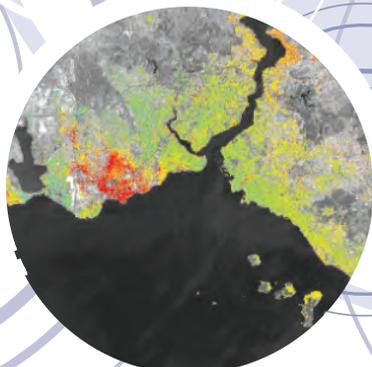
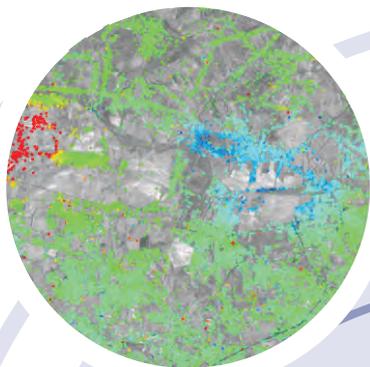


TERRAFIRMA



INTERNATIONAL GEOHAZARD INFORMATION SERVICE



What is Terrafirma?

Terrafirma is one of a number of services being run by the European Space Agency under the GMES Service Element Program as part of the Global Monitoring for Environment and Security initiative of the European Union. Terrafirma started in 2003 and will continue until 2012.

Terrafirma harnesses the unique power of satellite radar interferometry to detect and measure Earth-surface terrain motion. These data, in combination with geophysical expertise, are delivered to users to identify and mitigate risk.

Terrain motion can be related to subsidence, landslides, tectonic activity, flooding, coastal erosion, unstable buildings and infrastructure, and even poor engineering standards. Many of these phenomena and their associated hazards are made worse by the effects of rapid climate change.

The socio-economic cost of terrain motion across Europe runs into tens of billions of euros a year, and is becoming higher as populations increase, cities become larger, resources become scarcer and the climate becomes more unstable.

[WIDE AREA]

As the trend toward urbanisation continues and pressure on space grows in both vertical and horizontal domains, ground stability becomes an increasingly critical concern. Issues such as metro tunnelling, historical and contemporaneous mining, compressible substrates, oil and gas production and watertable change can all have adverse effects to property and people. Furthermore, many mega-cities already lie on vulnerable flood plains, in coastal lowlands or in earthquake prone zones. In the past, these kinds of hazards have been monitored in a purely reactive manner.

For the first time, Terrafirma offers a wide-area synoptic overview of terrain motions, allowing for proactive remediation and planning.



Suppliers and Users

Terrafirma services couple advanced satellite interferometry products with expert interpretation.

Its services are delivered to civil protection agencies, disaster management organisms, and coastal, rail and motorway authorities to support the process of risk assessment and mitigation.

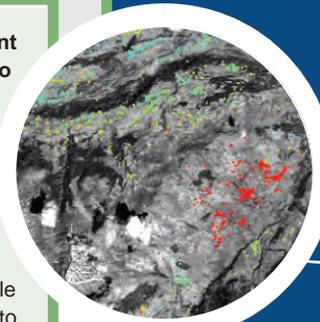
Terrafirma has consolidated and standardised the supply of interferometry products from the European companies specialising in this type of processing. In combination with this, the project has federated most of Europe's national geological surveys, provided services to Europe's Civil Protection Agencies and enrolled high profile engineering companies. This federation not only forms a primary user-base, but also provides the best source of the interpretation and value-adding skills necessary to maximise the products' utility. Terrafirma, therefore, represents a single point of contact for information on terrain motion hazards in Europe.

[MOUNTAINOUS AREAS]

Landslides account for a significant number of deaths and damage to economies in many mountainous parts of Europe. Terrafirma products have been successfully used to both identify unstable slopes and monitor known slides.

The result for Lumnez, Switzerland, shown here, identified two unstable sectors which are currently home to several villages.

This information is being used by the Federal Office for the Environment who have responsibility for landslide risk monitoring and management in Switzerland.



Thematic Products

- Hydrogeology**
 - Groundwater
 - Mountainous Area
 - Inactive Mine
- Flood
- Tectonics
- Wide Area
- Stage 1&2 Products

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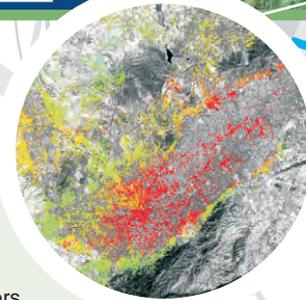
Technique

The technology underpinning Terrafirma uses data collected by European radar satellites in a process called Persistent Scatterer Interferometry, or PSI. The synoptic view of the satellite covers whole cities and regions, and because an archive exists of repeat satellite coverage dating back to 1991, PSI is unique in being able to look back at past terrain motion with millimetric precision.

Terrafirma involves the integration of InSAR measurements with conventional ground-based in situ measurements within a GIS environment, where data are merged and interpreted by geologists and geophysical experts to produce value-added, higher-level products.

[HYDROGEOLOGY]

In Europe, many sites of groundwater exploitation are experiencing subsidence related to over-pumping. The city of Murcia in Spain was chosen by Terrafirma as a test site because of its susceptibility to subsidence linked to water abstraction from local aquifers. The ground motion map produced by Terrafirma partners indicates that the southwest and northeast areas of the city of Murcia are affected by significant (between -1 and -4cm) displacements. This motion is due to a fall in the water table in the urban area, as measured during the drought of 1993-1995. There is a clear coincidence in the subsidence extent and location of aquifers. Terrafirma hydrogeology products provide accurate estimates of the evolution of deformation in order to identify vulnerable zones.



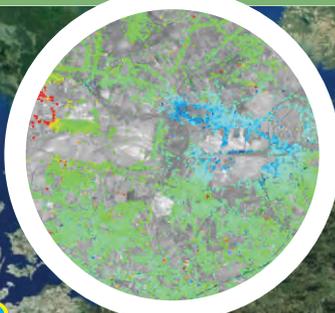
[FLOODING]

For major regions in the world, water defence systems such as dykes, dams and levees form the only protection against flood risk. Inspection of the structural stability of dykes relies on visual surveys, often rather infrequent as levee-failures in New Orleans demonstrated. A PSI-based method for monitoring of dyke stability has been developed and is currently applied to the dykes of the Netherlands.



[INACTIVE MINES]

Historical inactive mines are a major concern across many parts of Europe because they represent a significant environmental threat, that of ground instability. Many urban areas experience subsidence due to the proximity of such abandoned mines. Some mines are mapped but many are unknown until some collapse occurs. Terrafirma products evaluate historical trends of this phenomenon, and combined with geological and structural interpretation, are able to contribute to urban planning by providing a synoptic view over whole regions. This contributes to a more proactive approach to remediation. In Poland, PSI results over the region of Bedzin will help the Polish Geological Institute in hazard and risk analysis.



[TECTONICS]

Understanding fault mechanisms is critical to earthquake forecasting, and large amounts are spent in the US and Japan in monitoring crustal deformation using satellite positioning. GPS, however, can only be deployed in relatively sparse networks and is typically less accurate in the horizontal plane, whereas PSI provides high vertical accuracy and integrations between the two techniques can help de-correlate motion vectors as well as highlight localised motions which might be biasing GPS results. In Turkey, PSI results have been useful in detecting zones of old sediment which have the potential to liquefy and amplify the effects of earthquakes. This product led to a re-evaluation of risk zonation within the city. In other cities, for example Lisbon, PSI has revealed deep basement geology and improved tectonic modelling. Terrafirma know-how and products have the capability to create 'virtual GPS networks' with a historical timeseries reaching back 15 years for all earthquake-prone cities of Europe.



Products

The Terrafirma terrain motion products are used by civil protection agencies and the civil engineering community to identify and mitigate related risks at an early stage. These services are organised along three thematic lines: Hydrogeology, Tectonics and Flood, as well as a Wide Area mapping product.

Hydrogeology:

This service delivers geo-information for hydrogeological hazards affecting urban areas, mountainous zones and infra-structures. Areas where groundwater has been severely exploited often experience subsidence as a result. Likewise, many European towns and cities built above abandoned and inactive mines experience strong ground deformation. The hydrogeology theme products study these phenomenon as well as slope instability in mountainous areas.

Tectonics:

This product presents information on seismic hazards. The crustal block boundaries service provides users with information on terrain motion related to major and local faults, earthquake cycles, and vertical deformation sources. The vulnerability map service combines radar satellite data with in situ measurements to identify regions that may be vulnerable in the case of an earthquake.

Flood:

The flood plain hazard product assesses flood risk in coastal lowland areas and flood-prone river basins. The advanced subsidence mapping service combines PSI with levelling data and GPS to enable users to interpret subsidence maps within their geodetic reference systems. The flood defence monitoring service focuses on flood protection systems such as dykes and dams.

Wide Area:

The wide area mapping product is offered as of 2010. It complements the service by offering terrain motion studies that cover areas much larger than 100 Km wide at a scale of 1:250 000. It is especially designed to give an overall ground deformation map in order to pinpoint critical areas for further investigation. An area of approximately 400 x 300 km in Greece is currently in production in addition to Northern Germany and an area centred on the Belgian Dutch border. The Wide Area Product is designed to take advantage of future Sentinel-1 SAR data.

TERRAFIRMA PARTNERS



"The PSI data provided shows some astonishing results in urban areas and it seems that this technique is ideal to detect ground motions in highly populated areas."

ALP-infra Consulting & Engineering (Austria)

"TerraFirma provided subsidence data with a detail that would have been nearly impossible to detect in most circumstances."

Dr. Mahmut Bas, Istanbul Metropolitan Municipality (Turkey)

"Results have shown that the TerraFirma product provides estimates of the deformation evolution in time with an absolute difference below 6mm consistently in all comparisons, for example comparing with extensometer data."

Institute of Minerals and Geology of Spain - IGME (Spain)

"Over the last year, our approach to the study of the active tectonics of the Lower Tagus Valley was re-defined following the advent of PSI."

Dr. Joao Fonseca, Institute of Engineering and Structures (Portugal)

If your organisation is interested in receiving more information on how to access a TerraFirma product for a particular area, please contact:

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Altamira Information

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Please follow the TerraFirma group on **LinkedIn**



TerraFirma is one of a number of Service Element projects being run by the European Space Agency under the Global Monitoring for Environment and Security (GMES) initiative. **TerraFirma** is establishing a **pan-European ground motion hazard information service in support of policies aimed at protecting the citizen.**

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