Scientific Visualization for Geophysical and Remote Sensing Applications: Experience, Potential and Requirements

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Abstract

Many questions might confront any researcher, who is interested to have his results presented in front of his eyes in an appealing way. Questions such as:

- How far can he exploit the visualization software to show, experts and non-expert people, his findings or results in a convincing way?
- Is this visualization software is the proper one for his tasks?
- Can this visualization process play an important and active role in the interpretation process OR is it only a final stage for showing others some pretty colored figures, pictures and animations.

Furthermore, it is known that visualization can be considered as one of the final stages in the process of handling any kind of geophysical and remote sensing data. However, many researchers in this field consider that visualization is a luxury phase during the major data handling. Many of them deny that it is part of the interpretation process. We try here to prove the opposite.

To do so, five projects were discussed in this work are:

- Creation of DTM for whole Iraq and surrounding,
- Uplifting deformation due to hydraulic head difference in a faulted area.
- Monitoring of deformations in a water barrier dike in the Netherlands,
- Evaluation of Two Laser Altimetry surveys (AHN1 and AHN2) in the Netherlands.
- Presentation of atmospheric water vapor of Mexico City for InSAR signal corrections,

It is concluded in this work that visualization process, using Fledermaus software, proved to be quite impressive and important stage especially when there is a huge amount of data to handle. Its ability to - calculate the statistical parameters to describe the surface, creating profiles, draping different layers or surfaces on each other, gridding non gridded data, the ability to make comparison and/or correlation between the different obtained surfaces/layers, handling 2D/3D polygon lines, differentiating and handling many data formats, converting / editing geo-references and many other features. All of these features with addition to the direct interactive display of the data add an extra momentum which leads to the conclusion that the visualization stage should be considered as part of the interpretation process.

Key word: - Scientific visualization, Geophysical, Remote sensing applications.

Introduction

The human visual system has an enormous capacity for receiving and interpreting data quickly and efficiently and therefore should be an integral part of any effort to understand

complex data. It has been estimated that well over half of the brain is absolutely dedicated to things we see and there is the enormous capability of the human brain to detect patterns in data, **[1]**. 3D visualization seeks to present data graphically in an intuitive fashion to expose information hidden in data and provide new insight. This means that the 3D data visualization is part of the solution to meet this challenging processing and analysis problem. It is inevitable that without the complete picture, maximum value will not be obtained and information will be missed. A significant area for visualization is the preview of data. Currently, it is common to use 3D data visualization only in the latter stages of processing once it is believed that the data are clean and ready for final analysis.

Interactivity provides a dual benefit. Being able to move around the 3D scene and view it from any position or orientation, further aids in the interpretation of the scene.

Motion also assists in extracting information from the data. If the objects can be analyzed while they are in motion, the observer will see more information than if the image is static.

If we consider surface data, there are several techniques that are commonly used to visualize data. These include pseudocoloring, by selecting different color maps, ready ones or designed by the user. It will make the surface highlighted and more interpretable. Another visualization technique commonly used is illumination and shading. Here a light source is added to the scene and the surface is shaded accordingly. Applying a lighting model to a surface greatly enhances the features of the visualized data, which leads to more effective analysis like increasing dramatically the ability to perceive certain types of terrain features such as mountainous relief.

These aspects of visualization and many others are implemented in a software system known as Fledermaus for the interactive visualization and analysis of data in 3D. Fledermaus incorporates a number of sophisticated rendering, viewing and data manipulation tools. What is perhaps most important is the fact that these tools are combined in a highly interactive integrated package, [2]. Additional and /or supportive softwares were used in completing the process of visualization such as the Adobe Photoshop [3], the Keyhole Markup Language Editor such as the Northgate KML editor, [4], Google Earth and Generic Mapping Tool (GMT), [5].

Furthermore, it is debatable whether visualization should be considered as one of the final stages in the interpretation process when handling any kind of geophysical and remote sensing data. However, many researchers in this field consider that visualization is a luxury phase during the major data handling. Many of them deny that it is part of the interpretation process. We try here to prove the opposite.

Many projects which have general trend in visualization of remote sensing and sonar data are presented here. Generally, the data involved are obtained by different sources of airborne or space-borne sensors that are set to observe the earth surface such as Interferometry Synthetic Aperture Radar (InSAR), [6] data. These data has been obtained by many satellites such as ENVISAT, [7], TERRASAT, [8] ERS, [9] and Space Shuttle Topographic Mission (SRTM), [10]. Airborne data by many earth observation sources such as laser altimetry (LiDAR), [11][12][13] are also dealt with to create some multi – dimensional models. Digital Elevation Models such as Digital terrain Models (DTM) and Digital surface models (DSM), [12][13] are created to show the close- to- reality earth surface.

Five examples are stated below with some brief comments about the nature of the data as well as the processes and softwares involved. One of the main goals of this work is to shed some light on the potentials and abilities of visualization in handling remote sensing and geophysical data. The five projects stated below were selected to demonstrate the different features and abilities of visualization. Our main goal is to show the readers as well as the professionals the importance of visualization in remote sensing and geophysics fields and whether visualization is part of the interpretation process of data or not. Any details of the different processes were deliberately avoided due to lack of space. Some important features in visualization, such as surface differences, adding extra layers, enhancement of resolution, conversion between data formats, and many more are not mentioned here too.

Project One: Creation of a DTM for Iraq and surroundings from SRTM data

Height data for Iraq and surrounding areas is obtained from the Shuttle Radar Topography Mission (SRTM), [10]. A DTM model is created and some Generic Mapping Tools (GMT), [5] color bar has been used, see figure (1) below.

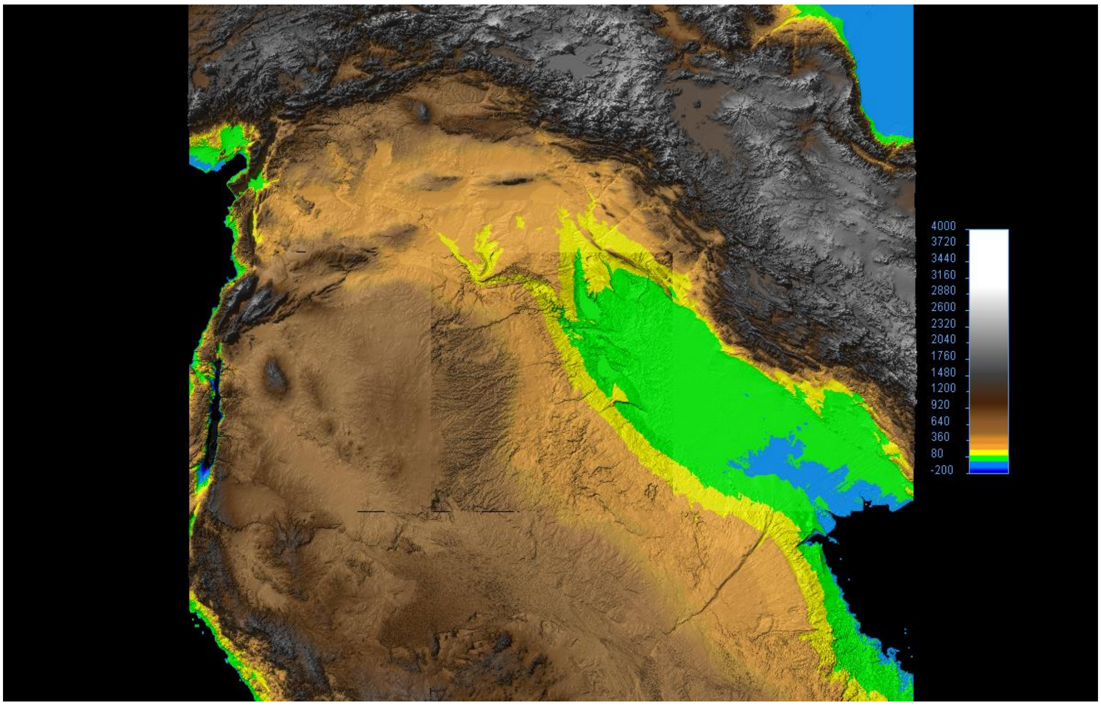

Figure (1) A DTM of Iraq and surroundings obtained from SRTM data. Color bar represents heights in meters. The blue color represents the zero and higher level.

In this project, the data were downloaded from the USGS and the NASA sites, [14] with pixel resolution 90 m. The area covers Iraq as well as part of Turkey, part of Iran, part of Jordan, part of Syria, part of Saudi Arabia and whole Kuwait.

This DTM is created using Fledermaus software package, [2] and the color map file was designed by the author to enhance the different topographic/ geomorphologic features that are present in the area. This example show the ability of visualization to analyze the radar 3D data to bring close to reality the whole geomorphologic features such as the mountains, the fluvial plain, the desert, the alluvial fans, the major lineaments and faults and many others.

It is so clear that visualization succeeded to outline the alluvial plain limits as well as the mountainous regions. So many other features are demonstrated here such as the low land and marshes. It has been succeeded to make a mosaic textured DTM 3D surface to the whole area. But the file became so large to go on dealing with it.

Project Two: Geleen Fault - Zuid Limburg, The Netherlands – Fault and surface uplift- Surface uplift due to rising water in an abandoned coalmine.

The water exerts an uplifting hydro-geologic piezometric pressure on the upper impermeable layers resulting in increasing pore pressure inside the sediments and resulting in an uplifting of layers above the mine. This deformation has been detected by InSAR data collected by the ERS1 & ERS2 satellites, [9]. The Interferometry Synthetic Aperture Radar (InSAR) data was provided by the MGP- DEOS, TUDelft University, The Netherlands.

The DTM of the deformed area is obtained for different years (between 1992 to 2001), three year deformation stages are presented here (1992,1999 and 2001). A textured image for the radar data is demonstrated in figure (2). The DEM of the deformational events for the different years are presented in, (Figs. 3, 4, and 5).

The DTM of the deformation stages were dealt with for the whole span of time and the color map file were designed to represent the deformation (uplifting and subsidence) in the area. The shading and illumination features were applied here to enhance the deformation events.

Textured DTM is created too by draping the radar image and /or the panchromatic space image on the created DTM 3D model. The deformation speed is in mm/year and the vertical axis is exaggerated for the sake of demonstration.

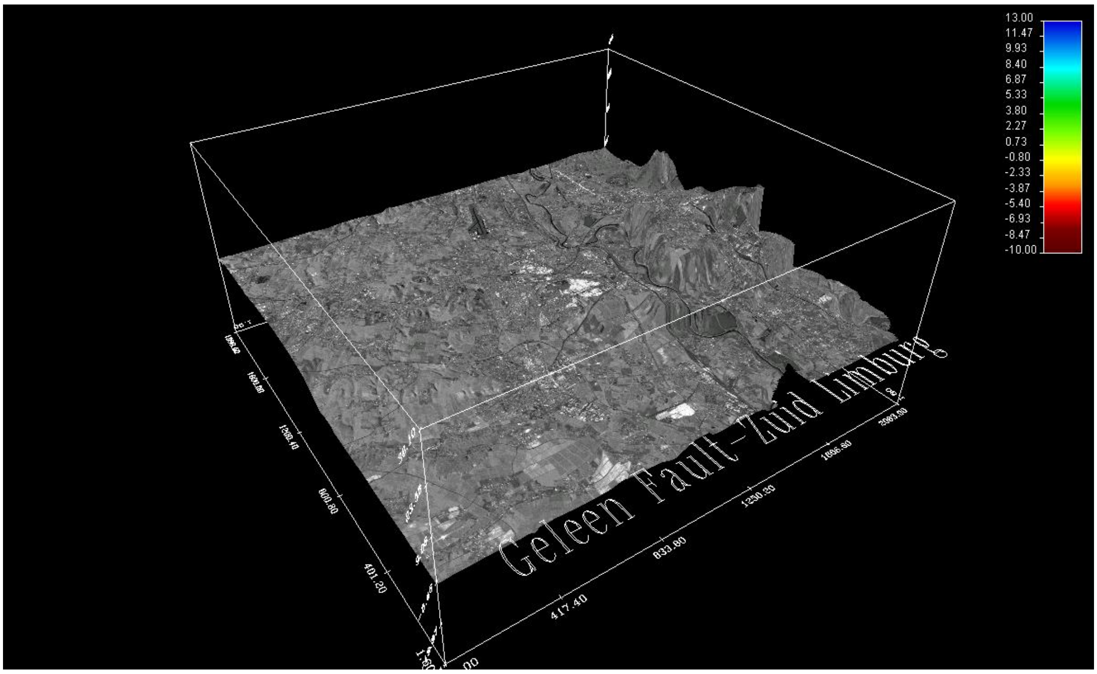

Figure (2) The Geleen Fault area in Zuid Limburg in a textural three-dimensional form resulted from overdraping of a radar image over a DTM data.

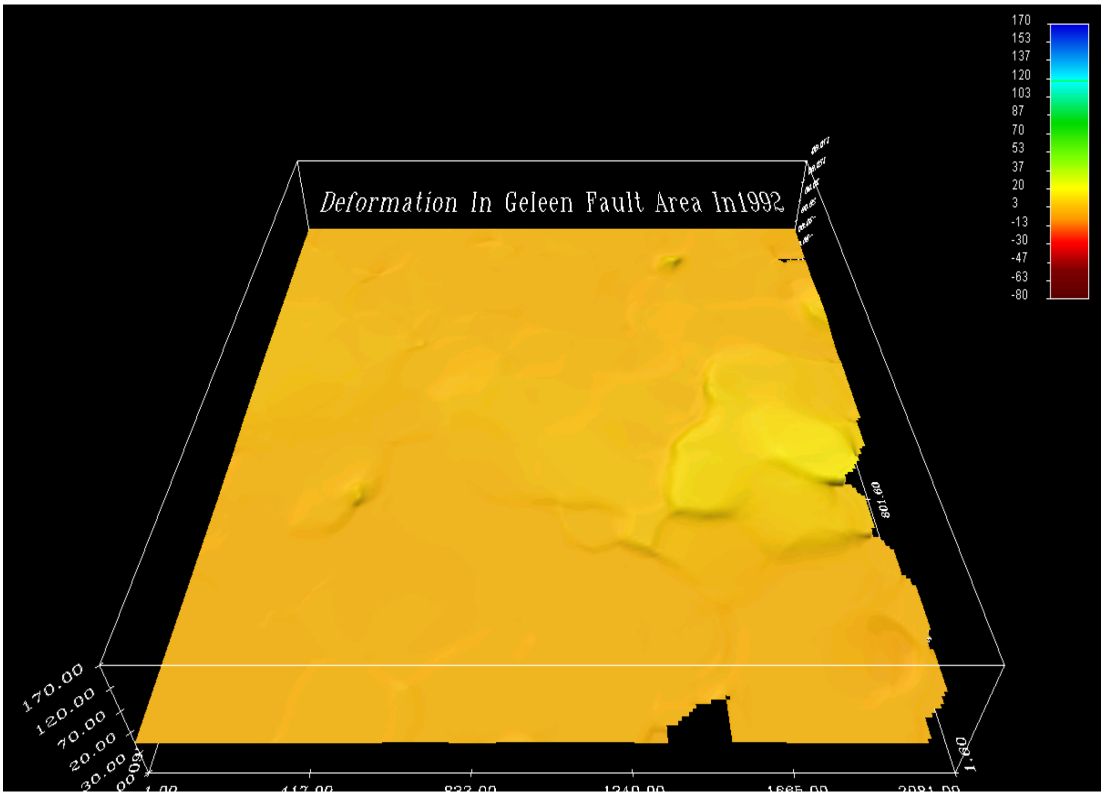

Figure (3) A DTM of the deformed area of Geleen Fault – Zuid Limburg during the year 1992.

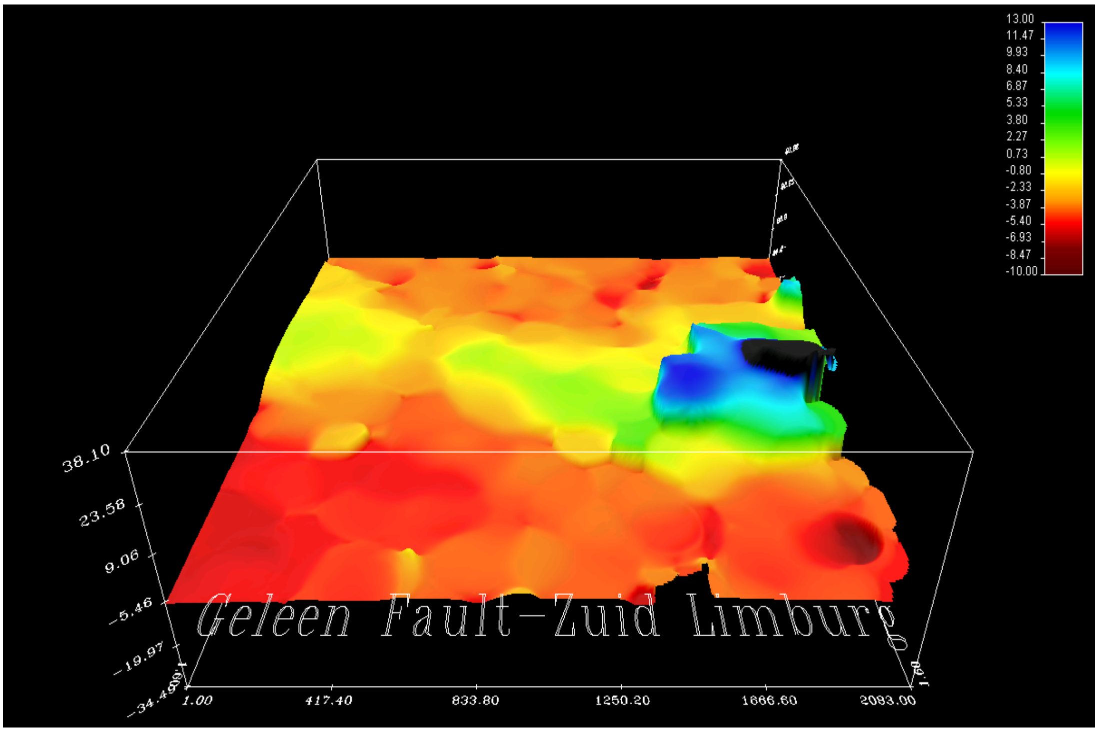

Figure (4) A DTM of the deformed area of Geleen Fault – Zuid Limburg during the year 1999

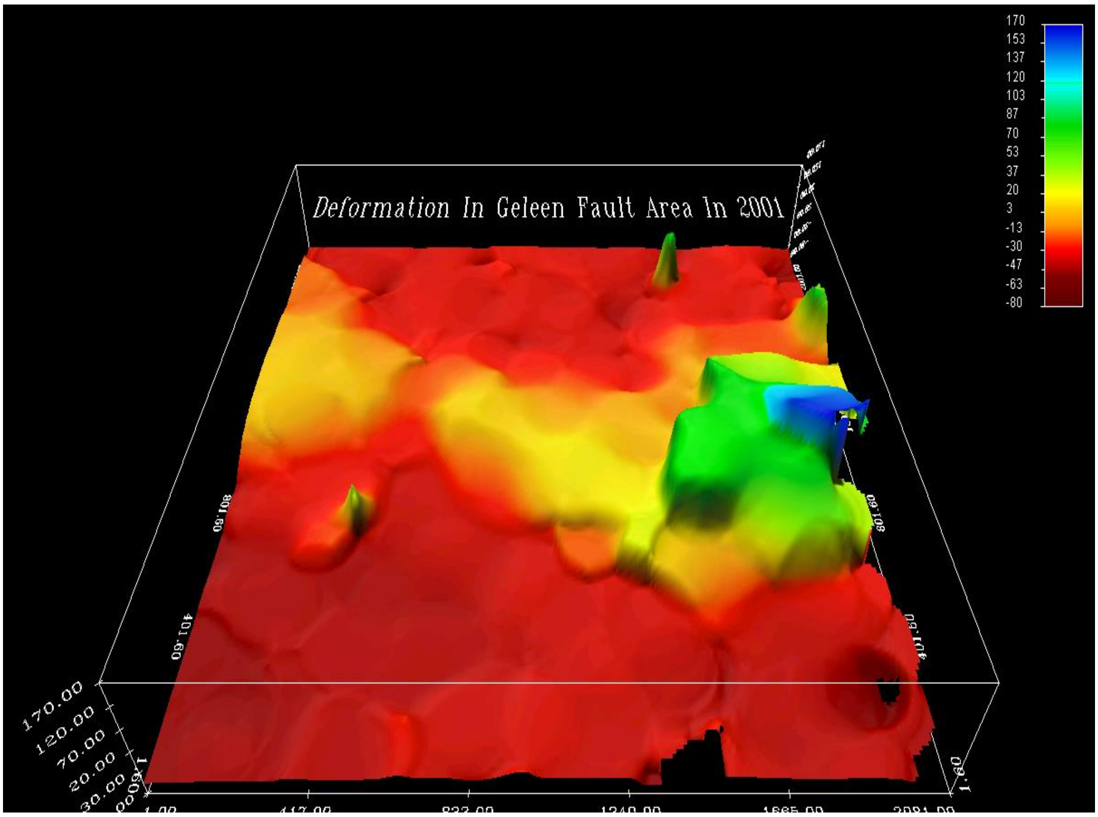

Figure (5) A DTM of the deformed area of Geleen Fault – Zuid Limburg during the year 2001.

Figure (6) a textured DTM of the deformed area of Geleen Fault – Zuid Limburg during the year 2001.

<u>Project Three</u>: Hondsbosschezeewering Dike – North Holland case – Monitoring for any deformation.

Monitoring dikes and dams in the Netherlands is a very crucial job due to the fact that most of this land is below sea level and the dikes and dams play an important role to prevent flooding of water. There is a network of dikes and dams constructed for this purpose. The Hondsbosschezeewering Dike is part of this network and it is located in North Holland, Figs. (7 and 9).

One of the ways to monitor these dikes is by detecting any kind of deformation which might occur in them. Detection of surface deformations using InSAR method is used for this monitoring purpose. To achieve this goal, InSAR surveys were performed using many radar satellites such as ENVISAT-ASAR, [7] ERS, [9] ALOS-PalSAR, [15] and TerraSAR-X,[8], Figs.(8 and 9). Furthermore, high resolution LiDAR and optical airborne surveys were performed along portion of this dike, Figs. (7, 11 and 12). The data of this project was provided by the MPG-DEOS of TUDelft.

Many visualization processes were performed here to handle airborne/ spaceborne data such as creation of 3D digital terrain models (DTM) and the textured DTMs after overdraping optical images on them, Figs.(7, 10,11,12 , 13 and 14). Fledermaus software was used for this purpose and for other functions.

Deformation vectors (the vertical and along the line of sight (LOS) components) were determined from the InSAR data and the data were superimposed on the textured DTM of the dike, Figs. (13 and 14).). A Simple 3D model of the dike and a model for the real location of the three radar satellites covering the area of the dike were done for the purpose of measuring the vectors of deformations. Google Earth, [16] Northgate KML editor, [4] and Adobe Photo Shop, [3] softwares were used for achieving this purpose, Figs. (7, 8 and 9).

Some zoomed 3D DTM portions of the dike are illustrated here to show the ability of the DTM 3D models to present any small details on the ground, Fig. (10).

Contoured DTMs and textured DTMs are also illustrated here for the purpose of showing the heights and the 3D form of the dike, Figs. (11 and 12).

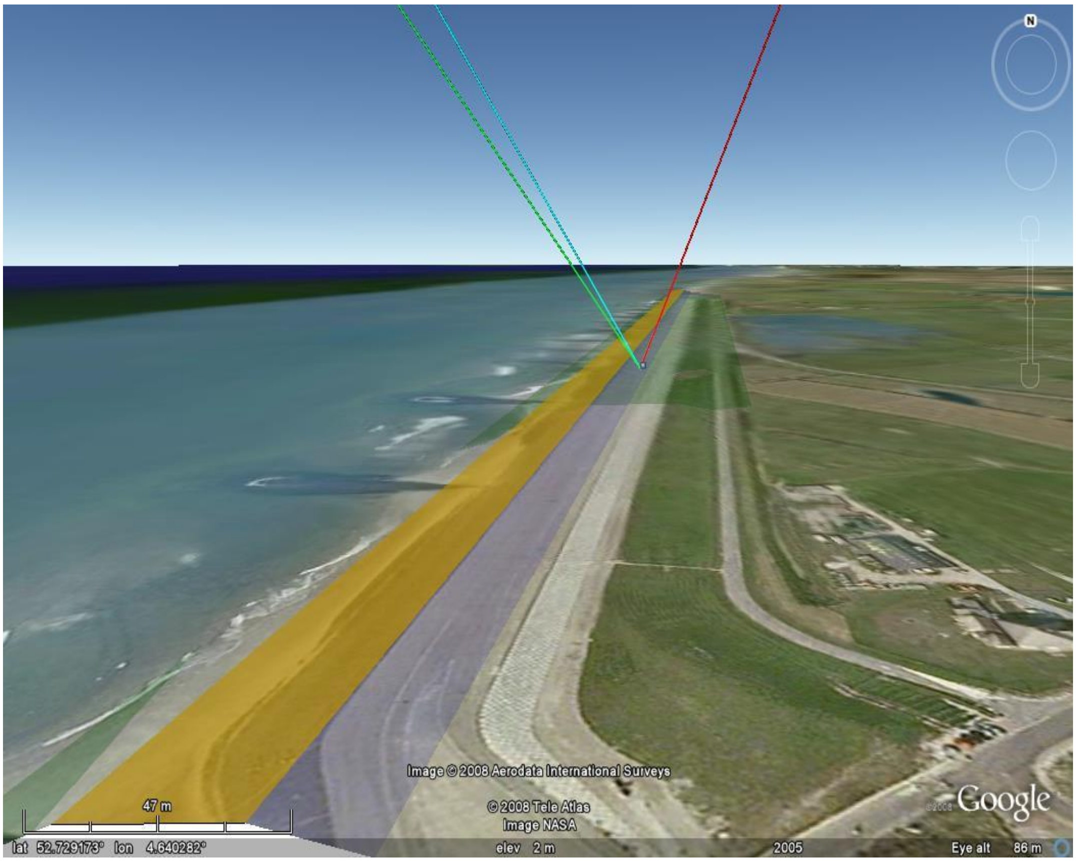

Figure (7) a 3D model superimposed on the dike with three lines connecting a point on the dike to three satellites (ERS, TerraSAR-X and PalSAR-

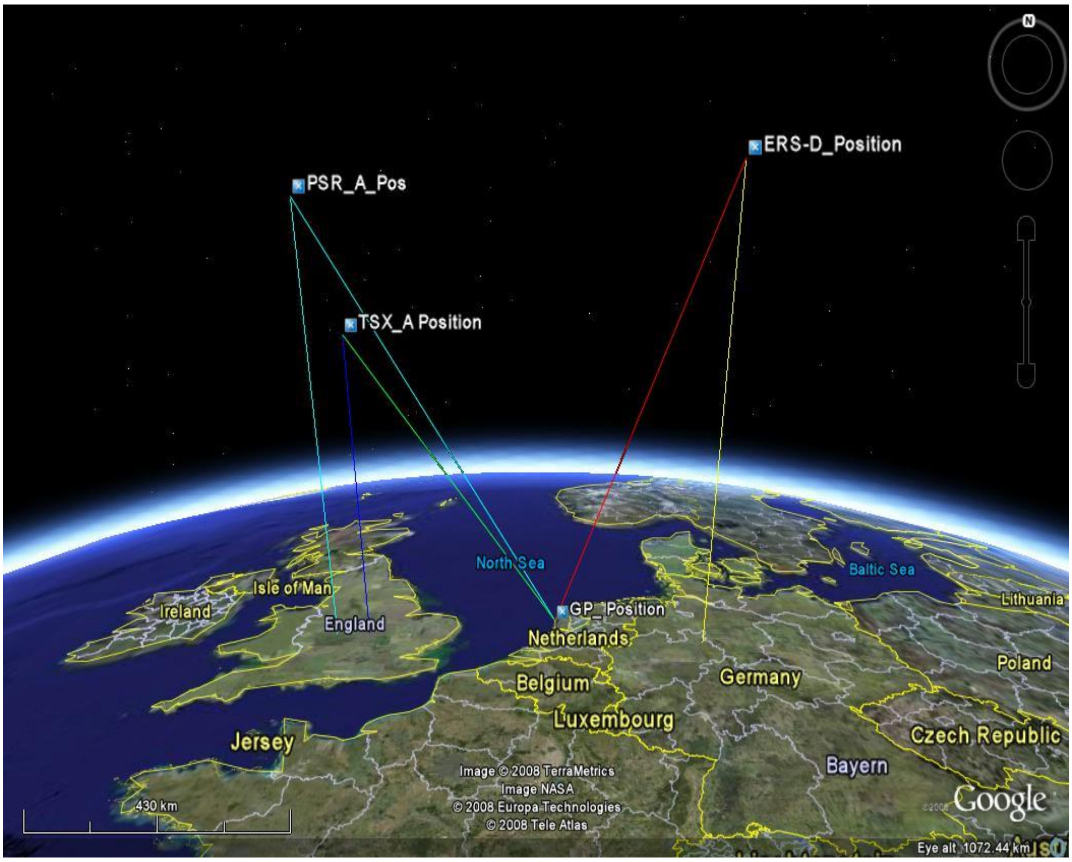

Figure (8) the positions of ERS (descending), TerraSAR-X (ascending) and PalSAR (ascending) covering the same dike area.

It is concluded from this work on this project that visualization in this project played a quite important role in the process of interpretation. It helped the researchers to measure the deformation vectors which take place on the dike. The constructed two models for the location of the satellites and the dike gave the researchers a quite clear view which helped in measuring the deformation vectors.

Quite detailed 3D DTM, textured 3D DTM and contoured forms, Figs.(10,11 and12) helped in the examination of the dike from any real damage as well as giving a ready descriptive real shape of the dike. This can help always during the process of the monitoring.

Figure (9) three positions of ERS (descending) and looking at the Hondsbosschezeewering Dike.

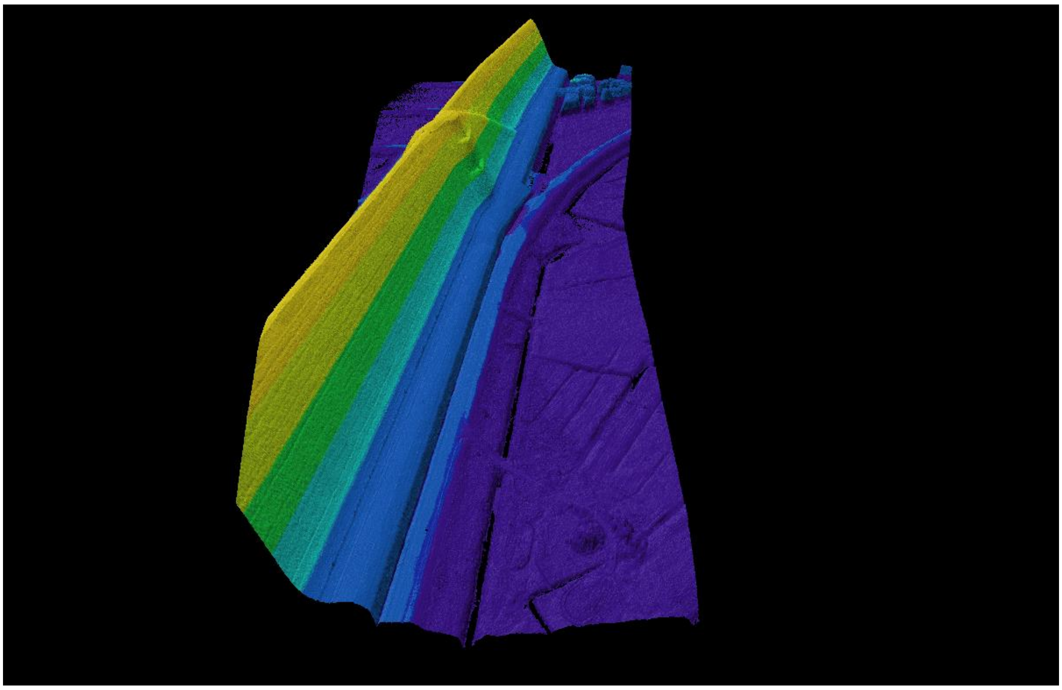

Figure (10) a zoomed DTM portion of the dike showing some details of some features.

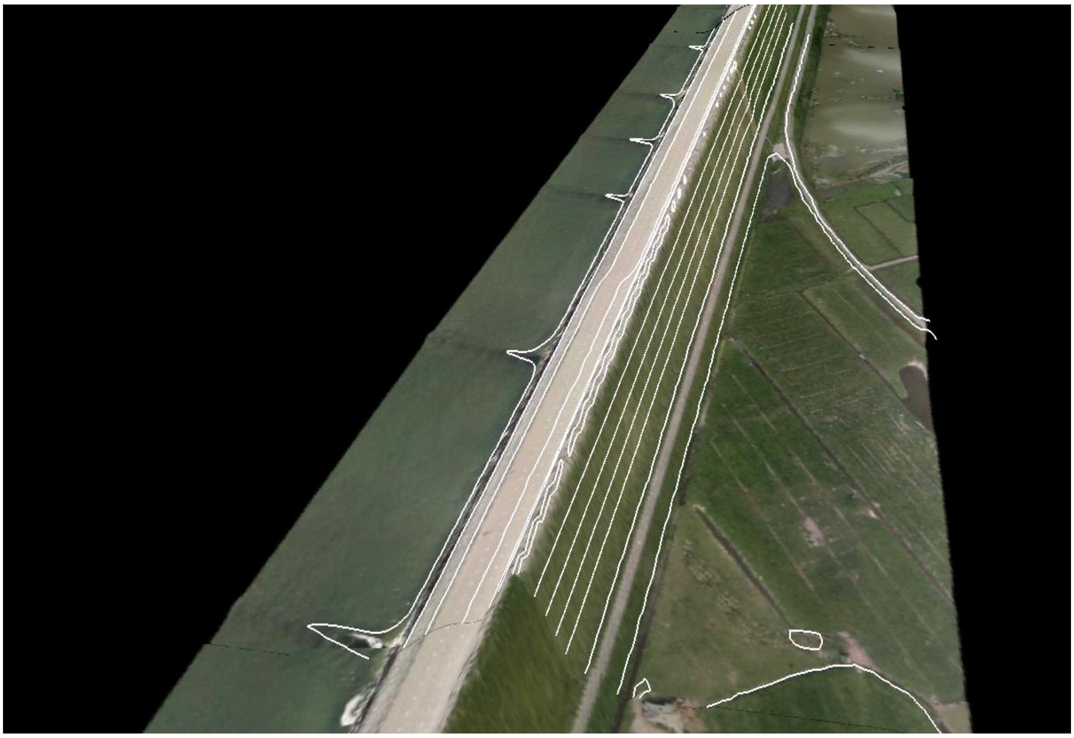

Figure (11) a zoomed textured DTM portion of the dike showing some details of some features with addition of contour lines representing the heights.

Figure (12) a side perspective view of the textured DTM showing the Hondsbosschezeewering dike

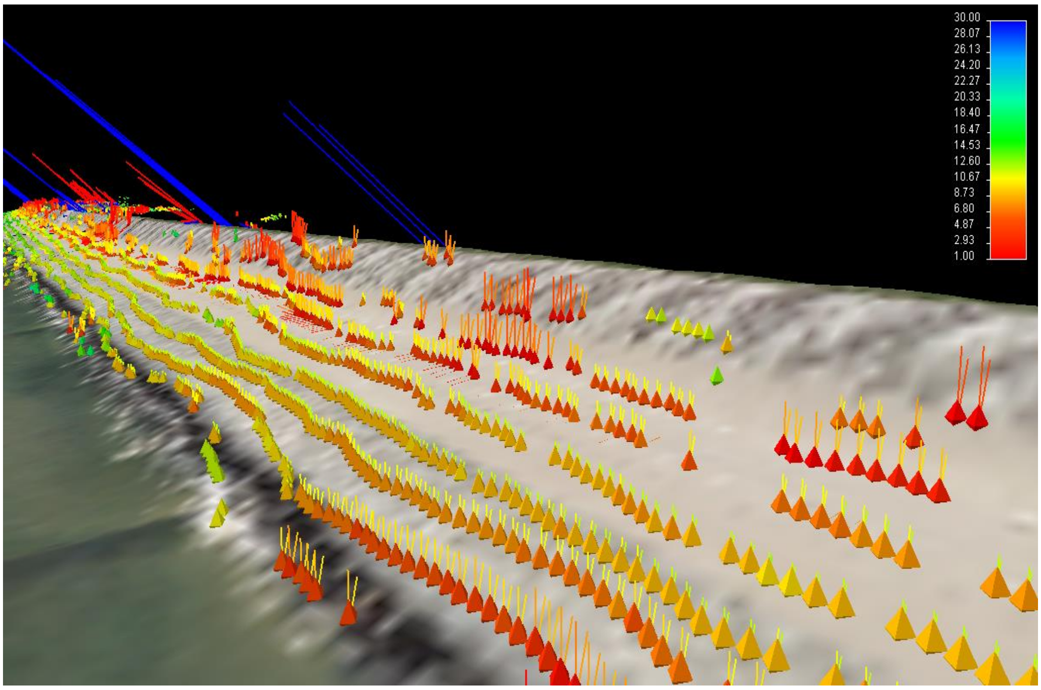

Figure (13) Vectors of deformation of many Persistent Scatterer Points superimposed on the textured DTM of the Hondsbosschezeewering dike. InSAR data is obtained by ERS satellite.

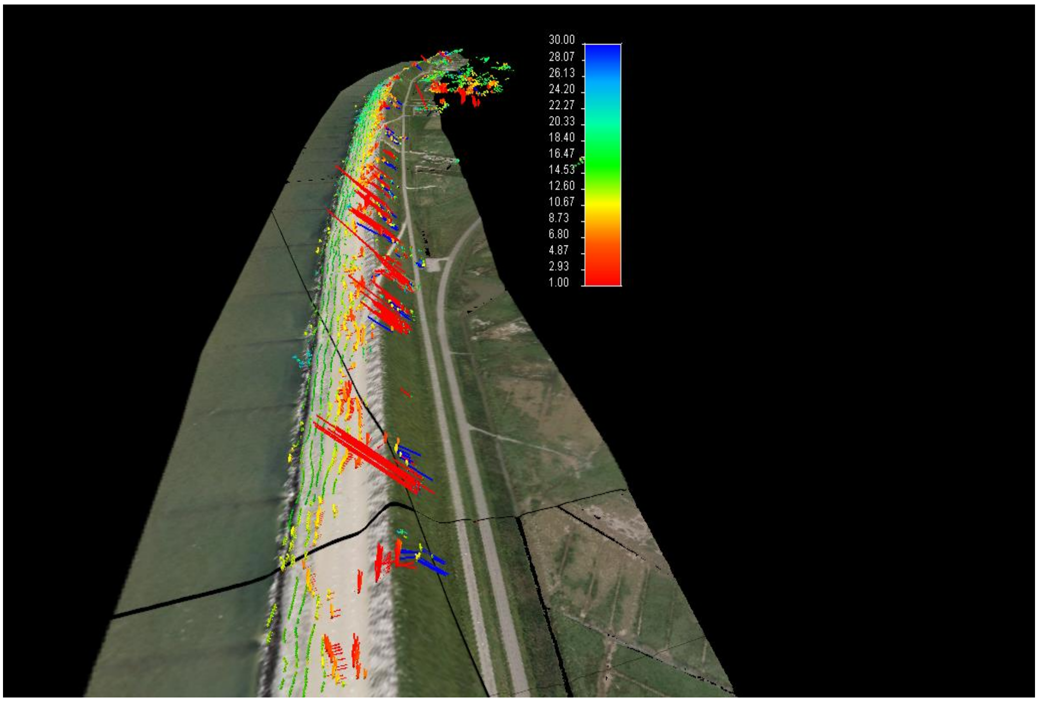

Figure (14) Vectors of deformation of many Persistent Scatterer Points superimposed on the textured DTM of the Hondsbosschezeewering dike. InSAR data is obtained by ERS Satellite

Project Four: Evaluation of Two Laser Altimetry surveys (AHN1 and AHN2) in the Netherland.

Two main LiDAR surveys (AHN1 and AHN2), [17] at different times were performed in the Netherlands. One of the objectives of this study is to evaluate the two surveys. The data which has been chosen is that of an area which is located in Zeeland, The Netherlands. Data of 5m resolution is chosen. Filtered AHN1 data and filtered and unfiltered AHN2 data were treated. A mosaic DTM of filtered and unfiltered data are illustrated in Figs. (15 and 16). Surface differences, statistical surface evaluations, slope surface evaluation and textured DTMs were done, Figs. (17, 18, 19 and 20).

This study leads to conclude that there are quite difference between the different surveys as well as between the filtered and unfiltered data.

Many visualization features which help in the interpretation of the data is illustrated here, among which the statistical evaluation of the surface, the 2D profiles along specific direction and the slope representation of the surface(s). Mosaicing of data for the whole area is used to gather the data in one frame is another feature of helping us in having a comprehensive and complete view of the collected data. This will help in evaluating the results during the process of interpretation.

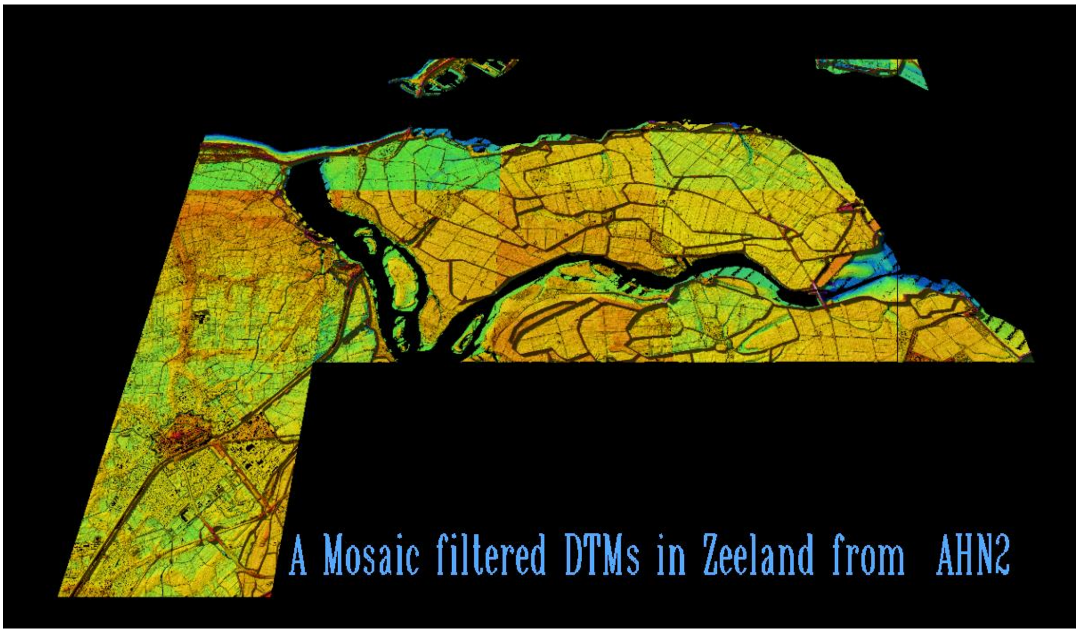

Figure (15) Mosaic DTMs obtained from filtered data from AHN2 survey.

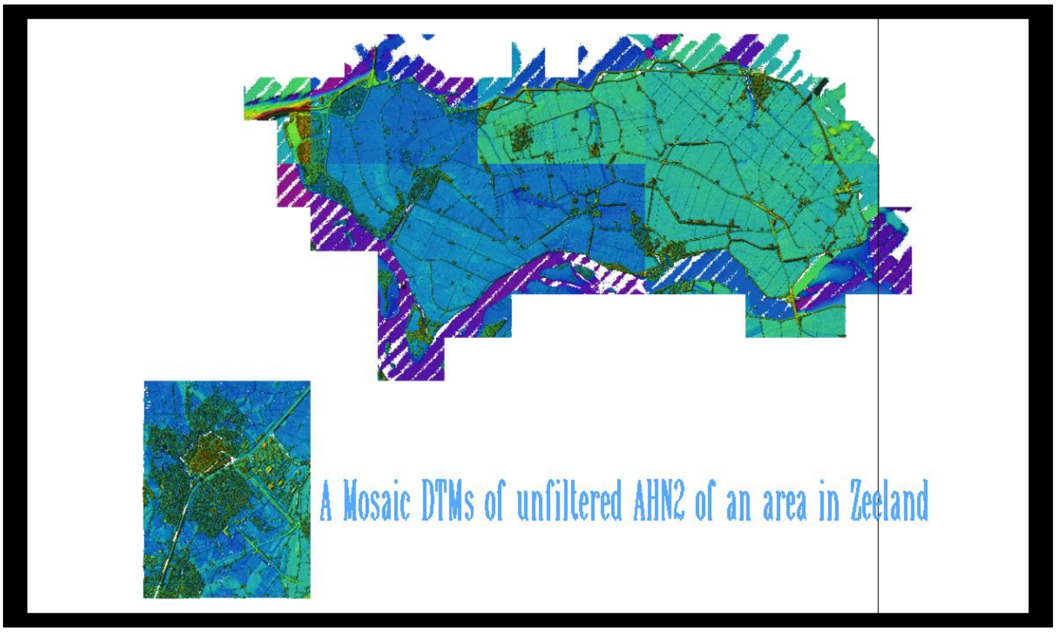

Figure (16) Mosaic DTMs obtained from unfiltered data from AHN2 survey.

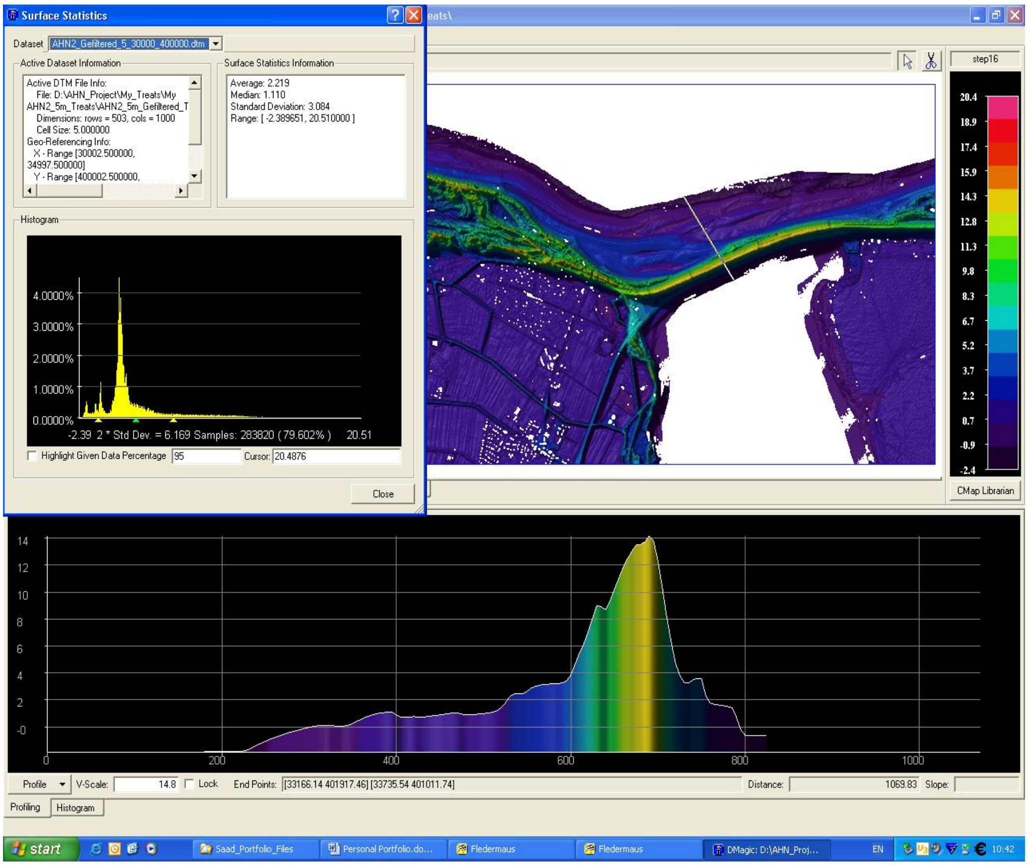

Figure (17) Statistical parameters and profile of a frame of a dike area obtained from filtered data of AHN2.

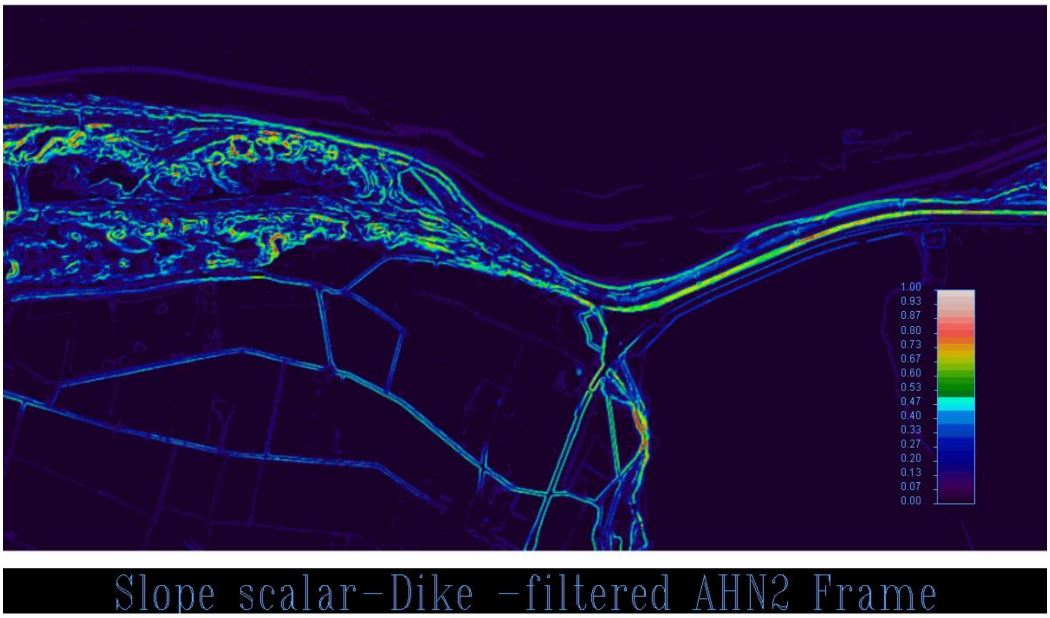

Figure (18) Slope surface of the dike frame

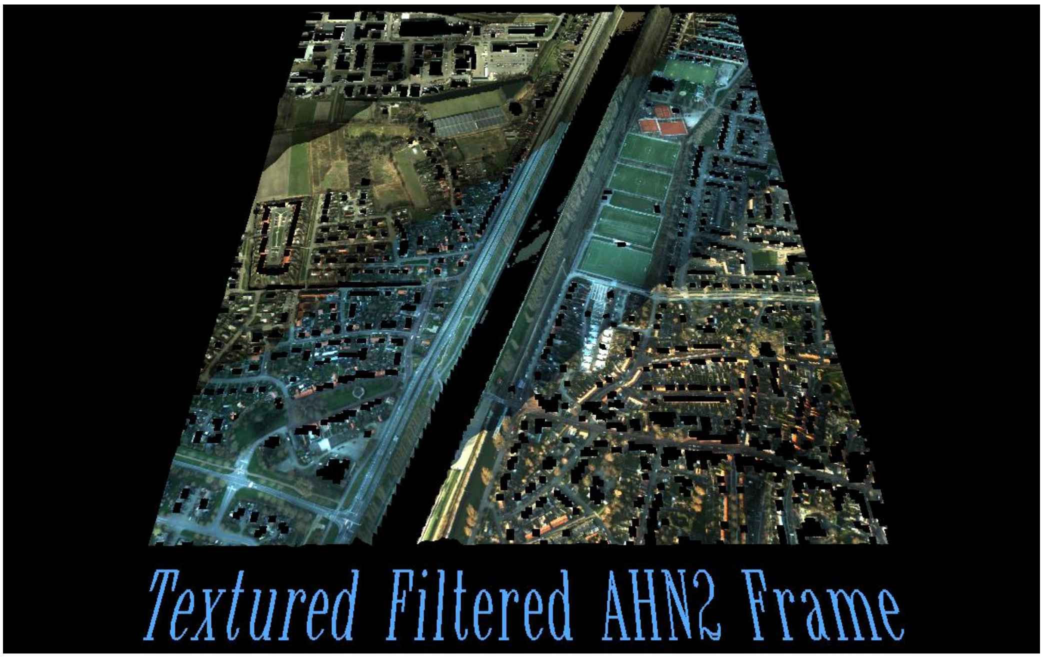

Figure (19) Textured DTM obtained by draping optical image on its DTM for filtered AHN2 data.

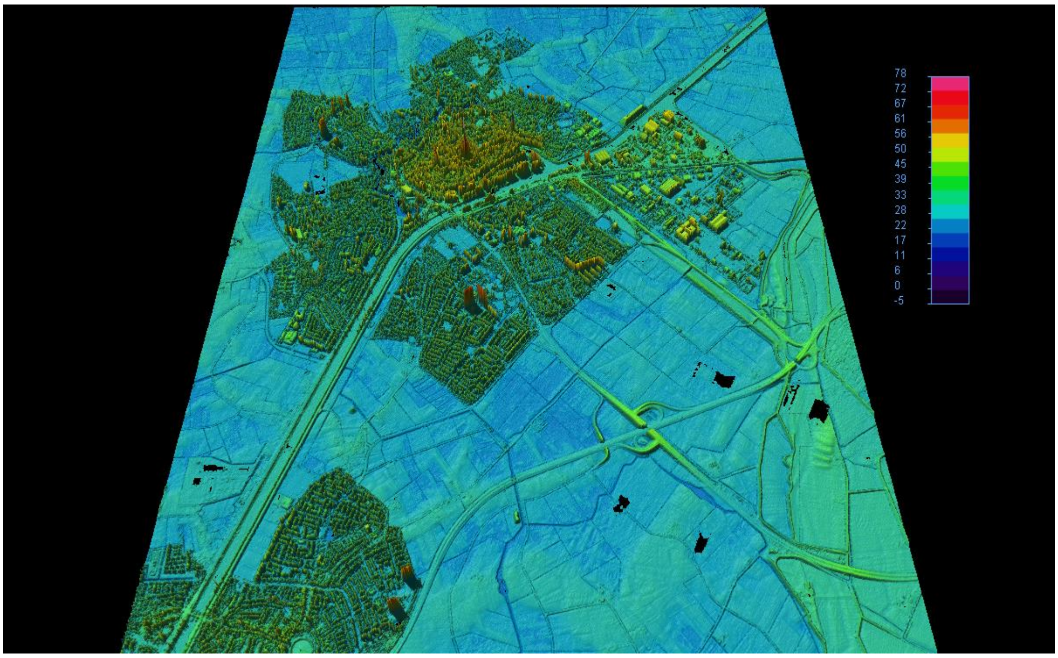

Figure (20) DTM 3D frame obtained from AHN1 filtered data.

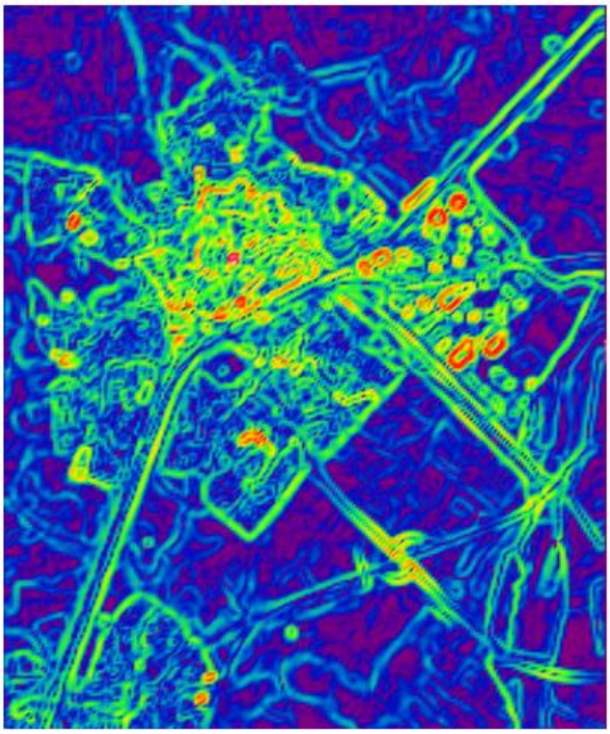

Figure (21) Slope surface of the same frame of fig. (20) Obtained from AHN1 data.

Project five: Presentation of the atmospheric water vapor of Mexico City – A case study for atmospheric corrections for InSAR studies.

A research work of the atmospheric effects on the radar signals of the InSAR data is going on since few years in the MGP-DEOS- Delft University of Technology. Part of the research work is to show the effect of the water vapor and its relation with the topography. Mexico City, as an example, were chosen here for this purpose. One of our tasks was to show the distribution of the water vapor on the whole Mexico City region. Two presentations are shown here; one represents a shaded DTM of the water vapor over the city, Fig. (22) and the other shows contoured values of the water vapor draped over a DTM of the morphology of Mexico City area, Fig. (23). Shaded surfaces with illumination is illustrated here to show the water vapor concentration and its relation with topography. This will help in the interpretation approaches. Contour lines of the water vapor values were draped on the DTM surface, as a layer was so successful to show how far the relation between the moisture contents in the atmosphere and the topography of the area. It is so clear that the lower regions/ areas of the city has quite low water vapor ratio whereas the high regional areas have high ratios of water vapor. This fact will be taken in consideration by the researchers in this field for InSAR signal corrections.

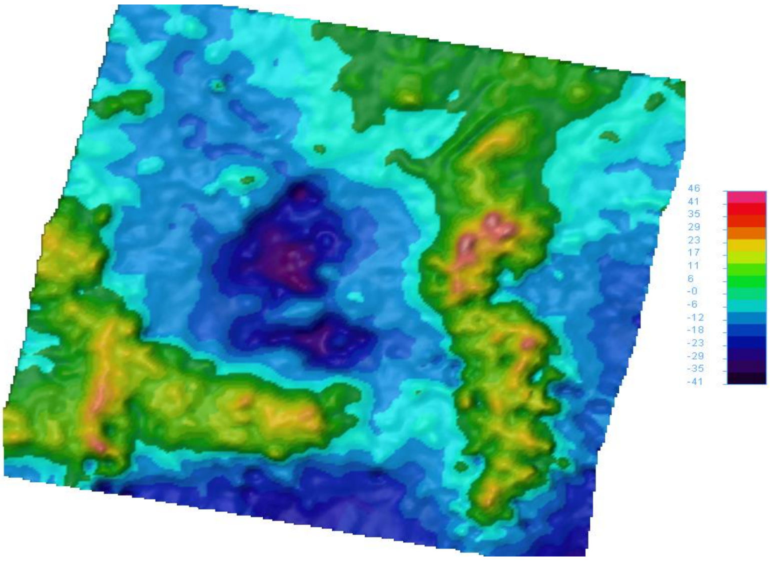

Figure (22) a shaded DTM of the water vapor over Mexico City.

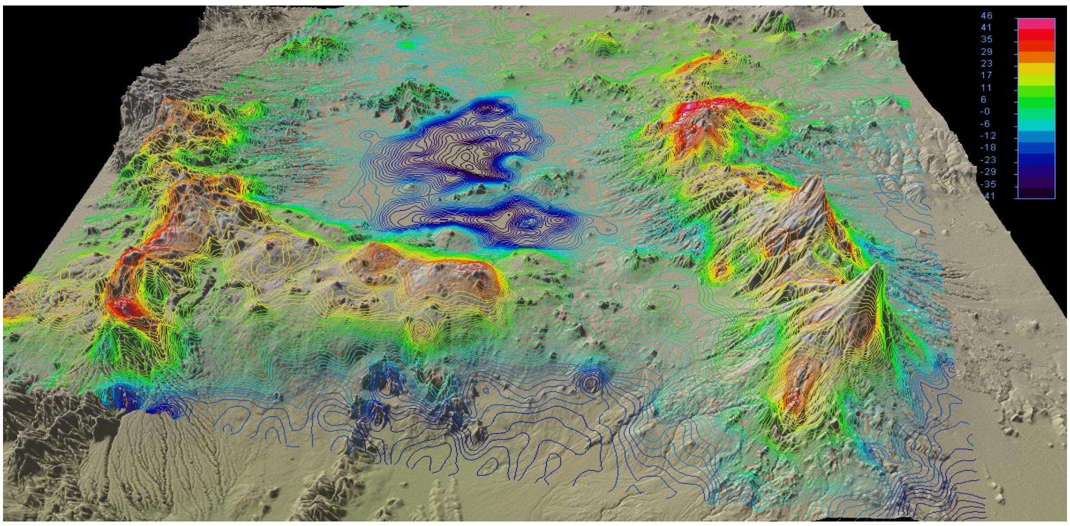

Figure (23) Contour lines representing the distribution of the water vapor draped on a DTM representing the morphology of Mexico City. Blue colored contour lines in the middle, located on the heart of the city, represent low ratios of water vapor whereas high water vapor ratios are presented in the high-level areas with red color contour lines.

Conclusion:

It is concluded in this work that visualization process, using Fledermaus package, Google Earth, Adobe Photoshop and other additional softwares, proved to be quite impressive and important stage in the process(s) of handling remote sensing and/ or geophysical data. Fledermaus software proved to be a quite efficient package of softwares compared with other visualization softwares especially when we have huge amount of data to handle. Its ability to:

- create 3D DEMs for the 3D data with addition to any extra attributes.
- using the direct interactive way of display and creating animation makes the way of displaying the data so clear and easy for interpretation refining.
- calculate the statistical parameters to describe the surface.
- creating profiles.
- draping different layers or surfaces on each other.
- Gridding non-gridded data.
- The ability to make comparison and/or correlation between the different obtained surfaces/layers.
- handling 2D/3D polygon lines and adding them to the outputs as additional layers.
- Differentiating and handling many data formats.
- converting / editing geo-references.
- Mosaicing of different scenes.
- And many other features.

All of these features with addition to the direct interactive display of the data adds an extra momentum which leads to the conclusion that the visualization stage should be considered as part of the interpretation process.

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[15] http://www.palsar.ersdac.or.jp/e/index.shtml

[16] http://earth.google.com

[17] http://www.ahn.nl/

تطبيقات التقديم المرئي للبيانات الجيوفيزيائية والتحسس النائي: الخبرة والامكانيات والاحتياجات

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الخلاصة

هنالك الكثير من الاسئلة تطرح من خلال الباحثين، الذين يعرضون بياناتهم ونتائجهم بالطرق المرئية الاستعراضية مثل – ما مدى امكانية البرامج التي استخدمها لاظهار بياناتي وهل فيها المواصفات الكافية لتلبية توضيح النتائج؟

-وهل ان البرنامج هو الامثل لهذا الغرض ؟

– هل ان طرق الاستعراض المرئية التعدد الابعاد قد نجحت في ان تكون جزءا من عمليات التفسير ام انها مجرد استعراض صور بألوان جميلة؟

للاجابة على هذه الاسئلة وغيرها نعرض هنا خمسة امثلة من مجموعة مشاريع بحثية قام بها الباحث عندما كان يعمل في هندسة الطيران والفضاء في جامعة دلفت في هولندا.

كل المشاريع المقدمة لها قاسم مشترك واحد الا وهو استخدام التمثيل ثلاثي الابعاد لتمثيل البيانات والنتائج المستقاة من الاقمار الصناعية او المسوحات الجوية الليزرية لقياس التحورات والتشوهات التي تحدث او حدثت لعدة حالات مراقبة جوية او فضائية.

تشمل المشاريع الممثلة ما يلي:

– خلق نموذج رقمي ثلاثي الابعاد لسطح ارض العراق والمناطق المحيطة به.

– تمثيل التشوهات او التحورات التي حدثت في منطقة في هولندا والمتسببة من الضغط الهايدروليكي للمياه في منطقة معروفة بوجود فوالق.

– مراقبة التحورات او التشوهات في السدود المانعة للمياه في هولندا.

– تقييم تحليلي للفوارق بالجودة والدقة بين مسوحات جوية ليزرية بين مجموعتين من المسوحات التي غطت هولندا اثناء فترتين متباعدتين.

– تمثيل نسبة رطوبة المياه لمدينة مكسيكو في المكسيك وذلك لتصحيح الاشارات الرادارية من الاقمار الصناعية.

خلال هذا البحث توصل الباحث الى اهمية التمثيل المرئي متعدد الابعاد وانه جزء مهم من مراحل التفسير بسبب المواصفات التحليلية المختلفة التي يتمتع بها برنامج فليدرماوس المستخدم لهذا الغرض. كذلك نجاح التمثيل المتعدد الابعاد في تقليل نسبة الخطا الموجود بالبيانات او النتائج.

الكلمات المفتاحية: - تطبيقات التقديم المرئي، الجيوفيزيائية، التحسس النائي.