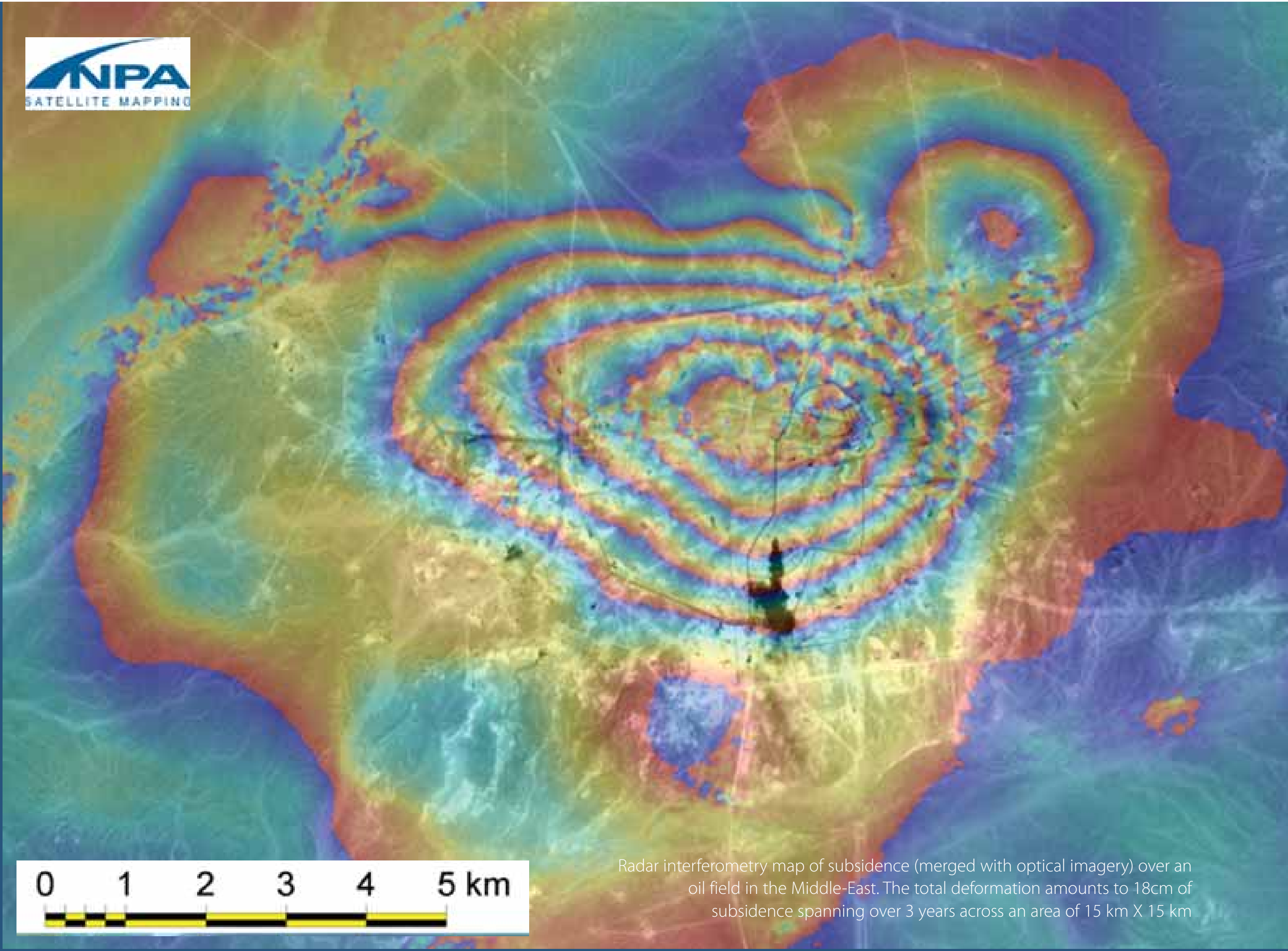

Radar interferometry map of subsidence (merged with optical imagery) over an oil field in the Middle-East. The total deformation amounts to 18cm of subsidence spanning over 3 years across an area of 15 km X 15 km

MONITORING GROUND HAZARDS FROM SPACE

ADAM THOMAS AND MARK HAYNES OUTLINE THE TECHNOLOGIES AND SERVICES CURRENTLY IN USE FOR DETECTING AND MONITORING GROUND AND STRUCTURE MOTION HAZARDS FROM SPACE.

Through the use of state-of-the-art remote sensing a diverse range of past and present ground and structural motions can be detected and monitored across the world. NPA Group, a satellite mapping company based in the UK, demonstrate their technology and services used in mapping motion hazards.

Ground motion hazards and conventional detection

Hazards relating to structure motions, subsidence, landslides, natural resource extraction, earthquakes and volcanic deformation, conventionally require a range of surveying techniques, but these are inherently expensive, time consuming and potentially dangerous, especially in areas that are remote and difficult to access.

NPA Group regularly assist government and commercial organisations, such as the geo-technical and civil engineering industries, by processing and analysing large quantities of satellite radar data in order to successfully detect, assess and validate a range of past and present ground motion hazards, as well as to detect and monitor the motions of civil engineering structures at risk.

Satellite radar data: A window to hazards, past and present

Since 1991 the European Space Agency (ESA) has been acquiring radar imagery across the world using the European Remote Sensing Satellites (ERS-1 and ERS-2). The result is an extensive data archive that, for a given region of the Earth, may yield up to 100 radar images, each covering an area of 100km X 100km.

Each radar image contains information about the position of the ground at the time when the data was acquired by the satellite. As the satellite orbits the Earth it sends a signal towards the ground which gets scattered back to the satellite. The strength and time delay of the radar signal back-scattered to the satellite sensor is recorded as an image (Fig.1). As subsequent images are acquired (generally one every 35 days) over the same location it is possible, through complex processing, to assess the change in ground positions over time. These images offer an important retrospective insight into the Earth's ground motions dating back as far as 1991, something unachievable by any other surveying method.

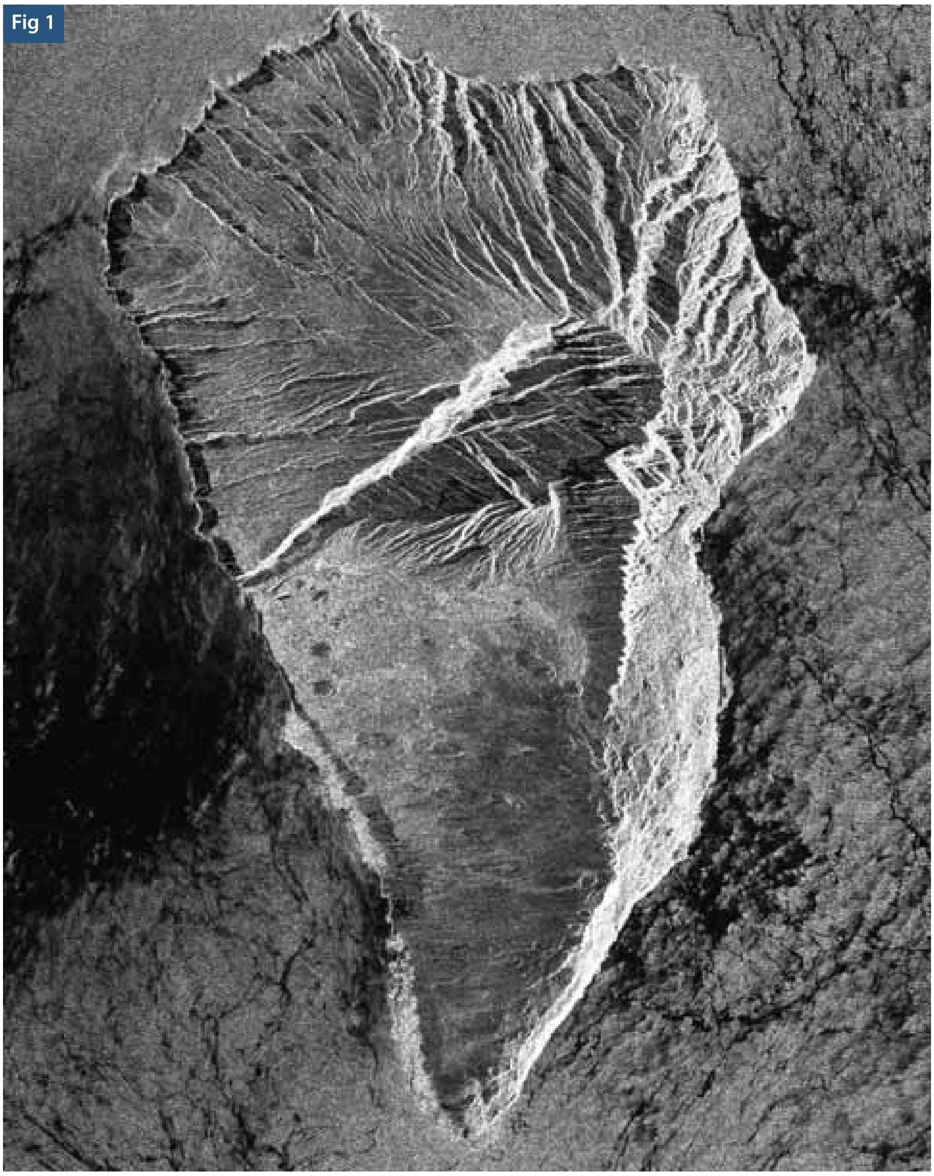

FIG. 1: ERS-1 Satellite radar intensity image of La Palma, Canary Islands. Image acquired 29th May 1992. ERS data copyright ESA 1992.

As new radar data are acquired, motion monitoring over a particular site can extend into the future. Data continuity is assured by the launch of new satellites, such as the European Space Agency's Environmental Satellite (ENVISAT), which was launched in March 2002, as well as the Canadian Space Agency's RADARSAT-1 satellite (currently in orbit) and RADARSAT-2 which is due to launch in March 2007.

Enhancing information and knowledge

NPA have developed a range of motion mapping services based on satellite radar interferometry analysis techniques. Each service is capable of deriving ground motion data at different scales and extents and is applicable to different scenarios. Techniques range from: Wide-area mapping - for measuring deformation caused by earthquakes and natural resource extraction (Main image); Historical point-specific motion mapping – using large quantities of radar imagery to isolate and measure motion histories (dating from the present day back to 1991) of urban structures; and Site-specific monitoring - deploying artificial radar reflectors (Fig. 2) to monitor ground and structure motions at very specific locations.

The result of each service is the delivery of georeferenced motion data files (image rasters, point vectors and databases) that are ingested into a user's Geographic Information System (GIS). By combining those data with pre-existing data layers, it is possible to validate existing data to provide a better understanding of the phenomena occurring, and to elucidate previously undetected and unmonitored areas of motion, all at a fraction of the normal survey cost.

Technology in action – A case study from Manchester, UK

In 2002 a sequence of minor earthquakes swept across Manchester, UK. By combining digitised earthquake epicentres, a georeferenced 1:50,000 solid geology basemap, and historical ground motion derived from satellite radar imagery, it was possible to reveal the relationships between independent layers of data in order to gain a better understanding of the events taking place.

Figure 3 shows radar-derived ground motions for the period 1992 - 2003. It reveals distinct zones of uplift and subsidence across Manchester and surrounding regions. By combining this data with mapped geology (1:50,000 solid geology basemap) for the same area one can examine the relationship between geology and the ground motions (Fig. 3A). The combination of these two independent data layers suggests that the fault lines (black lines running NW-SE)

FIG. 2: Photograph showing artificial radar reflectors. The metallic structure is a Corner Reflector (CR) which reflects the radar signal back to the satellite. The smaller unit is a Compact Active Transponder (CAT), which offers additional facilities for point motion monitoring.

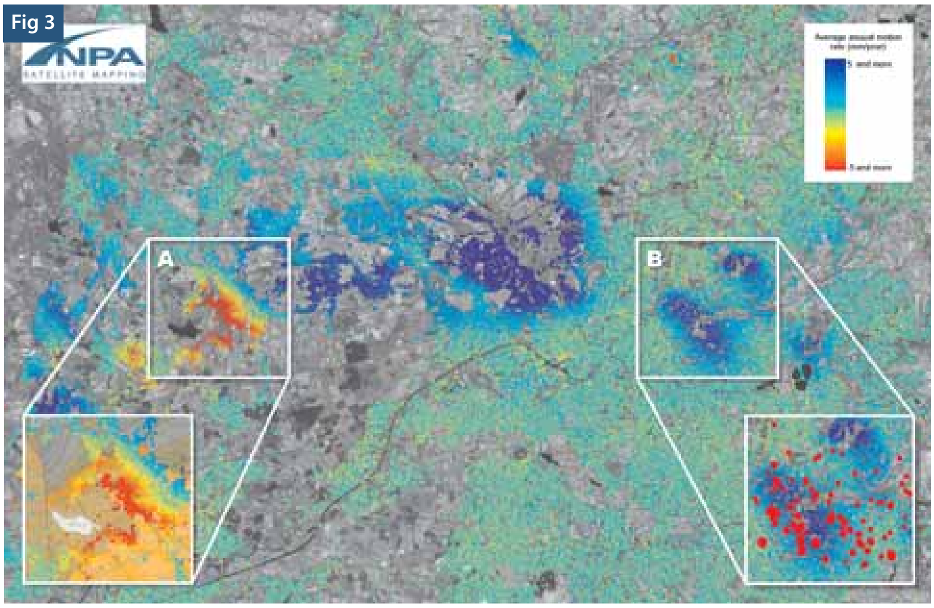

FIG. 3: Derived ground and structure motions overlaid on Landsat Enhanced Thematic Mapper (ETM)+ Band 8 imagery. Red represents areas exhibiting downward motions of at least -5mm/yr. Green represents stable areas. Dark blue represents areas exhibiting upward motions of at least +5mm/yr. ERS and ENVISAT data copyright ESA 1992 - 2003.
FIG. 3A: Derived ground motion data superimposed over a 1:50,000 Solid geology map.
FIG. 3B: Earthquake epicentre locations superimposed over derived ground motion data and Landsat ETM+ Band 8 satellite imagery. Landsat ETM+ imagery courtesy of the U.S. Geological Survey.

delineate the motion trend running from SW-NE (red to blue), thus indicating a possible relationship (active or not) between the geology and the detected ground motion. The result is localised deformation caused (or controlled) by the fault structures. Taking the analysis a step further, earthquake epicentres from the 2002 earthquake swarm were digitised and overlaid on the ground motion data. When compared, the clustered earthquake swarm epicentres appear to correlate with the detected uplift patterns (Fig. 3B). A theory is that this highlights pre-seismic strain accumulation prior to the earthquake swarm.

This case study demonstrates how data from different sources can be merged to reveal new and interesting relationships, as well as the causes and effects of often low magnitude ground and structure hazard events.

A European perspective

NPA are leading a European Space Agency project, Terrafirma, which aims to help mitigate the risk of ground hazards throughout Europe. The project applies state-of-the-art processing of radar imagery to detect ground motion data for major cities and landslide sites across Europe. Users (such as geologists) can compare this new information with existing data, geological maps, borehole and seismic data, as well as satellite and aerial imagery, to help build up a picture of the causes, scales and extents of ground motion hazards within their city. This information is invaluable in guiding planners, engineers, and the public, and assists governments and policy-makers to take steps to further mitigate these hazards.

Looking into the future

As more people are forced to live under the influence of geo-hazards, climate change and extremes of weather, and we continue to place a higher emphasis on our natural resources, it is imperative that we have a detailed understanding of the effect we are having on our environment and the effect that it is having on us. This application of remote sensing makes it possible to see the larger picture, it helps to cut costs and logistical challenges and, due to its compatibility with other geo-data, allows users to build on their current knowledge, and helps to reveal new sites in need of investigation.

Whether the requirement is the study of localised subsidence resulting from past mining activities, the structural assessments of dams and water reservoirs, the analysis of ground settlement after tunnel construction (Fig. 4) or the regional study of oil reservoir deformation and earthquakes, NPA provide new or complimentary motion information that users require. With the planned launch of new satellites and sensors, NPA's radar mapping technology and the study of ground and structure hazards are likely to experience increasing future demand.

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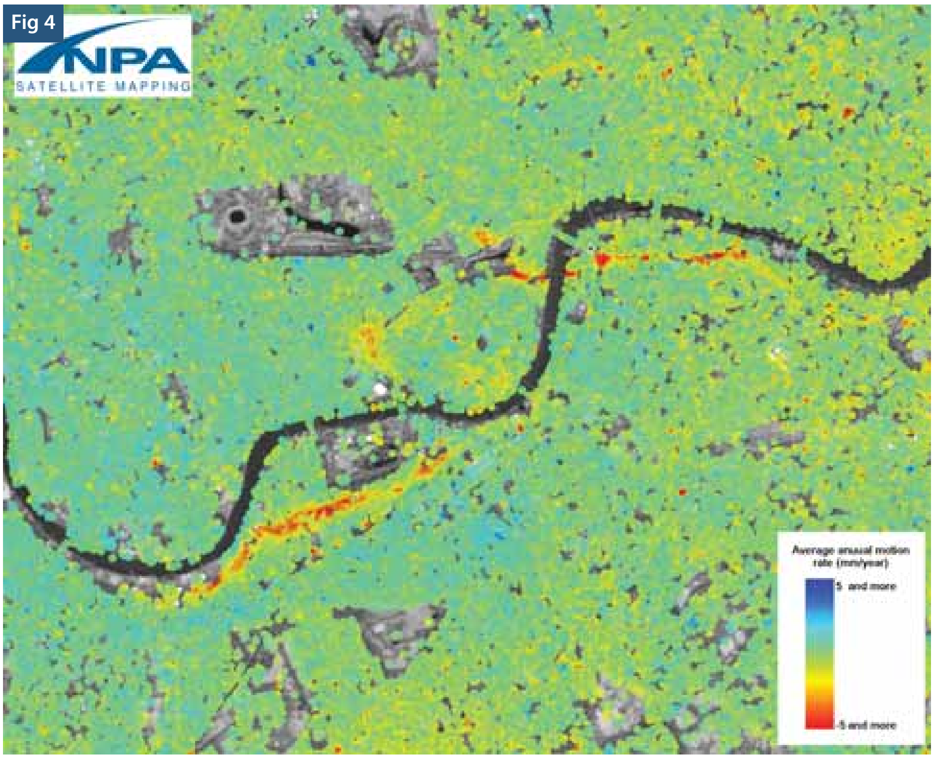

Fig. 4 - Historical point-specific motion mapping of ground and structures in central London over a 13-year period (1992 - 2005). Faster ground settlement (red linear feature right of centre) correlates with the construction of the Jubilee Line Extension. ERS and ENVISAT data copyright ESA 1992 – 2005.