Institution:

University of Leeds

Unit of Assessment:

7, Earth Systems and Environmental Sciences

Title of case study:

Case study 6: Improvements in satellite-derived gravity data lead to more efficient hydrocarbon exploration

1. Summary of the impact (indicative maximum 100 words)

Research carried out at the University of Leeds has been used to develop data sets that are now routinely used in offshore oil exploration to identify prospective areas faster, and with reduced cost. New techniques applied to satellite altimeter data have been used to compute gravity anomalies in marine areas with increased accuracy and reliability relative to earlier products. These anomalies have been developed during the REF period in association with a University of Leeds spin-out company (Getech) into a global data set, which has been sold and licensed extensively within the hydrocarbon exploration industry. The global data set has delivered economic and reputational benefits to Getech, and has been employed by oil companies in more than 50 exploration projects per year. Shell values the improved gravity data at $2.5M per project.

2. Underpinning research (indicative maximum 500 words)

By the mid-1990s, the use of marine gravity data sets derived from satellite altimeter data had become well established for offshore hydrocarbon exploration, as well as for general geological studies and for the development of global geoid and gravity models. However, although satellite altimeter data with good coverage were available (~4 km track spacing over most of the oceans), the resolution of the derived gravity grids was significantly worse, particularly in coastal regions. In consequence, the potential applications of satellite gravity anomalies were limited in scope by the available data.

Between 1996 and 1998, Leeds researchers **Derek Fairhead**, **Chris Green**, and Stefan Maus (Researcher, 1996-1998) developed an improved method of detecting marine gravity anomalies using satellite altimeter data. Their approach was to use the most basic altimeter data available – the raw waveforms transmitted from and recorded by the satellite. This relatively large data set required sophisticated processing, and a range of new techniques were developed to pick the exact return time of the radar echoes, and to test the robustness and accuracy of the retrievals. The results demonstrated a significant improvement over previously-available along-track data, enabling the production of improved gravity anomaly grids **[1].**

Subsequent research (1997-1998) by **Green** and **Fairhead** in association with Getech reviewed the whole process of generating satellite gravity data. By modifying the details of the various techniques, it was shown that the improved along-track satellite altimeter data could be processed to provide improved gravity anomaly grids. Paper **[2]** and report **[5]** describe these techniques and demonstrate that the improvement in results compared with gravity data from other sources is better than 10% (see also corroboration **[B, C]**). These new techniques were later (2002-2004) applied by Getech to develop a new gravity data set for the continental margins of the world **[6]**. Paper **[3]** looks at a specific area of interest and quantifies the improvement achieved by applying the new techniques.

Sustained collaboration between Getech and the University of Leeds has driven further advances in the technology. In 2008, **Fairhead** led research on the effectiveness of combining gravity data sets derived from different satellite missions, resulting in the production of Getech's new *Trident* marine gravity product with improved resolution and reliability **[4]**. In 2012, **Green** and **Fairhead** initiated a joint research collaboration with Leeds to maintain their industry-leading position by incorporating the latest generation of interferometric satellite altimeter data. This project has now evolved into a major 3-year oil industry sponsored study (2013-2016) to improve, yet further, the resolution of the data.

The impact of the research has been achieved via Getech, primarily through the sale of gravity data products, which are used by oil companies in hydrocarbon exploration.

Key researchers:

Derek Fairhead, Lecturer and Professor (now Emeritus) (1973-present) of Applied Geophysics in the School of Earth and Environment, University of Leeds; Managing Director (1991-2011) and President (2011-present) of Getech

Chris Green, Research Assistant (1983-1992) and Teaching Assistant (2010-present) in the School of Earth and Environment, University of Leeds; Scientist (1992-2010) at Getech

3. References to the research (indicative maximum of six references)

This list includes both academic references and commercial reports as both are important in the disemination of the research.

Academic references

1. **Maus**, S., **Green,** C.M. and **Fairhead**, J.D. **(1998).** Improved ocean-geoid resolution from retracked ERS-1 satellite altimeter waveforms. *Geophysical Journal International,* **134,** 243-253. doi:10.1046/j.1365-246x.1998.00552.x.

   Paper describing the research that led to the impact.

2. **Fairhead**, J.D., **Green**, C.M. and Odegard, M.E. (2001). Satellite-derived gravity having an impact on marine exploration. *The Leading Edge,* **20,** 873-876. doi:10.1190/1.1487298.

3. Bansal, A.R., **Fairhead,** J.D., **Green**, C.M. and Fletcher, K.M.U. (2005). Revised gravity for offshore India and the isostatic compensation of submarine features. *Tectonophysics,* **404,** 1-22. doi:10.1016/j.tecto.2005.03.017.

Commercial reports

4. **Fairhead,** J.D., Williams, S.E., Fletcher, K.M.U, **Green**, C.M and Vincent, K. (2009). *Trident – A New Satellite Gravity Model for the Oceans*. Extended Abstract, 71st EAGE Conference and Exhibition, Amsterdam.

5. *Towards the Ultimate Resolution of Satellite Gravity*. Confidential **Getech** report G9815. May 1998.

   Commercially funded R&D project.

6. *Global Continental Margins Gravity Study (GCMGS).* Confidential **Getech** report G0411. June 2004.

   Industry funded R&D and processing project leading to a near-global gravity grid.

The research described in **[1]**, **[2]** and **[3]** is of international significance as approaches similar to those described have been used in recent satellite gravity data sets produced in both Europe and North America. The work reported in **[4]** is the best publically-available description of the Trident development. Commercial reports **[4]**, **[5],** and **[6]** have led to significant sponsorship of follow-on studies and sales of the products developed.

4. Details of the impact (indicative maximum 750 words)

The impact of the research has been to aid the effectiveness and efficiency of global oil exploration, especially in frontier continental margin areas. Oil companies have used the improved satellite gravity data sets **[4, 6]** to perform many rapid, low cost geological evaluations of marine areas.

The construction of the GCMGS data set (2004) was initially sponsored by ENI, Shell, Statoil and Total, but the reach has been subsequently extended by Getech licensing the product in part or in full to most of the world's leading oil companies. A further enhanced product, the Trident data set, released in 2008 has maintained the reach and market leadership. Letters from the initial sponsors **[A1, A2]**, **[B]**, **[C]**, **[D]** attest to the widespread use of the derived data sets, whilst the added value of the Trident data set is noted in letters **[A1, A2]**, **[C]** and **[D]**.

Exploring for hydrocarbons offshore is an expensive and risky business and hence oil companies use a variety of data sets in the process (see **[A1]**). Gravity data can be used as a tool to map and model target geological structures beneath the seabed. Access to spatial data sets, such as satellite gravity, can have a massive impact on targeting potential oil structures which can be followed up by more detailed and expensive exploration methods such as 3D seismic and CSEM prior to drilling.

Satellite-derived gravity data sets were available in the mid-1990s. However, take-up of these early products as a commercial exploration tool was modest due to their limited accuracy, resolution and reliability. The improvements in resolution that were made through this research led to a step change in the use of satellite altimeter data to grade frontier offshore areas for exploration. Satellite gravity data are now widely used throughout the offshore oil industry, and Getech is a major supplier.

Although gravity data measured on a ship or on the seabed can provide better accuracy and resolution than satellite gravity, they are relatively expensive and time consuming to acquire - and speed is a major factor in exploration as it is competitive and often needs to be carried out to specific timetables. Satellite data, on the other hand, are valuable, because they are already available for any offshore area and enable rapid assessment of new exploration areas. In consequence, satellite gravity data continue to be used by oil and gas companies for hydrocarbon exploration – especially in frontier areas or at regional scales (see **[A1]**).

The economic value of the underpinning research can be measured in terms of the value of the Getech marine gravity data to their customers; this is related to the value of the data for each offshore exploration and the number of times the data have been employed. According to Shell **[A1]**, cost savings afforded by the use of satellite marine gravity data are related to the improvement in quality (accuracy, resolution and reliability) over alternative products, and they estimate that a 10% improvement in the reliability of marine gravity data yields at least US$2.5M increase in the value of a single project. Two other Getech customers confirm that the use of Getech Trident data set has indeed led to a 10% improvement in the reliability of marine gravity data for prospecting **[B, C]**. Four Getech customers **[A1, A2, B**, **C,** and **D]** confirm that the Getech marine gravity data have been used routinely for frontier exploration in offshore areas, and three of these customers **[A2, B, C]** state that the Trident data set has been used in 3, 35-40, and 12 exploration projects per year, respectively.

In addition to reducing commercial risk, the increased use of satellite data has the added advantage of mitigating other risks associated with exploration (see **[A1]**). Limiting risks to personnel and the environment is very important to exploration companies; thus, technologies which do not involve people working on the ground have important advantages.

The underpinning research has of course also been of economic value to Getech itself **[E]**; the improved gravity anomaly data have benefited the company through income and through reputational gain. Getech received £1.2M between 2002 and 2004 from six leading oil companies for their initial marine gravity data set, helping enable the company to be floated in 2005. Since then, and during the REF period, Getech has licensed updated versions of the gravity data sets to sponsors, developed as a consequence of technological improvements derived from the underpinning research. The long-standing collaboration between Getech and the University of Leeds has therefore maintained the economic impact and reach of the underpinning research.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A1. Letter from senior scientist at Shell (dated 8/11/2011). This provides an indication of the impact of the results of the research on the hydrocarbon exploration process. This letter is particularly helpful, as it aids in quantifying the commercial impact of the work. Available on request.

A2. Letter from senior scientist at Shell (dated 21/11/2013) clarifying the number of exploration studies in which the data have been used. Available on request.

B. Letter from ENI (dated 21/11/2013). This indicates that the data set derived from the research is in regular use for oil exploration by ENI and is considered to represent an improvement on previously available data sets. Available on request.

C. Letter from Statoil (received 21/11/2013). This provides evidence that the data set based on the research has been extensively used in Statoil's exploration process; it indicates how the new data are better and their perceived importance to Statoil. Available on request.

D. Letter re. Total (received 3/11/2011). This letter was written by a former Total employee who headed up Total's involvement in the satellite derived data products. It confirms that the data sets have been routinely used by Total and that the Trident data set has further improved the product. Available on request.

E. Letter from Getech (dated 21/11/2013). This letter written by the Chief Executive Officer describes the economic and reputational impact of the underpinning research for the spin out company.