Submarine water discharge detection, nearby urban areas in Greece, using Aster and Landsat images.

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International Conference on Land and Water Degradation Processes and Management

6th - 9th September 2009 in Magdeburg, Germany

INTRODUCTION

In this poster presentation we investigate the contribution of satellite image processing in submarine springs detection in certain karstic areas in Greece. Aster and Landsat images of possible or identified coastal and submarine springs in karstic areas have been processed and analyzed. The results have been compared and presented here. The regions that have been selected as research areas are Eastern Korinthia and Eastern Crete.

RESEARCH AREAS

Both regions that were chosen for this research are similar in geological and hydrogeological conditions (karstic environment) and in both there have been problems of sea water intrusion and ground water salinization, which are major problems not only for drinking water supply quality but also for the agriculture and tourism, which are the main financial resources of both areas. By identifying the ground water discharge into the sea water, the sea water intrusion areas are also identified. The lithology of both research areas area is mainly composed of limestones and neogene formations. In Eastern Crete the known submarine springs that were identified are Malavra spring on the northen part and a spring near Agia Irini on the southern part of the area. In Eastern Korinthia the known springs that were identified are : Almiri, Selonda, Orea Eleni and Korfou and a new possible submarine spring was also identified and pointed with white arrow in figures 3, 4 and 5.

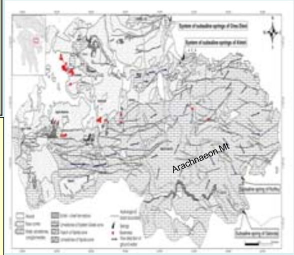
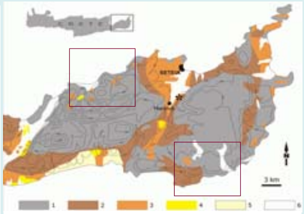


Fig.1 Hydrogeological map of the Eastern Korinthia research area



1, pre-Neogene basement; 2, continental Miocene (fluvio-lacustrine sediments); 3, shallow-water marine Miocene–Lower Pliocene; 4, shallow-water marine Pliocene; 5, continental Pleistocene; 6, alluvium. Contour interval: 200 m.

Fig. 2 Simplified Geologic Map of Eastern Crete (Athanassios Athanassiou, 2004, based on Creutzburg et al., 1977). In the red frames, the study areas are displayed.

LANDSAT 7 ETM+

Landsat 7 is the latest satellite of the Landsat program. It was launched on April 15th, 1999. The primary goal of Landsat 7 is to refresh the global archive of satellite photos, providing up-to-date and cloud free images. Although the Landsat Program is managed by NASA, data from Landsat 7 is collected and distributed by the USGS. The NASA World Wind project allows 3D images from Landsat 7 and other sources to be freely navigated and viewed from any angle.

The ETM+ sensor on Landsat 7 has a number of enhanced features, including:

- New panchromatic band with 15 metre spatial resolution,co-registered with the multi-spectral bands
- Thermal infra-red band 6 has increased resolution from 120m to 60m, and now has two gain settings
- Worldwide data - the solid state tape recorder can collect 100 images per day from anywhere in the world

A summary of the band information is contained in the table below :

	Band Width	Spatial Resolution
Band 1	0.45 - 0.52μ (blue)	30 metres
Band 2	0.52 - 0.60μ (green)	30 metres
Band 3	0.63 - 0.69μ (red)	30 metres
Band 4	0.75 - 0.90μ (near infra-red)	30 metres
Band 5	1.55 - 1.75μ (infra-red)	30 metres
Band 6	10.4 - 12.50μ (thermal infra-red)	60 metres
Band 7	2.08 - 2.35μ (near infra-red)	30 metres
Band 8	0.52 - 0.90μ (green - near infra-red)	15 metres

ASTER

Aster images have been used because of the 5 thermal bands and the better resolution in all wavelengths.

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is an advanced multispectral imager that was launched on board NASA's Terra spacecraft in December, 1999. ASTER covers a wide spectral region with 14 bands from the visible to the thermal infrared with high spatial, spectral and radiometric resolution. An additional backward-looking near-infrared band provides stereo coverage. The spatial resolution varies with wavelength: 15 m in the visible and near-infrared (**VNIR**), 30 m in the short wave infrared (**SWIR**), and 90 m in the thermal infrared (**TIR**). Each ASTER scene covers an area of 60 x 60 km. (ASTER User Handbook)

Band	Label	Bandwidth (μ)	Resolution (m)
B1	VNIR Band 1	0.520-0.600	15
B2	VNIR Band 2	0.630-0.690	15
B3	VNIR Band 3N	0.760-0.860	15
B4	VNIR Band 3B	0.760-0.860	15
B5	SWIR Band 4	1.600-1.700	30
B6	SWIR Band 5	2.145-2.185	30
B7	SWIR Band 6	2.158-2.225	30
B8	SWIR Band 7	2.235-2.285	30
B9	SWIR Band 8	2.295-2.365	30
B10	SWIR Band 9	2.360-2.430	30
B11	TIR Band 10	8.125-8.475	90
B12	TIR Band 11	8.475-8.825	90
B13	TIR Band 12	8.925-9.275	90
B14	TIR Band 13	10.250-10.950	90
B15	TIR Band 14	10.950-11.650	90

Contribution of Remote Sensing in fresh water discharge detection

Combined with geologic and hydrogeologic data and with in situ research, Remote Sensing can provide useful information about the positions and the size of submarine springs. Thermal channels and/or sensors onboard of satellites such as LANDSAT 7 or ASTER can provide more accurate information on temperatures contrasts.

Landsat 7 ETM + was used for the Eastern Korinthia area and Aster was used for Eastern Crete area.The date of the Aster image is 26-11-2001 and the date of the Landsat 7 image used in this research is 5-4-2002 . Various image processing techniques were applied on the Landsat and Aster images, including thermal band processing, selected RGB composites, band ratios and principal components analysis. Thermal band processing and was proven to be the most helpful and suitable method in submarine springs detection, by identifying thermal anomalies on the sea. ER Mapper (version 7.0) is the image processing/GIS software that was used in this research. In this poster presentation the best image processes are displayed.

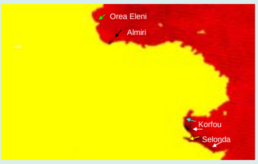


Fig. 3 Colour composite 6,2,1 (R, G, B) of the Landsat 7 ETM image with limits to actual and histogram logarithmic transform. The dry land has been masked out. Springs Orea Eleni, Almiri, Korfou, Selonda and two possible unidentified (so far) ground water discharges are being displayed.

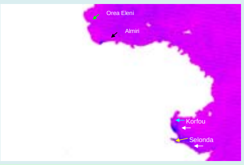


Fig. 4 Colour composite 6,4,1 (R,G,B) of the Landsat 7 ETM of the research area, with histogram equalize transform. The dry land has been masked out. Springs Orea Eleni, Almiri, Korfou, Selonda and two possible unidentified (so far) ground water discharges are being displayed.

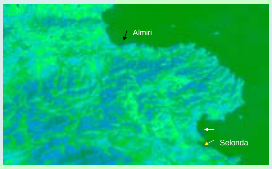


Fig. 5 Thermal band 6 of the Landsat 7 image of the research area, as displayed with the ER Mapper palette RGB reduce and default exponential transform. Springs Almiri and Selond and a possible unidentified (so far) ground water discharge are being displayed.

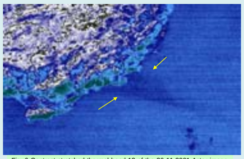


Fig. 6 Contrast stretched thermal band 12 of the 26-11-2001 Aster image displayed with the ER Mapper amphase palette (limits to actual). Darker blue areas indicate a submarine spring near Agia Irini on the south eastern part of the study area.

Fig. 7 False colour composite (13,10,14) R,G,B of thermal bands that displays the submarine spring near Agia Irini (darker grey areas indicate lower temperature ground water discharge into the higher temerature sea water.

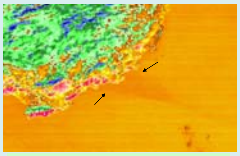


Fig. 8 Contrast stretched thermal band 13 of the 26-11-2001 Aster image displayed with the ER Mapper step palette. Darker orange areas indicate the submarine spring displayed also in figures 3 and 4.

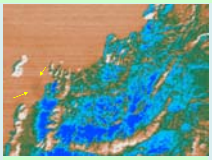


Fig. 9 Thermal band 12 of the 26-11-2001 Aster image displayed with the ER mapper elevation palette. Darker areas on the left display thermal anomalies that show the Malavra submarine spring.

CONCLUSIONS

- **It is not certain that remote sensing methods and techniques can identify all existing submarine springs. That depends on the extent and the depth of the springs and the difference between the ground water and sea water temperature. Still, as it is displayed in this presentation, remote sensing is a very useful tool in locating submarine springs, combined with knowledge of the geological and hydrogeological conditions of the areas and in situ identfication and research.**
- **Both Aster and Landsat 7 ETM + were proven successful in identifying submarine springs and fresh water discharges into the sea water.**
- **Aster's advantage is the five thermal bands and Landsat 7 ETM +'s advantage is the better resolution of the thermal band (60m) compared to Aster's thermal bands resolution (90m).**

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