

**Institution:** University of Liverpool, School of Environmental Sciences

**Unit of Assessment:** 7 - Earth and Environmental Sciences

**a. Overview** The School of Environmental Sciences (SoES) was created in 2009 to provide an integrated and collaborative research environment in Earth and Environmental Sciences. The School is organised into two Departments: (1) the Department of Earth, Ocean and Ecological Sciences (DEOES), returned to UoA 7, and (2) the Department of Geography and Planning (DGP), returned to UoA 17. DEOES was formed by combining the previous Department of Earth & Ocean Sciences and Ecology & Marine Biology research grouping (previously in the School of Biological Sciences). The Department organises its research *via* three research groups: *Earth Sciences* (13 Returned Staff, 19 RAs, 22 PhDs ongoing, 48 PhDs completed); *Oceans and Climate* (9 Returned Staff, 10 RAs, 13 PhDs ongoing, 18 PhDs completed); and *Ecology & Marine Biology* (4 Returned Staff, 4 RAs, 5 PhDs ongoing, 5 PhDs completed).

**b. Research strategy**

Our research objective is to address fundamental questions about how the Earth system operates, including the effects of a changing environment.

**i. Evaluation of current position with reference to RAE2008**

Our strategic goal is to strengthen and broaden the scope of our research achievements in RAE 2008, where 75% of the research submitted was deemed Internationally Excellent or World Leading, with aspects of Oceanography, Climate Science, and Geophysics being identified in the 4\* category. Our research strategy involves:

- Restructuring our research groups to enable existing staff to fulfil their research potential, as well as attracting and recruiting talented researchers to these research groups (appointing three Chairs and six Lecturers, and giving permanent positions to two Fellows);
- Consolidating the link with the National Oceanography Centre (NOC) (as identified as a goal in RAE2008) by appointing two Chairs, Hughes and Sharples, jointly with NOC;
- Winning investment in facilities and equipment (>£2M investment provided by external and University funding) resulting in a growth and diversification of research income;
- Raising our international profile by increasing international collaborations (65% of REF outputs with an international co-author) and increasing the number of high-profile publications (18 returned papers in *Science*, *PNAS*, *Nature*, *Nature Geoscience* and *Nature Communications* compared with three from these journals in RAE2008).

Our restructuring of research groups, leading to fewer and larger research groupings, is designed to develop new interdisciplinary research and foster good practice:

1. The ***Earth Sciences*** research group led by Rietbrock has formed out of four smaller research groupings in RAE2008 (involving stratigraphy, microstructure, geodynamics and geomagnetism). This reorganisation has led to successful grant applications, such as a NERC grant by Faulkner & Rietbrock on unravelling fault zone properties by combining geophysical imaging and rock deformation laboratory measurements, and a Joint Industry Project (JIP) led by Faulkner on cap rock integrity during CO<sub>2</sub> sequestration (Impact Case #2). During the REF2014 period, the group has been strengthened by establishing a new research area in Physical Volcanology (Professors Lavallée and Kokelaar, and Lecturers Kavanagh and De Angelis). We also appointed a new Lecturer, Ryder, in geodynamic modelling based on InSAR and GPS measurements to complement our research in active tectonic processes (supported by a NERC urgency grant).

2. The ***Oceans and Climate*** research group led by Williams has major strengths in two areas. First, the group brings expertise in ocean dynamics to the problem of how the ocean is warming and sea level is rising (Williams, outputs #1 and #4, Hughes, #4; supported by three NERC responsive-mode grants). Second, combining expertise in ocean physics and biogeochemistry, the group is addressing how carbon, nutrients and trace metals are cycled and transported, and how they affect the ecosystem (evident in the NERC Shelf-Seas Biogeochemistry Consortium led by Sharples). Both research activities are strengthened by the Chair appointments of Hughes and Sharples, joint with NOC, and augmented by Woodworth and Tamisiea for sea level and by Palmer

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and Thorne for shelf seas (all four returned from NOC as category C, being involved in joint PhD supervision and grants). At the same time, ocean biogeochemistry has been enhanced by the appointment of Lecturers, Tagliabue and Salaun, providing expertise in the modelling and real-time monitoring of trace metals, respectively.

3. The **Ecology & Marine Biology** research grouping led by Marrs is a new research group and leads on understanding ecological functions from individuals to populations to communities and how these are affected by environmental pressures. This area has been strengthened by the Lecturer appointment of Parr with her expertise in fire and tropical ecology. The group focuses on two themes: First, understanding the community and ecosystem response to intrinsic and extrinsic drivers, from the marine environment through to upland peat bogs and forests (NERC grants to Spencer and Parr); Second, the scientific underpinning for an ecosystem-based approach to managing the environment and natural resources emphasizing ecological modeling using empirical data (Biodiversa grant and Impact Case #3, Marrs).

Following our reorganisation, there has been more than £2M investment in our facilities (section d) provided by external (RCUK, EU, Industry) and University support. In addition, individual staff are supported via internal workshops, the competitive opportunity to bid for pump priming, and sabbaticals (section c). Positive outcomes from our research strategy are:

- *Improved grant success rates* (46% in 2010 rising to 63% in 2012), growing our research income (including in-kind) by 67% and involvement in a series of major research grants (listed in section d).
- *Growth in PhDs* by 14% with 75.1 completed PhDs (PhD strategy in section c), whilst maintaining an excellent completion rate, 95% for all PhD students within four years.
- *Increase in international profile* through more outputs appearing in high-profile journals: 30 outputs over the REF2014 period (two in *Science*, six in *Nature*, three in *Proceedings of the National Academy of Science*, as well as 18 in the recently formed *Nature Geosciences*, one in *Nature Climate Change* and one in *Nature Communications*); 18 of these outputs in high-profile journals are returned compared with 3 outputs in RAE2008.

Scientific breakthroughs during the REF period, aided by our people strategy (in c), include:

- One of our new research fellows, **Biggin** has identified long-term links between geomagnetic variations and whole mantle convection (Biggin, #1).
- A new Chair appointment, **Lavallée** has identified how kimberlite ascent is fuelled by buoyancy (Lavallée, #2).
- A senior Professorial fellow, **Kusznir** has developed satellite gravity inversion techniques for mapping ocean-continent transition structure (Kusznir, #3), which is now widely used by industrial partners in deep water oil and gas exploration (Impact Case #1).
- A new Lecturer appointment, **Tagliabue** has identified the importance of hydrothermal iron inputs for ocean biogeochemistry (Tagliabue, #1).
- One of our joint Chair appointments with NOC, **Sharples** has demonstrated how heat waves lead to harmful cyanobacteria blooms (Sharples, #1).
- Drawing on an international collaboration, **Williams** has identified how the warming of the North Atlantic Ocean over the past 50 years is not uniform, but instead has opposing wind-induced patterns over the subtropical and subpolar gyres (Williams, #1).
- **Spencer** has identified how coral-reefs ecosystems respond to natural and anthropogenic forcing (Spencer, #1), and this collaboration has been strengthened by a sabbatical in the USA and a subsequent NERC grant.

### ii. Future Vision and strategic plans

Building on our recent success, we have identified high-profile research areas where we are well placed to make significant contributions:

- *Living with Environmental Change* (LWEC): assessing how the ocean is warming, how sea level is rising, how nutrients are cycled and eutrophication occurs in shelf seas and coastal waters, and ecological responses to environmental change (aligns with the RCUK Challenge, LWEC theme and the University institutional research theme, LWEC);

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- *Geohazards*: identifying the relationship between active tectonics, fault processes and earthquake occurrence and establishing quantitative physical models for volcanic eruptions (links to the University Institute for Risk and Uncertainty);
- *Exploiting Natural Resources*: developing industry links via Joined Industry Projects (JIPs).

To address these challenges, we plan to develop three new research centres by 2015:

- 1) The *Liverpool Centre for Coasts and Oceans*, drawing on our unique clustering of world leading experts in sea-level science (DEOES, NOC), coastal sea modelling (NOC), fisheries and ecosystem services (DEOES), maritime integrated management, planning and assessment (DGP) and sea defences (School of Engineering). This grouping will draw on the sea level data collated at NOC and understanding of extreme events and climate change to provide advice as to the impacts of sea level.
- 2) The *Liverpool Tectonic Observatory* focussing on understanding the physical processes leading to faulting and earthquakes, earthquake rupture dynamics, and volcanic eruptions. Both (1) and (2) will form the core of our collaboration with the University's *Institute for Risk and Uncertainty*.
- 3) A research centre for *Hydrocarbons and Mineral Resources*, which will provide a point of contact for industry, especially SMEs, and a base for our JIPs.

Measures of success will be strengthening our research activity, including raising our national and international profile, leading more major research grant programmes (RCUK, EU Horizon and collaborations with Industry), increasing our PhD base, as well as growing our impact agenda (detailed in REF3a), including advising regional and national government.

### c. People, including:

#### i. Staffing strategy and staff development

There are two parts to our staffing strategy: how we recruit new staff and how we ensure existing staff experience a supportive and creative environment. For recruitment, we usually advertise internationally the post over broad research areas, rather than over narrow topics, in order to recruit the best researcher. This has led to the appointments of a Chair, Lavallée (Munich, Germany), and six Lecturers, De Angelis (Fairbanks, USA), Duller (Imperial College), Kavanagh (Monash, Australia), Parr (Oxford, previously Darwin, Australia), Ryder (Berkeley, USA) and Tagliabue (Cape Town, S. Africa). We also develop targeted appointments if there is a particular strategic need, such as the strengthening of the collaboration with the National Oceanography Centre (as identified as a goal in RAE2008), involving Chair appointments, Hughes and Sharples, joint with NOC.

Research support is provided throughout the career of staff, taking into account the different challenges they face:

- For Early Career Researchers there is a *formal mentoring system* (overseen by a School mentor manager), where new staff receive formal advice via workshops and individual advice from experienced staff members, such as on how to develop grant applications.
- We welcome staff with *personal research fellowships*, we have three current fellows: Biggin, NERC Advanced Fellow (2009–2013); Salaun, EPSRC Advanced Fellow (2008-2012); and Jeffreys, Leverhulme Fellow (2013–present). Biggin and Salaun are now permanent. In taking Fellows on, we provide support in developing their research career, for example Biggin was mentored in obtaining a further NERC grant resulting in new explanations of how long term geomagnetic variations are controlled (Biggin, #1).
- All newly-appointed Lecturers (De Angelis, Duller, Kavanagh, Parr, Ryder, Salaun and Tagliabue) are given start up funds and initially a *reduced teaching load* (typically one 15 credit module or less) in order to embed their research; they are all returned in the REF2014.
- For all staff, but especially new staff, there is an opportunity to bid for *pump priming grants* to develop proof of concepts from within the School (17 awards for a total of £51K, and two equipment awards for a total of £27K) or the University via the University Research themes, particularly '*Living with Environmental Change*' (four awards for a total of £13K). For example, over the course of the REF period, Mahaffey has exploited a series of pump-priming grants to develop a new nutrient laboratory, strengthening her nitrogen fixation work (Mahaffey, #1 and #2), and helping her win major grants (e.g. NERC awards on phosphorus cycling) and a UK Challenger Prize. Parr has received pump-priming support from the University (LWEC) and the

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School to enable the testing of field protocols that will be used in her recently awarded NERC consortium grant and to explore complementary research in fire and ecology in East Africa.

- All staff are encouraged to interact with the *Athena Swan* initiatives, addressing gender inequalities; the School is preparing a bid for a Bronze award in April 2014. There is a '*Female career research network*', which provides a forum to discuss issues related to women in science and advice on career development from senior female academic staff. The proportion of female academic staff has risen from 13% to 28% over the REF period; Mahaffey has been promoted to Senior Lecturer.
- The School promotes a family-friendly policy, enabling staff to work flexibly after maternity leave and three academic staff and one research fellow in DEOES have taken advantage of this opportunity. They also have a lighter teaching load for several months after returning to work and we have supported Hill (0.5 FTE) and Robinson (0.8 FTE) in their wish to work part time in order to spend more time with their children.
- We have instigated internal *training programmes* for staff designed to share good practice, on '*How to publish in high profile journals*', evident in the increased number of outputs in these journals (30 in *Science*, *Nature*, *Nature Geoscience* and *PNAS*; rising from four in 2009 to eight in 2013), and '*How to develop successful grant applications*', evident in improved grant success rates: rising from 46% in 2010 to 63% in 2012 and 57% to date in 2013. We are repeating these training exercises annually, as they have been positively received.
- All staff participate in internal grant review processes designed to strengthen submissions (including reviews of a concept note and a full proposal well in advance of the deadline); this process particularly benefits from our experience on grant review panels (section e).
- All staff are annually appraised through PDRs in terms of their progress and individual goals are set appropriate for their career stage (designed to deliver our research strategy).
- *International engagement* is particularly encouraged through the use of *sabbaticals* at all levels across the School; research leave has been taken by Faulkner, Leach, Mahaffey, Rietbrock, Robinson, Spencer, van den Berg and Williams. For example, Spencer used a sabbatical at Universities of Otago and Tennessee to develop a new mathematical approach to measuring community rates of change, drawing on his previous work on coral reefs (Spencer, #1). Williams had a sabbatical at Duke University in 2008, to complete a new textbook and strengthen his collaboration with Lozier in ocean climate change (Williams, #1 and #4); this now forms part of a collaborative NSF and NERC large grant. Rietbrock visited California Institute of Technology for seven months drawing on his seismological work in subduction zones (Rietbrock, #1) and established a new collaboration on seismic slip inversions and geodesy.
- *International visitors* are particularly welcomed, 48 visiting DEOES for periods of over two weeks, being attracted to our facilities (section d), as well as collaborating with our research leads, such as A. Barton (NSF fellow, Duke) visiting Williams and Sharples for 10 months in 2013 and R. Hough (CSIRO) extending a previous microstructure collaboration with Wheeler (Wheeler, #4).
- Finally, as they approach retirement, research-active staff are encouraged to *retain* links with the Department to share their experience; for example, Kuszniir, a senior Professorial Fellow continues to develop new views of crustal deformation (Kuszniir, #2 and #4), as well as maintain strong industrial collaborations (Kuszniir, Impact Case #1).

## ii. Research students

PhD students are at the core of our research activities. Over the REF period 75 students have completed PhDs (28 NERC supported) and there are 40 current PhDs (21 NERC supported).

To maximize the success of our PhD students, we adhere to the following procedures:

- PhD topics are put forward by research-active staff, the topics are internally reviewed, and each project has a supervisory team with at least one experienced supervisor. The best students are appointed based on an interview and assessment by an independent panel.
- Students have an Induction process including a University and Departmental training program, followed by a regular series of progress meetings with the supervisory team. This training framework includes an online Personal Development Record, a Research Skills Workshop for

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research students in their first year, a Career Skills Workshop for second and third years, annual Research Days where research students present a poster of their research.

- Progress of PhD students is reviewed annually, including written reports and progress interviews, and assessed independently by a Departmental progress panel.
- All students are expected to present their research at national and international conferences and receive training in research presentations; 95% of our PhD students presenting at international conferences over the REF period. 16 students have received prizes, including five students in 2012: C. Williams and K. Kenitz won prizes for best talks (UK Ocean Challenger and Ocean modeling meetings), T. Garth and M. Thomas won prizes for the best talk and poster (British Geophys. Assoc.), and L. Cowie won a prize for the best talk (Conjugate Margins). Recently S. Hicks led a geophysics team to win a NERC Environment YES competition in Oxford 2013, designed to raise business awareness.
- Student engagement helps develop a vibrant research atmosphere, for example students organise an Earth Sciences seminar series and lead the Ocean Sciences journal club.
- Students are encouraged to consider internships to gain wider experience; nine students have taken internships, four in Industry and five in Government and the Public Sector, e.g. E. O'Rourke completed a three month placement at Westminster in 2008, gaining skills in communicating policy to stakeholder groups, leading to her current post as Science Coordinator at the Swedish Meteorological and Hydrological Institute; N. Carson completed a three month placement at Marine Scotland leading to her current post at DEFRA.
- Students and supervisors work closely together to ensure that research outputs in high-quality journals are produced, encouraging the thesis to be structured in a format to aid the output of papers. This engagement has led to 24 PhD students being co-authors of REF outputs (23 of which are first or second author). For example, PhD students R. Mather & S. Reynolds are the lead authors on a *Nature Geoscience* study identifying how phosphorus is cycled differently in the North and South Atlantic Ocean (Wolff, #2).

Adopting the above procedures has ensured an excellent PhD completion rate within four years, 95% for all PhD students and 100% for NERC supported students over the REF period (taking into account approved breaks of study, such as internships). Upon completion, PhD students are encouraged to apply their skills to research and industry, and when appropriate to apply for fellowships and seek international experience. Over the REF period, 31% of our graduates have moved to academic research, 50% to the private sector and 19% to the public sector.

Our strategy is to consolidate and grow the number of PhD students. The Department was engaged in two successful NERC Doctoral Training Partnership bids '*Training the Next Generation of Environmental Scientists*' (involving thematic training in Atmospheric, Ocean and Earth Sciences with Manchester University and the National Oceanography Centre) and '*Adapting to the Challenges of a Changing Environment*' (ACCE) (Ecology thematic training with Sheffield & York Universities). There will be 26 funded studentships between the two DTPs and these will be further augmented by additional resource from the School.

### **d. Income, infrastructure and facilities**

Over the REF2014 period, DEOES staff have generated research and KE income (including in-kind) of £13.3M representing an increase of more than 67% in comparison to RAE 2008 (averaged per year). Since the School became a financial entity three years ago, we have gradually introduced our staffing strategy (see section c), which has led to a 30% increase in the number of grant applications and an increase in awards of over 20%; this increase reflects success rates improving from 46% in 2010 to 63% in 2012 and 57% to date in 2013.

Our aim after RAE 2008 was to maintain high RCUK funding, whilst simultaneously diversifying our funding base to make our infrastructure more resilient to changes. This strategy has been highly successful, evident in our research income now consisting of RCUK 38%, Industry 31%, EU 17%, and Charities 14% (whereas only 10% came from UK Industry in RAE 2008); this change represents a 100% increase in EU funding, a 100% increase in funding from industry, and a 250% increase in funding from Charities. As part of increasing our industry portfolio with JIPs, we have

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also increased our impact, as reflected in the returned Impact Cases #1 and #2.

As part of our research performance monitoring, in 2011 we identified that we needed to strengthen our large grant applications and we have been successful in leading two large grants in 2013,

- Sharples, Mahaffey and Wolff, NERC Consortium on the *Shelf Sea Biogeochemistry Theme Action Plan*, led by Sharples - £3.2M plus ship time,
- Lavallée, European Research Council large grant, *Strain Localisation in Magmas* - €1.9M, as well as collaborating in three large grants in 2013 (involving each of our research groups),
- Williams, NERC large grant, the *UK Overturning in the Subpolar North Atlantic*, joint project with the US NSF programme - £3M from NERC plus ship time,
- Parr, NERC Consortium on *Biodiversity and Biogeochemical cycling in tropical forests* - £3.6M,
- Rietbrock, NERC Consortium on *Volatile recycling at the Lesser Antilles Arc: Processes and Consequences* - £3.4M plus ship time.

Our aim is to continue this engagement in major grant submissions, particularly exploiting the formation of our new research centres (section b).

### ii. Facilities and Infrastructure.

Facilities and laboratories are central to our research strategy in providing the equipment to enable our research activity, as well as being essential in the training of our PhD students. The Department is committed to support the knowledge base and expertise in the laboratories by providing bridging funds for technical staff and providing a research support budget to enhance equipment (e.g. in 2012 we invested £250K to replace and update equipment). Support for our facilities is provided on various levels (e.g. staffing, funding of research equipment, space allocation) taking into account the specific needs of the facility including:

#### 1. Actively manage the facility in the event of staff retirement and turnover

Two of our most successful facilities, **Geomagnetism** and **Electron Microscopy & Electron backscatter diffraction**, have had changes in leadership (retirement and departure of the lead academic, respectively). Proleptic appointments of academic staff (Biggin & Hill) were made in *Geomagnetism* and Wheeler now leads the research laboratory in *Electron Microscopy & Electron backscatter diffraction*, ensuring that both these facilities are sustained. The **Geomagnetism** laboratory has supported 70 peer-reviewed, international publications, including *Nature*, *Science*, and *Nature Geoscience*, during the REF period. It is internationally unique in terms of its facilities (e.g. two high frequency microwave palaeo/archaeo-intensity systems) and supports research in diverse areas: deep Earth, tectonics, climate change, and archaeology. It has received more than 20 international visitors (for more than two weeks each), won nine research grants (NERC & Royal Society of New Zealand), and has supported seven PhD students. It currently supports two PDRAs, four PhD students, and two emeritus staff. Major ongoing research collaborations are with Utrecht (Netherlands), Wellington (New Zealand), Cumhuriyet University (Turkey), and the Chinese Academy of Sciences. The **Electron Microscopy & Electron backscatter diffraction (EBSD)** laboratory applies crystallographic relationship and mineral chemistry data to research areas from rock deformation and metamorphism to mineral deposits and diagenesis within the Earth Sciences. The laboratory has supported 40 peer-reviewed publications, including *Nature Geoscience*, has won 10 NERC, CSIRO, Carbon Trust and Knowledge Exchange grants, and supported 12 PhD students. The facility has a h index = 22 and it is one of the best 10 laboratories in the world for its visibility at conferences and peer-reviewed papers on EBSD; six of the 10 most visible laboratories are run by ex-PGRs, PDRAs and staff from the Liverpool laboratory. International collaborations include Otago, CSIRO Australia, Munich, Oviedo, Zaragoza, Barcelona, and Catania.

#### 2. Developing existing laboratories by adding new capabilities

(a) Following RAE2008, the University invested £500K to form the **Liverpool Isotope Facility for Environmental Research (LIFER)**, which is a School Facility drawing on existing carbonate isotope, organic geochemistry and nutrient biogeochemistry facilities. LIFER adds the capability for organic and compound specific isotope ratio analysis (C, N and H), aqueous inorganic nitrogen species and spectroscopy for water isotopes. The laboratory has led to more than 60 peer-reviewed publications, including *Nature Geoscience*, in the REF period. The facility has won six NERC and EU grants, a Leverhulme Foundation grant, a Leverhulme Fellowship and a Knowledge

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Transfer Partnership (funded by Chemostrat Ltd, NERC and the Welsh Government). 19 PhD students, five PDRAs and a RA have used the facilities, as well as visiting students from Manchester, Southampton, UCL, Exeter and York, the Federal Universities of Espírito Santo and Paraná. There are also ongoing collaborations with the Universities of Sydney and Ghent.

(b) The **Rock Deformation Laboratory** was established in 2003 with a small investment of £18K, but has grown through research funding exceeding £3.5M in the REF2014 period and contributes to our active tectonics research theme. The equipment in the laboratory is designed and built in Liverpool and replicates *in situ* conditions from the surface to the upper mantle. The laboratory has contributed 38 peer-reviewed publications, including two in *Nature Geoscience*, and was supported by six NERC grants and industrial funding. 13 PhD students have worked in the lab (six UoL, plus five Overseas, and two UK). International collaborations include Universidad Catolica (Chile), Wellington, Otago and GNS (New Zealand), Ecole Normale Superieure, Paris and Hiroshima (Japan).

### 3. Developing new laboratory facilities for new academic staff

We are currently establishing an **Experimental Volcanology** laboratory with investment exceeding £1M (from ERC and University funds). The facility includes cutting-edge rheological, thermo-mechanical, petrological and monitoring equipment – designed to foster a *Geomaterial Science* approach to the fundamentals of magmatic, volcanic and tectonic processes in the Earth systems. Upon completion in early 2014, the laboratory will rank amongst the largest experimental volcanology facilities in the world.

Staff have extensive collaborations in volcanology and rock mechanics: nationally with UCL, Bristol, Lancaster and Leeds and internationally with the LMU-Munich (Germany), Canterbury (New-Zealand), Kochi Core Centre (Japan) and volcano observatories (Mexico, Japan and Guatemala).

### 4. Consultancy and professional services

Our facilities provide our outward face to consultancies, such as *LIFER* providing analytical services to Selonda, GHG and Chemostrat Ltd, the *Rock Deformation Laboratory* working with the BP-Statoil-Sonatrach JIP leading to Impact Case #2, and Salaun and van den Berg working with Metrohm UK on voltametric detection of trace elements, such as arsenic and mercury.

### e. Collaboration and contribution to the discipline or research base

Earth System and Environmental Sciences has been restructured at Liverpool, so that our research spans the full range of disciplines within the School. The University has developed institutional inter-disciplinary research themes, one of which '*Living with Environmental change*' (LWEC) is led by DEOES (aligned with the RCUK theme). The Department is also strongly engaged with the *Institute for Risk and Uncertainty* on translating environmental hazard into risk assessment. Collaboration with Industry now represents 31% of our income, and directly influences our Impact agenda, as represented by Impact cases #1 & #2: **Kusznir** leads the *Modelling of Margins Phase 2 & 3*, funded by industry and **Faulkner** has worked closely with by BP to assess the impact of carbon sequestration on reservoirs.

**International Collaboration** and increasing the profile of our work are key parts of our research strategy. These are aided by overseas sabbaticals and pump-priming to develop grant applications with international partners (section c), as well as support for overseas studentships with partner institutions. This collaboration is reflected in 65% of our REF outputs having an international co-author. Highlights for research collaboration include:

- **Rietbrock** and **Ryder** spearheaded UK seismic research following the Chilean earthquake in 2010 collaborating with US and Chilean scientists; this relationship was consolidated with a sabbatical period for Rietbrock at Caltech. Liverpool collected the International Maule Aftershock Dataset, as well as organised an international workshop in Chile to disseminate the data.
- **Faulkner** has participated in the International drilling project in the Southern Alpine fault system of New Zealand, one of the most ambitious in the Southern Hemisphere.
- **Sharples, Mahaffey, Wolff, van den Berg, Tagliabue** and **Leach** have led or participated in

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15 cruises on British, German, US and Irish research vessels in the REF period collaborating with US and European scientists.

- **Williams** collaborates strongly with Lozier at Duke, supported via a NSF & NERC grant OSNAP, which is being taken forward via a bid to NSF to form a virtual institute, *North Atlantic Virtual InStitute*, NAVIS, linking North Atlantic Ocean researchers at 11 institutes (including Woods Hole, Duke, NOC, Liverpool, Oxford, IFREMER and IFM-GEOMAR) to enable collaboration and PhD student exchange.
- **Robinson** has led ODEMM, a multi-partner > £1M International Programme, which informs policy, namely the EU Marine Strategy Framework Directive.

**Leadership in the academic community** is provided by our involvement in international advisory boards. Examples include: **Hughes, Tamisiea** and **Woodworth** involved in altimetry and gravity missions (GOCE Satellite Mission Advisory Group, Global Geodetic Observing System (GGOS), IAPSO Commission on Mean Sea-Level and Tides); **van den Berg** and **Tagliabue** working on organic ligands (SCOR Working group) and **Tagliabue**, co-chair of GEOTRACES data management; **Woodworth**, Review Editor for the latest IPCC AR5 WG1 Chapter 13 on Sea Level Change', Member of the Foreign and Commonwealth Office Science Advisory Group for the British Indian Ocean Territory. In addition, staff provide **leadership roles** within the Research Councils, such as the NERC peer review college (**Mahaffey, Marrs, Rietbrock, Sharples, Williams**) and the DFG (German Research Council) review panels (**Leach, Rietbrock, Wolff**), and the British Ecological Society review college (**Spencer**). In particular, **Wolff** is the Senior Scientist in the project to commission a new NERC research vessel (£75M) and Chair of the National Marine Facilities Board, and **Hughes** is Chair of NERC Space Geodesy Facilities Steering Committee.

Staff are involved in **organising international meetings**: **Robinson & Spencer**, the 44th European Marine Biology Symposium, 2009 at Liverpool and **Hughes**, an international Southern Ocean Theory Workshop at NOC in 2008 and **Hughes and Tamisiea** a meeting on Causes of Sea-level Changes, Geological Society 2008. Staff are also engaged in **organising sessions** at meetings: e.g. **Hughes**, ESA 2013, **Lavallée**, AGU 2010, EGU 2010-2013; **Marrs**, ECCB, 2012, IAVS 2012; and **Tamisiea**, AGU 2008-2011, EGU 2008, UNAVCO 2008.

Staff provided over 169 invited international talks, including 10 keynote and 4 plenary talks. Selected examples: **Biggin**, AGU 2008-2010, 2012; **Faulkner**, AGU 2009, 2011 & 2013, Gordon 2010, EGU 2008; **Hughes**, WRCP-IOC, 2011, AGU 2011 & 2013, MIT, 2013; **Kusznir**, AGU 2008-2013, EABS 2008, 46 Brazil/Geol Congress, TSG 2011; **Marrs**, ECCB SER 2009, 2012; **Wheeler**, AGU 2008, EGU 2009; **Williams**, Ocean Sciences 2012, US AMOC 2013, WCRP/CLIVAR 2013; and **Wolff**, AGU Chapman Conf. 2009.

Staff provide a **wider contribution to the discipline base** by journal editing.

As **Editor**: **Marrs** - Persp. Plant Ecol. Evol & Syst., Biol. Conserv., J. Veg. Sci., Appld Veg. Sci.; **Wheeler** - J. Geolog. Soc.. As **Associate Editor**: **Faulkner** - J. Geophys. Res.; **Kokelaar** - Geology; J. Geolog. Soc.; **Marrs** - J. Vegetation Sci., Applied Vegetation Sci.; **Parr** - J. Biogeography; **Palmer** - Ocean Dynamics; **Ryder** - J. Geophys. Res.; **Sharples** - Continental Shelf Res.; **Spencer** - Methods in Ecology & Evolution; **van den Berg** - Marine Chemistry. As **Editorial board members**: **Biggin & Holme** - Geophys. J. Intern.; **Kokelaar** - J. Volcanic & Geothermal Res.; **Parr** - Biotropica; **Spencer** - Sys. Biology; **van den Berg** - Analytica Chimica Acta.

Staff and students have been rewarded by **prizes and awards**: including **Kokelaar** - Murchison medal, Geological Soc., 2013; **Marrs**: "Greatest number of publications in the 50 years of J. Applied Ecology"; **Mahaffey** - UK Challenger Society for Marine Science, 2008; **Woodworth**: 2009: Vening Meinesz medal, EGU, 2010; Member of the Order of the British Empire (MBE), 2011, Intergovernmental Oceanographic Commission 50th Anniversary Commemorative Medal, 2011; and our PhD students have won 16 prizes (examples in section c).