A MODEL FOR RISES AND DOWNS OF THE GREATEST LAKE ON EARTH

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Figure 1: West of Novshahr in the Iranian coast of Caspian; the dam constructed to protect the coast from sea rise.
Rising of the water surface at **Caspian Sea** causes difficulties and damages.

This endangers *installations* and the *people* living in the vicinity.

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 the region for *sustainable development*.

As the largest lake on Earth sited in Asia, **Caspian** covers an area of nearly 371,794 sq. km. It is so large that is called sea.

**Caspian** covers an area from 46 degrees and 38 minutes to 54 degrees and 34 minutes East, and 36 degrees and 34 minutes to 47 degrees and 13 minutes North.
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.

It is the biggest remaining part of the greater sea named Thetis that was fragmented due to the generation of mountain chains Alborz and Caucas.

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.

The water volume of Caspian is estimated to be 79319 cubic km that consists 40 percent of the total water of all the lakes in the world.
Figure 2: Map of the **Caspian** Region
THE PROBLEM THAT CONTINUES

- *Surface level change* of **Caspian** is one of its *important characteristics* since very ancient times.

- Its *water level* has seesawed dramatically for *millennia*. But recently, increasingly *warm weather* and wider uses of *irrigation* have lowered the sea level.

- Although chronic *degradation of soil, water, and air* plagues the region, 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.

- **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.
• 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.
• 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 26.2 m and minus 29m by 1978.
• By 1993 the average water level of the sea had risen by more than 2 m.
• Since 1995 the sea level has been decreasing but there are evidences that the Sea’s water surface has begun to rise since 1999.
• Between 1978 and 1995 the Caspian rose 2.4 m causing flooding and washing oil from lowland wells into the water.
MONITORING FROM SPACE

- 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 rise at Caspian there is a realization that remote sensing data can 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, most of the littoral states are mostly ill-equipped to monitor it.
- 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 organizations in Iran that uses earth space data.
- This project proposes setting up a model for monitoring the fluctuations of Caspian for incorporation to a forecast and warning system.
The main input to the system is frequent satellite data of region. 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 microwave parts of EM 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. 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.
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- **HROI** data taken from Landsat-TM gives a *spatial resolution* of nearly 30 m and *temporal resolution* of about 16 days.
- SPOT, with the *resolution* of 20m in spectral and 10m in panchromatic mode has a 26-day temporal resolution, but IRS-Pan mode has the spatial resolution of 10 m and temporal resolution of 5 days.
- 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 likelihood of obtaining the cloud-free images.

With SAR data the sensors operate at wavelengths where signals travel almost unaffected through clouds.

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 10 sq.km.
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- The resolution of MROI sensors ranging from hundreds of meters to tens of kilometers 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, modeling, quality control and forecasts would then all have to be completed within the scheduled period.
Figure 3: Medium resolution image of Caspian Region collected by NOAA-AVHRR
• 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.

• The respective graphs will be prepared then.

• 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 modeling work.

• Then the changes will be detected in the progressive images and using topographic data and the Digital Terrain Model of 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 rising.

• This information of course will be much reliable when validated by the ground truth.
The investigations by the experts and specialists in IRSC shows the results confirming the proposed model.

Applying the data of the southern 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.


Comparing the images reveals the sea surface changes and map of the changes is produced for the period of 1976 to 1998.

This study aimed to find and highlight the environmental impacts of sea surface rising and its consequent water transgression along nearly 1000 km of the Iranian coastline in south of the Caspian Sea.
Figure 4:
Topographic map of the south-eastern Caspian
Figure 5-a:
MSS-1976 data of the south-eastern Caspian, the changes can be seen clearly comparing with the two other images.
Figure 5-b:
TM-1984 data of the south-eastern Caspian, the changes can be seen clearly comparing with the two other images.
Figure 5-c:
TM-1998 data of the south-eastern Caspian, the changes can be seen clearly comparing with the two other images.
Figure 6:
Map of changes for the period of 1976 to 1998

Caspian Sea Shore Line Changes 1976 - 1998

Inundated area highlighted by blue color
Figure 7-a:
The composite image generated from the MSS-1977 and TM-1991 data showing 300-400 meters of water transgression.
Figure 7-b:
The composite image generated from the MSS-1977 and TM-1998 data showing the water transgression
• The *ER Mapper* software was employed successfully for *geometric correction* and *image Mosaic generation* as well as *other processing*.
• The boundary between water and land was extracted through *water masking* of *infrared and visible bands* on the MSS and TM data.
• Then extracted boundaries were *mapped* on the digitized map of the area to *delineate* a sharp contact between water body and the land.
• Finally all maps in vector format were overlaid on the latest image to show changes in coastline.
• Applying the distance tool in *ER Mapper* coastline changes were easily detected on composite map.
• The results of this study shows about *300-400* meters of water transgression along *south-western* coastlines of *Caspian Sea* (Rasht to Astara area), which is due to *very steep slope* in this area, while because of very *gentle slope* along *south-eastern* coast (Ghomishan and Bandar-e-Turkman area) the rate of transgression even reaches to about *10 kilometers*. 
EMERGING CONDITIONS AND POTENTIALS

- Not only the study of sea surface rise at Caspian, but also the results acquired through this project can lead to a joint co-operation between Caspian’s littoral states.
- The results can be used 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.
- The results of the project 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 organizations in governmental as well as private sector, including the organizations involved in urban, housing, fishing, forestry, agriculture, environment, tourism issues and many more.