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EPHESUS: REMOTE SENSING FOR COASTAL PROCESSES IN SOUTHERN BOHAI SEA - CHINA

Abstract: Hydrological processes in coastal areas of the Southern Bohai Sea are highly impacted by morphological changes and mixing between continental fresh waters (surficial and groundwater) and marine waters. Natural factors combine with human perturbations such as excessive exploitation of natural resources. The effects of overexploitation are evident in coastal areas, considering e. g. salt contamination, land degradation, pollution and subsidence, which determine serious damages to the soils, freshwater resources as well as jeopardize the ecological system. The main purpose of the ongoing project "EPHESUS - Ecological and Physical Effects of the Surficial and groundwater exchanges between land and Sea" is directed to identify, assess and monitor the effects on coastal ecosystem, which is exposed to those hazards, in order to prevent further deterioration. In this work we present the rationale of the project and describe the satellite data and the methods of investigation which will be used.

Keywords**:** remote sensing, Yellow River Delta, coastal processes, land-use and land-cover, water quality.

Scientific Rationale

The project "EPHESUS - Ecological and PHysical Effects of the SUrficial and groundwater exchanges between land and Sea" is performed in the framework of Dragon 3 programme (2012-2016), which is a cooperation between ESA (European Space Agency) and the Ministry of Science and Technology (MOST) of the Popular Republic of China. Dragon 3 focuses on exploitation of ESA, Third Party Missions and Chinese satellite data for geo-science and applications development in land,

ocean and atmospheric applications. The Programme brings together joint Sino-European teams to investigate 50 thematic projects. The project EPHESUS will last four years and it was formally started at the Beijing Symposium, in June 2012. It aims to develop an integrated monitoring approach by satellite products, in situ measurements and hydrological models, and to provide detailed information for an understanding of hydro-morphogeological processes on coastal areas.

EPHESUS has been resulted from previous cooperation projects between Italian and Chinese scientific teams on the study of hydrologic processes in coastal ecosystems for the understanding of the relationship between continental and marine waters in the Yantai (China) and Venice (Italy) areas. These activities gave some basic results for the knowledge on the current conditions, but lack of specific information about the effect of hydrologic processes on the coastal ecosystem. So, within EPHESUS we will take advantage of using European and Chinese satellite data, provided in the framework of Dragon programme, integrating them with the outcomes of previous studies. The main purpose of this project is the identification of key parameters, which highlight the effects of seawater contamination and inland water discharges on the sea and are connected to continental and marine waters exchange in coastal ecosystem of the Southern Bohai Sea. The monitoring of key parameters could get the chance to understand the interactions between these processes and the evolution of the coastal zones, via analysis of vegetation stress, morphological and land-use changes and events of water quality anomaly (algal bloom, coastal discharge). The remote sensing (RS) data is used for detecting and characterizing such significant ecological and physical parameters. Moreover, efforts to exchange, build on and also develop new methodologies for the retrieval of Earth Observation (EO) products from RS data will be addressed and experts on hydro- bio- geomorphologic processes will benefit the understanding of ecological and morphological EO products and vice-versa.

Coastal zones are very important for human development. The pressure on these systems by agriculture and aquaculture, urbanization and industrialization, the exploitation of mineral resources etc. will continue to increase and the development in coastal areas will tend to concentrate in a narrow strip close to the coastline.

From 1980's, in the coasts of Southern Bohai Sea the local resources and environment have been severely depleted by excessive exploitation of natural resources. The limited supply of freshwater, saltwater contamination, soil salinization, contamination from extensive fish-farming and offshore pollution became major problems. These problems, which had a negative feedback on the development of agriculture and fishery economies, also threatened the health of local communities. For example, effluents from aqua-farms contain a large amount of nutrients (such as nitrogen, phosphorus), which sometimes are discharged into sea without any treatments directly causing offshore pollution and

inducing phytoplankton and macro-algae proliferation. Investigating the algal blooms, pollution and sediment transport, saltwater intrusion, dynamics and causes of coastal erosion and subsidence, is then a priority for the management of coastal hazard and the definition of risk-mitigation measures. It requires multidisciplinary methods of in situ investigation (e.g., geology, geomorphology, geophysics, environmental geology, geochemistry) and RS observations (e.g., water quality, land-use and land-cover, detection of anomalies, coastal mapping).

Objectives of the project and state-of-the-art

The specific objectives of EPHESUS are: a) to identify the effects of seawater contamination on soil and vegetation; b) to detect the effects of land subsidence on coastal morphologies; c) to characterize water quality anomaly events (algal bloom, coastal discharge), also connected to human impacts; d) to integrate multi-source information and multi-temporal data for the interpretation of hydro-geo-morphological processes at regional and local scale. EPHESUS will focus on two extreme conditions: i) a natural site of the Yellow River Delta (YRD), the YRD Ecological Research Station of Coastal Wetlands, CAS research station, build for interdisciplinary studies and cal/val site, and ii) a coastal area of the Laizhou Bay subjected to intense human activities (Fig.1). Remote sensing has been successfully used in the past, and the results were encouraging, particularly in the ocean color monitoring, land use, dynamic coastline monitoring and beach detecting. Some results of RS data analyses for the study areas are summarized, they will be updated and implemented during the EPHESUS project.

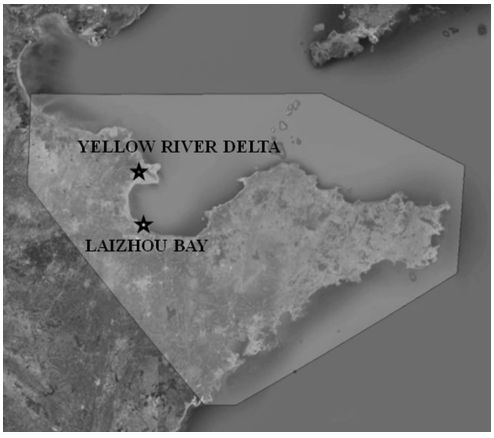

Figure 1 – Test sites of EPHESUS project: Yellow River Delta and Laizhou Bay.

Spatial-temporal Dynamics of vegetation coverage, river channel and coastline in the Yellow River Delta and Laizhou Bay

Normalized Difference Vegetation Index (NDVI) is one of the most successful index used to simply and quickly identify vegetated areas and their "health conditions" from multispectral RS data. It was applied to the coastal area of Southern Bohai Sea in order to analyze the space-temporal evolution of vegetation coverage, in the recent 10 years. On the basis of 372 images of SPOT/ Vegetation from 1998 to 2008, decreasing NDVI trends dominated the Shandong Peninsula, along the coastline, while increasing trends gradually became more prominent from the coastline to the inner land. Human activity and its spatial distribution were the main causes of NDVI changes: urbanization, industrialization and exploitation of the coastal wetlands resulted in a decay of NDVI (Liu et al., 2010). The increasing NDVI trends dominate the majority of YRD, despite the almost constant NDVI value in the north and northeast (Li et al., 2011). Under the influence of deposition of suspended matter, erosion of coastline and embankment works, the distribution of vegetation varied with time dramatically. After the Yellow River changed its course in 1976, deposition was replaced by erosion in the north and northeast, the distribution of vegetation decreased. However, the suspended matter brought by the Yellow River developed new land in the southeast, which expanded the vegetation distribution. In the late 1980's, artificial levee and jetty were built in the east and northeast, which restrained the erosion significantly, so that the vegetation distribution seldom changed significantly since then. From 1997 to 2004, the boundary of vegetation kept stable in north and east, extended along with the deposition in southeast, as a whole, the vegetation coverage increased (Zhang et al., 2010).

An interesting analysis was made by Wu et al. (2009), in a coastal ecosystem in the YRD. They tested if the elevation gradient interacts with the redistribution of water and soil solutes to determine regional vegetation pattern. According to values of NDVI, the vegetation could be separated into low, medium and high levels. The low level area was high in soil salinity; the medium level lied in the low salt area with meadows; the high NDVI level area was located in high altitude region and the soil is lower in salt, mainly covered by cultivated land, reeds and meadows. The results show highly significant correlations between NDVI of the major plant communities and elevation at all scales, which may closely associate with the groundwater depth at smaller scales and with water redistribution at larger scales.

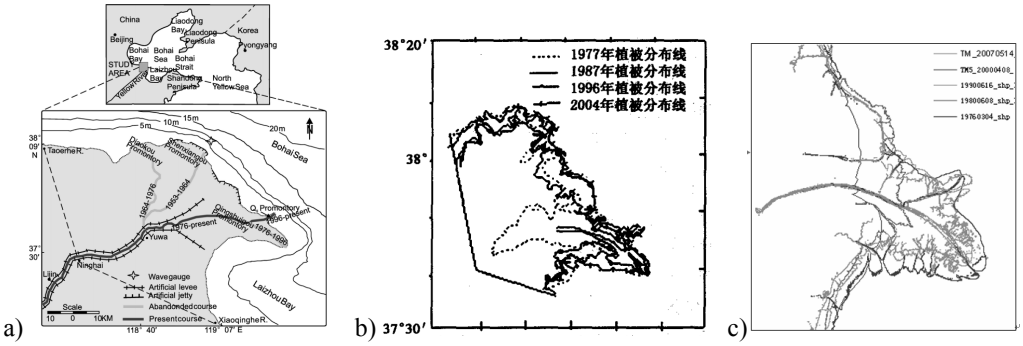

Figure 2 - a) The modern YRD (Chu et al., 2006); b) Change of the vegetation boundary from 1977 to 2004 (Zhang et al, 2010); c) Evolution of coastline at the YRD during the 1976-2007 period.

Land subsidence of Yellow River Delta

Several studies have been carried out to determine YRD land subsidence (Liu et al., 2001; Bie et al., 2006; Song et al., 2004; Liu et al., 2009). Although there are differences both in spatial-temporal range and analysis methods, we can conclude that the subsidence phenomenon is exactly widespread in the YRD. At present, the main approach to the research on land subsidence of YRD is conventional repetitive leveling measurement but intensive and systemic study of YRD should be developed with interferometry technique. InSAR and PS-InSAR techniques are becoming more and more important in this field of research. Combining with leveling, InSAR has great potential in the further subsidence monitoring of the YRD. Some interesting applications of such techniques were made by Yao et al. (2008) in the YRD and by Liu (2010) in south of Xiao Qing River (fig. 3).

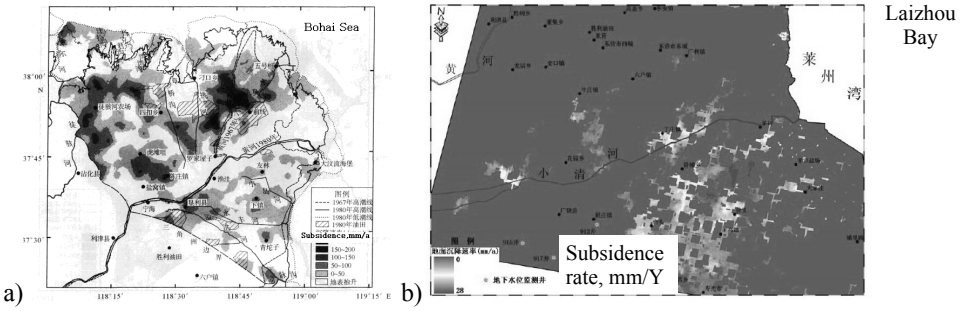

Figure 3 - a) Distribution of vertical surface deformation rate in the YRD from 1956 to 1980 (Bie et al., 2006); b) Monitoring result of the land subsidence in south of Xiao Qing River from 2007 to 2008 by D-InSAR technique (Liu, 2010).

Materials and methods

Advanced remote sensing techniques integrating optical, thermal and microwave imageries will be applied for identifying changes in land-cover and land-use over the last decades, highlighting the transformations from agricultural to industrial use or from wetlands to fish farms which impacted coastal ecosystems. Moreover, RS data will be used for monitoring water quality parameters and for studying ecological vegetation responses to soil salinization. By combining multi-hyperspectral and Interferometric SAR-based data the feedback in time and spatial scale of the bio-geophysical parameters will be analyzed and integrated with in-situ knowledge and investigations. Analytical methods are here summarized:

- identify the effects of seawater contamination on soil and vegetation. Vegetation could be sensitive to soil salinization, which is a common problem in areas with low precipitation, frequent storm surges and high evaporation. Salt affects plant growth, the early signs of salinity damage and when the problem becomes serious are visible on the spectral response. Optical data, in particular hyperspectral imagery, could provide accurate vegetation stress index maps, which are connected to water and saline soil contents. Many spectral indices will be applied on images acquired by optical sensor and they will be used as an ecological indicator to identify salt water contamination. We will provide those maps at regional and local scale, collecting ground truth data on YRD test site, simultaneously to PROBA-CHRIS acquisitions. Multi temporal analysis will enhance the pre-disturbance and post-disturbance conditions.

- detect the effects of land subsidence on coastal morphologies. In the study area, land subsidence is influenced by natural and human-induced factors and has generated marked environmental changes, particularly with respected to coastal erosion, wetland shrinking and salt water incursion. So, recent ground subsiding value, obtained by Differential SAR Interferometry and Persistent Scatterer Interferometry (PS-InSAR) will be related to the system of morphological evolution, build on high resolution multispectral imagery. The Differential SAR Interferometry and Persistent Scatterer Interferometry techniques are suitable for applications concerning environmental studies, as the monitoring of delta evolution and coastal erosions as well as the analysis of seasonal groundwater variations especially due to human impact. The available large amount of SAR and multispectral data, in conjunction with field information let us to produce deformation maps and time-series from 1990 up today to point out the temporal evolution.

- characterize water quality anomaly events (algal bloom, coastal discharge), also connected to human impacts. EO data, mainly of MERIS of ESA and HY-1B sensors COTCS and CZI of Chinese satellites, will be utilized to monitor quality parameters of southern Bohai Sea. We plan to produce

products regarding the distribution of suspended matter, light attenuation (Kd) and algal blooms. In particular, we consider bloom of cyanobacteria, red tides and also macro-algae. Such products could be implemented in a rapid-response remote-sensing based monitoring system to provide timely information on the occurrence and characteristics of water quality anomaly events (location, size and potential trajectory).

- integrate multi-sources information and multi-temporal data for the interpretation of hydro-geo-morphological processes with a special focus on the surficial and groundwater exchanges at regional and local scale. Finally, hydro-geo-morphological processes will be reconstructed by means of interpretation of spatiotemporal, seasonal and interannual changes. It should be possible to provide regionally specific information to government agencies and non-governmental organizations working to mitigate natural and human impact.

Expected resultsAn EO monitoring methodology integrating EO products and surface/subsurface land information and hydrological models to detect the effects of seawater contamination and continental water discharge on the coast.

The RS data will be used for detecting and characterizing significant ecological and physical parameters. An integrated analysis of multi-temporal data from optical and SAR sensors is proposed at regional and local scale.

- ✓ Experts on hydro- bio- geomorphological processes will benefit from the understanding of ecological and morphological EO products and vice-versa.

Acknowledgments

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