Institution: University of Southampton

Unit of Assessment: 07 Earth Systems and Environmental Sciences

a. Overview

This submission is for University of Southampton (UoS) staff based at the National Oceanography Centre Southampton (NOCS). Natural Environment Research Council (NERC) scientists at the National Oceanography Centre who have demonstrable links to the research of Category A staff (PhD student supervision, publications, grants) are included as Category C (names underlined).

NOCS was created in 1995 jointly between the UoS and NERC, and is one of the world's leading centres devoted to research, teaching, and technology development in Ocean and Earth science. NOCS is a superb purpose-built dockside campus with modern facilities, which provides a vibrant research environment for both UoS and NERC researchers. In 2010 the University and NERC components demerged, and the NERC-managed component became the National Oceanography Centre (NOC – with the Proudman Oceanographic Laboratory). The two components of NOCS continue close collaboration through the jointly run Graduate School (GSNOCS), shared research facilities and laboratories, complementary research groups, and many joint research grants and publications. The University component "Ocean and Earth Science, National Oceanography Centre Southampton" (OES) is part of the Faculty of Natural and Environmental Sciences (FNES).

OES comprises six research groups: (a) Geochemistry (Geochem), (b) Geology & Geophysics (G&G), (c) Palaeoceanography & Palaeoclimate (P&P), (d) Physical Oceanography (PO), (e) Marine Biogeochemistry (BGChem), and (f) Marine Biology & Ecology (MB&E). Coastal research is coordinated through a cross-cutting theme, and is closely aligned with the new Southampton Marine and Maritime Institute (SMMI), which facilitates links with marine and coastal engineers in the Faculty of Engineering and Environment. The Institute for Life Sciences (IfLS) integrates Biosciences across UoS including NOCS.

b. Research strategy

ACHIEVEMENT OF STRATEGIC AIMS: We aim to remain at the forefront of international research in oceanography and marine geoscience, a position we have strengthened since RAE 2008. Our 2008 submission set out the following questions:

- *How has climate changed through Earth History?…what lessons for the future?* We led equatorial Pacific IODP Expeditions 320/321 (Pälike) and North Atlantic Exp 342 (Wilson), refined the analysis of $\delta^{11}B$ as a tracer of ocean pH (Foster), developed atmospheric CO_2 and ocean carbonate saturation records (Pearson et al. 2009; Pälike et al. 2012), and improved understanding of their links to climate (deConto et al. 2008; Merico et al. 2008; Foster & Rohling, 2013; Bijl et al. 2010; Lunt et al. 2008; Rohling et al. 2012).
- *How are ocean circulation and climate change linked? How might changes to the North Atlantic affect European climate?* We led or participated in NERC consortium projects RAPID-WATCH (£3.4M), DIMES (£3M), ANDREX (£1.5M), TEA-COSI (£3M), Ocean2Ice (£1.5M), OSMOSIS (£3.7M). We measured Arctic circulation (Tsubouchi et al. 2012; Aksenov et al. 2011). We advanced understanding of ocean impacts on seasonal climate variability (Taws et al. 2011), and of mixing and its role in large-scale ocean circulation (Naveira Garabato et al. 2011; Meredith et al. 2012). We determined the variability of the ocean overturning circulation from seasonal to interannual timescales (Kanzow et al. 2010, McCarthy et al. 2012), and the dominant role of overturning in fluxing heat northwards (Johns et al. 2011).
- *What are the current and projected rates of sea-level change; …regional effects…and…socio-economic impacts?* New sea-level records informed future projections (Rohling et al. 2008, 2009; Grant et al. 2012). We lead NERC consortium project iGlass on past and future sea-level (£3.3M) and contribute to consortium iCoast on methods to forecast coastal change. We synthesised new sea-level datasets for the UK (Haigh et al. 2009). This topic is also addressed in our impact case study (ICS) on the relevance of past sea-level to the future.
- *What are the major natural hazards…? How do we…improve hazard assessment and prediction?* We investigated landslide processes and tsunami potential (Lefriant et al. 2010; Hunt et al. 2011; Trovimovs et al. 2012; Sumner et al., 2013), and imaged magma beneath Montserrat (Paulatto et al. 2012). Within a NERC consortium (£2.5M), we identified controls on plate boundary slip (Dean et al. 2010) and on rupture extent (Gulick et al. 2011).
- *What controls ocean biodiversity and ecosystem health; will they alter with changing climate?*

We led development of the £12M UK Ocean Acidification research programme UKOA. We studied the geoengineering implications of natural (island) Fe fertilisation (Pollard et al. 2009; Salter et al. 2012). We developed new molecular techniques to study the biogeochemical role of marine microbial communities (Richier et al. 2012). We demonstrated that imbalanced levels of dissolved inorganic nutrients increase the susceptibility of reef corals to heat-stress induced bleaching and mortality (Wiedenmann et al., 2012).

- *How do we responsibly exploit natural resources?* We lead international programmes studying the use of algae in biofuel generation (Carbon Trust, BBSRC/NSF consortia totalling >£3M) (Zubkov & Bibby 2011). A new approach identified open-ocean Atlantic salmon feeding grounds and migration routes (MacKenzie et al. 2011). Research on the Zambian copper belt has defined a new mineral exploration paradigm (Roberts et al. 2009; see also the Impact Case Study (ICS) on economic geology).
- *What are the…processes in cycling of key elements, such as carbon, in the ocean and earth system? How will these…react to climate change?* We characterised the origin of past hyperthermals (Sexton et al. 2011). We determined how past weathering variations impact ocean chemical budgets (Vance et al. 2009), developed a new method for estimating the cation chemistry of past oceans (Coggon et al. 2010; Coggon & Teagle, 2011), and discovered methane venting off Svalbard (Westbrook et al. 2009). We demonstrated links between atmospheric dust inputs and North Atlantic plankton (Maranon et al. 2010; Rijkenberg et al. 2011) and Southern Ocean Fe fertilisation (Pollard et al. 2009; Planquette et al. 2011). We determined the role of nitrogen fixers in Atlantic waters (Moore et al. 2009) within a wider global context (Duce et al. 2008).
- *What are the mechanisms of the solid Earth cycle… ?* We led IODP Expedition 335 to sample a complete section of upper oceanic crust (Teagle and Ildefonse 2011; Teagle et al. 2012). We defined the nature of the lithosphere-asthenosphere plate boundary and the mechanisms controlling its position globally (Rychert et al. 2009), characterised continental rifting (Armitage et al. 2010; Keir et al. 2011; Bastow et al. 2011), and identified an earlier-than-anticipated plate convergence in the Indian Ocean (Bull et al. 2010).

We also said that we would:

- **Provide leadership in…international science programmes.** We provide international leadership in scientific ocean drilling, including key roles in 50% of the *JOIDES Resolution* expeditions since 2007. Teagle and Pälike co-authored the 2013-2023 IODP science plan and led international workshops to define it. Teagle now chairs the UK-IODP committee. Pälike, Teagle, McNeill, Bohaty and Rohling contributed to ECORD/IODP-sponsored international summer schools. We led NERC consortia across all of our disciplines (Henstock–Sumatra subduction; Tyler–ChEss; Naveira Garabato–DIMES; Rohling/Haigh–iGlass; Purdie–Macro-nutrients; Minshull–IPY hydrates; Tyrrell–Ocean acidification; Foster–Descent into icehouse; Solan, Statham–Shelf Sea Biogeochemistry).
- **Promote knowledge transfer (KT) to business and government…** See section e) below.
- **Develop Molecular Biology/Marine Biology/Biological Oceanography.** We made 10 new appointments in this area: S. Hawkins (Dean), Brownlee and Sims (Chairs), Solan (Reader), A. Bates, Fenberg, Godbold, Lam, Rius, and Smale (Lecturers). Brownlee, Sims and Hawkins consolidate long-standing links with the Marine Biological Association.
- **Expand Coastal Zone Research.** We appointed Haigh and Gallop, as well as experimental ecologists who focus on the coastal zone (Hawkins, Solan, Smale, and Godbold). Haigh, Thompson and Wells are returned in UoA 15 (Engineering).

EVALUATION OF CURRENT POSITION: We have attained internationally acknowledged strength in all RAE 2008 targets as evidenced by (i) international recruitment of outstanding academic staff (29 new permanent Cat A staff - section c.I), (ii) investment in an exceptionally wide range of facilities (section d), (iii) expansion of the Graduate School NOCS that is an international benchmark (section c.II), (iv) year-on-year growth of research income (section d). We have expanded our world-leading research groups in Palaeoceanography & Palaeoclimate and Physical Oceanography, and built new strengths (section c.I). These initiatives provide the basis for an ambitious future programme (below) boosted by wider University developments. We are strongly engaged with the Institute for Life Sciences (IfLS - 2010) that draws together University-wide

expertise in science and engineering to address the Life Sciences. IfLS has fostered links with the main University campus and Southampton General Hospital, including access to state-of-the-art imaging, bioinformatics, proteomics and lipidomics facilities and expertise. We provide one of two Deputy Directors (Teagle) and three of eight Theme Leaders (S. Roberts, Solan, Tsimplis) for the Southampton Marine and Maritime Institute (SMMI - 2012), a University partnership with Lloyd's Register (LR) and other business, civic and industrial societies. SMMI aims to become the world's leading centre for marine and maritime research, innovation and education. Lloyd's Register's £129M investment is the largest single joint venture between business and a UK University. SMMI incorporates a unique cross-disciplinary spectrum covering humanities, natural, physical, and social sciences, engineering, and law. NOC is a partner in SMMI.

FUTURE AIMS AND GOALS: We aim to lead international research in oceanography and marine geoscience. The 2008 questions remain pertinent to our research focus, along with new questions: *How do we measure anthropogenic impacts on the Earth's environment?* And *How can we mitigate the effects of environmental change?*

We will address these research questions through focused research programmes by individual research groups described above and appropriate collaboration with NOC, IfLS and SMMI, and nationally and internationally. We will:

- **Develop and apply new geophysical imaging techniques.** We will use seismic and EM inversion to provide quantitative information on sub-surface processes at a wide range of scales, including natural methane seepage and planned and unplanned release from subsurface reservoirs, and the thermal effects of offshore high voltage power cables. We will develop broadband seismic instrumentation to image lithospheric plates and determine their physical and chemical properties. *(G&G, Geochem, SMMI*)
- **Investigate the processes determining the rate, structure, and climatic role of the global overturning circulation.** We will use innovative instrumentation and models to study how turbulent processes shape the Southern Ocean overturning circulation, its sensitivity to climatic changes, and its role in the carbon cycle. High-resolution modelling will determine how mixed-layer processes regulate the atmospheric forcing of ocean circulation. We will investigate the sensitivities, stability and climatic context of oceanic overturning using mathematical techniques models and continuous, real-time autonomous observations (RAPID). *(PO, NOC)*
- **Determine the impact of the retreating cryosphere on ocean circulation, sea level and climate variability.** We will use observations and models to study the physical processes that regulate the transfer of heat and meltwater between ice shelves and the ocean. We will investigate consequences for sea level rise with new and historical measurements and novel statistical techniques. We will assess how the magnitude of Arctic ice cover has influenced climate variability and determine the relationships between low- and high-latitude climate change through greenhouse–icehouse transitions. *(PO, P&P, SMMI, NOC)*
- **Study carbon cycling, climate sensitivity and biotic change in past and future high CO_2 worlds.** We will assess how the carbon cycle and climate are coupled, to determine what controls long-term and short-term CO_2 change. Assessing the sensitivity of the climate system to past CO_2 forcing will inform prediction of possible future change. We will develop the boron isotope pH/pCO_2 method into a rapid-throughput palaeoclimate research tool, thus greatly increasing the resolution of records of past pCO_2 variability. (*P&P, Geochem, MB&E*)
- **Investigate the biogeochemical evolution of Earth surface processes.** We will use existing and new geochemical proxies to investigate how the composition of the Earth's ocean-atmosphere system has evolved in response to solid Earth processes (both unidirectional and stochastic) and the evolution of life. *(Geochem, BGChem*, *MB&E, NOC)*
- **Investigate biogeochemical cycles and their response to climate change.** We will study water column and sedimentary processes impacting on carbon, iron and nutrient fluxes (e.g., through NERC programmes Shelf Sea Biogeochemistry and Greenhouse Gas consortia). We will study the effects of nutrients on the stress resilience of reef corals (Wiedenmann, ERC grant). We will examine nutrient cycles in estuaries (e.g., NERC Macronutrients consortium), and develop novel instrumentation and numerical models. *(BGChem, NOC)*
- **Investigate the importance of sediment dynamics in biogeochemical processes.** We will use in-situ and laboratory techniques to study sediment stability and the role of resuspension in

nutrient and carbon cycling across the sediment water interface. We will strengthen further our staffing in sediment dynamics to take advantage of UoS £21M investment in Hydrodynamics. *(G&G, BGChem, MB&E, Geochem, NOC, SMMI)*

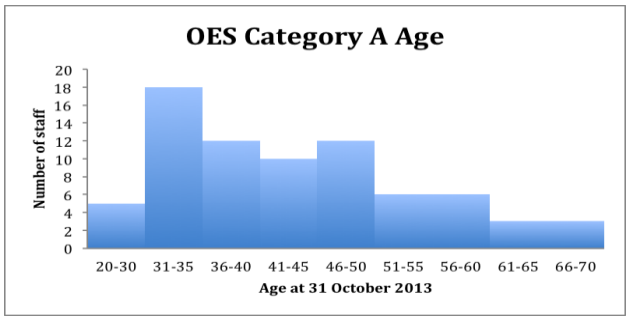
- **Establish relationships between anthropogenically forced environmental change, biodiversity loss and ecosystem processes to inform sustainability.** We will couple sustained observations from natural systems with field and laboratory experimentation plus modelling to advance basic evolutionary and ecological theory and its application to solving problems associated with global environmental change in coastal and oceanic ecosystems. We will develop novel environmental control facilities and technologies capable of simultaneously quantifying abiotic and biotic processes. *(MB&E, SMMI, IfLS, NOC).*

c. People, including:

I. Staffing strategy and staff development

OVERALL STRATEGY: Our strategy comprised expansion of academic staff numbers, with a focus on research excellence, and fulfilling the strategy set out in our RAE2008 return (see section b). We will continue this in the future with specific strategic objectives set out in the Looking Forward section below. Within a broader UoS strategy we have made appointments at the interface between OES and Biological Sciences to capitalise on IfLS. Since the last RAE census, we have appointed 29 new Category A staff to permanent University positions, including Professors in Physical Oceanography (**Drijfhout**) and Marine Biogeochemistry (**N. Bates**). We have increased our breadth through appointments in global seismology (**Rychert**), carbon storage/geoengineering (**Matter**), environmental statistics (**Beaulieu**), organic geochemistry (**Whiteside** and **Bohaty**) and vertebrate palaeontology (**Dyke**).

A particular focus of our recruitment strategy has been to identify early career researchers (ECR) who will become future leaders, as is shown by our submission containing 19 ECRs. The median age of Cat A staff submitted is 41, and this relatively youthful age profile means we are well placed for the future. We invite outstanding fellowship candidates to visit us and pay for their travel and subsistence during scoping visits. We assign them mentors to help develop full proposals. Once awarded we ensure staff development is available as for all ECRs (see below), and many progress to permanent positions at NOCS or elsewhere.



We have 58 post-doctoral fellows and research assistants within OES. Personal Chair promotions since 2008 include Croudace, Mills, Naveira Garabato, Pälike, Purdie, S. Roberts, Tyrrell, and Wiedenmann. Physical infrastructure investments are made to support new appointments (see, section d).

Our research groups now comprise:

Geochemistry (Coggon (ECR), Croudace, Foster, James, Matter, Mills, Palmer, S. Roberts, R. Taylor, Teagle, Trueman, Cat C: Connelly).

New academic appointments have boosted the group's strengths in boron isotope geochemistry, geoengineering, CO_2 sequestration, and the methane cycle. New appointments are **Matter** (from Columbia); **Foster** (from Bristol); **Coggon** (Dorothy Hodgkin Fellow, from Imperial) and **James** (from NOC).

Geology & Geophysics (G&G) (Amos, Bull, Dix, Gallop (ECR), Gernon, Harmon, Henstock, Keir, McNeill, Minshull, A. Roberts, Rychert (ECR), Sumner (ECR), Vardy (ECR), Weitemeyer (ECR), Cat C: Talling, Wright, Wynn).

We have built critical mass in areas of existing expertise (electromagnetics, geological flows, volcanology) and enhanced our core strength in marine exploration seismology with appointments in passive seismology. In seismology we have appointed **Rychert** (from Bristol), **Keir** (from Leeds) and **Harmon** (from Scripps). **Weitemeyer** (from Scripps) has taken over leadership of marine controlled-source electromagnetics. In sedimentology we have appointed **Sumner** (from Leeds via MBARI) and **Gallop** (from UWA), and in volcanology **Gernon** (from Trinity, Dublin)**.**

Palaeoceanography & Palaeoclimate (P&P) (Bohaty, Gibbs, Goodwin (ECR), Hain (ECR), Harding, Kemp, Marshall, Pälike, A. Roberts, Rohling, Wilson, Whiteside, Xuan (ECR).

We have invested to sustain and enhance our recognised strength in this area with the appointment of three lecturers and two research fellows since 2008. Two new appointments support the development of organic geochemistry: **Bohaty** (SMMI Lecturer) and **Whiteside** (from Brown Univ.). **Xuan** (from OSU) will lead our development in environmental magnetism. New NERC Fellows are **Goodwin** (from Cambridge) and **Hain** (from Princeton)**.**

Physical Oceanography (PO) (Beaulieu (ECR), Bryden FRS, Drijfhout, Frajka-Williams (ECR), Haigh (ECR), Naveira Garabato, Marsh, Oliver, Shepherd FRS, Sevellec (ECR), Tsimplis, Wells, Zika (ECR); CAT C: Bacon, Josey).

New appointments are **Drijfhout** (Chair, from the Royal Dutch Meteorological Office); **Sevellec** (from Yale), **Oliver** (from the OU), **Frajka-Williams** (from NOC), **Haigh** (from UWA), **Beaulieu** (from Princeton) and **Zika** (NERC Research Fellow, from UNSW). We have invested to bring in leading modellers at both senior and junior level. These appointments have considerable strength in the use of innovative theoretical and modelling approaches to investigate the dynamics of ocean circulation and its role in climate. Continuity of RAPID analysis/observational oceanography is assured through the appointment of **Frajka-Williams**.

Marine Biology & Ecology (MB&E) (A. Bates (ECR), Brownlee, Copley, Dyke, Fenberg (ECR), Godbold (ECR), Hauton, S. Hawkins, Lucas, Rius (ECR), Sims; Smale (ECR); Solan; Thatje; Tyler; Wiedenmann; Cat C: Anderson, Gooday, Ruhl).

New appointments are **Hawkins** (Dean, from Bangor), **Brownlee** (Chair joint with MBA), **Sims** (Chair joint with MBA), **Solan** (from Aberdeen), **Dyke** (from Dublin), **A. Bates** (from U.Tasmania), **Fenberg** (via U. Colorado), **Godbold** (from Aberdeen), **Rius** (from UC Davis), and **Smale** (from UWA via MBA). These appointments enhance our capabilities in molecular and cellular biology, advanced imaging and modelling, and link well with proteomics facilities in IfLS. We will advance general ecological and evolutionary theory by combining observations and experiments in the laboratory and field using marine and other model organisms and systems.

Marine Biogeochemistry (BGChem) (Achterberg, N. Bates, Bibby, Gledhill, Hickman (ECR), James, Lam, Moore, Purdie, Statham, Tyrrell; Category C: Henson; Mowlem, Sanders, Zubkov).

New appointments have strengthened our expertise in carbon and nutrient cycling (**N. Bates**, Chair, from Bermuda), microbe-mediated nitrogen cycle processes (**Lam** from MPI Bremen) and phytoplankton ecology (**Hickman,** a NERC Fellow).

LOOKING FORWARD: With 29 new permanent academic appointments since 2008 we are well placed for the future and we envision the next few years as a period of consolidation and enabling (see Career Development section). As well as addressing our future research aims and goals, we will:

- **make joint appointments with NOC in autonomous marine observing** with particular focus on sensor development and autonomous systems (all groups, NOC, SMMI). This will capitalize on shared strength in autonomous vehicles, and environmental microsensors.
- **invest in an academic position in radiochemistry** to develop our recognized strength.
- **continue to invest in coastal oceanography**
- **make additional appointments in biogeochemistry** from among the following areas: ocean carbon, nutrient and trace metal cycling, organic biogeochemistry, and molecular approaches to microbially-driven processes.

CAREER DEVELOPMENT

Research Assistants: Research assistant (RA) positions are advertised internationally with job descriptions, skills and attribute requirements available on-line. Candidate selection is carried out by a trained, experienced panel. Induction of new RAs is conducted locally and at University level. Following a one year probation period, RAs are annually appraised. Workshops, events and resources to support the career and professional development of RAs are provided at University level through the Professional Development Unit. All RAs can request mentors who are distinct from their direct supervisors to provide career development support. A NOCS ECR association organises social and career development events.

Early Career Researchers: All ECRs are appraised through their research group and provided with a mentor to support establishment of career goals. Teaching and administrative workloads are built up from initially low levels over a 3-year period, to allow new staff to establish and consolidate their research. New ECRs are prioritised in the allocation of internal funding for equipment and

research studentships and are allocated start-up budgets to allow them to travel and network.

Established academic staff: Clear targets for research are set through an annual staff appraisal scheme, which defines development and training needs and provides the basis for promotion. Periods of study leave are encouraged every four years (during 2008-2013, 42 Category A staff had sabbatical leave), as are fellowships and prizes that provide resources for teaching replacements (e.g., Philip Leverhulme Prizes to Pälike, Naveira Garabato). Mechanisms are in place to adjust teaching commitments to enable research fieldwork. Priorities for allocation of technical staff are set by the needs of major research facilities and funded research programmes. Expansion in laboratory-related research is supported by new technical support, and cost recovery through research grants is encouraged.

Concordat to Support the Career Development of Researchers: OES has a research and teaching fellow network to ensure a cohesive identity and that the seven principles of the Concordat are implemented. FNES has launched the Dean's prize to recognise excellence in ECR research, enterprise and teaching that reflects the Concordat principle of recognition and reward. Following consultation with researchers our Faculty has developed a Concordat Action Plan with a focus on induction, mentorship, and performance review and appraisal. The Faculty policy complements institutional policies that have been in place since 2009 that focus on disseminating the Concordat; raising awareness among all staff, seeking input from research staff, seeking appropriate implementation mechanisms, identifying lines of responsibility, institutional review of practice, and establishing professional development support for researchers.

Personal research fellowships: Our return includes seven ERC, Royal Society or NERC-funded independent research fellows (Coggon, Gibbs, Goodwin, Hain, Hickman, Wiedenmann, Zika) and five others who held such fellowships during the REF period and have progressed to open-ended positions (Foster, Gledhill, Moore, Naveira Garabato, Rychert). Fellows are invited to staff meetings, are fully integrated into research groups, and are encouraged to contribute to teaching, to co-supervise PhD and masters students, and are fully supported to develop their careers.

International links: Academic posts are advertised in international media, and of our 29 new staff, 18 have either come from overseas institutions (USA, Australia, Germany, Holland, Ireland) or have non-UK nationality. International visiting scholars are encouraged (45 as official visitors during the REF period), as are visiting international research students (57 visitors). Distinguished scientific leaders who have visited include: Bernsten, Church, Cushman-Roisin, Farmer, Kelemen, Munk, Polzin, van Keken, Van Mooy, Wunsch, Zachos. Van Mooy and Kelemen are UoS Diamond Jubilee Visiting Fellows (2013-2016). European links are strengthened through participation in the informal G3 network with NOC, Geomar and Ifremer. Memoranda of Understanding govern activities such as PhD student exchange with Woods Hole Oceanographic Institution. We have also capitalised on the University's membership of the Worldwide Universities Network (WUN) through running video-conferenced seminar series and extensive participation in staff and PhD student exchanges.

Equality & Diversity: Since RAE2008 we have appointed 12 female permanent academic staff, which has moved us towards a better gender balance. The University of Southampton recognises that there are national challenges with gender and diversity inequality in STEM disciplines that can negatively affect female and/or minority group career progression. UoS has a long held commitment to addressing these issues as a founding signatory of the Athena SWAN Charter, so we can maximise the potential of all our staff. Several initiatives have been implemented following an institution-wide well-being survey, including greater career guidance, peer mentoring, more family friendly policies and changes to recruitment and selection policies. UoS efforts have been formally recognized with a Bronze Athena SWAN Award since 2006.

In May 2013 we were awarded an Athena Swan Departmental Bronze Award after a self-assessment team (lead, Solan) facilitated a consultation with staff and analysis of perceptions and culture across OES. By documenting evidence of good practice and identifying areas for further improvement, targeted focus groups have formulated an action plan that will implement equality and diversity policies, and widen awareness. We will apply for Athena *Swan* Silver department award within 2 years. In 2013, 3 female Cat A staff members have taken advantage of a new scheme, developed as part of the Athena Swan action plan, to ensure continuity of career during parental leave. This can include the costs of employing an individual to continue specific research projects during parental leave.

II. Research students

The Graduate School of the National Oceanography Centre Southampton (GSNOCS) is a long-standing, joint venture between UoS and NOC. With nearly 200 doctoral researchers, GSNOCS presents a vibrant, large, diverse, international, and truly multi-disciplinary research community. Although principally administered by UoS staff, NOC research staff are fully engaged in supervision, training, recruitment, and progress-monitoring of graduate students, with strong representation on the GSNOCS management committee.

In October 2014 the SPITFIRE (Southampton Partnership for Innovative Training of Future Investigators Researching the Environment) multidisciplinary NERC Doctoral Training Partnership (DTP) will start with a cohort of 15 students per year. This DTP will build from GSNOCS, working with nine Research Organisations as partners, as well as other parts of the UoS.

Recruitment: Doctoral student recruitment has increased steadily from ~30 students per year in 2007 to more than 60 for 2012/13 and 2013/14. PhD completions were steady for 2008-2012 (27 – 29 per year), but increased to 39 in 2012/13, reflecting growth in recruitment. The cohorts have a strong international membership with ~25% from the EU and ~15% from overseas. PhD students are supported by a variety of NERC Doctoral Training Grant (DTG), CASE, and tied awards, EPSRC grants, University (e.g., SMMI, IfLS, and Vice Chancellor's awards) and NOC funds, and a range of European and international scholarships, as well as direct industry support. PhD topics are peer-reviewed before being widely advertised. Our philosophy is to attract the best students possible and provide guidance to enable them to choose the most appropriate projects. Students selected for interview visit NOCS for a full day of assessment including a formal independently chaired interview panel. We have increased the size of our Masters in Research cohort from 12 in 2008 to 19 in 2013, and these students often progress onto a PhD.

Training and support: All PhD students receive stipends at RCUK levels (or higher) and are treated equally with regards to supervision and training opportunities. All students engage in subject-specific training (e.g., mass spectrometry, computational methods, environmental statistics) as well as generic skills training. We run a short first semester training course "Research Horizons for PhD researchers" where all students explore, refine, and plan their PhD research and identify their individual training needs with their supervisory teams. Each student then presents their research to their peers and supervisors as an AGU-style hypothesis-defining oral presentation followed by a written *Nature*-style article. These submissions are peer-reviewed by the student's advisory panel and the academic staff overseeing the course. In addition to the weekly flagship NOCS Seminar Series in which well-known external speakers present their science to the broad NOCS audience, there are many weekly, discipline-specific seminar series with a mix of external and internal speakers including PhD students. All PhD students are expected to attend international meetings, and are encouraged to participate in annual competitions for exchanges with Woods Hole Oceanographic Institution and Worldwide University Network partners as well as other international initiatives (e.g., InterRIDGE Fellowships). All GSNOCS students are encouraged to take advantage of our close engagement with international marine and Earth research programmes (e.g., IODP, GEOTRACES) to gain experience of major international science expeditions, even if these are not directly related to their PhD research.

Monitoring and Outcomes: Each graduate student has an Advisory Panel that includes their supervisory team (at least two approved GSNOCS supervisors) and a Chair independent of the specific research project. Supervisors must be approved by the GSNOCS committee, and ECRs taking on students for the first time co-supervise with more experienced staff. This panel meets at least every six months to monitor progress of the student and the evolving research project. Written evidence is provided in a format designed by recent PhD student representatives on the GSNOCS committee, and the process is overseen by the Head of GSNOCS. The upgrade from MPhil to PhD registration occurs after ~12 months, to achieve early engagement with this process, to encourage fast-track to publication, and to identify and rectify any progression issues as early as possible. The upgrade process involves a talk in one of the internal seminar series (or externally if the panel can be present), a formal report and a viva. This quality assurance system is key to GSNOCS delivery of highly successful outcomes, evidenced by an under 4-year PhD submission rate of >98% for NERC-funded students, and average of 2.7 peer-reviewed papers per student (with one in Nature or Science per 9 students), and 98% employment of GSNOCS graduates in highly skilled first destination jobs (42% academic, 32% in the environment- and energy-related

private sector, and 24% in government science; data 2003-2013).

d. Income, infrastructure and facilities

OES has state-of-the-art facilities in all of its research groups; many of these have been and continue to be co-developed and co-funded with NERC NOC. The NOCS Operational and Research Committee co-ordinates future research plans and investments. Research facilities are operated on behalf of multiple principal investigators, and typically are run by core experimental officers who are responsible for their efficient management and on-going development. Where appropriate we run integrated facilities across NOCS. OES and NOCS benefit from the annual UoS Multi-User Large-Scale Equipment for Research Scheme (MULSER). Significant investment recently made into facilities includes ~£700k in a trace-metals laboratory, £350k into a radionuclide laboratory suite, £150k into high-specification biogeochemistry facilities, and £300k into marine biology and ecology facilities. £500k is being invested in the development of an organic geochemistry suite. A marine molecular laboratory will be completed in 2014 (>£1.7 M), as well as a new high-performance computing cluster to be used for ocean modelling (>£350k). In this section we describe current research facilities first, followed by, future (funded) investments.

CURRENT RESEARCH FACILITIES:

Facilities available to all research groups include: coastal and shelf research vessels *Callista* (20 m catamaran funded by OHM-spinout, see Impact Template) and *Bill Conway* (12 m) which are supported by 4 FTE staff; and our sample preparation/thin-sectioning laboratory (2 FTE staff).

Geochemistry: Research activities are supported by a suite of high quality mass spectrometry, and clean chemistry laboratories. The mass spectrometers are housed in two Class 1000 clean rooms and comprise a multi-collector ICP-MS, a high-resolution ICP-MS, a collision cell ICP-MS and two thermal ionization mass spectrometers (one with negative ion capabilities and a WARP filter). Each of the ICP-MS instruments can be coupled with a new Excimer laser ablation system. The Class 100 laboratories comprise four separate areas, each of which are equipped with boron-free HEPA filters. In collaboration with users from G&G, P&P, BGChem as well as elsewhere in the University (e.g., Engineering, Medicine, Archaeology) and NOC, we have been successful in bids to the University's MULSER scheme (£1M over the census period) and EPSRC.

Geology & Geophysics: The newly installed Fluid Dynamics Facility allows the study of dynamics/processes of gas flow through porous media in terrestrial and marine environments. The most recent addition to the laboratory, funded by an EPSRC 'Bridging the Gaps' grant, is a state-of-the-art large-scale sediment testing tank (2.5 x 2 x 0.1 m, 1 tonne capacity), which currently is being used for validation of subsea high voltage cable operation. Our seagoing equipment ranges from multibeam bathymetry systems, to chirp, boomer and sparker seismic reflection systems with both single and multichannel hydrophones. The Ocean Bottom Instrumentation Facility (co-run with Durham) is a NERC facility that provides the academic and commercial communities with access to multi-sensor, versatile seabed instruments to enable sub-surface geophysical imaging at high vertical and lateral resolution. Our history of innovation in electromagnetic (EM) research means we have several different types of EM sources and receivers. Our hardware is complemented by a full suite of 2D and 3D seismic processing and interpretation software (including Promax and Petrel).

Palaeoceanography & Palaeoclimate: Research benefits from a suite of stable isotope, trace metal and scanning electron microscope (SEM) facilities. There is a particular focus on measurement of stable isotope ratios of various materials including $\delta^{13}C$ and $\delta^{18}O$ in carbonates (sediments and foraminifera), $\delta^{13}C$ and $\delta^{15}N$ in organic materials (plankton and soils), $\delta^{18}O$ in water samples. A cryogenic magnetometer in a shielded room, and ancillary equipment provides an excellent in-house environmental magnetism facility.

Physical Oceanography: Instrumentation for ocean mixing studies (including ADCPs, microstructure profiler, current meters, moored profilers) has been purchased as part of NERC grants. The instruments will become part of the UK's National Marine Equipment Pool. Our modellers benefit from an on-site 768 core high performance computing facility, in addition to a pool of workstations, racks and high-memory machines for smaller jobs, and make use of the UKRC national supercomputing service (HECToR) and the Met Office/NERC joint supercomputing system (MONSooN).

Marine Biogeochemistry/Marine Biology & Ecology: Specialised clean rooms and associated

equipment are used for water column trace metal measurements. We host the UK Ocean Acidification (OA) Carbonate Chemistry Facility, providing high quality measurements for the UK OA community on both seawater samples (VINDTA-3C) and on small volume samples from laboratory experiments (Apollo). Portable laboratories (customised shipping containers, both refrigerated and non-refrigerated) enable trace-metal clean-work in iron-controlled regions of the ocean as well as shipboard incubation experiments to test limiting nutrients and effects of anthropogenic stressors such as OA. We have the capacity to grow, maintain and cryo-preserve ecologically relevant microbes under environmentally appropriate conditions that simulate marine environments spanning in-shore to open-ocean, tropical to polar, and past to future climate scenarios. Phytoplankton culture facilities, flow cytometers, the SEM facility, photo-physiological instruments and molecular biological facilities are used to assess the biogeochemical role of marine-microorganisms, as well as to assess them as biotechnological solutions relevant to environmental, medical and energy industries (biofuel). We host a hyperbaric experimental facility capable of maintaining in vivo experiments at high pressure and under controlled environmental conditions. We have a Biodiversity-Ecosystem Futures Facility that includes mesocosm chambers in which multiple environmental variables (e.g. T, CO_2, O_2) can be manipulated alone or in combination, and at high replication. We have a temperate aquarium facility for holding macroalgae, invertebrates and vertebrates. We host a tropical coral facility for holding coral communities at appropriate temperature, nutrient and light regimes.

UNDERWAY AND FUTURE PLANNED INVESTMENTS IN RESEARCH FACILITIES:

Geology & Geophysics: Planned investment in large-scale seagoing equipment includes further development of our deep-towed electromagnetic source DASI as part of start-up funding for Weitemeyer, and investment in seafloor instrumentation through the Ocean Bottom Instrumentation Facility. This includes the development of a new logger capable of simultaneous recording of signals from multiple sensors (e.g., seismic, electrical and magnetic), enhanced recording of electric field signals, and development of low-noise seabed broadband seismometers (Harmon). We will make use of large flumes (£1.2M committed) as part of a £21M initiative in hydrodynamics at the new Engineering complex at Bolderwood campus (SMMI), as well as NOCS-based calibrated and annular flumes for sediment dynamics research. We will expand our facilities for studying turbidity currents by investments in an ultrasonic Doppler velocity profiling system.

Geochemistry/Palaeoceanography & Palaeoclimate: We will invest (2013-2016) in organic geochemistry (set up Whiteside, Bohaty) with the establishment of a laboratory allowing streamlined sample flow and utilization of a variety of extraction and column separation methods to support instrumental analysis by GC- and HPLC-mass spectrometry. This laboratory will also house two new isotope ratio mass spectrometers (EA-IRMS and GC-IRMS; £500k). We are purchasing (2013-2014; £100k) a stable carbon isotope analyser and a supercritical fluid autoclave system reactor for laboratory water-rock-carbon dioxide reaction experiments (set up Matter). We will continue to develop the Geochemistry and Palaeo Groups as one of the UK's leading units in (palaeo)environmental geochemistry by buying two further mass spectrometers (£900k) in 2014: another multi-collector ICP-MS and a high-precision stable oxygen and carbon isotope ratio-MS.

Physical Oceanography: To support our investment in new staff, we have committed £150k into the new NOCS High Performance computing cluster (£350k) that will become operational in January 2014 and is dedicated to ocean and climate research. This cluster will run NEMO for large-scale oceanographic problems on interannual to centennial timescales, which are well suited to this model. In addition the cluster will allow the development of NEMO in two additional directions. First, we will carry out large ensembles at coarse resolution. Second, we are leading a major collaboration of the UoS with NERC and Met-Office to set up coupled climate modelling.

Marine Biogeochemistry/Marine Biology & Ecology: We are currently building (completion late 2013/early 2014) a shared (UoS, NOC) high-grade (Grade 2), clean molecular laboratory for biomolecular preparation and analysis, including next-generation DNA/RNA sequencing, with a total investment of £1.7M. UoS (Bibby, Hauton, Lam, Moore, Rius, Wiedenmann) and NERC staff (Mowlem, Ruhl, Zubkov) have developed a vision for a state-of-the-art environmental biomolecular research facility enabling the preparation and analysis of biological samples. A Next-Generation Sequencing Platform will be included, which will allow rapid sample preparation, automated data analysis and storage. The laboratory will include automated robotics for high-throughput sample analysis, and big-data storage capacity. The co-location of flow cytometry, epifluorescence

microscopy, and next-generation sequencing will be a unique facility in an environmental research institution in the UK and will be a focal point to drive research across the life and environmental sciences. We will also continue development of the Biodiversity-Ecosystem Futures Facility built during 2012. We will expand aquarium facilities in support of an ERC Starting Grant to enable study of nutrient, temperature and salinity effects on the stress tolerance of corals.

RESEARCH FUNDING PORTFOLIO AND PLANS: Total research income over the census period was £24.6 M, with an average research income per year of £4.9 M, and shows steady growth: £3.3 M (2008/09); £4.8 M (2009/10); £5.3 M (2010/11); £5.3 M (2011/12); £5.9 M (2012/13). Research income from UK research council sources totals £17.4 M, and has grown steadily from £2.0 M in 2008/9 to £4.6 M in 2012/13. NERC was the main funding agency, followed by the Royal Society, EPSRC, and BBSRC. Funding from the European Union and other overseas sources is typically in the range of £0.8 M to £1.0 M per year. Other major funders over the census period include DEFRA, TOTAL Foundation, Office of Naval Research, Leverhulme Trust, and Carbon Trust (total about £1.4 M). Research funding from UK industry amounted to a total of £1.3 M. Over the census period our research income in-kind is £6.8 M which is dominated by support for ship costs, reflecting the strong sea-going focus of our research.

We have been successful with NERC Blue Skies Consortium and in Standard Grants as well as in Theme Action Plan funding rounds, and will continue with NERC applications. We strive to have a diverse research income portfolio and actively encourage staff to apply to a wide range of funding organisations. In consultation with our Stakeholder Advisory Board, NOC, and contacts through the SMMI and LR, we are diversifying our income streams to work on invasive species, oil spill response, submarine cables, arctic/sea-state studies, greater development of sensors and autonomous systems, and coastal research. This will be greatly aided by our investment in new staff with an applied focus (e.g. Matter, Weitemeyer, Sumner, Rius, Solan, Haigh, Gallop, Gernon), and our expanded international staff, which will ensure international income growth.

CONSULTANCIES AND PROFESSIONAL SERVICES: Consultancy is undertaken in both equipment and method development (e.g. European Space Agency), and in environmental and policy issues (e.g. nuclear decommissioning and coastal protection). The largest consultancy in terms of income is undertaken by the GAU Radioanalytical group (see ICS on radionuclide waste assessment) which has made a major contribution to the analysis, characterisation and disposal of waste in the nuclear industry and related sectors, delivering techniques and insights that have resulted in cost savings and safety benefits in the UK and around the world. GAU has provided regular expert advice on sampling and analysis strategies, both directly and through input into the Nuclear Industry Code of Practice (NICP). Over the period 2008-2013 the GAU has generated income of £3.6 M. We will invest in an academic appointment in Radiochemistry to enhance this area. We have used NERC impact accelerator account and HEIF funding to support the establishment of a new marine archaeo-geophysical consultancy group (2013) related to a wide-range of major offshore infrastructure developments (see ICS on “Managing the Seabed…”). Total consultancy income over the census period was £4.7 M. See Impact template for more details.

e. Collaboration and contribution to the discipline or research base

We *have made a very significant contribution to the discipline as demonstrated by: 1,845 ISI publications with 13,652 citations since 2008 (NOCS); an H index since 2008 of 30 (for UoS staff); the graduation of 154 PhD students; brought in £24.6 M of research grant income.*

International research collaborations: Our research has a strong focus on observational science. OES is a leading player in the Integrated Ocean Drilling Program (IODP, 2003-2013), the largest and most successful longstanding international collaboration in the Earth and marine sciences. We have demonstrated leadership by providing 4 Co-Chief Scientists on recent expeditions (2008-2013; McNeill, Pälike, Teagle, Wilson) and 17 shipboard scientists since 2008. Five Category A staff have served on UK, European and international committees. IODP science leadership is also demonstrated by significant involvement in more than a dozen drilling proposals currently under evaluation by the IODP science advisory structure. Since 2008 our Cat A staff have been Principal Scientists on 25 research cruises for a total of 680 days, on all of NERCs research fleet and also international vessels (US, German, Spanish). These research cruises are highly collaborative with participation from 22 international and 21 UK institutions. A good example was in the discovery of new hydrothermal vents in the Southern Ocean and the world’s deepest vents in

the Cayman Trough (Copley, Connelly, Mills, Thatje, Tyler – see ICS – Explore the Deep).

The Physical Oceanography group plays a leading role in several high-profile international projects. These include two major NERC-funded consortia: the RAPID programme, which seeks to monitor and understand the variability of the Meridional Overturning Circulation (MOC) in the North Atlantic (in collaboration with the Univ. Miami, NOAA, and MPI-M-Hamburg); and the DIMES experiment, which investigates how mixing processes in the Southern Ocean control the MOC (in partnership with the WHOI, MIT, Scripps, Univ. Washington and Florida State). Other prominent research collaborations involve jointly funded projects with CSIRO and Univ. Tasmania (observations of turbulence in the Antarctic Circumpolar Current), with several of the major European modelling centres (such as CNRS and Mercator-Ocean in France, KNMI in the Netherlands, GEOMAR in Germany, and the UK Met Office) on state-of-the-art modelling of the role of the ocean in climate change and the stability of the MOC. The circulation and climate of the Arctic Ocean and the high-latitude Southern Ocean is investigated in collaboration with BAS, the Centre for Polar Observation and Modelling and UEA.

OES is a major partner in EU projects related to ocean acidification CalMaRO and EPOCA (the latter comprising 32 institutes in 10 European countries), as well as HERMES and HERMIONE studying the deepwater margins of Europe in the Atlantic and Mediterranean. We have made key contributions to international biogeochemical programmes, providing project leadership, leading major international research cruises (e.g. GEOTRACES and SOLAS programmes, Mills, Achterberg) and leading international synthesis exercises (Moore). Moore led an International Geosphere–Biosphere Programme/Scientific Committee on Oceanic Research-funded workshop on Upper Ocean Nutrient Limitation. Bibby and Moore had key roles in bilateral (UK-US cruises) PRISM study of iron limitation in the Ross Sea. The QICS experiment (Bull, Hauton, James, Connelly, Wright, six Japanese institutions, 5 other UK institutions) investigates the impacts of CO_2 on marine ecosystems by a man-made sub-seabed CO_2 release. Minshull led the Southampton contribution to one of the biggest marine seismic experiments ever (with Rice, Lamont, GEOMAR, Birmingham), which gives unprecedented three-dimensional constraints on the process of continental breakup (offshore Iberia, 2013). The UoS-led (McNeill, Henstock, Bull, Sumner) Sumatran consortium had partners from Indonesia, UT Austin, plus 4 other UK institutions. OES was a major partner in the Census of Marine Life Programme hosting the field programme (ChEss) identifying biodiversity at hydrothermal vents and cold seeps, involving direct partners from the US, Canada, Russia, Sweden, France, Germany, India and Japan (Tyler, Copley).

Interdisciplinary research: This is greatly facilitated by SMMI, IfLS, the environment at NOCS, and other University Strategic Research Groups. Physical oceanographers and geochemists are working with fisheries scientists (CEH, funded by DEFRA) to study salmon migration in the ocean (Trueman, Wells), and are collaborating with biogeochemists (NOCS, WHOI) to quantify vertical iron fluxes and carbon sequestration (Naveira Garabato). Biogeochemists collaborate with engineering groups (NOC and UoS) to develop and deploy novel lab-on-chip sensor systems for nutrients, trace elements and pH, pCO_2 and alkalinity (Achterberg, Statham, Purdie, Palmer). Geophysicists (Dix) employ high resolution imaging and interpretation techniques to reconstruct landscapes associated with the hominid occupation of NW Europe (with UoS Archaeology). Geochemists (Teagle/Palmer) and UoS Medicine investigate the respiratory health effects of atmospheric particles including the impact of helicopter usage in deserts by the military.

Collaborations with research users: Our strategy is guided by interactions with our Stakeholder Advisory Board, which meets twice a year (see Impact Template). The following research activities are examples with explicit user involvement. Sinha continued to develop seafloor electromagnetic imaging methods through collaborative projects with spin-out company OHM Ltd and its successor Rock Solid Images (see marine electromagnetic ICS). Weitemeyer has been appointed to continue this work. Bull, Dix and Henstock developed and commercialised with Kongsberg-Geoacoustics Ltd a 3D chirp imaging system. Croudace developed a thermal desorption instrument that has been commercialised and acquired by 30 nuclear institutions worldwide (see radionuclide ICS). Robinson developed validation methods for sea-surface temperature (SST) measurements used by ESA (see SST ICS). Moore developed fast Repetition Rate fluorometry (FRRf) with the instrument manufacturer Chelsea Technologies Group UK. Shepherd chaired the Royal Society study “Geoengineering the climate: science, governance, and uncertainty” (see geoengineering ICS). Rohling and Haigh provided evidence informing debate about the nature and remediation of

future sea-level rise to EA, DEFRA, UKCP09, and IPCC AR5 (see sea-level ICS). Dix developed strategies for the management of our Submerged Cultural Heritage for UK Government, Crown Estate and English Heritage (see "Managing seabed" ICS). Trueman regularly has provided scientific advice to ICES for conservation of salmon stocks.

International academic leadership: We provided leadership in the IODP Science Advisory Structure (McNeill, Pälike - SSEP Chair, Teagle, Wilson), European co-ordination (James), as lead proponents of and co-chief scientists on expeditions (Pälike, Teagle, Wilson), including the first European co-chief on IODP riser drill ship *Chikyu* (McNeill), co-authored the 2013-2023 IODP science plan (Teagle, Pälike), are members of the "*Chikyu* +10" steering panel (McNeill), and the UK-IODP Steering Committee (James, McNeill, Pälike, Teagle – Chair from Oct 2013, Wilson). Other international roles include: InterRidge co-Chair (Copley), Scientific Advisory Board of GEOMAR (Minshull), Chairman International Marine Global Change Study programme (Rohling, IMAGES), IPCC AR5 Expert Reviewer (Rohling, Hawkins), European Environment Agency Expert Panel (Drijfhout), Census of Marine Life Scientific Advisory Committee (Solan), Chair ANR France Grant Panel (Hawkins), Technical Committee of the European Sea Level Service (Tsimplis, Chair), Chair World Conference on Marine Biodiversity 2011 (Solan), Council Society for Geology Applied to Mineral Deposits (S. Roberts), President American Association of Stratigraphic Palynologists (2013) and Chair UK Palynology Group to 2010 (Harding), IGBP Fast Track Initiative 'Upper Ocean Nutrient Limitation' (Moore, convenor). RAPID-WATCH Programme Advisory Group (Bryden).

National academic leadership: Bryden and Shepherd are Fellows of the Royal Society. Other roles include DEFRA Science Advisory Council (Hawkins, Shepherd), NERC Oceans 2025 Strategic Marine Science Advisory Board (Hawkins), Natural England Science Advisory Committee (Hawkins), NERC Training Advisory Group (Mills), DECC Scientific Advisory Group (Chair, Shepherd), BAS Management Board (non-exec member, Shepherd), Regional/Deputy Director of the Tyndall Centre for Climate Change (Shepherd), Director of the Marine Biological Association (MBA; Brownlee), Council of the MBA (Hawkins, Vice-President; Tyler, member), President of Challenger Society (2010-12; Bryden), NERC Ocean Acidification Advisory Group (Achterberg, member), EPSRC Grand Challenge Expert Panel (Minshull), Chair of Ocean Bottom Instrument Consortium (2011-present; Henstock). We provided members of the NERC Peer Review College (15 Cat A) and Principal Scientists for 25 major oceanographic cruises since 2008.

Prizes and Fellowships 2008-2013: Naveira Garabato: EGU Young Scientist Award, Honorary Fellowship of Challenger Society and Philip Leverhulme Prize. Bryden (FRS): Fridtjof Nansen EGU medal, AGU Fellowship and Prince Albert I Medal. AGU Jason Morgan Award (Keir). President's Award, Geol. Soc. Lond. (Gernon; PhD student Paulatto). IMAREST Stanley Gray Silver medal (Sims). Discovery Magazine Top 100 Science stories (Rychert). Biosciences Federation award for Science Communication (Copley). Yale Flint Faculty Visiting Fellowship (Foster). ERC starting grant (Wiedenmann). NERC Research Fellowships (Goodwin, Hain, Hickman, Zika). Gibbs: Royal Society Fellow. Coggon: Royal Society Dorothy Hodgkin Fellow. Royal Society Wolfson Merit Awards (Achterberg, Pälike, Rohling, Teagle). Thompson Reuters highly cited scientist (Palmer). Bullerwell lecturer awards (Keir, Rychert).

Membership of editorial boards for leading international journals (examples): Geology (IF: 4.8) (Bull, McNeill, Wilson), Reviews of Geophysics (IF: 12.3) (Rohling), Geophysical Journal International (Minshull, IF: 2.4), Earth Science Reviews (IF: 7.3) (Wilson), Paleoceanography (IF: 3.4) (Rohling, Editor), Ocean Sciences (IF: 2.3) (Wells), New Phytologist (IF: 6.6) (Brownlee), Journal of Animal Ecology (IF: 4.9) (Sims), Biological Conservation (IF: 4.1) (Hawkins), Naturwissenschaften (IF: 2.3) (Thatje, Editor), Advances in Marine Biology (IF: 3.9), (Tyler, Editor).

85% **of our Cat A Staff have delivered invited keynote lectures**, e.g., at Goldschmidt 2009 & 2013 (Foster), Goldschmidt 2011 (Gibbs), SOLAS Open Science conference 2012 (Moore), on Carbon Capture and Storage in Tokyo and Kyushu 2013 (Bull), EGU – Bullerwell Lecturer 2013 (Keir), EGU General Assembly 2008 (Naveira Garabato), AGU Ocean Science 2010 (Portland) and 34th IGC 2012 (Rohling), AAAS meeting Vancouver 2012 (Thatje), Gordon Conference 2010 (Brownlee, Gledhill). Geol. Soc. Shell Lecture 2011 (McNeill), Iron Fertilisation meeting Woods Hole 2012 (Moore). Marine Electromagnetics Symposium Singapore 2012 (Weitemeyer). NSF-IODP-ICDP-InterRIDGE Mineral Carbonation, Oman 2011 (Teagle, Matter), ICDP Oman Drilling Project, New York (Teagle, Matter). Opening Keynote Soc. Econ. Geol. Denver 2011 (S.Roberts).