SURFACE RISING MODEL OF CASPIAN SEA

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ABSTRACT

Surface level change of Caspian is one of its considerable characteristics since very ancient times. Its water level has seesawed dramatically for millennia. In this concern there are records available since 3500 years ago. The sea level change has had physical, chemical, biological as well as economical and social impacts on the Caspian's littoral countries.

For estimating the damages and monitoring the process of sea surface rise at Caspian there is a realisation that remotely sensed data could be used. Due to the importance of sea level rise at Caspian and its influence on environment especially the coastal areas there has been proposed some couples of projects by the relevant organisations in Iran that uses earth space data. One of these propositions has been presented by the author from the Iranian Remote Sensing Centre (IRSC).

SAR, MROI and HROI in combination are the most reliable sensors for monitoring the sea surface rises and downs, with SAR's cloud penetration capability, MROI's daily image acquisition and HROI's high resolution. The project uses MROI and HROI data in visible and near infrared range including NOAA-AVHRR, SPOT and IRS, and the European ERS or Canadian RADARSAT data in microwave range.

The project consists of two phases. In the first phase a mathematical model of the rate of sinking the coastal lands due to sea surface rise will be set up. In second phase the places likely exposed to highest risk will be identified using land-use, land-cover and topographic data. The data thus acquired will be useful in preventing the damages, which may be caused due to sea surface raising. Not only the study of sea surface rise at Caspian, but also the results acquired through this project can be lead to a joint co-operation between Caspian's littoral states.

INTRODUCTION

Over the recent decade, raising of the water surface at Caspian Sea in different times causes many difficulties and damages to the installations as well as the people living in vicinity of its coastal zones. This is due to the climate and environmental changes in the region enhanced by the human careless activities such as changing artificially the situation of its watersheds.

The environmental changes of such a wide region cross over national boundaries and extend to many fields of research. This provides a broad opportunity for space technologies, specially remote

sensing to link these fields for better understanding, monitoring and well-managing of the region for sustainable development.

As the largest lake on Earth sited in Asia, Caspian covers an area larger than Norway. It is so large that is called sea. Over the recent five million years Caspian has sometimes been a lake and other times a true sea linked to free oceans through the Black and Mediterranean Seas and the Sea of Azov. Researchers agree that its shoreline has been shaped by global climate shifts that determine sea levels and rainfall.

Once being the exclusive domain of Iran and the USSR, five littoral countries since the disintegration of the Soviet Union in 1991 have surrounded Caspian. In addition to Iran these new states include Russia, Azerbaijan, Kazakhstan and Turkmenistan.

Caspian's total area exceeds to 371,794 sq. km with a watershed area of nearly 3.5 million sq. km. Its depth varying from 6 in north to 1025 m in the nearly centre has the average of 170 m, whereas its water ranges from nearly fresh in north to brackish in south.

Figure 1: Map of the Caspian Region

THE PROBLEM THAT CONTINUES

Surface level change of Caspian is one of its considerable characteristics since very ancient times. Its water level has seesawed dramatically for millennia. This phenomenon is not understood entirely. Recently, however, increasingly warm weather and wider uses of irrigation have lowered the sea level.

Chronic degradation of soil, water, and air plagues the region. However, in current century human activities have become an important factor with dams, irrigation systems, and industrial applications that rapidly changes all of its major tributaries. Irrigation decreasing the flow from the rivers has been causing a drop in sea level.

Volga is the greatest watershed of Caspian. Of all water withdrawn from natural sources in Russia, 33 percent comes from the Volga, which drains two-third of European Russia. In addition to Volga, Ural, and Terek rivers each with an extensively developed delta empty into northern Caspian. In south Sefid Rud and other Iranian rivers that empty to southern Caspian comprises 5 percent of all water entering the Sea. Presently the sea has no outlet and is linked to the Baltic, White, and Black Seas by a network of inland waterways.

Due to sea surface rise there is the danger that 1 million hectares of its coastline, including Volga River delta, will be flooded, and based on a report 300,000 hectares in Dagestan already had been inundated.

According to the historical records Caspian was in its higher level of surface with the amount of minus 22m nearly 38000 years ago. However, by nearly 21000 years ago the sea level diminished to minus 64m. Since 3500 years ago the average sea level has been minus 28 m. In the early years of the 20th Century between the years 1900 and 1929 the sea level reached minus 26.2m and minus 29m by 1978. But from 1978 to 1995 its level was increasing with the rate of 14 cm each year. During this period floods has endangered nearly 200 sq. km in Iran forcing thousands of people to leave their homes. By 1993 the average water level of the sea had risen by more than 2 m. Since 1995 the sea level has been decreasing. Between 1978 and 1995 the Caspian rose 2.4 m causing flooding and washing oil from lowland wells into the water. Although the water is slowly receding, its patterns have still been unpredictable.

MONITORING FROM SPACE

The sea level change has had physical, chemical, biological as well as economical and social impacts on the Caspian's littoral countries. For estimating the damages and monitoring the process of sea surface rise at Caspian there is a realisation that remotely sensed data could be used.

Although monitoring the damaged ecosystem of Caspian caused by sea surface fluctuations as well as the pollution and other human careless activities is much less expensive than the work of mending them, majority of the littoral states are mostly ill-equipped to monitor it. This is rather worsened by mismanagement in these states.

Due to the importance of sea level rise at Caspian and its influence on environment especially the coastal areas there has been proposed some couples of projects by the relevant organisations in Iran that uses earth space data. One of these propositions has been presented by the author from the Iranian Remote Sensing Centre (IRSC). The project proposes setting up a model for monitoring and forecasting the rises and downs of Caspian to be incorporated to a forecast and warning system.

DATA

The main input to the system is frequent satellite data of region. But this requires to be combined with parameters such as topographic, land-cover and land-use maps, to create useful and objective predictions that could be produced exactly and regularly.

Either the visible and near infrared or the microwave parts of electromagnetic spectrum can be used for remote sensing of water bodies. Water is highly reflective in the microwave range. It is

nearly the same for good extent in visible range. Therefor using Medium Resolution Optical Image (MROI) as well as High Resolution Optical Image (HROI) data are applicable. Advanced Very High-Resolution Radiometer (AVHRR) sensor of NOAA provides MROI data, while the data of Landsat-TM, High Resolution Visible and InfraRed (HRVIR) of SPOT and Indian IRS-Pan data are HROI data useful to differentiate water bodies.

HROI data taken from Landsat-TM gives a spatial resolution of nearly 30 m and temporal resolution of about 16 days. SPOT, on the other hand, with the resolution of 20 m in spectral and 10 m in panchromatic mode has a 26-day temporal resolution, while the IRS-Pan mode has the spatial resolution of 10 m and temporal resolution of 5 days. Consequently the IRS-Pan and SPOT data are more suitable in comparison to Landsat-TM data. However, the problem of cloud cover in this case should not be ignored. MROI data acquired by NOAA-AVHRR has the spatial resolution of 1 km and temporal resolution of 12 hours.

In microwave spectrum Synthetic Aperture Radar (SAR) images can be used. The two European ERS satellites with spatial resolution of 30 m and temporal resolution of 16 days and the Canadian RADARSAT with spatial resolution of 25-28 m in standard mode for four looks and the temporal resolution of 24 days are suitable.

The choice of which earth observing sensors to be used for the model is determined by a number of factors including spatial resolution and repeat cycle as well as spectral characteristics. AVHRR as a typical MROI sensor, generally provides several high-latitude images every day suitable for observing the Caspian region. Although cloud cover is still a problem, increasing the frequency of coverage will increase the likelihood of obtaining the cloud-free images. With SAR data the sensors operate at wavelengths where signals travel almost unaffected through clouds.

Figure 2: Medium resolution image of Caspian Region collected by NOAA-AVHRR

The main reason for using MROI data is their much higher and more suitable repetition rates. The relatively long repeat period of HROI data ranging from 5 to 26 days, combined with the high likelihood of cloud cover in many places of interest means that for applying such kind of data the necessary cares should be taken. HORI and SAR data can be used for the areas of less than nearly 10 sq.km. The resolution of MROI sensors ranging from hundreds of meters to tens of kilometres

limits the size of the area to be monitored. For AVHRR with nadir resolution of 1.1 km an area of at least 200 sq. km is needed that can provide an overall view of the area of interest. For HROI data the limits of the area under study ranges between 25 to 1000 sq. m, that is much convenient for studying the details of water level fluctuations.

SAR, MROI and HROI in combination are the most reliable sensors for this mean, with SAR's cloud penetration capability, MROI's daily image acquisition and HROI's high resolution.

The project uses MROI and HROI data in visible and near infrared range including NOAA-AVHRR, SPOT and IRS, and the European ERS or Canadian RADARSAT data in microwave range. Geo-coding, information extraction, modelling, quality control and forecasts would then all have to be completed within the scheduled period.

MODEL

In the mentioned research program, the study area is situated in the southern coastal area of the Caspian in northern Iran that can be extended to all the coastal area of Caspian. The program consists of two phases. In the first phase a mathematical model of the rate of sinking the coastal lands due to sea surface rise will be set up. Based on this model the rate of sinking the lands will be determined for monthly and yearly periods. Then the respective graphs will be prepared. Using the obtained graphs the most risky periods during which the probability of sea rise is the highest will be determined accurately.

To make the first phase to operate the multi-date high-resolution images of SPOT or IRS from the study area is necessary. In addition the model uses a variety of GIS and image analysis tools including ER-Mapper, Erdas Imagine to combine the remote sensing data with other parameters such as land-use, land-cover and topographic data and will carry out subsequent modelling work.

Then the changes will be detected in the progressive images and using topographic data and the Digital Terrain Model the area and volume of the raised water will be determined. Comparison of the resulted information from the progressive images will give the rate of sinking of the lands, and the most risky places exposed to damages of sea surface rise will be determined.

In the second phase the places likely exposed to highest risk will be identified using land-use, land-cover and topographic data. The data thus acquired will be useful in preventing the damages, which may be caused due to sea surface raising. This information of course will be much reliable when validated by the ground truth.

EMERGING CONDITIONS AND POTENTIALS

The investigations by the experts and specialists in the Iranian Remote Sensing Center show the results confirming the proposed model. Applying the data of the south-eastern area of Caspian situated in Iran for sea level fluctuations one can easily see the ups and downs of the sea level in different periods. The data includes processed and geo-corrected MSS-1976, TM-1984 and TM-1998 imagery. Comparing the images reveals the sea surface changes and map of the changes is produced for the period of 1976 to 1998.

Although the methods and the results from the project are still need to be tested sufficiently, already there is considerable commercial interest. Not only the study of sea surface rise at Caspian, but also the results acquired through this project can be lead to a joint co-operation between Caspian's littoral states. They can use the results for sustainable development of region and its environmental management as well. Recommending the instructions based on the results of the project to the

respective countries, they can take economic and convenient actions that may prevent the damages or diminish their effects.
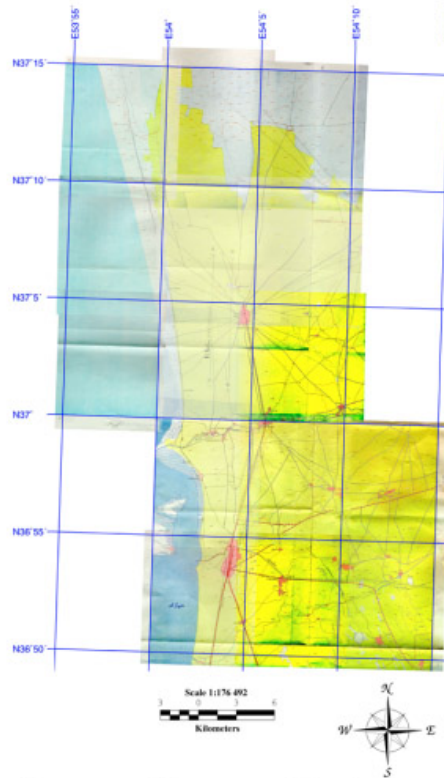
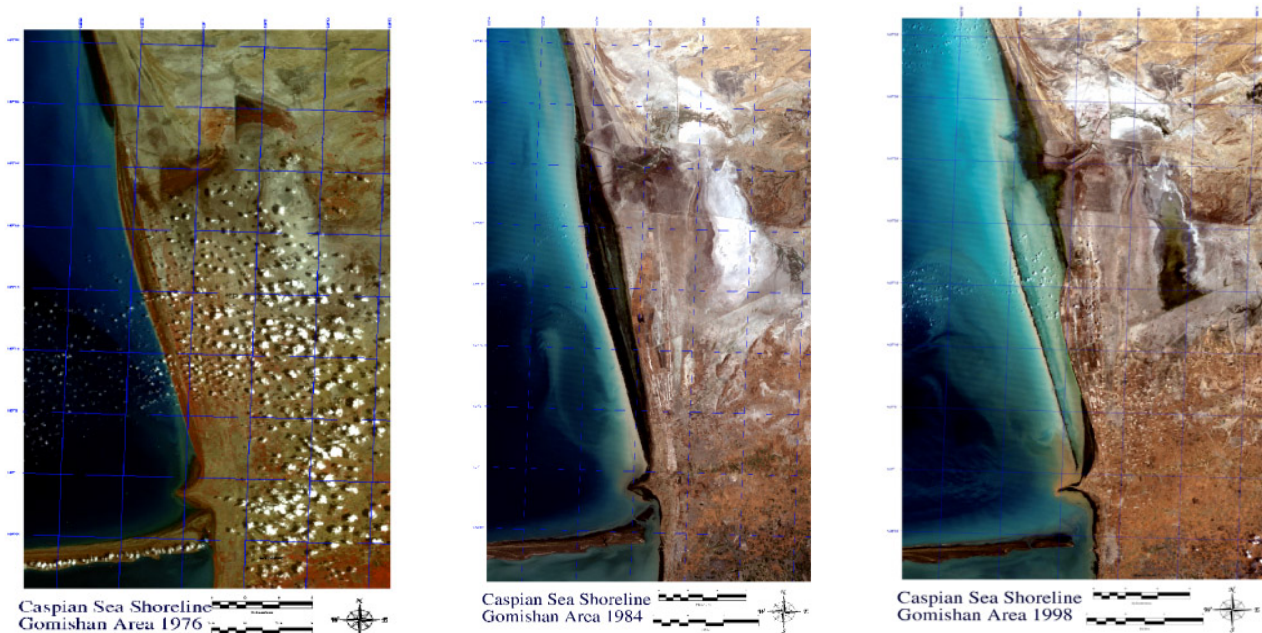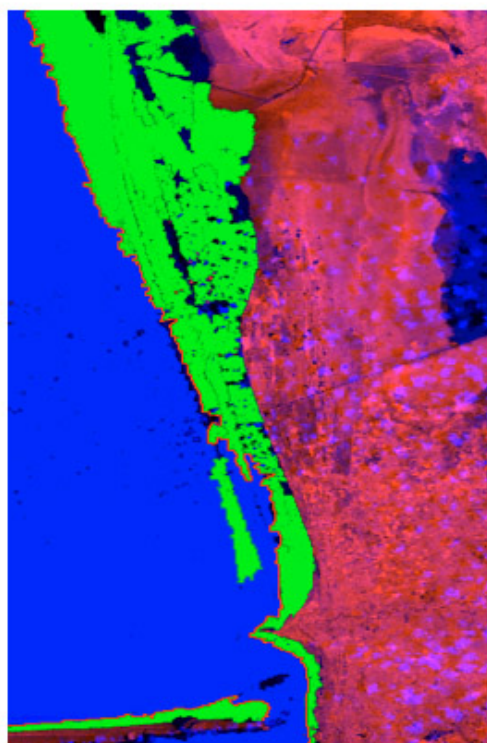Figure 3: Topographic map of the south-eastern of Caspian

Figure 4: MSS-1976, TM-1984 and TM-1998 data of the south-eastern Caspian from left to right. The changes can be seen clearly.

CASPIAN SEA SHORE LINE CHANGES
1976 - 1998

Inundated area highlighted by blue color

Figure 5: Map of changes for the period of 1976 to 1998

Furthermore, the results of the projects will enable decision-makers and planners to suggest the beneficial uses of the sea surface rise for industrial, technical and environmental concerns. The potential users of the results of project include the organisations in governmental as well as private sector. The organisations involved in urban, housing, fishing, forestry, agriculture, environment, tourism issues and many more are the potentially interested organisations in the results of the project.

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