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«USE OF LIDAR TECHNOLOGY FOR ATMOSPHERIC CORRECTION OF DIGITAL REMOTE SENSING IMAGES WITH GER 1500 RADIOMETER. DEVELOPMENT OF AN ATMOSPHERIC CORRECTION MODEL»

Project code 65/1314

(research in progress)

SCIENTIFIC RESPONSIBLE:
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The research project «USE OF LIDAR TECHNOLOGY FOR ATMOSPHERIC CORRECTION OF DIGITAL REMOTE SENSING IMAGES WITH GER 1500 RADIOMETER. DEVELOPMENT OF AN ATMOSPHERIC CORRECTION MODEL» (code 65/1314) started in March 2003, with the approval of the project's proposal in the framework of NTUA basic research support programme THALES. The project's study area is the Athens Basin, in which the LIDAR system of the Laboratory of Laser and Laser Applications, NTUA Department of Physics, is located.

The project: investigates atmospheric effects on the quality of high-resolution satellite digital imagery and develops an atmospheric correction model which utilizes LIDAR, satellite and radiometric (GER 1500) field measurements of radiance reflected by the surface of an object.

Sites for radiometric field measurements were selected on the following criteria:

- The sites should be accessible, so that measurements using a GER 1500 radiometer could be taken at SPOT and Landsat image capture time (starting 08:30 – 11:30 am).
- Each should include a diversity of targets (vegetation species, bare soil, road etc) to be measured.
- The targets should be clearly distinguished on the satellite image used.
- The target areas should not be heavily affected by atmospheric pollution.

Five sites around the National Technical University (NTUA) Zografos campus were chosen. Seven targets were defined on each site: grass (approximately 4cm high), bare soil, asphalt, bush (approximately 1m high), limestone, white pine, olive leaves. Target reflectance was also measured using GER 1500.

Older digital satellite images available at the NTUA Laboratory of Remote Sensing (LANDSAT TM of June 10, 2001 and November 27, 1999, Spot XS of April 16, 1999) were used to confirm the quality potential of imagery of the specific sites and the ability to interpret and identify distinct targets on them. Topographical maps and diagrams of these sites and relevant aerial photographs (taken in 1979, scale: 1:8,000 and in 1983, scale 1:7,000, available at the NTUA Laboratory of Remote Sensing) were gathered and extensive ground surveys were conducted.

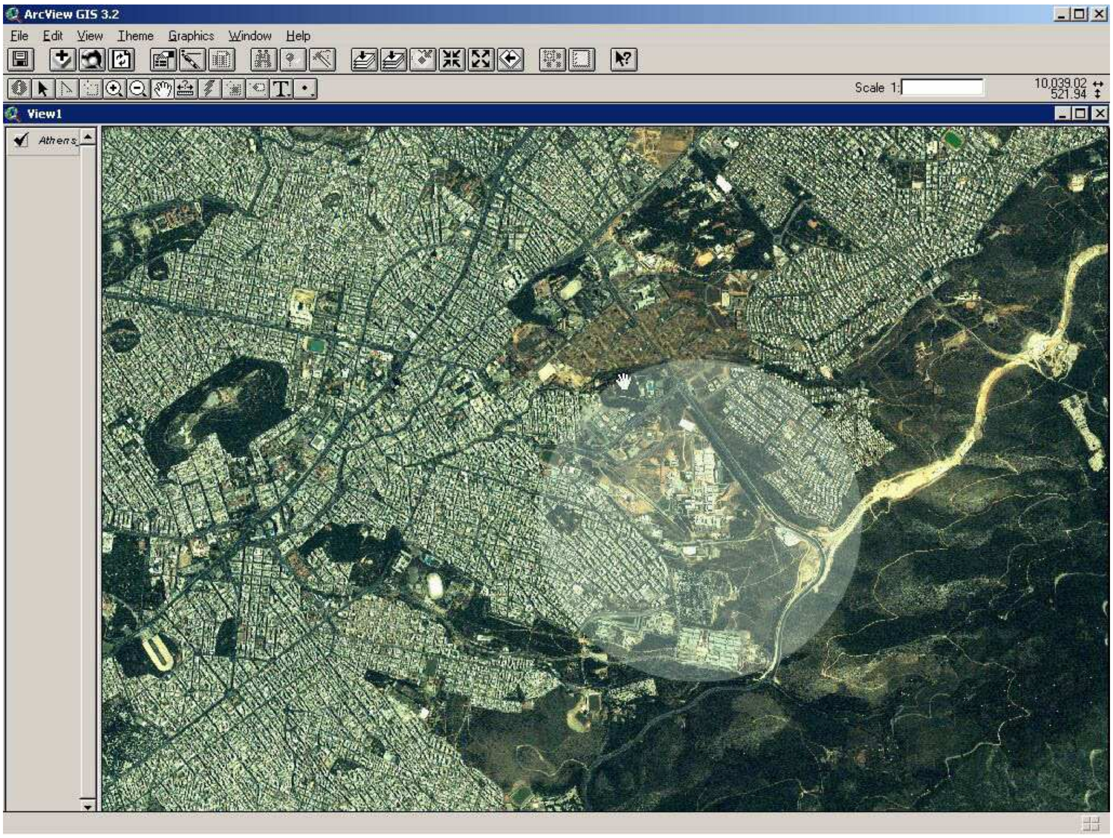

Image 1: The broader field measurement area. The white circle marks the NTUA Zografos Campus, where the LIDAR system is located.

Field measurements (image 2) using GER 1500 were taken on September 10, 13 and 23, 2003, October 6, 11, 13 and 20, 2003, November 1 and 15, 2003 and December 2, 4, 6, 8, 15 and 28, 2003. These dates were selected so as to coincide with Landsat TM and SPOT XS image capture for the area concerned. Measurements by the LIDAR system of the Laboratory of Laser and Laser Applications, NTUA Department of Physics, were taken on the same dates. For various reasons (cloud cover, power failure, LIDAR system calibration), these measurements are used with varying specific weights.

Image 3: Field measurement areas in the NTUA Zografos campus. Red marks the five field measurement sites selected. Green marks the location of the LIDAR system.

The LIDAR system measures major atmospheric parameters in the direction of the light pulse(s) transmitted and estimates optical depth at two wavelengths: 355 nm (infrared) and 532 nm (in the visible part of the electromagnetic spectrum). The latter permits comparisons of LIDAR system measurements with radiometer measurements and digital satellite image values. Two or more pulses of light are transmitted. Atmospheric molecules absorb part of the light and send a fraction of it back to the LIDAR system receiver telescope. This process makes it possible to estimate the vertical distribution of suspended particles in relationship to extinction and backscatter coefficients at approximately 8,500 m altitude over an area, such as the Athens basin. Daily changes in the backscatter coefficient in the part of the electromagnetic spectrum where measurements are made can, therefore, be estimated.

Extinction coefficient values for each target have been calculated on the basis of GER 1500 measurements and satellite image digital values and then compared to coefficient values provided by LIDAR system measurements.

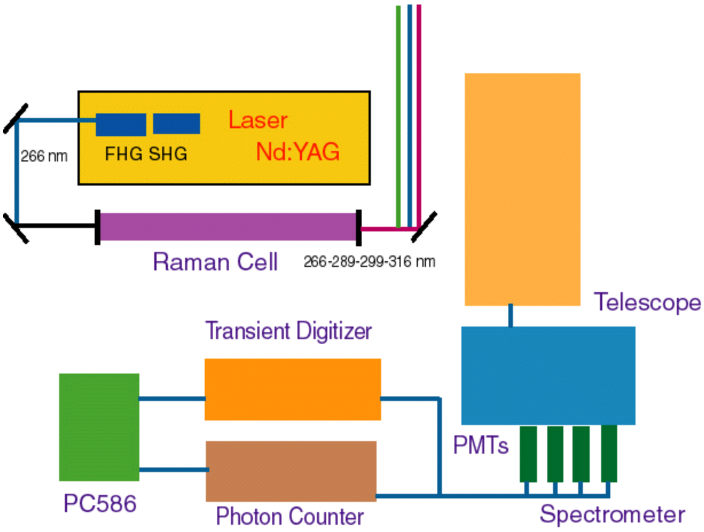

Image 3: LIDAR experimental structure for measurement of suspended particles (Laboratory of Laser and Laser Applications, NTUA Department of Physics)

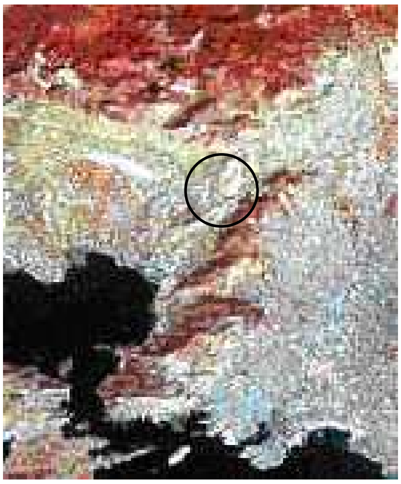

Image 4: Quick Look of the SPOT XS image (December 28, 2003) used. Clouds in the north and north-eastern part of the image do not affect the study area, marked by the circle.

Digital values (DV) of the SPOT XS satellite image for the ground targets have been converted to radiance (R) using R = DV * ACG, where ACG are the absolute calibration gains for the specific image (table 1).

SPOT XS	**Absolute calibration gains**
	w^{-1} m^2 sr μm
Channel 1	**0.85047**
Channel 2	**0.97747**
Channel 3	**1.15374**

Table 1. Absolute calibration gains for SPOT XS image of 28/12/2003

Radiometer-measured radiance values can thus be compared to target digital values of the SPOT XS image (table 2).

Target	Digital value SPOT XS			Radiance SPOT XS (w^{-1} m^{2} sr μm)			Radiance GER 1500 (w^{-1} m^{2} sr μm)		
	channel 1	channel 2	channel 3	channel 1	channel 2	channel 3	channel 1	channel 2	channel 3
Asphalt	107.00	130.00	78.00	91.00	127.07	89.99	19.54	20.43	17.07
Limestone	72.00	89.00	41.00	61.23	86.99	47.30	13.37	14.28	13.20
Pine	157.00	167.00	104.00	133.52	163.24	119.99	29.54	26.86	24.15
Grass	32.00	25.00	64.00	27.22	24.44	73.84	22.65	20.02	17.09
Bush	40.00	44.00	98.00	34.02	43.01	113.07	38.09	40.66	44.55
Soil	35.00	68.00	56.00	29.77	66.47	64.61	7.52	13.28	16.13
Olive leaves	18.00	19.00	52.00	15.31	18.57	59.99	11.30	12.92	11.69

Table 2. Radiance calculated from SPOT XS digital values and radiance measured by GER 1500.

Considering that change of radiance (**dI_λ**) along a path **ds** in the atmosphere is proportional to the extinction coefficient **k_λ**,

$$\mathbf{dI_\lambda = - k_\lambda (s)\, I_\lambda(s)\, ds,}$$

the extinction coefficient **k_λ** has been calculated for every target.

Comparisons of **k_λ** calculations for each SPOT XS channel with the **k** coefficient measured by the LIDAR system are given in table 3, which also presents the mean value of **k** for each channel. Of particular interest are values for channel 1, as both they and LIDAR system measurements refer to the same part of the electromagnetic spectrum (green).

Extinction coefficient (k)				
k (LIDAR) measured	**k (channel 1) calculated**	**k (channel 2) calculated**	**k (channel 3) calculated**	**Target**
0.1335	**0.0884**	**0.1243**	**0.0877**	**Asphalt**
0.1335	**0.0594**	**0.0851**	**0.0455**	**Limestone**
0.1335	**0.1296**	**0.1597**	**0.1168**	**Pine**
0.1335	**0.2419**	**0.2176**	**0.7156**	**Grass**
0.1335	**0.2893**	**0.3758**	**1.0712**	**Bush**
0.1335	**0.2876**	**0.6470**	**0.6246**	**Soil**

0.1335	**0.1380**	**0.1685**	**0.5843**	**Olive leaves**
MEAN VALUE	**0.17633**	**0.25399**	**0.46367**	

Table 3. Extinction coefficient **k**

The accuracy of **k** (k=0.1335) provided by the LIDAR system is approximately 10% (0.1214 - 0.1485).

The mean value of the extinction coefficient (k=0.1763) calculated for channel 1 has been compared to the extinction coefficient value measured by the LIDAR system (k=0.1335).

Their difference (table 4) is possibly due to:

- the contribution of neighboring targets to target radiance and
- the fact that the LIDAR system measures the extinction coefficient at 8,500m, where suspended particles are present, whereas the SPOT XS image is taken at 700,000m.

Extinction coefficient (k)			
	k (LIDAR) measured	**k (channel 1) calculated**	**Difference**
Minimum value	**0.1214**	**0.1763**	**0.0549**
Maximum value	**0.1485**		**0.0278**
Mean value	**0.1335**		**0.0428**

Table 4: Minimum, maximum and mean estimated difference of extinction coefficient **k** values

Further research will use radiometer measurements so as to systematically investigate the contribution of neighboring targets to target radiance and therefore evaluate the difference in extinction coefficient values derived by satellite imagery and the LIDAR system. This will result in the most appropriate extinction coefficient, which will contribute in the development of an empirical model of atmospheric correction.