Institution: University of Leicester

Unit of Assessment: UoA9 Physics

Title of case study: Building industrial capacity through exploitation of Earth Observation data and (physical) methods

1. Summary of the impact

Data generated by sensors on-board satellites orbiting the Earth have become extremely important to businesses and public sector organisations. They are the essential ingredient in satellite-enabled consumer services, from GoogleEarth to disaster management, insurance and agriculture. The Earth Observation Science group at Leicester has played a leading role in the transfer of cutting-edge Earth Observation techniques and know-how to the private and public sectors, enabling more businesses to use the technology for commercial gain. Leicester experience in technology translation led to its invited contribution to the UK space industry-led report to government, an Innovation and Growth Strategy for Space.

2. Underpinning research

Problems studied by the EOS group in Physics have always been quite diverse ranging from remote sensing of sea surface temperatures to remote sensing of algae in lakes. At its core, the basis to the research is the use of Physics to fully determine spectroscopy and physical radiative transfer in satellite remote sensing, to determine the information content of the Earth Observation (EO) data from satellites, and to obtain ever more accurate mathematical inversion of the data to geophysical parameters. The consolidation of this research occurred in the last decade when the outputs became particularly fruitful, and the group, led from 2002 by Professor John Remedios, expanded to approximately thirty strong.

In the early 2000s, Leicester EOS research resulted in a number of breakthroughs best exemplified by papers in two distinct areas: 1) the development of spectral inversion techniques which allow one to model the satellite signal and then determine Earth atmosphere and surface parameters (for example reference [1]); 2) new methods to look at the accuracy of long-term, high quality data sets for (climate) change detection [2]. This type of research is typical of recent EOS research development of physically-based, state-of-the-art methods to derive, mathematically, parameters from EO data in a robust manner, and to assess their quality.

A very significant component of this research has been the extension of conventional" (but difficult) optimal algorithms, based on Bayes theory, to challenging inversion problems such as highly ill-constrained problems, multiple scattering situations and data sets requiring high accuracy (better than 1%) such as greenhouse gases and cloud/precipitation. Reference [3] was amongst the first of a number of key papers in this area from Dr. Michael Barkley, Dr. Roland Leigh, Professor John Remedios, and other EOS academics at Leicester. This type of research has been particularly important in enhancing our capability to determine new parameters and change products (greenhouse gases [1], burnt area from fires [5], algal production in lakes [6]).

Our research also identified areas in which scientific goals were closely aligned with areas of societal interest for science: urban air quality [4]; burnt area (important for deforestation and international REDD treaty [5]); most recently, water quality and ecology [6]. Both the scientific research and the applications have relied heavily on our ability to quantitatively model and correct for radiative transfer in the atmosphere [1, 3], to interface between data and applications and to merge different knowledge streams. Tellingly, these application developments arose from Physics and Astronomy academics undertaking collaborative research with the Departments of Chemistry [3, 4]; Geography [5] and Biology [6].

3. References to the research

Leicester names are given in italics; Physics/Astronomy names are in bold italic.

1. ***Barkley, M. P., U. Friess***, and *P. S. Monks* (2006), Measuring atmospheric CO2 from space using Full Spectral Initiation (FSI) WFM-DOAS, Atmospheric Chemistry and Physics, 6, 3517-3534.
2. ***Noyes, E. J.,*** P. Minnett***, J. J. Remedios, G. K. Corlett, S. A. Good, and D. T. Llewellyn-Jones*** (2006), The Accuracy of the AATSR Sea Surface Temperatures in the Caribbean, Remote Sensing of Environment, 101, 38-51.
3. ***Friess, U***., *P. S. Monks*, ***J. J. Remedios***, A. Rozanov, R. Sinreich, T. Wagner, and U. Platt (2006), MAX-DOAS O_4 measurements: A new technique to derive information on atmospheric aerosols: 2. Modeling studies, Journal of Geophysical Research, 111, doi:10/1029/2005JD006618
4. ***Kramer, L. J., R. J. Leigh, J. J. Remedios***, and *P. S. Monks* (2008), Comparison of OMI and ground-based in situ and MAX-DOAS measurements of tropospheric nitrogen dioxide in an urban area, J. Geophys. Res., 113, D16S39, doi:10.1029/2007JD009168.
5. *Tansey, K*. J., J-M. Gregoire, P. Defourny, ***R. J. Leigh***, J-F. Pekel, E. v Bogaert and E. Bartholome, A new, global, multi-annual (200-2007) burnt area product at 1 km resolution and daily intervals, Geophys. Res. Lett., Vol. 35, No. 1, L01401, 10.1029/2007GL031567
6. ***Tebbs, E.J., J.J. Remedios***, and *D.M. Harper*, Remote sensing of chlorophyll-a as a measure of cyanobacterial biomass in Lake Bogoria, a hypertrophic, saline–alkaline, flamingo lake, using Landsat ETM+, *Remote Sensing of Environment,* **135**, 64–76, 2013; 10.1016/j.rse.2013.03.028.

4. Details of the impact

The strength of this EOS research, with its wide ranging set of Physics-based Earth Observation (EO) capabilities has been carried forward into impact through translation of EOS technologies (methods and data) into the private sector at both regional and national levels. The expertise of Remedios has also been called upon at national level to provide input into the development of UK industry and government strategy.

Translation of Earth Observation Science Technology to the Private Sector.

1. Regional.

Translational activity on a regional scale began in 2009 with the launch of the Global Space Technology Exchange Partnership (G-STEP), a bespoke service offered by the University of Leicester to open up opportunities derived from Earth Observation technologies to small and medium-sized businesses in the East Midlands.

This business-facing service “de-mystifies” Earth Observation data and shows how more information can be obtained from these data beyond the GoogleEarth-type approach. The driver for G-STEP was the realisation by Remedios and Professor Monks (Chemistry) that their work on the analysis of EO data had significant and valuable potential for the private sector.

In its first 3 years, G-STEP added more than £1 million in value to the regional economy through engagement with SMEs [a]. Auditable benefits [b] to the regional economy include three collaborative projects with industry partners, collaborative projects with regional authorities, over 30 direct engagements with regional SMEs with no previous awareness of space technologies leading to six active projects with SMEs with identifiable business benefits.

In addition, G-STEP has arranged twelve graduate placements into businesses; six young graduates have been given career starts through internships; two start-up companies [c] have worked in the G-STEP incubation unit; 25 high value jobs have been created with an estimated three times as many new positions in the relevant supply chain. Projects are also being undertaken with national companies in agricultural and urban markets.

2. National

The G-STEP service experience showed that reliable EO data supply and EO data quality were key concerns for business. Leicester was able to promote academic Earth Observation methodologies as a solution. This led to Leicester involvement in the national industry-led Climate and Environment Monitoring from Space (CEMS) Facility at Harwell. This purpose-built facility [d], now part of the newly formed Satellite Applications Catapult, offers Earth Observation data to businesses and organisations, giving users access to extensive data holdings and a range of applications, tools and services that help them analyse their data more effectively.

Leicester played a key role in the design, set-up and initial operation of the facility, advising on system usage and operations. Remedios led the Leicester CEMS effort, which was directed through the National Centre for Earth Observation and STFC RAL. As a member of the Project Implementation Team, working alongside industrial partners from Astrium GeoInformation Services and Logica Plc (now CGI), he was instrumental in setting the user specifications of the system, leading a CEMS data quality study with a major Earth Observation company (Vega UK, now Telespazio Vega UK) and providing demonstrations of EO data which were used to “prove” the system [e]. The CEMS system went live in July 2012 and has since been accessed by 15 commercial projects in its first year, paying £250,000 to CEMS and earning revenues several times this number [e].

Development of UK industry and government strategy

The extensive experience of Professor Remedios through G-STEP and CEMS led to his invitation by the Department of Business, Innovation and Skills to serve as a Steering Board member for the Innovation and Growth Strategy (IGS) Restack – an update of the 2010 strategy being undertaken for BIS. The Board is led by Andy Green former CEO of multinational IT and management consultancy company Logica Plc (now CGI). It reports directly to Mr. David Willetts as Minister of State for BIS, and to his Space Leadership Council.

Professor Remedios has been one of the Board members “sponsoring” the market analysis for IGS, which projects and justifies a growth of £40 billion in the space sector by 2030 with 100,000 new jobs. He is involved because approximately 20% of this growth is forecast in EO markets and his key responsibilities are to verify the market analyses, refine project recommendations for government and industry, and advise on strategic ways forward for the space industry [f]. In doing this, he has worked alongside CEOs of major UK space companies, SMEs and the UK Space Agency particularly in the first half of 2013 when the bulk of the work occurred. [g]

5. Sources to corroborate the impact

a. G-STEP brochure; http://www2.le.ac.uk/projects/g-step/info/collaborations show case studies.

b. Verification of G-STEP impacts are available through ERDF A13/A16 audits

c. http://www.geospatial-insight.com/. Based at G-STEP incubator, Readson House, Leicester

d. https://sa.catapult.org.uk/climate-and-environmental-monitoring-from-space; Leicester demonstrators are land surface temperature and methane monitoring; EOS-Leicester is part of the distributed National Centre for Earth Observation.

e. Letter from EO Strategy and Engagement Manager responsible for CEMS at the Satellite Applications Catapult

f. https://connect.innovateuk.org/web/space for IGS presentation and consultation report July 2013; see: https://connect.innovateuk.org/web/space/space-igs-2014-30 for final report.

g. Letter from Head of Growth and Investment Organisation, UK Space Agency