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Monitoring Lake Ecosystems Using Integrated Remote Sensing / Gis Techniques: An Assessment in the Region of West Macedonia Greece

Stefouli Marianthi[1], Charou Eleni[2] and Katsimpra Eleni[3]
[1]*Institute of Geology and Mineral Exploration, Olympic Village, Acharnai,*
[2]*N.C.S.R. "Demokritos", Institute of Informatics & Telecommunications,*
[3]*Geographer, Independent Researcher,*
Greece

1. Introduction

The environment and its land and water systems are put into constant stress through the various human activities, natural and climate processes. Water resource managers have long been incorporating information related to climate in their decisions. They also increasingly recognize that climate is an important source of uncertainty and potential vulnerability in long-term planning for the sustainability of water resources (Hartmann, 2005). These are leading to questions about the relative impacts of shifts in river hydraulics, land use, and climate conditions. Prospects for climate change due to global warming have moved from the realm of speculation to general acceptance. Climate change will have different effects on lakes. Lakes can be extremely sensitive to short- and long- term changes in the weather and so are intrinsically sensitive to climate change through a direct effect, or indirectly by affecting processes that take place in the catchment. Understanding the response of lakes to climate change is of great importance since year-to-year changes in the weather patterns can influence water quality and the ecological status of a lake in the terms of Water Framework Directive.

Characterizing the heterogeneity and temporal change of water quality across surface waters is difficult through conventional sampling methodologies (Tyler et al., 2006). In situ measurements and collection of water samples for subsequent laboratory analyses provide accurate measurements for a point in time and space, but do not give either the spatial or temporal view of water quality needed for accurate assessment or management of water bodies (Schmugge et al., 2002). Traditional monitoring of water quality as well as other environmental parameters involves specialized personnel and both on site and laboratory analysis. Field measurements for monitoring the environment are expensive and difficult to conduct. For example, the water quality monitoring of lakes often includes the monitoring of water clarity using a Secchi disk. Therefore the use of Sechi Disk Transparency (SDT) has been widely adopted in many lake monitoring programs worldwide (Bukata et al. 1988; Wallin and Hakanson 1992; Lee et al., 1995).

Substances in surface water can significantly change the backscattering characteristics of surface water. Remote sensing techniques for monitoring water quality depend on the ability

to measure these changes in the spectral signature and relate these measured changes by empirical or analytical models to water quality parameters. The spectral resolution of most satellite imagery is insufficient to identify (concentrations of) individual components that affect water quality. In most cases, satellite remote sensing is used to investigate the dynamics of sediment loads in reservoirs and lakes (Vrieling, 2006). Many studies found significant linear or nonlinear relationships between in situ determined suspended sediment concentration near the surface of inland water bodies and atmospherically corrected spectral reflectance derived from satellite remote sensing data, such as Landsat (Nellis et al., 1998; Schiebe et al., 1992) and SPOT-HRV (Chacon-Torres et al., 1992). Because sediment characteristics, like texture and color, influence the water reflection, developed empirical relationships are not easily transferable to other regions where erosion entrains different sediment types. Therefore, until a universal equation does not exist, most models of suspended sediment are site-specific (Liu et al., 2003). Thermal infrared (TIR) satellite images can be also used to study transport processes in lakes, such as wind-driven upwelling and surface circulation, providing a measure of spatial variability and horizontal distribution of water temperature that conventional field-based measurements cannot provide, (Steissberg et al., 2006, Zhen-Gang Ji et al., 2006). There still remain many unanswered questions about the effective implementation of integrated remote sensing / GIS techniques into a lake / environmental monitoring program, and these are analyzed in this presentation.
The objective of our research is to better understand the use of integrated application of remote sensing / GIS techniques on monitoring various environmental factors of lake ecosystems.

2. Pilot project area

About 65% of the surface waters of Greece are in its north-western part, in the periphery of West Macedonia. Some of the most valuable lakes of Europe in terms of biodiversity are located in this area, (Figure 1). The analysis of the basins of Macro Prespa and Vegoritis lakes are included in the Chapter.

Fig. 1. Pilot project area

Macro Prespa lake is a transboundary lake that it is shared between FYR of Macedonia, Greece and Albania. The study area is extended to include the catchment of lake Macro & Micro Prespa, as well as that part of the region that is hydro-geologically related to Ohrid lake. The study area has a size of 4769 Km^2 while the Prespa basin covers an area of 1380 Km^2 and is bounded between latitude 40° 38. 3 N to 41° 19.3 N and longitude 20° 33.2 E 21° 18.6 E. Prespa lakes are selected for use as a case study because they have been used in a variety of settings, by multiple agencies, over a long period. Furthermore, Prespa and Ohrid lakes can explicitly accommodate a broad range of resource management concerns (e.g., transnational management, environmental protection / biodiversity concerns, recreation / tourism, water supply, water quality, and power plant support). The study area consists of mountainous ridges, surrounding valleys and the Macro / Micro Prespa and Ohrid lakes. The elevation of the study area lies within ~600 and ~2500 masl with the highest elevations being observed in the central and eastern part of the Prespa basin.

Vegoritis lake basin covers an area of 1894 sq kms and it is bounded between latitude 40° 18. 4 N to 40° 54.2 N and longitude 21° 24.2 E 22° 06.6 E. The lakes range in surface area from 1.8 to 59.7 sq kms with a mean of Secchi depth of 2 m. Emphasis is given on the environmental aspects of Vegoritis lake. Mean depth of the lake is 20 meters. The annual rainfall is about 600mm. There are two main aquifers in Vegoritis hydrologic basin. One of the acquifers is of phreatic type and it is developed in the loose sediments of the basin. Depth of groundwater table varies from about 0 m to more than 40 m. The other one is developed in the karstified limestones and is hydraulically connected directly with the lake.

The criteria for lake monitoring involve complex considerations of meteorological, hydrological, geomorphic and socio-economic factors. The necessary secondary data sources are not always available, or they are out of date. The relevant lake features are either not on the maps or they are inaccurate. Hence the advantages of satellite RS imagery. Both lakes show an abrupt drop of water level during the last decades. Analysis of meteorologic data could not explain the abrupt drop in water level, Figure 2.

3. Data

Optical sensors are widely used for environmental impact monitoring. Satellite images with moderate to high spatial resolution have facilitated scientific research activities at landscape and regional scales. Different sensor properties are important to be considered, when evaluating their possible use for environmental monitoring.

These properties refer to spatial, spectral, radiometric temporal resolution, signal-to-ratio and finally launch date, length of the time series. Multi-temporal Landsat images are the main source of information. LANDSAT-1 was the world's first earth observation satellite, launched by the United States in 1972. Following LANDSAT-1, LANDSAT-2, 3, 4, 5, and 7 were launched. LANDSAT-7 is currently operated as a primary satellite, although an instrument malfunction occurred on May 31, 2003, with the result that all Landsat 7 scenes acquired since July 14, 2003 have been collected in ‘SLC-off’ mode. Of all remotely sensed data, those acquired by Landsat sensors have played the most pivotal role in spatial and temporal scaling: given the more than 30-year record of Landsat data, mapping land and vegetation cover change and derived surfaces in environmental modeling is becoming commonplace (Cohen and Goward, 2004).

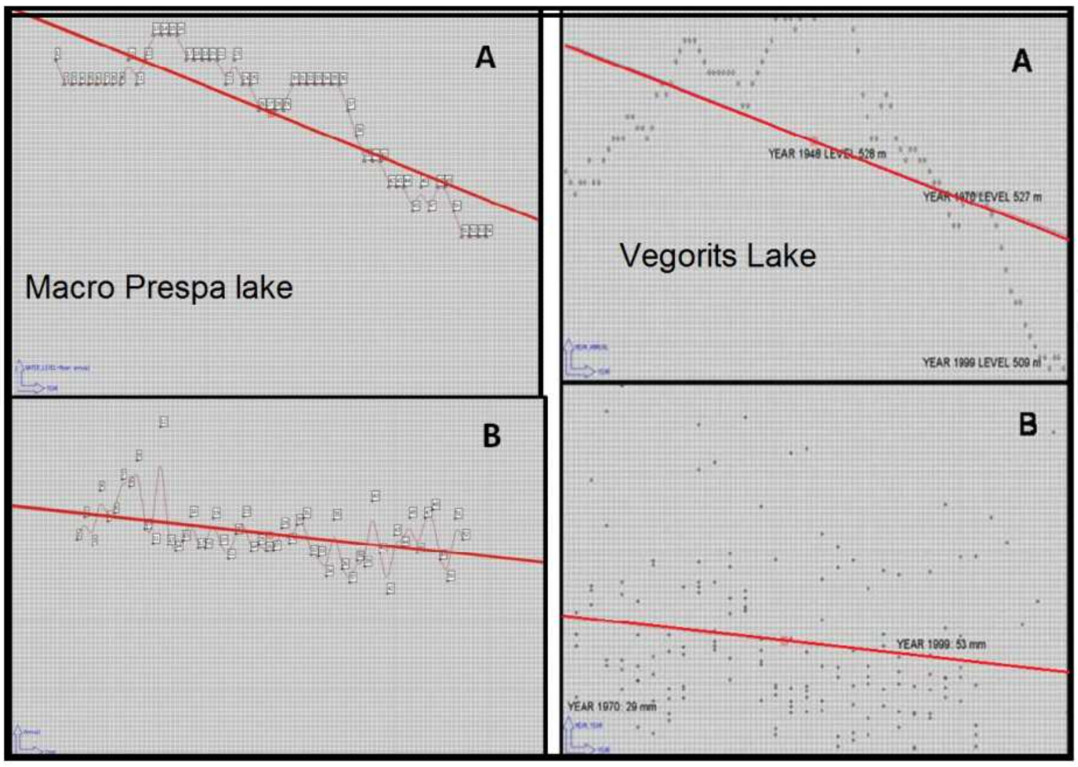


Fig. 2. Climate - rainfall (B) vs hydrology water level(A) measurements of Macro Prespa (A / B left) and Vegoritis lake (A / B right)

The Landsat images that have been used in the current study have been acquired from the USGS / NASA: http://edcsns17.cr.usgs.gov/NewEarthExplorer/ . SRTM DEM data that are available from the USGS server at http://dds.cr.usgs.gov/srtm/ and ASTER-DEM http://www.gdem.aster.ersdac.or.jp/ have been also included in the analysis.
ENVISAT / MERIS, ASTER satellite systems are relatively new systems and their data are also evaluated as far as monitoring the lake water systems is concerned. Much emphasis is given to extract information concerning a variety of parameters like land cover change that influences (indirectly) lake water quality. The effects of anthropogenic land cover modification on lakes are also analyzed by incorporating detailed information about land surface properties derived from Earth Observation data. The data inventory that is prepared and reported in the current submission includes acquisition of land cover maps, geological maps, compilation of hydrogeological maps based on analysis of relevant data, compilation of digital elevation models, analysis of multi-temporal satellite data and land cover maps. The amount of the above information is reviewed and analyzed and the result of the compilation is shown in the form of various maps.

4. Processing techniques

Various data like multi-temporal optical / thermal satellite images of Landsat ETM+, ASTER, ENVISAT systems and image processing / GIS techniques are used for the analysis, Figure 3. To compile the data from the various sources of information, the following problems had to be overcome:

- Different scales of maps, charts and imagery.
- Different coordinate systems.

- Different units of measurement.
- Different types of data.

The interpretation process is set up and activated upon receipt of each image. There are several factors which can influence the quality of RS images and can affect whether or not they are even worth acquiring, e.g.: *Weather, Smoke, Time, Sensors and Sensor performance.* Analysts should be familiar with these factors when interpreting the RS data.

Flawed images, or those having too much cloud cover, were rejected and alternatives sought. Only images with less than 10% cloud cover for the watershed areas or lakes of our pilot study area were used for the analysis. For example 5 out of the 7 collected images for the year 2011 shown in Fig. 4 were used while scenes D and H were rejected. This criterion significantly reduced the pool of images suitable for analysis but most years had at least one winter-spring / one summer-autumn image that met the criterion. From the pool of 38 images we selected 10 Landsat TM images, 2 Landsat ETM and 1 MSS images for reference spanning a ~ 35- year period (1974-2011). Another restriction refers to the scan line problem of the LANDSAT ETM scanner which made practically unusable these images for the analysis of Vegoritis lake. However, Prespa lakes are recorded properly and so Landsat ETM images with acquisition dates after the 2003 have been included in the analysis.

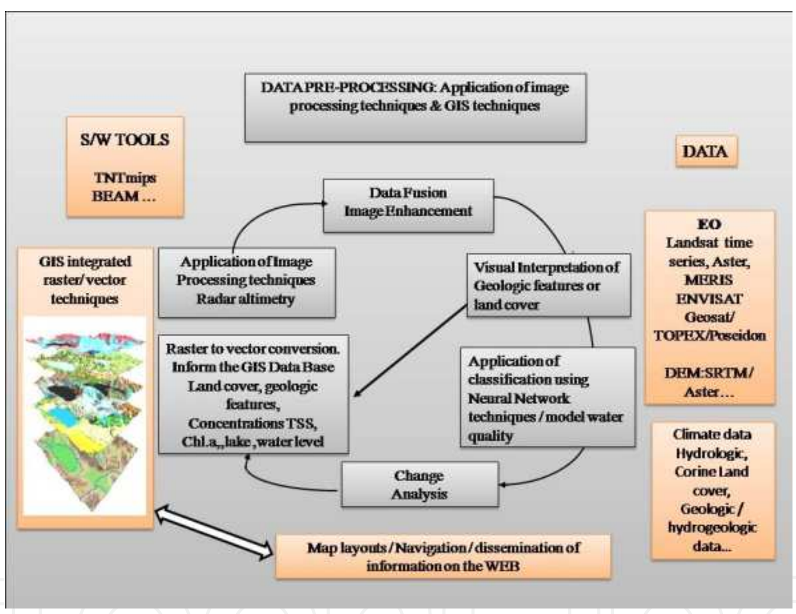


Fig. 3. Data and methods of analysis

All Landsat images were registered to the Greek Geodetic Datum of 1987 (EGSA '87) using the Landsat 17 January 2011 scene as a reference. The root mean square error (RMSE) for positional accuracy was generally less than 0.5 pixels (~ 10 m for Landsat TM). A nearest-neigbour resampling scheme was used to preserve the original brightness values of the images. The most rigorous method of radiometric calibration involves the use of radiative transfer models to produce an absolute correction. However, some data required to perform such a calibration are unavailable for historic images. We tested simple radiometric correction techniques such as dark pixel subtraction, Sun angle correction and normalization of multi temporal images to a single reference scene but found these insufficient as the area should have: (1) similar elevation to the rest of the scene, (2) minimal vegetation, (3) a relatively flat surface, and (4) constant pattern or general appearance over time.

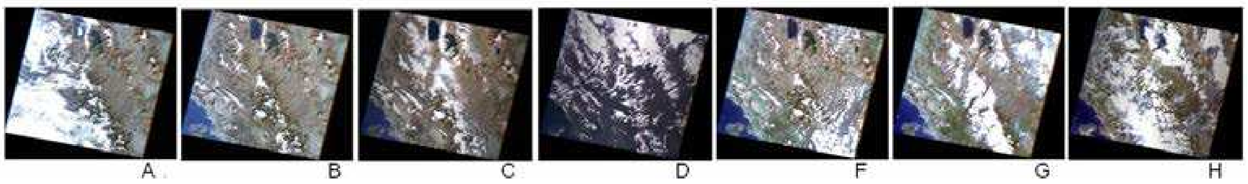


Fig. 4. Available acquisitions of Landsat images for the year 2011: L5:1/January B. L5 17/January C. L7 10/February D. 30/March E. L5 7/April F. 23/ April G.2/June

Data fusion techniques have been used in creating enhanced images at ~ 15 meters resolution for the Landsat ETM images for the watershed areas of the lakes. Digital image processing techniques are applied, plus some necessary image enhancement. The next step in extracting image data for lakes used an unsupervised classification method based on a clustering K Means algorithm with 10 classes and 20 maximum iterations that were then aggregated to land and water classes. Raster to vector conversion techniques were used to outline the polygons of the water surfaces. Due to intense topographic relief of the area shadows were also classified as water surfaces especially in winter scenes. These were eliminated as they have small area extent using vector editing techniques. Auxiliary information was also used to guide AOI selection and correction and this included the use of vector (GIS) layers of map coastlines, bathymetric maps and sampling point locations, Figure 5. Each Lake_AOI polygon was assigned a unique identification number and database fields so as to join the satellite data to the observation database.

The Lake_AOI polygons were used to create the water-only images of the lakes. Multitemporal water-only images of Macro Prespa, Vegoritis and Ohrid lakes have been created and these have been stored as a raster database. Metadata information describing the image acquisition information was also included. Lake surfaces have then been further analyzed using unsupervised classification techniques. Self-organizing Map Classifier – unsupervised classification using neural network techniques proved quite effective in analyzing the lake water surfaces. Available SDT and Cl data are not readily available for the lakes of our region and so some ground measurements are used just for general verification purposes.

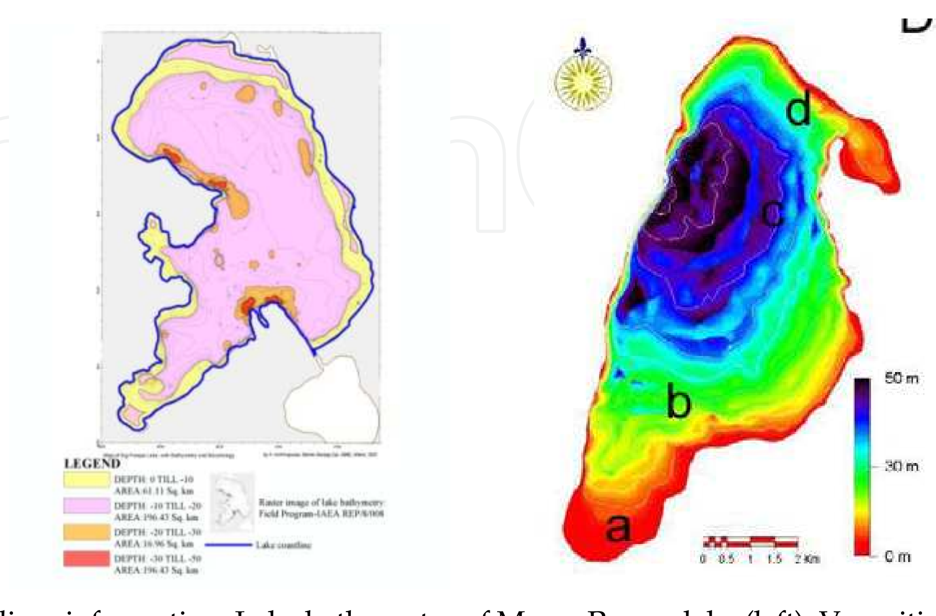


Fig. 5. Auxiliary information: Lake bathymetry of Macro Prespa lake (left), Vegoritis lake (right)

Various ratios of the Landsat bands have been calculated as these are related to SDT measurements. The TM3/TM1 ratio has been tested because previous investigators found it to be a strong predictor of SDT (Cox et al., 1998; Lathrop, 1992), but this was not confirmed by our analysis. All results have been stored to the raster database. Conversion of raster to vector of the lake water surfaces gave the opportunity to identify and store in the database the spatial variability of quantity / quality data of the lakes. GIS techniques have been used to overlay the results obtained from the multi temporal analysis, Figure 14.

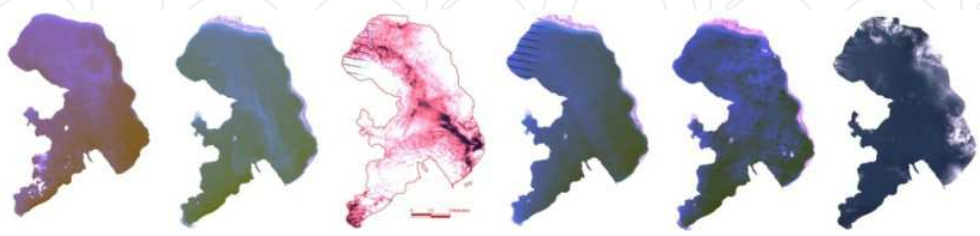


Fig. 6. Extracted surfaces of Macro Prespa lake, using the available map coastline.

High resolution of about 0.5 m ortho-photos available through the WMS service of Greek Cadastral Agency of Greece have been also used to acquire information and verify the results obtained from the analysis of Landsat data. The GIS system gives the opportunity of using the ortho-photos as a background while overlaying any type of GIS data and updating the information. All processing techniques have been applied using the TNTmips Image Processing / GIS S/W system (www.microimages.com). Our case study is intended to give a recent example of the practical applications of RS and GIS to lake monitoring. The RS study is placed first, followed by the GIS study, and finally an integrated interpretation is attempted.

5. Information gathering from remote sensing

Lake physics plays a fundamental role in limnology as temperature structures, circulation patterns and turbulent mixing, all set the environment in which the biology and chemistry within a lake operate. It is also through physics that the initial impact of any changes in climate will be felt within a lake.

5.1 Lakes

5.1.1 Lake inventory

Delineation of water bodies is essential for the estimation of the water balance of the area. Water authorities need to know date, location, extent and variations of these water bodies. The test area covers a broad region while the transnational Prespa lakes basin is included. The problems that are faced are related to:

- The fact that maps are not readily available
- There is lack of updated information
- Digital data are in different scales or coordinate systems
- Accurate measurements of surface areas of Macro – Micro Prespa lakes are lacking.

The 17th of January 2011 Landsat image has been used to make an inventory of all the lakes of the region at a scale of ~ 1:50000, Figure 3. The lake water surfaces have been extracted using classification of infrared bands & conversion of raster to vector techniques. There is up to date information which is readily available in a digital format for the whole of the translational region. Extraction of surface areas / perimeter and spatial context of the location of the lakes is easily obtained. Relationships of the different lake water bodies are also obtained, Figure 7. Accurate mapping of surfaces of the Greek lakes in scales up to ~5000 (Figure 8) is obtained using the WMS - Web service of the Hellenic Cadastre, http://gis.ktimanet.gr/wms/ktbasemap/default.aspx . The acquisition dates of the aerial photography are in the time period of 2007 to 2009.

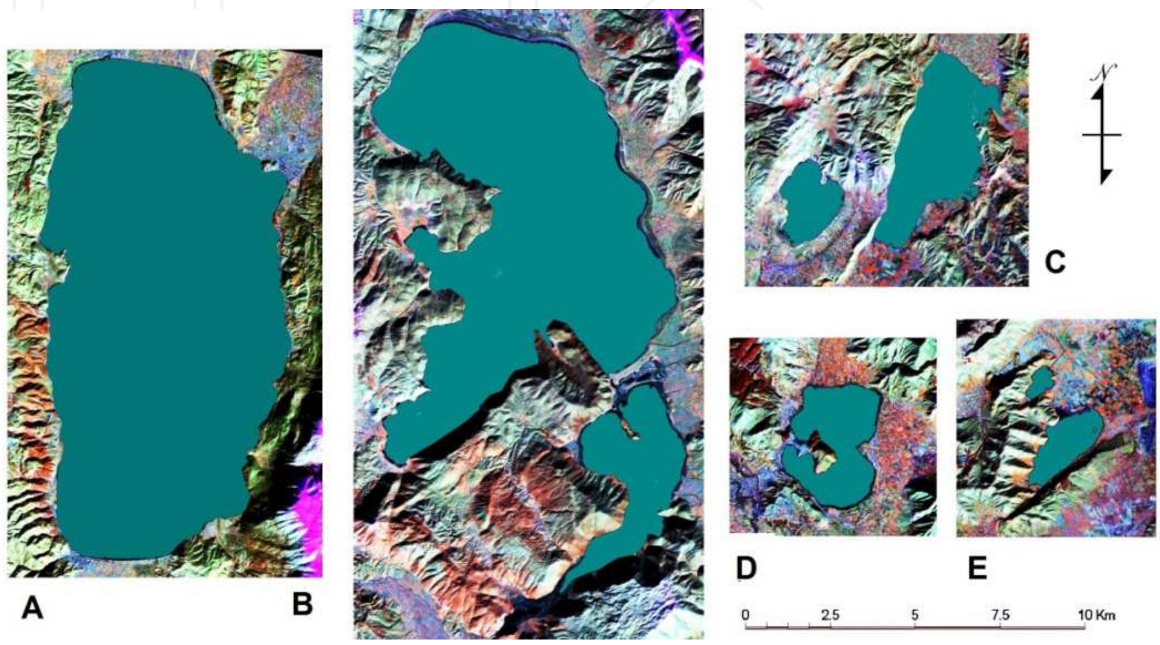


Fig. 7. Lake inventory from the 17th January 2011 image scene. Polygons of the water surface of the lakes have been extracted using classification techniques: A. Ohrid lake B. Macro / Micro Prespa lakes C. Vegoritis / Petron Lake D. kastoria Lake E. Chimaditis / Zazari lakes

A B

Fig. 8. Overlay of the coastlines extracted from the 17th January 2011 image to the orthophoto of 0.5 m resolution A. south part of Vegoritis lake B. South part of Macro Prespa lake.

5.1.2 Multitemporal analysis of change in surface area / size / shape of lakes

Lakes are sensitive to both climate change and to anthropogenic influence. Drop of water level has been observed in both Macro Prespa and Vegoritis lakes, Figure 2. Time series water level data are available for both lakes even though these measurements are not comparable for Macro Prespa lake as different reference levels are used between the three countries. Water level also does not show the spatial variability of the water surfaces, as changes depend on the bathymetry, the amount of sediment input due to erosion or other factors like geomorphology / geology. Satellite and especially Landsat data can be used to perform multi-temporal studies of lake surfaces.

Data collection included the acquisition of lake coastlines as these are available by the national / local authorities or on the Web. The only readily available data for Vegoritis lake are those of maps provided by the Greek Geographic Service of the Army of 1970s while the boundary of Macro Prespa lake has been made available for a time period on the Web (Traborema EU project). The stored in the GIS database map coastlines have been used to assess changes in water surfaces. These coastlines have the same areal extend as these extracted from the Landsat MSS images of the 1974 and therefore are used as a reference. These lake surfaces / coastlines dated since the 70's have been compared to the ones extracted from the multi-temporal Landsat images and stored as GIS vector layers.

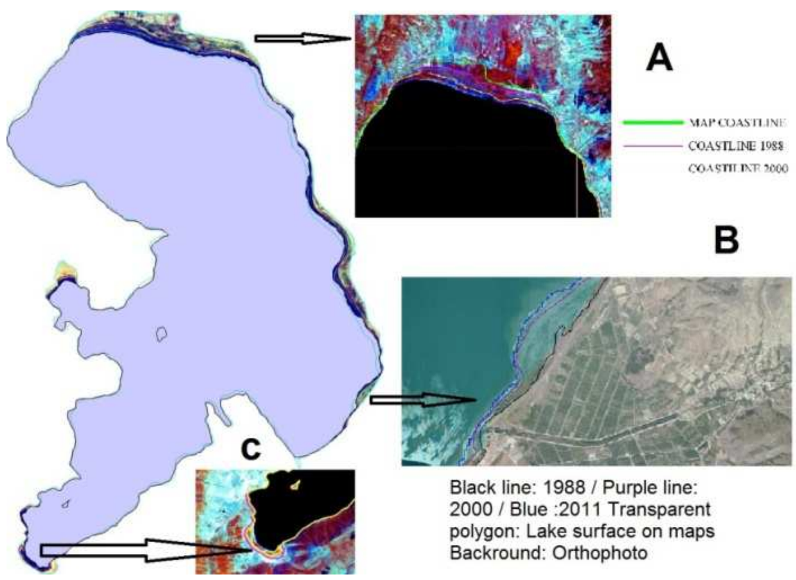
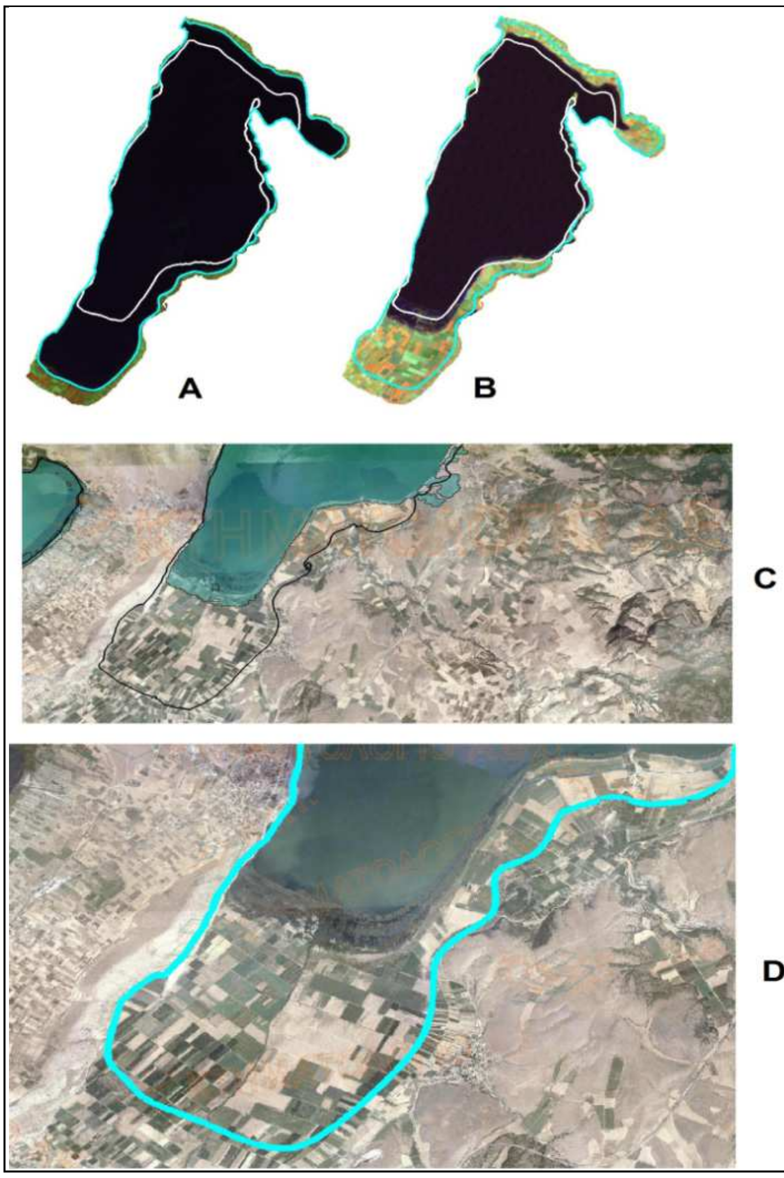


Fig. 9. Incremental changes of Macro Prespa lake for the last ~ 30 years: Changes in the North (A), South East (B)and South West (C)

Both Vegoritis and Macro Prespa lakes have lost their water surface area. A reduction of the surface area of Macro Prespa lake is evident, as estimates of its surface are as following: 20 November 1974 - ~276.5 km², August 1988 ~ 273.7 km², August 2000~265.2 km², 21 August 2008 ~257.2 km² and 17 January 2011~ 256.7 km². Macro Prespa lake has lost nearly 19.8 km² of its surface in the period 1973 to 2011.

Sharp drop of water level of Macro Prespa lake occured in 1975/1977 (1.2 m), 1987 /1990 (3.7m) and 2000/2002 (2.2m.) Figure 9. It is further evident that Macro Prespa lake is still losing its surface, even though the entire Prespa basin has been declared as a trans-boundary protected area, with the establishment of the "Prespa Park" by the Prime Ministers of Albania, Greece and the FYR of Macedonia on 2 February 2000.

Vegoritis lake has lost 30% of its surface (1970: 59.7 km² – 2011: 43.8 km²) in the last ~ 30 years. Changes on its coastline are observed in its southern part, Figure 10. This can be partly explained by its bathymetry as the waters are shallow in the southern part, while its deepest area is in its western part, Figure 5. Comparison with the multitemporal analysis of the other lakes of the area shows that Ohrid, Micro Prespa and Petron lakes have lost only a small part of their surface area. Analysis of the space imagery of the years 1975 and 2011 respectively clearly revealed areas of shore line changes. It is now possible to draw accurate maps which look at the future incremental changes of Vegoritis / Prespa lakes. The modeling of this process is efficiently performed in the GIS.



A & B	A. & B. The coastlines of 1988 (blue line) as well as that of 2011 (white line) have been plotted on the Landsat 1984 image scene.
C	C. South part of Vegoritis lake: The black line shows the coastline of the map. The transparent polygon of the lake surface has been outlined from the17th January 2011 Landsat image.
D	D. The 1988 coastline plotted on the orthophoto: Estimates of the land use change of the lake to agricultural land can be obtained and used by authorities.

Fig. 10. Changes of the Vegoritis lake surface area.

In the framework of the assessment of remote sensing techniques a small scale experiment has been carried out using radar altimetry techniques by Alexei Kouraev (Stefouli et al 2008). Results show that there are annual variations of Ohrid lake water level and these can be measured using radar altimetry. As Macro Prespa lake is hydraulically connected to Ohrid lake and located in higher altitude these could explain its drop of the water level. For some ENVISAT cycles estimates of water level have not been made due to quality control. The difference between the two time series can be up to 15-20 cm, apparently due to land influence in altimetric signal, but in general both in situ and altimetric observation are in good agreement, Figure 11. Time series water level measurements can be obtained through the process of radar altimetry and if it is combined with the estimated surface areas, lake bathymetry can give an indication of the quantitative characteristics of the lakes.

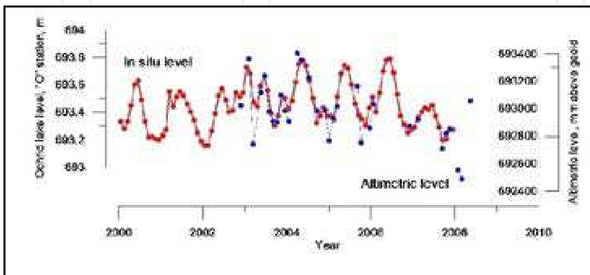
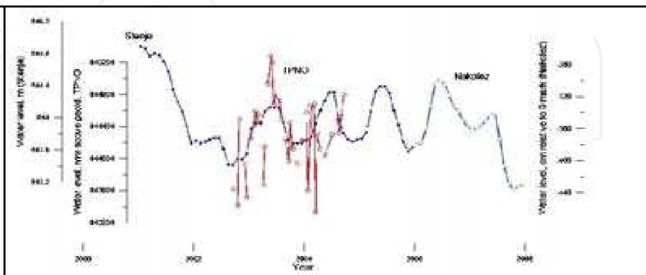
	
(A) In situ (red line and dots) and altimetric (blue line and dots) water level time series of Ohrid lake. Though absolute values differ for Y axis, vertical scales are identical for both.	**(B)** In situ (blue line and small dots for Stenje station and dark blue line and open circles for Nakolez station) and altimetric TPNO (red line with open circles) water level time series for Macro Prespa lake. Though absolute values differ for Y axis, vertical scales are identical.

Fig. 11. Results of applying test for estimating water level of lakes from radar altimetry data.

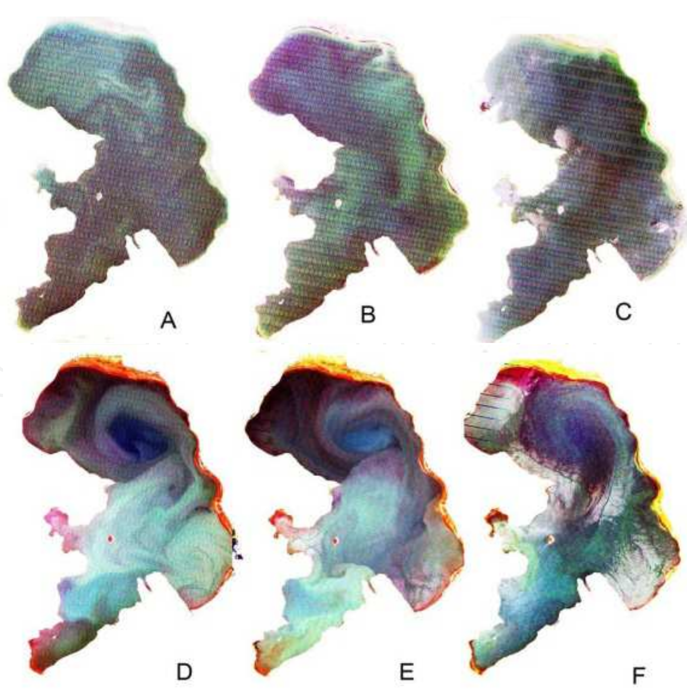


Fig. 12. Seasonal changes of Macro Prespa lake shown on the Landsat images of the year 2010: A. 14 / November B. 4 / April C.7 / June & D./ E./F. 2 / 18 / 26 of August respectively.

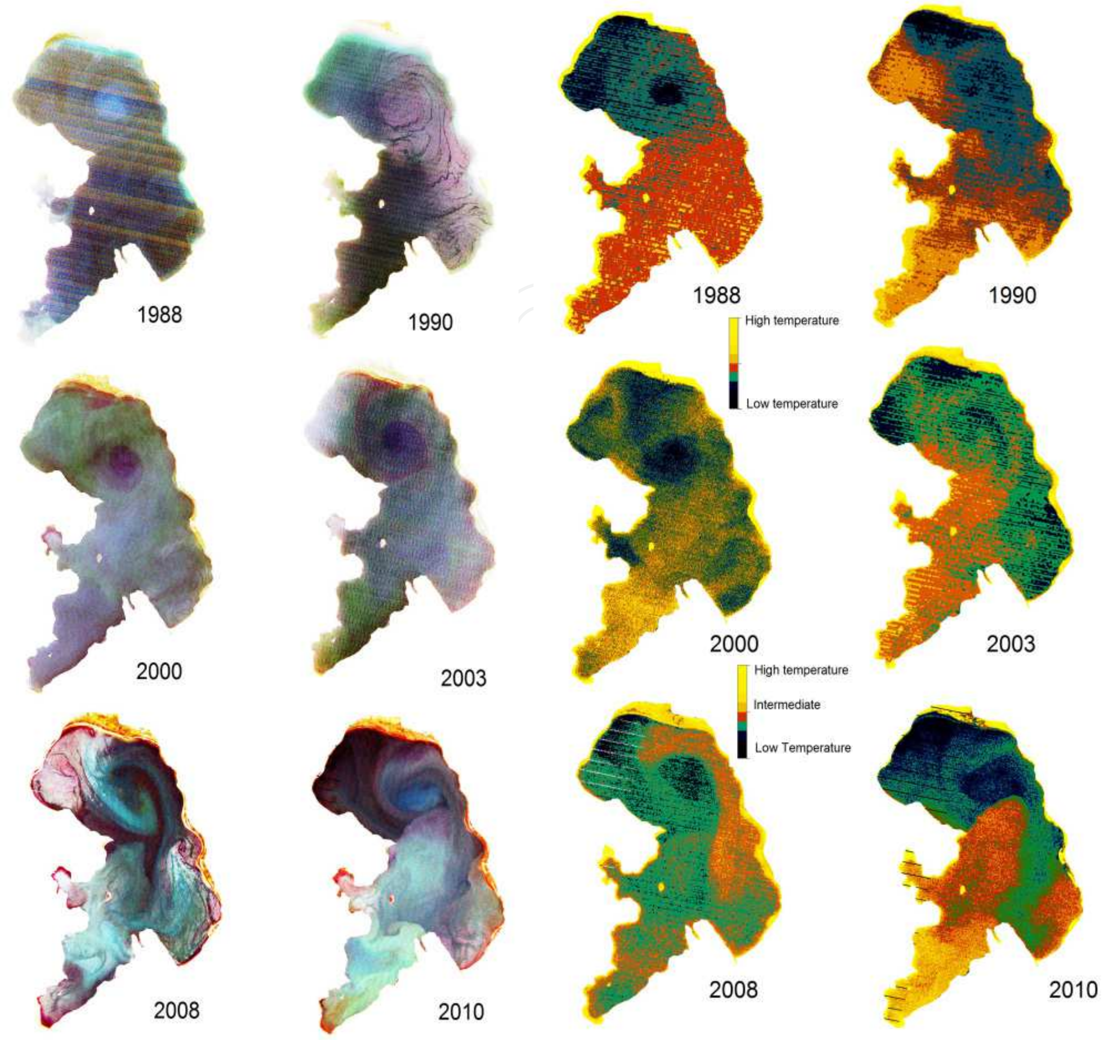


Fig. 13. Surface currents as mapped on using visible part of the spectrum (left image) and the thermal bands (right image) of the summer Landsat images for the period 1988 – 2010.

The images have shown that wind-driven partial upwelling events occur at least throughout the summer stratified period, transporting water from intermediate depths to the surface. These are important events that contribute to the patchiness and heterogeneity that characterize natural aquatic systems. The circulation in Lake Prespa is typically dominated by the northern two-gyre pattern, especially in the summer. The north wind leads to a cyclone (a counterclockwise rotation gyre) in the southwest and an anticyclone (a clockwise rotation gyre) in the northeast.

Analysis shows that a well formed system of gyres is formed during summer D,E,F of the year 2010 while this is not apparent in other seasons of the year i.e. winter / spring or autumn. These results have also been confirmed from the lake surfaces extracted from the ~ 30 years time span. Inter annual changes of the surface currents have been also evaluated. Circular features have been mapped in summer season of every year while some results are shown in Figure 13. These prominent features have been identified in most of the Landsat images. Self organization techniques classification techniques of the visible part of the spectrum proved to be quite effective in mapping lake circulation patterns. Multitemporal data are stored in the GIS database, while synthetic maps can be produced, Figure 14.

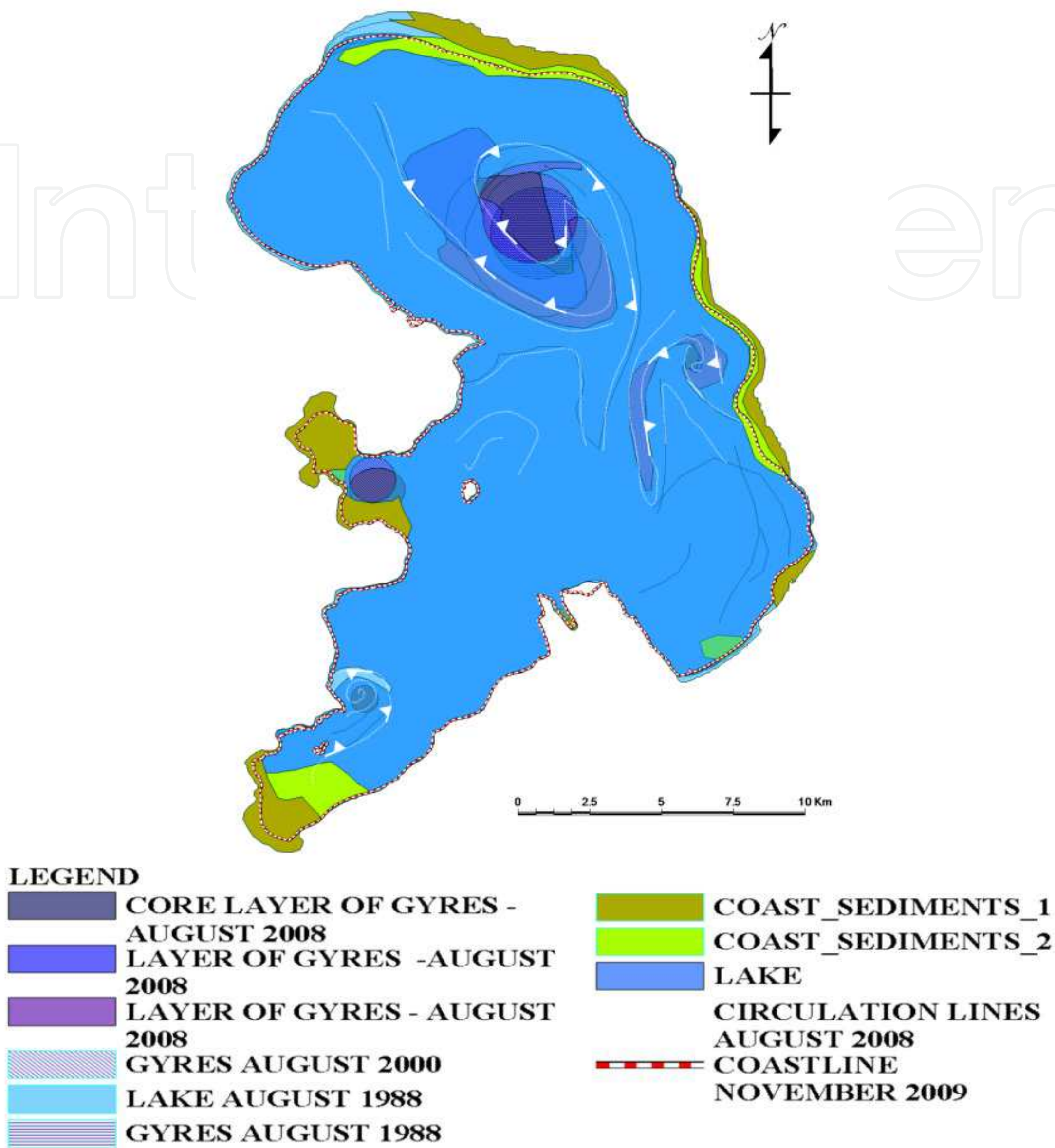


Fig. 14. Synthetic map concerning coastal sediment concentrations surface currents in the form of gyres.

The Landsat and ASTER data have been analyzed for estimating differences of suspended sediment content in Vegoritis lake. The data of band 2 of Landsat images (A, B in Figure 15) and band 1 of the ASTER image (C in Figure 15) have been used in the analysis as they correspond to the same spectral region of 0.52-0.60 μm. The same color palette has been used for displaying the multi-temporal images. Blue-green colors show relatively low sediment content while red - yellow colours high content. The Vegoritis lake thermal regime is also displayed in Figure 15. Inflow patterns of sediments can be interpreted on the satellite imagery in the different acquisition dates. Numbers 1 to 4 show the location of the streams / canals that discharge into the lake.

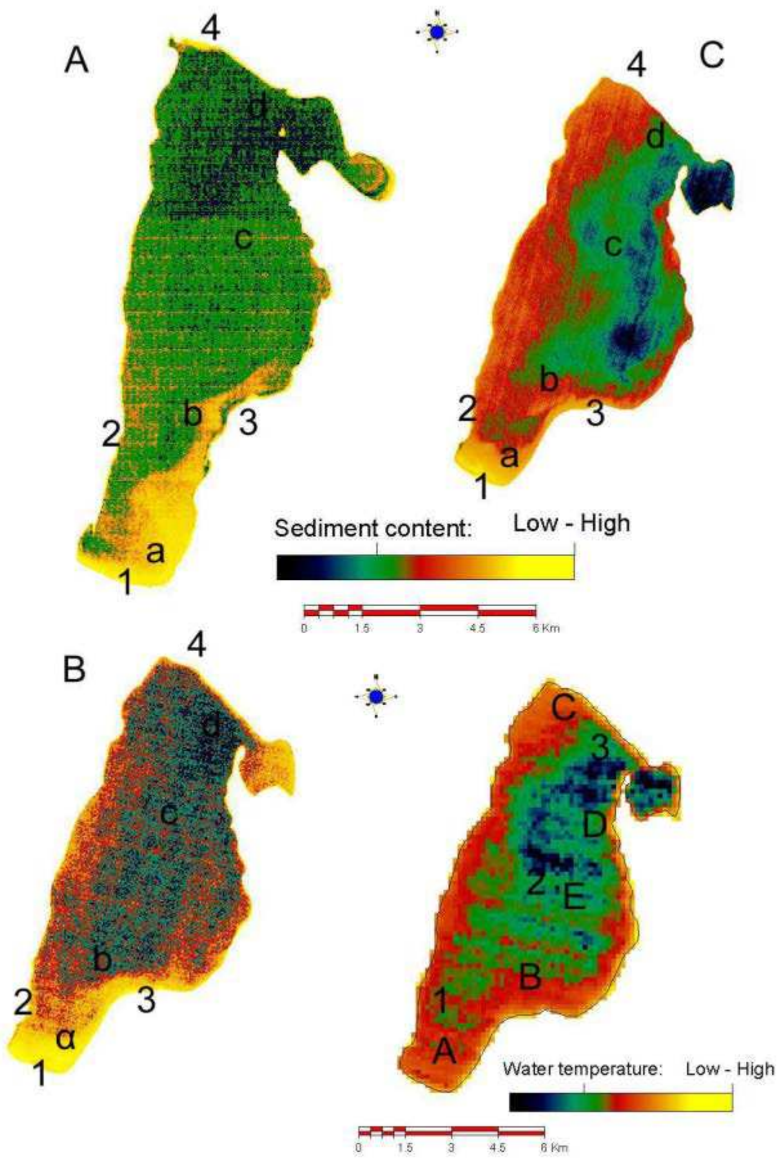


Fig. 15. Circulation patterns of Vegoritis lake a to d: field sampling points.

The high-spatial-resolution TIR images provide a detailed view of fine-scale processes, such as surface jets, that cannot be clearly resolved in moderate-resolution images, and they enable the accurate measurement of surface transport and circulation patterns.
The high spatial resolution of ASTER and ETM+ images allow the surface currents and general circulation in lakes and coastal environments to be accurately delineated. The vector field delineates three gyres as shown in Figure 14, Convergence and divergence zones and inflows can also be clearly resolved in the thermal patterns of the high-resolution TIR satellite images. The analysis enabled the characterization of wind-driven upwelling and the measurement of surface currents and circulation at lakes of West Macedonia. Trends during the last ~25 years of lake hydraulics, concerning surface currents, turbulence charactiristics and transport phenomena are identified.

Dates	(a) Depth 0,5m	(b) Depth 0,5m	(b) Depth 5m	(c) Depth 0,5m	(c) Depth 5m	(d) Depth 0,5m	(d) Depth 5m	Mean value
21-03-2000	1,0	2,1		2,6			2,6	2,1
4-04.2000			2,20		2,80		2,60	2,5
16-04-2000		2,40		2,60		2,60		2,5
7-05-2000	0,50	1,00		2,20		2,40		1,5
22-05 2000	0,7	1,60		1,70		1,50		1,4
5-06-2000	0,5	1,80		2,80		2,40		1,9
21-06-2000	0,8	2,20		2,60		2,40		2,0
10-07-2000	0,5	2,10		2,30		2,20		1,8
16-07-2000	0,6	1,6		1,8		2		1,5

Table 1. Sechi measurements in locations a,b,c,d of Figure 15 with variable depth and in various dates of the year 2000

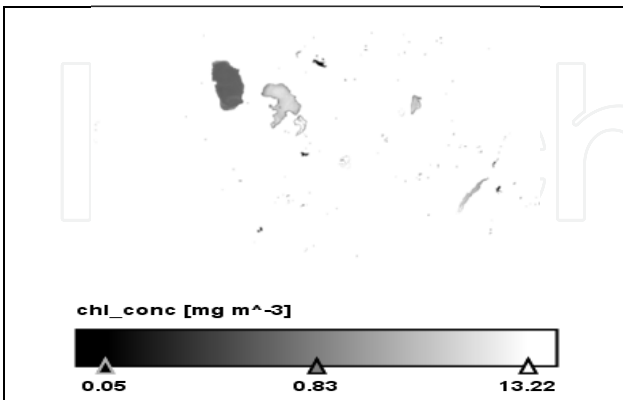
5.1.3 Suspended sediments – chlorophyll

Optical remote sensing of inland waters has become a task of increasing importance, since the availability of clean fresh water is one of the great environmental challenges. In particular natural lakes and artificial reservoirs have to be monitored on a regular basis to ensure the quality of the water. With its 300 m spatial resolution and 15 spectral bands the imaging spectrometer MERIS on ENVISAT can be used for monitoring of at least larger inland waters. However, the standard algorithms as used for open ocean or even coastal waters are not appropriate because different water constituents occur in particular different phytoplankton blooms with partly extreme high concentrations. To this end the CASE 2 REGIONAL (C2R) processor of the BEAM 4.9 (Envisat/Brockman Consult) has been developed.

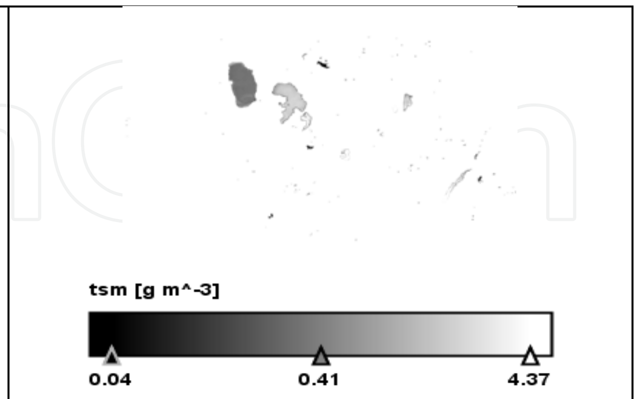
A time series of MERIS full-resolution (300 m spatial resolution at nadir) imagery was obtained from ESA's rolling archive at ESRIN https://oa-es.eo.esa.int/ra/mer_frs_l1/index.php and processed using BEAM 4.9. Images were subset to a geographic region bounded by the lat/lon limits of the study area. The BEAM 4.9 C2R processor was applied to data to extract atmospherically corrected radiance and the algal product C2R Chl_conc, according to the methods of Doerffer and Schiller (Doerffer and Schiller, 2008a, b). Default settings were accepted for all processing parameters. The algorithm used for the retrieval of water constituents is based on the Case-2-Water Bio-Optical Model. The input to the algorithm are the water leaving radiance reflectances (i.e. the output of the atmospheric correction) of 8 MERIS bands. The algorithm derives data of the inherent optical properties total scattering of particles (total suspended matter, tsm) b_tsm, the absorption coefficient of phytoplangton pigments a_pig and the absorption of dissolved organic matter a_gelb (gelbbstof) all at 443nm (MERIS band 2). Hence the concentrations of phytoplankton chlorophyll and of total suspended dry weight are determined. The algorithm is based on a neural network which relates the bidirectional water leaving radiance reflectances with these concentration variables. We estimated the concentrations of two parameters: chlorophyll and total suspended matter.

As was already pointed the test area is a cross border area between 3 different countries so it is not easy to establish a classification scheme and find the suitable variables and classification limits for a common water quality classification system. However, a relative classification scheme can be created using MERIS images. According to results shown in

Fig. 16, the quality of water in the lake Ohrid is the highest among all lakes. Then follows Macro Prespa, Micro Prespa and Vegoritis while Petron shows the worst water quality. This MERIS based relative classification of lakes coincides with the classification based on the available in situ data observations.



CHL Concentration August 2007



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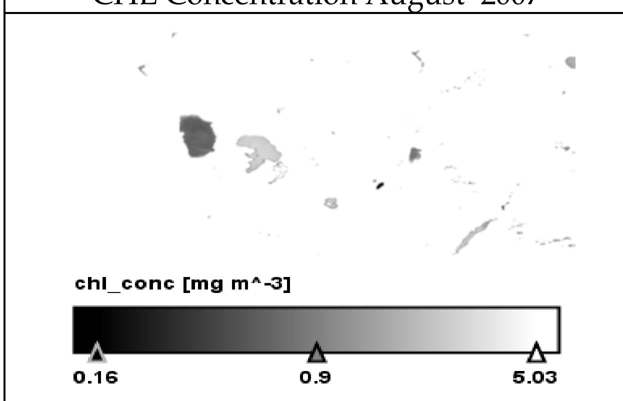

CHL concentration August 2009

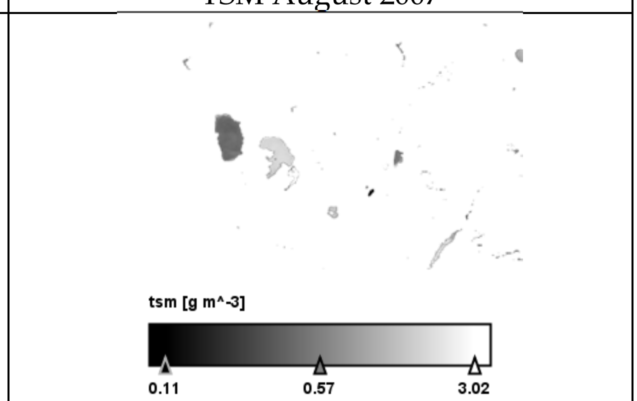

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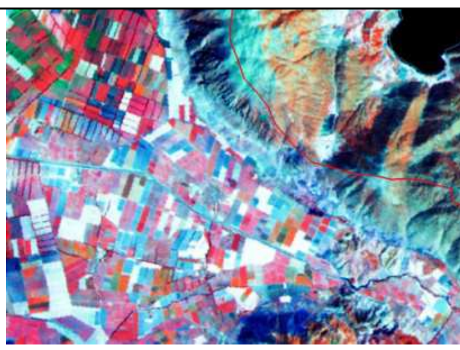
Fig. 16. Chl concentration and tsm

5.2 Catchment areas of lakes

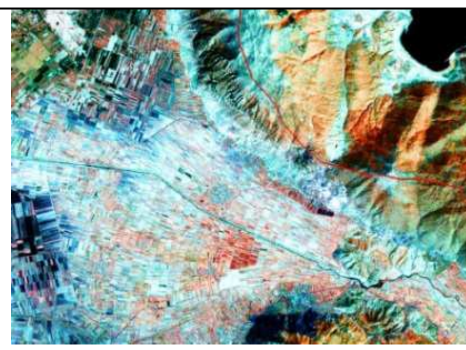
Water authorities need tools to monitor and assess the status and the changes of basins so as to optimize and regulate their usage and to avoid depletion of the water resources. Up to date information about land cover, land use, vegetation status and their changes over time (e.g. seasonally) is important for the understanding and modelling of hydrological processes such as infiltration, runoff rates, evapotranspiration and water needs. Additional EO-derived information such as land cover, DEMs (digital elevation models) or surface water variations can be used to infer properties of surface waters and aquifers, or used in water cycle models (e.g. to calculate evapotranspiration). In order to interpret these discrepancies the water basin status and the changes that are taking place need to be analyzed.

The collected information is reviewed and analyzed and the result of the compilation is shown in the form of various maps. Multi-temporal analysis of Landsat- 5 / 7, Enhanced Thematic Mapper Plus (ETM+) scenes, Envisat MERIS and one ASTER scene have been used in the analysis of the catchment areas. Special emphasis is given on the catchment delineation using DEMs available for the lake basins. The analysis included various types of DEMs like the SRTM (100 m resolution) and ASTER (30 m resolution) DEMs. Catchments of river networks are fundamental to the automation of flow-routing management in distributed hydrologic models and for the morphometric evaluation of river network structure. The analysis of the DEM resulted to the delineation of the hydrographic network of the area of the transnational Prespa basin. The ASTER DEM has been used to delineate the changes of the relief of the Vegoritis lake basin.

Geology plays a role in the region as it allows the interconnections of adjacent river basins, which is the case of Prespa and Ohrid lakes. Ground waters cannot be observed directly by existing EO satellites, however, location, orientation and length of lineaments can be derived from EO and can be used as input for studies of fractured aquifers (e.g. location of sites for water harvesting). Available geologic maps have been scanned, geo referenced, digitized for the whole region within the context of the GIS system, Figure 3. The original maps have been of different scales and information content. A great variety of rocks with varying age and lithology constitute the catchment areas. Available information on location of springs has been also integrated in the GIS database.

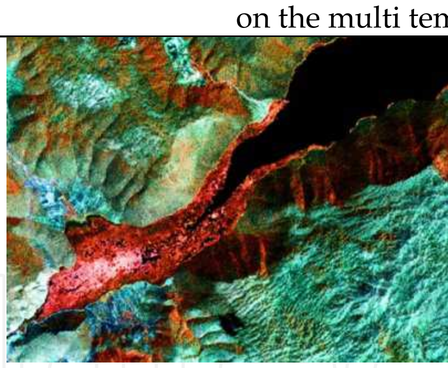


A1. 1988

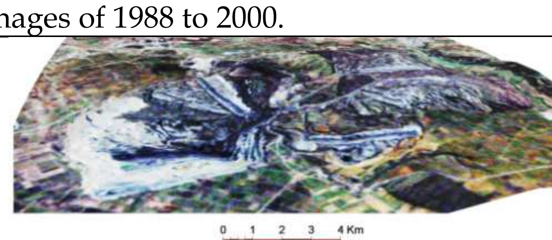


A2. 2000

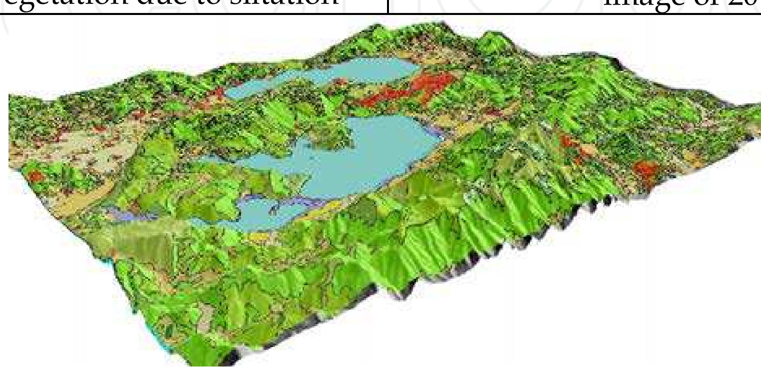
A1 & A2. Impact of the implementation of Government policies after the 1990's as it shown on the multi temporal images of 1988 to 2000.



B. Emergent vegetation due to siltation



C. Mining activites. 3D representation of relief changes due to surface mining as it is mapped by the ASTER DEM & Landsat image of 2011.



D. Red areas show burned by forest fires of 2007 overlayed on the Corine land cover map.

Fig. 17. Impact of anthropogenic factors to the lakes of the study area.

Natural and anthropogenic processes take place in the basins of Prespa and Vegoritis lakes and these have an impact on the water resources of the basins. The catchments of the three lakes have been described by the GIS based analysis of "Corine Land Cover Classification" Figure 17-D. MERIS data has been used for Corine land cover map updating because of their improved temporal resolution. Burnt areas due to the 2007 forest fires are detected and mapped on the MERIS data.
Surface mining takes place in Vegoritis lake basin with negative impacts of mining on the water resources, both surface and groundwater, which occur at various stages of the life cycle of the mines and even after their closure: 1.From the mining process itself, 2. From dewatering activities which are undertaken to make mining possible. 3. During the flooding of workings after extraction has ceased 4. By discharge of untreated waters after flooding is complete.
Anthropogenic factors seem to play a key role on the deterioration of the water resources of the region. Integrated Earth Observation / GIS techniques help to monitor changes in lake basins and can cover specific water management requirements, Table 2, Figure 17.

Anthropogenic Impact		**Comments**
Transnational treaties	First aggrement 1959- 2nd 2000 Prespa Park 2/2/2010, Petersberg Process (1998), Athens Declaration Process Water Convention 1992, Karipsiadis2008	Implementation is suffering from problems like lack of information, insufficient data.
Infra-structures	Diverson of Aghios Germanos (1936) Diversion of Devolli river (mid-70's) It has deposited about 1.2 million m3 of alluvium in the shores of Micro Prespa Lake. Sluice gates controlling flow of waters from Micro to Macro Prespa lake (2004).	Figure 17_B shows the effect of Devolli river diversion to Micro Prespa lake.
Mining	The environmental effects of the extraction stage: Surface disturbance, and the increased amount of sediments transported to the lake.	Figure 17 C shows the effect of surface mining in the Vegoritis lake basin.
Land cover changes	Multitemporal changes of the surface of lakes 1972-2009 period.	Land cover changes due to forest fires, Figure 17 D
Social changes	After the fall of the Eastern Block regimes the land was redistributed in Albania.	The total 550 agricultural cooperatives were converted to 467,000 small holder farms. These land management practices could have driven or intensified different water usage across Albania that would have influenced hydrologic lake water balances..Figure 17, A1 & A2
Agriculture	Irrigation schemes / pumping stations were created during the period 1950-1980, and occur on mainly flat, or gently sloping and river terrace	Agriculture influence both the quantitative / qualitative characteristics of the lakes

Table 2. Selected natural / anthropogenic impacts on the water resources of lakes

An advantage of using remote sensing is that data for large areas within a single image can be collected quickly and relatively inexpensively, while this can be repeated through selected time intervals. It is clear that in order to make regional assessments, one must develop a means to extrapolate from well-studied areas, as the site of our inter-comparison, to other lakes. Since the strength of satellite imagery for lake monitoring is the regional scale dimension, more than one location has to be taken for reference in order to learn how to separate crucial environmental parameters from all kinds of important interfering phenomena. Deterioration of water quantity and quality parameters is interpreted for Macro Prespa & Vegoritis lakes, while Ohrid lake remains stable.

6. Discussion

Monitoring of the lake ecosystems is of paramount importance for the overall development of a region. Remote sensing provides valuable information concerning different hydrological parameters of interest to a lake assessment project. Monitoring is supported due to the multi-temporal character of the data. Temporal changes for the last 30 years can be analyzed with the use of satellite imagery. Processing techniques that have been applied include integrated image processing / GIS vector data techniques. Satellite data generate GIS database information required for hydrological studies and the application of models. Neural network algorithms are quite effective for the satellite data classification. Generated database can be used to assess changes that are taking place in the lakes and its surrounding environment. The areal extent of the lakes has been mapped accurately in all cases. Using the adopted methodology various parameters concerning the lakes and their basins can be extracted related to the description of catchments, surface area, water-level, hydrogeology and water quality characteristics of the lakes.
Water quality parameters of the lakes can be retrieved from remote sensing. Peristrophic movements (gyres) can be clearly identified in the time series images, both in the optical and thermal bands of the Landsat satellite system for the Macro Prespa lake. Understanding the naturally occurring mixing processes in the lake aids in determining the ultimate fate of pollutants, and supports the application of good management strategies and practice. The high spatial resolution of the satellite images allow the surface currents and general circulation in lakes to be accurately identified using the multi-temporal imagery. This can assist in monitoring the clarity and general water quality of lakes. ENVISAT MERIS satellite data have been used for the assessment of spatio-temporal variability of selected water quality parameters like dispersion of suspended solids and chlorophyll concentration. Deterioration of water quantity and quality parameters is interpreted for both Macro Prespa and Vegoritis lakes. It is indicated that satellite monitoring is a viable alternative for spatio-temporal monitoring purposes of lake ecosystems. However, technology alone is insufficient to resolve conflicts among competing water uses. A more useful approach is to have specialists to support decision makers by making available to them the use of data and techniques.

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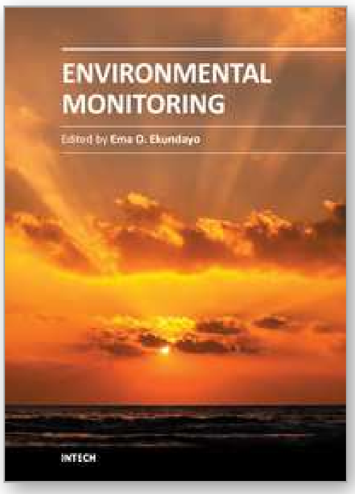

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