m)	Time of max storm surge	Country	Event Classification	Atmospheric Source	Code Source	SSCS Bulletin
9	MED50		29 Feb 2016 00:00	0.7	29 Feb 2016 04:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				1.1	29 Feb 2016 04:00	Italy	CALC	AM	JRC-HYFLUX	
8	MED50		28 Feb 2016 12:00	0.8	29 Feb 2016 04:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.9	29 Feb 2016 04:00	Italy	CALC	AM	JRC-HYFLUX	
7	MED50		28 Feb 2016 00:00	0.8	29 Feb 2016 03:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				1.0	29 Feb 2016 03:00	Italy	CALC	AM	JRC-HYFLUX	
6	MED50		27 Feb 2016 12:00	0.8	29 Feb 2016 02:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.6	29 Feb 2016 02:00	Croatia	CALC	AM	JRC-HYFLUX	
5	MED50		27 Feb 2016 00:00	0.8	28 Feb 2016 20:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.9	28 Feb 2016 20:00	Italy	CALC	AM	JRC-HYFLUX	
4	MED50		26 Feb 2016 12:00	0.8	29 Feb 2016 02:00	Italy	CALC	ECMWF	JRC-HYFLUX	
3	MED50		26 Feb 2016 00:00	0.7	29 Feb 2016 00:00	Italy	CALC	ECMWF	JRC-HYFLUX	
2	MED50		25 Feb 2016 12:00	0.4	28 Feb 2016 03:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.5	28 Feb 2016 03:00	Italy	CALC	AM	JRC-HYFLUX	
1	MED50		25 Feb 2016 00:00	0.3	27 Feb 2016 23:00	Italy	CALC	AM	JRC-HYFLUX	

More information

Data resources

For a full list of available products related to this event, please refer to the GDACS Resources page.

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***Figure 51 -** GDACS wind impact*

(5) METEOROLOGICAL SITUATION

Title: "Meteorological Situation"

Description

This page includes the meteorological situation at the time of the bulletin.

The following images are included:

Current situation

- current meteorological situation (MSLP, fronts) and the "Storm Names", for example like the FU-Berlin map shown below (see more information in Section 8.2).

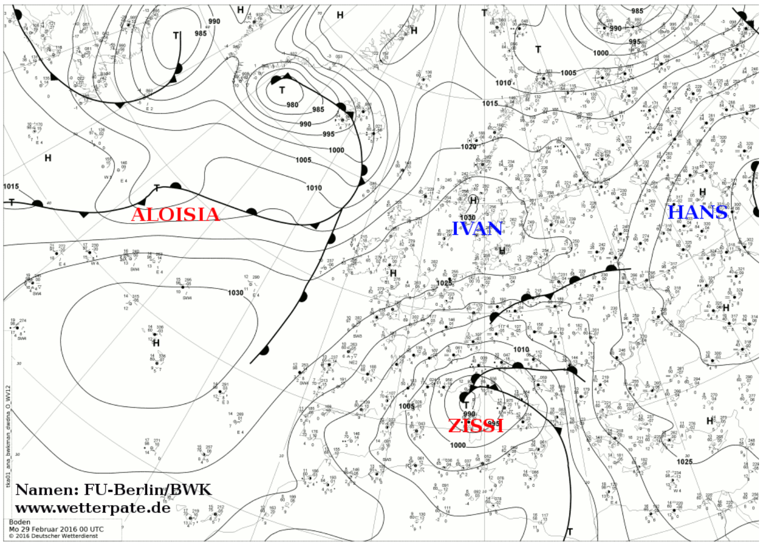


Figure 52 - *MSLP, fronts, Storm Names (source: FU-Berlin)*

- Satellite images

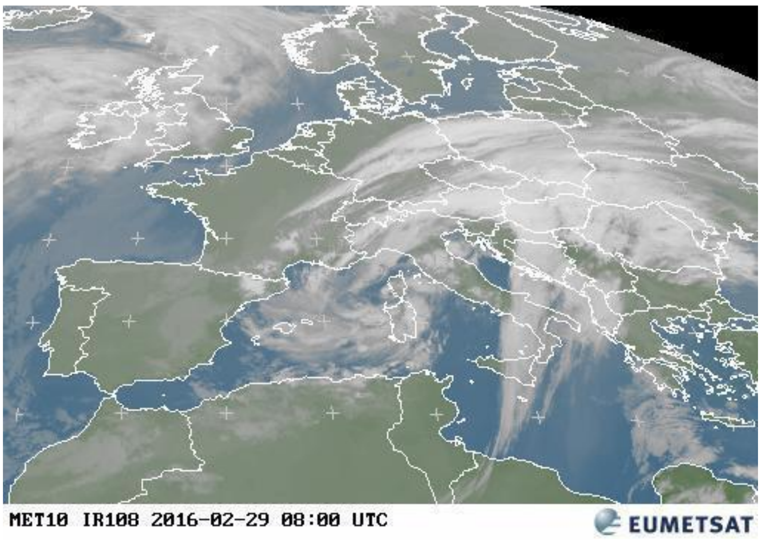
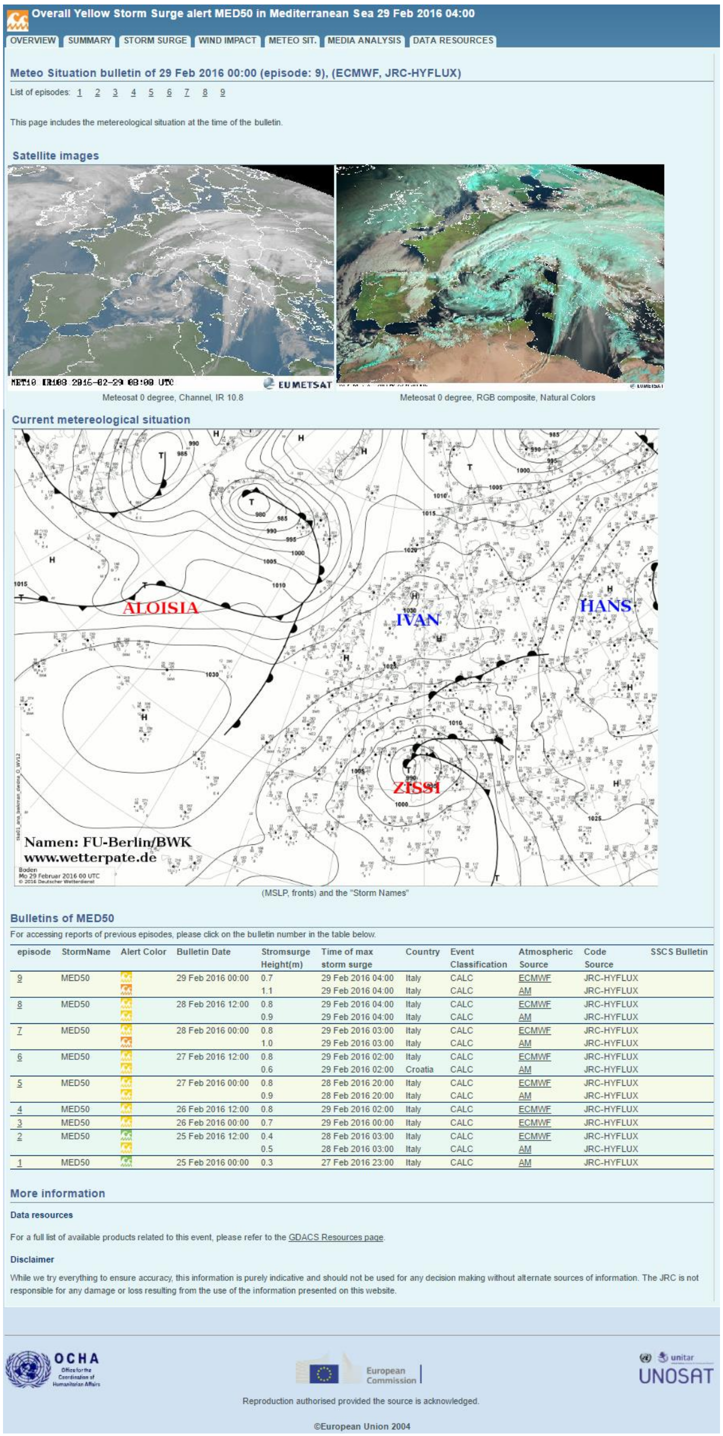


Figure 53 - *Satellite image (source: EUMETSAT)*


Overall Yellow Storm Surge alert MED50 in Mediterranean Sea 29 Feb 2016 04:00

OVERVIEW | SUMMARY | STORM SURGE | WIND IMPACT | METEO SIT. | MEDIA ANALYSIS | DATA RESOURCES

Meteo Situation bulletin of 29 Feb 2016 00:00 (episode: 9), (ECMWF, JRC-HYFLUX)

List of episodes: 1 2 3 4 5 6 7 8 9

This page includes the metereological situation at the time of the bulletin.

Satellite images

Meteosat 0 degree, Channel, IR 10.8

Meteosat 0 degree, RGB composite, Natural Colors

Current metereological situation

(MSLP, fronts) and the "Storm Names"

Bulletins of MED50

For accessing reports of previous episodes, please click on the bulletin number in the table below.

episode	StormName	Alert Color	Bulletin Date	Stromsurge Height(m)	Time of max storm surge	Country	Event Classification	Atmospheric Source	Code Source	SSCS Bulletin
9	MED50		29 Feb 2016 00:00	0.7	29 Feb 2016 04:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				1.1	29 Feb 2016 04:00	Italy	CALC	AM	JRC-HYFLUX	
8	MED50		28 Feb 2016 12:00	0.8	29 Feb 2016 04:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.9	29 Feb 2016 04:00	Italy	CALC	AM	JRC-HYFLUX	
7	MED50		28 Feb 2016 00:00	0.8	29 Feb 2016 03:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				1.0	29 Feb 2016 03:00	Italy	CALC	AM	JRC-HYFLUX	
6	MED50		27 Feb 2016 12:00	0.8	29 Feb 2016 02:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.6	29 Feb 2016 02:00	Croatia	CALC	AM	JRC-HYFLUX	
5	MED50		27 Feb 2016 00:00	0.8	28 Feb 2016 20:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.9	28 Feb 2016 20:00	Italy	CALC	AM	JRC-HYFLUX	
4	MED50		26 Feb 2016 12:00	0.8	29 Feb 2016 02:00	Italy	CALC	ECMWF	JRC-HYFLUX	
3	MED50		26 Feb 2016 00:00	0.7	29 Feb 2016 00:00	Italy	CALC	ECMWF	JRC-HYFLUX	
2	MED50		25 Feb 2016 12:00	0.4	28 Feb 2016 03:00	Italy	CALC	ECMWF	JRC-HYFLUX	
				0.5	28 Feb 2016 03:00	Italy	CALC	AM	JRC-HYFLUX	
1	MED50		25 Feb 2016 00:00	0.3	27 Feb 2016 23:00	Italy	CALC	AM	JRC-HYFLUX	

More information

Data resources

For a full list of available products related to this event, please refer to the GDACS Resources page.

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Figure 54 - *GDACS Meteorological Situation*

(6) MAPS & REPORTS

Detailed analysis of the most important events (like the GDACS for the ECHO Daily Maps)

(7) MEDIA ANALYSIS

Media reports (emm), using the filed "storm name"

(8) DATA SOURCES

This page includes all the data resources:

Figure 55 *- GDACS Data sources*

Other than the pages described above, the "storm surge events" will be included in the GDACS archive and in the Register page.

9 Application of the SSCS

9.1 Northern Sea – Storm Xaver (December 2013)

An intense low pressure system, named “Storm Xaver”, affected several countries of northern Europe in December 2013, causing inundation and damages along its path (see *Figure 56*).

A brief description of this event is shown in this section, while more information are available in Annunziato and Probst 2015.

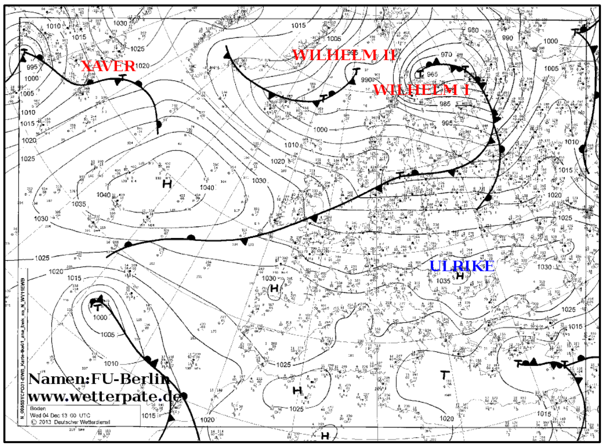


Figure 56 *– Weather map, Storm Xaver (source: Free University of Berlin)*

Meteorological situation

This intense low pressure system formed over the North Atlantic Ocean off the west coast of Iceland on 4 December 2013 and moved towards northern Europe, intensifying. Its center passed off the coast of northern UK in the morning of 5 December, over southern Norway and southern Sweden in the following hours and reached the Baltic Sea on 6 December (see the weather maps in *Figure 57*).

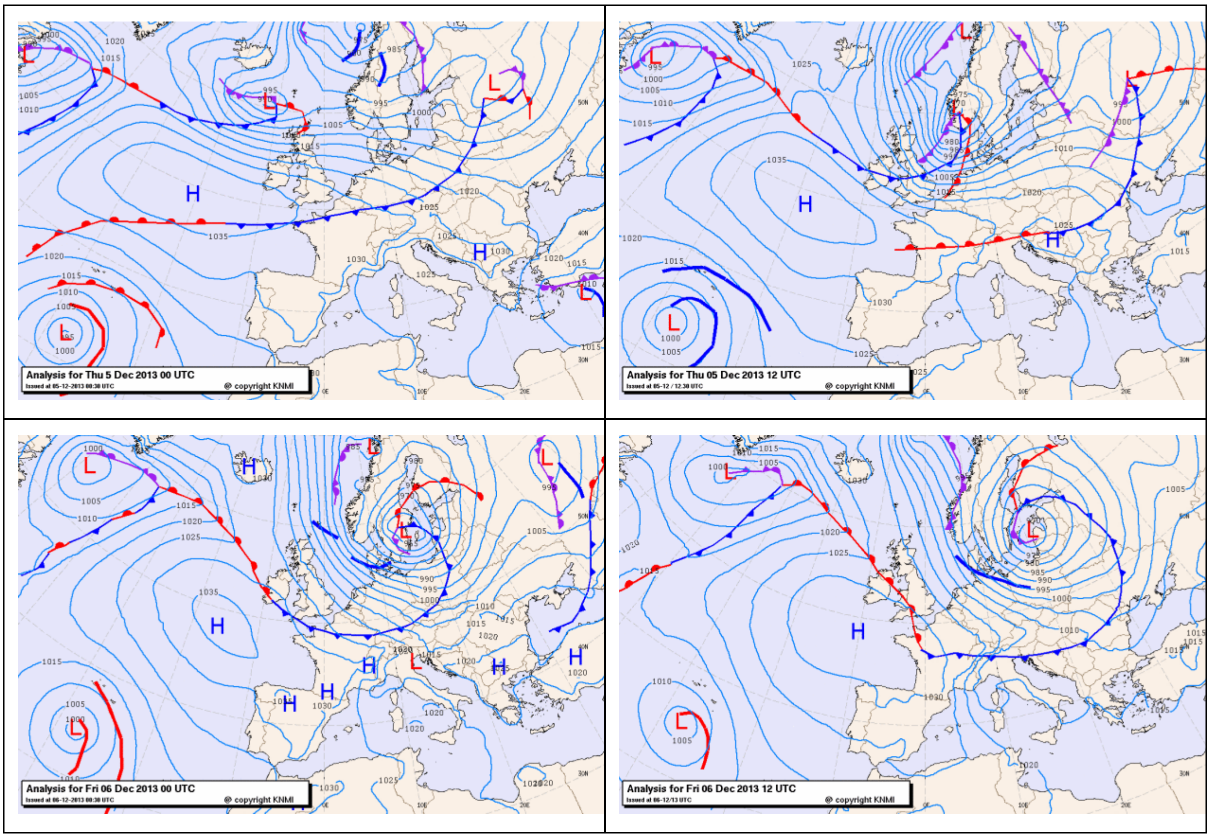


Figure 57 *- Weather Maps from 05 Dec 2013 00:00 UTC to 06 Dec 12:00 UTC (source: KNMI)*

Storm Surge analysis

Storm Xaver caused a large storm surge in several countries of northern Europe, especially in Germany, were there was a peak of up to 4 m (see *Figure 58*).

This storm surge event was well represented by the JRC calculations. Only in some areas of Germany (e.g. Cuxhaven) the maximum of storm surge was underestimated (see *Figure 58*). It is important to note that in this area the forecasted winds, used as atmospheric input in the JRC storm surge model, were also less intense compared to the measurements (max. winds forecasted: 80 km/h, measured: 130 km/h, see more information in Annunziato and Probst 2015).

It should be notice that the storm Xavier was one of the first cases simulated by this new system that was established just a few months before this event.

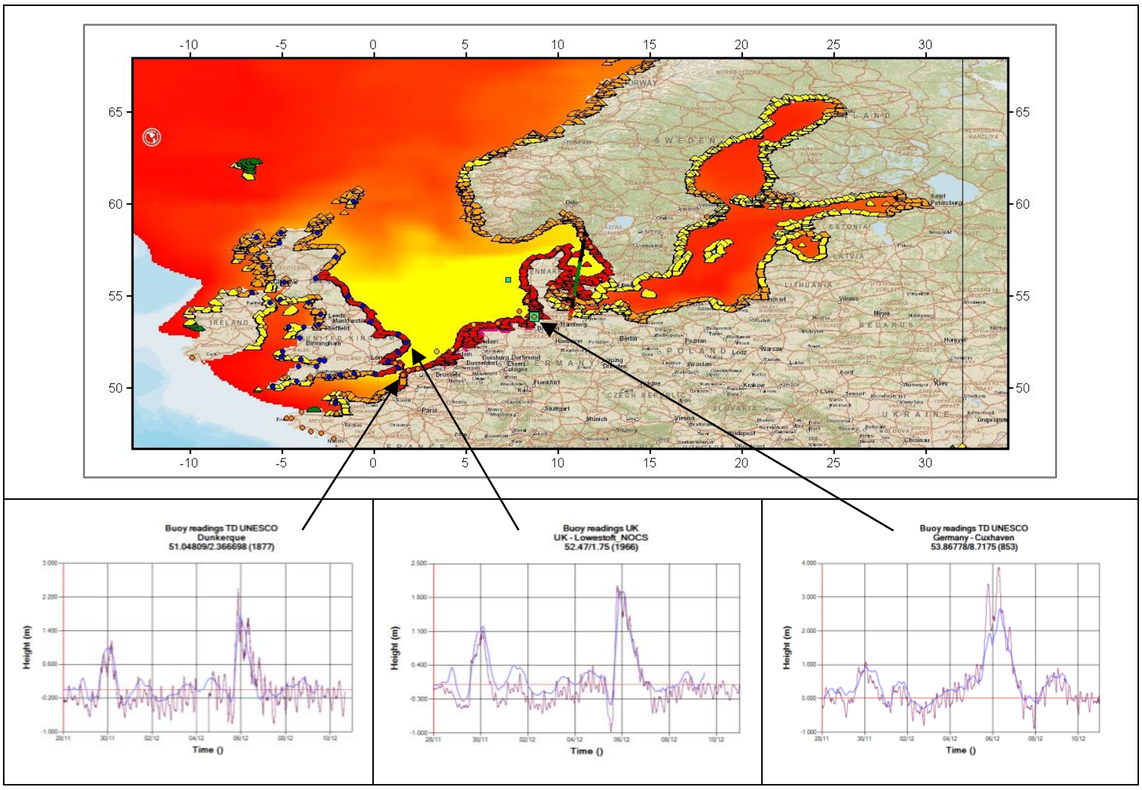


Figure 58 - *Storm Surge due to the passage of the storm Xaver in December 2013 (in the graphs blue line represents the calculations, purple line the observations).*

9.2 Northern Adriatic Sea (February 2015)

The passage of an intense low pressure system caused heavy snowfall, strong winds, heavy rains and storm surge in several areas of northern Italy on 5 – 6 February.

In particular, a large storm surge was measured along the coastal areas of the northern Adriatic Sea on 5 February evening / 6 February morning. The area most affected was Ravenna, with a max. of storm surge of 1.1 m.

Media reported damage due to storm surge and winds in several coastal areas of northern Adriatic Sea, especially in the area near Ravenna (see *Figure 59*).

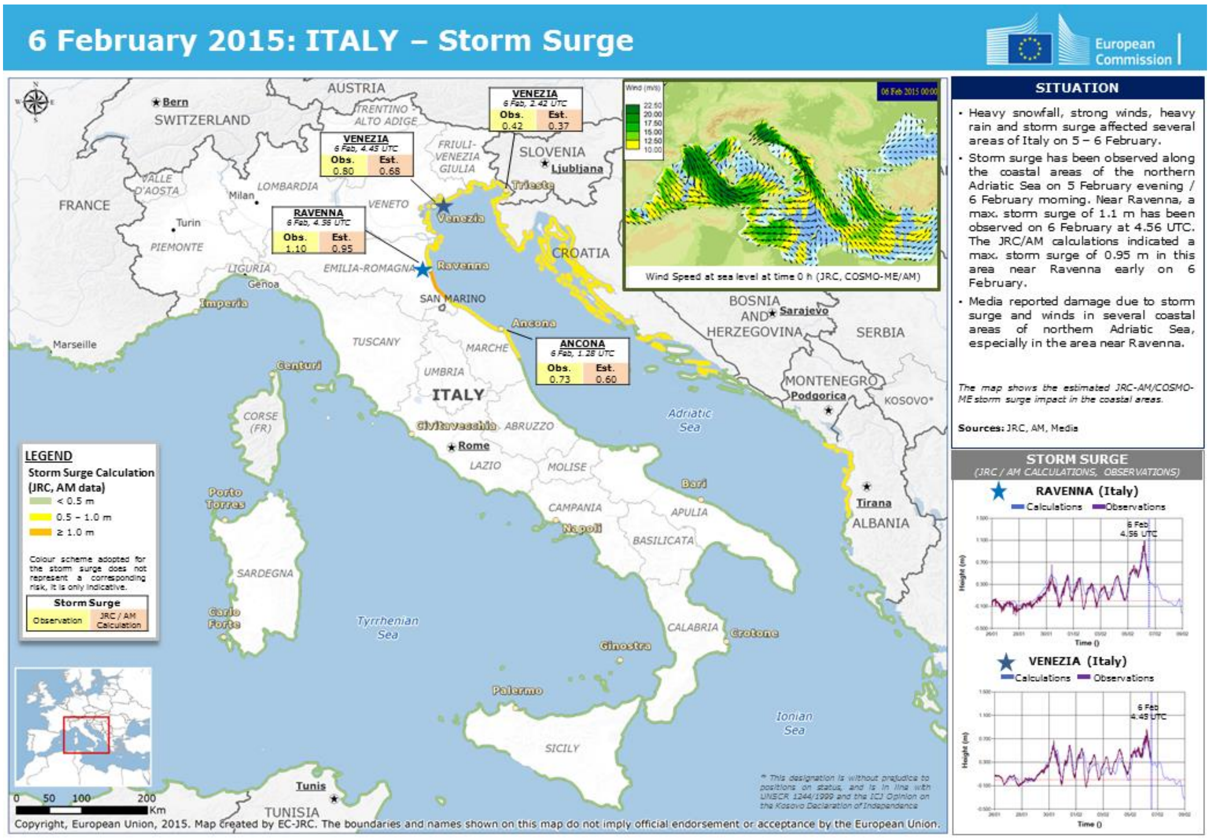


Figure 59 *- Situation map for the Storm Surge event in north-eastern Italy on 5-6 February 2015. JRC calculations, using as input the data COSMO-ME AM of 6 Feb 2015 00:00 UTC.*

Meteorological situation

An intense low pressure system formed close to Sardinia on 5 February and started moving east, reaching northern Sardinia in the afternoon of 5 February and mainland Italy on 6 February (see the weather maps in *Figure 61*).

Very strong winds affected the norther Adriatic on 5-6 February.

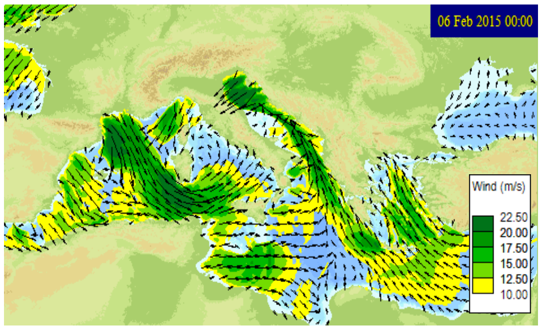


Figure 60 *- Wind speed at 10m height*

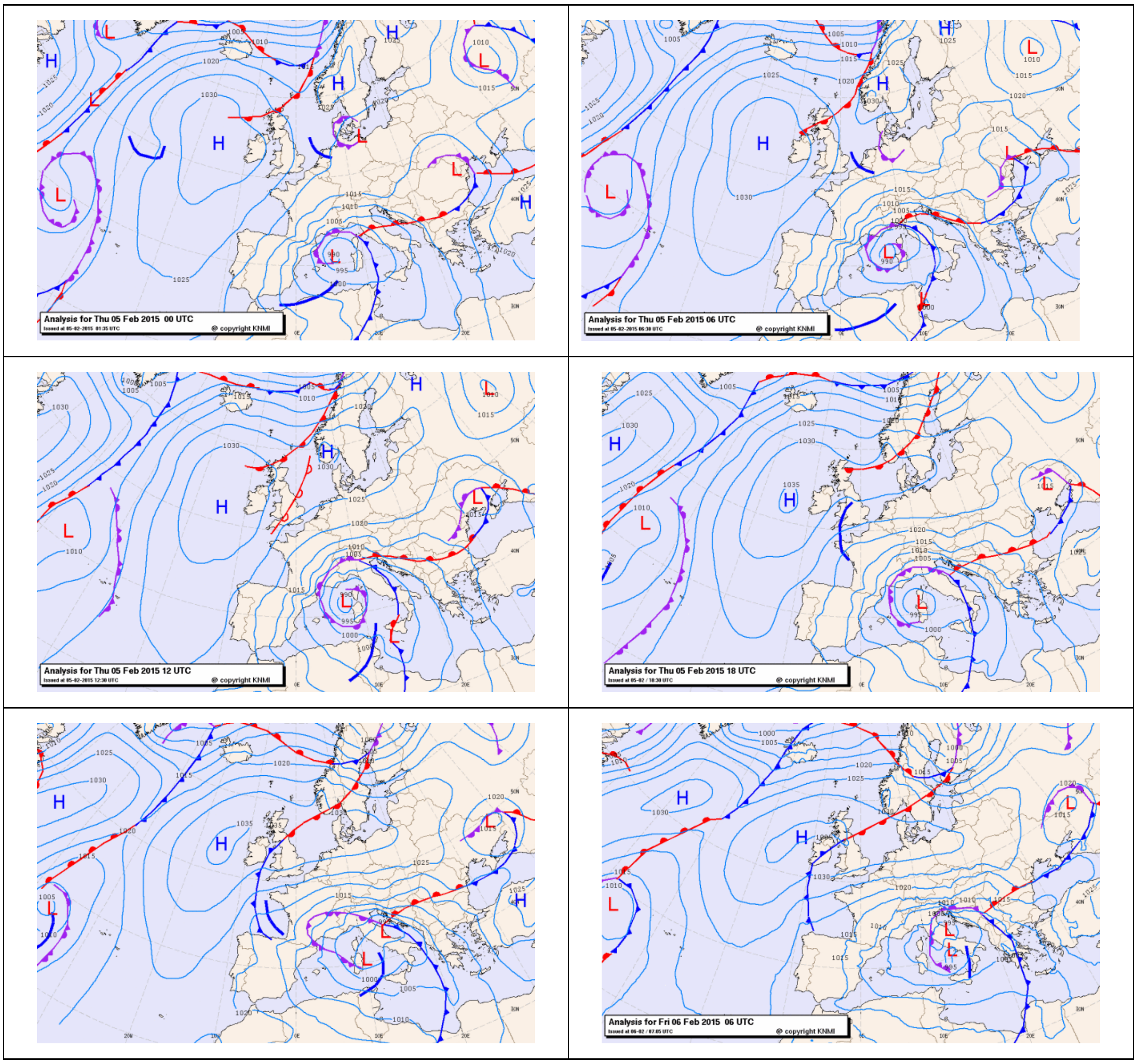


Figure 61 *- Weather maps from 5 Feb 2015 00 UTC to 6 Feb 06 UTC (source: KNMI)*

Storm Surge analysis

A large storm surge affected the northern Adriatic Sea on 5-6 February, especially in the area of Ravenna, were a max. storm surge of 1.1 m has been measured on 6 February at 4.56 UTC. This event caused floods also in Venice (see the inundation in Piazza San Marco in *Figure 62*).

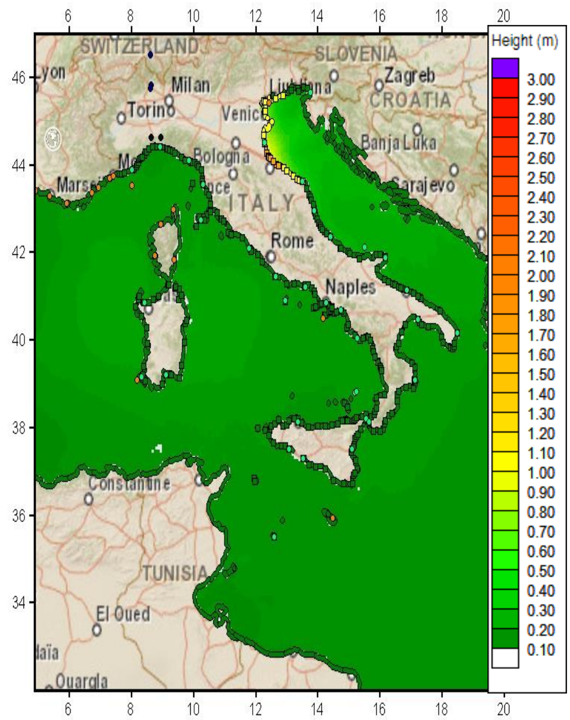
Figure 62 *- Webcam in Piazza San Marco in Venice (Istitutuzione Centro Previsione e Segnalazione Maree).*

Input: COSMO-ME AM

This event has been well forecasted with more than 24 h in advance by the JRC SSCS using as input the data of COSMO-ME AM (see *Table 35*). A max. storm surge of 1.1 m was estimated for Marina di Ravenna early on 6 February (see *Figure 59*), using as input the data of 5 Feb 2015 12:00 UTC.

	Input Data: COSMO ME-AM of					**Measurements**
	4 Feb 00 UTC	4 Feb 12 UTC	5 Feb 00 UTC	5 Feb 12 UTC	6 Feb 00 UTC	
Ravenna	0.7 m	0.7 m	0.9 m	1.1 m	1.0 m	1.1 m
Venice	0.7 m	0.8 m	0.8 m	0.8 m	0.8 m	0.8 m

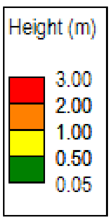
Table 35 *- JRC storm surge estimation using as input the COSMO-ME AM data.*



Actual Time	Country	Location	Height	ID		
06 Feb 2015 03:00	Italy	Riccione	1.0		44.01	12.66
06 Feb 2015 03:00	Italy	Cattolica	1.0		43.97	12.74
06 Feb 2015 03:00	Italy	Pesaro	0.9		43.92	12.91
06 Feb 2015 03:00	Italy	Fano	0.9		43.85	13.01
06 Feb 2015 02:00	Italy	Senigallia	0.8		43.73	13.21
06 Feb 2015 05:00	Italy	Montemarciano	0.6		43.66	13.33
06 Feb 2015 05:00	Italy	Falconara Marittima	0.6		43.64	13.40
06 Feb 2015 01:00	Italy	Chioggia	0.8		45.22	12.28
06 Feb 2015 04:00	Italy	Chioggia	0.8		45.21	12.30
06 Feb 2015 05:00	Italy	Caorle	0.5		45.59	12.88
06 Feb 2015 05:00	Italy	Mestre	0.8		45.45	12.27
06 Feb 2015 05:00	Italy	Venezia	0.8		45.43	12.31
06 Feb 2015 05:00	Italy	Lido di Jesolo	0.6		45.50	12.65
06 Feb 2015 03:00	Italy	Lido di Estensi	0.9		44.68	12.25
06 Feb 2015 03:00	Italy	Cervia	1.1		44.26	12.36
06 Feb 2015 03:00	Italy	Cesenatico	1.0		44.20	12.41
06 Feb 2015 03:00	Italy	Cesenatico	1.0		44.18	12.42
06 Feb 2015 03:00	Italy	Bellaria	1.0		44.15	12.47
06 Feb 2015 03:00	Italy	Rimini	1.0		44.08	12.57
06 Feb 2015 03:00	Italy	Marina di Ravenna	1.1		44.49	12.29
06 Feb 2015 05:00	Italy	Ancona	0.6		43.63	13.51
06 Feb 2015 05:00	Italy	Ancona	0.6		43.62	13.53

Figure 63 *– JRC storm surge calculations using as input the data of COSMO-ME AM of 5 Feb 2015 12:00 UTC.*

Estimated storm surge on the left. List of the locations affected by a storm surge > 0.5 m (above).



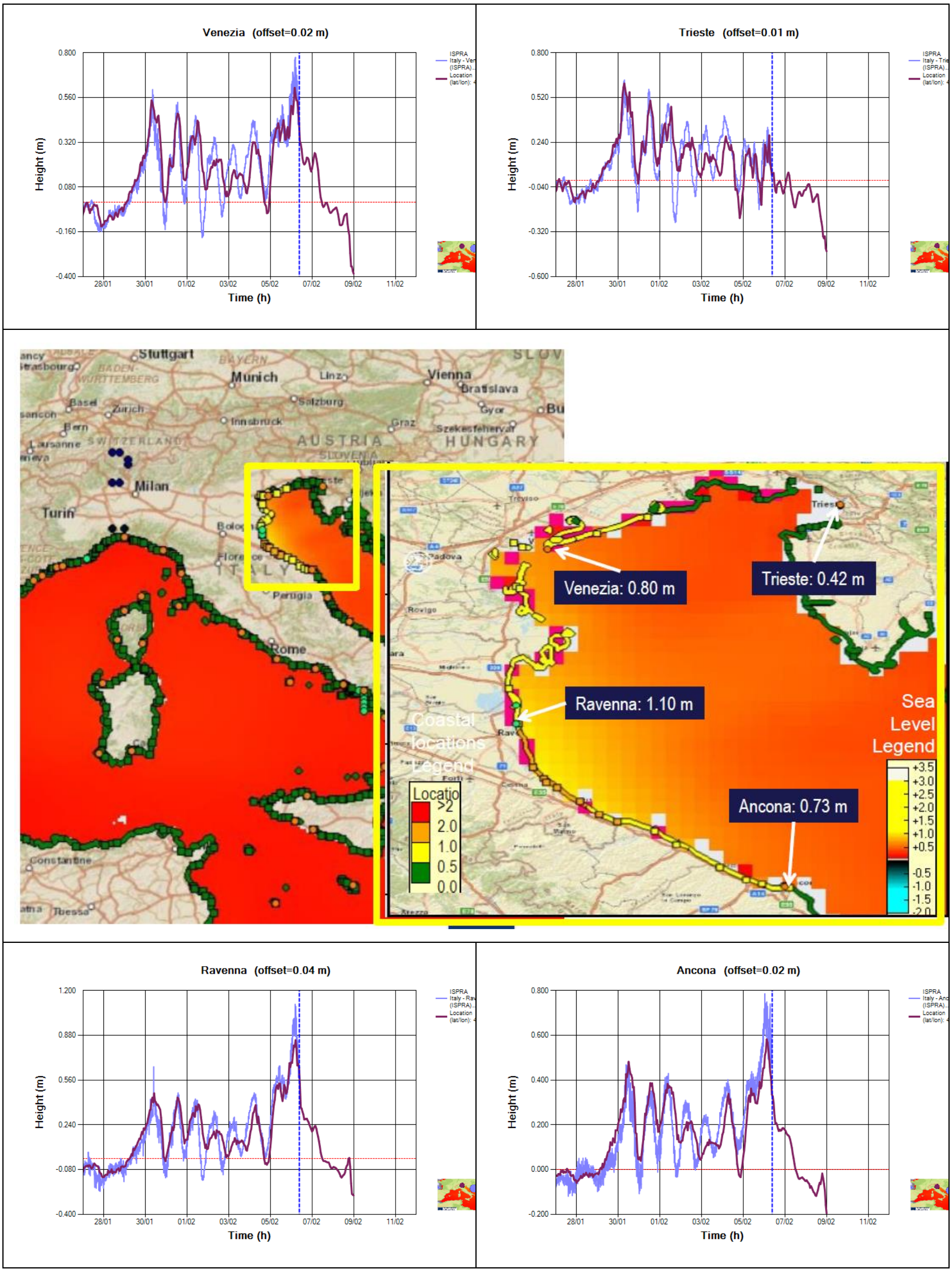


Figure 64 *- Storm surge calculations using as input the data of COSMO-ME AM.*

10 Conclusions

A new storm surge calculation system has been developed by the JRC in order to estimate the impact of the storm surge in several areas of Europe: the JRC Storm Surge Calculation System - SSCS. This system has been established at the JRC in the frame of the GDACS and it is intended as a series of procedures that use meteorological forecasts produced by the European Centre for Medium Weather Forecast (ECMWF), the Italian Air Force Meteorological Weather Service (AM) and the Hellenic National Meteorological Service (HNMS) in order to estimate the storm surge caused by strong winds and pressure gradient, due to the passage of an intense low pressure system. An automatic procedure has been developed for each dataset by the JRC.

Every day several SSCS bulletins are created for different areas of Europe:

- North Sea
- UK and Ireland
- Mediterranean Sea
- Italy
- Greece
- North Atlantic

These bulletins are published on the SSCS website and sent by mail to different users. All the automatic procedures developed by the JRC for this new storm surge system and the SSCS bulletins produced every day are described in this report.

The JRC is currently using the HyFlux2 code as Hydraulic model in the SSCS, but it has recently developed a new procedure in order to use also another solver (DELTARES Delft3D) in this system. This new SSCS bulletin has been also described in this report.

This calculation system has been tested over the last 3 years and it has well estimated the most important events that affected the European coasts (eg. Storm Xavier in 2013 and the storm surge events along the coast of the Adriatic Sea in 2015 and 2016). The JRC is currently preparing a detailed validation of this system that will be presented into a specific report, in order to provide a systematic estimation of the calculation uncertainty.

The use of ensemble bulletins, collating several calculations performed using various forcing or solvers models proved to be an effective method to indicate the possible uncertainties in the estimation of the impact parameters; therefore a wider implementation of this technique is envisaged for the future.

The JRC is currently implementing this system in GDACS.

Acknowledgements

The authors would like to thank **Stefano Paris** for his work in the development of the GDACS - Storm surge website.

Authors

Alessandro Annunziato and Pamela Probst

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List of abbreviations and definitions

AM - Italian Air Force Meteorological Weather Service

EC - European Commission

ECMWF - European Center for Medium Weather Forecast

GDACS - Global Disasters Alert and Coordination System

GLOSS - Global Sea Level Observing System

HNMS - Hellenic National Meteorological Service

JRC - Joint Research Centre

NOC - UK National Oceanography Centre

NTSLF - National Tidal and Sea Level Facility

SSCS - Storm Surge Calculation System

TC – Tropical Cyclone

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