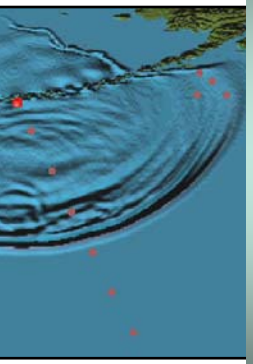

Remote Sensing and GIS Contribution to

Tsunami Risk Sites Detection

of Coastal Areas in the Mediterranean

The speaker's attendance
at this conference was sponsored
by the
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http://www.humboldt-foundation.de

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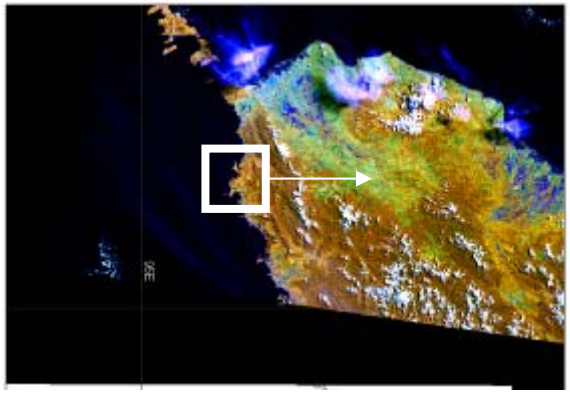
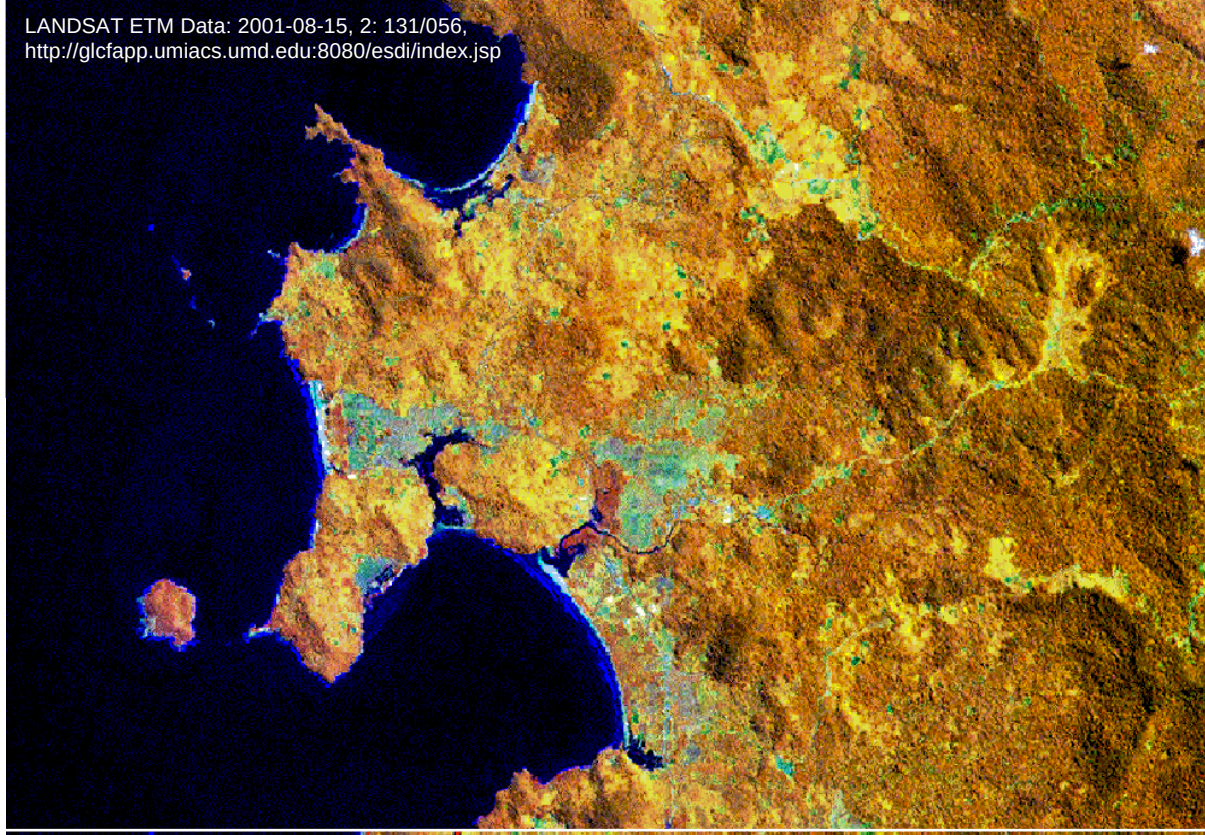


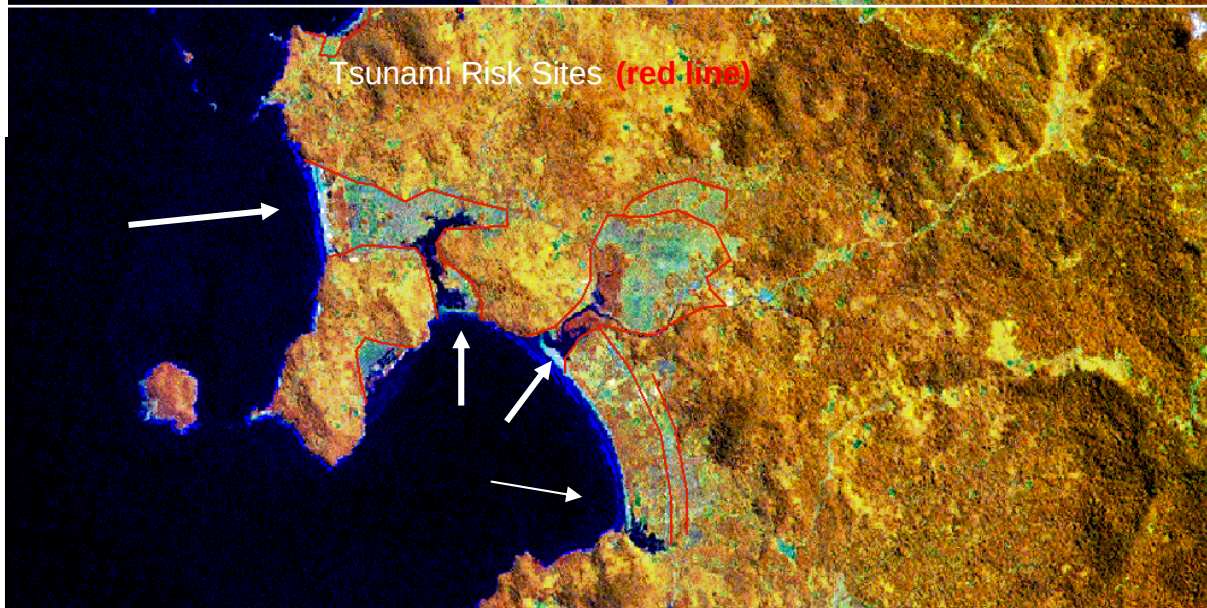
Lessons learnt from the 26.12.04 Tsunami….

Comparisons of satellite imageries before and after the 26.12.2004 – Tsunami clearly show that similar, catastrophic events must have happened before.
The same areas flooded in December 2004 are visible on the LANDSAT image from 2001 in greenish colours forming flat depressions.

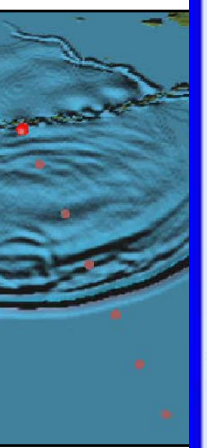
These methods of analyzing satellite imageries are used to detect similar traces in the Mediterranean.

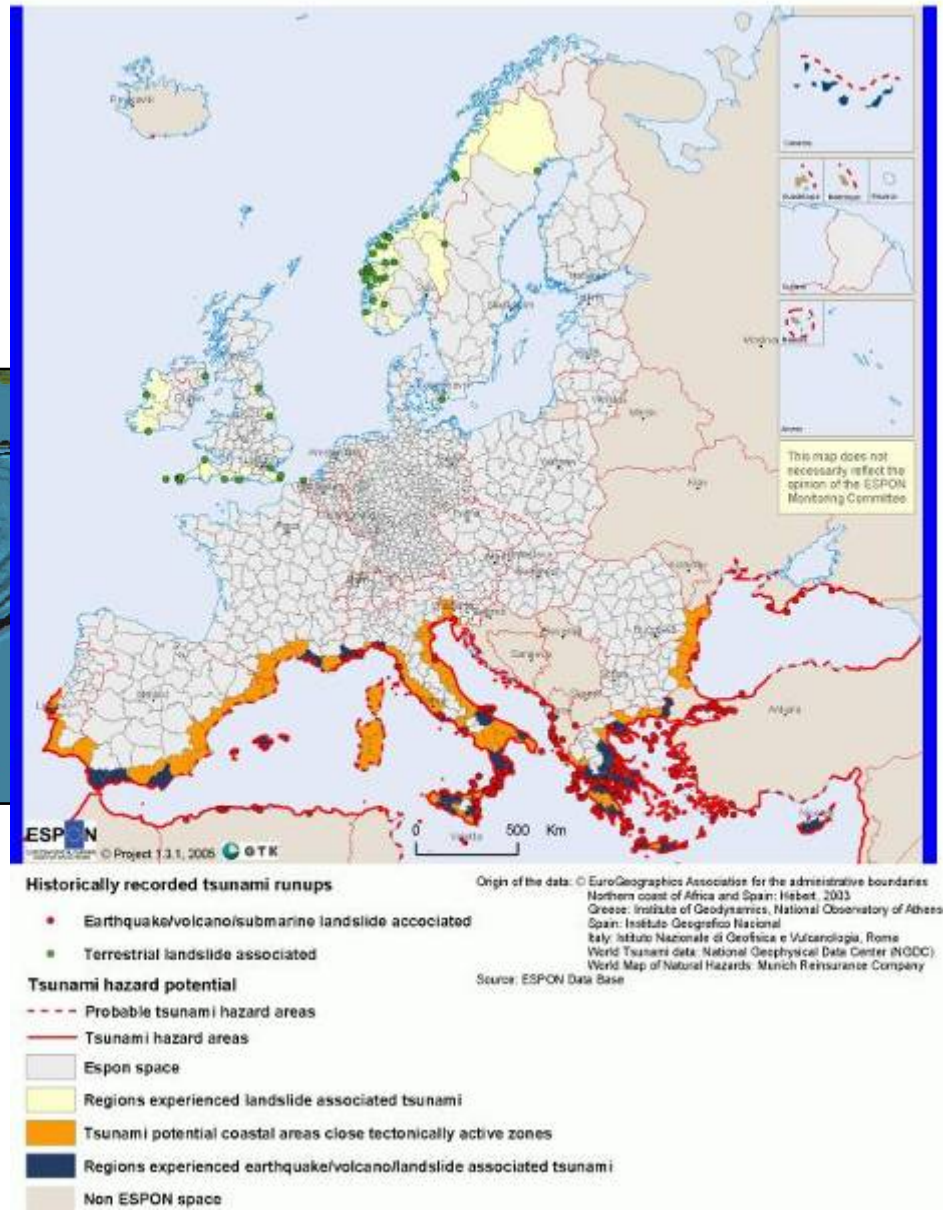
http://space.about.com/library/graphics/banda_aceh_south_010205.jpg





Sites of Potential Tsunami Hazard in the Mediterranean





Images from earth observing satellites have become a valuable support tool for tsunami damage detection in the aftermath of the disaster. This contribution, however, considers the use of remote sensing data for the detection of traces indicating past, catastrophic tsunami events. It can be assumed that coastal areas that were hit in the past by catastrophic tsunamis might be affected by similar events in the future again. Most detailed maps of those areas susceptible to tsunami flooding are an important step towards disaster prepardness and mitigation.

Sites of Potential Tsunami Hazard in the Mediterranean are presented in this map (in orange colours).
These coastal areas are investigated more detailed in order to detect typical geomorphologic and hydrologic features assumed to be related to past tsunamis.

http://www.gsf.fi/projects/espon/Tsunamis.htm

Geomorphologic Features visible on Remote Sensing Data of Areas Prone to Recent Catastrophic Tsunami Events

- fan shaped flat areas
- irregular, ponds and lakes near the coast
- arc-shaped small walls with arcs opened to the sea, terraces and scarps parallel to the coast
- concentration of lagoons
- fan-shape like arranged drainage pattern
- seawards orientation of the slopes
- traces of seawards oriented erosion and abrasion
- landslides at slopes undercut by floods

Lithologic Features visible on Remote Sensing Data of Areas Prone to Catastrophic Tsunami Events

- sedimentary covers visible due to characteristic, spectral properties
- abrasion areas visible due to characteristic spectral properties

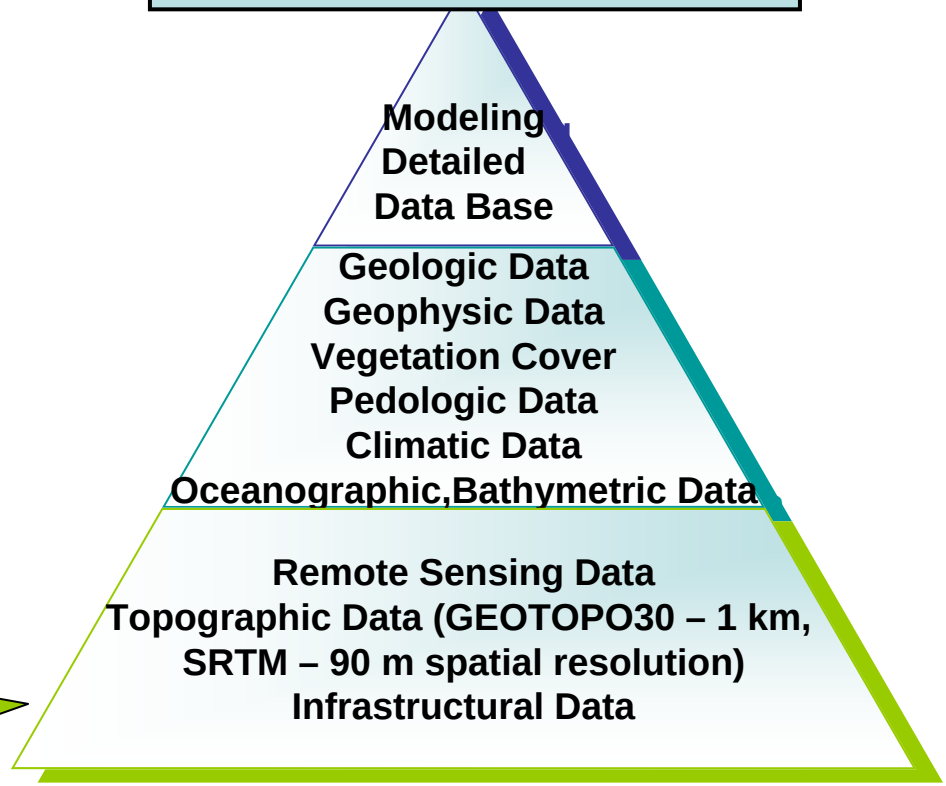
Methods

Geographical Information Systems (GIS) provide the appropriate platform for the registration and management of information on tsunami hazard. Satellite imageries and digital elevation data are used as layers in a **Tsunami Hazard GIS** and combined with different geodata and thematic maps.

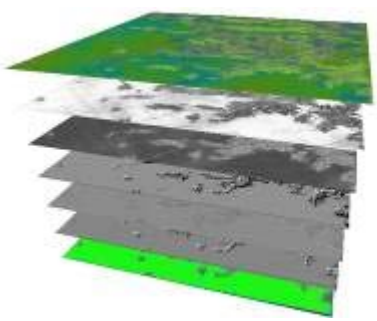
Remote Sensing Contribution:

- Basic layer for general information (landuse)
- Detection of potential tsunami risk sites
- Specific layers of the investigation areas for getting geomorphologic / geologic information and information of sites susceptible to landslides, neotectonic movements, subsidence, etc.

Geographic Information System (GIS) Data Base



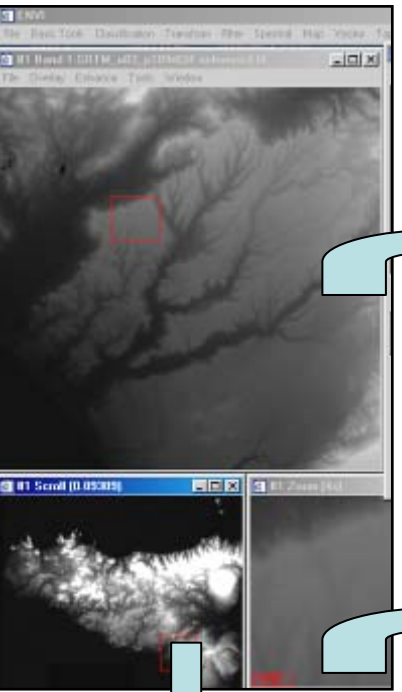
Remote Sensing Data

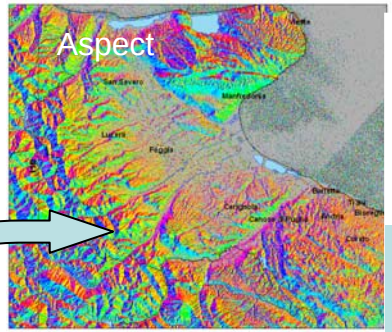


- **LANDSAT ETM (Spatial Resolution - 15 m)**
- **ERS, ENVISAT, SRTM Satellite Radar Data (~12 m)**
- **IKONOS, QUICKBIRD, Aerial Photographs (1 - few meters)**

Digital Image Processing and Enhancement of SRTM (Shuttle Radar Topography Mission) Digital Elevation Data (DEM)

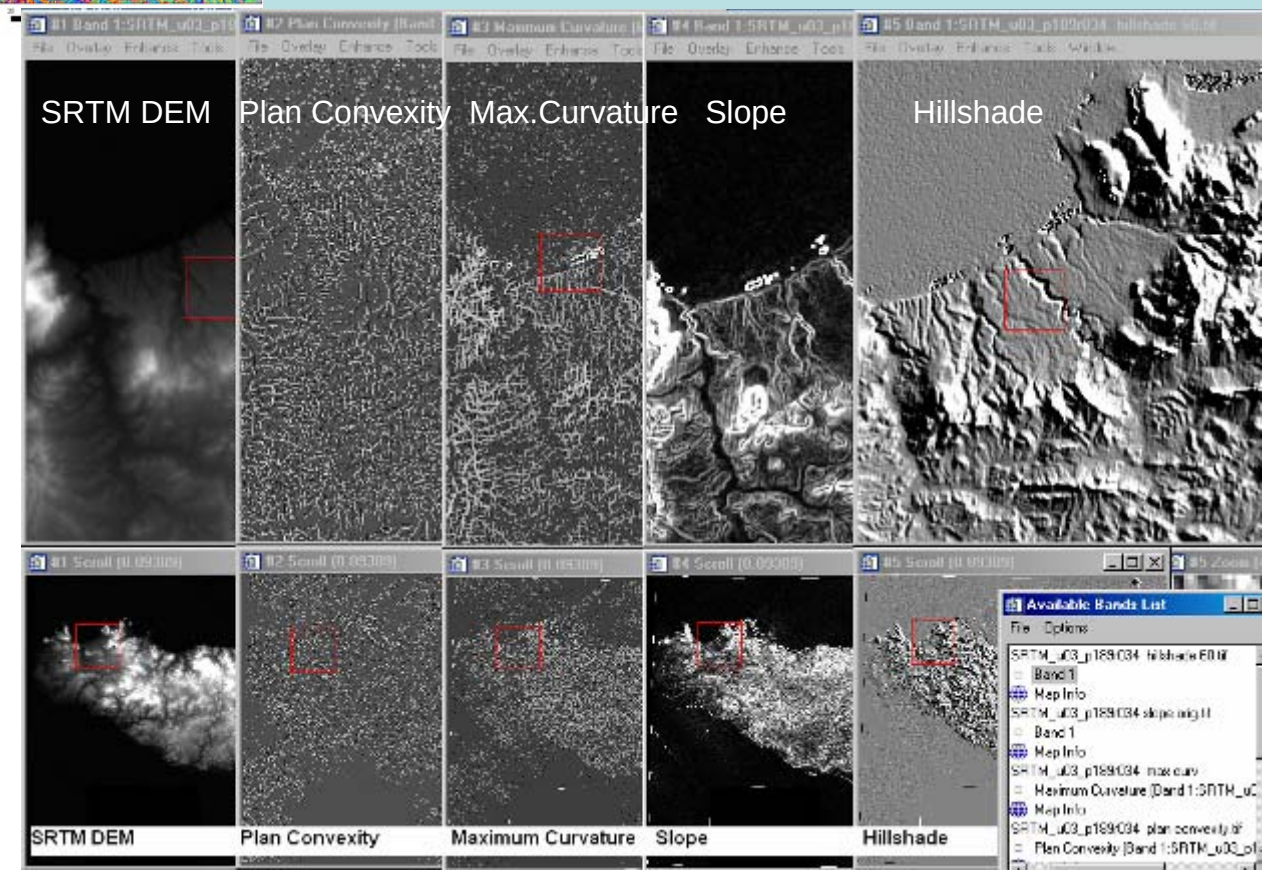
SRTM - DEM



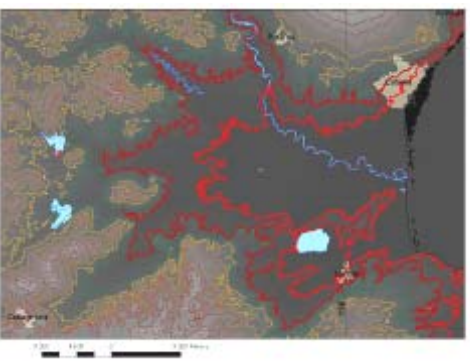


The evaluation of digital topographic data is of great importance as it contributes to the detection of the specific geomorphologic settings of tsunami prone areas. Geomorphometric parameters as slope degree, minimum or maximum curvature, hillshade or aspect provide information of the terrain morphology indicating geomorphologic features that might be related to tsunami events.

Based on SRTM DEM data different **morphometric maps** can be generated:



Contour Lines



SRTM data provide a more or less homogeneous dataset for 80% of the globe at 10 times greater detail than previously available.

Traces of Past Tsunami Floods Visible on DEM Derived Morphometric Maps

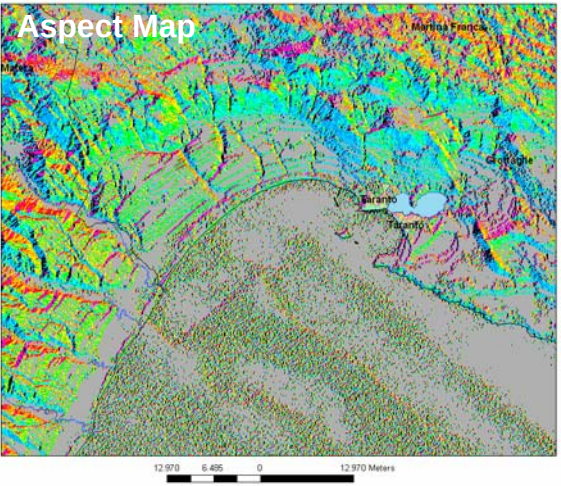
Aspect: Orientation of walls and terraces towards the sea

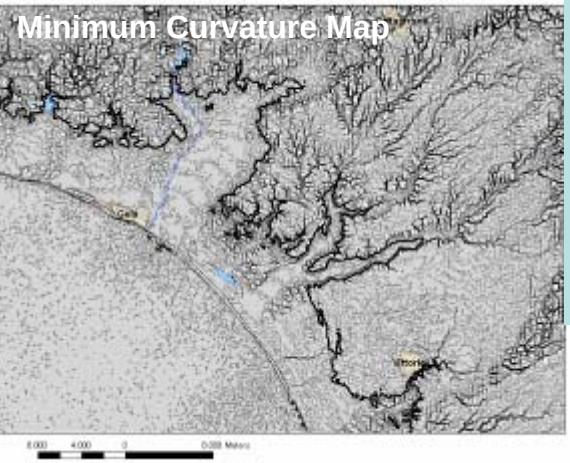
Minimum and Maximum Curvature: Detecton of walls, terraces and scarps, arc-shaped and opened towards the sea

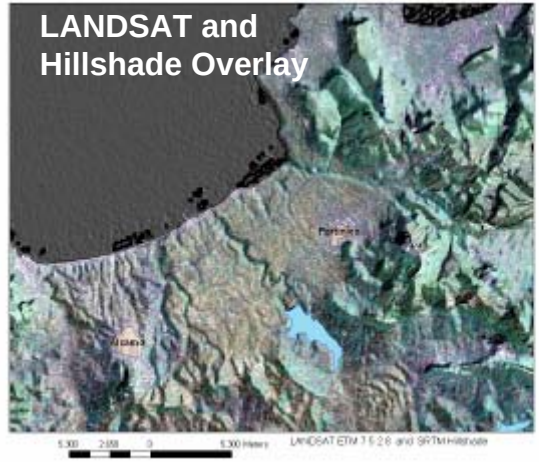
Hillshade: Fan-shaped Morphology

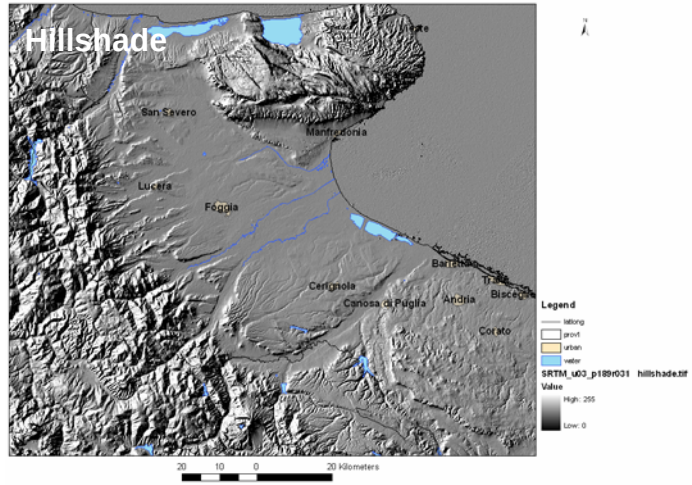
Color Coding of the SRTM DEM: Detection of Potential Run-up Sites

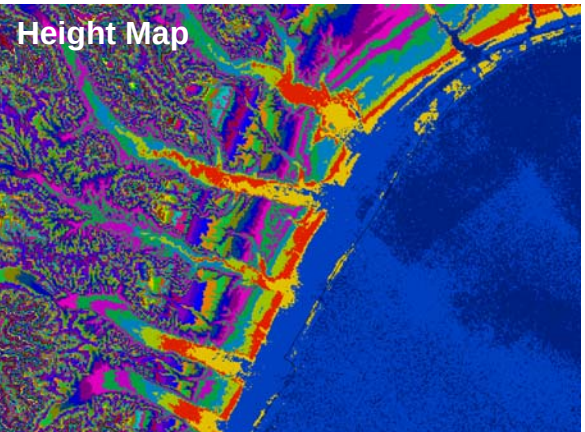
Slope: Traces of Abrasion

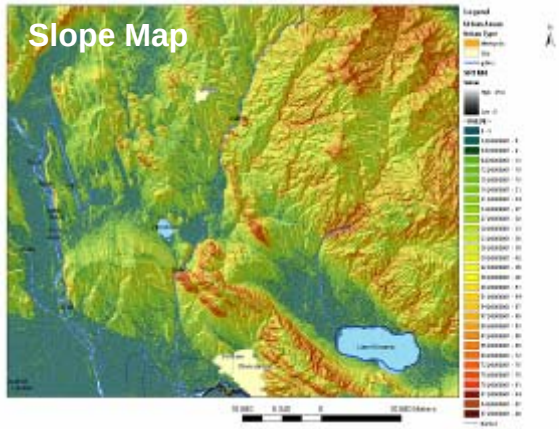


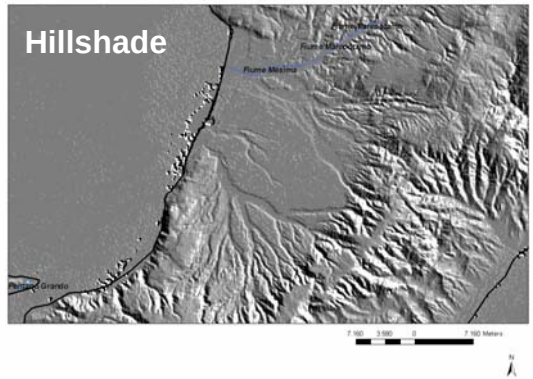




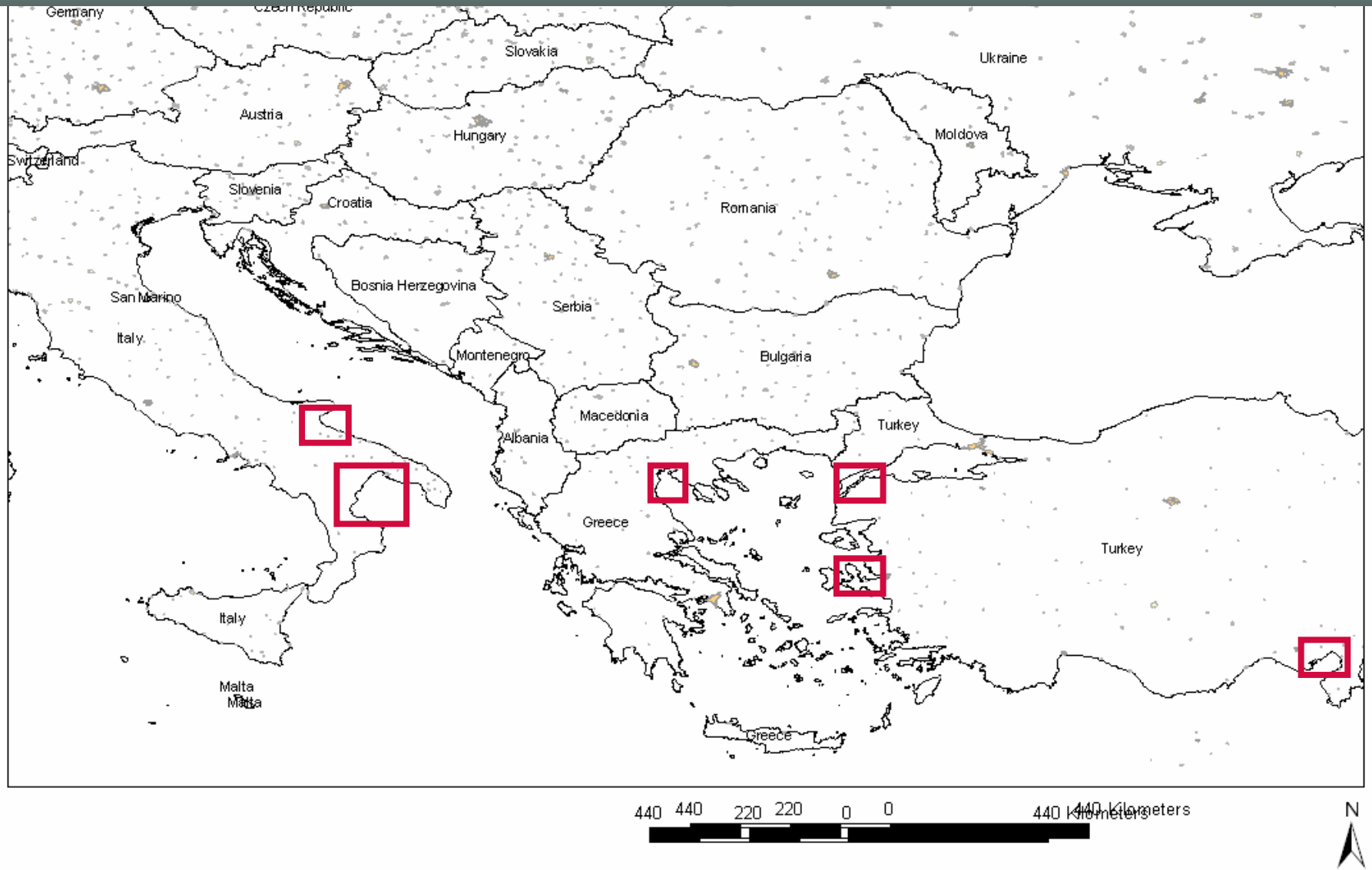






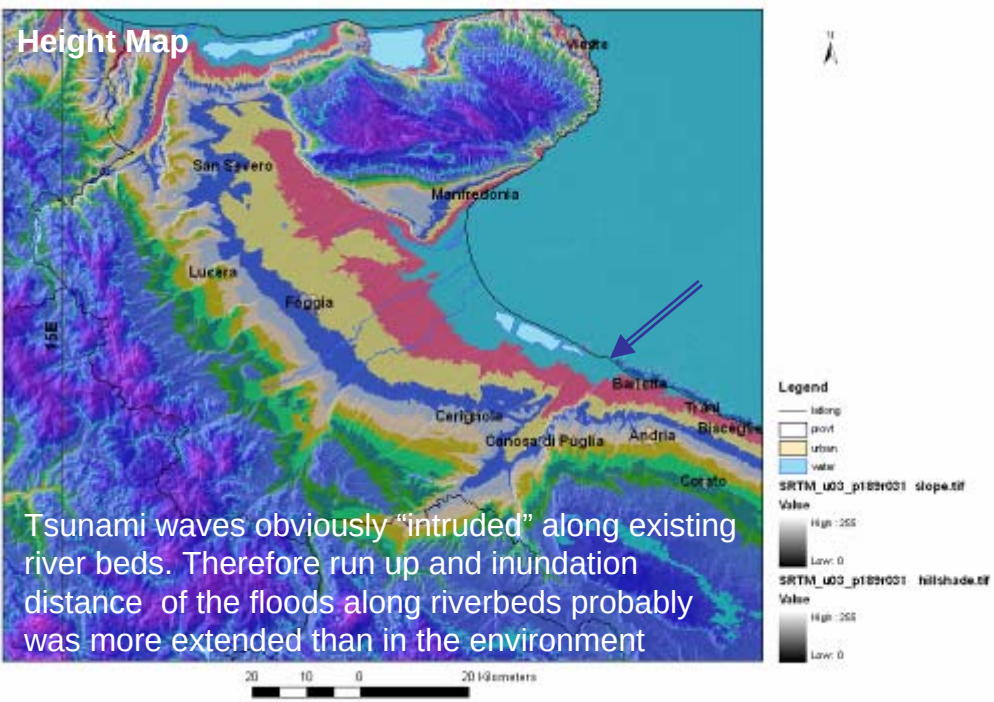


Use of Remote Sensing and GIS Methodology for Tsunami Hazard Site Detection - Position of the Examples

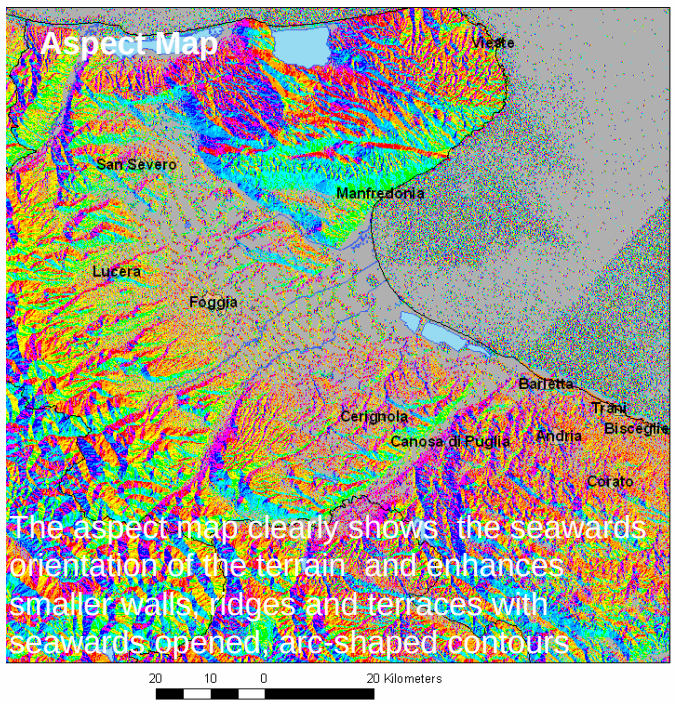


Position of the Examples

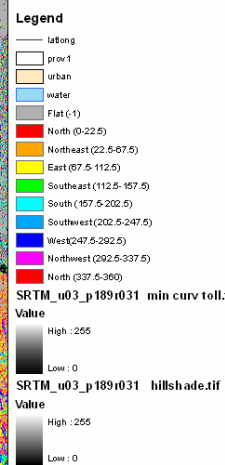
Potential Tsunami Risk Sites inSoutheast Italy



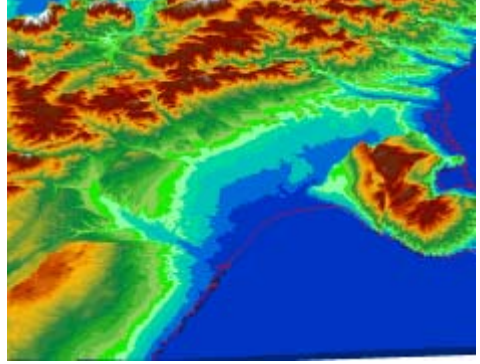
Tsunami waves obviously "intruded" along existing river beds. Therefore run up and inundation distance of the floods along riverbeds probably was more extended than in the environment

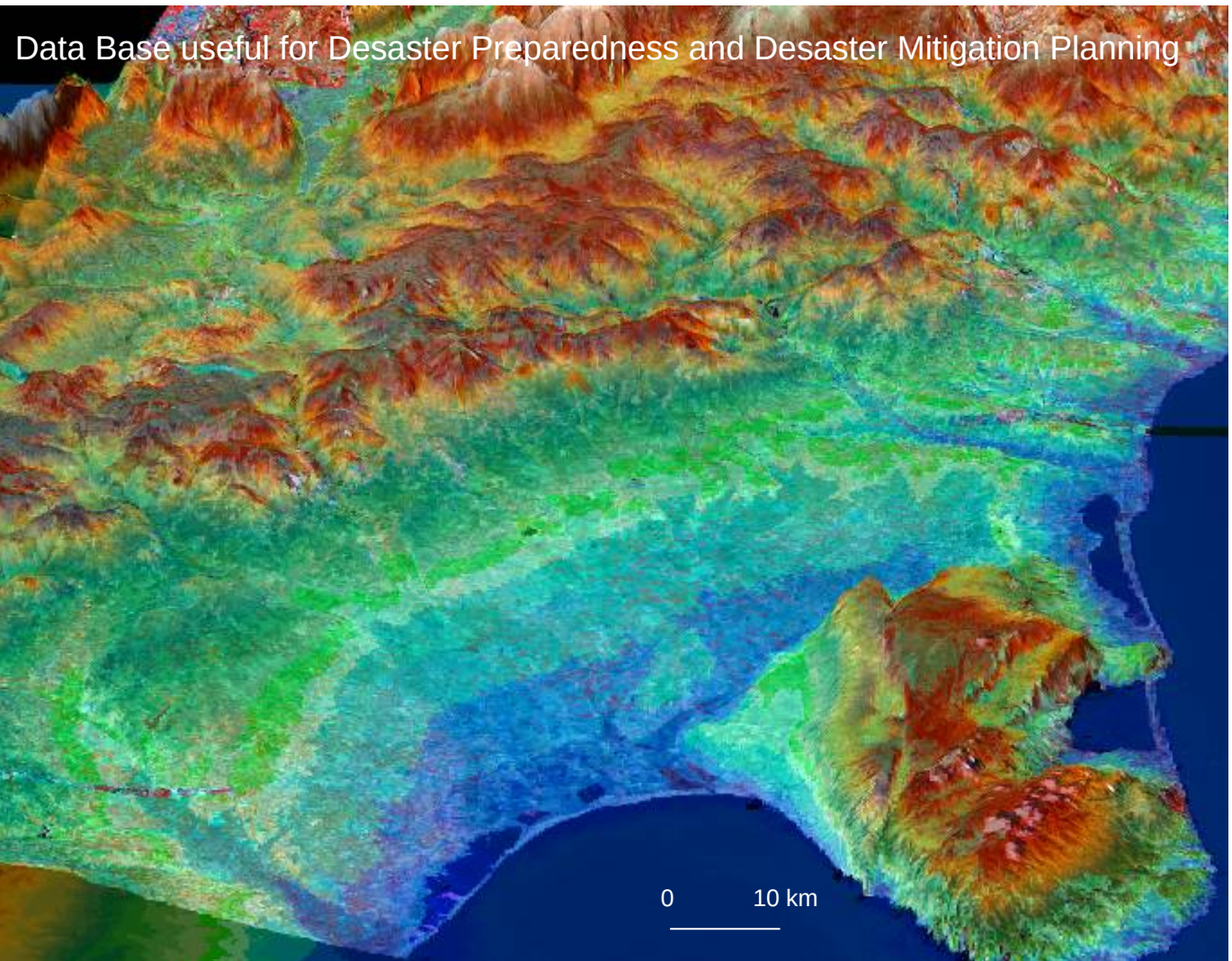


The aspect map clearly shows the seawards orientation of the terrain and enhances smaller walls, ridges and terraces with seawards opened, arc-shaped contours



Perspective 3D-Views of LANDSAT ETM Imageries and SRTM Elevation Data

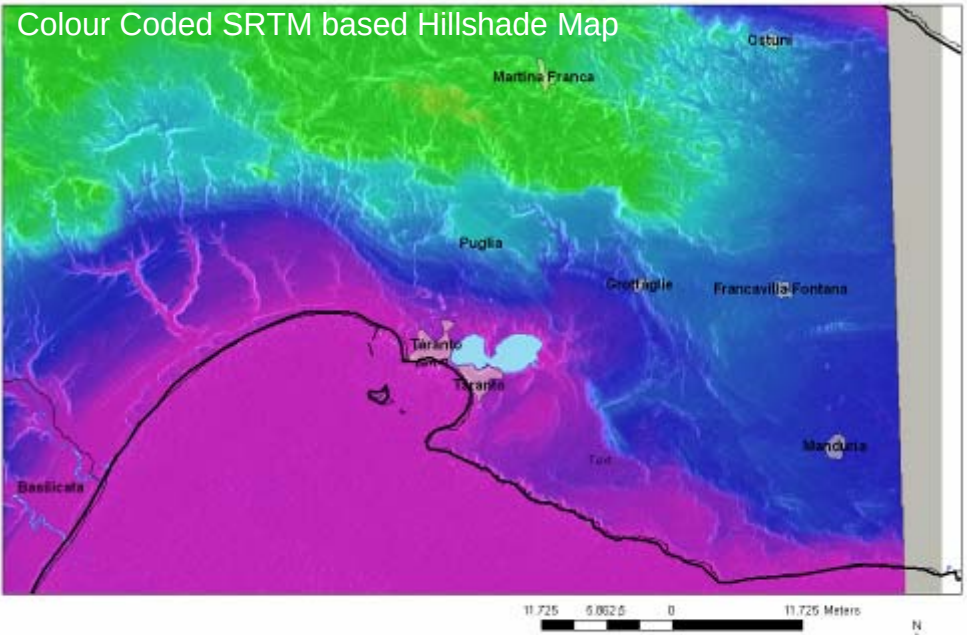




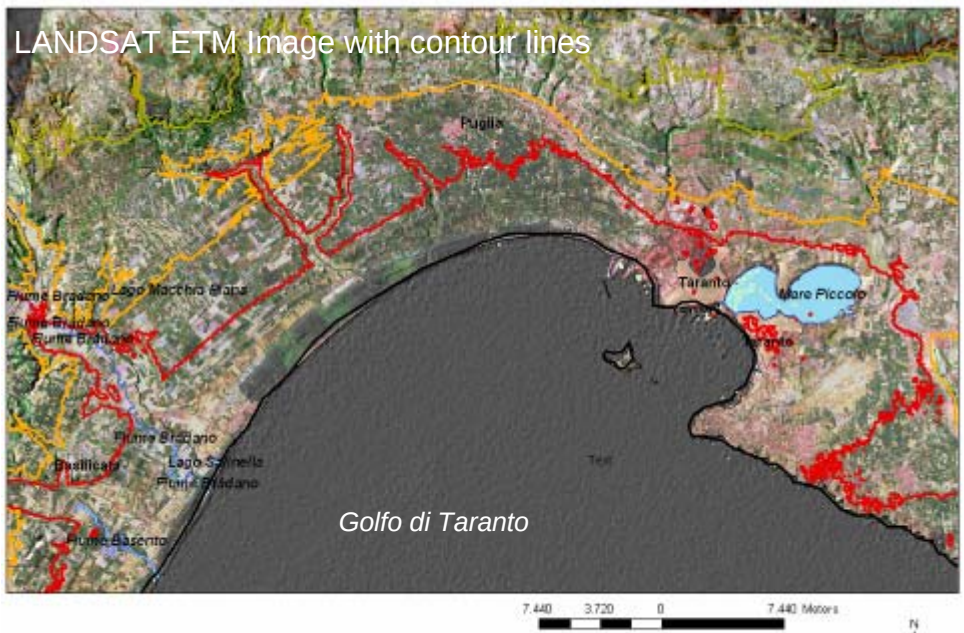
The perspective view of the LANDSAT / SRTM height map overlay visualizes the areas prone to potential flooding risk.

Combined Analysis of SRTM and LANDSAT ETM Data from the Golfo di Taranto Area

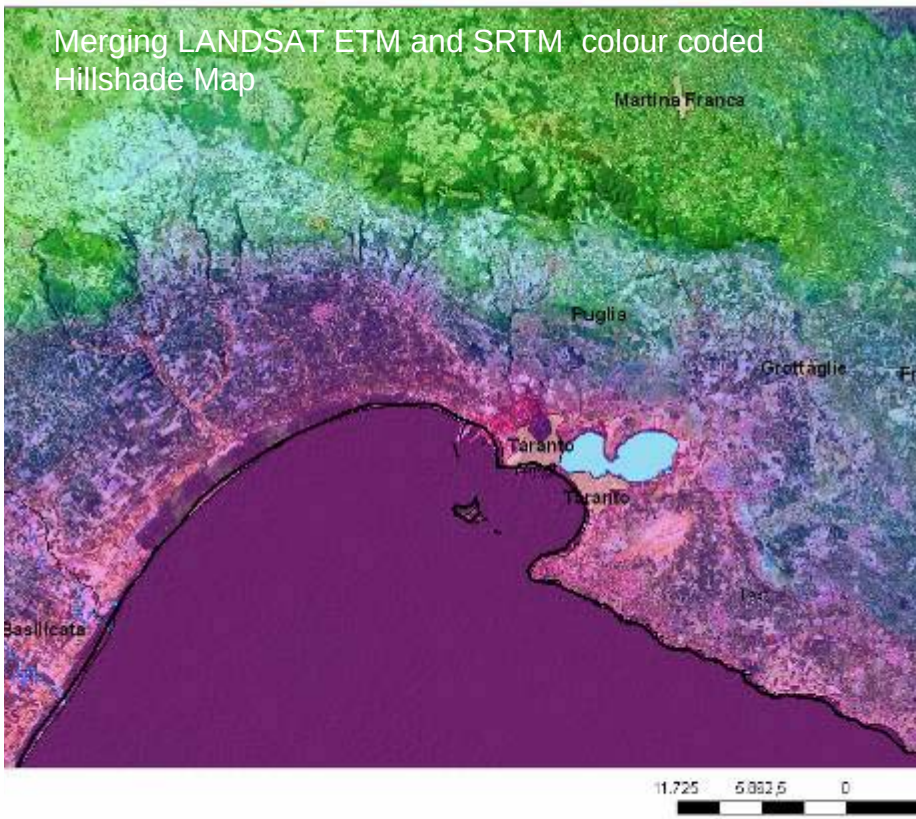
- for deriving information of areas prone to tsunami hazard



SRTM hillshade colour coded, merged with SRTM hillshade and LANDSAT ETM HSV 3,6,5,8



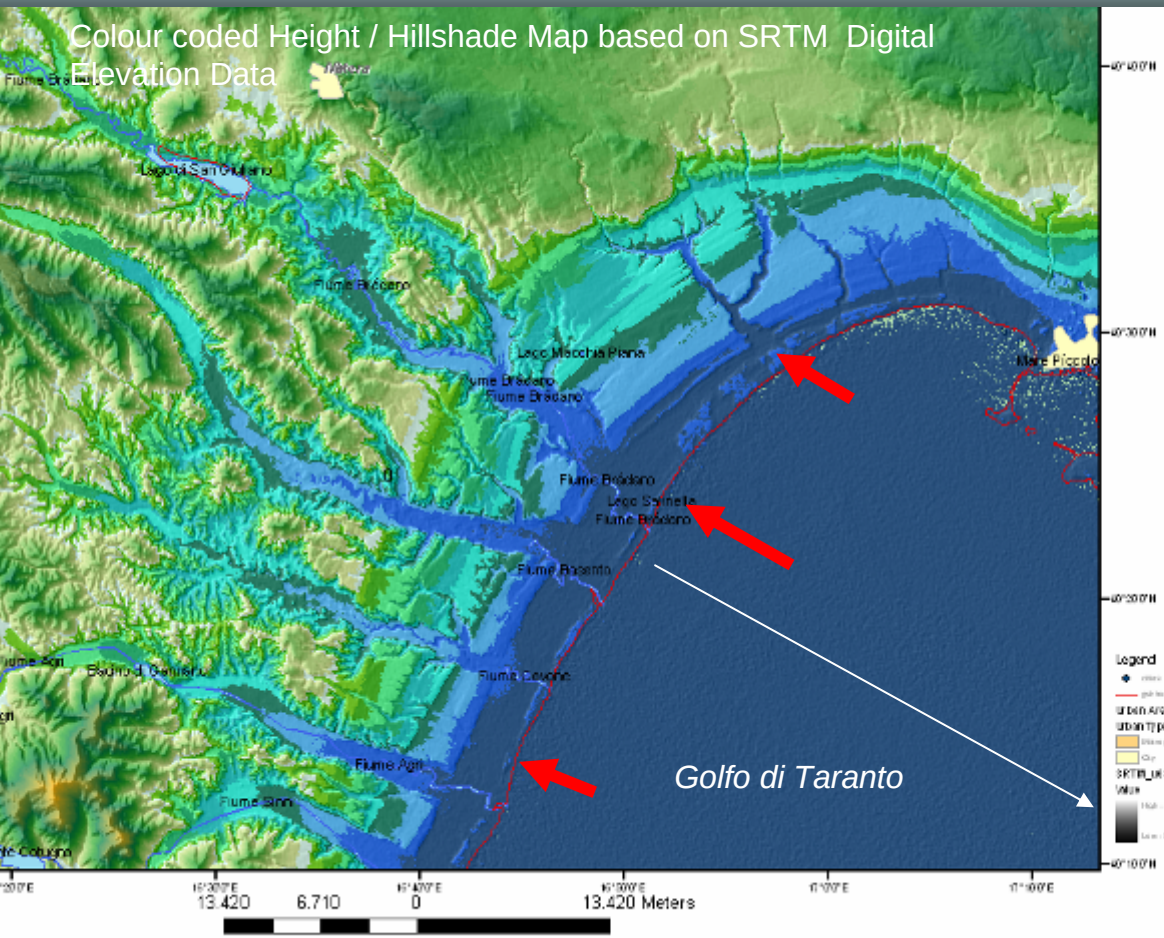
SRTM slope and LANDSAT ETM HSV 3,6,5,8



TM hillshade colour coded, merged with SRTM hillshade and LANDSAT ETM HSV 3,6,5,8

Red line - high tsunami risk potential
Yellow line - moderate tsunami risk potential

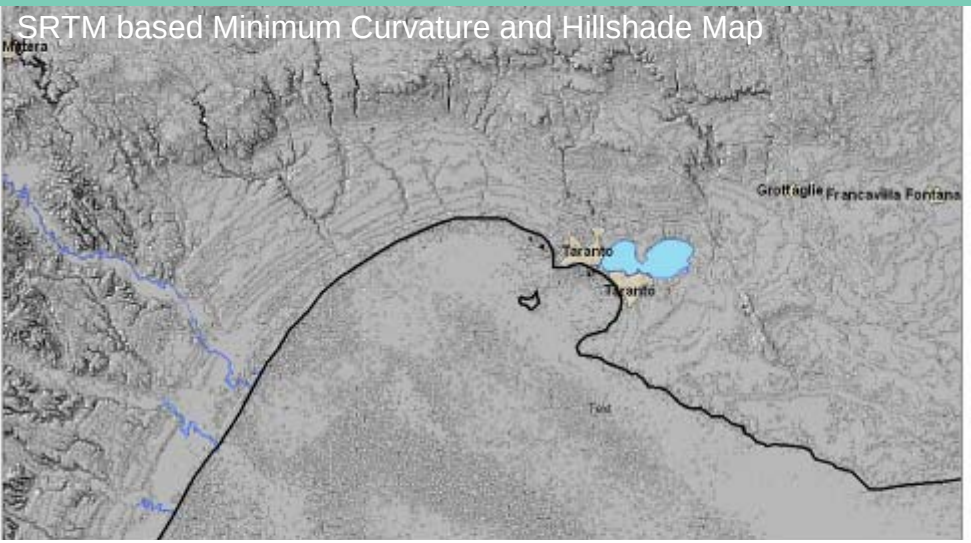
Inundation and Run-up of Tsunami Waves in the the Bay of Taranto /South Italy?

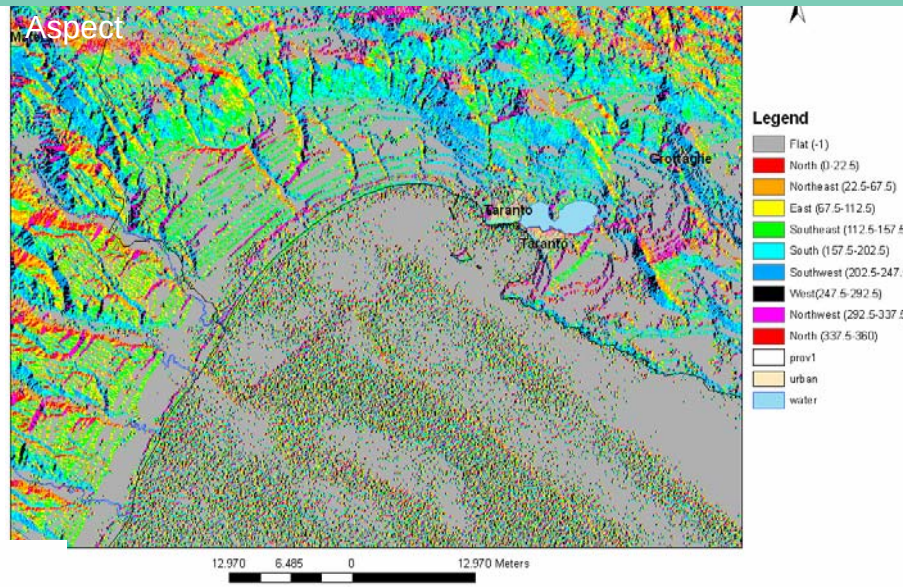


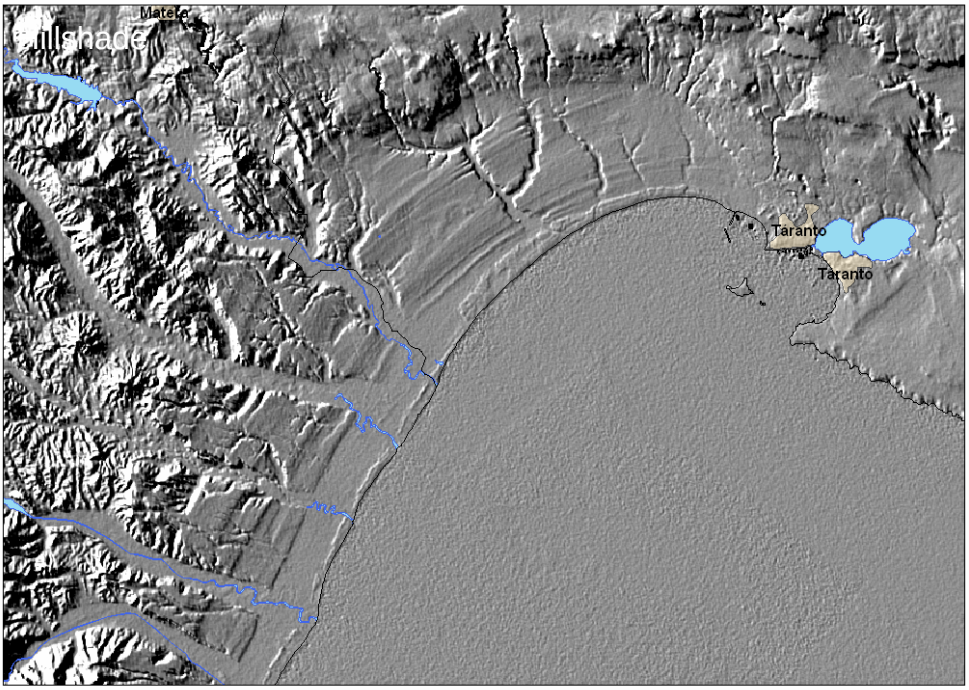
In the case of a catastrophic tsunami event estuary plains and broader river beds are probably prone more to tsunami wave propagation than the environment. River mouths represent a large entrance for tsunami waves.

Analyzing the height map there is a strong geomorpholologic evidence that flash floods - probably related to catastrophic tsunami events - have occurred in the geologic past.

Similarities in the Landscape Development of the Coast at the Taranto Bay and the Coast of Sri Lanka

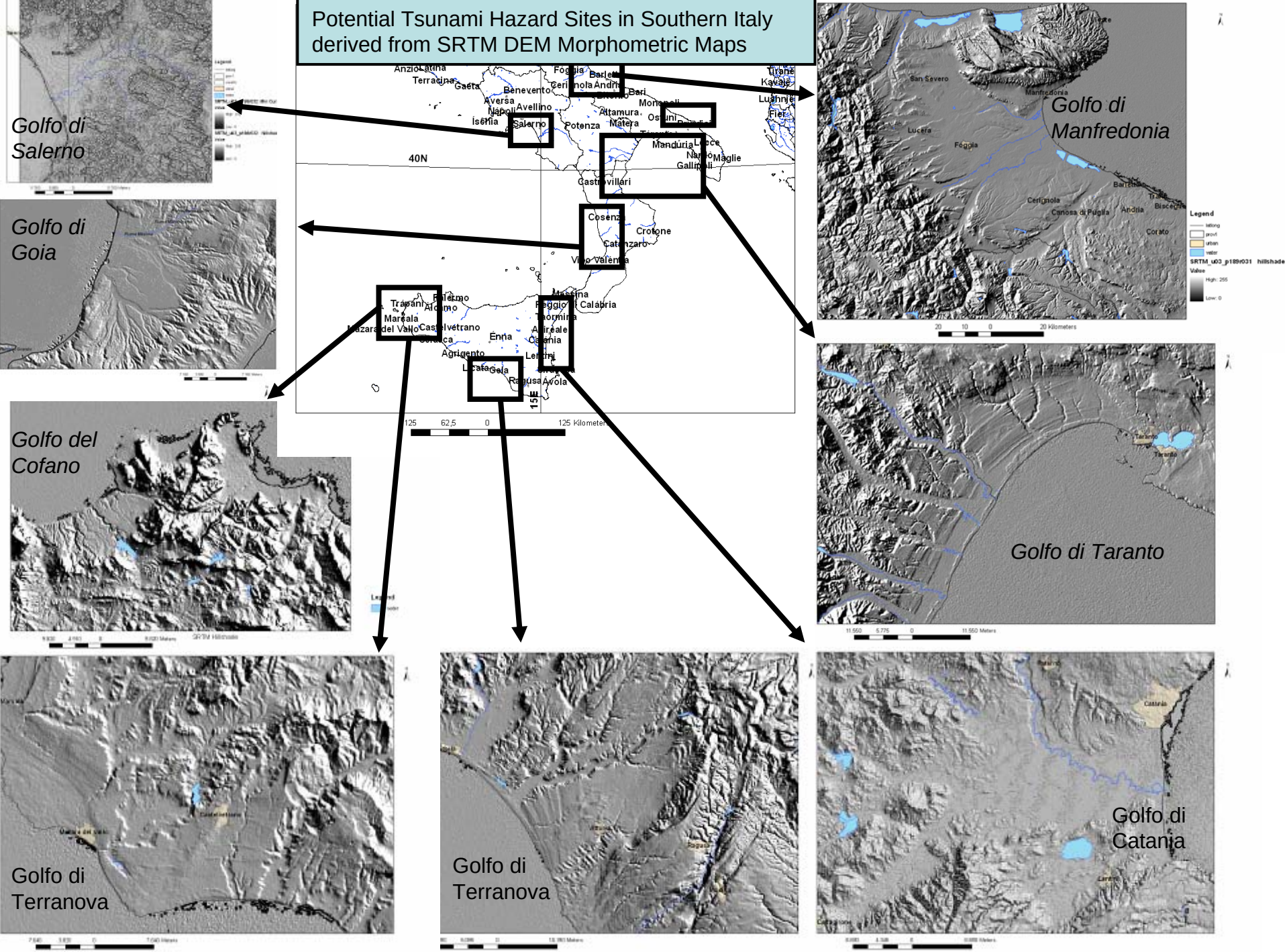






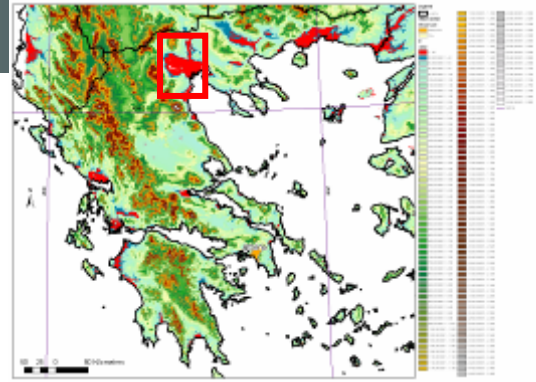
The landscape of the Bay of Taranto shows characteristic geomorphologic features that are similar to areas hit by recent catastrophic tsunamis as in the East of Sri Lanka.

Potential Tsunami Hazard Sites in Southern Italy derived from SRTM DEM Morphometric Maps

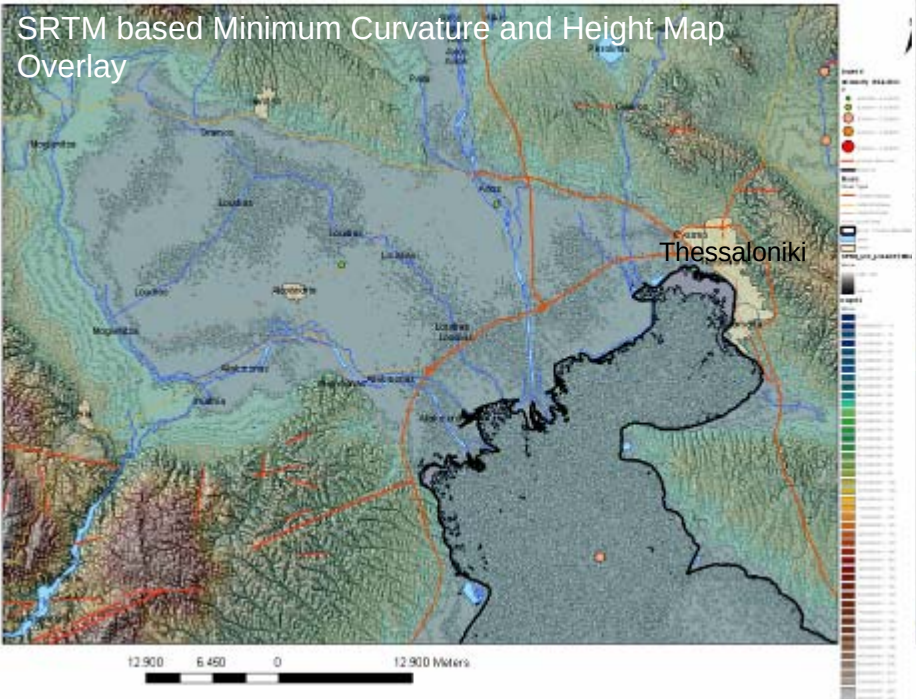


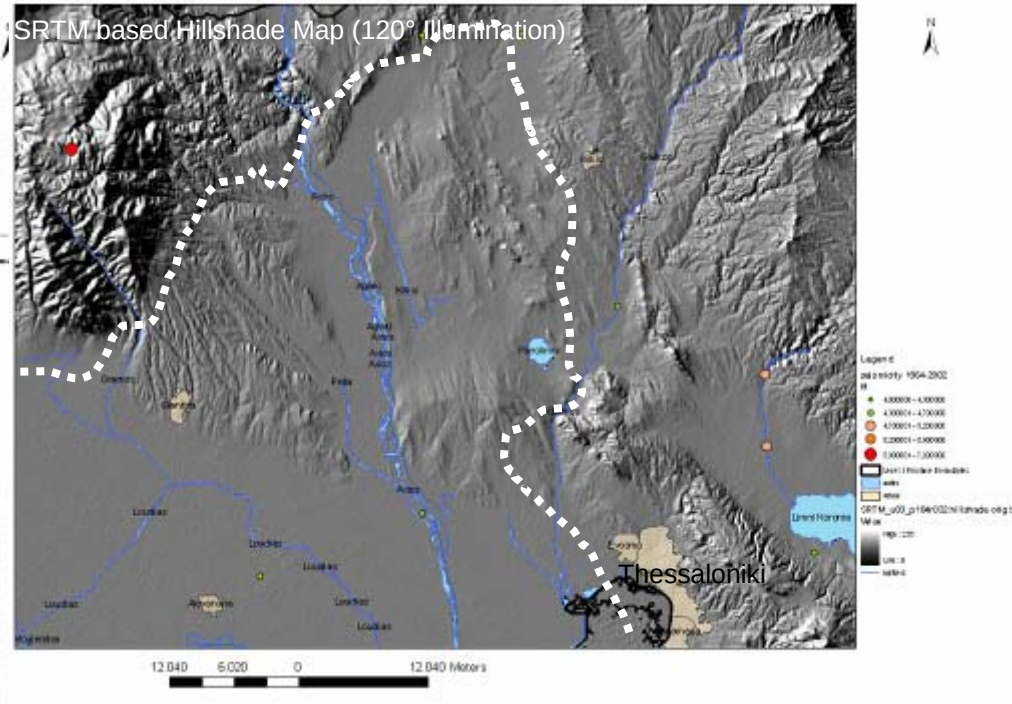
Potential Tsunami Risk Sites in Greece

SRTM based Morphometric Maps - showing traces of earlier inundations?

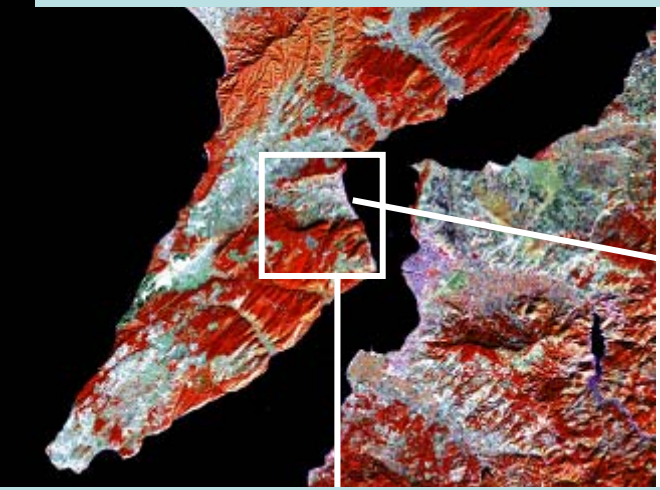


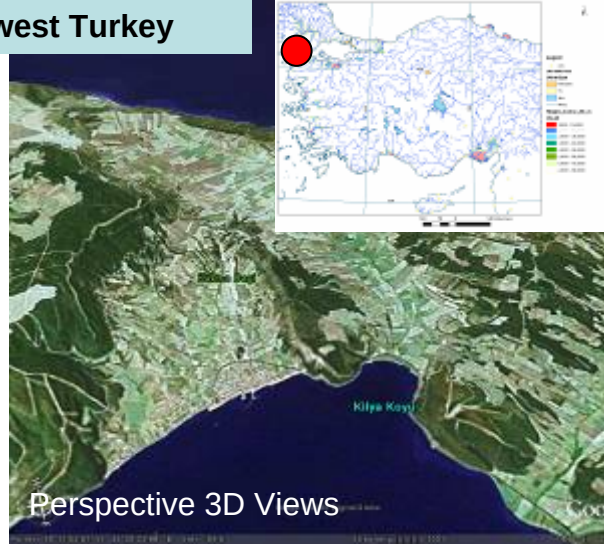
The dashed line on the hillshade map illustrates the area assumed as flooded by probably catastrophic tsunami events according to the geomorphologic properties of the area. The surfaces seem to be "smoothened" by abrasion and erosion. There is a distinct morphologic difference to the surrounding area.



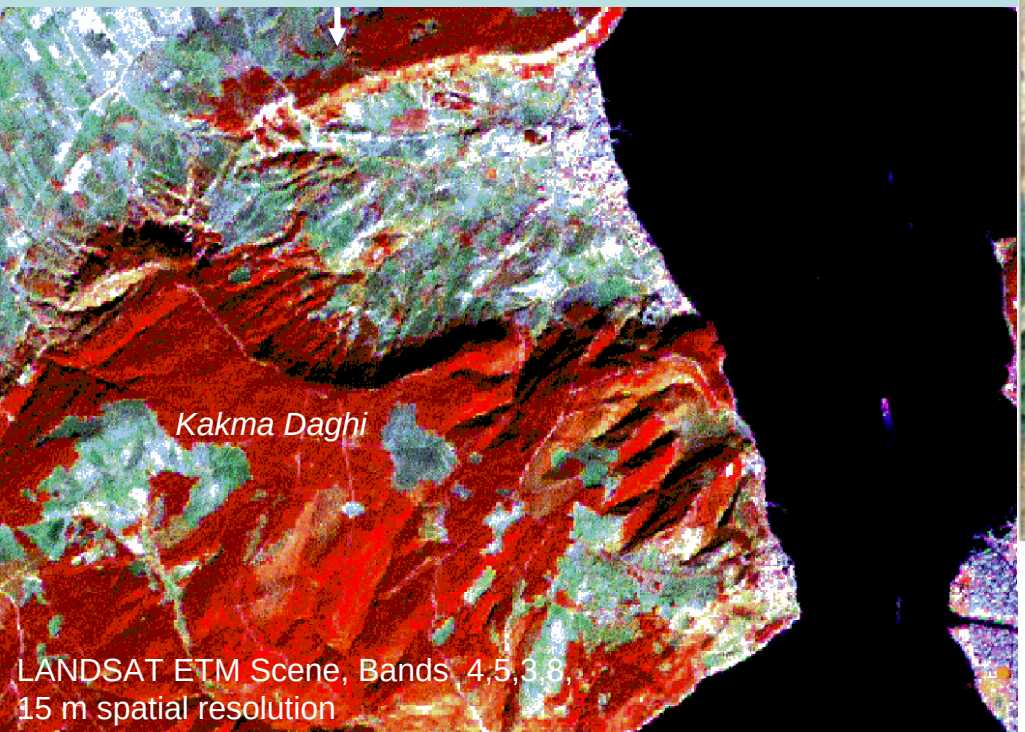


Evaluations of LANDSAT Enhanced Thematic Mapper (ETM) Imageries from Northwest Turkey

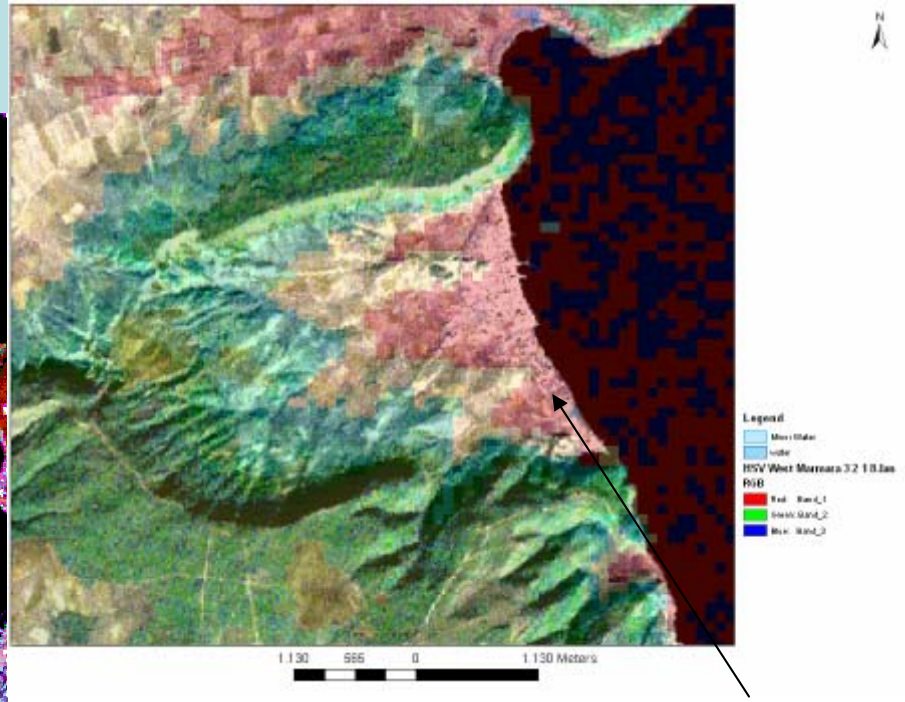




The bowl-shaped morphology of the Kakma Daghi area seems to be the result of flood waves. Due to the coastal shape forming a channel high energy flood waves could have been generated after a stronger earthquakes forming this landscape.

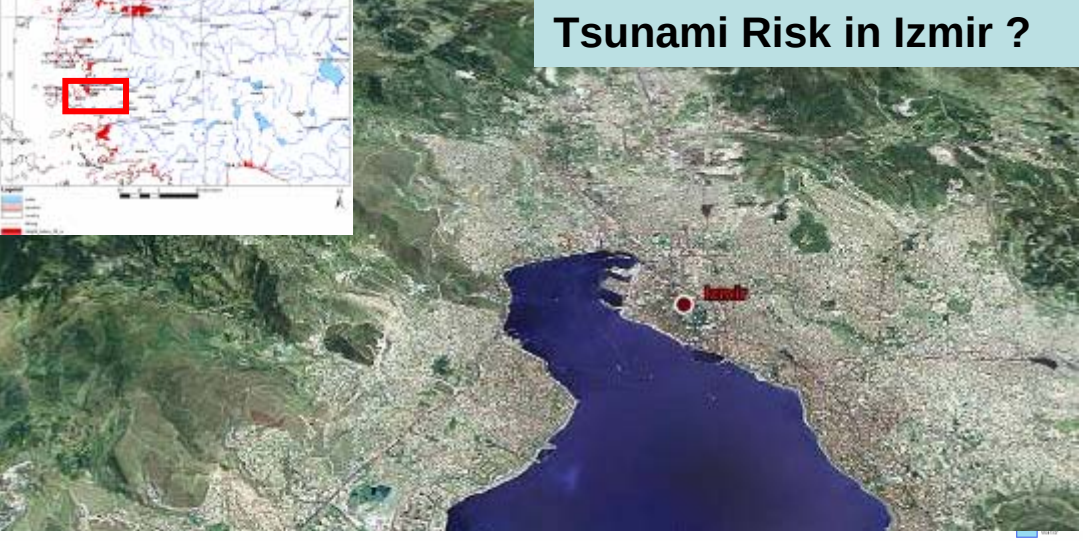


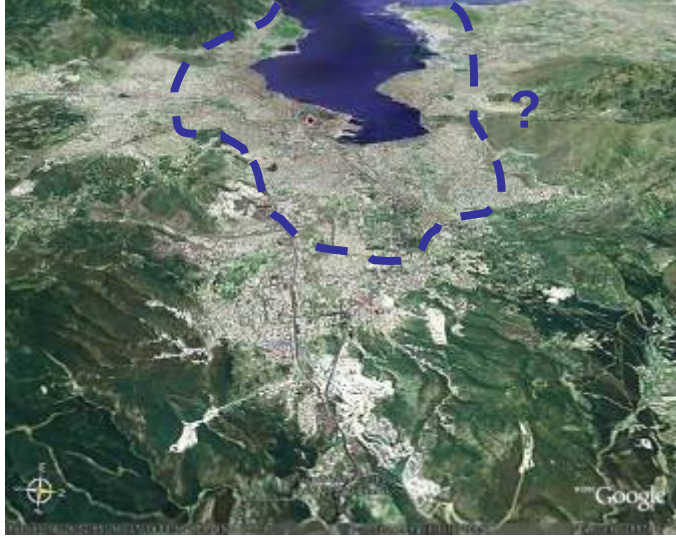
LANDSAT ETM Scene, Bands 4,5,3,8,
15 m spatial resolution

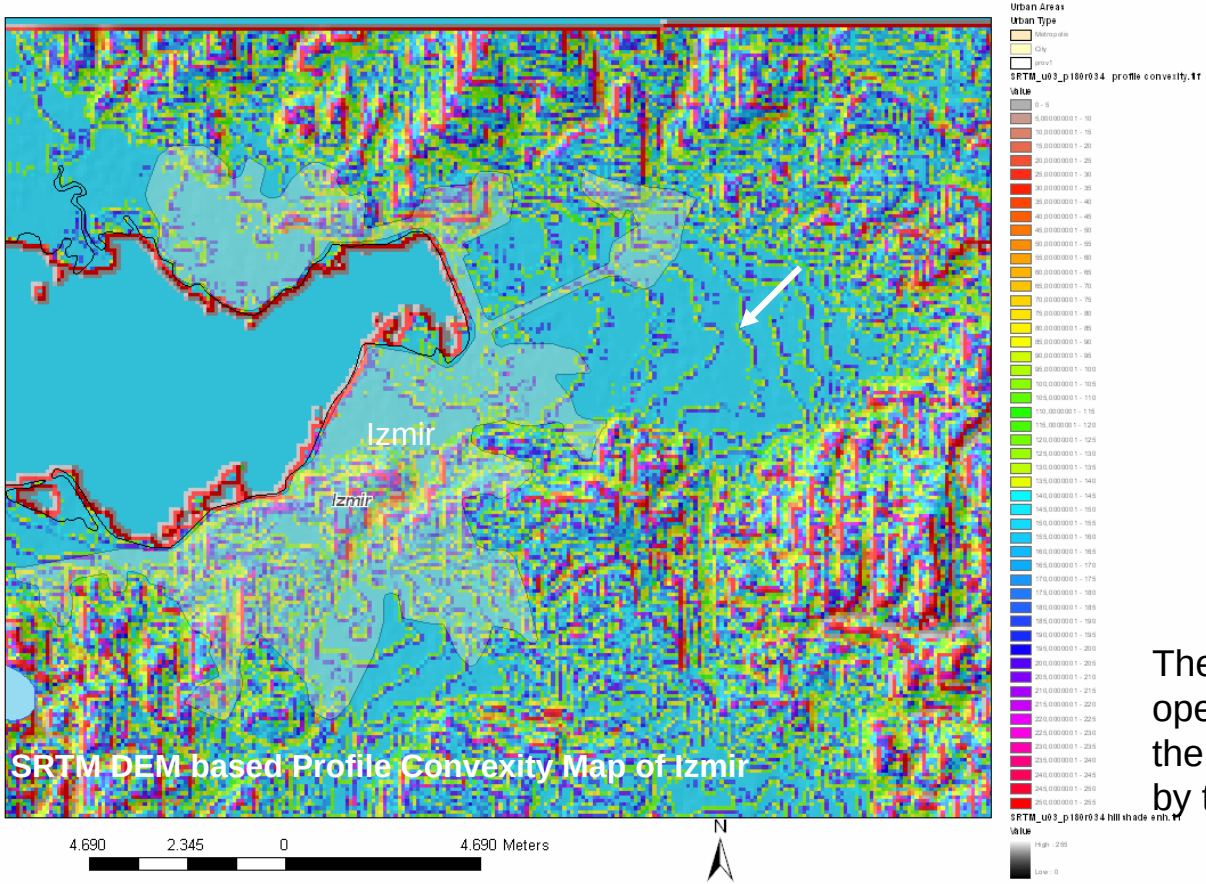


Sites Susceptible to Tsunami Floods (red)
LANDSAT ETM Scene merged with SRTM Height Data

Tsunami Risk in Izmir ?



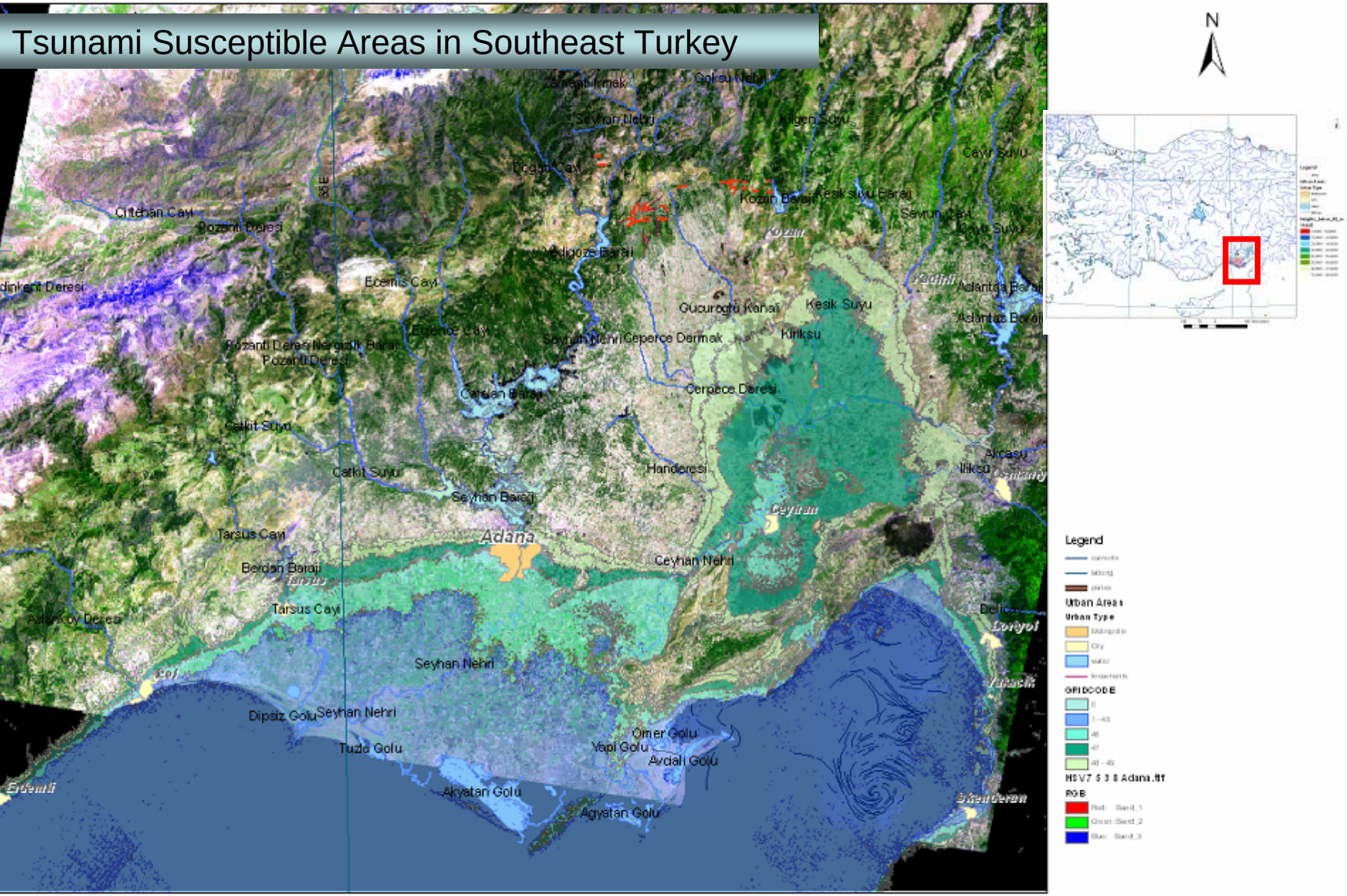




Traces of Ancient Tsunami Waves on SRTM DEM Data derived morphometric maps of Izmir?

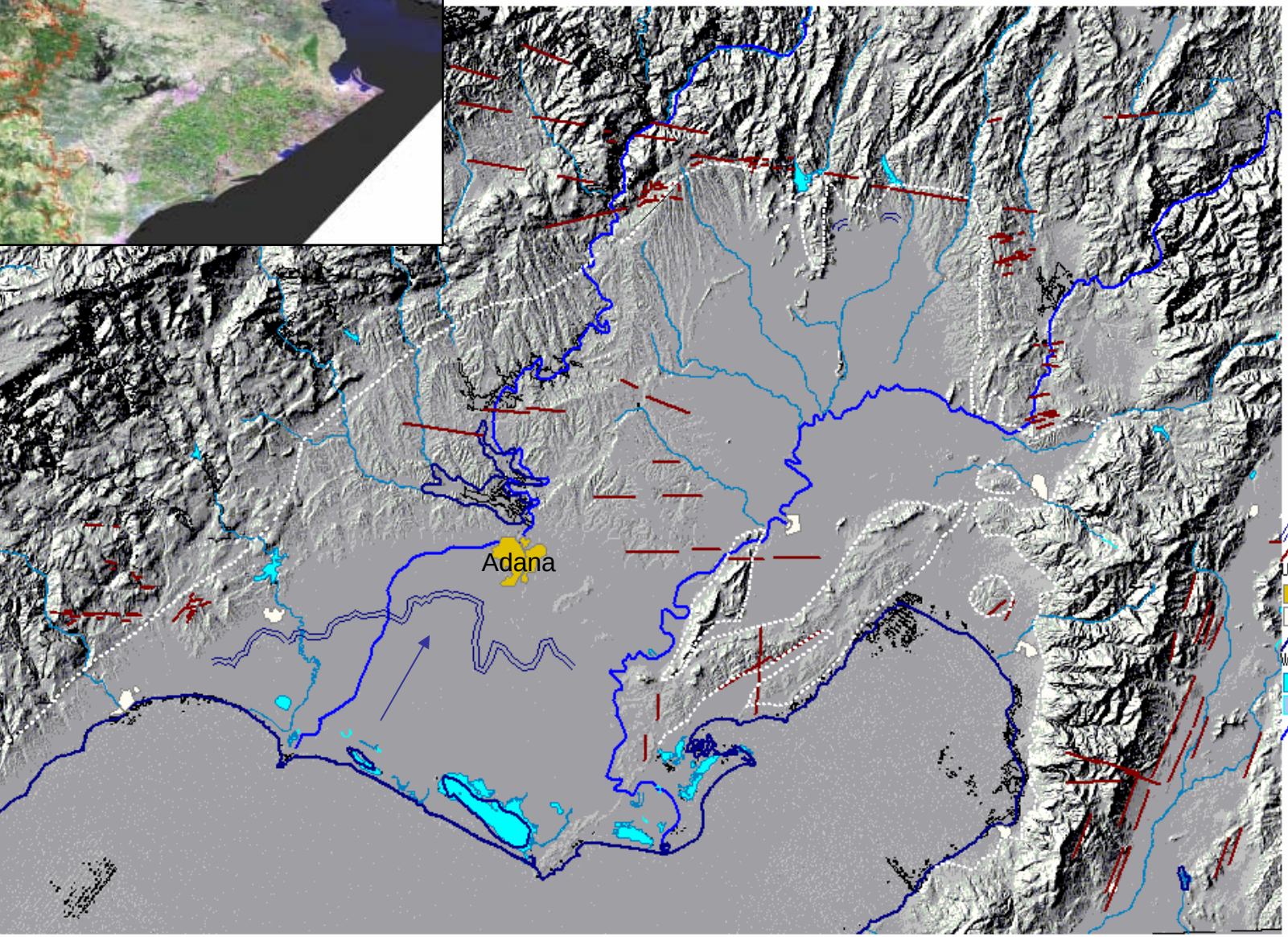
The arc-shaped form of „height-terraces“, opened towards the sea seems to confirm the assumption, that this area was flooded by tsunami waves.

Tsunami Susceptible Areas in Southeast Turkey



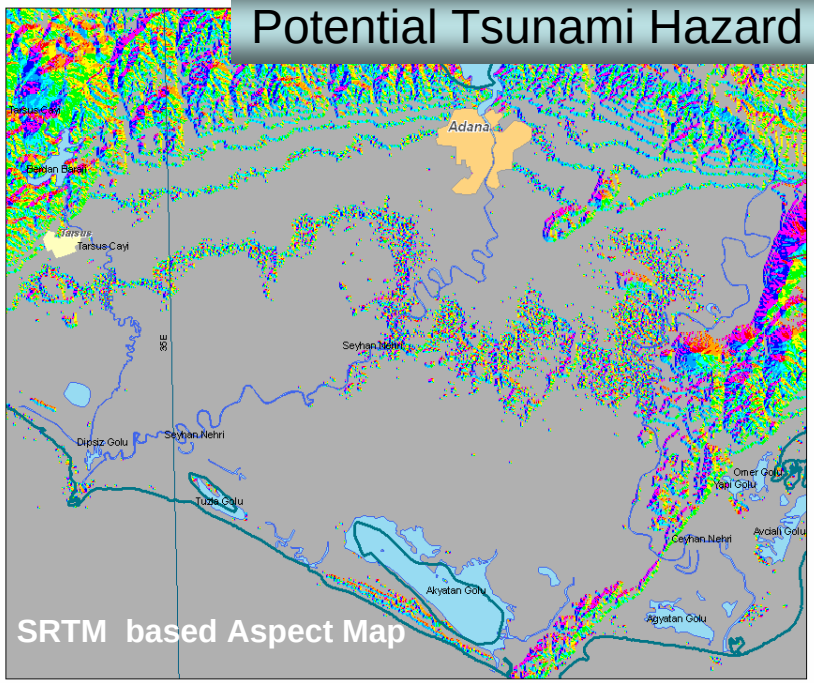
Overlay of LANDSAT ETM Image and SRTM based Morphometric Map (Minimum Curvature)

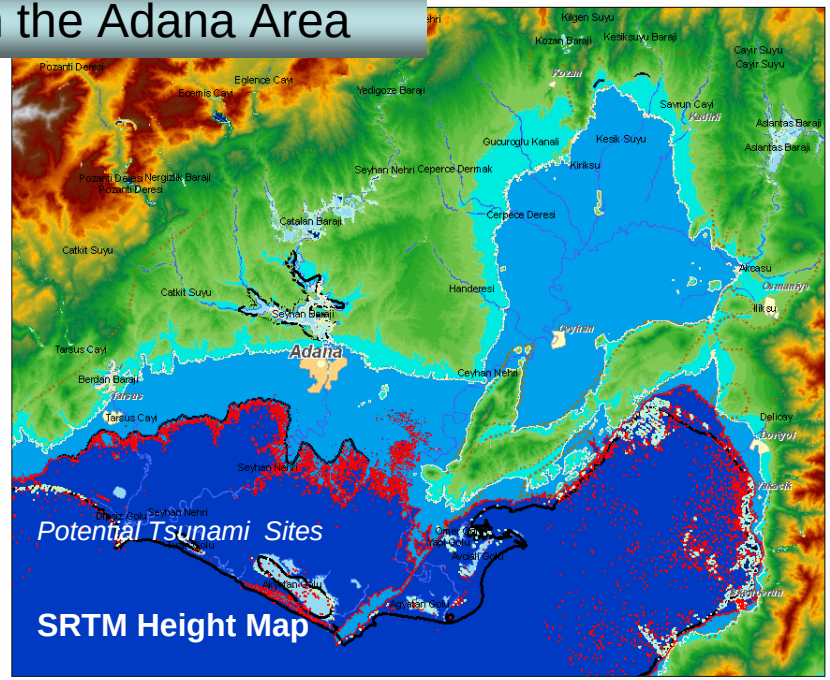
„Smoothened „ Morphology due to Abrasion by Tsunami-Waves and Erosion ?



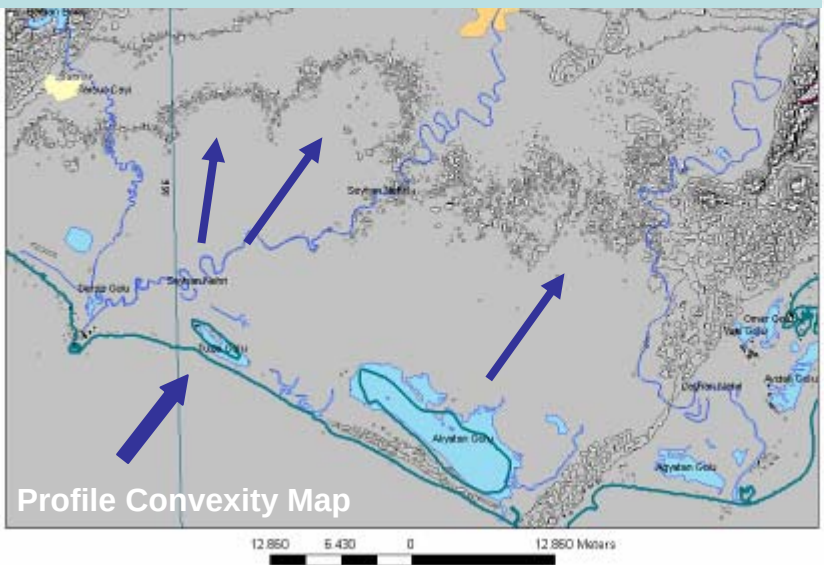
SRTM based Hillshade Map (120° Illumination)

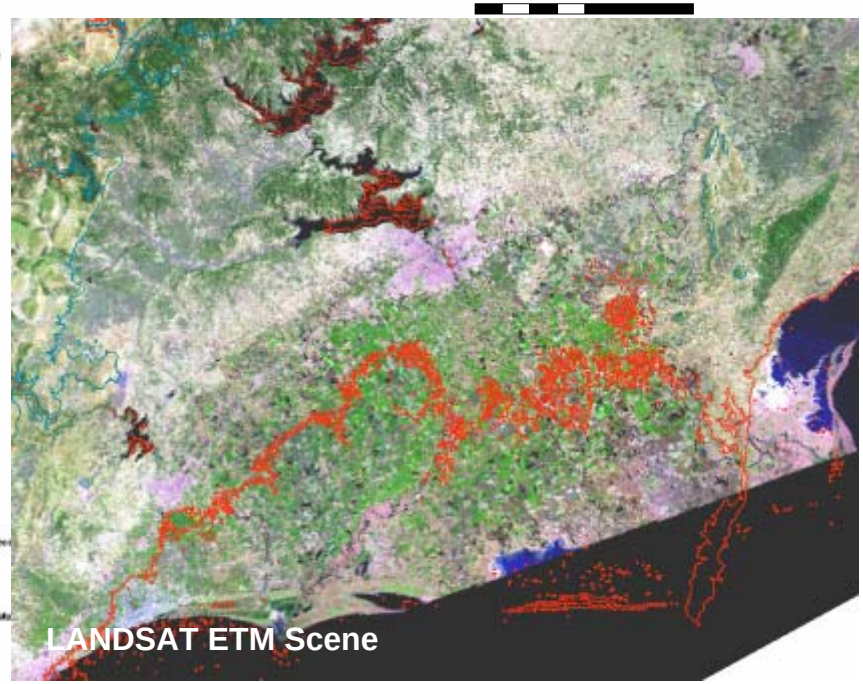
Potential Tsunami Hazard Sites in the Adana Area





The morphometric maps obviously show traces of flood waves as indicated by arrows. Potential tsunami hazard sites are presented on the height map in dark-blue colours (less than 10 m above sea level).





Conclusions

The design of a common GIS database structure - always open to new data - can greatly contribute to the homogenisation of methodologies and procedures of tsunami risk management.

Guidelines for the standardization of the GIS layer structure in a Tsunami Hazard Information System have to be elaborated.

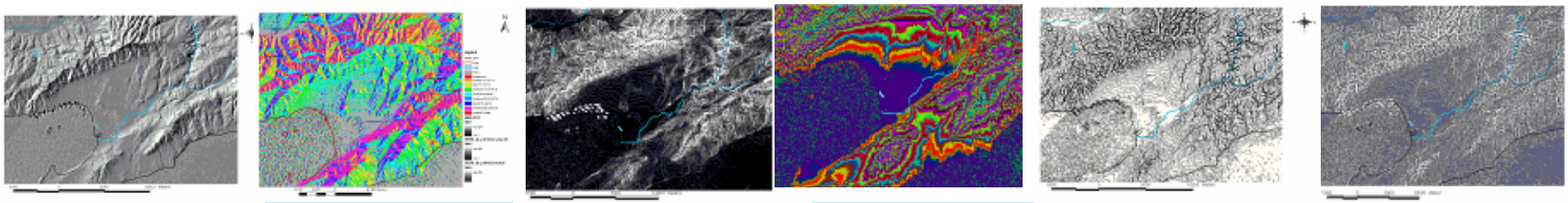
As one component of such a GIS the following approach is recommended :

- **extracting morphometric parameters based on DEM data and**
- **combining the resulting maps with satellite and other geodata.**

1. Step in a Tsunami Hazard Information System : Deriving DEM based Morphometric Maps

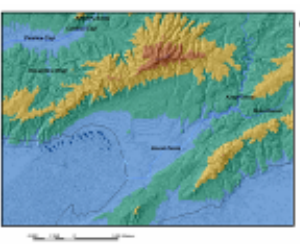
Deriving Maps based on SRTM Data

- Hillshade Map
- Aspect Map
- Slope Gradient Map
- Height Map
- Minimum Curvature
- Maximum Curvature



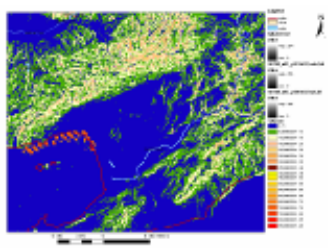
2. Step in a Tsunami Information System: Extraction of Causal Factors leading to Hazard Susceptibility

Overview of the geomorphologic setting

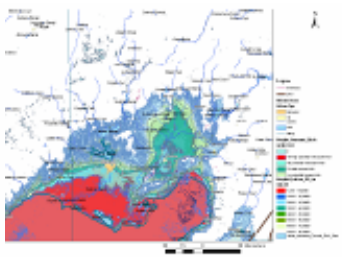


Deriving the orientation of slopes- seawards orientation

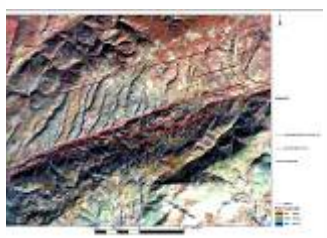
Deriving slope gradients >30°, creating slope gradient isolines



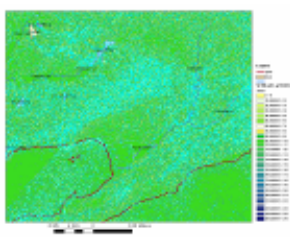
Detection of highest areas, or areas prone to flooding risk



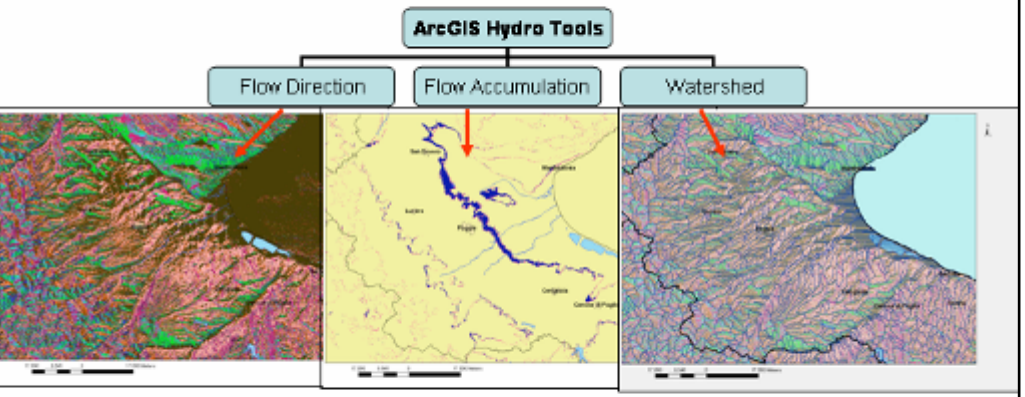
Detecting neotectonic movements



Deriving slopes with high curvature



3. Step in a Tsunami Information System: Deriving Hydromorphometric Properties (Morphologic Watersheds, Flow Accumulation,etc.) based on SRTM DEM Data using the Hydro-Tools of ArcGIS

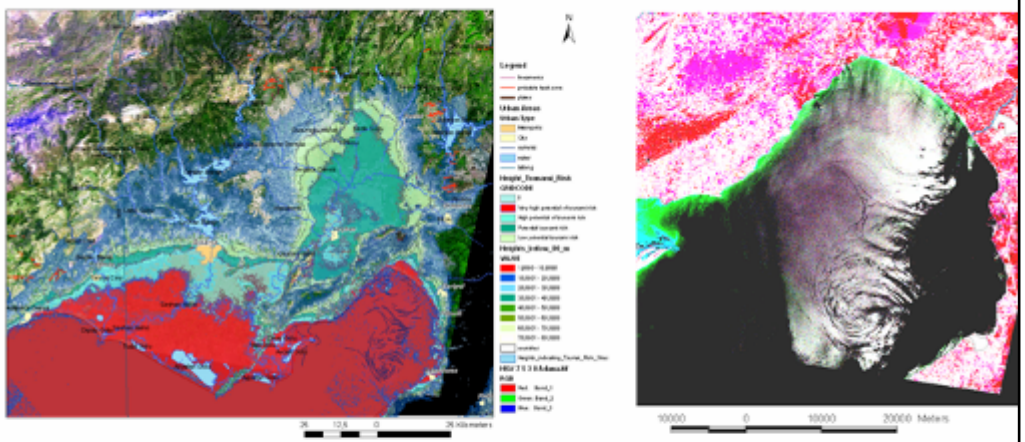


The **flow direction map** indicates the direction of flooding

The **flow accumulation** map indicates areas were floods will move and accumulate

The morphologic **watershed map** provides information of surface water run-off.

4. Step in a Tsunami Information System: Merging SRTM based Morphometric Maps with High Resolution Satellite Imageries and other Geodata



Evaluation of the LANDSAT ETM image in order to detect traces of the tectonic pattern, traces of neotectonic movements, potential areas of slope failures and currents of the sea surface

Remote Sensing and GIS Contribution

EWC III
Third International Conference on Early Warning
From concept to action

Meanwhile, the so-called Free–GIS software fulfilling the basic GIS requirements, as for example DIVA-GIS, MapWindow GIS, SAGA GIS, etc., can be used without costs.

Additional Free-GIS software is available also for the spatial analysis of DEM data.
Basic LANDSAT ETM and SRTM data are provided free of charge for scientific research purposes for example by the University of Maryland/ USA.

Therefore the use of the remote sensing and GIS technology for tsunami hazard site assessment according to the presented approach can be considered as being mainly a a question of *knowledge transfer*.

Thank You for Your Attention