The use of Combine Active and Passive Remote Sensing Methods for subsurface Soil Mapping

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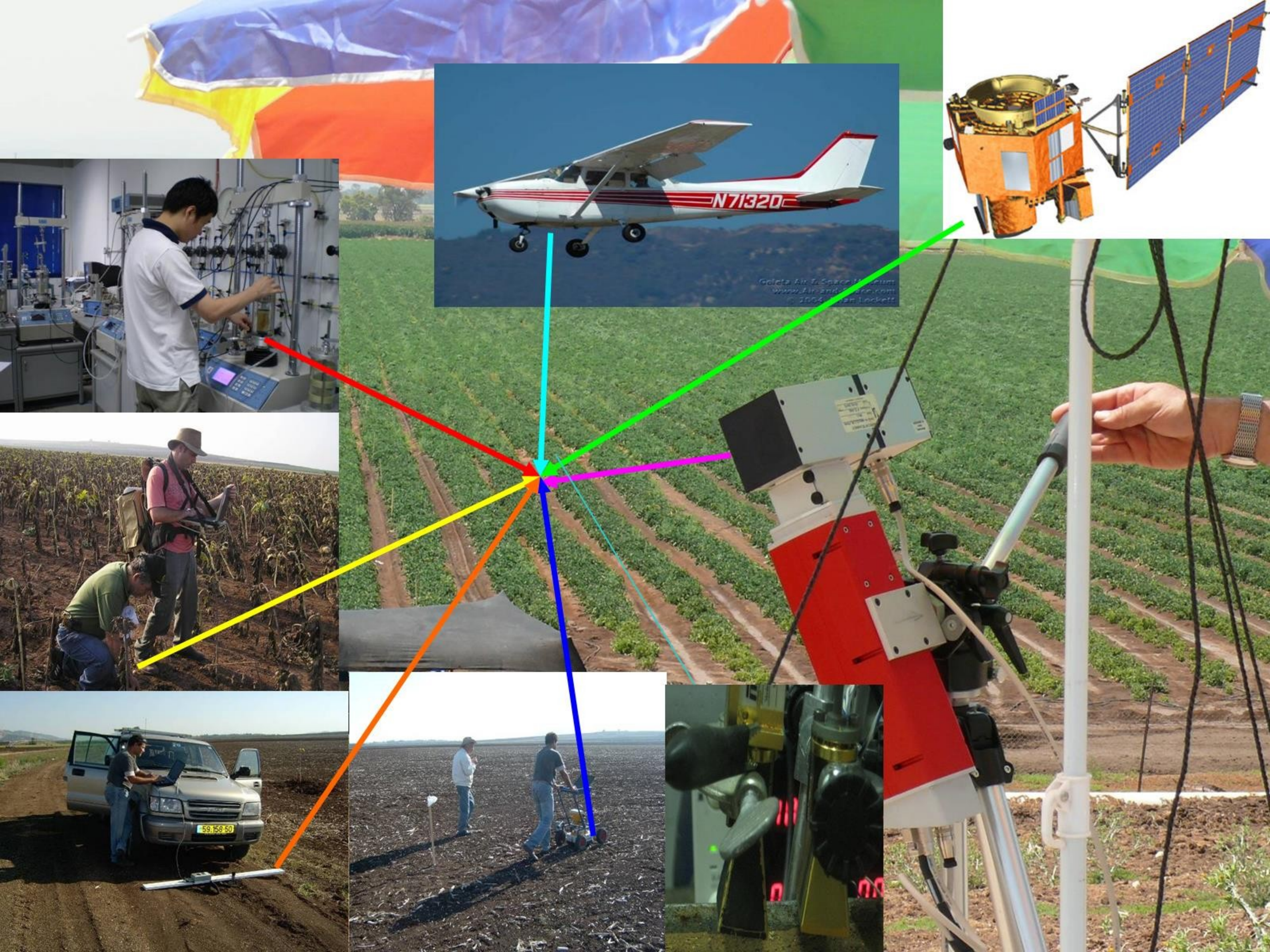
Aim

- To demonstrate the use of the combination between active and passive remote sensing methods for subsurface soil monitoring.



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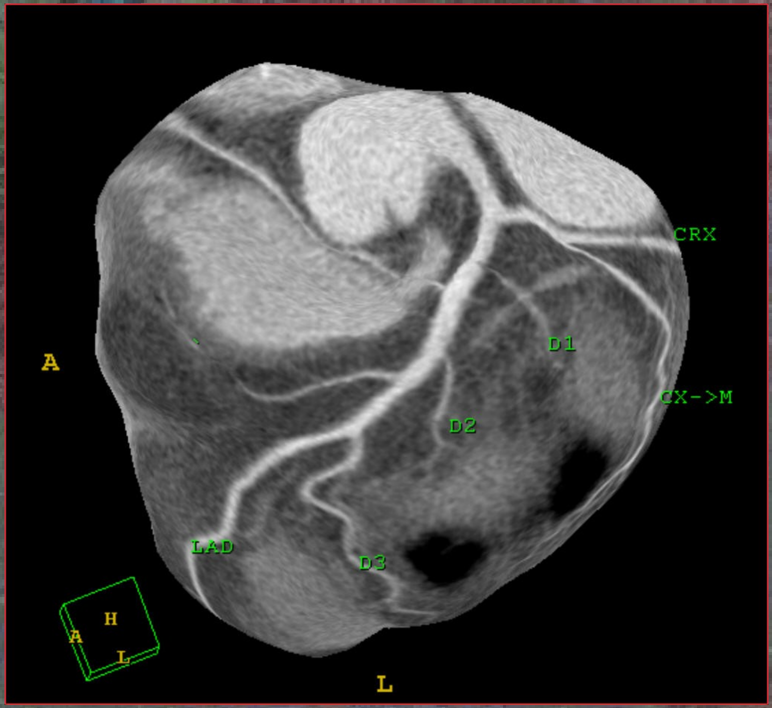
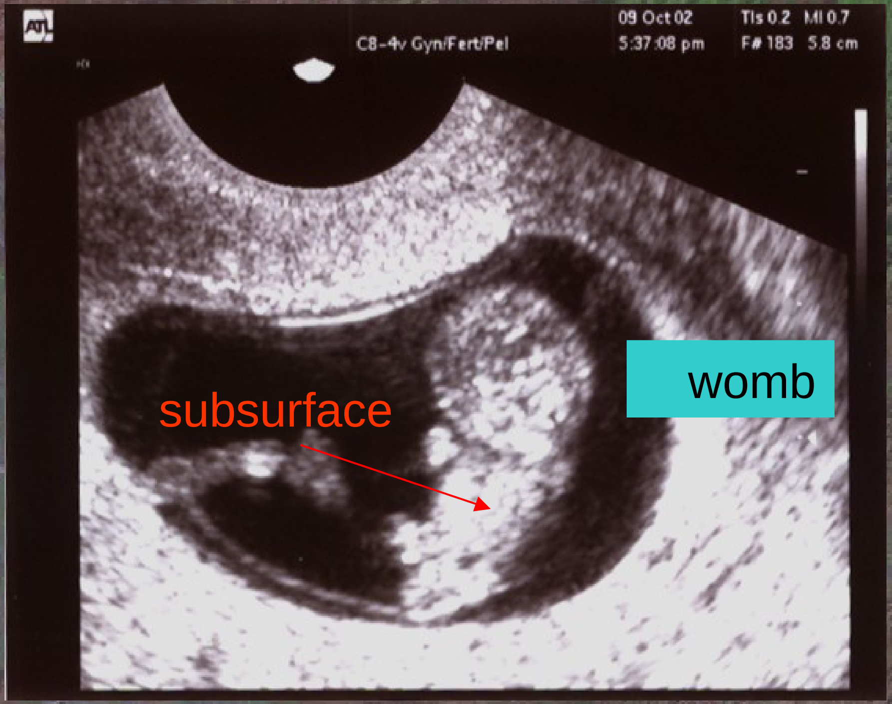
Medicine and soil science a lot of similarities between the methods

Medicine

- Ultra sound and CT is an imaging tests for imaging the Inside body :limbs their size , structure

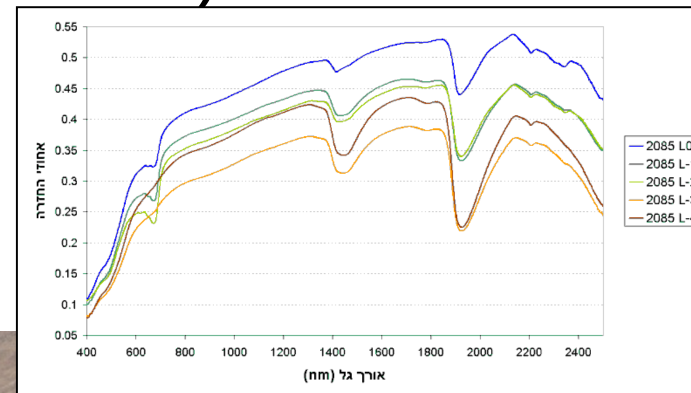


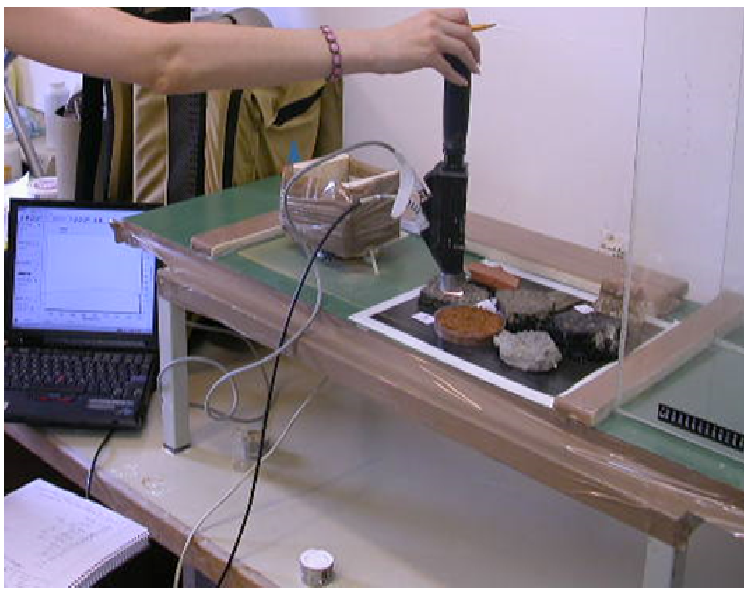


Catheterization

Methods

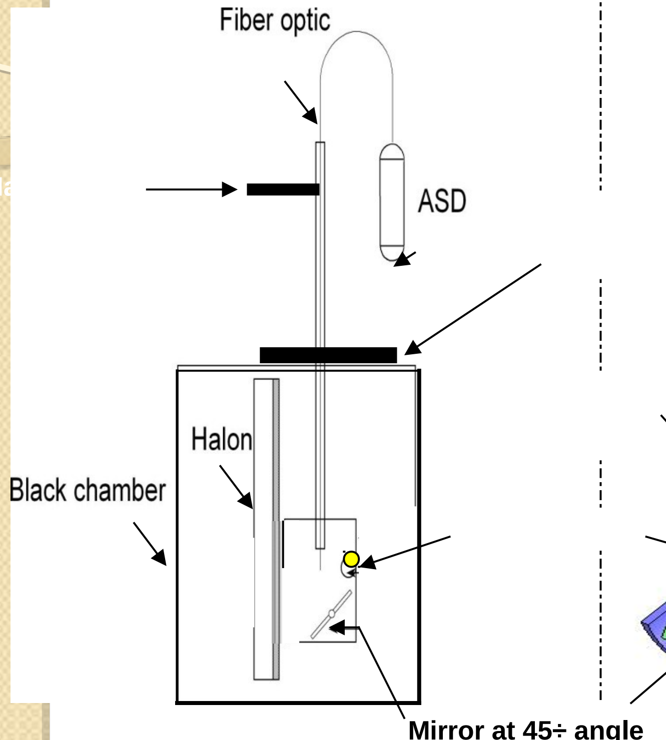
An Analytical Spectral Device field spectrometer was used, which covers the VIS-NIR-SWIR regions (350–2500nm).



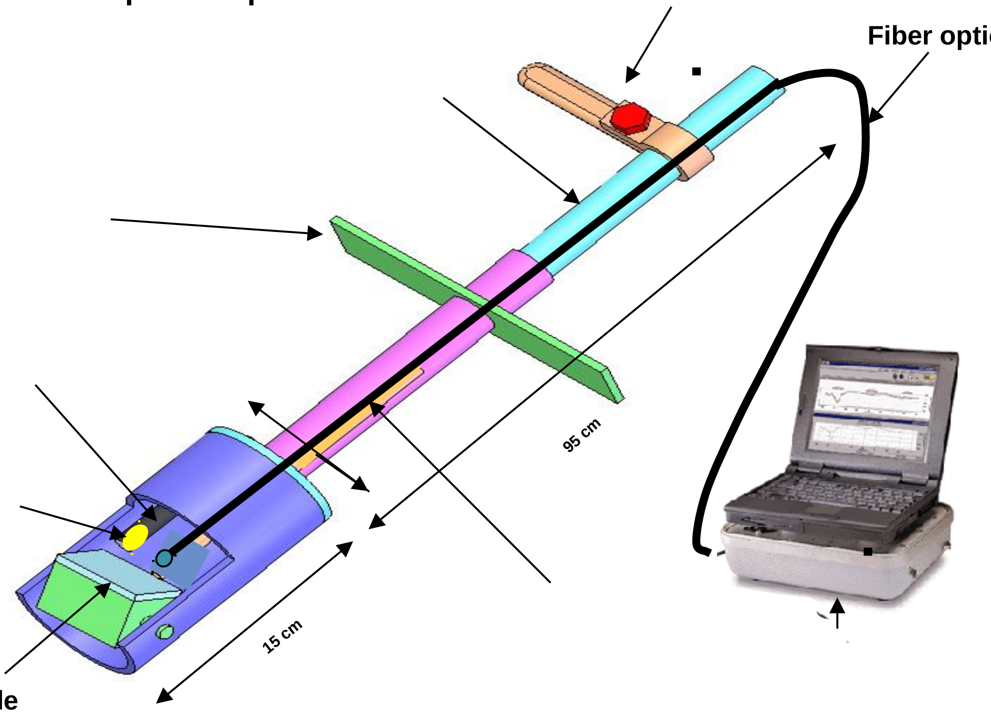


Hyperspectral definition: receiving continuous spectrum from a given cell area .

The 3S-HED assembly: Parts and operation



In addition we used "In-Depth" optical fiber



POS Penetrating Optical Sensor

AISA-ES ***in Israel***

Spectral Bands between 401-2372nm (FWHM 3.3-6.84nm)

FOV 9^{o}, IFOV 0.525 mRad

I d

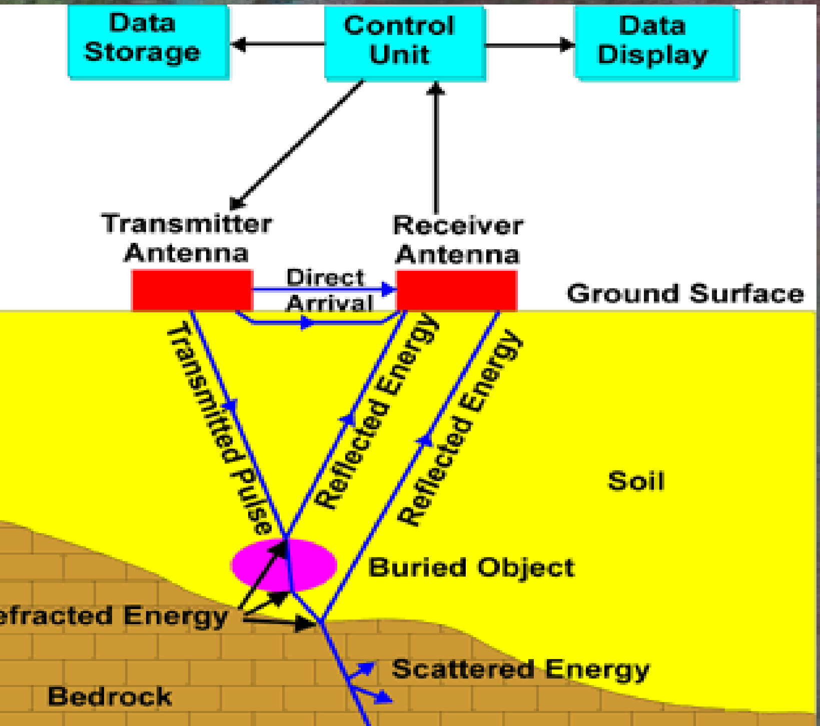
Aisa

- AISA hyperspectral systems are complete, push-broom imaging systems, consisting of a hyperspectral sensor head, The AISA family includes the following models

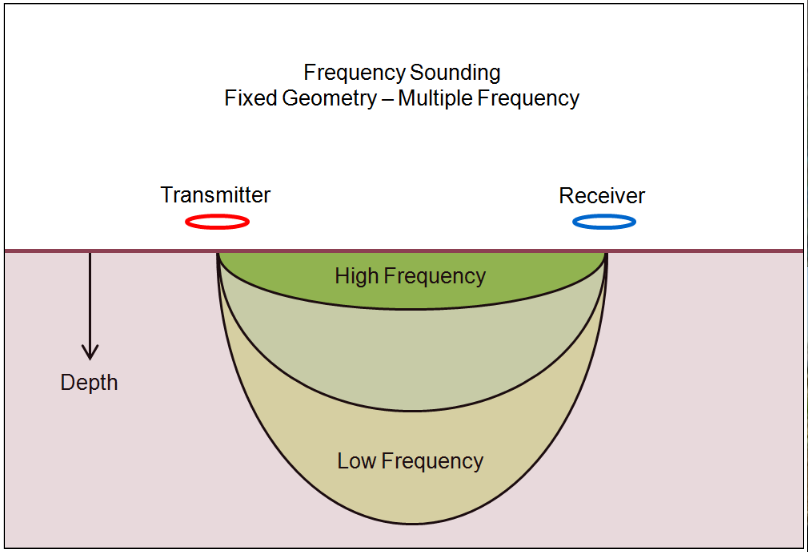
GPR

GPR (Ground Penetration Radar) Transmits radar pulses into the ground; and receives wave signals reflected off of the interfaces below.

- The calibration and spatial repair of the data, provide a visual cross section of the soil layers at different depths.



FDEM (Frequency Domain Electromagnetic)



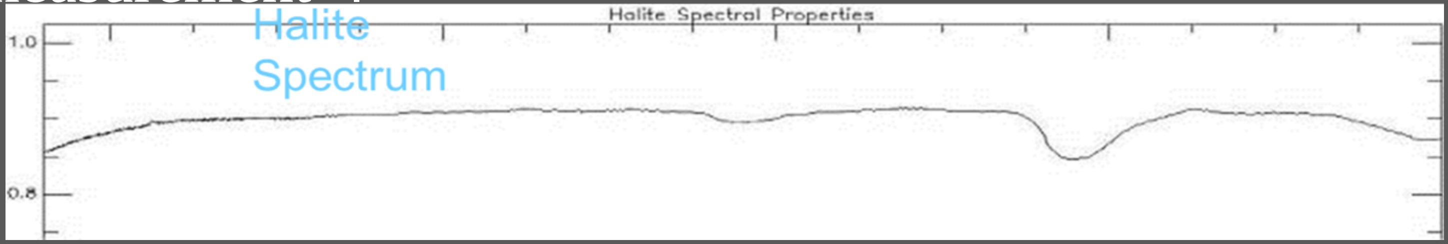
- A geophysical method and tool for measuring electrical conductivity (EC) and magnetic susceptibility of subsurface rocks, soils and minerals. EC is mainly a function of the soil and rock matrix, percent saturation, and conductivity of pore fluids. (500Hz-

Statistic

- In order to determine the salinity content
- we use complex statistical methods based on multivariate regression type:

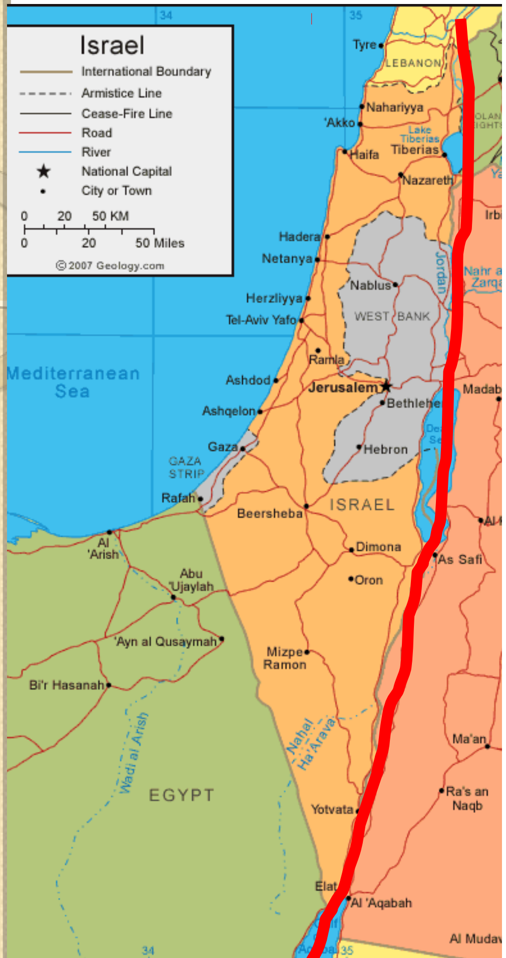
$$Y = A + A_1 X_1 + A_2 X_2 + A_3 X_3 \ldots + A_n X_n$$

- When Y is a chemical measurement (Na and Cl), A-coefficient   for return specific spectral wavelength and X spectral data. Here, we are looking at the relationship between the measured reflectance(Depended) and Chemical measurements(In depended). The final product is a development model that's predict salinity from the spectral measurement .



Remote Sensing Methods Summary

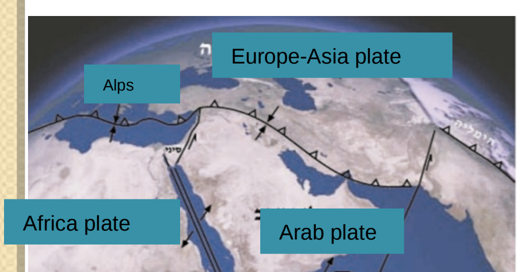
Method	Task for which used	Frequencies / EM Spectral Region	Depth of Penetration
Frequency Domain Electromagnetic (FDEM)	Spatial imaging and measuring of Electrical Conductivity (EC) and Magnetic Susceptibility (MS)	300 Hz - 70 kHz, multi-frequency operation	0 - 30 m (best in conductive areas, soils-rocks-fluids depending)
Ground Penetration Radar (GPR)	Spatial subsurface reflection imaging of soil-rock interface, layers, moisture content, leaks, voids and sink hole	50 MHz - 2.4 GHz	0 - 30 m (best in resistive areas, soils-rocks-fluids depending)
Analytical Spectral Devise (ASD)	Quantities soil and subsoil qualities and contamination \ compositions	350 - 2500 nm	Surface
Penetrating Optical Sensor (POS)	Quantities soil and subsoil qualities and contamination \ compositions	350 - 2500nm	1.5 m (operate inside narrow boreholes, can be extended upon request)
Aisa (Airborne) sensor	Soil and vegetation quantities and qualities and contamination	350 - 2500nm	0.5 m from 2 KM High



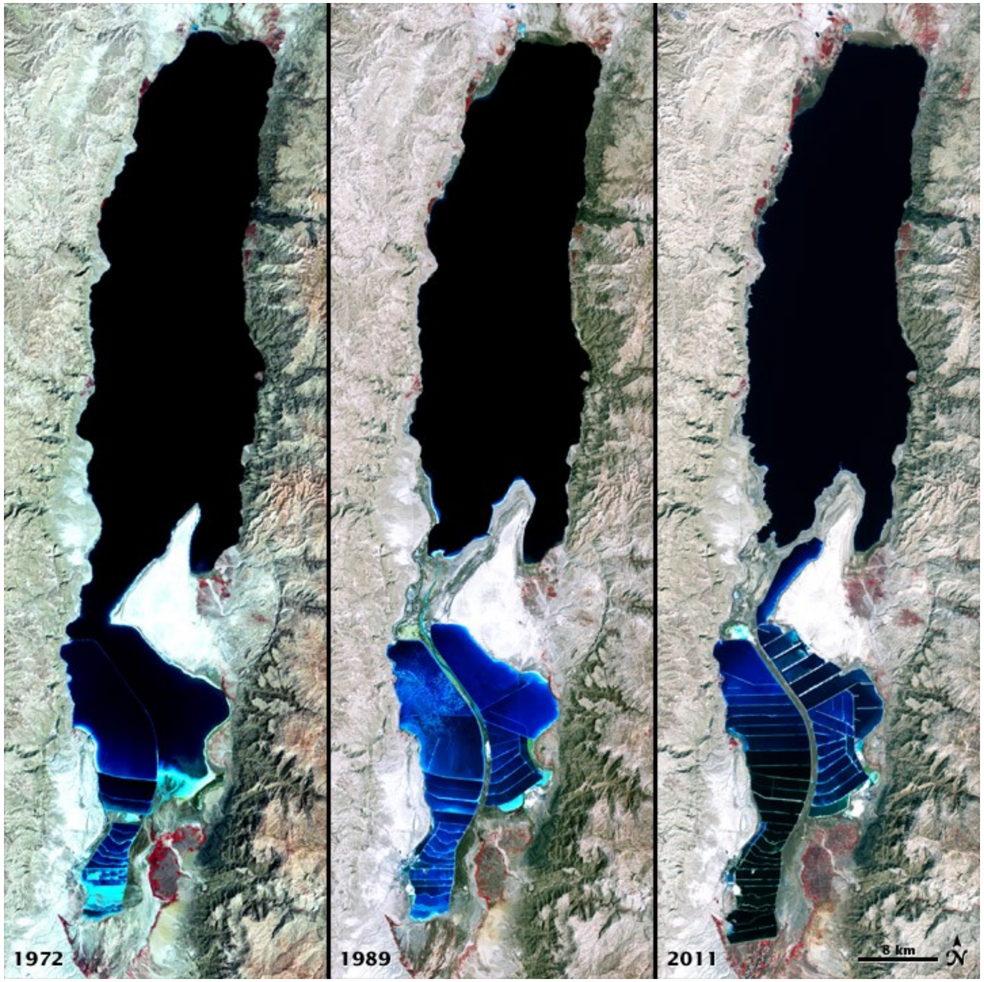
Mapping and predicting sinkholes appearance by integration of active remote sensing and spectroscopy methods

The Dead Sea is located in the rift known as “Dead sea transform” connected to the "African Rift".

- A sinkhole is a topographic depression that occurs due to sudden or gradual collapse of underground rock layers.
- The formation of sinkholes is connected to the Dead sea area in Israel. In recent years, over 3500 sinkholes have been created from the collapse of the upper soil layers. Large sinkholes that are visible on the surface can reach a diameter of 50 m and a depth of 20 m.



The increase in sinkhole activity resulting from the continuous decrease in the Dead Sea's level(40m). During the 20th century, human intervention included: water pumping of Dead Sea water into evaporation ponds damming of rivers



Policy Document
Dead Sea Basin,
In 2006

NASA's Earth Observatory -
The Dead Sea 1972-2011

$1015 km^2$ -1930
$605 km^2$ -2012

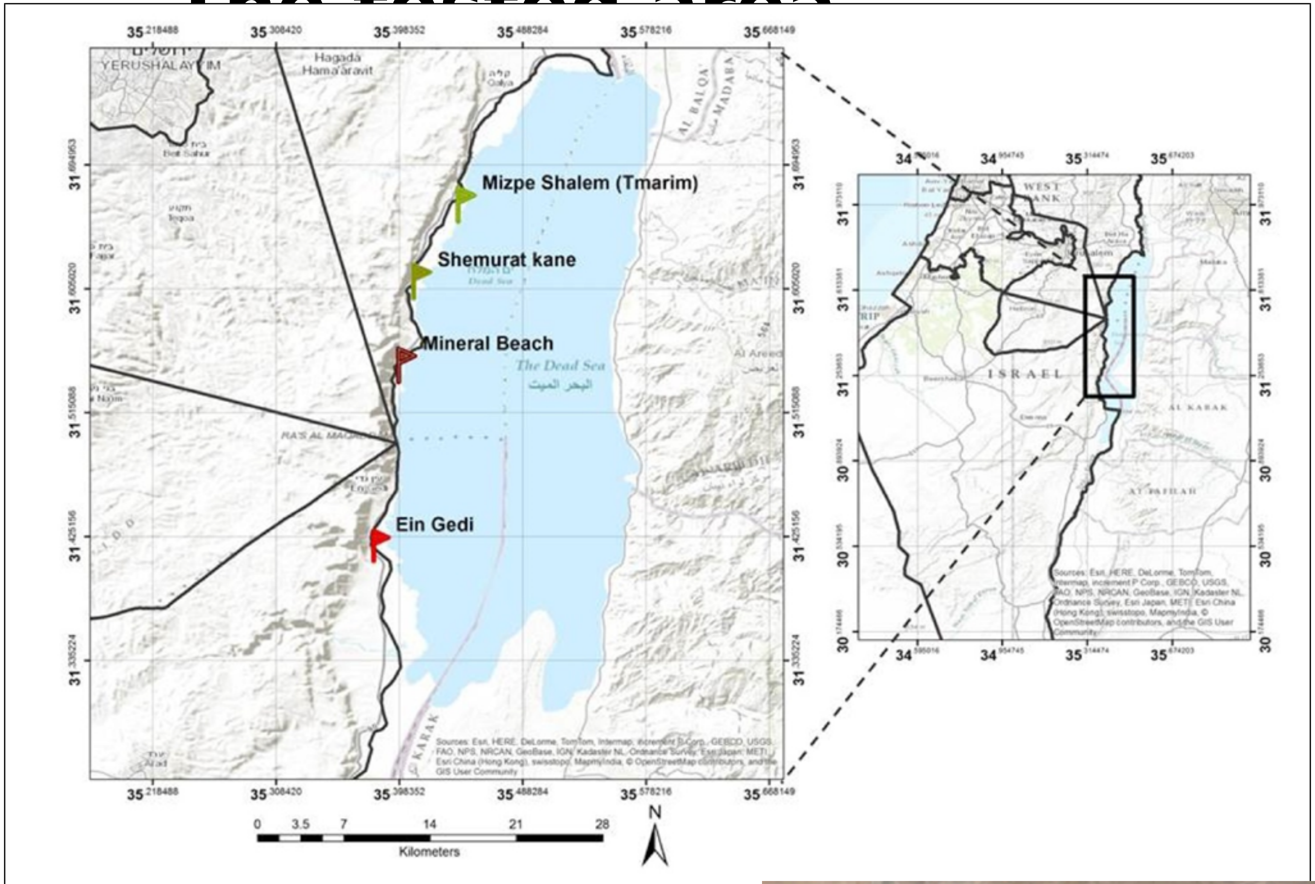
Projected area

The Sinkhole phenomenon

The formation of sinkholes is the results of creating spaces of underground dissolved salt layers by an unsaturated water penetration from the mountain to the shore direction.

- The phenomenon changes the shape of the coast, soil, water and vegetation in these areas and caused Infrastructure destruction.

The tested area



Ein Gedi Springs

GPR

- A RAMAC GPR was used. We chose to work at a frequency of 100 MHz which enables penetration to a depth of approximately 10-15 m at a resolution of about 0.25 m. Such depths allow initial detection of the sinkholes below the surface. A series of cross sections were taken to obtain a radar reflection sample of 0.25 m along the incision.

FDEM (Frequency Domain Electromagnetic)

- A geophysical method and tool for measuring electrical conductivity (EC) and magnetic susceptibility of subsurface rocks, soils and minerals. EC is mainly a function of the soil and rock matrix, percent saturation, and conductivity of pore fluids.

EC analysis

- In the "Ein Gedi South" plot, sinkholes were observed on the surface. In "Ein Gedi North", no sinkholes were observed on the surface. Five different frequencies from 625 to 60,025 Hz, at depths of between 0 and 15 m. In "Ein Gedi South" the red-purple color expresses high EC values of about 4,000 mS/m. The blue-green color expresses relatively low EC values of about 2000 mS/m. The purple strip in the northeast represents an area close to a sinkhole developing on the surface.
- When comparing the two monitoring dates, the western region was stable the western region was widen between the two time points.

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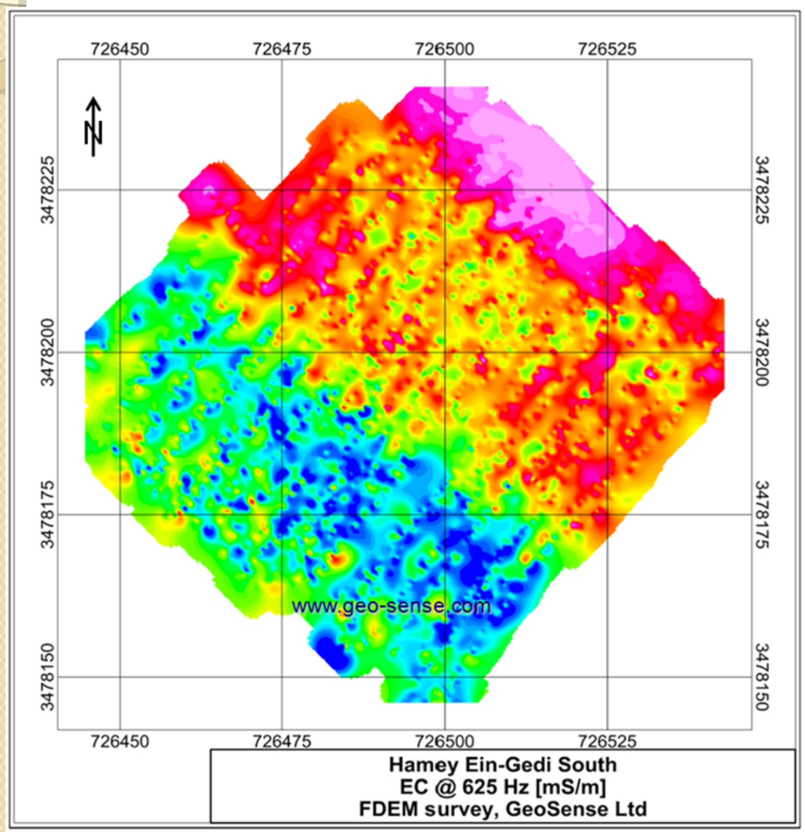

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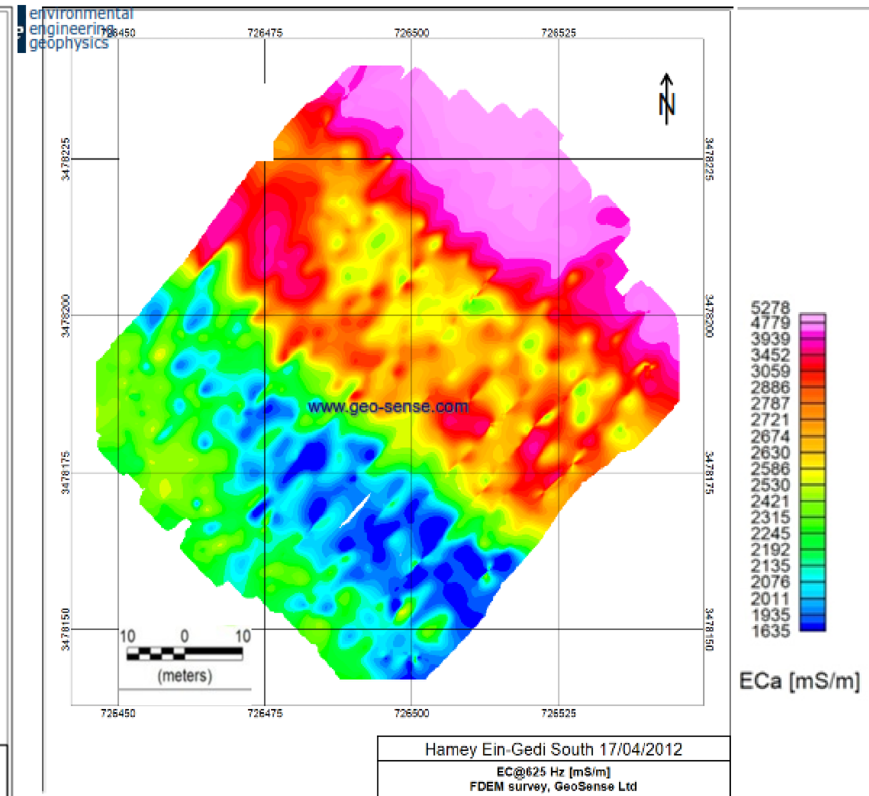
www.geo-sense.com
Hamey Ein-Gedi South
EC @ 625 Hz [mS/m]
FDEM survey, GeoSense Ltd



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www.geo-sense.com
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2245
2192
2135
2076
2011
1935
1635
ECa [mS/m]
Hamey Ein-Gedi South 17/04/2012
EC@625 Hz [mS/m]
FDEM survey, GeoSense Ltd

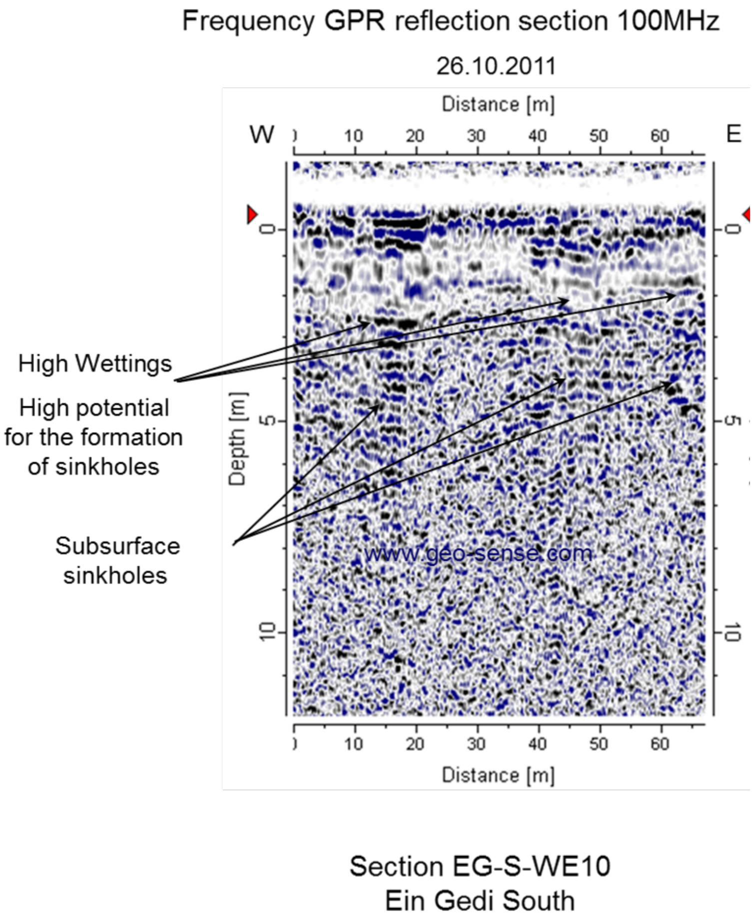
results :GPR

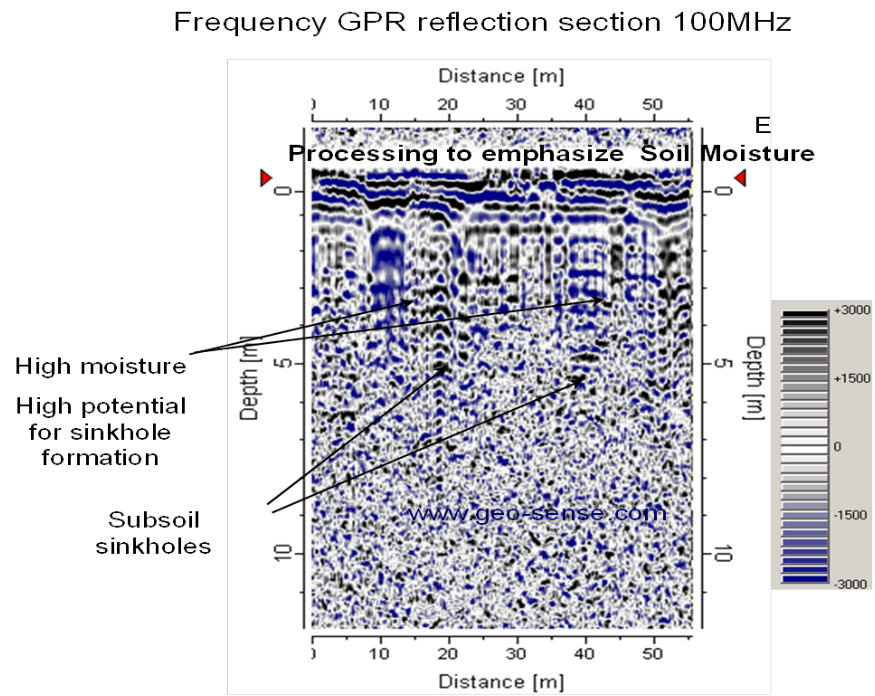
- Cross-section reflectance was monitored by GPR at a nominal frequency of 100 MHz. Two different analyses are presented for each section: the first was performed to highlight the presence of sinkholes in cross section relative to an area without sinkholes. The second highlights the areas of relatively high moisture near the sinkholes and near the surface.

GPR

- The cross section taken in April 2012 in the same location in “Ein Gedi South” was compared to the 2011 analyses, the latter reflecting the development of sinkholes in the area. In the western part, a new sinkhole is located right at the beginning of the section, while in the east, one can see the development of an existing sinkhole or the start of a new one.

GPR



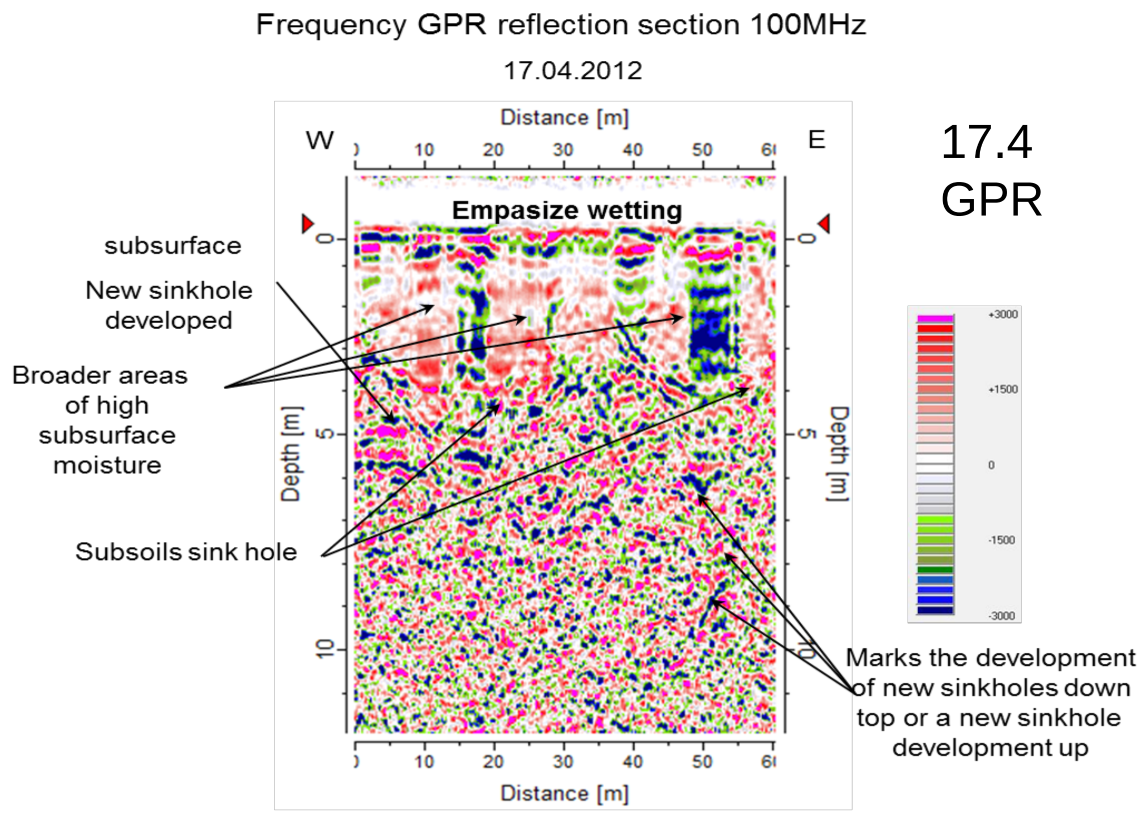


Section **EG-S-WE10**

Ein Gedi South

Figure 13

GPR



Section EG-S-WE10
Ein Gedi South

17.4
GPR

Identification of sewage leaks by remote-sensing methods

The research aim

- Our aim was to develop practical tools that would provide a snapshot of changes in spatial soil moisture content to depths of about 3–4 m in areas covered with asphalt at relatively low cost and in real time.

Back Ground

- The spatial measurements were made with FDEM and Radar systems (GPR) that allow measuring tens of thousands of points per hectare and thus enable monitoring the spatial situation along the pipeline.
- Implementation of the acoustic (the most used method) is possible only on the metallic lines which pumped water under pressure and therefore the method is not applicable to sewage and drainage lines.
- In order to "hear" and locate leakage position requires a minimum quantity of 600 liters per hour at a minimum and thus can disappear leaking water amounts of tens of thousands, of cubic meters per year.

Research area

"Control"
"Leaking"

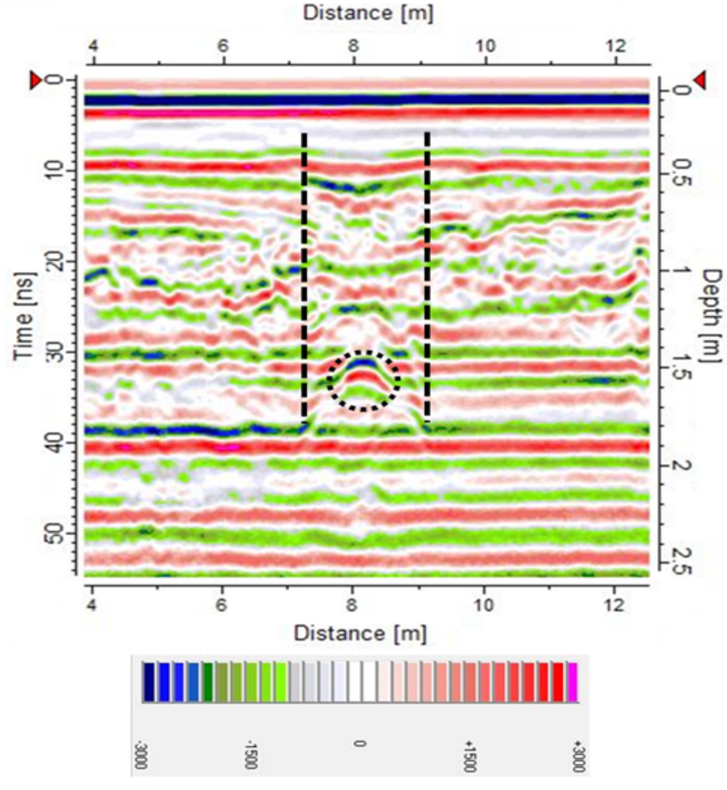
GPR

FDEM

FDEM

- **checks were made at different frequencies. The measurements were done in six frequencies:** 2,025 Hz, 4,725 Hz, 11,025 Hz, 25,725 Hz, 60,025 Hz**.**
- **The figure shows The use of 15,525Hz frequency magnetic susceptibility in order to show the location where the water pipe was used .**
-

Calibration



The black circle displays diffraction created by the drain pipe. Above it, the trench is detected as well. The horizontal scale describes the measurement location (in meters) along the profile. The vertical scales describe the time (in nanoseconds) and depth (in meters). The amplitude-intensity scale is shown as well.

GPR

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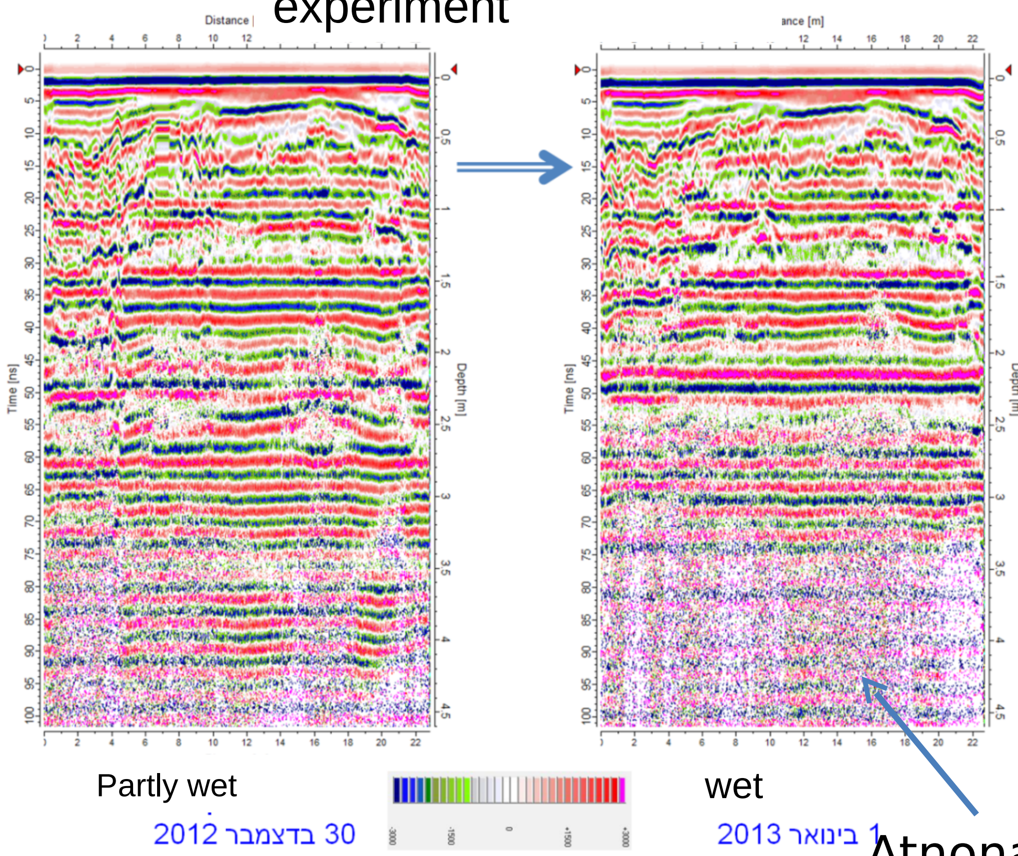
Moisture content experiment



The left figure was made before the start of the leak and the other after a leak of 3.59 cubic meters occurred during the 46 hours .

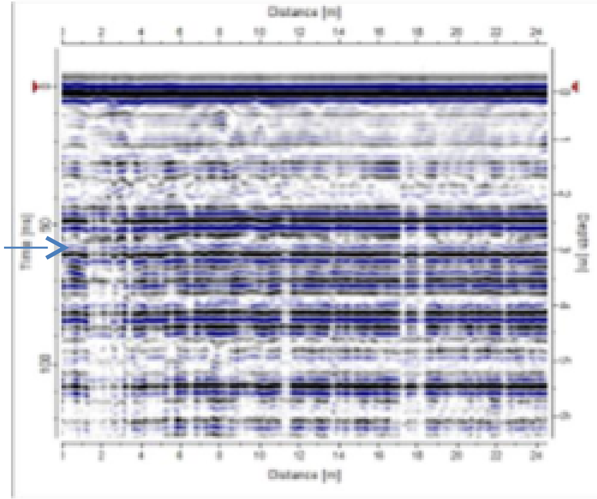
The differences - the first major difference is the addition of reflector depth of 2.1 m as a result of a puddle of water that had accumulated under the pipe and strong absorption under the reflector

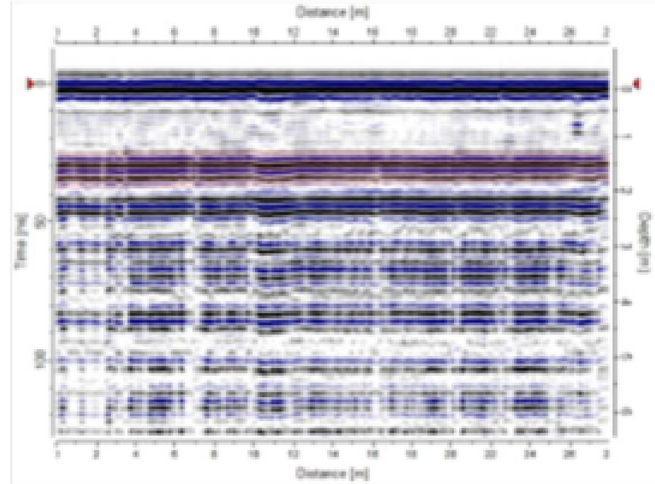
GPR

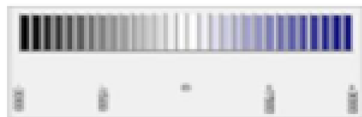
Dry section

Wet section

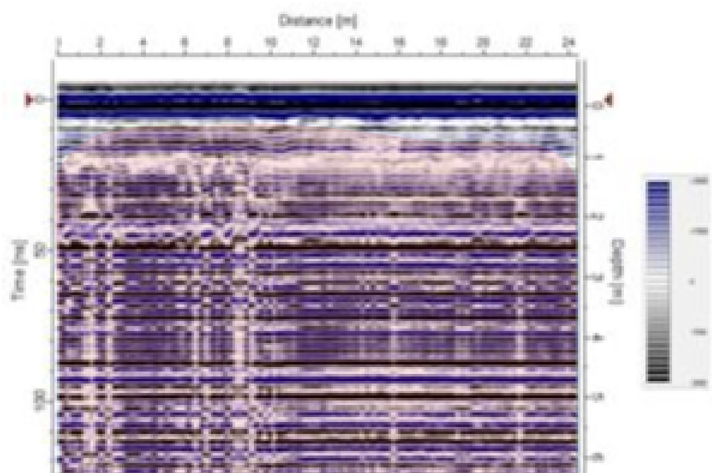
m 3







Max. Wet section



Course of the experiment

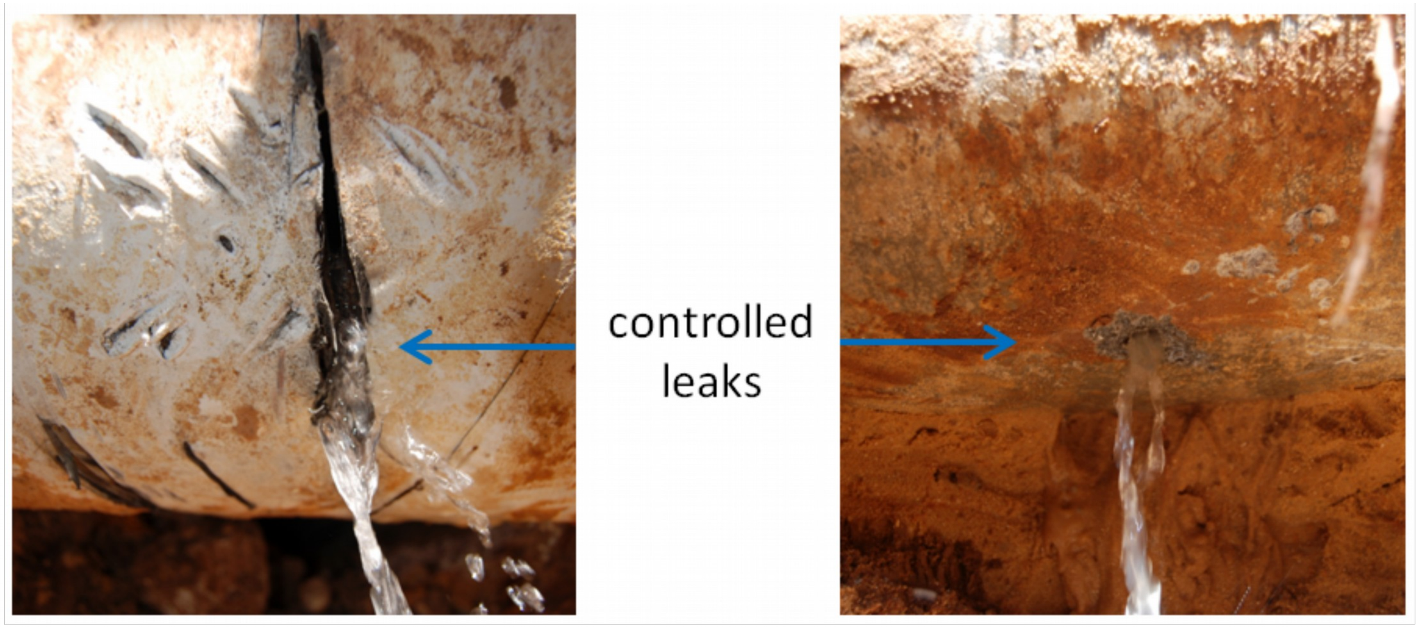
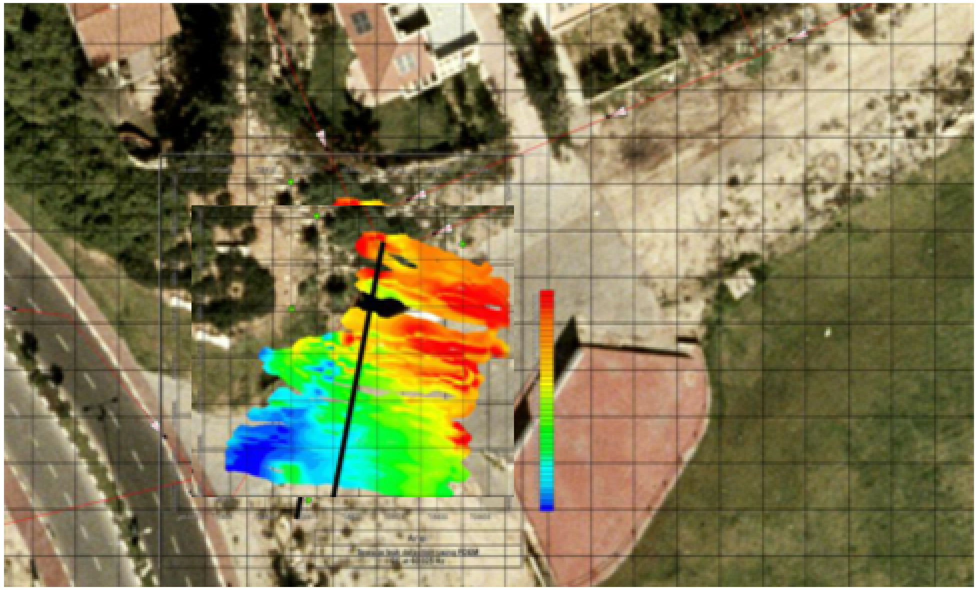
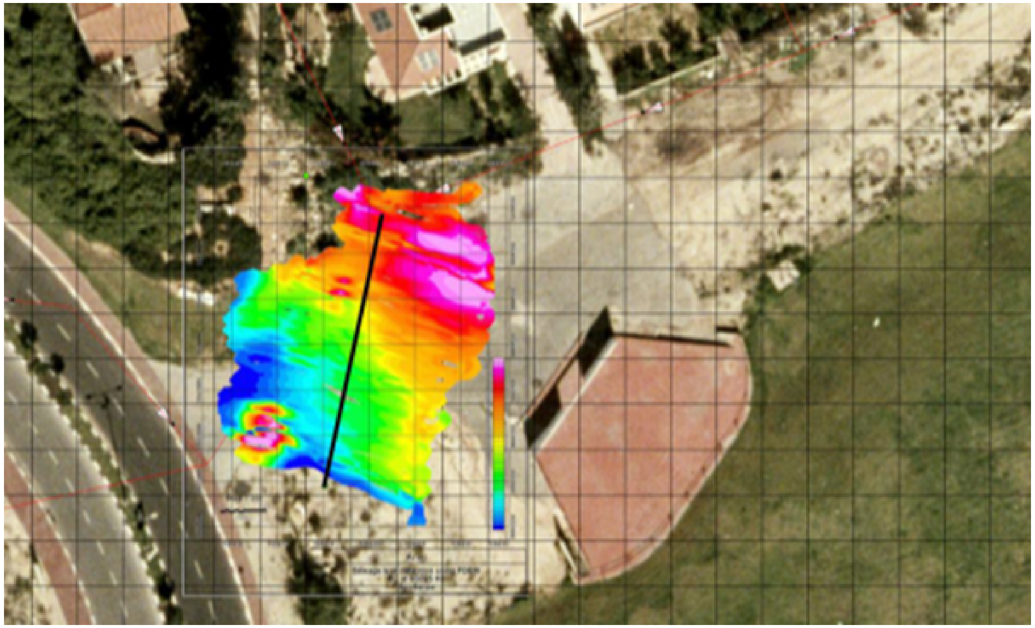


Figure 9: Pictures of the two cracks made in the sewer pipes for the controlled leakage experiment.

FDEM - DRY



Map of the integrated electrical conductivity at 60,025 Hz before the start of the controlled leak at the western site. The location of the sewer pipe is marked by a black line.



- Map of the electrical conductivity at 60,025 Hz after about 4 days of leakage. Measurements were collected during the sewage leak. The highest conductivity values were about 95 mS/m. The significant increase in electrical conductivity is a result of the sewer liquids that were spilled during the 4 days of the controlled leak, in both the southwestern and northeastern sides of the area, probably due to a subsurface .topography gradient

GPR

- The first cross section was obtained before the leak started and reflects the typical dry state of the. An incision was made a few days after initiation of the leak and shows a relatively wet subsoil. The right cross section shows an incision made at a lower depth, 10 days after leak initiation, indicating a further increase in wetness. Similar data processing was carried out for the three cross sections to highlight their differences.

Soil salinity as an environmental problem

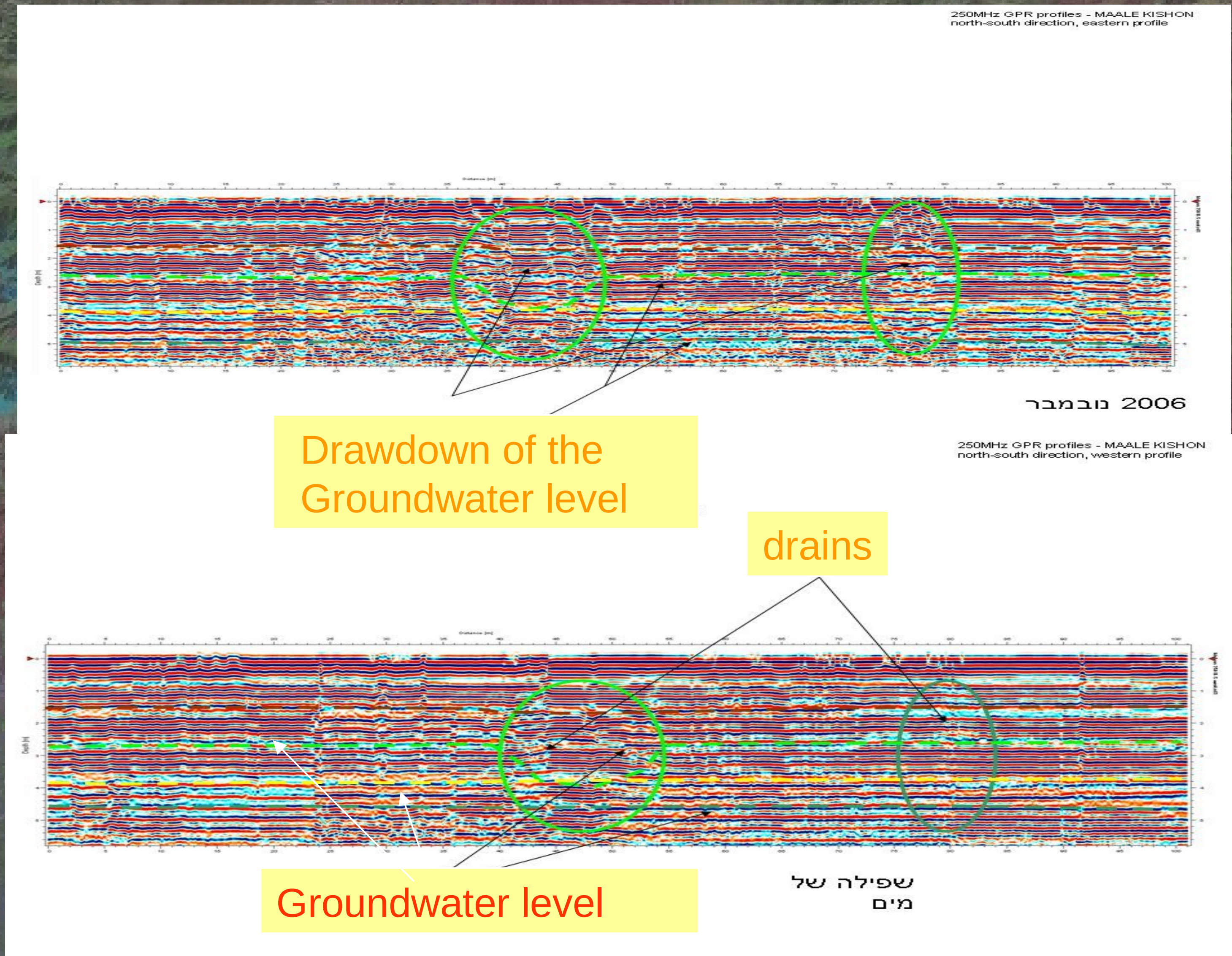
Soil salinity is common soil degradation processes, found in agricultural areas in arid and semi-arid regions.

Soil salinization is a process in which dissolved salts concentrate on the soil surface and in the upper soil layers.

Salt contamination monitoring methods represented in this lecture will be used as an example for monitoring other contamination like

PO_4, CaCl, $CaCo_3$, SO_4

The use of GPR



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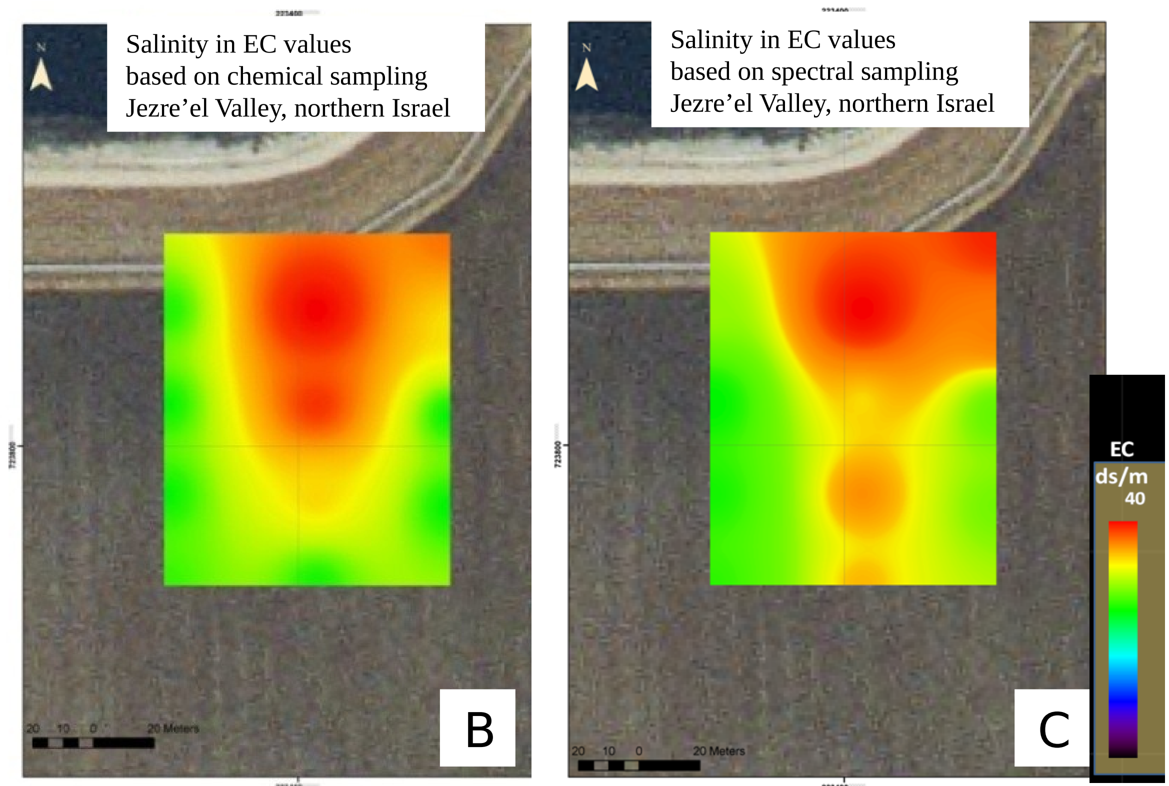
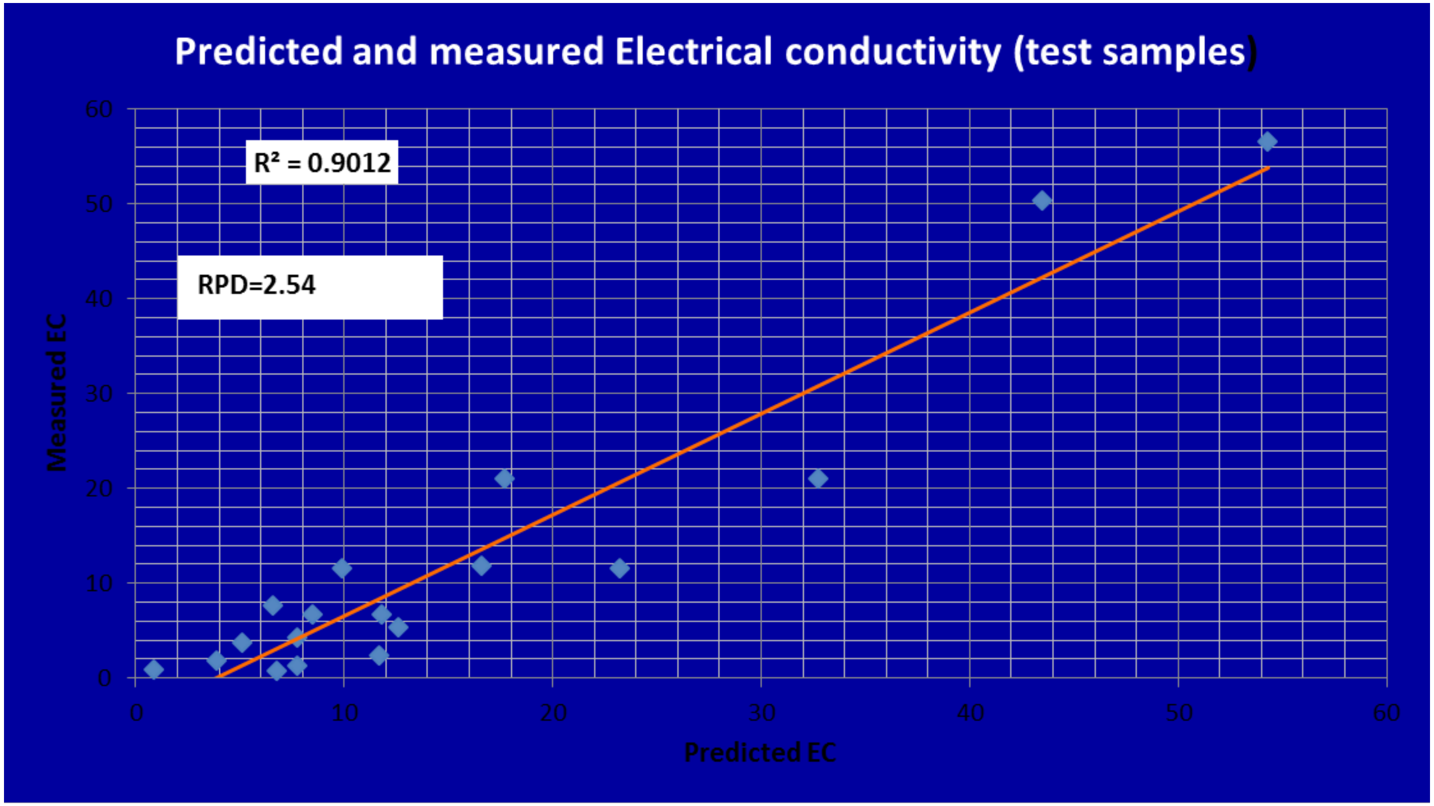


Mizra Field

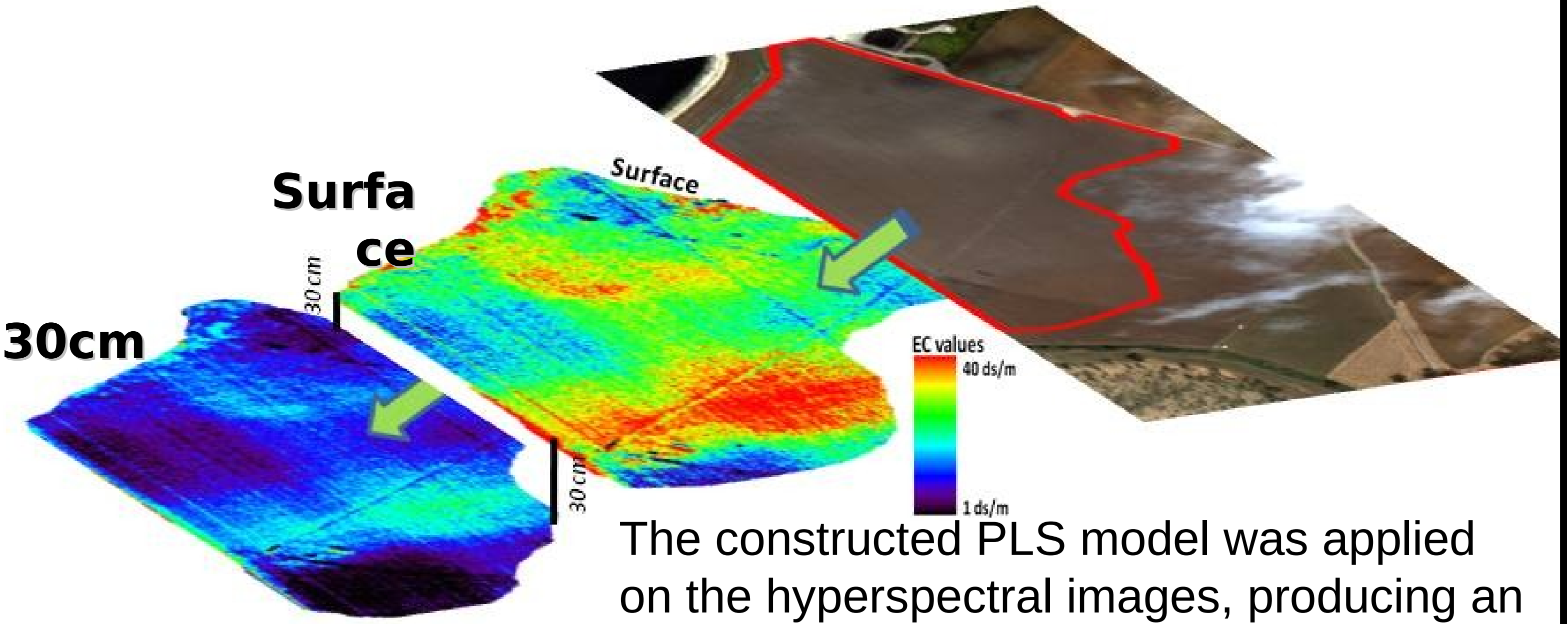


Wavelength (nm)	Factor (for continuum removed spectrum)
b0	*634.109192*
540.74	166.6197357
1503.06	-918.8959961
1989.99	-1519.586548
2036.36	2564.280273
2175.48	-919.4611206
2187.08	-951.8460693
2221.86	874.7788696

(EC) measurements were correlated to soil reflectance spectra using Partial Least Squares Regression (PLS).

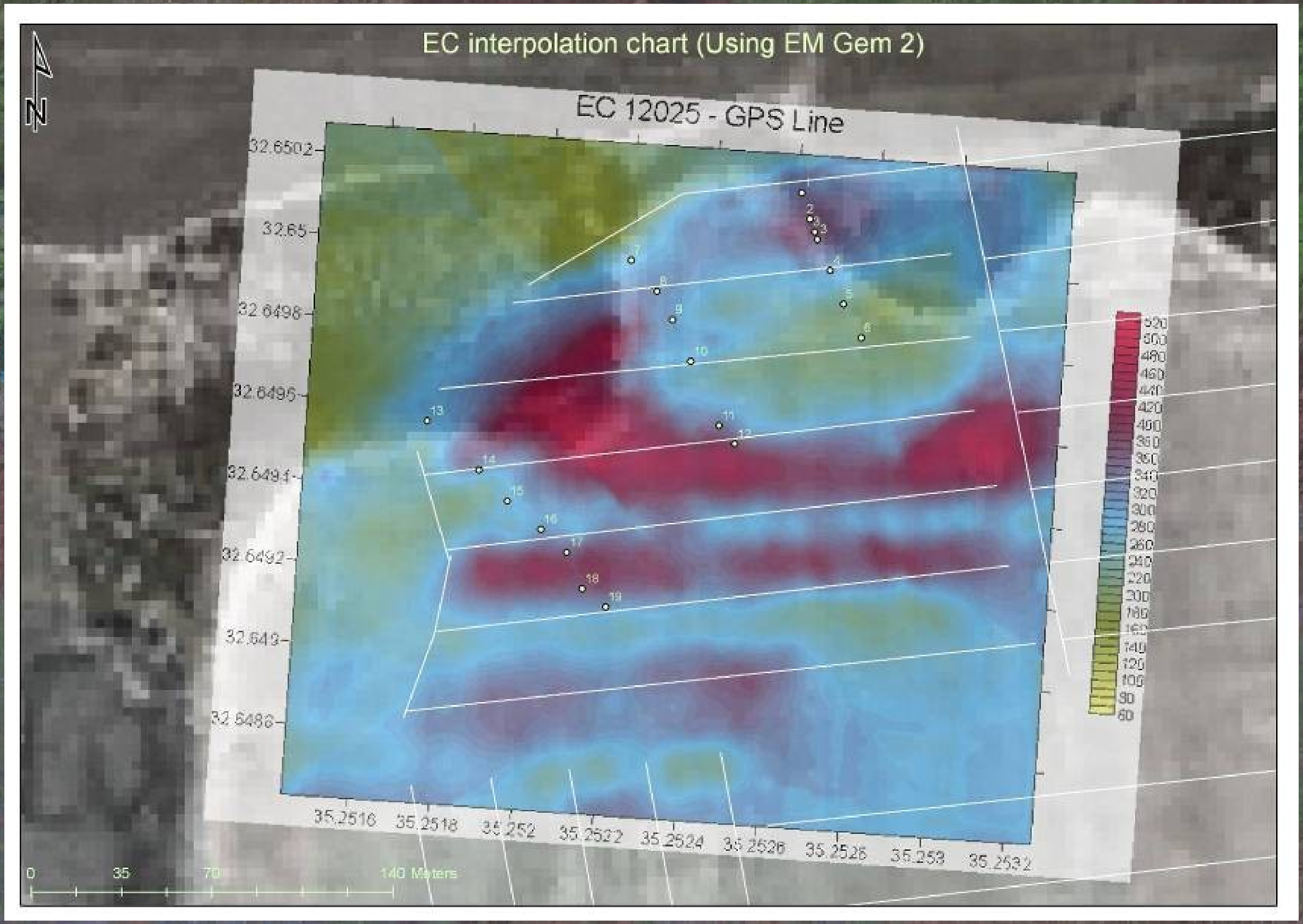
- Multivariate calibration models were calculated by the Partial Least Square (PLS) regression [14]. The PLS regression was based on latent variable decomposition of two blocks of variables matrices: X matrix based on ASD spectral data and Y matrix based on measured EC data (Israel: *n=101*, Uzbekistan: *n=72*).

Soil Salinity Mapping of the surface and at 30cm depth



The constructed PLS model was applied on the hyperspectral images, producing an EC thematic map of the surface. In addition, a sub-surface salinity map was generated by applying the surface – sub-surface correlation on the surface EC thematic map.

FDEM


EC interpolation chart (Using EM Gem 2)
EC 12025 - GPS Line
N
0 35 70 140 Meters

General Summary

- The goal of this lecture is to represent developing methods and approaches to precisely and cost-effectively assess subsurface information like salinity and water\moisture content in agriculture, leaking water and intentify embryotic sinkholes.
- These was done by combining passive and active remote sensing methods and by combine innovative ground-based remote sensing methods with satellite and airborne based remote sensing techniques.
- The combination of active remote sensing methods includes like GPR and FDEM systems with passive remote sensing methods like POS.
- These make it possible to evaluate moisture and salinity content. and then upscale the results to identify the basic subsurface structure and detect changes in the subsurface larger areas.

General Summary

- Designers and engineers might implement the combined methods used in these methods to plan and build better infrastructures on the ground and in the subsurface.
- This new direction will establish for small and large areas which concurrent use of various remote sensing methods complement each other and can ultimately replace conventional methods in the study agricultural crop and soil qualities and Infrastructure.