# IMPACTS OF CLIMATE CHANGES (SEA LEVEL RISE AND INCREASED NUMBER OF EXTREME METEOROLOGICAL EVENTS) ON SANDY COASTS. EXAMPLE OF THE EMILIA-ROMAGNA REGION (NORTHERN ITALY)

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**Keywords:** Climatic change, coastal evolution, vulnerability, subsidence

Coastal zones are important for the economy, the environment and the Mediterranean Culture. The equilibrium state and the position and morphology of coastlines vary with time in response to the different processes which act on them. At a geological scale three evaluative trends could be observed according to the sedimentary successions (Curray, 1964): progradation, retrogradation and aggradation.

Nowadays it is well accepted that the global climate is changing rapidly, largely due to carbon dioxide emissions from human activities (IPCC, 2001; 2007). Accelerated sea-level rise is one effect of climate warming that will have profound impacts on all coastal regions. The impact of an elevation of sea level are numerous and include elevation of water table in low-lying coastal areas, salinisation of aquifers, increase of the intensity and frequency of storm effects along the coast, beach erosion, flooding, etc... These physical changes are also leading to biologic responses such as changes in the range of species, loss of habitat, such as coastal wetlands (IPCC, 2007).

According to the last IPCC report (2007) nearly all European regions are anticipated to be negatively affected by some future impacts of climate change. This change is expected to present regional differences in Europe's natural resources and assets. For instance in Southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism, and in general, crop productivity.

IPCC estimates that the global average sea level will rise between 0.18 to 0.59 meters in the next century (IPCC, 2007). Evidence indicates that rising sea level will first affects regions with large areas of near sea-level land and areas with low tide rage, such as the Mediterranean (Day and Templet, 1989). In Italy, Mosetti & Purga (1991) indicate an increase of the mean sea level between 1.08 and 1.64 mm/yr according to the method used. Adamoli (1979), using tide measurements of the Northern Adriatic, indicates that the mean sea level increased of 20 cm during the last 100 years. This increase induces a retreat of 3-6 meters in 100 years (3-6 cm/yr) for beaches with a gradient of 2°-4°.

The evolution of the littoral of Emilia-Romagna Region, northern Italy, 130 km length, is characterized by the succession and superposition of complex environmental events and human actions especially during the last century. Erosion of the beaches began after 1940 and was particularly intense between 1960 and 1970. Today 39 km of the littoral of the Emilia-Romagna are in accretion, 59 km are stable and 32 are in erosion. The stability and accretion trends are principally due to the presence of defense and harbor structures. In addition the extraction of fluvial inerts, particularly intense in the 1960's, reduced the solid transport: in 1979 the extraction of inerts from the Po was twice of the material transported to the sea from 1964 to 1973 (IDROSER, 1983).

The subsidence rate of this territory, about 2-3 mm/yr, that could be enhanced due to subsurface fluid withdrawal, affects the coastal evolution. The subsidence on the low coastal beaches of Emilia-Romagna induces a shoreline retreat as well as an increase of the nearshore gradient, thus determining a reduction of the sandy coastal body (a subsidence rate of 1,5 to 3 mm/yr induced a lost of 0,6 $Mm^3$/yr of sand).

In the framework of the beachmed-E-Medplan project three methods were applied in order to identify the coastal stretches with the higher trend to the submersion during sea storms events and "Acqua Alta": scoring proposed by Eurosion (2004) ; method developed by Gornitz (1994) ; model of collapse according to the STRUREL code (Gollwitzer, 1994).
The first method, based upon a simplified DPSIR model and using geoindicators, intends to determine the priority of shoreline management. The original method, developed at European scale, has been modified to be applied at a regional scale.
The second method first identifies the potential vulnerability of the coastal stretches and then calculates the real vulnerability according to the mitigation effects of the defense structures. Finally the risk is obtained by multiplying the real vulnerability by the codified land soil use.
Finally the last method used is strictly statistical and may be used as a first approach to identify the most vulnerable stretches due to the limited number of variable used. The mechanism of collapse corresponds to the landward ingression of the sea.
These three methods were applied to determine the vulnerability to submersion related to sea storms characterized by a 5 and 10 years return period. The first results indicate that the southern part of the Emilia-Romagna region present a high probability of collapse. Furthermore the altimetry asset of the territory (Ferrara and Ravenna) will favor submersion events in the short time, affecting also landward territories. Such phenomenon requires the development of accurate scenarios of risk to define prioritary intervention to protect the coastal zone.

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# COASTAL ECOSYSTEMS FROM THE BLACK SEA ROMANIAN LITTORAL UNDER THE OMEN OF THE ECOLOGICAL HAZARD/RISK

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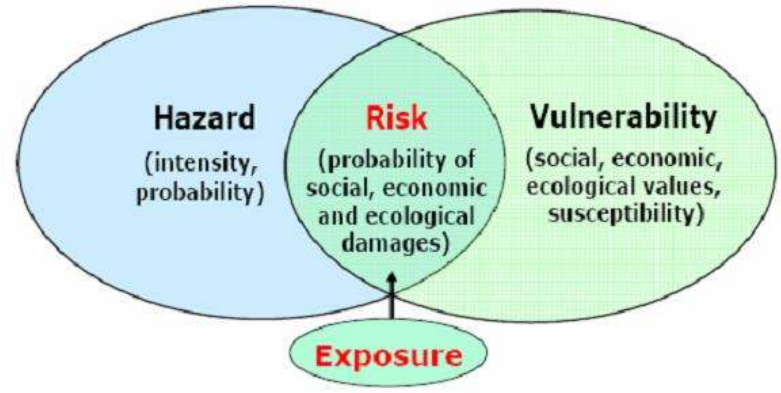
**Keywords**: hazard, perimarine, water balance, ecosystem, overexploitation

On the basis of the experience and expertise achieved as marine ecologist during the past 50 years, the author presents in the paper some opinions concerning the ecological hazard at the Romanian Black Sea coast. First, the author affirms that the history, mostly the natural history of the ecosystem is nothing else but a succession of hazards – risk events generated by the synergism of some potential conditions and the transformation of uncertainties into certainties.
In dealing with hazard, the paper also presents a short view of the ecological risk and vulnerability with impact on the ecosystems and human society → **Hazard** = risk; danger / exposure or vulnerability to injury, loss, evil, etc. / chance; accident / a thing likely to cause injury, etc. / (instance of) possibility or chance of meeting danger, suffering loss or injury, etc.




The author considers the following well known entities influencing one another:

- The perimarine lake complex – mainly the Lagoon Complex Razelm – Sinoe (LCRS);
- The Danube Delta and the adjacent wetlands;
- The sandy littoral belt Chituc separating LCRS from the Black Sea;
- The cliffs in southern Romanian littoral (Cap Midia – Vama Veche);
- The beaches in northern Romanian littoral (the Danube mouths – Cap Midia);
- The marine coastal waters of the Black Sea.

The issues tackled with in the paper also include the following important aspects concerning the researches on and evidences of hazard high potential at the Black Sea Romanian coast:

- Historical – archaeological proofs: the ancient ruins of coastal settlements lying nowadays behind the littoral sandy belts separating the perimarine lake system (Plate I);
- Stratigraphical proofs;
- The rising sea level → sea level and water balance changes in the Black Sea:

  - sea level in the Black Sea has been rising even when the Mediterranean Sea level was going down
    (Tsimplis, http://wcrp.ipsl.jussieu.fr/Workshops/SeaLevel/Posters/2_6_Tsimplis.pdf );
  - an observed increase in the sea level of this basin by 2.5 mm/yr over the last 80 years;
- Global climate changes → changes in temperature and salinity regime;
  - Rising air temperature → increase in storm frequency and intensity;
  - Increase in evaporation → Slight cooling of ocean waters → Population and bio-productive changes;
  - Wave energy increase;
- Active erosion processes of the sandy littoral belt prevail → northern sector of the Romanian littoral – sector of high potential of ecological hazards; Coastal erosion → gradual disappearance of the littoral sandy belt and lagoon system → opening of „marine bays" with estuarine character → changes in the water salinity regime from stable freshwater to oscillating brackish-marine → the Black Sea coastal zone under direct stress from the Danube waters; Chituc littoral sandy belt → general negative balance:
    - Fragmentation;
    - Sediment re-distribution on new sites;
    - Assuming other forms of the land/seascape;
- Decrease in beach sediment supplies;
- Subsidence;
- Anthropogenic changes in the watershed, in the tributary rivers (dams, course rectification, embankments, draining etc.) and in the marine coastal zone (harbor building, hydro-technical defense works for beach protection, canals opening etc);
- Direct and indirect, chronic and accidental pollution; pollution issues, mostly in the coastal marine waters:
  - Massive over-fertilization by nitrogen and phosphorus compounds, coming largely from agricultural, domestic and industrial sources;
  - Microbiological contaminants by discharge of insufficiently treated sewage;
  - Oil pollution as a result of operational discharges of vessels, accidents, land based sources and atmospheric deposition;
  - Pollution by toxic substances (pesticides and heavy metals mostly) appear in some 'hot spots';
  - Radioactive substances pollution, mostly as a result of the Chernobyl accident in 1986;
  - Solid waste pollution by dumping garbage into the sea, from ships, coastal settlements and tributary rivers.
- Development of maritime transport → Favoring the introduction of exotic species by uncontrolled de-ballasting from ships, with severe consequences on native populations;
- Exploitation of marine and coastal resources → overexploitation, with high risk potential;
- Urban and/or industrial coastal development, without considering the precaution principle and anticipatory action. The elements of the policies based on Precautionary Principle being promulgated in much of the European Union (EEA, 2001) include:
  - Research and monitoring for the early detection of hazards.
  - A general reduction of the environmental burden.
  - The promotion of clean production and innovation.
  - The proportionality principle, where the costs of actions to prevent hazards should not be disproportionate to the likely benefits.

- A cooperative approach between stakeholders to solving common problems via integrated policy measures that aim to improve the environment, competition, and employment.
- Action to reduce risks before full "proof" of harm is available if impacts could be serious or irreversible.
- With an increasing adoption of this precautionary philosophy, we may be moving forward as a society for a better environment and state of health.

The paper discuss, as an example for a target which should be touched at the Romanian littoral, the stages of the managerial process of the coastal hazards, including the effects of climatic changes (Fig. 1-3).

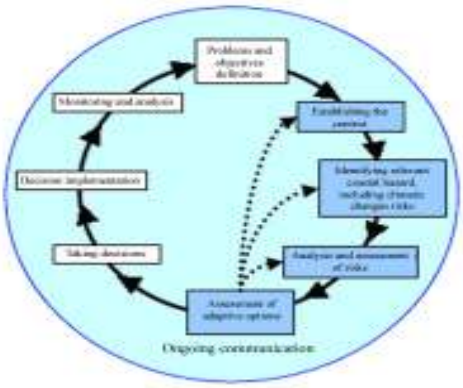


Fig. 1 – Management of coastal hazards including the effects of global climatic changes

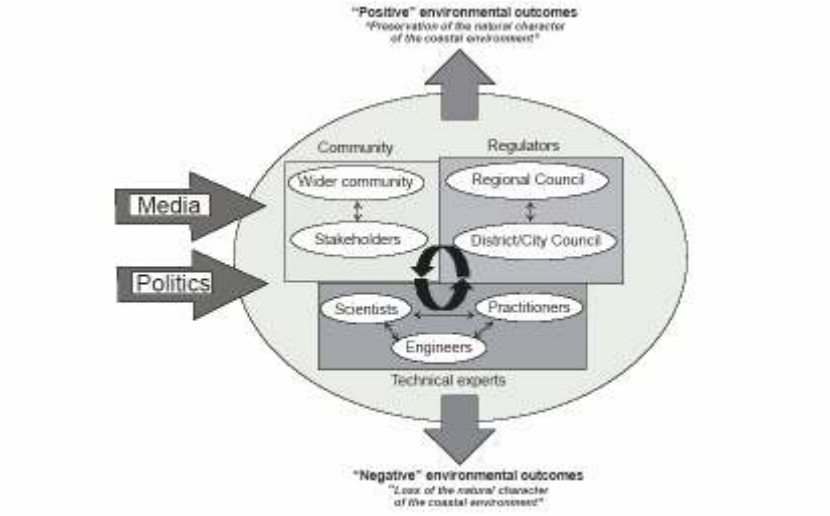



Fig. 2 - Conceptual model of the interactions between various groups involved in coastal management. Key drivers of environmental outcomes (Blackett & Hume, 2007) .

In the last part of the paper the author discusses some issues less known and applied at the Romanian coast of the Black Sea, namely the problems of local community involvement in managing the coastline zone

The coastline, characterized by the two interfering entities - nature system and the socio-economic system, presents numerous challenges to scientists, resource managers and human populations, inhabitants and tourists. The range of physical hazards, such as erosion, slides, weathering of sea cliffs and sometimes flooding of low-lying areas, are perceived by people as risks to the things they own and value. That brings about a considerable conflict over the decisions concerning coastal development and hazards.

The international experience has shown that the involvement of community groups in decision making may lead to improved quality of decisions and overall environmental results, may build community relationships, increase local capacity to understand and manage environmental issues (Beierle & Konisky, 2001). At the Black Sea coasts community groups of riparian countries should be more interested in issues concerning coastal erosion mitigation and pay more attention to voluntary environmental actions. In Romania, especially, local communities are at the beginning of understanding their role and involvement in the environmental issues.

The author, summarizing the specialty information (Blackett & Hume, 2007; Hume & Blackett, 2007), supports and recommends the approach to community involvement in coastal hazard mitigation. The environmental outcomes, either positive or negative, depend on the relations established between the community regulators and technical experts and the way those groups interact between them, on the one hand and with the local communities, on the other hand. Positive results can be obtained by:

- Developing cooperative relationships
- Facilitating group learning by local authorities
- Ensuring access of communities to resources (funding, technical knowledge and assistance)
- Developing awareness, cooperation, transparence and trust within the local community
- Considering the possible risks
- Disseminating scientific information at the right time and in understandable language
- Disseminating good records of past experience in order to minimize the time spent finding solutions to new situations.

Instead of happy end, far from the nowadays real situation, the author reproduces some words from a report based on EcoSummit 2007 – 'Ecological Complexity and Sustainability: Challenges and Opportunities for 21st Centaury', held in Beijing, China during 22–27 May 2007 (Anitha and Narendra, 2007) mentioning, once again that:

*"The world is experiencing catastrophic global environmental problems such as climate change, global warming and rise in sea-level. Rapid urbanization, industrialization and globalization have enhanced the pace of these changes, and have exerted severe ecological stress on the earth and its life-supporting systems from local to regional and global scales. Water shortage, desertification, soil degradation, greenhouse gas emission, elevated sediment and nutrient flux to the coastal seas and other environmental problems are increasingly becoming the common side effects of those human activities. Sustainability can only be assured with an ecological understanding of the complex interactions among environmental, economic, political and social/cultural factors, and with careful planning and management grounded in ecological principles."*

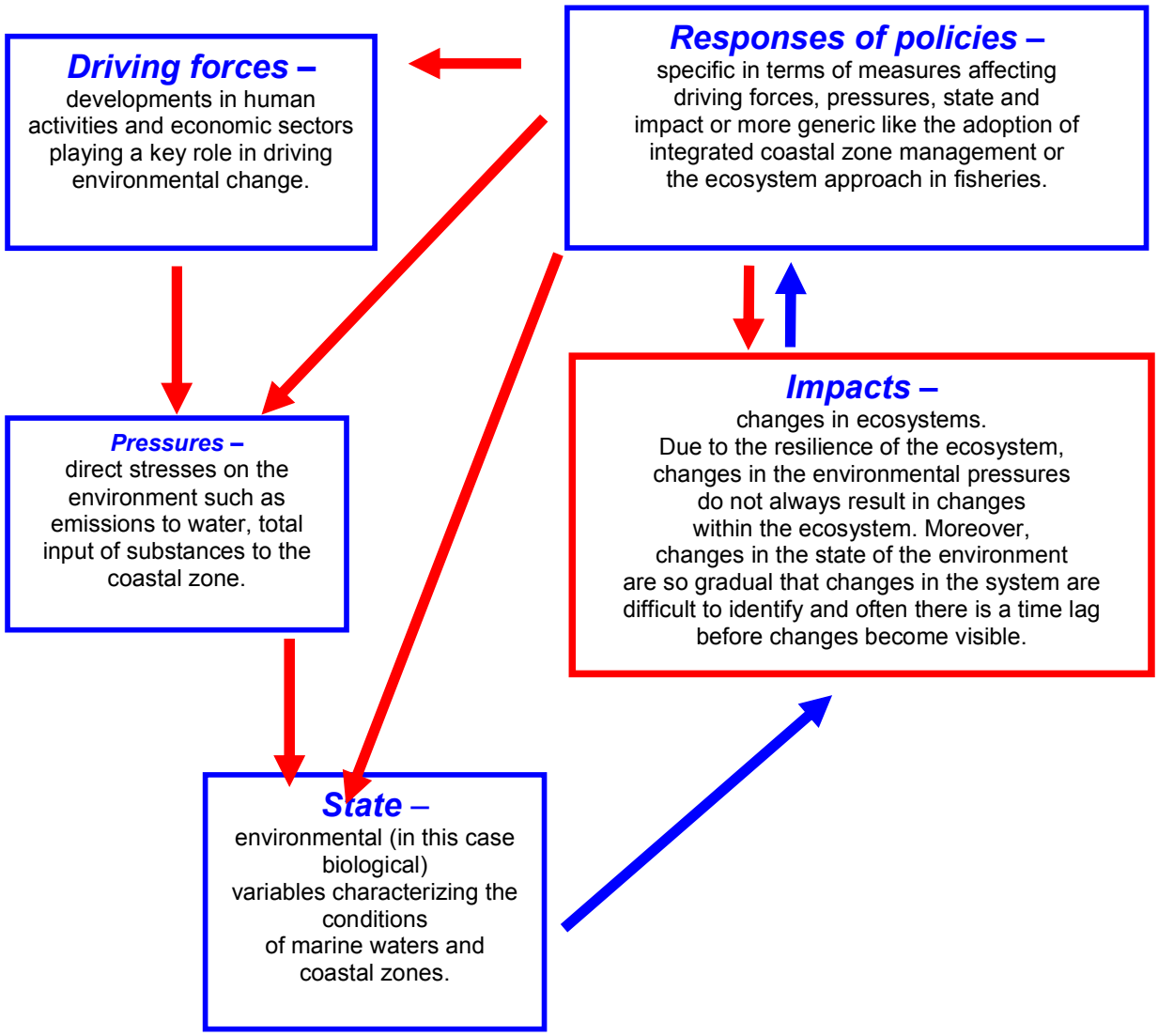



Fig. 3 - Assess the main challenges and problems for the marine and coastal waters in Europe – the general conceptual assessment framework of the EEA, known as the DPSIR approach (Driving Forces, Pressures, States, Impacts and Responses) (UNEP/MAP/MED POL, 2004)

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**Plate I**

**Fugit irreparabile tempus!**
**Sic transit gloria mundi!**

**Histria**

**Histria**

**Argamum**

**Aerial view of Dobrogea**


**Scythia Minor - Dobrogea historic sites**

**Argamum**

**Enisala**

**Enisala**

# IMPACTS OF THE WAVE SET-UP AND SEA SURGE GENERATED BY EXTREME STORMS ON THE BEACHES IN FRONT OF THE DANUBE DELTA, BLACK SEA

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**Keywords**: sea level, Danube Delta, beach, storm surge

The paper tries to understand how the significant increase of sea level generated by storms affects the coastal morphology.
The Danube Delta low lying sandy beaches with a general North – South orientation are easily affected by storms from various wind conditions. The paper contains outputs from modeling showing how do the wave set up and sea surge vary under the influence of winds with various velocities and directions. These results are compared with morphological data measured on the field along several transverse profiles along the Danube Delta beaches.
Based on regional wind data and a shallow water wave model (SWAN) a morphologically representative wave climate along the depth contours of the Danube Delta coastal zone was determined (Dan et al., 2007). The wind data were recorded at Sulina station and cover a period of 10 years (1991 – 2000). A number of wave conditions, considered to be representative, were extracted from the simulated wave climate. A state-of-the-art numerical model (DELFT3D) was used to simulate the storm surge and wave setup for different wave directions and heights.
The highest waves (over 10 m, offshore) during the period taken into consideration (1991- 2000) occurred in December 1991.
Their impacts in the various beach sectors are estimated and results discussed.

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# SOME ASPECTS REGARDING EROSION HAZARD VULNERABILITY OF ROMANIAN COAST

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**Keywords**: sandy beach dynamics, coastal erosion, man-induced activities

The coastlines of the world represent an equilibrium interface between the earth's three major masses: the land, the water and the air.
Romania has territorial coastline extending about 244 km along the northwestern side of the Black Sea (about 6% of the whole coastline around the Black Sea), that is divided into the *Northern Unit* from Musura (Ukrainian border) to Cap Midia and the *Southern Unit* with the boundary at Vama Veche (Bulgarian border).
The present paper examines the annual beach changes in order to assess the coastal medium scale evolution and to produce a relative ranking of coastal processes (accretion/relative stability/erosion).
The beaches in the Northern Unit represent low accumulative sandy coasts and are mainly composed of beaches with terrigeneous gray sand of fine to very fine grain size, a large amount of which has been supplied by the Danube and shell fragments as the secondary source of beach sand.
The northern unit of Romanian coastal area, which is designated as the Danube Delta Biosphere Reserve, is most affected by coastal processes (erosion). During the past few decades the most vulnerable areas are Câşla Vădanei, Zaton and northern part of Chituc barrier sand (annual beaches change assessment indicate a shore retreating of more than 300 m).
The Southern Unit between Cap Midia and Vama Veche is essentially a cliff coast, with several barrier beaches in front of seaside lakes, which were land-locked by along-shore transport of sediment in the past. Beach sand in the area is composed of shell fragments supplemented by fragments of limestone at the base of cliffs. No trace of terrigeneous sand from the Danube is found in the Southern Unit. The shoreline of cliffs is estimated to retreat about 0, 5 m per year.
This Unit is also endangered due to strong economic activity, including the tourism industry which attracts some 800 thousands check-in tourists every year.
The coastal erosion not only threatens the tourism industry through the loss of beach area but also endangers the safety of housing and public welfare.
The paper generalizes some of the Romanian beach vulnerability and highlights some of the specific physical and socio-economical factors with greatest influence on the vulnerability of the Romanian shore. The results can be summarized as follows:

- there is a significant difference between Northern Unit and Southern Unit of the Romanian coastal zone regarding natural and antrophic factors that affect coastal vulnerability;
- the Northern Unit processes have a significant influence upon biodiversity and natural environment;
- the Southern Unit processes have a greater influence upon coastal communities and human activities (tourism, agriculture, buildings, ports, hydrotechnical structures, etc), biodiversity and natural environment as well.

# MODELLING THE IMPACT OF EXTREME METEO EVENTS ON COASTAL WETLANDS. CASE STUDY: THE VENICE LAGOON

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**Keywords:** Storm surge, forecast, Venice, SHYFEM, extreme events

In many countries extreme events are a serious problem for the coastal zones. Every year severe hurricanes cause inundations with the loss of human lives and create damage through coastal erosion. Even in less exposed sites storms can cause damages if the elevation of the coastal area is low, as in the case of the Northern Adriatic Sea. For these reasons a good prediction system, linked to a good alert system, is of main importance in order to limit the damages caused by these events (Subashisa et al., 2002).
In the first part of this work an introduction to the several physical factors that influence the phenomenon of storm surge is given. There are four contributions to the storm surge: the wind, the atmospheric pressure, the waves and the rainfall (Harris, 1963). For a correct prediction of the sea level through a dynamic model also the astronomic tide and the seiches have to be computed (Tomasin et al., 1999). In many cases some of these contributions can be neglected but to do so a study of the magnitude of each of them has to be made, and a good knowledge of the environmental features of the area is necessary.
In the second part an operational model, named SHYFEM, for the sea level prediction in Venice is presented. Venice is situated in a very flat zone and small sea level variations can cause the flooding of large parts of the City. Passing from 110 cm of surge to 140 cm the flooded zone changes from 12% to 90%. The presence of important historical places requires an accurate forecast, despite the low resolution of the wind fields and the bad quality due to the complex orography of the geographic location (Zampato et al., 2006, 2007).
The model is based on the shallow water equations and uses a spatial discretisation based on the finite element technique. The time discretisation is made with a semi-implicit scheme. It runs daily at the Centro Previsioni e Segnalazioni Maree (ICPSM) of the Venice Municipality, giving a 6-day forecast of the sea level. Several improvements were developed to obtain a better forecast. Some of them are described. To correct the input forcing the model, a zonal correction of the wind speed depending on the wind direction was set up. To improve the accuracy of the initial state of the dynamic system a restart procedure was implemented and the use of two grids, one for the Mediterranean Sea and one for the Venice lagoon, allows for a good reproduction of the physical quantities inside the lagoon (Bajo et al., 2007). Finally several post-processing routines utilize observed data to improve the forecast of the dynamic model. In this way the final forecast can be considered to come from a hybrid hydrodynamic - statistical model. All these improvements have contributed to make this operational system one of the best for the sea level forecast in Venice.

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