Monitoring changes along receding lake environments

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Background

- Receding lakes
  - Climate
  - Anthropogenic changes
- Landscape reshaping
  - Environmental change
  - Infrastructure damages
- Span
  - Quantification of these phenomenon is complex

Dead Sea coastal plains as an example

The Dead Sea

- Terminal lake
- Drains extensive regions in the surrounding countries

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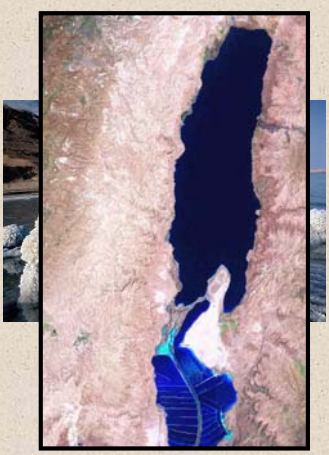
The Dead Sea

- Terminal lake
- Drains extensive regions in the surrounding countries
- Lowest point on earth -424 m
- High salinity level
  - Unique tourist attraction



The Dead Sea

- Past 40 years lake level have been dropping by 30 m from its high stand
- Increased rate in the last decade – > 1 m/y
- Alternation of the region environment

Receding Dead Sea Lake

- Coastal plain widening

Channel incision

- Rapid incision due to exposure of steep slopes

Channel incision

- Rapid incision – 20 yrs

Channel incision

- Infrastructure damage

Dead Sea - sinkholes

Dead Sea - sinkholes

- Halt to agricultural development

Monitoring

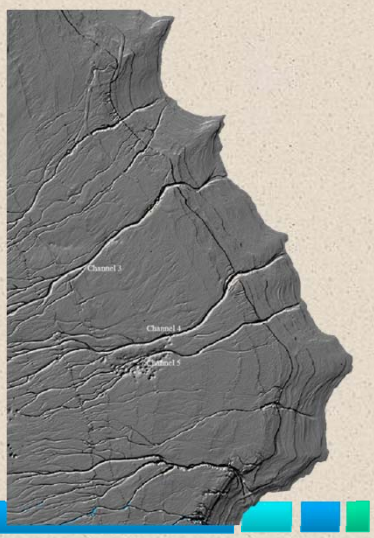
- Difficulty in tracing at early stages
- Identifying subtle features

Monitoring

- Land surveying
  - Large span
  - Difficulty to trace
- Aerial images
  - Scale and resolution
  - Misinterpretation
  - Largely planimetric

Detection of geomorphological changes via airborne laser scans

- Wide coverage
- Dense 3D data
- High level of accuracy.



Detection of geomorphological changes

- Efficient monitoring means
  - Global scale analysis
    - General assessement of the total change
    - General measures – volume, area, etc.
  - Detailed scale analysis
    - Monitoring the reshaping process
- Understanding underlying mechanisms

Global scale analysis
Difference Map

- DEM subtraction for global for general assessement of the total change

$$Diff(i,j) = DEM_{epoch1}(i,j) - DEM_{epoch2}(i,j)$$

  - Detection limit: $m_{diff} = \sqrt{2}\, m_z$
    - m_z - accuracy estimate of the laser scanning data.

Global scale analysis
Difference Map

- DEM subtraction for global for general assessement of the total change

$$Diff(i, j) = DEM_{epoch1}(i, j) - DEM_{epoch2}(i, j)$$

  - Advantage
    - Efficient and simple computation.
  - Disadvantage
    - Partial description of the evolving phenomena.
    - Difficulty describing non-vertical changes.
    - Difficulty detecting detailed changes.

Detailed analysis

- Focusing on the area of interest
- Detecting the phenomenon in the dataset
- Phenomenon description (geometrical)
- Change quantification

Characterization of geomorphic features

- Focusing on the area of interest - detecting the phenomenon and characterizing it
- principal curvature analysis

$$\mathbf{H} = \begin{pmatrix} \frac{\partial^2 Z}{\partial x^2} & \frac{\partial^2 Z}{\partial x \partial y} \\ \frac{\partial^2 Z}{\partial x \partial y} & \frac{\partial^2 Z}{\partial y^2} \end{pmatrix}$$

- Eigenvalue analysis for feature detection

Multi-scale feature detection

- Variety of feature forms and sizes in the dataset
- Common fixed-kernel fixed-threshold detection practices may lead to loss of information
- Multi-scale analysis – searching for a "significant" response

Thalweg detection

- Eigenvalues accuracy

$$m_{\lambda_{\max,\min}} = \pm\frac{\sqrt{6}}{d^2} m_Z$$

- hypothesis test for point characterization

$$\lambda_{\max} > z_{1-\alpha} \cdot m_\lambda + \frac{2\Delta Z}{d^2} \quad \text{and} \quad |\lambda_{\min}| \le z_{1-\frac{\alpha}{2}} \cdot m_\lambda \qquad \text{(for gullies)}$$

  - z - normalized Gaussian distribution.

Gully banks detection

- Using steep ascent along the profile crossing the channels up to the fan surface level

$$|DEM_{i+1} - DEM_i| < k$$

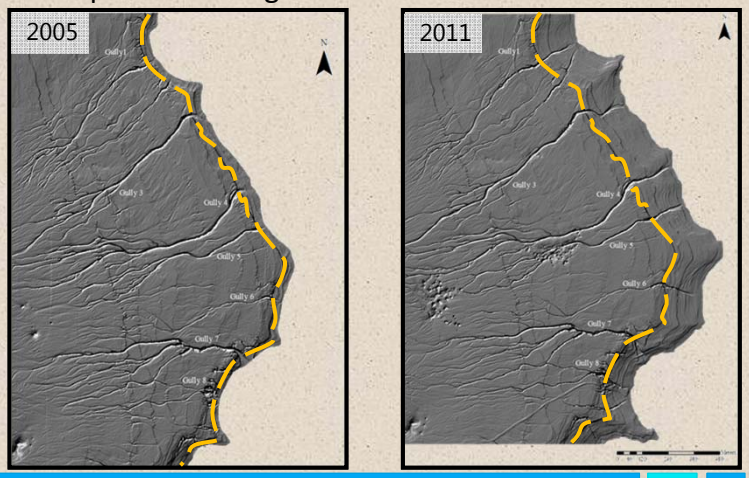
  - k - threshold
  - i – thalweg point
  - $i+1$ – perpendicular point to thalweg direction

Results

- Two airborne laser-scanning campaigns have been carried out along the Dead Sea coastal plains
  - first conducted in Nov., 2005.
  - second in Oct., 2011.
- Analyzing the total change and local processes

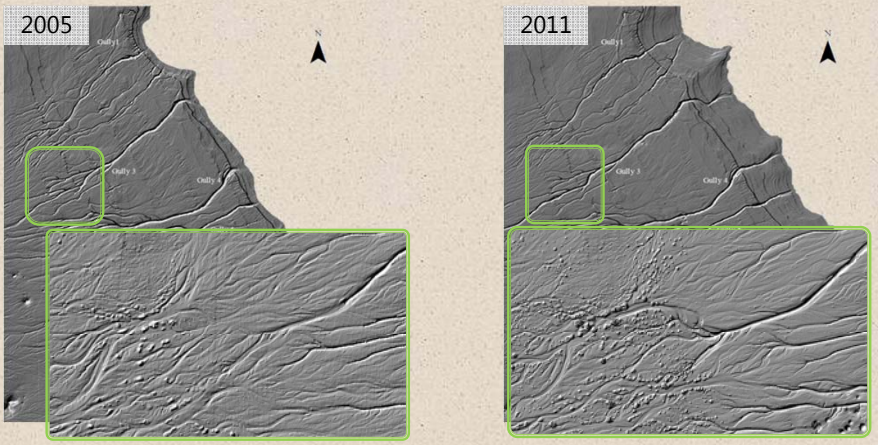
Receding Dead Sea Lake

- Coastal plain widening



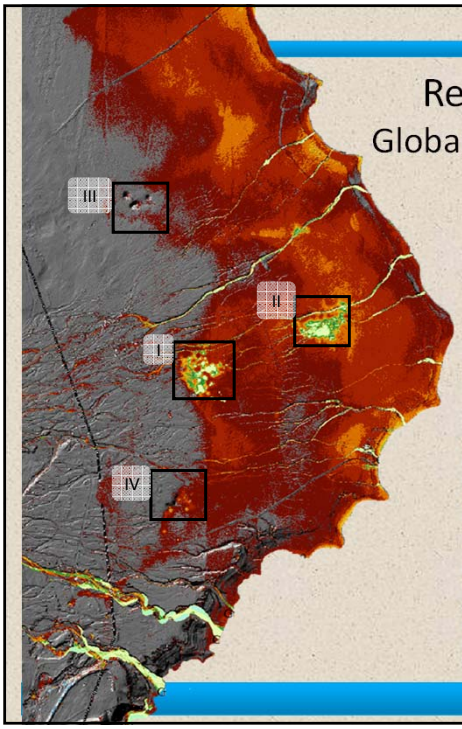
Main geomorphic processes along the lake coasts

- Intensive incision of streams and gullies in the newly exposed mud flats.



Results

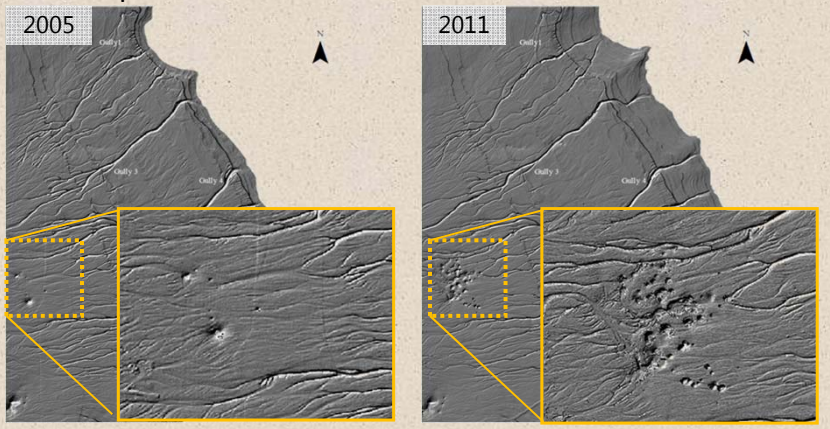
Global analysis



- Three key components that the difference map reveals
  - Fan surface modification
  - Collapse sinkholes' evolution

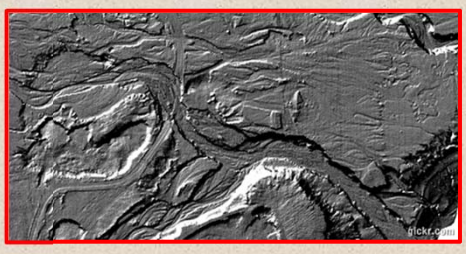
Results
Global analysis

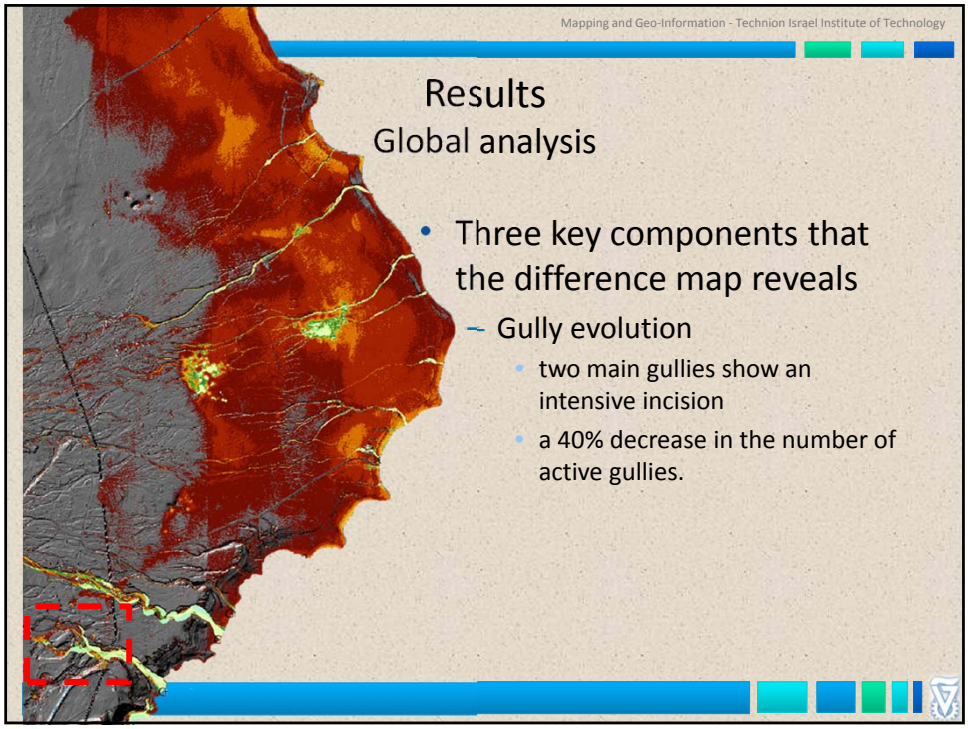
- Collapse sinkholes' evolution



Results
Global analysis

- Three key components that the difference map reveals
  - Gully evolution
    - two main gullies show an intensive incision

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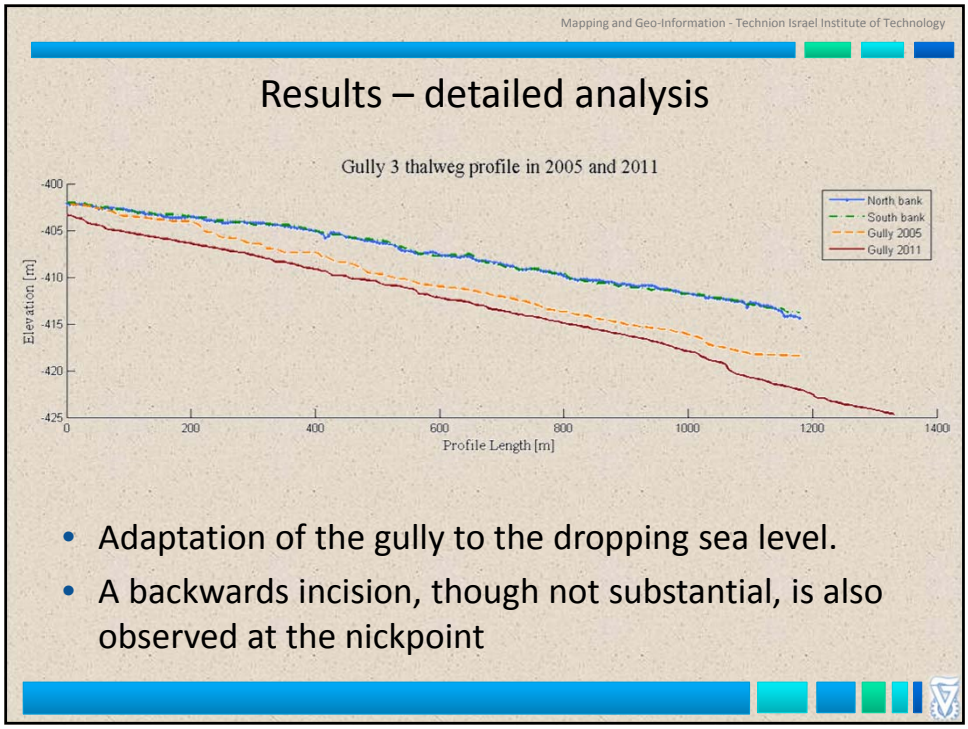
Results
Global analysis
Three key components that the difference map reveals
Gully evolution
two main gullies show an intensive incision
a 40% decrease in the number of active gullies.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Results – detailed analysis
Gully 3 thalweg profile in 2005 and 2011
North bank
South bank
Gully 2005
Gully 2011
Elevation [m]
-400
-405
-410
-415
-420
-425
0
200
400
600
800
1000
1200
1400
Profile Length [m]
Adaptation of the gully to the dropping sea level.
A backwards incision, though not substantial, is also observed at the nickpoint

Conclusion

- Analysis of the development of gullies and collapse sinkhole fields reveals:
  - Fossil areas
  - Rapidly changing areas
- Vital for planning future development of the region.
- Applicable in regions around the globe facing geomorphic changes.

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