

# 25.- Sea level rise and extreme weather conditions

## Key message

- Almost all monitoring stations evidence a rise in the relative sea level (the max. rate is 5 mm/year). However, there are clear differences among them, what reveals the incidence of local factors on this value.
- Spite the efforts of definition a common methodology, the incidence of marine storms in the coast have been measured in different ways.
- Results do not point out an increase in marine storms but it can not be asseverated that this is not being taking place.



## Why monitor the sea level rise and extreme weather conditions?

The indicator is related to coastal vulnerability and it can get evident two reported effects of the climate change: the commonly known of sea level rise (some predictions calculates the global sea level is likely to rise about 3 mm/year as a result of human-induced climate warming), but also the effect of increase in the incidence of coastal storms.

The effect of rise in coastal storms is problematic because coastal storms cause temporal flooding, due to wave run-up, but mainly because it is responsible of most coastal erosion. The erosion is more related with extreme events that current wave incidence.

Sea level rise as such as is a very relevant information for coastal zones. The sea level rise has a clear and transcendent consequence: the permanent inundation of coastal land coast. The height of sea relative to the land determines the shape of the shoreline. There are global factors that produce relative sea level rise (RSLR), mainly thermal expansion of ocean waters but also geodetic changes. In addition, it is influenced by the regional process uplift or subsidence in coastal areas related to various tectonic processes, fluid withdrawal and sediment deposition and compaction.

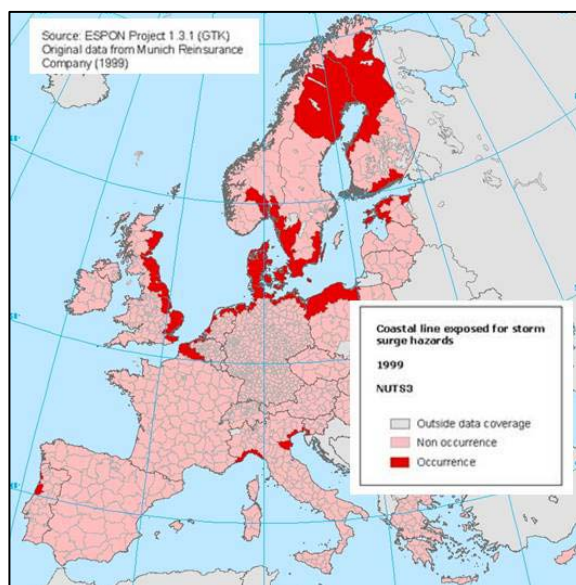
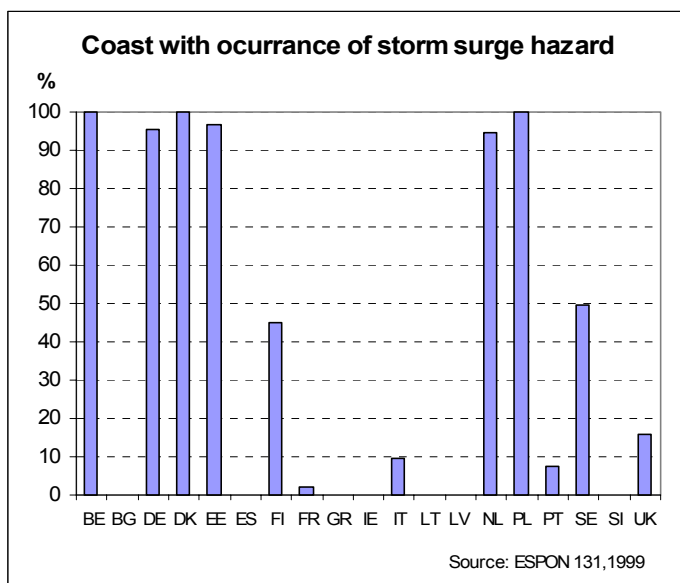
Moreover, this monitoring has an important role for sensitization on the need of acting against climate change.

The indicator has 2 measurements: Number and intensity of stormy days and Rise in sea level relative to land. This IFS includes results of the 2 measures.

## What does the indicator show from European to local level?

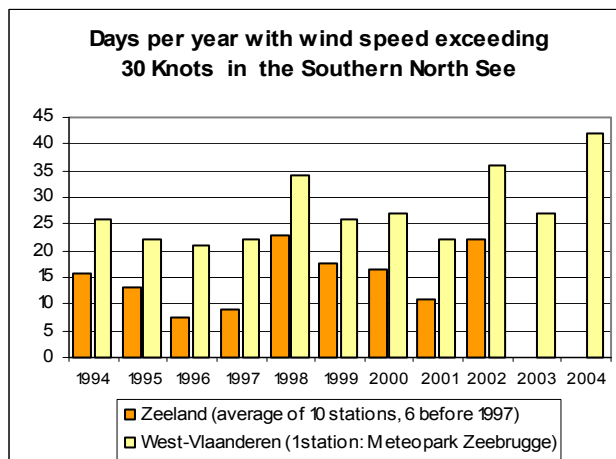
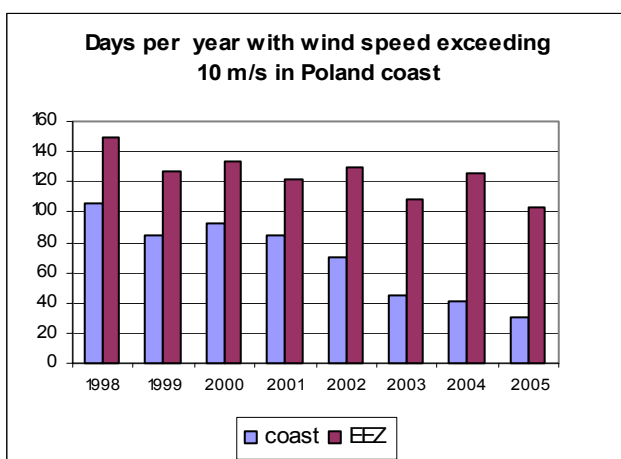
In spite of a common methodological definition, the calculation of **the measure Number and intensity of stormy days have been calculated in different** ways for each scope. It is due to the different monitoring systems.

At **European** scale the incidence of extreme weather conditions is measured by means of **proportion of coast with risk of storm surge hazard** in each country. It has been calculated by the **ESPON project** for the year 1999. The calculation of ESPON project is for the year 1999. Its results allows comparisons between countries but it do not offer temporal evolutions.



The results evidence that the **highest probability of occurrence of storms is located the in Northern European coastline**. The countries with the biggest portion of exposed coastline to the occurrence of storm surge hazards are Poland, Belgium and Denmark, with the 100% of the coastline, and Germany, Netherlands and Estonia, which present around 95%. Finland and Sweden have near the half coastline. In United Kingdom the value is around 15%, however all the oriental coastline of Great Britain is affected.

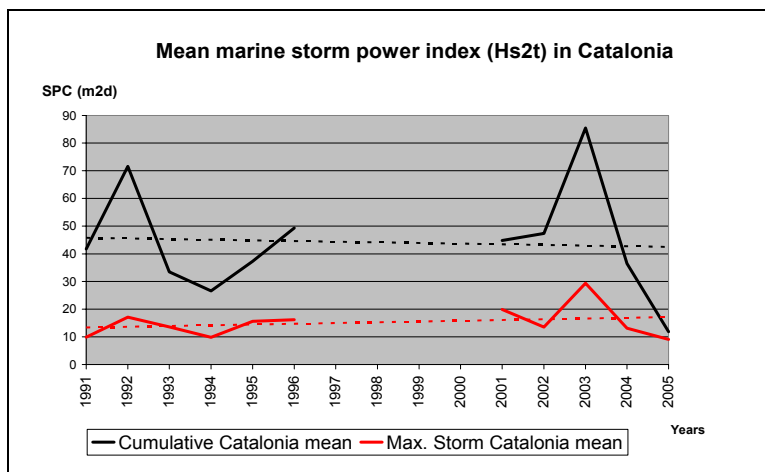
In **Poland**, the incidence of storms in coast has been measured by means of the amount of **days per year with storm wind conditions exceeding 10 m/s**. The results for whole Polish show a **decreasing trend** within the last 7 years in the marine coverage EEZ (Exclusive Economic Zone) and in the coastal area. The yearly number of days fluctuates between 150 in 1998 and 103 in 2005 in the EEZ and 106 days in 1998 and only 31 in 2005. The results in Poland present a descendant trend, very clear at the coast.



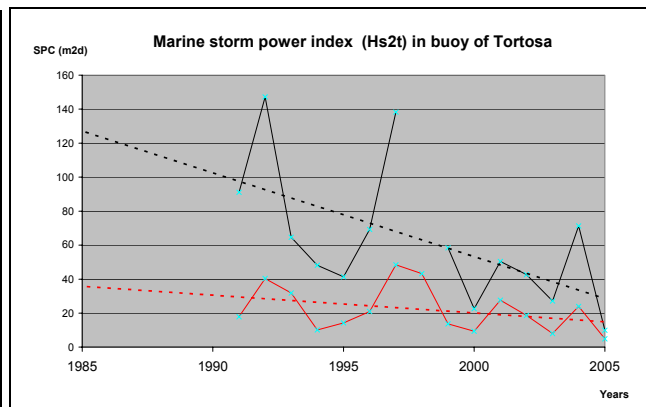
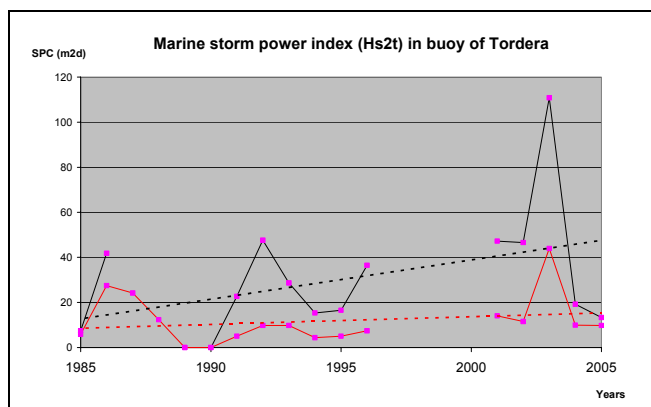
The **SAIL sub-regions** have reported also the **number of stormy days** per year in relation with high wind speeds. It has been considered the **days with maximum wind speed gust above 30 knots**. There are data from Zeeland (Netherlands) since 1959 with 1 station, and since 1994 in West-Vlaanderen, on contrary

data for significant wave height is available just from 2001. The stormy days ranges between 26 and 42 in West Vlaanderen and between 8 and 22 in Zeeland. The annual variability is so high that there is not clear trend, however we can see in the graph the top values last years and, furthermore, there is an ascendant trend in records of Zeeland along last 50 years. Studies in the UK reveal no clear trends in the long-term.

In **Catalonia**, the evolution of storms in the coast has been measured by means of **specific power index of waves**. The measure uses the records in marine buoys of the wave heights. The measure integrates by time along each year, the square of **heights beyond 2 m** (when they cause coastal erosion).



Results in Catalonia show a high **fluctuation between years and a clear trend is not evidenced**. The calculated linear regression is ascendant in 3 of the 4 analysed buoys, but the average of them is descendant in the cumulative storm power. The highest incidence of marine storms happens in the North and South of the Catalan coast, respectively the Gulf of Rosas and The Delta of the Ebro river. The upper registered yearly accumulative storm powers are 147 m<sup>2</sup>day and 140 m<sup>2</sup>day, in contrast of 10-20m<sup>2</sup>day obtained some days.



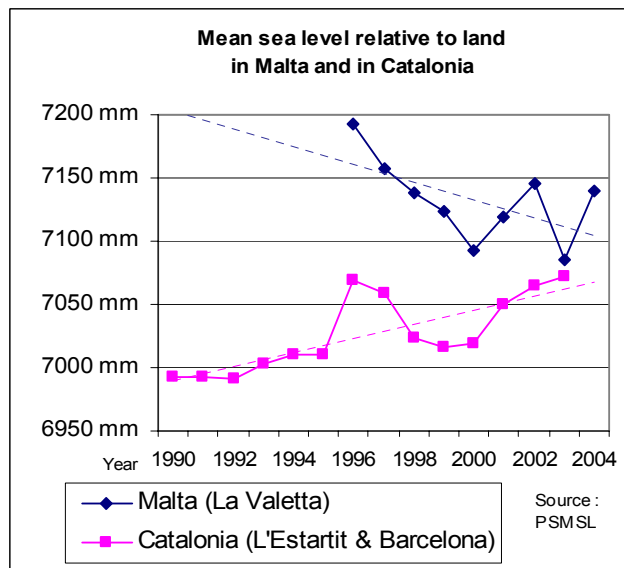
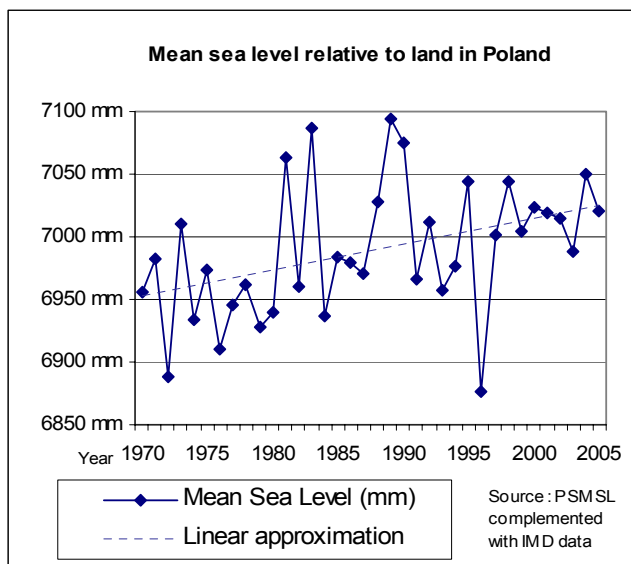
In conclusion, the offered data on stormy days can not demonstrate the forecast on climate change of the increase of incidence of extreme weather conditions; much more data and statistical studies are needed for demonstrating statistically change in a very erratic parameter of weather.

On contrary to the measure on marine storms, the calculations of **relative sea level (RSL)** are **homogenous** among partners. It is due to the evidence of the measured concept and, mainly, of the existence of a **common source: the Permanent Service for Mean Sea Level (PSMSL)**. The offered data have not sense in absolute terms but are valid in relative terms: comparison along years.

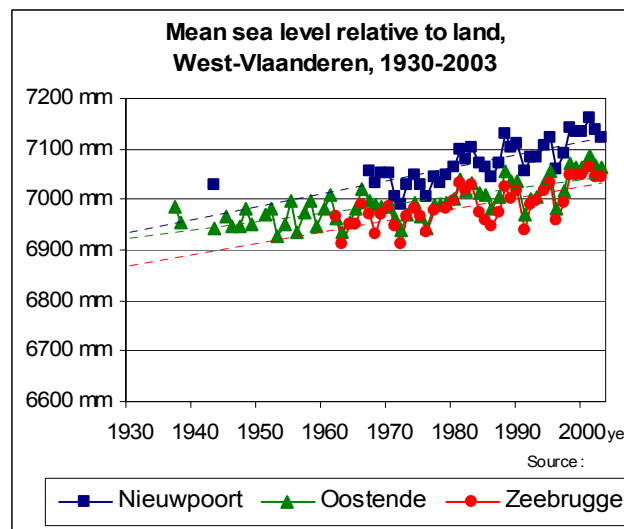
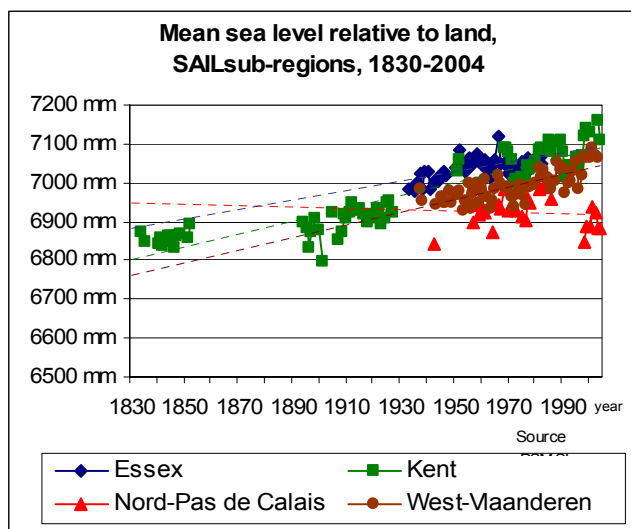
As it can be seen following, the **results evidence a clear ascendant trend**, except for results coming from Malta, but **annual rates of increase move between 5,5 mm/year and 0,14 mm** year depending mainly of station but moreover of series duration.

The results of the 35 years sea level monitoring in 7 stations for the whole **Polish coast** show the **increase** in the sea level relative to land with the mean value about **1,8 mm/year**. The mean value differ depending on monitoring stations and the strongest increasing trend is noted in Gdansk and Władysławowo - the lowest value in Swinoujscie. All the stations experience the quite strong yearly fluctuations of the mean sea level.

In **Malta**, the RSL has increased **191 mm in front the records in 1942**. **On contrary**, the graph for Malta shows **a decrease in sea level in the last 9 years**. This recorded reduction is in line with the decelerations in Mediterranean sea levels and even decreases in the latter part of the century that is reported by the IPCC in the 2001 (Third Assessment Report on Climate Change). The IPCC suggest that it may be caused by increases in the density of Mediterranean Deep Water and air pressure changes connected to the North Atlantic Oscillation (NAO).



Mean sea level at the coast of **Catalonia** describes a rising trend of **5,5 mm/year**, but the calculated measure does not include land vertical displacements.



Sea levels relative to land are **rising** at the longest active gauging station in all **4 sub-regions around the English Channel: West-Vlaanderen, Nord-Pas de Calais, Kent and Essex**. The rise in relative sea level is highest in Sheerness (in Kent), with an average **1,65 mm/year since 1834**, and lowest in Dunkerque (in Nord-Pas de Calais), with an average **0,14 mm/year since 1942**. Oostende (in West-Vlaanderen) and Southend (in Essex) experienced a rise of 1,44mm/year and 1,2mm/year respectively since measurements started. In Essex apparently **considerable differences are recorded between stations, 0,96 mm/year** in Harwich and **5 mm/year** in Walton on the Naze. which are explained partly by local differences in vertical land movement. According to the measurements in Vlissingen, sea level has risen by an average of **2 mm/year** in relation to the NAP (Nationaal Amsterdamsch Peil), **since 1900**.

Finally, sea level changes are a result of different phenomena and short term trends at localised levels. It must be very careful with data interpretations; definitive conclusions can not be obtained with these results, they must be justified by statistical studies.

# Policy and management for a sustainable coast

## What are the implications for planning and managing the coastal zone?

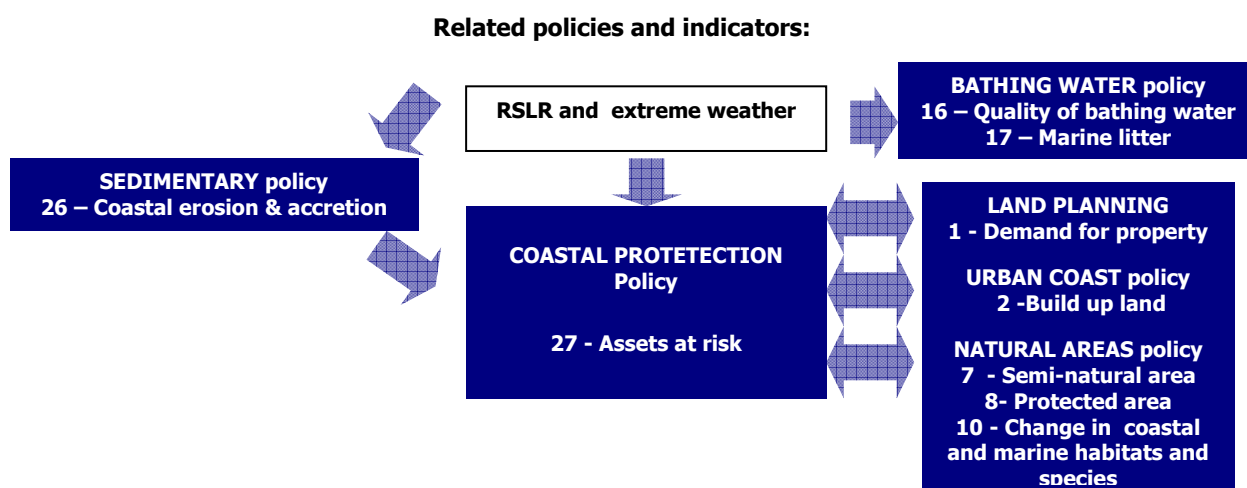
As it has been explained in the part of justification of monitoring this indicator, the sea level and the marine storms are very important for the shape of the coastline. Therefore this indicator is extremely important for managing the coastal areas.

The statistical study of both measures (storms and sea level) can advance future scenarios of coastal zones affected by permanent or temporal inundation and eroded.

Combining the obtained data with others like, policy makers must know probable damages caused by storms or RSLR. The level of surge is partly determined by the slope of the continental shelf, the tide and waves parameters and the wind from winter storms. Others parameters to be combined are indicators on infrastructure capacity and economic aspects of reconstruction after big storms in the coast. Also with parameters related to local insurance and other hazards at the coast, such as floods and exceptional climatic events. These results can be combined with the population living at the coast and ecological value.

Beyond global measures about climate change, reducing occurrence of storms and the detected sea level rises is not possible. The main question is how we are going to adapt our conservation and development strategies in the might of the increasing risks in coastal zones due to the impact of climate change. It is possible to reduce the extension of damages by means of defensive structures and by the reduction of assets and population in the risk zone. New developments in low lands must be avoided and displacement of settlements in future disappeared coastal land must be initiated.

Marine storms and RSLR may also create or destroy coastal wetlands and salt marshes and induce salt-water intrusion into aquifers, leading to salinization of groundwater. Coastal ecosystems are bound to be affected, for example, by increased salt stress on plants.



## Further work needed

To obtain consensus for a common methodology on marine storms.

To avoid in the future gaps in series.

To take conclusions using these measurements and other complementary on the effect of global warming separately from natural evolution on RSL and incidence of storms. By now, series on marine storms are too short for obtaining such conclusions.

To study evolution of processes rates not only linear evolution with constant rates.

To define scenarios for modelling the probability of storm surges occurrences.

To know effects of local or regional factors.

To standardise levels for measuring RSLR.

## Data sources

The common source for relative sea level is Permanent Service for Mean Sea Level (PSMSL), ([www.pol.ac.uk/psmsl/](http://www.pol.ac.uk/psmsl/)). It is the global data bank for long term sea level change information from tide gauges.

For incidence of storms the sources are varied:

**European Topic Centre Terrestrial Environment (ETC-TE), from de European Environment Agency:** ESPON project database. ([www.gsf.fi/projects/espon/natural.htm](http://www.gsf.fi/projects/espon/natural.htm))

**Maritime Institute Gdansk:** ICM using a mesoscale numerical weather prediction system UMPL, based on the Unified Model developed in the UK Meteorological Office.

**Province of West Vlaanderen:** Agenschap Maritieme Dienstverlening en Kust (MDK) – Afdeling Kust

**Department of the environment and Housing of Catalan Government:** Catalan net of oceanographic measurement called XIOM ([www.xiom.cat](http://www.xiom.cat)).

## Reliability of the indicator

For obtaining reliable conclusions on sea level and incidence of marine storm, which are climatic parameters, long term and coherent data sets and specialised high level studies are needed

The results on extreme weather conditions are offered by means of different measures, that demonstrate general problems in the quality of monitoring this parameter.

The obtained for the ESPON project parameter uses a homogeneous methodology but it has not a graduated classification on incidence: coast line exposed or not.

To judge the real impact on the coast is not enough with the days of stormy days using wind speeds (although this data are very reliable) because wind direction and intensity determine the effects on the coast.

About storm power index used for measuring incidence of storms, the temporal and territorial variation of the parameter, the gaps of registers and the short duration of series makes impossible to extract conclusions on affection by climate change.

The Power of Marine storm depends essentially of the threshold of significant height of wave (results are very different with a threshold of 1,5 m or 2 m e.g.) The frequency of records is different along years: the first registers are significant heights for a period of 4 hours, the last years there is a register each hour. A part of calculation that introduces mistakes is the maximum power of a marine storm because the records must be aggregated or separated according to the time among them. There are some years without data and a lot of other without data during all the year. The temporal series are interrupted and the years of available data are not the same for the 4 buoys.

The measure of relative sea level is very reliable and strong because all the raw data come from common databank, and it is measured specifically in a homogeneous way. It is positive too that means come from a lot of records. On contrary, obtained results shows different rates, which might come from local factors but also they may be caused by errors from monitoring stations (light displacement of base level). The individual stations are responsible of their records, but PSMSL performs additional quality checks and follows up them.

## References

Institute for Environment and Sustainability – JRC. (2006). Marine and Coastal Dimension of Climate Change in Europe. [pdf document]. [http://ies.jrc.ec.europa.eu/fileadmin/Documentation/Reports/Varie/cc\\_marine\\_report\\_optimized2.pdf](http://ies.jrc.ec.europa.eu/fileadmin/Documentation/Reports/Varie/cc_marine_report_optimized2.pdf)

Intergovernmental panel on Climate Change (2001) - IPCC Third Assessment Report: Climate Change 2001. <http://www.ipcc.ch/pub/reports.htm>

Proposal of 18 January 2006 for a Directive of the European Parliament and of the Council on the assessment and management of floods.



Projet cofinancé par la  
Union Européenne

