

National **Science** Challenges

THE DEEP SOUTH

.....
Te Kōmata o
Te Tonga



Research and Business Plan

19 December 2014

Executive Summary

The mission of the *Deep South* (Te Kōmata o Te Tonga) National Science Challenge is to transform the way New Zealanders adapt, manage risk, and thrive in a changing climate.

To help achieve this, we will develop a world-class numerical earth system model to predict New Zealand's future climate. The model will identify the impacts of a changing climate on our key climate-sensitive economic sectors, infrastructure and natural resources, and will be underpinned by improved knowledge and observations of climate processes in the Southern Ocean and Antarctica, our Deep South.

To ensure this Challenge benefits all New Zealanders, we will incorporate and develop innovative engagement practices to connect our science with Māori, industry, regulators and planners and communities. This will give New Zealanders a greater level of certainty in their planning and decision making in the face of a changing climate. This collaborative approach will ensure that the science remains focused on and directed by societal needs, help build capability within Māori, stakeholder organisations and communities, and is used by all.

We will apply Vision Mātauranga to the governance, management, research and activities of the Challenge, and observe kaupapa Māori research principles. This will ensure the Challenge meets the needs of iwi/hapū and Māori business objectives and goals, now and in the future.

The science in this Challenge will build on long-standing, successful collaboration with leading international science institutions, and New Zealand's geographic proximity and access to the Deep South. Our science capacity and capability, logistics expertise and assets will ensure the Challenge makes an unprecedented contribution to international efforts to understand how Antarctic and Southern Ocean processes moderate our climate.

We will link the Challenge with existing New Zealand research and international collaboration in the Antarctic and Southern Ocean, in order to cement New Zealand's status as a custodian of the region between Aotearoa and the South Pole. This will also provide credible input into New Zealand's contribution to international agreements and foreign affairs.

NIWA will host the *Deep South* Challenge. An independent Governance Group of New Zealand leaders in Māoridom, industry, government, finance and science has been formed. This independence will ensure that the Challenge responds and evolves to meet the needs of society, remains focused on the mission, and links with aligned research.

The Parties to the *Deep South* Challenge have formed an interim Science Leadership Team that has advanced establishment of the Challenge, developed the science strategy, and implemented a funding allocation process. A new Independent Advisory Group, with expertise aligned to the breadth of science covered by the Challenge, will review the *Deep South* science strategy and ensure that the Challenge research is innovative and follows best practice.

1. Research Plan

1.1 Objective, Mission, and Vision

The **Objective** set by Cabinet for the Deep South (Te Kōmata o Te Tonga) National Science Challenge is:

To understand the role of the Antarctic and Southern Ocean in determining our climate and our future environment.

The following **Mission** has been developed to meet the *Deep South* Challenge objective, and guide the vision, future research priorities and activities of the Challenge as it progresses:

This Challenge will enable New Zealanders to adapt, manage risk, and thrive in a changing climate. Working with our communities and industry, we will guide planning and policy to enhance resilience and exploit opportunities associated with those climate drivers that uniquely impact Aotearoa/New Zealand. The Challenge will focus on the effects of a changing climate on key climate sensitive economic sectors, infrastructure and natural resources.

To achieve the *Deep South* Challenge Science Mission, we will:

- Identify the climate sensitivities, risks and opportunities of Māori, communities, industry, planners and regulators through in depth scientific engagement.
- Improve predictions of our future climate based on:
 - developing a world-class Earth System Modelling capability, underpinned by improved understanding of *Antarctic and Southern Ocean* processes, to better simulate key climate drivers and impacts; and,
 - acquiring new observations and process information from the *Antarctic and Southern Ocean* region as required to refine/support the models.
- Incorporate our new science into the planning and management of climate risks and emerging opportunities by working directly with key decision makers.
- Develop targeted collaboration between physical scientists, social scientists and practitioners, incorporating Vision Mātauranga, to ensure research uptake.
- Build science capability through growing international collaborative scientific effort, focused on *Deep South* model development, process understanding and observations, to leverage offshore science resources and knowledge.
- Enhance national status and contribution to international agreements through our science to protect Aotearoa/New Zealand's environmental, economic and Antarctic interests.

Changing global climate is a complex and long-term societal challenge that requires sophisticated, coordinated, multi-disciplinary and integrated understanding, analysis and interpretation. Past and current research confirms that many communities throughout Aotearoa/New Zealand acknowledge that our climate is changing and its potential impacts and implications. Capability and skills vary considerably, however, and many New Zealanders struggle to sensibly embed climate science into their planning and decision making. Existing efforts, while laudable, often fail to achieve significant climate science uptake and use.

1.2 The Opportunity

This Challenge will make a step-change in Aotearoa/New Zealand's ability to anticipate, respond to, and adapt to a changing climate. As a core part of the Challenge, we will work closely with a range of **communities** to: (i) increase their understanding of climate science and their ability to guide and

prioritise future research, and (ii) integrate our tools, skills and information into their policy and decision processes.

Past and recent workshops with communities have identified the key climate-affected **outcomes**. While not pre-judging what might eventually emerge, and that priorities are expected to change over the life of the Challenge, key outcomes targeted by the Challenge will include:

- responses that will provide a basis for strong growth in climate-sensitive economic sectors;
- actions that reduce climate change risks and limit the effects of extreme weather; and
- economic, social and environmental systems that provide long-term resilience to a changing climate.

This initial work will build on the established relationships and stakeholder interactions in the *Climate Changes Impacts & Implications for Aotearoa/New Zealand* project that has been mapped into the Challenge. Through engagement with communities, both in this project and previous work by Parties to the Challenge, substantial progress has already been made in determining their outcomes and needs, and how climate science could better inform policy setting and decision-making. The *Deep South* Challenge will build upon and extend these initiatives to identify and engage with a broader set of key communities. As the Challenge progresses we will work with communities to re-assess decisions and outcomes through the open, transparent, traceable, participatory processes described below (see Engagement Programme below). Key communities already identified include:

- planners and regulators (e.g., Local Government Aotearoa/New Zealand, city and regional councils);
- economic sector groups (e.g., dairy, horticulture, pastoral, forestry, fishing, aquaculture, energy, tourism);
- Māori communities and enterprises (e.g., coastal groups, Māori farming and forestry, fisheries);
- Government agencies (e.g., The Treasury, Ministry for Primary Industries, Ministry of Business, Innovation & Employment, Ministry for the Environment, Ministry of Foreign Affairs & Trade, Department of Conservation); and,
- infrastructure providers (e.g., Transpower, Infratil, Transit NZ, Kiwi Rail, Telecom).

1.3 Realising the Opportunity

From the scientific knowledge base emerging from our modelling and process work-streams, we will take improved understanding of key climate impacts for Aotearoa/New Zealand and (i), work in and with communities to help make best use of this information, (ii) build on long-established advice regarding the human dimensions of climate change, including the deployment of a pluralistic approach to decision-making, and (iii), incorporate (sometimes called “mainstreaming”) climate change into other more immediate issues, such as economic development, infrastructure development, resilience-building and public health. Scientists will set priorities based on a combination of scientific and community input, and not on the basis of scientific preference alone.

By taking the above approach we believe the *Deep South* science community can deliver the following national benefits:

- planned development of future infrastructure resilient to the risks of a changing climate (e.g., freshwater management¹);

¹ Land and Water Forum. 2010. Report of the Land and Water Forum: A Fresh Start for Fresh Water.

- industry adaptation to a changing climate, thereby increasing production while reducing costs, to ensure that our climate sensitive sectors contribute to the New Zealand Business Growth Agenda's² aim to increase exports relative to GDP;
- better management of climate risks to enable higher living standards³; and
- enhancement of Aotearoa/New Zealand's reputation as a global leader in climate science and adaptation, thereby aiding sustainable development in developing countries, especially in the Pacific⁴.

1.4 Development of the *Deep South* Challenge

In April 2014 the Party organisations submitted a revised proposal outline for the *Deep South* Challenge. This outline addressed concerns raised by the Ministry of Business, Innovation and Employment (MBIE), based on their assessment of the first proposal for *Deep South* submitted in December 2013. This outline was developed by a new interim Science Leadership Team formed by the Parties, through a number of science sector meetings. Key changes to the Challenge included:

- Development of a new clear strategy (science mission), driven by the *Deep South* National Science Challenge objective, that builds on existing climate research capability and the priorities of end-users.
- A new governance structure with comprehensive representation of end-users and climate research organisations.
- A named independent Chair and independent Governance Board members.
- A new host organisation with the capability, capacity, willingness and sufficient resources to support the *Deep South* Challenge.
- Named leaders and managers to develop a revised *Deep South* proposal.
- A stakeholder management strategy that will leverage off existing engagement with key end-users, Māori and communities.

The MBIE Science Board accepted the proposal outline and suggested changes to the Challenge, and agreed to fund the Challenge for up to \$24 million to 30 June 2019. Initial funding was awarded to advance the establishment phase of the Challenge, and there were also a number of pre-contract conditions that needed to be met. Full funding of the Challenge, however, is contingent on resubmission of a full Research and Business Plan for the *Deep South* and its approval by the MBIE Science Board. This proposal represents the revised Research and Business Plan developed by the Parties for the *Deep South* Challenge.

² <http://www.mbie.govt.nz/what-we-do/business-growth-agenda>

³ NZ Treasury. 2011. Working Towards Higher Living Standards for Aotearoa/New Zealanders.

⁴ Ministry of Foreign Affairs & Trade, Aid Programme. 2011. International Development Policy Statement.

2. The Research Landscape

2.1 The *Deep South* Programme structure

The *Deep South* Challenge will transform the ability of New Zealanders to respond and thrive in a changing climate. This will be achieved through a framework that connects society with scientists through **five inter-linked Programmes** (Figure 1). These Programmes combine Vision Mātauranga and Engagement with an innovative climate prediction system, founded on advanced knowledge of processes and observations in the Antarctic and Southern Ocean, to inform impact studies and assess the implications accordingly. Under this proposed Programme structure, the three core inter-connected Challenge research Programmes (in blue) will be guided by and incorporate the research and related activities from within the Vision Mātauranga and Engagement Programmes.

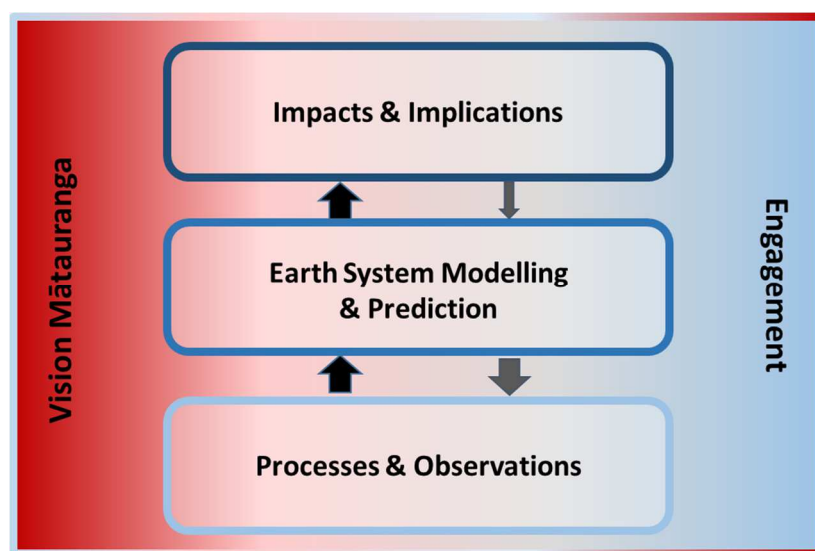


Figure 1. Proposed Programme framework for the *Deep South*.

The *Deep South* Challenge will continue to engage with Māori, stakeholders and communities. Their on-going needs, expectations, and economic well-being will be considered as part of a community engagement process, guided by participatory principles, and led by social and physical scientists. This, and our existing knowledge, will further identify the important Aotearoa/New Zealand centric sensitivities to climate impacts that will guide future development and evolution of the *Deep South*. This knowledge will be iteratively improved by using a New Zealand Earth System Model (NZESM) combined with targeted process studies. The NZESM is a central research component of the Challenge and encapsulates our understanding of relevant climate processes to provide a physically robust basis for future prediction. Its improvement depends on process studies, be they one-off observational campaigns, long duration monitoring, or efforts to develop physical models of components of the climate system. This framework demands that processes, observations and NZESM development be supported only where they actively demonstrate a direct and measurable contribution to the development of improved predictions. Establishing the new NZESM will significantly advance the quality of the high resolution input needed for detailed impact and implication studies. The results from all three research Programmes will be used to inform the continuing community engagement. The proposed structure is designed to ensure that the *Deep South* Challenge builds and extends Aotearoa/New Zealand science capability, while remaining responsive, through regular engagement, to the changing needs of Māori, stakeholders and communities.

2.2 Scope of the *Deep South*

The *Deep South* Challenge will achieve its Mission by funding the critical components that allow coherent connections to be built between new planned research and pre-existing aligned climate research programmes (Figure 2). Development of a New Zealand Earth System Model (NZESM) will sit at the heart of these connections.

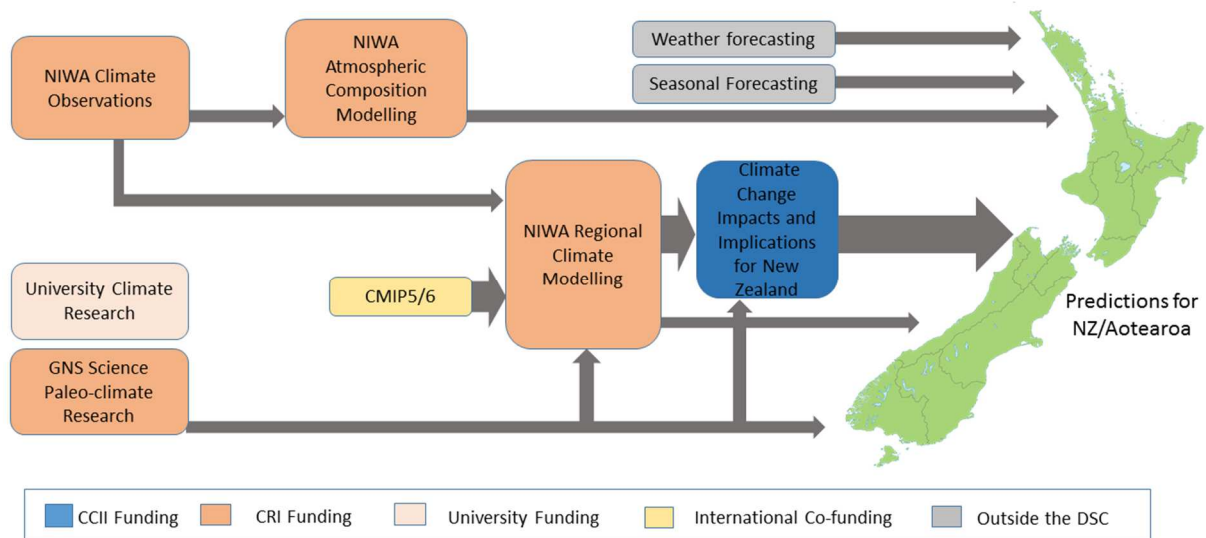


Figure 2. Pre-existing climate research Programmes contributing to predictions of New Zealand's future climate.

At present these existing programmes are poorly connected. Simulations of global climate models contributed to the Coupled Model Intercomparison Project 5 (CMIP5) are downscaled by the NIWA regional climate modelling programme, while atmospheric composition modelling by NIWA is independently used to consider the importance of processes such as ozone depletion. This work is independent of the GNS Science proxy-based observational records of the past and the universities work on understanding fundamental climate processes.

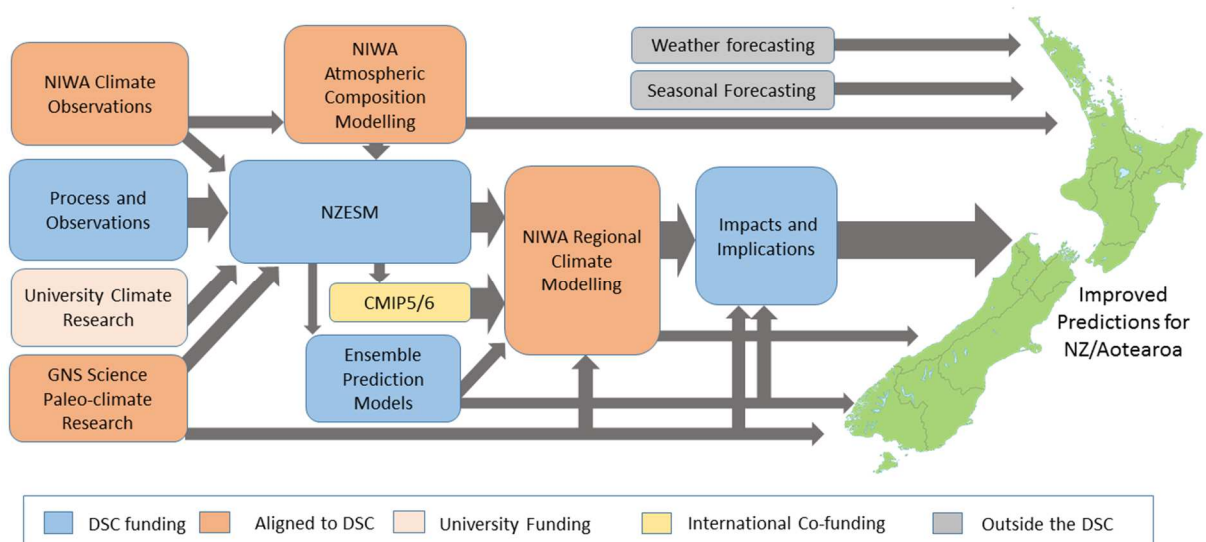


Figure 3. Development of a New Zealand Earth System Model within the *Deep South* Challenge will enable a coherent suite of inter-connected climate research programmes to be formed that will improve predictions of New Zealand's future climate.

Supported through *Deep South* funding, the NZESM will draw on improved understanding of Antarctic and Southern Ocean processes, based on existing and planned *Deep South* research, to provide improved climate predictions for the New Zealand region. The NZESM will in turn provide simulations that are additional but complimentary to those in CMIP5/6, and both will be downscaled through the existing NIWA Core Funded regional climate modelling programme to provide input into the *Deep South* Impacts & Implications Programme. A suite of less complex climate models, both existing and new, will remain important for undertaking large ensemble simulations that allow for predictions of changes in climate extremes and exploration of scenario uncertainty. The connections and integration of the pre-existing research supported through co-funding (see Business Plan), with research proposed in the *Deep South*, is illustrated in Figure 3 above. Developing and operating this integrated framework of research around the NZESM will stretch the climate community well beyond business as usual.

2.3 Out of scope research

While the Challenge will be responsive to the needs and priorities of New Zealanders, the following areas of science are currently considered out of scope. The effects of a changing climate on the Aotearoa/New Zealand marine environment and its associated resources is not anticipated to be a major area of focus in the first five years of the Challenge. Economic and societal impacts from ocean-based changes are of relatively less concern compared to those on land. Nevertheless, changes in the marine environment are expected to be important to Māori, and the impacts of ocean acidification are a growing societal and industry (especially aquaculture) concern. Greater emphasis on the oceanic influence of a changing climate is anticipated in the second term of the Challenge.

Climate science that does not target those processes and observations that improve model representation of Aotearoa/New Zealand's current climate are proposed to be out of scope. Thus, global drivers of change, such as the sources and sinks of CO₂, and the drivers of sea level rise, while related to the Challenge, are expected to be out of scope for Challenge support. Changes in scope of the Challenge over time will be at the discretion of the Governance Board.

3. The *Deep South* Programmes

The aim, scope, 10 year strategy and 5 year work plan for each of the five Challenge Programmes are provided below. The projects identified in the following Programme summaries reflect progress to date in identifying and prioritising the detailed research needs to 30 June 2019. Each project has its own set of objectives that support and help achieve the *Deep South* Mission through the Programme framework described above. Projects are also intended to form and support natural groupings of scientists, so in most cases lie across more than one Programme. By structuring projects in this way, the linkages between Programmes do not lie at the boundaries of projects, but instead lie within projects, thus ensuring linkage between Programmes.

3.1 Programme 1: *Engagement*

Scope and 10 year strategy

The National Science Challenges are expected to *respond to the most important, national-scale issues and opportunities identified by science stakeholders and the New Zealand public*. To achieve this requires effective engagement so that the *Deep South* research responds to the priorities of both stakeholders and publics, and that the research outcomes are both understood by and useful to these communities. Achieving these goals requires developing appropriate knowledge, skills, and capacity across the Challenge, science stakeholders, and New Zealand publics.

Engagement with Māori, communities, industry and central and local government is a unifying component across the Challenge. Successful public engagement with science is not only about communicating knowledge, but must involve an understanding and appreciation of public knowledge, knowledge-needs, values and attitudes. A successful public engagement strategy must acknowledge this and be developed in conversation with the needs and views of appropriate stakeholders, Māori, and other publics.

There will be multiple forms of engagement, including (but not limited to):

- formal processes to set transparent, open and traceable social priorities for the science research Programmes;
- structured processes to help co-produce evidence-based policy with Māori, communities, industry and government (e.g., current *Climate Change Impacts and Implications* project *Communities of Practice* surrounding climate change and local government);
- direct involvement of Māori, stakeholders and communities in the research and science of the *Deep South*. The citizen science of the weatherathome project is a role model for community engagement within the Challenge;
- targeted processes working with partners to improve public engagement with research, including its human dimension (e.g., work with museums; exhibitions and events within festivals and school programmes; collaboration with existing mechanisms related to climate change education and outreach such as workshops, field trips, and online content);
- opportunities for scientists and groups to engage directly with publics (e.g., public lectures, seminars, briefing sessions, and dialogue events such as science cafes); and,
- capability building to enable members of the *Deep South* to develop skills and theoretical grounding for effective engagement with stakeholders and publics, and for stakeholders and publics to be better able to make use of the knowledge produced by the Challenge.

All of these forms will be underpinned by a Challenge-wide commitment to Vision Mātauranga. By deepening our commitment to Vision Mātauranga, we believe we can improve scientists' ability to play constructive, respectful roles across the entire spectrum of our engagement; formal and informal, straightforward or complex.

Our innovative Engagement Programme will use an active mixed-methods research approach to ensure we are using international best practice. Through this process, we will design and deliver effective mechanisms for dialogue between *Deep South* scientists and different publics by drawing on literature on public and stakeholder engagement processes, and the research and practical expertise within Aotearoa/New Zealand. Engagement processes in the *Deep South* Challenge are illustrated in Figure 4. In this diagram the transparent circles represent the breadth of Aotearoa/New Zealand society within which this process sits. We acknowledge that individuals occupy many of these sectors concurrently, but choose three for simplification. Broadly speaking, the engagement processes can be categorised into public engagement on climate change and climate change science (on the right), and engagement between key stakeholders and the *Deep South* research (on the left). In all cases, the engagement process focuses on sharing information and co-production of knowledge (indicated by arrows) and capability building (indicated by circles). (The dashed line is beyond the direct remit of this Challenge).

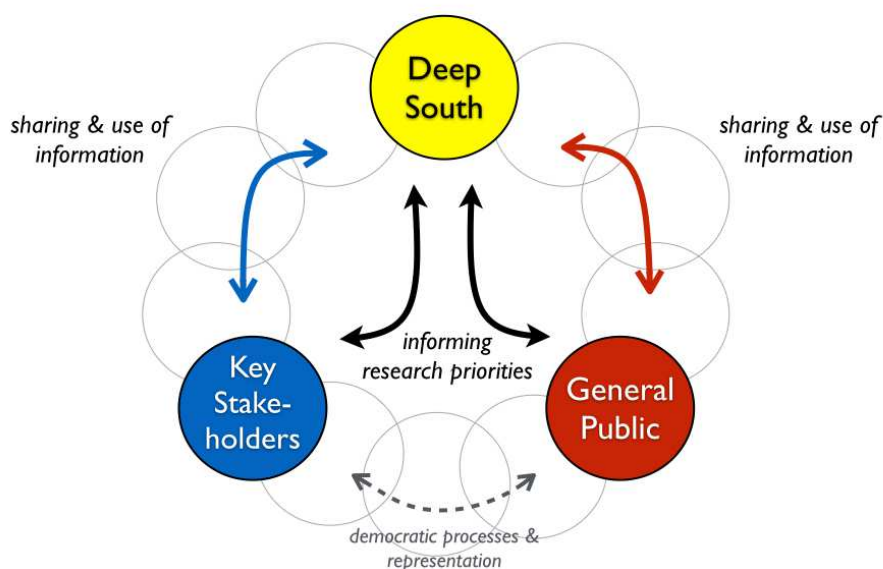


Figure 4. Processes in the *Deep South* Engagement Programme. Arrows indicate information sharing, circles indicate capacity-building activities.

5 Year Work Plan

We aim to create a continuous cycle of informing research priorities, sharing and using information, and building capability, which support and reinforce each other and lead to improved capacity in Aotearoa/New Zealand to respond to the effects of a changing climate and environment. We aim to monitor and measure our engagement and outreach so that information generated in the first five years of the Challenge will inform research priorities for the second five-year term of the *Deep South* Challenge. Key stages in this process are outlined here; in the first year the focus is on the development of strategies and action plans to guide engagement activities in the remaining four years.

1. Informing Research Priorities (inside arrows)

Citizen and stakeholder engagement in the prioritisation of *Deep South* research is central to this Challenge. This prioritisation will be carried out through a further series of stakeholder engagement workshops. Key stakeholders are defined as parties for whom the information produced by the Challenge will be decision-relevant, as well as additional representatives from a range of non-institutional publics and Māori society. We draw on extensive networks and effort already developed by the Climate Change Impacts & Implications for New Zealand (CCII) programme and prior end-user engagement processes held by Crown Research Institutes (CRI), the New Zealand Climate Change Centre, and the Victoria University New Zealand Climate Change Research Institute. An initial strategic workshop in November 2014 provided a first step towards both identifying and in some cases confirming existing priorities from a range of stakeholders. It also provided an opportunity to identify the strengths and weaknesses of this approach. Key points raised at the workshop have been incorporated into this proposal and are summarised in the Stakeholder Research Plan Workshop section (4.2).

Stakeholder engagement is also a central part of the Impacts & Implications Programme (see section 3.3), which will work in concert with the Engagement Programme to ensure a broad representation of publics are included and represented. Stakeholder workshops will continue throughout the lifetime of

the challenge and will assist in research priority setting. In addition, members of the *Deep South* Challenge Science Leadership Team will participate in on-going engagement activities led by CCII so as to ensure the *Deep South* builds upon CCII's capability and networks.

2. Sharing research outcomes and use of information (outer arrows)

The *Deep South* Challenge engagement process has been designed to not only inform and respond to priorities of stakeholders and different publics, but also to ensure that this information is shared with, and used by, communities. A coordinated *communication strategy* will be developed in collaboration with the *Deep South* institutions, the Science Media Centre, and other National Science Challenges, and will be central to guiding activities of this component. To that end, and in response to feedback that we received at our strategic meeting in November 2014, we are in dialogue with the National Science Challenges *New Zealand's Biological Heritage*, *Resilience to Nature's Challenges*, *Sustainable Seas*, and *Building Better Homes, Towns, and Cities*, to ensure that we maximise opportunities for coordinated cross-Challenge communication and engagement (e.g., through strategic media releases, connected museum exhibits, and contribution to educational programmes), while minimizing the possibility of 'Challenge fatigue' on the part of stakeholders and various publics. We hope to expand this network to include other National Science Challenges as they develop their plans for engagement.

The *Deep South* Challenge communication strategy will employ traditional forms of communication such as *delivery of reports* for stakeholders on their identified priorities for climate-related decisions (and associated events); *development of content* for online media and portals; use of *social media*; contribution to *science festivals and museum exhibitions*; delivery of *national lecture series* and seminars; strategic engagement with the *media*; opportunities for *science communication students*; and collaboration with *educators, policymakers, and communicators* as intermediaries to different publics. It also requires more *innovative forms of engagement*, dissemination, and information that will be developed as part of the dialogue and coproduction of knowledge with end-users.

3. Building capability (coloured circles)

Capacity building across all three sectors identified in Figure 4 is required in order to realize our goals of informing research priorities and sharing information. Capacity and capability building activities will therefore be used to (a) better equip communities in Aotearoa/New Zealand to be able to inform the research priorities of the *Deep South* Challenge; (b) develop effective mechanisms for translation and adoption of *Deep South* research in making climate-related decisions; and (c) build capability in the *Deep South* Challenge research community in skills and reflexivity required for effective engagement. Examples of such capacity-building activities include:

For the *Deep South* research community (yellow circle Figure 4): *formal training* in public engagement theory, science-policy processes, and climate policy through Master-classes and workshops; *opportunities* to develop or participate in engagement activities; *reflection* and evaluation of engagement experiences that enable researchers to understand different audience needs in order to make sense and use of results; and *capacity building* for graduate students and early career scientists in both science and public engagement.

For key stakeholders (blue circle Figure 4): *creation* of technical workshops (e.g., on understanding risk, interpretation of climate model data) that will enable stakeholders to understand and inform research priorities; *engagement* in existing science-policy roundtables and other policy-informing processes; *development* of new mechanisms for interpretation, translation, dissemination and incorporation of results and understanding from the *Deep South* Challenge. *Contribution to existing mechanisms* that ensure stakeholder views are representative of the interests of New Zealanders more broadly (e.g., events that bring together or otherwise

encourage connectedness between stakeholder views and public views in the context of climate change.)

For the general public (red circle Figure 4): *creation* of dialogue events such as science cafés and workshops that will enable publics to inform research priorities, and understand and use information from the *Deep South* Challenge; *collaboration* with educators around use and interpretation of climate science; *development* of opportunities to contribute to citizen science projects and learn how data is used and what it means; *contribution and participation* in existing mechanisms for education and public dialogue related to climate science and decision-making; *placements* for educators and artists within science research Programmes (e.g., through mechanisms such as the Royal Society of New Zealand Science Teacher Leadership Programme).

Delivery of the Engagement Programme

Working with the Science Leadership Team, this Programme will guide engagement activities across the other Programmes, linking closely with the Vision Mātauranga Programme. It will also incorporate recommendations from different stakeholders and publics, e.g., for particular modes of engagement and communication, representation at key conferences and activities, or delivery of information through specified networks or mechanisms. It is expected that several new initiatives will be the result of a coproduction process between researchers and different publics.

In order to acknowledge the varying abilities and interests of *Deep South* researchers with the engagement process, a portion of the engagement budget will be ring-fenced for *Deep South* researchers to use for events, activities, and capability-building related to engagement. The remainder will be open to any applicant, and is expected to catalyse new collaborations and opportunities for co-funding and co-sponsorship of events that build capability, raise the profile, or share information relevant to better understanding *Deep South* Challenge research, or the context of anthropogenic climate change within which this research sits.

The Engagement Programme will be facilitated by a Coordinator and supported by ‘engagement hubs’ to ensure national coverage and sensitivity to regional concerns about climate science and decision-making. In addition, an Engagement Technical Advisory Group will provide input into strategy development, strengthen connections with existing networks and activities, and ensure that the *Deep South* Challenge maximises opportunities for engagement. A mixed-methods evaluation and research process will ensure that engagement processes and outcomes are evaluated to identify the most useful and cost effective methodologies for *Deep South* engagement. Potential members of the Engagement Technical Advisory Group include: Professor Nancy Longnecker, Professor of science communication, University of Otago, Dunedin; Peter Griffin, Manager, Science Media Centre, Wellington; Dr Rhian Salmon, Senior lecturer, Science in Context and Climate Change Research Institute, Victoria University of Wellington; Dr Joanna Goven, Independent consultant with expertise in evaluation and participatory processes, Christchurch area; and a representative from the education sector.

3.2 Programme 2: Vision Mātauranga

Ko ngā mahi inaianei hei oranga mo rātou apopo.

For those whom we hope will benefit from our efforts today.

Scope and 10 Year Strategy

The *Deep South* Challenge will give effect to the MBIE Vision Mātauranga objectives through strategic planning and research. These efforts will contribute innovative, practical and sustainable solutions for Māori and all New Zealanders. Implicit within this approach is a commitment to the Treaty and the sharing of information, resources and opportunities. This includes a commitment towards shared decision-making concerning the relevance of the programme to iwi/hapū/whānau and Māori business goals.

This section outlines (i) the strategic elements that will help contribute to realising Vision Mātauranga and related policy objectives within the *Deep South*, and (ii) information pertaining to the establishment phase of the Vision Mātauranga Programme (Years 1-3) and the enhancement phase (Years 4-10).

Strategic elements

Element 1: Kaupapa Māori Research Principles

Established kaupapa Māori research principles will be observed and applied throughout the term of this Challenge. The principles are made up of elemental cultural values that remain relevant in the Māori world and thereby are also relevant to Māori research design and practice. Core principles include: aroha (sincerity, mutual-respect, love); kanohi kitea (seen face, in person, literally means ‘face to face’); mana (dignity, authority, control, prestige, power); manaakitanga (to support, take care of, give hospitality to visitors, protect, look out for); whakapiki tangata (empowerment); māhaki (humility); whakatuia (integration); tūpatotanga (caution); and whakawhanaungatanga (kinship, process of strengthening relationships).

Element 2: Governance Māori

The governance structure of the *Deep South* has been designed to increase Māori involvement across all stages of the research. Formal Māori involvement from different sectors, systems and groups (includes Māori business and iwi authorities) will ensure that the Challenge responds to Māori issues, needs and aspirations. Further, it is expected that these different levels of involvement will help to facilitate relationships between Māori, government, the science system and industry to grow opportunities for knowledge transfer, as well as iwi/hapū led research and development strategies. Māori involvement (representation and participation) can now be confirmed in all governance and management levels (see Business Plan) of the *Deep South*, and includes the Governance Board, Science Leadership Team, Kāhui Māori (Māori Council), and the science project (delivery) teams.

Importantly, the purpose of the Kāhui Māori, which is new to the governance structure, is to provide external expertise and counsel to the Science Leadership Team and the Governance Board. In some cases, these members will lead (and/or be involved in) research projects and related initiatives. Terms of Reference as well as formal selection for this group will be determined prior to the establishment phase of the Vision Mātauranga Programme. The interim Kāhui Māori comprises:

- Garth Harmsworth (Te Arawa, Ngāti Tuwharetoa, Tuhourangi, Ngāti Raukawa)
- Chris Insley (Te Whānau-a-Apanui)
- Darren-Ngaru King (Ngāti Raukawa)
- Aroha Mead (Ngāti Awa, Ngāti Porou)
- Helen Moewaka-Barnes (Ngāti Wai, Ngāti Hine, Ngāti Manu)
- Sandy Morrison (Ngāti Maniapoto, Ngāti Rarua, Te Arawa)
- Maria Pera (Ngai Tahu, Te Whakatohea, Ngāti Ruanui)

Element 3: Engagement, collaboration and partnerships

The *Deep South* will work closely with different sectors, systems and groups from across Māori society to: (i) determine Vision Mātauranga research directions and research priorities, (ii) increase understanding of climate change science, (iii) integrate new (and existing) information and tools into iwi/hapū and Māori business planning and decision-making processes, and (iv) co-produce new knowledge to deal with emerging social, economic, political and bio-physical system challenges. It is expected that engagement, collaboration and partnerships with different levels of Māori society will also facilitate relationships that help to grow opportunities for knowledge transfer.

Progress specifically related to the *Deep South* has already been made in facilitating counsel with (i) South Island iwi leaders at the Te Waka o Māui Iwi Chairs Forum, and (ii) senior Māori advisors and researchers involved with Māori-specific climate change matters and decision-making. Further, given that Vision Mātauranga research within the *Deep South* is expected to have strong linkages with work taking place in other National Science Challenges, efforts have been made to discuss cross-challenge priorities and the sharing of resources and relevant information with other Vision Mātauranga Science Leaders (e.g., the *Resilience to Nature's Challenges*, *Sustainable Seas* and *A Better Start*).

Significantly, these collective discussions have highlighted the importance of working together to reduce the requests placed on whānau, hapū and iwi authorities (as well as Māori business) for their time to participate in the Challenges. Notwithstanding this challenge ahead, it is expected that opportunities for sharing networks across the Challenges will assist with putting the 'right people' in touch with the 'right people'. Engagement, collaboration, and partnerships are thereby regarded as critical to realising any Vision Mātauranga successes within the *Deep South*.

Ongoing engagement activities and mechanisms are described in further detail in the establishment phase of the Vision Mātauranga Programme, as well as the Engagement Programme.

Element 4: Research capability, capacity and leadership

Building Māori research capability, capacity and leadership is crucial to meeting the emerging demands of increasingly complex social, economic, political and bio-physical system changes facing Māori and wider Aotearoa/New Zealand society. The Science Leader for the Vision Mātauranga Programme (with assistance from the Kāhui Māori) will work alongside the other Science Programme Leaders to facilitate Māori involvement across the different levels of the entire *Deep South*. Scholarships and internships have been identified as ways in which a new generation of Māori can become involved, inspired and leaders in Earth System Modelling and observations/natural processes science. Further, it is expected that Māori community researchers/research organisations will play a vital role in the delivery of the *Deep South*, and this involvement will contribute to the building of new capabilities through the exchange of knowledge and information from scientists, policy analysts, and decision-makers across indigenous and non-indigenous worlds. This strategic element of the Vision Mātauranga Programme is also expected to contribute to the longer-term need for specialist as well as interdisciplinary scientists/researchers in Aotearoa/New Zealand.

Element 5: Transformative context and future-focused research

Given the diverse realities and climate-sensitivities Māori face across Aotearoa/New Zealand, as well as the likelihood that climate change will exacerbate many existing socio-economic difficulties and disparities, there is growing interest to know more about the implications (includes opportunities and risks) of a changing climate on the different sectors, systems and groups that make up Māori society. Discussions with iwi leaders at the Te Waka o Māui Iwi Chairs Forum have already confirmed the need in the *Deep South* to (i) predict future impacts of climate on our environment and economy, (ii) adopt an intergenerational approach to future planning, (iii) enact a common *kaitiakitanga* or guardianship

ethic towards the land and sea, and (iv) recognise people as the solution. Meanwhile, in more recent months senior Māori advisors and researchers from across Aotearoa/New Zealand have helped to identify a range of research priorities and work-streams (projects) within the *Deep South* that would contribute new knowledge (and tractable outcomes) for iwi/hapū/whānau and Māori business. These priorities are outlined in detail in the next section.

In view of this setting, transformative research that is contextual, solution and future-focused will be developed through this Challenge. It is expected that this research programme will contribute practical and sustainable solutions for Māori and wider Aotearoa/New Zealand.

Establishing the Vision Mātauranga Programme (Years 1-3)

This section outlines the principal steps ahead in establishing the Vision Mātauranga Programme (2015-2017). It includes details for determining research priorities as well as brief summaries of potential research projects.

Pathways to research

Notwithstanding the early establishment phase efforts referred to above, additional Māori engagement activities are required during the remaining first year of the Vision Mātauranga Programme (January-June 2015) to confirm the research priorities as well as the teams capable of delivering on the identified priorities and challenges ahead. These engagement activities will broadly involve:

- (i) appointing members to the Kāhui Māori – including development of ‘Terms of Reference’;
- (ii) working and partnering with Science Leaders to give effect to Vision Mātauranga policy across all *Deep South* research Programmes;
- (iii) convening an ‘open’ forum/workshop with Māori in conjunction with complimentary Vision Mātauranga programmes and groups from other National Science Challenges; and
- (iv) promoting a Māori research core for Māori researchers to facilitate connections, identify skills, transfer learnings, and build research capacity.

As the Challenge progresses, we will work with the different sector, systems and groups across Māori society to re-assess decisions and outcomes through participatory processes. All of these requirements are consistent with the Kaupapa Māori research design underpinning this Vision Mātauranga Programme.

Potential Research Projects

Potential research projects are identified below, including the principal outcomes expected from such projects. These research projects were identified through direct engagement with senior Māori advisors and researchers involved with Māori-specific climate change matters and decision-making. The potential research projects sit within four initial themes.

Please note that further information about each research project will be provided following engagement activities planned during the first period of the Vision Mātauranga Programme (January-June 2015). This information will help to assess and give confidence that the research can be carried out.

Theme 1: Understanding climate change - linkages, pressure points and potential responses

1. Climate change resources for Māori society

Communicating climate change science, risks and uncertainties can be complex and challenging. New educational resources and initiatives are proposed to raise awareness of what we already know about

climate change and to develop more effective communication of the future risks (e.g., visualisation tools for learning and raising awareness). Tailored information as well as the ‘right people’ to convey messages would greatly assist any communication strategies designed for the different sectors, systems and groups that make up Māori society. This project has linkages with the *Resilience to Nature’s Challenges* programme ‘Transformative Mātauranga Māori Research’.

2. Learning from resilient sectors, systems and groups across Māori society

What makes some stakeholders more resilient than others? This project seeks to promote learning about the mistakes and successes of different sectors, systems and groups across Māori society. This is not only common sense but crucial for building resilience and designing scale-appropriate adaptation options for different regions and communities in the context of changing climate and policy conditions.

3. Māori land development, water resources and climate change

This project seeks to make sense of the complexity surrounding Māori land development, water resources and climate change. Information is needed to assist Māori land-owners to make informed decisions about future needs, allocation, and adaptation measures. The outcomes from such research are likely to have immediate implications for Māori land development, as well as longer term climate-change adaptation benefits.

Theme 2: Exploring adaptation tracks for Māori communities

4. Māori coastal communities, sea level rise and extreme events: implications and adaptation tracks

This place-based project will work alongside two Māori coastal communities facing short- and long-term sea level rise and natural hazards challenges. In this decision intensive and complex space, it will (i) articulate the linkages between climate change, natural hazards management and sustainable development, and (ii) work through in detail tactical and strategic adaptation tracks (options) that are acceptable to iwi, hapū and whānau (e.g., land-use transformation). This project has strong linkages with the *Resilience to Nature’s Challenges* programme ‘Living at the Edge – Transforming the Margins’. Co-funding arrangements have been agreed in principle.

5. Water stress, climate change and Māori communities

This century, the number of Māori living under water stress is likely to increase substantially, as increased water demand is heightened during hot, dry summers. Higher temperatures and lower rainfall are expected to reduce soil moisture, groundwater supplies and river flows for some areas, further aggravating water availability and water quality problems. Meanwhile, the effects of changing hydrological regimes on water supplies are likely to seriously affect those places and populations where reticulated supply systems are poorly developed (or non-existent), and where there are inadequate resources to import water or pay for private treatment facilities. Within these groupings are a handful of highly vulnerable communities that should be targeted for water supply planning and adaptation research.

Theme 3: Assistance to Māori businesses to aid decision-making and increase productivity

6. Modelling the economics of different adaptation tracks for the Māori agricultural sector.

Understanding the economic implications of climate change on the Māori agricultural sector is critical for future adaptation decision-making. This must be informed by thorough and ongoing analysis of the vulnerability, sensitivity and exposure of the Māori agricultural sector to climate change, recognising all the inter-linkages and dependencies between people and the physical environment.

This work would enable organisations, businesses and government to assess the economic payoff of different adaptation tracks. It is also expected to assist the incorporation of climate change considerations into the matrix of factors that influence resilience thinking and decision-making.

7. Scenario planning for impact assessment, decision-making and the building of Māori resilience

We will work with climate sensitive primary sectors through the *Deep South* Engagement Programme to explore the use and applicability of diverse scenarios for assessing impacts, risks and implications of climate change for Māori decision-making. As the *Deep South* progresses, coupled human-natural systems models will expand and transition to using the NZESM outputs. This work will produce evidence-based tools for simulating transition pathways to resilience at varying scales. It will also offer support to linked kaitiaki-initiatives to manage risks to customary resources and design responsive actions within tribal territories and cultural environments.

Theme 4: Products, services and systems derived from Māori knowledge

8. Revitalising traditional indicators to anticipate environmental change and extremes

The use of environmental indicators to plan activities and monitor risks reflects the Māori world view that all things are connected and that subtle signals in nature can reveal much about changes in atmospheric conditions. This programme will scaffold off earlier research efforts and promote the application of traditional indicators held by South Island iwi/hapū and whānau to forecast and thereby anticipate environmental change and extremes. This project has linkages with the *Resilience to Nature's Challenges* programme 'The Integration of tikanga Māori in building Resilience'.

Enhancing the Vision Mātauranga Programme (Years 4-10 Outline)

Longer-term research objectives/projects relevant to Māori within the *Deep South* will be confirmed following wider engagement with iwi/hapū/whānau and Māori business in 2015. While not pre-judging what might eventually emerge, and recognising that priorities will likely change, key outcomes are nonetheless expected to include:

- responses that will provide a basis for strong growth in climate-sensitive economic sectors;
- actions that reduce climate change risks and limit the effects of extreme weather;
- economic, social and environmental systems that provide long-term resilience to a changing climate.

Finally, it is important to emphasise that we are not “starting from scratch”. There have been significant advancements in thinking (including actions to understand Māori needs and aspirations) since the earliest formal work by the New Zealand Climate Change Office in 2001 considered how aspects of Māori society might be impacted by changes brought on by a warming climate. It is thereby crucial that the resources available to this programme of research be used to scaffold off the domestic (and international) research science advances made to date.

3.3 Programme 3: Impacts & Implications

Scope and 10 Year Strategy

A robust and thorough characterisation and assessment of the potential implications of climate change for Aotearoa/New Zealand will require an integrated and holistic understanding of both direct and indirect impacts. For example, direct impacts of climate change very probably already cost Aotearoa/New Zealand considerable sums of money. Research suggests that joint greenhouse gas and ozone effects exacerbated the New Zealand drought of 2013, which Treasury estimated to cost around

\$1.5 billion (0.7% of GDP). Similarly IPCC's Working Group II Fifth Assessment Report⁵ documents a range of climate change effects globally, both on human and natural systems. Those effects will in turn generate positive and negative indirect impacts and implications for Aotearoa/New Zealand and create corresponding opportunities and risks.

Better preparing New Zealanders for a changing climate and environment is a large and on-going task. Decision needs vary greatly among the many stakeholders such that it is impossible to develop results tailored to every situation. In fact the greater the specificity of decision needs, the stronger the case for working collaboratively with stakeholders to explore co-generation of knowledge and on-going resourcing to meet their evolving needs. We are fortunate insofar as we are starting from a solid base of information on climate change preparedness in New Zealand – previous and current research gives us a good starting place from which we can make progress.

The *Deep South* provides a 10-year pathway to collaboratively advance New Zealand's capacity to understand, identify, and assess direct and indirect climate change impacts and implications globally, nationally, regionally, and locally and at timescales ranging from a few years, to many decades, to even a century or more. Impacts & Implications Programme research will achieve those advancements by developing a shared climate futures "space". A range of stakeholders, including Māori, industry (e.g., agriculture, energy, and tourism), government, and communities, will be able to experience and explore the improved climate predictions generated by the Earth System Modelling & Prediction, and Processes & Observations Programmes, and connect and apply it to their own experiences, needs, and decision-making processes via the Engagement and Vision Mātauranga Programmes.

The Impacts & Implications Programme consists of three inter-related research themes, which together provide the collective set of skills needed for robust analysis of climate change impacts and implications:

- Integrated Assessment and Impacts – integrated modelling of physical and socioeconomic impacts models that let people explore the different social, economic and environmental dimensions of climate change scenarios. Some of this research has been initiated under the Climate Change Impacts & Implications (CCII) programme and will continue to develop under *Deep South* (e.g., some integrated assessment modelling), while other aspects will be continued in other arenas (e.g., CRI Core Funding, other National Science Challenges such as *Resilience to Nature's Challenges*, *New Zealand's Biological Heritage*, and the *Land and Water Challenge*).
- Implications – direct collaboration with stakeholders to understand what climate change might imply for them and to co-generate decision-relevant climate change knowledge and information. This work relies less on quantitative models and more on the social and policy sciences, as the Challenge engages directly with stakeholders to address their concerns.
- Climate Futures – 'futuring', including scenario development, is an integral component of global climate change research. Climate change, however, is just one of many factors of overall global change to consider. We will build on the work by CCII, and iteratively work with New Zealand's best social scientists and policy thinkers to improve New Zealand's collective capacity to engage effectively with the global climate futures research, including recognising that the broader topic

⁵ IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

of anticipating, responding and adapting to global change will be an area for collaboration across many Challenges.

The second stage (Years 3-5) will focus on improving capacity to uptake new climate information and data emerging from the Earth System Modelling & Prediction and Processes & Observations Programmes, and integrate this into the three research themes. Working both with the Engagement and Vision Mātauranga Programmes, a key focus will include a comparative study to evaluate the utility and value of updated (e.g., initial outputs from the NZESM) versus current (e.g., CMIP5 based data as used in CCII and elsewhere) climate information to improve knowledge and understanding of extreme events, which most stakeholders consider essential for robust decision-making.

We expect that the scope and sophistication of climate change impacts and implications research in Aotearoa/New Zealand will continue to improve during the life of the Challenge. While New Zealand research effort will remain to some degree dependent on global climate change research trends, New Zealand will have developed by then the capacity to undertake independent global assessments tailored to meet New Zealand questions and needs, making Aotearoa/New Zealand for the first time at the global level a knowledge maker rather than just a knowledge taker.

Despite the anticipated improvements, we expect that the consideration of uncertainty will remain a key limitation to understanding impacts & implications. Therefore we anticipate in Years 6-10 focusing substantial effort on improving the characterisation, modelling, analysis and interpretation of uncertainty across the impacts & implications research themes. While the specific scope and exact nature of the research will emerge as we gain experience with Earth System Modelling and associated impacts & implications analysis capabilities evolve, we can currently outline our broad thinking from the perspective of each of the three themes:

Integrated Assessment and Implications: The main goal will be to move towards ensemble modelling (e.g., many runs of a model) for integrated assessments and impact modelling. We know from work within CCII to date that coupling climate and impact models in ensemble approaches has strong potential to help address uncertainty. However implementation of climate model ensembles as part of impact modelling remains challenging in simple impact models, and becomes progressively more challenging in integrated assessments involving multiple, often coupled, impact models. Therefore the key focus of this research theme during Years 6-10 will be to develop, adapt and/or improve methods and techniques for characterising uncertainty by undertaking ensemble modelling approaches that draw on corresponding climate prediction ensemble modelling from the Earth System Modelling & Prediction and Processes & Observations Programmes.

Implications: Stakeholders continually request better knowledge of uncertainty to include in their decision-making processes. During Years 6-10 of the Challenge we plan to work with stakeholders to improve the understanding and consideration of climate change uncertainty within decision-making processes, including understanding the different types of uncertainty (e.g., measurement uncertainty, model uncertainty).

Climate Futures: Effort will concentrate on increasing the consideration of uncertainty into the scenario process, with a key focus on how the enhanced climate and impacts can be leveraged to increase the scope and robustness of climate change scenarios and support exploration of a broader range of possible future conditions.

5 Year Plan

Years 1-2

CCII Continuation and Completion: The existing MBIE-funded 4-year CCII programme provides a launching point for this element of the *Deep South* Challenge (as well as the Engagement Programme). CCII is breaking new ground in establishing the first integrated assessments of climate change impacts for Aotearoa/New Zealand, assessing end-user needs and capabilities for using climate change information, and developing a set of globally-linked future socio-economic scenarios specific to Aotearoa/New Zealand. The project is highly collaborative, involving over 30 physical and social scientists from 11 research organisations, as well as multiple stakeholders (e.g., councils, central government, business, Māori, land owners, and special interest groups). The CCII programme is scheduled to finish in September 2016 (Year 2 of the Challenge) and will have delivered by that time:

- Improved downscaled climate predictions to 2100 for New Zealand based on IPCC AR5/CMIP5 modelling, including enhanced characterisation of variability and extremes.
- A framework for designing and evaluating globally-linked, nationally focused climate change scenarios and a set of 4-6 specific scenarios, including first set of futures literacy material, for broad dissemination.
- A national and five cases-study based integrated assessment and impact modelling studies that explore climate change impacts and implications for the suite of 4-6 globally-linked, New Zealand focused scenarios.
- Synthesis of decision-relevant climate change impacts and implications knowledge and information needs from a range of stakeholders, including local government, industry, and Māori.

CCII Transition Plan: A transition plan will be developed to evaluate and review the elements of the current CCII programme, of relevance to the *Deep South*, starting in Year 3. As indicated above, the CCII programme has various components, some of which fall within the *Deep South*, while others fall within the missions of other Challenges. For example aspects of coastal inundation and the effects of a changing climate on primary production may fit more logically within *Resilience to Nature's Challenges* and *Land and Water*, respectively. In addition, some CCII components are expected to meet the priorities of the Impacts & Implications Programme, while others may more logically fit into the Earth System Modelling & Prediction, Processes & Observations, Engagement or Vision Mātauranga Programmes.

Climate Change Research Cross-Challenge Collaboration Plan: During Years 1-2 of the Challenge we will work with other Challenges and endeavour to develop a cross-Challenge climate change collaboration plan. This plan would aim to a) get climate change considered holistically across all Challenges, and b) develop a collaborative research strategy to help link relevant aspects of research across the Challenges (e.g., streamlining provision of climate data generated in *Deep South* for use by other Challenges for impacts and implications research).

There are five National Science Challenges in the environmental sector, and three (*Ageing Well, Better Start* and *Healthier Lives*) from the health sector which overlap with the *Deep South's* Mission to “transform the way New Zealanders adapt, manage risk, and thrive in a changing climate.” There is much potential for the Challenges to work together to deliver joint benefits to New Zealand – evidence indicates that multiple benefits (so-called “co-benefits”) from actions can play a significant role in people’s choices. By working collaboratively and interactively with the other Challenges, we have the opportunity to have the effects of climate change better integrated into decisions-making processes which might otherwise neglect these dynamic risks. One example is that coastal management or infrastructure decisions might typically be made one way if only considering geological risks (tectonic

movement), but might be made another way if the additional stresses and risks generated from changing climate are also considered (such as higher frequency or return times of extreme events, or higher sea levels). We have already begun conversations with partners involved in the *Resilience to Nature's Challenges* and *Our Biological Heritage* Challenges regarding engagement and some aspects of research scope. We will expand our interactions to include other Challenges during Years 1-2, starting with a potential conference or workshop hosted by the New Zealand Climate Change Centre that could facilitate development of a collaboration plan.

New Zealand Climate Change Impacts & Implications Research - Review & Synthesis: In parallel with the Transition Plan and Collaboration Plan, we will undertake a review of climate change impacts and implications research within Aotearoa/New Zealand to date, leveraging initially off the Australia-New Zealand Chapter of the IPCC Working Group 2 5th Assessment Report⁶. The review will help synthesise knowledge of climate change impacts and implications research to date within New Zealand, and inform both the transition of the CCII programme and advance collaboration with other Challenges, by helping to identify research priorities.

Years 3-5

Years 3-5 of the Impacts & Implications Programme will have two primary goals, predicated on the assumption that data from the NZESM will then be available for use both directly (i.e., NZESM outputs) and indirectly (i.e., outputs from the New Zealand Regional Climate Model based on inputs from the NZESM). The first goal will focus on improving capacity to uptake and utilise new climate information and data in impacts and implications research, and by stakeholders more broadly. The second goal will ask the questions: "To what degree does the new/updated climate data result in changes to impact modelling outputs and, more importantly, do those changes tangibly alter implications for stakeholders?."

To achieve the above goals, we will leverage from the CCII programme to compare the potential differences for impacts and implications based on current (e.g., IPCC AR5/CMIP5) climate versus emerging (e.g., pre-CMIP6/NZESM) modelling. The comparison will focus on characterisation of extreme events, which has utility as one (but not the only) tangible indicator for assessing differences and meets a key, on-going information need of stakeholders. The three Programme research themes (above) will work in a collaborative and complimentary manner to achieve the two goals. We will use the results of our learning to feedback suggestions for future research across the *Deep South* Challenge and more broadly, such as via collaborations with other Challenges.

Integrated Assessment and Impacts: Based on national and case study integrated modelling developed under CCII, we will run new analyses using climate information derived from the NZESM and compare with results obtained using CMIP-5 based climate information. We will work with stakeholders as described below to tailor analyses to meet specific needs. As indicated earlier, some of this effort will be led by *Deep South*, while some of the effort is expected to be led by other Challenges, with *Deep South* in support.

Implications and Adaptation: Stakeholders express a desire to work with the best and most up-to-date climate science knowledge and information. Stakeholders also have limited capacity, however, to uptake, apply and interpret climate science. Working with our existing networks developed in CCII and

⁶ Reisinger, A., R. Kitching, F. Chiew, L. Hughes, P. Newton, S. Schuster, A. Tait, P. Whetton (2014): Australasia. In: Climate Change 2014: Impacts, Adaptation, Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C., Barros, V., Mastrandrea, M., Mach, K., Dokken, D. (eds.)]. Cambridge University Press, Cambridge, UK.

also with the Engagement and Vision Mātauranga Programmes, we will tailor the impact re-analyses to help stakeholders evaluate whether the different projections of extreme events tangibly alter the implications of climate change for decision-making.

Climate Futures: As part of the re-analysis, we will undertake a novel experiment in which we re-analyse the set of 4-6 globally-linked, New Zealand specific scenarios holding all information constant, except for the new climate data, and reinterpret the results. Through the reanalysis, we can begin to address critical questions regarding how often and to what degree do we update scenarios or undertake scenario exercises, etc. to best support decision making in Aotearoa/New Zealand.

3.4 Programme 4: Earth System Modelling & Prediction

Scope and 10 Year Strategy

The objective of the Earth System Modelling & Predictions Programme is to deliver improved climate predictions for Aotearoa/New Zealand. Any coherent, fully-informed scientific prediction relies on a combination of models and data. In physical climate change research, General Circulation Models (GCMs) are the only tools that can coherently assess the relative influences of the diverse plethora of drivers of Aotearoa/New Zealand's complex climate and provide robust predictions.

The focus of the *Deep South* proposed modelling approach will be assembling the first-ever New Zealand Earth System Model (NZESM). Critically, this model will allow the science community to break free from the constraint of basing our climate projections only on existing overseas climate models that are known to poorly represent some oceanic, atmospheric and cryospheric processes in the Antarctic and Southern Ocean. The resulting biases in existing models have serious consequences for the fidelity of predictions over Aotearoa/New Zealand. An Earth System Model has been chosen as the climate modelling approach because it incorporates not only the physical climate system but also the important chemical and biological processes that contribute to Aotearoa/New Zealand's climate. Establishing Earth System Modelling represents a commitment to best possible predictions.

It is emphasised that developing our "own" NZESM represents a 10 year goal for the *Deep South* Challenge. It is recognised that the New Zealand science community does not have the capacity to develop an Earth System Model alone. The NZESM is expected to have a core suite of components obtained from our long standing collaborations with premier international modelling institutions. The primary institution will be the UK Met Office, who in conjunction with The Natural Environment Research Council (NERC) are developing a community-based UK Earth System Model (UKESM) built around the Unified Model of the UK Met Office. The use of Earth System Models being developed by the Centre for Australian Weather and Climate Research (ACCESS model) and the Geophysical Fluid Dynamics Laboratory (GFDL-ESM2 model) will also be considered at the beginning of the challenge.

The development of NZESM will proceed in stages and build on existing global climate modelling expertise in Aotearoa/New Zealand and establish a wider climate modelling infrastructure within Aotearoa/New Zealand universities and CRIs (see Figure 3). It represents both a scientific and technological advance, and an enhancement of our capability in high performance computer programming. From the beginning of the *Deep South*, simulations of the latest physical climate model of the UK Met Office (HadGEM3-GC3), the physical core of UKESM, will be analysed for our region and made available for other programmes in the challenge. This model also represents a significant technological advance on those available from the CMIP5 archive currently used for predictions of Aotearoa/New Zealand's climate. It is expected that UKESM will be available for testing on the NIWA high performance computer by June 2016. Work on improving models components through observational and process studies will begin at the start of the Challenge, but are unlikely to be fully

incorporated in the Earth System Model used for predictions until the second 5 year term of the challenge. Thus, during this second term we expect to have made sufficient model development to identify the NZESM as a distinct model. It is hoped that many of these model improvements will bring wider global benefits that will be of use to other Earth System Models.

The first 5 years of research in this Programme will be undertaken through a series of science projects which have been identified for funding as a result of the process outlined in the 'Science Meeting' (section 4.1). Most of the projects span both this Programme and the Processes & Observations Programme as part of a joint 5 year research plan. Having projects that cross both themes ensures that process oriented research has a clear pathway to contribute to improving the NZESM, and that the NZESM will inform the collection of observations and the understanding of processes in the Antarctic and Southern Ocean. There are also some projects that only involve using the NZESM or related climate models to provide predictions that directly improve predictions to Aotearoa/New Zealand, so sit only in the Earth System Modelling & Prediction Programme. These are summarised here:

- *Establishing a New Zealand Earth System Modelling Capability:* This will establish an Earth System Model capability for New Zealand and support all Earth System Model research within the *Deep South* through the provision of supercomputer access. It will also build a wider climate modelling infrastructure across universities and CRIs. Simulations using the NZESM for the past 150 years, and up to 200 years into the future, will be the outputs of the project.
- *Improving predictions and understanding the Deep South drivers of New Zealand's climate:* To make better predictions of New Zealand's climate requires identifying which processes have the most influence, including upon its extremes. To do this large ensembles of model runs are used to understand the range and sensitivity of responses to differing conditions. This project aims to deliver initialized predictions for the next decade of mean climate, and likely changes in extremes for selected future time periods.
- *Reduced-form simulation of the Earth System Model:* The NZESM will be computationally expensive to run, and unable to fully span the full range of possible emissions trajectories, or the full range of uncertainties, even though these are both important aspects of a full understanding of 21st Century climate change. To address these gaps two reduced form climate models will emulate the high level results of the NZESM, making possible full exploration of the future scenario space.

The following projects consist of research in both the Earth System Modelling & Prediction and Processes & Observations Programmes. The contribution they make to the Earth System Modelling is summarised here:

- *Targeted observation and process-informed modelling of Antarctic sea ice:* Building on New Zealand's expertise in observing sea ice processes, the NZESM will be enhanced by developing and implementing parameterisations to represent wave break up of sea ice and the potential influence of melting ice shelves on sea ice.
- *Reducing biases in the representation of clouds and aerosols in NZESM:* Typically clouds over the Southern Ocean are poorly represented. Here, informed by new observations, the treatment of clouds and aerosols within the NZESM will be refined with the objective of removing the warm temperature bias found in models of the Southern Ocean.
- *Assessing and validating NZESM using modern and historic observations:* Using semi-empirical techniques will allow for process-oriented validation of the NZESM. This will provide a rigorous validation that key processes are well represented in the NZESM.

- *The Southern Ocean in a Warming World and its Influence on New Zealand's Climate:* New Zealand has a maritime climate that is strongly influenced by the ocean. Building on analysis of ocean observations, this project will improve the fidelity of ocean processes within the NZESM by considering the need for higher resolution of ocean processes around New Zealand.
- *Assessing and validating NZESM predictions through Paleoclimate Modelling and observations:* This will establish paleoclimate modelling capability in New Zealand, by applying a version of the NZESM adapted for longer runs, to time intervals in the past which allow validation of the physics in NZESM over climate trends not observed in historical times.

More extensive details on each project are presented in the Processes & Observations Programme in the joint 5 year Work Plan.

3.5 Programme 5: Processes & Observations

Scope and 10 Year Strategy

There is a major information deficit in our understanding of the physical and chemical processes in the atmosphere, ocean, and cryosphere in and over the Southern Ocean and Antarctica. Over the 10 years of the *Deep South* Challenge we will address these deficiencies with targeted process and observation studies, prioritised by their potential to improve the skill of the NZESM, and hence climate prediction for Aotearoa/New Zealand.

To address these needs in the first 5 year term, research in this Programme will be undertaken within a series of projects that span both this and the Earth System Modelling & Predictions Programme. Having projects that cross both Programmes ensures process studies, the analysis of new observations, the re-examination of old observations, and the development of model parameterisations will seamlessly inform the development of the NZESM.

For the second 5 year term of the Challenge research in the Processes & Observations Programme will continue to focus on addressing deficiencies in the NZESM through targeted process and observation studies. A review in year 4 of the Challenge will help identify the specific processes that are the highest priority targets for observational and process studies. As part of this review, it is anticipated oceanographic observations and processes will be more prominent. This is in line with expectations that the oceanic influence on climate is anticipated to increase in priority within the Challenge (see Out of scope research, section 2.3).

The full objectives of each project are described in the joint 5 year research plan detailed below. The summaries of the components of these projects that contribute to the Processes & Observations Programme are:

- *Targeted observation and process-informed modelling of Antarctic sea ice:* How Antarctic sea ice responds to ice shelf melt water and ocean waves is not fully understood, but these processes do play a vital role in controlling sea ice. By taking new observations a better understanding of these processes will be developed which can be implemented into the NZESM.
- *Reducing biases in the representation of clouds and aerosols in NZESM:* Resolving the poor representation of clouds and aerosols within the NZESM needs to be informed by new observations over the Southern Ocean. These observations will be collected on opportunistic voyages in the Southern Ocean, along with fixed observations on Macquarie Island and Antarctica.
- *Assessing and validating NZESM using modern and historic observations:* Improving the validation of the NZESM requires the extension and enhancement of key data sets. Here historical weather

observations will be rescued through digitisation, and along with work on global ozone climate data records, will provide products for validation of the NZESM.

- *The Southern Ocean in a Warming World and its Influence on New Zealand's Climate:* The Southern Ocean is absorbing most of the additional heat in the global climate system, yet there is no understanding of how this influences New Zealand climate. By examining an ocean "reanalysis" and observations a better understanding of what change in the Southern Ocean means for New Zealand will be developed.
- *Assessing and validating ESM predictions through Paleoclimate modelling and observations:* Additional paleoclimate observations will be collected from key zones of the Antarctic and Southern Ocean that currently lack high resolution data series, in particular on the Auckland Islands, where pre-instrumental records fills a knowledge gap in understanding how the westerlies drive climate changes in the Southern Ocean. This research will be closely integrated with existing research on climate archives from Antarctica, the Southern Ocean and New Zealand.

5 Year Plan for Earth System Modelling & Prediction and Processes & Observations Programmes

Eight projects have been identified for support in the Earth System Modelling & Prediction and Processes & Observations Programmes. Their final levels of support and form will be determined through a full proposal and peer-review process (Section 4.1). A summary of each project, its goals, how it contributes to the Challenge, its key investigators and brief budget information follows. References are included, by project, in the Appendix.

Establishing a New Zealand Earth System Modelling capability

Investigators: Sam Dean (Contact Investigator), Olaf Morgenstern, Eric Behrens, Stuart Moore (NIWA).

This project will establish an Earth System Modelling capability for New Zealand and support all Earth System Modelling done within the *Deep South* Challenge. It will enhance our existing partnership with international modelling centres and build a wider climate modelling infrastructure across New Zealand universities and CRIs by funding access to an Earth System Model for all participants in the *Deep South* Challenge.

A climate model covers physical elements of the Earth System, i.e., the dynamics and physics of the atmosphere, ocean and land surface, while an Earth System Model also accounts for its chemistry and biology. This is important because the terrestrial and marine biospheres are important emission sources for the atmosphere and interact with the chemical and physical climate, potentially changing the radiative characteristics of the atmosphere. It is now also international best practice to take a multidiscipline Earth System Modelling approach to acquiring the knowledge, understanding and information to tackle the complex needs of government, industry and the community. In particular wide ranging and interdependent issues can be tackled systematically in a coherent framework to inform environmental and economic planning. Developing our "own" Earth System Model (NZESM) represents a 10-year goal to deliver better New Zealand climate predictions.

The first task in this project will be to engage with all relevant stakeholders to identify the climate modelling system that is best suited to predicting New Zealand climate and will sit at the heart of NZESM. The most likely candidate is UKESM, a NERC/UK Met Office collaboration, pooling expertise and resources to develop a community based Earth System Model for use in CMIP6. Another possible candidate is the ACCESS Earth System Model developed jointly by the Australian Bureau of Meteorology and CSIRO. ACCESS also uses the Met Office atmosphere, but employs different ocean and land surface schemes. Both choices rely heavily on the existing collaboration between NIWA and the Met Office.

To emphasize our capability in undertaking this task, it is noted that NIWA is currently already running two models of relevance to this proposal. The first is the state of the art HadGEM3-GC2, the physical climate model that currently forms the basis of UKESM. The second model is NIWA-UKCA^{1, 2, 3}, a prototype HadGEM3-GC1 configuration that includes full atmospheric chemistry.

The responsibilities of the technician/scientist employed by this project will be to:

- Install the selected Earth System Model on the NIWA HPCF.
- Version-control and code-manage the core version of NZESM.
- Undertake historical simulations of the last 150 years and evaluate the simulation of New Zealand and Antarctic/Southern Ocean climate using standard reanalysis products.
- Manage NZESM output data and make available to national and international users. This could be developed into a core contribution of the *Deep South* Challenge to CMIP6, but would require additional co-funding.
- Provide technical support to other *Deep South* NZESM users.
- Upon maturity of NZESM, undertake simulations out 200 years into the future.
- Work with NIWA aligned Programmes to deliver NZESM output dynamically downscaled to high resolution over New Zealand, and assist with the development of tools for integrating NZESM outputs with impacts assessments.
- When time permits assist with technical contributions to the modelling framework, e.g. speeding up the UKCA atmospheric chemistry component of UKESM.
- Any improvements to the NZESM developed in this project will be shared with our international partners.

Budget	
Scientific Programmer based at NIWA, Wellington	\$850 k
ESMP science leader time	\$106 k
Purchase of high performance computing resource (compute and data)	\$956 k
Total	\$1.91 M
Aligned co-funding	
	None

Targeted observation and process-informed modelling of Antarctic sea ice

Investigators: Pat Langhorne (Contact Investigator; Otago), Wolfgang Rack (Canterbury), Craig Stevens, Alison Kohout, Mike Williams, Natalie Robinson, Sam Dean (NIWA), Greg Leonard, Inga Smith, Vernon Squire, Fabien Montiel (Otago), Jim Renwick (VUW), Kelvin Barnsdale (Canterbury), Tim Haskell (Callaghan Innovation).

Antarctic sea ice has a significant influence on both the ocean and atmospheric components of the climate system (Vaughan et al., 2013), and variability in sea ice extent is coupled with the occurrence of weather systems over New Zealand (Pezza et al., 2008). Despite this, present GCM's (General Circulation/Global Climate Models – a subset of an Earth System Model) are unable to reproduce recent trends in sea ice coverage (Maksym et al., 2012). Satellite observations show that the maximum total extent of sea ice around the Antarctic has been increasing slowly over the past three decades (Comiso et al., 2011), a behaviour superficially at odds with “global warming”. This project seeks to understand this paramount climate question of our time and develop methods to improve representation in NZESM, and by doing so ensure better predictions of New Zealand climate.

A number of hypotheses have been proposed to explain this poor predictive ability (e.g., Holland & Kwok, 2012; Polvani & Smith, 2013; Bintanja et al., 2013; Kohout et al., 2014). The present lead

hypothesis suggests that decadal-scale changes in the atmospheric circulation are closely associated with trends in ocean-atmosphere heat flux. A sea ice modeller, informed by the observations outlined below, will explore two aspects of this problem:

- i) The role of ocean waves and pack ice motion in controlling heat exchange and thus sea ice extent (Kohout et al., 2014). Observations in a variety of sea conditions will be made by specially-developed wave-ice buoys deployed from an icebreaker. These observations will inform well-developed waves-in-ice theory (e.g., Squire, 2007) to develop a parameterisation of wave-sea ice conservative and dissipative processes. The waves-sea ice interaction parameterisation, combined with wave-induced floe breakup theory and the inclusion of a floe size distribution at the ocean-ice interface, can then be incorporated into an enhanced version of a sea ice model, such as CICE (the Community Ice CodE).
- (ii) The influence of ice shelf basal meltwater on sea ice growth and decay (Hellmer, 2004). The melting leads to supercooled water, a precursor for enhanced sea ice growth (Gough et al., 2012). It also results in increased stratification in the Antarctic coastal ocean, which in turn affects heat exchange. The geographic extent of the influence of meltwater on sea ice will be mapped on a regional scale using airborne EM induction sounding along satellite altimeter paths. EM induction techniques are the only reliable method of estimating sea ice thickness from the air (Haas et al., 2009; Rack et al., 2013), and continent-wide satellite estimates of Antarctic sea ice thickness are only now becoming available (e.g., Kurtz and Markus, 2012; Price et al., 2013). These need to be validated by sea ice transects, and ice-ocean and oceanographic observations relating to heat transfer in ice shelf-affected waters, collected on-ice and from an icebreaker. International collaborators will fly coincident airborne snow radar, while other satellite platforms will support the measurements. Process-scale modelling will synthesize these new targeted observations so as to improve parameterisations of under-ice turbulent heat transfer in relation to ice growth and decay. Once operating satisfactorily, the parameterisations will be incorporated into the chosen sea ice model (e.g., CICE) that will sit within the NZESM.

This will connect with other projects, in particular the *Southern Ocean in a Warming World and its Influence on New Zealand Climate* through sea ice-ocean interaction. In addition, the heat fluxes derived in *Reducing biases in the representation of Clouds and Aerosols in NZESM* condition sea ice advance and retreat.

This project will focus on 21st century sea ice processes and parameters that can be directly fed into the sea ice component of NZESM. It leverages off the high international profile of the science team, and ensures international cooperation in this New Zealand-led project.

Budget	
Contribution to sea ice modeller salary	\$638 k
Waves-in-ice	\$744 k
Ice shelf – sea ice – ocean interactions	\$744 k
Total	\$2.13 M
Aligned co-funding	
NIWA (per year)	\$370 k

Improving predictions and understanding the Deep South drivers of NZ's climate

Investigators: Sam Dean (Contact Investigator), Suzanne Rosier, Stephen Stuart (NIWA), James Renwick, David Frame, (Victoria).

The *Deep South* will undertake targeted process and observational studies with the goal of improving the skill of the New Zealand Earth System Model (NZESM), and hence increase our ability to predict climate for New Zealand. But which processes in the Antarctic/Southern Ocean have the most influence on New Zealand's climate, including its extremes? Previous research has identified the Southern Annular Mode (SAM) as a strong influence on mean climate and extremes¹⁻³, and new evidence suggests that joint greenhouse gas and ozone effects exacerbated the North Island drought of 2013⁴. Decadal-scale climate variability also plays a critical role in New Zealand climate and, as identified in the last IPCC report⁵, useful predictions of the next few decades require improved characterisation of these effects. We propose to run a suite of climate model experiments to quantify and rank the relative importance of different climate drivers. Identifying the importance of drivers will help guide decisions made in other *Deep South* projects and allow this project to contribute to improved predictions of changes in New Zealand surface climate (temperature, rainfall etc.). To complement this knowledge we will also use reanalysis products such as ERA-Interim to diagnose variability and trends in the behaviour of the SAM, and the interactions between the westerly winds, surface climate, ocean, sea-ice⁶, tropical and upper atmospheric circulation.

To investigate the sensitivity of hydro-meteorological changes in New Zealand to greenhouse gases, aerosols, sea surface temperatures (SSTs), the El-Niño Southern Oscillation (ENSO), sea ice and ozone, we will undertake historical simulations with a suite of climate models. This will include: (1) atmosphere-only simulations of the NZESM; (2) a fully coupled atmosphere-ocean version of the NZESM model run with a large ensemble of 10 year simulations which differ only in their initialisation; and, (3) massive ensembles of a regional climate model utilising the power of the *weather@home* experiment.

Using state-of-the art reanalysis products we can better specify variability and teleconnections in the large-scale circulation. In particular we will advance understanding of how the ENSO cycle interacts with the SAM, and thereby modulates the Southern Ocean storm track. As well as advancing fundamental understanding of the Southern Hemisphere general circulation, this work will allow us to better diagnose how well the NZESM captures Southern Hemisphere circulation variability and teleconnections.

The NZESM to be developed as part of the *Deep South* Challenge will be computationally expensive and only a handful of simulations for the next 200 years are likely to be completed. In order to establish the drivers and predict changes in climate extremes, we will create massive ensembles of thousands of historical simulations of the last 10 years using a regional climate model of New Zealand via the *weather@home* platform. We will also produce a *weather@home* climate ensemble for a future time period (e.g., 2030) using bias-corrected SSTs from CMIP5 models (produced by aligned NIWA co-funded research) to make better predictions about how and why extremes change in a warming world. This will also provide inputs to downstream impact models and allow uncertainties to be better explored.

Atmosphere-only simulations allow many different combinations of atmospheric forcing to be investigated, while treating the ocean in a relatively idealized manner. However, as “memory” provided by persisting patterns in the ocean and atmosphere may dominate our climate on the timescale of seasons up to the next decade^{7,8}, we will also evaluate these drivers using simulations with a fully coupled atmosphere-ocean version of the NZESM. Evidence exists that climate models have decadal predictive skill in areas near New Zealand, but the Pacific is more complex than other basins because of the strong role of initial condition uncertainty, as well as the subtlety of the ENSO signal⁹. The ultimate aim of the NZESM coupled modelling work in this project is to enable the NZESM to deliver useful seasonal to decadal forecasts for New Zealand, which will assist in decision making.

Budget	
Earth System Modelling and reanalysis	\$1.06 Mk
Weatherathome modelling	\$425 k
Total	\$1.49 M
Aligned co- funding	
	None

Reducing biases in the representation of clouds and aerosols in NZESM

Investigators: Adrian McDonald (Contact Investigator; Canterbury), Olaf Morgenstern, Mike Harvey (NIWA), Roger Davies (Auckland University).

The Southern Ocean region is characterized by large biases in clouds in climate models relative to satellite measurements. This allows too much sunlight to penetrate to the surface, causing warm-biased sea-surface temperatures and a shift in the position of the storm tracks^{2,3}. These biases have a direct relationship to climate sensitivity in models⁴. A major observational campaign (SOCRATES⁵), led by the US, is planned for 2017/2018; this provides an opportunity to contribute to observational and modelling studies on cloud and aerosols. The cloud-radiation problem is present in an early version of the NZESM (the NIWA-UKCA climate model), highlighting the need for model developments. We propose to address this issue using a three pronged approach:

1. **Modelling assessment:** At the start of the project simulations will be performed to assess how the cloud-radiation error described above responds to plausible variations of model parameters and forcing fields. These include DMS and sea salt aerosol production, DMS oxidation to form sulphate, possibly other precursors, aerosol- cloud interaction, cloud process parameterisations, and the boundary layer parameterisation.
2. **Observations and Model Validation:** Shortcomings in 1 will guide the measurement programme. As well as participating in SOCRATES, measurements are proposed ahead of SOCRATES, using NIWA's RV *Tangaroa* and other ships, to gain experience in measuring relevant quantities in this challenging environment, and to inform model simulations. Instruments will also be deployed to Macquarie Island, Davis and possibly Cape Adare under the ACRE¹ program (an Australian component of SOCRATES run between 2015 and 2018). Later work will focus on satellite remote sensing for scaling up the observational results for validation studies; this analysis will be the observational basis for testing model refinements in 3. The integration of detailed in-situ measurements with satellite observations mirrors the work programme defined in SOCRATES and allows improved satellite retrievals critical to validation efforts.
3. **Modelling studies and refinement:** Nudging will be used to suppress dynamical biases and allow direct comparisons of the model to observations. Using new and existing measurements of cloud and aerosol properties for validation, the treatment of clouds and aerosols in the NZESM will be refined to improve the realism of clouds over the Southern Ocean. These modelling studies will complement a project led by the UK MetOffice to reduce the Southern-Ocean warm bias in the HadGEM3 / UKESM model.

The IPCC 5th Assessment Report finds that shortcomings in the simulation of clouds over the Southern Ocean limit the quality of climate simulations for the Southern Hemisphere; hence addressing this issue is squarely within the remit of the *Deep South*. New Zealand has a relatively small community working in this area at present, but the problems identified are considered central to improving the NZESM. The focus of a significant portion of the relevant international community on Southern Ocean clouds via SOCRATES and other efforts also offers opportunity for New Zealand to address this problem. The observational task will benefit from the extensive remote sensing and observational

experience within the team with processes governing the marine emissions of aerosols and their precursors.

The modelling task will use the UK Chemistry & Aerosols (UKCA) module, which O. Morgenstern has been a lead developer of. The group formed is also well connected to UKCA users in the UK and Australia and the SOCRATES planning team.

<i>Budget</i>	
Observations	\$1.05 M
Modelling Studies and development	\$0.86 M
Total	\$1.91 M
<i>Aligned co-funding</i>	
NIWA (per year)	\$300 k
University of Canterbury (per year)	\$50 k

Assessing and validating NZESM using modern and historic observations

Investigators: Greg Bodeker (Contact Investigator), Stefanie Kremser (Bodeker Scientific), Andrew Lorrey, Sam Dean, Richard Querel (NIWA), Adrian McDonald, Ursula Rack, (Canterbury).

The purpose of this project is to capture and apply observations-based data sets from measurement programmes, both within the *Deep South* and elsewhere, to assess and validate the NZESM components deemed most important for providing reliable projections of the climate parameters identified as highest priority by stakeholders. The observations will include satellite-based measurements, reanalyses and in-situ instrumental records sourced locally and internationally. The comprehensive data collection will allow us to go beyond simple inter-comparisons of outputs from hindcast simulations by the NZESM with observations, to using observations to conduct process-oriented validation of the NZESM. Any shortcomings in the NZESM will most likely result from inadequate simulation of key processes. The goals of this project are to use measurements through the instrumental period (typically since 1850) to identify weaknesses in the NZESM, the mechanics underlying those weaknesses, and to suggest improvements to those processes that are fundamental to the fidelity of the NZESM. A team of researchers from NIWA, Bodeker Scientific, and University of Canterbury will address the research goals. The overarching project comprises one small 2-year project and two large 4.25-year projects. The small project will use semi-empirical techniques for NZESM validation, whereby semi-empirical models are trained, both on model diagnostic variables and on real-world observations, and fit parameters are compared to reveal differences between NZESM sensitivities and those in real-world processes. The large projects will:

- Add the *Deep South* to ACRE (Atmospheric Circulation Reconstructions over the Earth). Critical past weather observations will be rescued for the purpose of extending global reanalysis (day-to-day weather reconstructions) into the 1800s. Primary work will consist of digital scanning, keying data, quality control of data, and archiving the observations at NIWA.
- Construct global ozone climate data records. Such data sets are required to (i) provide the ozone boundary conditions for NZESM simulations that exclude an interactive stratosphere, (ii) provide a benchmark for comparisons of ozone from NZESM simulations that do include an interactive stratosphere, and (iii) provide databases that can be used to assess whether the Montreal Protocol is working as expected. Simulations with the NZESM will be too computationally demanding to provide a more explicitly probabilistic, risk-based approach of expected future changes in ozone levels. Thus, this project will focus on developing and using simple climate models as emulators of the complex NZESM to conduct ensemble simulations.

The defining feature of an NZESM is the incorporation of multiple, interconnected Earth system processes. This is both a strength and a weakness of the model - a strength because it captures the real-world feedbacks that result from interconnected processes, and a weakness because single-process inadequacies may compromise the fidelity of the model results as a whole. Managing risk, a key aim of the *Deep South*, requires either adaptation or mitigation actions, both of which can be costly. Willingness to bear those costs depends on confidence in the perceived threat. This project seeks to minimize uncertainties and maximize confidence in projections of climate change.

The development and management of an Earth System Model is a massive task, requiring many hundreds of scientists working across the development, validation and application of the model components. Such a programme is beyond the resources of the *Deep South*. In the same way that the niche skills and expertise of *Deep South* modellers will define how NZESM will diverge from its parent model, the skills and expertise of model validation scientists will determine which components of the NZESM are targeted for process-oriented validation. These skills include the validation of chemistry-climate models using observations, meteorological reanalyses and construction of climate data records.

Many of the techniques that will be used to validate the NZESM are new and therefore carry some risk, but some (e.g., the extended reanalysis that ACRE Antarctica will feed into) are proven. The construct of this Challenge defines a new relationship between measurement programmes and model development in the Earth sciences community in New Zealand, whereby the primary motivation for making measurements is to provide the necessary data for process-oriented validation of the NZESM.

Budget	
Semi-Empirical Models	\$120 k
ACRE data rescue	\$440 k
Ozone in the climate system	\$715 k
Total	\$1.28 M
Aligned co-funding	
	None

The Southern Ocean in a warming world and its Influence on New Zealand's climate

Investigators: Mike Williams (Contact Investigator; NIWA), Melissa Bowen (Auckland), Steve Chiswell, Phil Sutton, Graham Rickard, Erik Behrens (NIWA).

The ocean's heat capacity dominates the heat balance of the earth, with 93% of the global energy increase between 1971 and 2010 being taken up by the ocean (Rhein et al., 2013). It is now clear that despite a hiatus in surface warming (Huber and Knutti, 2014) there has been a steady increase in ocean heat content, almost all of which has occurred south of 20°S (Roemmich et al., 2014). The rate at which the overturning circulation moves heat through the ocean has also been linked to the warm biases in CMIP5 Southern Ocean temperatures (Wang et al., 2014).

Thus, better simulation of Southern Ocean temperatures, which is critical to projections of New Zealand's climate, relies on understanding the processes controlling heat transport and circulation in the Southern Ocean. We propose two tasks that identify the main ocean processes controlling temperature changes in the oceans around New Zealand:

- Task 1 will focus on understanding where heat is changing in the Southern Ocean, and the processes driving these changes. We will analyse the heat content and heat transport in the Southern Ocean using both observations (Argo, satellite SST and SSH) and an ocean "reanalysis"

product (Southern Ocean State Estimate; Mazloff et al., 2010). The analyses will be compared to the heat transport in existing climate models (e.g., CMIP5 class models) to identify the processes that are most poorly simulated. This will also assist with identifying areas where better observations can inform both ocean “reanalyses” and processes in the NZESM.

- Task 2 will support numerical ocean modelling in the NZESM. The initial focus will be on validating both the global and New Zealand regional behaviour of the ocean model component of the NZESM. Following validation the ocean model will be used to investigate processes through which the Southern Ocean influences New Zealand, and areas where future process studies could inform parameterisations that will enhance and improve the model. We will then look to improve the fidelity of the NZESM around New Zealand by investigating where higher resolution will significantly improve the representation of physical processes in the NZESM.

This project addresses the *Deep South* Mission by investigating key processes in the Southern Ocean and ensuring these are well represented in the NZESM for better predictions of New Zealand’s climate.

The team have been intimately involved in the development of aspects of these state of the art approaches to quantifying ocean temperatures and their role in New Zealand climate. This research builds on non-aligned NIWA research on ocean observations and climate, and utilises decades of combined research experience into the oceanography of the New Zealand region, using both in situ and remote sensing data (e.g., Chiswell et al., 2015). It also links to co-funded GNS Science research on isotopic tracers that examine ocean dynamics, and builds capacity by developing and expanding New Zealand’s global ocean modelling expertise.

Budget	
Analysing Observations and Reanalyses	\$425 k
Ocean modelling in the NZESM	\$638 k
Total	\$1.06 M
Aligned co-funding	
GNS Science (per year)	\$50 k

Assessing and validating NZESM predictions through paleoclimate modelling and observations

Investigators: Marcus Vandergoes (Contact Investigator, GNS Science), Nancy Bertler (Victoria University/GNS Science), Giuseppe Cortese, Joe Prebble, Chris Hollis (GNS Science), Gavin Dunbar (Victoria University), Chris Moy, Gary Wilson (University of Otago), Steven Phipps (University of New South Wales), Matt McGlone (Landcare Research), Helen Bostock (NIWA).

This project aims to assess and validate climate predictions derived from the NZESM by testing the performance of model components on relevant episodes of past climate change. It will establish paleoclimate modelling capability for New Zealand, assist in the development of new time series records, and be closely integrated with existing research effort on climate archives from Antarctica, the Southern Ocean and New Zealand to support NZESM development.

Pre-instrumental climate or paleoclimate records serve to improve future climate predictions in two ways. They extend the record of climate variability and in this way provide a means to calibrate models to assess their skill at reproducing long-term natural variations in the climate system¹. Secondly, they provide insight into climate trends and states that have not been observed in historical times, but are predicted to occur in the future². Importantly, paleoclimate data provides an opportunity to examine climate transitions where the climate signal is larger than background variation or uncertainty and therefore test and validate model performance at simulating significant climate events or transitions in the past.

A version of the NZESM, adapted for longer runs at a reduced resolution, will be applied to time intervals in the past where detailed reconstructions of climate change exist (Task 1), especially for times where large scale changes in the climate system have occurred (such as the Last Interglacial², Glacial-Holocene transition³ and the Holocene thermal optimum⁴. This project will draw from past and on-going modelling efforts within the Paleoclimate Modelling Intercomparison Project (PMIP)⁵ and contribute to PMIP by improving integration of paleoclimate observations and models for the *Deep South*. Using high resolution paleoclimate observations, calibrated to instrumental records, across a meridional transect from Antarctica and the Southern Ocean to New Zealand to simulate the most critical climate drivers and responses will provide a basis for comparison and assessment of model outputs.

Integration and comparison of paleoclimate modelling outputs with NZESM simulations will require new targeted observations within the Anrtarctic/Southern Ocean, including meteorological and environmental monitoring and collection of specific paleoclimate records (Task 2). Study of a Subantarctic site, such as the Auckland Islands, will be undertaken to reconstruct pre-instrumental records of precipitation, temperature, and dust flux variability that will be used to better to understand long-term variability within the westerly wind system and its influence on Southern Ocean and New Zealand climate.

The outcome of this project will be to improve the skill of the NZSEM and refine and validate its ability to predict climate for New Zealand. This will provide an important tool for the, investigation of processes currently poorly captured in NZESM, such as variability in westerly winds, SAM and sea ice extent; ocean temperature and stratification; teleconnections with ENSO.

This project is centred on climate modelling but is underpinned by observational data, both from the modern climate system and climate archives from Antarctica, the Southern Ocean and New Zealand. It also contributes to understanding the impacts of climate change on New Zealand's natural systems, especially precipitation and extreme events. Paleoclimate studies also provide valuable opportunities for engagement, from the public interest in multi-institutional science (such as ice and lake coring projects) to the hands-on opportunities to learn how local environments have changed through time. Relating changes in the Antarctic/Southern Ocean to local environmental impacts have proven a successful approach to iwi engagement and helps to address the aims of Vision Mātauranga.

Budget	
Paleoclimate modelling position	\$744 k
Collection of proxy records from the Subantarctic	\$319 k
Total	\$1.06 M
Aligned co-funding	
GNS Science (per year)	\$500 k

Reduced-form simulation of the Earth System Model

Investigators: Dave Frame, (Contact Investigator; VUW) Greg Bodeker, Stefanie Kremser, (Bodeker Scientific).

The *Deep South* will undertake targeted process and observation studies with the goal of improving the skill of the New Zealand Earth System Model (NZESM), and hence increase our ability to predict climate for New Zealand.

Earth System Models provide an unparalleled and coherent synthesis of our understanding of the physical and biological world, but because they include so many processes coupled together in so

many ways, they are computationally expensive and need to be run on a supercomputer. Only a handful of simulations for the next 100 years are likely to be completed (and the scenarios used to drive them will be carefully chosen so as to make best use of the available resources).

The downsides of this comprehensive approach to our understanding of Earth Systems processes are that it is not possible to deliver a rounded treatment of the scientific uncertainties associated with Earth Systems processes, nor is it possible to quantify the sensitivity of results to specific greenhouse gas, ozone and other forcing scenarios.

Quantifying and communicating these uncertainties is important, and though it is not a perfect treatment of the issue, we propose to utilize models of reduced complexity that mimic the high level, aggregate response of the climate system to a range of forcings of interest to stakeholders and scientists. To do this we will draw on a hierarchy of climate models. The simplest, energy balance models (EBMs), are still useful where they can help conceptualise and clarify atmospheric processes and model behaviour which bear on policy; the same is true of Earth System Models of Intermediate Complexity (EMICs) which resolve processes at a level between the simplicity of EBMs and the full complexity of general circulation models (GCMs).

We anticipate this research being of particular value in New Zealand: because of our unique emissions portfolio, New Zealand is more sensitive than most to issues such as the intercomparison of gases and the sequencing of mitigation initiatives. Since the *Deep South* will develop Earth System Model capability, it is important to ensure that this capability is well-aligned with the decision needs and interests of New Zealand's domestic and international policymakers, and that results are our best understanding of the climate system in New Zealand and inform the relevant decision processes.

This project will obtain and customize a set of simple climate models¹⁻⁶ and work alongside the NZESM development group to apply our best assessment of the climate system, plus associated uncertainties, and inform key issues raised by the *Deep South* stakeholders and users of NZESM output.

Budget	
Problem identification, policy-interaction and modelling work	\$100 k
Policy-interaction and simple modelling work	\$150 k
Total	\$300 k
Aligned co-funding	
Victoria University of Wellington	\$50 k

4. Scope and Priority setting to date

Development of the Research and Business Plans has been undertaken by an interim Director and Science Leadership Team (see Business Plan section), under the guidance and leadership of an interim Governance Board representing the Party organisations. Development of the science strategy and the Research Plan has been a national, multi-institutional collaborative effort that has included science, Māori, industry and central and local government. Strategic thinkers representing all these sectors have been engaged, both through the Challenge development and existing science-based initiatives, to determine the focus and priorities of the *Deep South*. The focus and Mission of the *Deep South* has been strongly endorsed by all stakeholders.

Two key stakeholder meetings were held to confirm and prioritise the focus and research activities within the Challenge, and these are outlined below.

4.1 Science Meeting

A Science Meeting was held 28 October 2014 to shape and prioritise research projects to be undertaken in the Earth System Modelling & Predictions, and Processes & Observations Programmes. Meeting attendees (chosen for their science expertise and representing 10 different science organisations) identified a list of 17 projects, that were discussed in depth, and ranked using criteria based on relevance (i.e., within scope and delivering the *Deep South* Mission; advancing Earth System Model capability; improving predictability of New Zealand's future climate; processes and observations from the Southern Ocean/Antarctica likely to be key drivers of climate) and feasibility (i.e., resources, expertise and capability available; international connections; existing support) These projects were further reviewed by the Science Leadership Team, and through consolidation (mainly merging of projects), reduced to 10 projects. A two page research project summary was then sought, from the key researchers of each project, that provided information on the project links to Programme objectives, project work plan, researchers involved, international connections, co-funding/aligned funding, responsiveness to Vision Mātauranga, budgets and timelines, communication and outreach, and links to other projects and Programmes within the *Deep South*.

Following a stakeholder-focussed strategic research plan workshop on the 27th November 2014 (described in detail later) the 10 projects were further assessed and refined through a one day vigorous review process by the Science Leadership Team. Criteria used included: potential to contribute to the Mission and Programme objectives (plus phasing/timing); relevance to the priorities identified by stakeholders in the strategic workshop; science excellence (novelty and impact; quality of team and collaboration; international links); funding/resourcing (co-funding, flexibility, scalability); dependence and connectivity to other *Deep South* projects/Programmes; engagement and capability (science skill development, stakeholder capability building and engagement); and responsiveness/potential re Vision Mātauranga. Key decision-making criteria for projects also included the ability of the project to contribute to Earth System Model development; the study of processes/observations south of New Zealand (Subantarctic to Antarctica) that are known/presumed to be major drivers of New Zealand's climate with potential to improve predictions where New Zealand expertise has critical mass and capability; linking with other projects and resources of aligned work to the Challenge, and avoidance of duplication; whether within the agreed scope of the Challenge, and credible team and resourcing.

Table 1. Priority ranking of projects resulting from priority setting to date. Projects with a rank of 6 are listed in no particular order.

Priority	Project Title
1	Establishing a New Zealand Earth System Modelling capability
2	Targeted observation and process-informed modelling of Antarctic sea ice
3	Improving predictions and understanding the Deep South drivers of NZ's climate
4	Reducing biases in the representation of clouds and aerosols in NZESM
5	Assessing and validating NZESM using modern and historic observations
6	The Southern Ocean in a warming world and its Influence on New Zealand's climate
6	Assessing and validating ESM predictions through paleoclimate modelling and observations
6	Reduced-form simulation of the Earth System Model

This process also involved some merging or picking elements of projects, and a final prioritised list of eight projects. While this list still represents more than can be funded by *Deep South* (\$300 k more per annum), the Science Leadership Team believe that further project refinements will be possible through feedback from the Independent Science Panel and detailed project peer review (see Business Plan). These prioritised projects form the basis of the initial five years of the Research Plan and are listed in Table 1.

4.2 Stakeholder Research Plan Workshop

A strategic Stakeholder Research Plan Workshop was held in Wellington on 27 November 2014, attended by 65 key Stakeholders from a range of sectors. The workshop covered the principles and criteria for National Science Challenges, the intended structure of the *Deep South* Challenge, and sought input from attendees on the scope and direction of the Challenge, including research priorities and mechanisms for the dissemination of research results. Key questions and responses from the workshop are summarised below:

1. *Question:* Considering the 5 and 10-year timeframes of this initiative, what information from the *Deep South* Challenge would help you to make climate-relevant decisions in your sector?

Responses:

- Making existing information available now (not wait for 5 – 10 years).
- Tailor already known information needs into forms relevant to diverse audiences.
- Emphasise positive opportunities, where present, rather than focus primarily on negative impacts.
- Improve communication around uncertainty and risk.
- Provide site specific information, relevant to communities, iwi, hapu and industry.

2. *Question:* The *Deep South* Challenge aims to improve our understanding of several physical impacts of climate change. Please list five physical impacts (in order of priority) that are most important or valuable to your sector.

Responses:

Of the forty individual responses and the general feedback received from the groups as a whole, the following physical impacts were the most common, in order of ranking:

- *Extreme events* (storms, flooding, drought, urban impacts, wildfire, land productivity).
- *Sea level rise* (coastal inundation, erosion, salt water intrusion).
- *Mean climate variability* (temperature, rainfall, wind, frosts, snow and ice cover).
- *Freshwater availability and quality* (land use pressure, salt water intrusion, climate impact on water takes (including groundwater).
- *Pests and diseases* (weeds, biosecurity and biodiversity).

Note: these impacts align closely with the initial research priorities identified in the research outline to MBIE, and detailed further in this Research Plan. This reinforces the strong signals provided through previous work with, and feedback from, key Stakeholders that has guided the priority setting within the Impacts & Implications Programme of the Challenge.

3. *Question:* What mechanisms would you like to see the *Deep South* Challenge implement to ensure the transfer of knowledge and outcomes to your sectors and wider Aotearoa/New Zealand?

Responses:

- Use simpler language to enable greater connection.
- Create or support citizen science projects.
- Use clever video formats to communicate ideas.

- Paint a picture of the future, show people how things will be different to the present.
 - Draft summaries of project reports and papers, suitable for decision-makers.
 - Provide internships or scholarships to raise capacity within communities.
 - Refine messages, find the most impactful facts and message and target dissemination.
4. *Question:* Based on the current *Deep South* Challenge plan, what else might contribute to meeting our mission to transform the way New Zealanders adapt, manage risk, and thrive in a changing climate?
- Responses:*
- Incorporate the social dimensions of the climate change issue within the *Deep South*.
 - Ensure the knowledge transfer is a two way engagement.
 - Recognise that the public's perception of climate change is not necessarily the same as *Deep South* researchers or Stakeholders; need to provide fundamental information that it is happening, before *Deep South* detail can follow.

Subsequent to these meetings there have now been six half day meetings by the Science Leadership Team to finalise the strategic priorities, project details and budgeting for the Challenge. As a result of these meetings the Science Leadership Team elected to further refine the Programme structure for the Challenge to ensure appropriate focus on engagement and Vision Mātauranga, and this now forms the basis of the Research Plan below.

5. Challenge structure and attributes

5.1 Building on existing research

Two existing MBIE contestable contracts held by NIWA, the *Climate Changes Impacts & Implications* (CCII; co-led with Landcare Research) and *Ross Sea Climate and Ecosystems* programmes, have been mapped into the *Deep South* and will continue until 2016. The CCII programme will become a key element of the Challenge, as described above. The current research within the *Ross Sea Climate and Ecosystem* programme is expected to be completed at the end of the contract period in 2016, and the funds from this Programme will then be allocated to *Deep South* priority projects.

The New Zealand Climate Change Centre (a virtual organisation set up to promote and manage collaboration between science providers in Aotearoa/New Zealand on climate change science, and with a membership including all the Crown Research Institutes and most of the universities) undertakes annual initiatives that aim to engage with key stakeholders on climate change issues. Opportunity exists for the *Deep South* to collaborate with the Centre on such activities.

There are significant areas of existing research being undertaken by the Aotearoa/New Zealand science community on Antarctic and Southern Ocean drivers of change in the global climate system. This research is world-class and linked to international Programmes and efforts, and underpins research proposed by the Challenge. Opportunity exists therefore for this research to be part of, and contribute to, the planned societal outreach and engagement activities of the Challenge.

5.2 Co-funding

GNS Science and NIWA have aligned approximately \$8.45M of their Core Funding to the Challenge over the first five years. This is funding that currently supports projects relevant to the *Deep South* (as shown in Figure 3), and on-going use of these funds will be guided by the Challenge (see Business Plan). This work will complement Challenge research, and is anticipated to include sea-ice processes and observations, ozone-chemistry modelling, regional climate modelling, atmospheric/ocean measurements, and high resolution paleoclimate records and modelling that define recent climate variability.

Other research of relevance to this Challenge includes that supported by Victoria University of Wellington, and the Universities of Otago and Canterbury, and Bodeker Scientific, and environmental hazard research by NIWA and GNS Science (especially forecast and risk modelling associated with coastal storm surge, surface water flooding and damaging storms (NIWA); social research on resilience to natural hazards (GNS Science)). Much of this research represents in-kind support, Marsden Fund research related to the Challenge, and organisational research funds. Significant opportunity exists to connect this research to the Research Plan priorities of the Challenge. The alignment of potential co-funded activities is expected to grow as the Challenge activities become established, especially over the coming year. Potential future research of relevance also includes the ocean research proposed by the Sir Peter Blake Institute Centre of Research Excellence, should this Centre of Research Excellence be funded.

5.3 Linkages to international research

Quantifying the impacts of a changing future climate, and understanding and helping communities to respond and adapt to these impacts, is a global issue. While Aotearoa/New Zealand specific impacts will need to be determined, and responses will need to accommodate national cultural and societal values and characteristics, there is significant opportunity to leverage off international research and initiatives. Building on existing international collaborations and networks will be a key element of the *Deep South* Challenge. Examples of how international connectivity will benefit each Programme area include:

- *Engagement:* we have a number of established collaborations with world leading centres in the area of societal engagement regarding climate change. Collaborations already exist with the Universities of Oxford, Reading and East Anglia (UK), CIRES and the University of Colorado at Boulder (USA). These organisations have units with core competencies in the broad human dimensions of climate change, and specifically in dealing with issues arising around climate “science in publics”. Elements of engagement which relate specifically to adaptation planning and the impacts of climate change, are listed below under impacts. We also have strong connections with the WCRP Climate and Cryosphere Project.
- *Impacts & Implications:* As demonstrated in the recently-published IPCC Fifth Assessment Report on Impacts, Adaptation and Vulnerability, climate change is impacting every country in the world. There is a large number of research institutes studying climate change impacts, though most studies are country-specific. Aotearoa/New Zealand-based research on climate change impacts is well established, with good international links, especially to Australia (CSIRO, Macquarie University, Bureau of Meteorology, NCCARF), the US (NOAA, CIRES, University of Colorado) and the UK (UKCIP, ClimateUK, Climate Change Committee, Universities of Reading and Oxford). The *Deep South* Challenge presents an opportunity to extend international linkages, particularly in research areas currently not well studied in Aotearoa/New Zealand, such as climate change impacts on marine and terrestrial biodiversity, natural ecosystems, natural capital, and ecosystem services.
- *Earth System Modelling & Prediction:* Established collaboration with the UK and Australia provides the opportunity for Aotearoa/New Zealand to establish a national Earth System modelling capability. Both the US and Europe have Programmes developing Earth System models that Aotearoa/New Zealand can link to. Key collaborations include the UK Met Office, National Centre for Atmospheric Sciences (UK), the Centre for Australian Weather and Climate Research, the University of Oxford, the Geophysical Fluid Dynamics Laboratory, Centre National De La Recherche Scientifique, Los Alamos National Laboratory, NOAA-CIRES, University of Colorado and the National Centre for Atmospheric Research (USA). All international climate modelling activities are ultimately co-ordinated and guided by the World Climate Research Programme (WCRP), with which we already have significant involvement. The WCRP mission is to “*facilitate analysis and prediction of Earth system variability and change for use in an increasing range of practical*

applications of direct relevance, benefit and value to society", and is in good alignment with the *Deep South* Mission statement.

- **Processes & Observations:** Understanding Antarctica and the Southern Ocean is inherently an international problem, as they have significant influence on the global climate. Opportunity exists to build on New Zealand's geographic proximity, and our logistics and science capacity to collect and analyse further observations. Examples of collaboration that will be enhanced include the Argo and Deep Argo Programmes (Scripps Institute of Oceanography, CSIRO, University of Washington, NOAA), collaborative sea-ice and Southern Ocean physics research (Antarctic Climate and Ecosystems CRC, CSIRO, York University, NASA, University of Southampton, Nansen Environmental and Remote Sensing Centre). We will also be able to contribute to international programmes such as the Global Climate Observing System Reference Upper Air Network (GRUAN), the Surface Ocean Lower Atmosphere Processes (SOLAS), the Atmospheric Circulations Reconstructions over the Earth (ACRE), the Southern Ocean Cloud Radiation Aerosols Experimental Study (SOCRATES), the Stratosphere-troposphere Processes And their Role in Climate (SPARC), and the Southern Ocean Observing System (SOOS). Antarctic research will contribute to priority themes identified by the Scientific Committee on Antarctic Research (SCAR) and its Antarctic Climate 21 Programme. Paleoclimate research is closely tied to priority themes within the Past Global Changes (PAGES) Theme within the International Geosphere-Biosphere Programme (IGBP).

5.4 Fit with sector and research strategies

The research proposed within the *Deep South*, especially within the Earth System Modelling & Prediction and Processes & Observations Programmes, is aligned to the *New Zealand Antarctic and Southern Ocean Science, Directions and Priorities 2010 – 2020*. It will contribute to the research goals of Outcome 1 (Climate, Cryosphere, Atmosphere and Lithosphere) of this strategy by 'enhanced modelling of Antarctic and Southern Ocean impact on, and responses to, climate change and variability', and 'improve(d) understanding of the Antarctic atmosphere's response to global change and its effect on New Zealand'. The *Deep South* Challenge is also aligned with the CRI Statements of Core Purpose of GNS Science, Landcare Research and NIWA, as outlined in their respective Statements of Corporate Intent. These organisations have objectives that explicitly require them to contribute national benefit from climate change research activities, and have aligned co-funding specifically to the *Deep South* for this purpose.

While many of New Zealand's sectors will be impacted by future changes in climate, and influence policy, planning and regulation, there are few sector strategies that acknowledge specific needs for climate adaptation. The strong sector engagement, both to date and planned, has ensured, however, that the Challenge is focussed on the direct needs of New Zealand's climate sensitive industries and communities.

5.5 Linkages to other Challenges

Several of the other National Science Challenges are expected to form important interfaces with the *Deep South* Challenge. There are both science and societal linkages between many of the Challenges, and we have had initial discussions with those parties preparing the other environmental-based Challenges on areas of potential collaboration. Areas of commonality and potential linkage, which will need to be further progressed as the *Deep South* and other Challenges develop, include:

- **Governance** – for some of the Challenges there is opportunity to have a single Governance Board overseeing more than one Challenge. This is especially relevant to Challenges with a common Host organisation, overlapping science teams and outcomes, and common interests by Māori and stakeholders. While separate Boards for the *Deep South* and *Sustainable Seas* Challenges have now been established, many of the Board members are common to ensure linkage between the

Challenges. There will be a need to also develop a mechanism for sharing ‘best practice’ in the governance of the Challenges (e.g., regular meetings of Challenge Chairs).

- *Science communication* – we are collaborating with the Science Media Centre and several Challenges to ensure our media and communications strategy includes coordinated media releases, activities, events, resources and sharing of best practice (see section 3.1). There may also be opportunities to connect with the MBIE *Science in Society* project.
- *Societal outreach and engagement* – integration of science and society is a common principle and prerequisite of the National Science Challenges. There will be significant benefit from sharing approaches and learnings between Challenges. Initial discussions between the Challenges have already identified potential joint initiatives, and these will need to be further developed through the establishment phase of the Challenges. Examples include a proposal by key museums to co-fund outreach activities relevant to all the Challenges; shared workshops on common themes; and cross-Challenge capacity building. Discussions for such initiatives have been held between the Challenges focused on the *Deep South*, *Sustainable Seas*, *Resilience to Nature’s Challenges*, *Our Biological Heritage*, and *Building Better Homes, Towns, and Cities*.
- *Vision Mātauranga* – all of the National Science Challenges will aim to involve, collaborate with, and deliver benefit to Māori. Combining engagement activities and capability building initiatives, for example, would be of benefit.
- *Environmental Data Management* – many of the Challenges will depend on and produce large quantities of environmental data. There is a need to ensure that management of this data, especially its accessibility, delivery and visualisation, is based on similar approaches to ensure that maximum benefit is derived from it, both within and between Challenges.
- *Natural hazards* – although the scope of the *Resilience to Nature’s Challenges* is still in development, there is potentially significant synergy and alignment between the *Deep South* and this Challenge. Areas of common interest include resilience and adaptation to coastal storm surge, surface flooding, wild fire and damaging storm events. Collaboration between these Challenges will be essential and links have already been established (many of the parties to *Deep South* are in common with *Resilience to Nature’s Challenges*).
- *Sustainable use of marine resources* - changes in ocean climate will impact living resources within the ocean and associated industries (e.g., aquaculture and fisheries). Impacts are likely to include ocean warming on marine farming and fish distribution, changes in recruitment levels in fisheries, increased risk of marine invasive species, sea level change induced erosion in intertidal regions, and the effect of ocean acidification on shellfish. While marine impacts will not be a major focus in the initial five years of the *Deep South*, there will be a need to link to *Sustainable Seas* in the second phase of the Challenge.
- *Water resources* – both *Land and Water* and *Our Biological Heritage* will potentially require knowledge of the impacts of future climate on freshwater resources. This connection with the *Deep South* will need to be explored once these other Challenges are established, given the importance of water resources to intensive farming and water quality management.
- *Biodiversity and biosecurity* – changes in climate are predicted to have a significant impact on terrestrial biodiversity and increase biosecurity risk. Opportunity exists to explore joint research on these elements between the *Deep South* and *Our Biological Heritage* Challenge.
- *Technology Development* – observation and modelling demands of this Challenge are immense, and new technologies for gathering data from the *Deep South* or managing the huge and complex ESM tasks may benefit from joint research with the *Science for Technological Innovation* Challenge, particularly in areas where the tools that are developed have the potential to create new export opportunities for Aotearoa/New Zealand software, consulting or high-tech manufacturing companies.

5.6 Organisations

The Party research organisations responsible for the establishment of the *Deep South* Challenge and providing support for the research and related activities within the Research Plan represent the core of the national science capability relevant to the Challenge, complemented by other organisations as appropriate, as summarised in Table 2 below.

Table 2. Significant areas of capability for the Challenge parties and collaborators in the *Deep South* Challenge.

Research capability	Organisation
Science Communication and Public Engagement	Antarctica NZ, GNS Science, Landcare Research, NIWA, University of Canterbury, University of Otago, Victoria University of Wellington
Māori Engagement	GNS Science, Landcare Research, NIWA, University of Canterbury, University of Otago Victoria University of Wellington
Atmospheric Processes and Climate Dynamics	GNS Science, NIWA, University of Canterbury, University of Otago, Victoria University of Wellington
Atmospheric Chemistry	Bodeker Scientific, NIWA
Oceanography and Ocean Modelling	NIWA, University of Auckland, University of Otago, Victoria University of Wellington
Sea Ice	NIWA, University of Canterbury, University of Otago
Glaciology and glacial modelling	GNS Science, University of Canterbury, University of Otago, Victoria University of Wellington
Carbon Cycle	GNS Science, Landcare Research, NIWA
Paleo and Historical Climate	GNS Science, Landcare Research, NIWA, University of Otago, Victoria University of Wellington
Remote Sensing	Landcare Research, NIWA, University of Auckland, University of Canterbury, University of Otago
Logistics (Antarctica, Southern Ocean)	Antarctica NZ, NIWA, University of Otago
Climate Modelling	NIWA, University of Canterbury, Victoria University of Wellington
Climate Change Impacts and Adaptation (including Economics)	Bodeker Scientific , GNS Science, Landcare Research, Lincoln University, Motu NIWA, University of Otago, Victoria University of Wellington

Core capability includes:

- *NIWA* - expertise in atmospheric and climate research was established over 50 years ago, and its oceanographic capability extends back over 70 years. NIWA maintains nationally and internationally significant measurement networks and databases (i.e., climate station network and the National Climate Database; ozone measurements (Lauder and Antarctica), greenhouse gas and atmospheric composition measurements and databases; Lauder as one of five international measurement locations of the Network for the Detection of Atmospheric Composition and Change); major research Programmes on atmospheric and oceanic climate variability and change; owns and operates a super computing facility and New Zealand's only deepwater research vessel; produces weather/climate forecasting products for multiple sectors.
- *Antarctica NZ* - Antarctica New Zealand is the Crown Entity responsible for developing, managing and executing New Zealand Government activities in Antarctica and the Southern Ocean, in particular the Ross Dependency. It manages Scott Base, New Zealand's Antarctic research station, provides logistical and operational support for science activities in the Ross Dependency, and

raises public awareness (in part through arts, media and youth Programmes) of the international significance of the continent.

- *GNS Science* – Expertise and major research programmes on paleoclimate research, impacts and reconstructions from sediment/ice core analysis, global carbon fluxes, cosmogenic (^{14}C and ^{10}Be) and stable isotope analysis, palynology and paleontology, glacial mapping, ocean-climate interactions, glaciology, ice sheet-climate interactions, and land to water interactions (nitrogen fluxes).
- *Landcare Research* – New Zealand’s foremost terrestrial environmental research organisation with responsibilities for improving the measurement, management and protection of New Zealand’s terrestrial ecosystems and biodiversity; achieving sustainable use of land resources; improving the measurement and mitigation of greenhouse gases; and increasing the ability of New Zealand industries and organisations to develop within environmental limits; skills in integrated assessment, ‘futuring’ and impact modelling spanning economics, biophysical and soils/land resources; maintains several nationally significant databases for climate change modelling and research (Land Cover Database, Land Resource Inventory, Fundamental Soils Layers, S-Map, National Vegetation Survey, Allen Herbarium and several Biosystematic databases).
- *New Zealand Antarctic Research Institute* – Established in 2012, NZARI is a virtual multi-disciplinary research institute dedicated to Antarctic and Southern Ocean Research. It partners with national and international research agencies and Antarctic New Zealand to deliver research on Antarctica’s cryosphere, atmosphere, lithosphere and terrestrial and marine ecosystems. Specific focus includes the impact of global change on Antarctic and its ecosystems, and increasing understanding of Antarctica’s response and impact on southern ocean processes, climate and ecosystems. NZARI is leading the development of new research initiatives on the Ross Ice Shelf, Cape Adare and Robertson Bay and the New Zealand Subantarctic region.
- *University of Otago* – University of Otago has expertise to contribute to the Challenge in ice-ocean processes and modelling, glaciology, atmospheric processes and climate dynamics and paleoclimate studies. Researchers in departments such as Marine Science, Geography, Geology, Physics, Mathematics and Statistics, Chemistry, Science Communication and the School of Surveying, are linked through the well-established University of Otago Polar Environments Research Theme. There is interdisciplinary capability in impacts and implications work, including climate change impacts (e.g., in CSAFE), and strongly embedded Māori engagement experience and processes.
- *Victoria University of Wellington* - Victoria University of Wellington has internationally significant research capability in climate modelling, climate dynamics and meteorology, climate adaptation, climate policy (domestic and international), environmental social science, glaciology and cryosphere science through the New Zealand Climate Change Research Institute, the School of Geography, Environment and Earth Sciences, the Institute for Governance and Policy Studies, the Antarctic Research Centre and through individuals in the Faculties of Humanities, Science and Law.

5.7 Research team and skills

Composition of research team

The Challenge Parties, supplemented with specialist skills from other research providers and/or via collaborations (especially Bodeker Scientific, University of Auckland, Callaghan Innovation), have formed teams of expertise that will be able to address the needs of the *Deep South* Challenge as they evolve. These teams have been formed using a ‘best team’ approach, whereby individuals with the skills required to meet the Challenge research and related activity priorities, regardless of institution,

have been chosen. These individuals are nationally recognised, and many internationally, for their skills, knowledge and achievements (as detailed in the appended CVs). Key areas of expertise/individuals that will lead Challenge projects and provide science leadership within the Challenge include:

- Vision Mātauranga – all parties to the Challenge have staff able to engage and manage relationships with Māori. Many are also currently undertaking research jointly with iwi/hapū and Māori business, building Māori research capability, providing information, data and knowledge for Māori, and developing tools/decision systems for Māori to aid Kaitiakitanga (King).
- Science communication – the Parties to this Challenge, and a number of their collaborators, employ teams of specialist marketing and communication personnel. These teams are able to cover different media types (publications, film, web etc.), journalism and education. They will operate within the engagement framework as outlined in previous sections (Salmon).
- Numerical modelling – a highly skilled but small team of numerical climate modellers, with ability to use high performance computers, currently exists in Aotearoa/New Zealand. The *Deep South* will build and expand this team and capability. Significant expertise also exists in climate impacts modelling as well as in modelling specific components of the climate system such as glaciers, land processes, oceans and atmosphere (Bodeker, Dean, Morgenstern, Renwick).
- Observations – an expert team of scientists experienced in making world-class observations and process studies in one of the most challenging regions of the planet to work in (Bowen, Kohout, Langhorne, Lorrey, McDonald, Rack, Rickard, Stevens, Vandergoes, Williams, Wilson).
- Science and Policy – significant expertise and experience in policy development, both in central and local government, exists among the parties to the Challenge (Frame).
- Sector engagement – networks and active collaborative research already exists with key sectors (e.g., fisheries, aquaculture, pastoral, horticultural, cropping, energy, regional government, central government, tourism, infrastructure, irrigation etc.) (Rutledge, Tait)
- Societal engagement – while the parties have expertise in societal engagement and social science, embedding public engagement within research (e.g., citizen science) is a relatively new process in Aotearoa/New Zealand. The Challenge provides an opportunity to further develop and find capability to advance and research areas such as community translation of science (e.g., quantifying and communicating risk and uncertainty) and implementation and evaluation of participatory engagement processes (Various).

Skills development

Building science capability and skills within communities, Māori, central and local government, industry and science providers will be an important outcome of the *Deep South* Challenge. This will be achieved through joint research projects, alignment of university graduate training with Challenge activities and projects, support for post-doctoral fellows (especially through the contestable funding mechanism, see Business Plan) and outreach activities and mechanisms as they develop. This will be strongly linked with the Engagement Programme planned for the Challenge. While the Challenge will aim to use and support existing expertise, there are some areas of science where New Zealand capacity is small and will need to be developed. Areas of specific skill development and initiatives will include:

- Building capacity and expanding expertise in climate modelling and paleoclimate modelling, with specific focus on Earth System Model programming and technical implementation and support, and inclusion of post-graduates within Challenge projects.
- Bringing Challenge participants, and teams associated with aligned or related research Programmes, together in multi-organisational/disciplinary teams to broaden existing expertise and increase understanding of the climate system and its likely future impacts on Aotearoa/New Zealand.

- Increasing science capability in technology transfer, science communication and outreach through increased inclusion and participation by researchers in joint stakeholder interactions and initiatives.
- Increasing community knowledge and skills in climate science by bringing together national capacity to enhance current minimal formal training in physical climate science, modelling and impacts within tertiary undergraduate education Programmes.
- Training of and exposure to te reo and Māori of those participating in the Challenge to ensure that the Challenge responds to and gains appreciation of the needs of Māori.
- Rotating members of the Science Leadership Team to provide new and emerging researchers science leadership opportunities and development.
- Annual Stakeholder and/or sector targeted workshops and hui for Māori to increase community, industry and central and local government knowledge of climate science. Implementing specific engagement activities across the Challenge, such as citizen science projects, will also aid this aspect of skill development.

Infrastructure

The parties to the *Deep South* have ready access to the key infrastructure needed to undertake the research anticipated in the Challenge. This includes:

- high performance computing via the NIWA IBM P6/7 supercomputer (3000 processors) for modelling (opportunity exists to secure computational resources to support access through the National E-Science Infrastructure, NeSI);
- research vessels - RV *Tangaroa*, NIWA's deep-water ice strengthened vessel; vessel time will be supported through NIWA/MBIE co-funding, and Antarctica NZ has agreed to help support an Antarctic voyage; *Polaris* – University of Otago research vessel capable of Subantarctic science;
- Antarctic logistics and support – Antarctica NZ will support science that aligns with its science directions and priorities;
- climate and atmospheric records and data bases (NIWA, GNS Science), remote sensing facilities and data sets (Landcare Research, NIWA, University of Canterbury), specialist laboratories, ice drilling and storage equipment (Victoria University, GNS Science, NIWA).

Should a need for specific equipment be required, the parties will negotiate a mechanism for its acquisition. The Collaboration Agreement between the Parties to the Challenge includes principles for access to infrastructure and avoidance of duplication.

Collaboration

The proposed integration of existing and proposed programmes of research and related activities through the *Deep South* Challenge will provide a key mechanism for collaboration, not only within the science community but also with Māori, Stakeholders and communities. The proposed Programmes will be multi-disciplinary and all are multi-organisational (see previous sections). The significant collaboration between the Parties to the Challenge has enabled establishment of the Challenge and development of the Research and Business Plans detailed within this proposal. Future collaboration will be guided through the Collaboration Agreement and the proposed governance and management structure.

5.8 End users

The *Deep South* Challenge represents an enormous opportunity to engage with New Zealanders to ensure that they acknowledge, respond to and adapt to a changing climate. Acknowledgement of the impacts of a changing climate across Aotearoa/New Zealand society is still mixed and patchy, and it is our intent that the Challenge uses science as a vehicle for addressing this fundamental national issue.

To accomplish this will require a collaborative approach across all elements (governance, management, research and other activities) of the Challenge with Māori, industry, local and central government and communities. This approach will:

- ensure that non-science participants do not feel isolated by their inclusion in ‘advisory groups’ rather than collaborating in decision making and the research, a desire expressed by many of the organisations we have approached (especially within government);
- assist with the translation, transfer and uptake of research generated by the Challenge;
- provide opportunities for climate sensitive sectors, Māori and communities to engage with one another, and transfer learnings and best practice associated with response to the impacts of a changing climate;
- afford and encourage potential for co-funding to complement and build on the resources of the Challenge;
- ensure that the Challenge acknowledges and responds to sector, Māori and government strategies and priorities relevant to the impacts of a changing climate on Aotearoa/New Zealand.

The engagement with Aotearoa/New Zealand society will be a key Programme of the *Deep South*, building on already well established relationships and networks of the parties. Engagement activities and mechanisms have been described in the earlier section.

5.9 Research portfolio, prioritisation and quality

Portfolio

The Challenge approach to integrate existing and new research across multiple organisations, disciplines and society is both exciting and high risk. Some of the research Programmes (e.g., Earth System Modelling) will require capability building, significantly stretching existing New Zealand research expertise. Given the relatively low levels of resource, to develop this new capability will require such Programmes to be innovative and resourceful. The projects proposed for the first five years of the Challenge demonstrate that it is providing opportunities for new innovative research. The research portfolio associated with *Deep South* is illustrated through Figures 2 and 3.

Prioritisation

The research priorities outlined in the above Challenge Programmes have been established with input from stakeholders and Māori. Detail of the criteria used to establish these priorities is outlined under Sections 4.1 and 4.2. We propose to base future priority setting on similar criteria, and this process will inform the basis of strategic investment decisions.

In summary, these will be based on benefit and feasibility criteria, followed by an analysis of key balance factors, relevant to the Challenge Mission. Relevance criteria will include: consistent with the scope and contribution to the Deep South Mission; advancing Earth System Model capability; improving predictability of New Zealand’s future climate; processes and observations from the Southern Ocean/Antarctica likely as key drivers of climate; the extent of new knowledge and/or technology generation, how enduring the benefit will be; and the timeframe to achieving benefit against required investment. Feasibility criteria will include: barriers to adoption and capability for uptake by stakeholder communities; credible pathways for adoption, research stretch, best team approach and track record; resources required; international connections; and level of existing support. Additional balance factors also considered will include: linkages and dependency with other projects/Programmes within the Challenge; co-funding levels; responsiveness to Vision Mātauranga and potential to benefit Māori; science excellence, especially novelty and impact; international reputation through science diplomacy; and skill development, especially stakeholder capability building.

Reprioritisation

The Challenge will build on the learnings of the Parties with processes for prioritising their research, and institute a reprioritisation process for research in the Challenge. This acknowledges that there needs to be the *capacity* to change the balance of projects in order to deliver the Challenge Mission. The Governance Board will direct the reprioritisation processes. Large changes are not expected unless the context changes significantly or more rapid than expected advancements are made.

Each year, the Director/Science Leadership Team will evaluate the performance of projects in the Challenge based on three criteria—the completion of milestones, progress toward the outcomes, and proposed plan of action for the year to come. Part of this process will be input from collaborative workshops between the researchers and stakeholders. The Science Leadership Team will also consider the status of external strategies and Government policies and how they may impact on the Challenge. Where change is needed, we will weigh up the gains to be made in continuing work in one area, against redirecting resources into another. The Governance Board will make a decision on any actions required (e.g., divert more resources into higher priority or new areas, stop/start a new area etc.). The Science Leadership Team will take responsibility for implementing any reprioritisation. Where decisions affect providers (e.g., their use of Core Funding), then the Challenge will discuss options with the affected provider parties in order to drive change in the Challenge.

Science Quality

The need for high-quality science is an important consideration of all providers. We will regularly review science quality by drawing on three fields of expertise—international, end-user and internal—to review from the perspectives of end-use and science. The Challenge will adapt existing systems to meet the needs of the Challenge. Internal review processes will still occur, the Governance Group will ensure that key end-users or stakeholders are involved more directly in science reviews, and the Independent Science Panel will help ensure that the science is innovative and meets international best practice (see *Business Plan* section). We envisage that review activities will occur annually, and will be one of two types. First, independent science reviews (e.g., utilising expertise external to the Challenge) will evaluate science quality within the Challenge, and reports will be provided to the Challenge Governance Board. Second, independent end-user reviews will be undertaken as and when required by the Governance Board to ensure that the Challenge is making progress towards its Mission. The main responsibility to organise and participate in these reviews will be with the Director and Science Leadership Team, while the Governance Board will provide oversight of the review process, and provide direction on actions to be taken as a result of reviews.

Dynamism

To ensure that the research within the Challenge is regularly refreshed with new approaches and ideas, skills and expertise, the Challenge will allocate approximately \$935K per annum to a contestable funding pool to support Innovation Seed Projects. These projects must introduce new approaches, capability, research and/or researchers into the Challenge, and will be funded for a maximum term of two years, and generally no more than \$150k per year. Proposals will be sought every two years through open contest and be based on issue of a Request for Proposals focussed on the Programme priorities of the *Deep South*. The Director and Science Leadership Team will be responsible for setting the Request for Proposals, developing the assessment criteria, running the process and assessing proposals. Funding recommendations for Innovation Seed Projects will be submitted by the Director to the Governance Board for final approval.

5.10 Monitoring of performance, evaluation of impact

The participatory emphasis of the *Deep South* Challenge, coupled with its focus on a complex global sustainability issue, requires new performance monitoring and evaluation processes. We will implement an impact-capturing framework, recognising that this is a new direction for research evaluation, operational evaluation frameworks are lacking⁷. And there is little guidance for the evaluation of large research initiatives. We will utilise a Challenge-specific framework that builds on the latest evaluation research and is linked with MBIE-developed indicators. It is expected that evaluation processes will need to be refined, particularly in Year 1 of the Challenge, as we determine the framework and processes that are most appropriate, and as MBIE further develops Challenge-wide processes.

The evaluation framework and indicators

We propose an evaluation framework that has four elements—assessment of: (i) the Challenge as an entity, (ii) the research as a scientific endeavour, (iii) relationships with all stakeholders and (iv) impact. Each element of the framework has associated indicators that allow monitoring on progress in important aspects of the Challenge.

1. Challenge entity assessment

Desired effects	Category	Example indicators
The Challenge is effectively managed and has appropriate processes in place to manage the initiative. <u>Assumption:</u> Internal management and governance processes that are fit-for-purpose and efficient will enhance the likelihood that the Mission will be delivered in a timely, effective manner.	Governance (effectiveness of governance processes)	<ul style="list-style-type: none">• Cost vs budget of governance activities• Decisions made and implemented
	Operational functions (appropriate financial and project management)	<ul style="list-style-type: none">• Annual budget met• Delivery of milestones (timeliness)• Efficiency in processes (e.g., time to respond, low administration burden)
	Strategic (effectiveness of strategic planning and prioritisation processes)	<ul style="list-style-type: none">• Stakeholder involvement in prioritisation• Feedback processes operating• Identification and management of risk

2. The science endeavour

Desired effects	Category	Example indicators
The Challenge has world-leading science that is dynamic and responsive to disciplinary advancements,	Professional validation (science quality, impact on advancement of science)	<ul style="list-style-type: none">• International recognition (awards, keynote invitations, editorial boards)• Bibliometric (citation) measures• Science Panel assessments

⁷ Wiek, A., Talwar, S., O'Shea, M., and Robinson, J. (2014). Toward a methodological scheme for capturing societal effects of participatory sustainability research, *Research Evaluation* 23, 117–132. doi:10.1093/reseval/ rvt031.

<p>and produces high-quality knowledge and products.</p> <p><u>Assumption:</u> High-quality science that is delivered in a timely manner is a necessary prerequisite to delivery of fit-for-purpose information to stakeholders, and subsequent uptake and application.</p>		<ul style="list-style-type: none"> • Peer-review metrics (assessor comments, submission to acceptance timeframe)
	<p>Dynamism and capacity (science is dynamic and delivered by high-quality “best” teams)</p>	<ul style="list-style-type: none"> • Incorporation of new ideas and approaches (portfolio analysis) • Flow of researchers (new staff, experience profile of teams) • Collaborative projects (number, proportion of Challenge) • International collaborations
	<p>Useable products (knowledge is produced and codified in such a way that it is used in science fields and is fit-for purpose for stakeholders)</p>	<ul style="list-style-type: none"> • Produced products, processes, services • Guidelines, manuals, handbooks • innovative technologies • Data and models used by the international science community

3. Relationships - productive interactions

Desired effects	Category	Example indicators
<p>“Exchanges between researchers and stakeholders in which knowledge is produced and valued that is both scientifically robust and socially relevant” (p. 212)⁸</p> <p><u>Assumption:</u> Productive interactions will lead stakeholders to use or otherwise apply the results of the research.</p>	<p>Direct (person-to-person interactions, which may be mediated by technology).</p>	<ul style="list-style-type: none"> • Membership in advisory/expert panels (type, scale, frequency of meeting) • Presentations (type, audience) • Media releases (media, audience, measures of interest, follow-up requests) • Nature and scale of community involvement in Challenge • Collaborative projects with stakeholders (number, diversity, scale)
	<p>Indirect (exchanges based on an independent carrier of information, such as texts, models, publications)</p>	<ul style="list-style-type: none"> • Publications (by category, rates per FTE) • Products and services (type, community of interest) • Web information services (pages, views)
	<p>Financial interactions (e.g., co-funding)</p>	<ul style="list-style-type: none"> • External contracts (number) • Co-funding (origin, amount) • In-kind support (origin, amount)

4. Impact- behavioural and functional change

⁸ Spaapen, J., & van Drooge, L. (2011). Introducing ‘productive interactions’ in social impact assessment, *Research Evaluation*, 20(3), 211–218. doi: 10.3152/059820211X12941371876742.

Desired effects	Category	Example indicators
<p>Persistent change in what the stakeholders are doing and how they are doing it, whereby this change is attributable to the research programme (freely adapted from⁹).</p> <p><u>Assumption:</u> The successful implementation of research to achieve outcomes requires behavioural changes among both researchers and end-users.</p>	Uptake (indications of uptake and assimilation of information)	<ul style="list-style-type: none"> • Novel tools to measure uptake (e.g., contextual response analysis) • Follow-up queries based on information (research results) provided • Joint publications with stakeholders (number, range of stakeholders) • Changes in language used by stakeholder community (e.g., quotes from research publications, word analyses)
	Capacity and network effects (increased information exchange, joint learning, skill development, stakeholder network development)	<ul style="list-style-type: none"> • Changes in stakeholder networks (e.g., creating alliances) • Boundary-crossing collaboration • Changes in Māori capability/capacity • Implementation of training programmes • Social network analysis (matrix definition)
	Use/implementation (actual application and use of developed products, processes or services)	<ul style="list-style-type: none"> • Developed products in use • Implemented guidelines/processes • Changed stakeholder processes • New stakeholder action plans • Changed business models or processes • New institutional frameworks

Measurement of behavioural/functional change requires stakeholder input (e.g., directed, tailored surveys). In some cases the information will be generated by the research team and reviewed by stakeholders for its validity and for the stakeholder perspective.

In addition to the indicator data, narrative-based descriptions of examples of outcomes and impact from the Challenge will be developed every year, and an evidence portfolio of impact will be built. Periodic formal evaluations of the Challenge as a whole will be linked with MBIE evaluation plans.

The framework will be implemented early so that progress can be measured and used at a formative stage to influence the directions of the Challenge activities and enhance the likelihood of delivery of the Challenge Mission and Objective. The intention is that it sharpens the focus of the research teams on interactions with stakeholders and the impact of the research, and enables them to be more aware of the value of their research. Similarly, significant stakeholders (e.g., policy agencies) will become

⁹ Gök, A. & Edler, J. (2012). The use of behavioural additionality evaluation in innovation policy making, *Research Evaluation* 21, 306–318. doi:10.1093/reseval/rvs015.

more aware of the functional linkages with the research and how it is influencing their decisions. Another advantage is that the framework enables the generation of data on significant stakeholders of importance (e.g., Māori) while still applying a consistent framework across the Challenge.

Reporting on the framework

The framework is designed to be flexible and enable reporting to all key parties—the Governance Board, the Independent Science Panel, stakeholders, Challenge members and MBIE—on the overall performance of the Challenge and progress toward the Mission and overall outcomes. The framework is drawn from the Challenge Mission, and is aligned with the MBIE Common Indicators set that is currently under development, as outlined in Table 3, to ensure the Challenge will meet MBIE reporting requirements. The following table also lists potential KPIs, which will be finalised in consultation with MBIE as they finalise their performance framework for the National Science Challenges.

Table 3. Common Challenge indicators.

Indicative Challenge Mission KPIs	Challenge evaluation framework components	MBIE Common Indicators
(Overarching component—do we have the right processes in place to work effectively to deliver the Mission?)	Entity assessment	1.1, 2.1–2
<ul style="list-style-type: none"> • Improve predictions of future climate • Acquire new observations and process information • Build science capability 	Science quality	3.1–4, 5.2
<ul style="list-style-type: none"> • Develop targeted collaboration between scientists and practitioners • Identify climate sensitivities, risks and opportunities of stakeholders 	Productive interactions	1.3, 4.1–2, 5.1, 6.1–2
<ul style="list-style-type: none"> • Incorporate new science into planning and management of climate risks • Enhance national status and contribution to international agreements 	Behavioural and functional change	1,2, 4.1, 5.4–5

5.11 Impact

Benefits and Costs

Climate impacts already known to be important for different sectors of society, through existing work and consultation with Māori, local and central government, a range of industry sectors and confirmed at the Strategic Research Plan Workshop on 27 November 2014, will guide the priorities of the Challenge and how they will benefit New Zealand. Many of these impacts are expected to increase under a changing climate, the social, economic and environmental costs will be significant if New Zealand does not plan for and adapt to these impacts. Key impacts include, but are not limited to:

- *Drought.* Extremes of climate such as increasing drought are a concern for many. The New Zealand Treasury estimates reduced agricultural production attributed to the 2013 summer drought cost the national economy at least NZ\$1.5 billion. It is known that summer droughts are strongly related to anomalous wind flow patterns (e.g., more westerly flow than normal can lead to drought in eastern areas), which are likely to change in the future, and known to be caused by increases in atmospheric greenhouse gases and changes in ozone concentrations. These drivers are also strongly influenced by changes to the ocean and atmosphere in Antarctica and Southern Ocean. Droughts are of particular concern for the primary production sector, and especially

Māori, given that a significant proportion of their assets and business is associated with the pastoral sector.

- *Flooding due to coastal inundation.* For the near future the impact of sea level rise will be felt most keenly through storm surge events and associated coastal inundation. Storm surge occurs when low atmospheric pressure combines with waves driven by strong winds and underlying long term sea level rise. Changes in all of these drivers have direct connections to aspects of change in the Antarctic and Southern Ocean. Significant infrastructure and many Māori communities are at risk from such events.
- *Damaging storm events.* Damaging storms events can bring heavy rainfall and/or destructive winds, freezing temperature, and extreme snowfall. Recent years have seen a number of devastating floods resulting from heavy rainfall in areas such as the Manawatū and Golden Bay. Increased moisture in the atmosphere is one of the most pronounced responses to increased warming and it has recently been demonstrated that Aotearoa/New Zealand's extreme rainfall events have already been influenced by human induced atmospheric warming. Critical to future changes in precipitation are the ways in which atmospheric and ocean temperatures around Aotearoa/New Zealand will respond to further global change. The severity of damaging wind events is also sensitive to a changing climate.
- *Freshwater availability.* Water lies at the heart of Aotearoa/New Zealand's economy and is essential to New Zealander's current lifestyle. It is especially important for the primary production and energy sectors, and our waterways are of paramount importance Māori. Our water resource is primarily controlled by long term rainfall, snow and glacial reservoirs. For the north of the country subtropical lows are an important rainfall source. For the majority of the country, and especially the South Island, it is the persistent and seasonal variability of the storm track that is important. The location of the storm track is predicted to change under increasing concentrations of greenhouse gases and stratospheric ozone with significant consequences for our precipitation.
- *Changes to mean climate and variability.* The impacts of changes to mean climate are less clear cut because of adaptive capability in natural and human systems. One of the most impacted sectors will be primary productivity, via changes to the seasonality of crops and growing potential. Additional readily identifiable impacts include coastal erosion, changes in natural ecosystems, and new threats to human health and biosecurity.

There have been few studies of the expected costs of a changing climate on New Zealand. The *Stern Review on the Economics of Climate Change*, a 700-page report released for the British government in 2006, however, does make some general global estimates of the costs associated with climate change. This report concludes that should global climate continue to change, and this is expected in the short-term, then the overall costs of climate change, especially impacts on water resources, food production, health, and the environment, will be equivalent to losing at least 5% of global gross domestic product (GDP) each year, now and forever. Including a wider range of risks and impacts could increase this to 20% of GDP or more, also indefinitely. For New Zealand a loss of 5% of GDP per year would be in the order of \$11.7B per year. The investment into the *Deep South* (\$24M) represents 0.002% of this loss. On this basis, we expect adaptation strategies informed by the *Deep South* research would provide savings significantly greater than the Challenge investment.

Pathway to impact

Working closely with key stakeholders we will identify important climate sensitivities, and propose four primary pathways to impact: working with existing agencies and institutions; utilising the CCII network; direct interactions and activities with decision makers; and connecting with other National Science Challenges. Each of these pathways is described below.

Stakeholders

Improved simulation of New Zealand's climate will have benefits to a range of stakeholders, including those who perform regional climate simulations for a range of private and public clients and stakeholders. As the Earth System Model develops, we will work closely with *regional impacts modellers* to improve the inputs to their regional models; since they already have the networks in place to work with stakeholders, the *Deep South* contribution will be upstream in the information chain, and hence largely invisible from a users' perspective. We think this can be done at very low cost, but can be of potentially large benefit, since it would improve information inputs to all users of regional climate information in New Zealand.

We also aim to work closely with those institutions that deal with the social and economic consequences of natural hazards, such as the *Disaster Research* community. As with the regional impacts modellers, the *Deep South* will aim to use its findings to improve the understanding of climate change that disaster and emergency response planners utilise when they prepare for floods, coastal inundation and other hazards which may be exacerbated or ameliorated by climate change.

CCII Network

We aim to leverage from, and continue to develop, the stakeholder networks and communities of practice built by the CCII programme. In particular, work exploring social consequences of, and responses to, climate change will form a valuable part of how stakeholders are informed about better understanding and improved predictions of the climate system. Decision-makers need to be capable of thinking about future climate change, no matter how uncertain it might be. This capability or understanding linkages, feedbacks and hierarchies across and within different systems. For example, local water availability and drought impact depend critically on international demand for our agricultural products, which is in turn influenced by global population growth and affluence, agricultural productivity and the international impacts of climate change.

The *Deep South* Challenge will extend and expand this initial work on futures literacy. We will continue to work with key stakeholders to further explore the use and applicability of scenarios and futures literacy for impact assessment and decision-making. A long-term key aim will be the development of more coordinated and programmatic approaches for formulating and applying globally-linked, New Zealand relevant, scenarios to a range of decision-making processes. The approaches and scenarios currently under development will serve as the initial framework, and we anticipate undertaking at least one more round of scenario development during the *Deep South* Challenge, coordinated with the likely (but not guaranteed) next round of global scenario development undertaken as part of a possible IPCC 6th assessment.

Decision makers

We propose to build a small number of new, targeted relationships that can make use of new and innovative products emerging from the NZESM. New information on the return periods of extreme weather events could, for instance, be used in sensitivity studies with New Zealand's fiscal models to better understand how we might expect the changing odds of climate events to improve or worsen fiscal conditions. Work with infrastructure specialists regarding New Zealand's *Lifelines* could provide similar insights for the teams tasked with keeping New Zealand functioning in the event of disruption to key infrastructure. Also, more closely working with city councils to better utilise the tools in the Urban Impacts Toolbox, together with new ESM output and a deeper understanding of scenarios of potential futures, will significantly improve the mainstreaming of climate change into long-term city planning and policy development.

National Science Challenges

Finally, we aim to work closely with the other National Science Challenges – especially (but not exclusively) those in the environmental sphere: *Resilience to Nature's Challenges*; *Our Land and Water*; *New Zealand's Biological Heritage*; and *Sustainable Seas*. We see these relationships as being conducted at a range of levels, from scientific collaboration right through to joint presentations on the public policy dimensions of climate risks (such as sea level rise).

Risks

We are very confident that we can improve model simulation of the southern half of the Southern Hemisphere, so we are very confident that the basic goals of the *Deep South* Challenge will be achieved. The *Deep South* team have extensive experience in working with stakeholders to deliver useful climate and climate change information to stakeholders, and we are confident we can do this efficiently and effectively. The main risks are:

- *reinventing the wheel* – we need to make sure we make good use of what we already know, and that where possible we use existing resources, people and institutions;
- providing information that is not usable – it is imperative that we keep all parts of the research, including the policy and social science dimensions, practical and focused on priorities and delivering benefits;
- *avoiding reversion to 'business as usual'* – the Challenges are a challenge to the science community to focus on creating suites of collaborative institutions to do things differently. We believe that keeping the Mission and the principles of Vision Mātauranga at the centre of the Challenge will help focus the research teams on the overall benefits of their projects to New Zealand.
- *trying to be all things to all people or spreading the resource too thinly* – we need some scale to ensure that progress is made on delivering the benefits of the *Deep South* to New Zealanders. Slicing the resource too thinly across multiple projects is inefficient, and frequently diminishes researchers' buy-in to projects. We will be mindful of this risk, especially as we manage the Impacts & Implications Programme, and prioritise accordingly.
- *making trade-offs in terms of stakeholder needs* - the best we can do is to make these as openly and transparently as possible, and we see this as a crucial element of the Engagement and Vision Mātauranga Programmes.

We believe that the commitment to using existing research links, information networks and communities of practice limits our vulnerability to reinventing the wheel, thereby minimising many of the above risks. We aim to work closely with NIWA's regional modelling group, the Joint Centre for Disaster Research (GNS Science/Massey University) and CCI's communities of practice, since these are obvious pathways along which improvements in our understanding of physical climate science can be used by large numbers of already engaged stakeholders. By working with networks which have already been established and which have considerable experience in working with the needs of climate-sensitive sectors, we are confident that we can focus resources on delivering information that meets the needs of key stakeholders.

5.12 Open data

The *Deep South* Challenge will be committed to the principles of open access to publicly funded research data and information. Subject to ethical, privacy or cultural reasons, or issues of commercial sensitivity, publicly funded research data from the Challenge will be made open for public access and re-use. *Deep South* will do so in accordance with the *New Zealand Government Open Access Licensing framework* (NZGOAL) and the *New Zealand Data and Information Management Principles* (NZDIMP). Projects undertaken in the Challenge that generate data and/or information will be required to give effect to the application of open access principles, standardised data and metadata management, and data federation and interoperability techniques.

5.13 IP management

The management, ownership and commercialisation of Intellectual Property (IP) associated with the Challenge is defined within the Collaboration Agreement between the Parties. These encompass the following principles:

- All background IP belonging to any Party will remain vested in that Party.
- Ownership of Challenge IP will vest in the Party or Parties that creates the IP.
- Where a project involves Māori traditional knowledge, the appropriate Parties will obtain necessary approvals for its use from the relevant iwi or hapū.
- Protection and commercialisation of any Challenge IP will be the responsibility of the Party owner(s).
- Owners of Challenge IP, and background IP where appropriate, will provide a non-exclusive royalty free licence to use of the IP for the purposes of meeting the delivery of the Challenge Objective and Mission.
- All Parties will promote the sharing of information generated by the Challenge and participate in joint initiatives to publish, present and disseminate research results.

6. Business Plan

6.1 Governance arrangements

Host organisation

In response to the MBIE Science Board feedback and the need to change the science focus and hosting of the *Deep South*, the parties have agreed that NIWA undertake the role of host. NIWA is currently engaged in a number of multidisciplinary collaborative research initiatives (e.g., New Zealand Hazards Platform, University of Auckland/NIWA Joint Graduate School in Marine Science, and the proposed Sir Peter Blake Institute for Ocean Sciences), experienced in managing multi-million dollar projects, and therefore has the capability, capacity and resources to host the Challenge. NIWA has also agreed to host the Sustainable Seas Challenge (funding approved for establishment and first five years of operation) and this provides opportunity to ensure connectivity between these related and complimentary Challenges (see below).

Revised governance and management structure

The parties have revised the governance and management structure (Figure 5) for the *Deep South*, along with proposed membership. A key element of this structure is the inclusion of stakeholders and Māori at all levels.

Key elements of the governance and management arrangements are detailed below.

Host Board: NIWA has now signed a National Science Challenge Investment Contract with MBIE, along with a Challenge Programme Agreement for the initial establishment of the *Deep South*, thereby accepting contractual responsibility for the *Deep South* on behalf of the Challenge Parties. The NIWA Board will take responsibility for oversight of the *Deep South* Governance Board, on behalf of all the Parties.

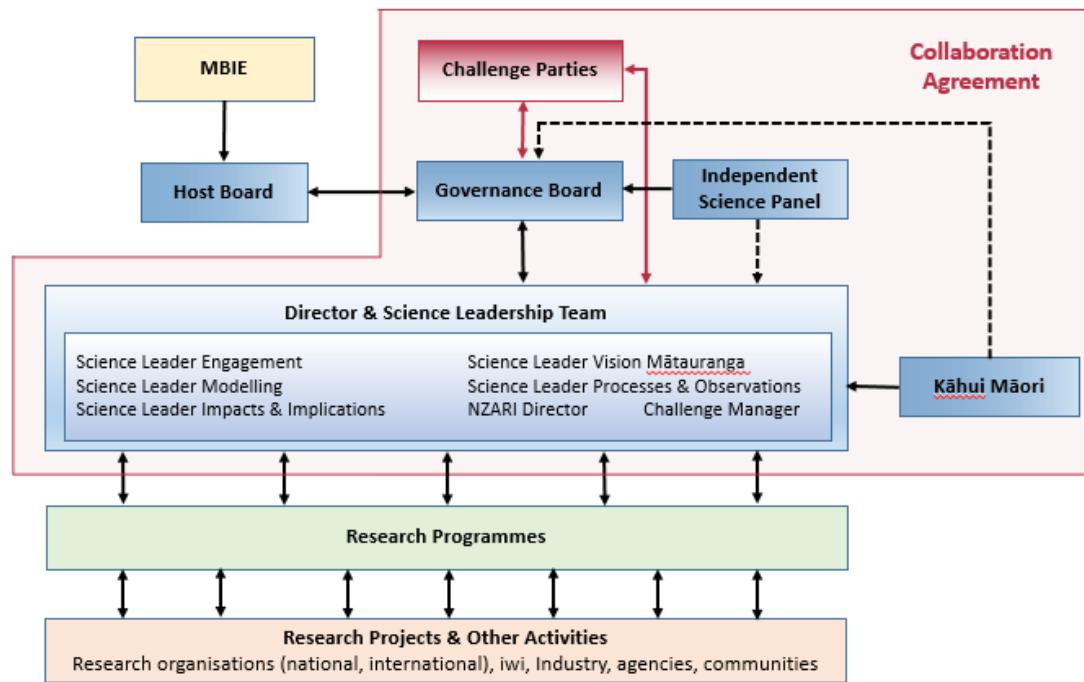


Figure 5. Proposed governance and management structure for the *Deep South*.

Challenge Parties: Antarctica New Zealand, GNS Science, Landcare Research, the New Zealand Antarctic Research Institute, University of Otago and Victoria University of Wellington have agreed to form a collaboration and provide resources to achieve the Mission of the *Deep South*. The Parties formed an interim Board (senior managers from each of the Parties), Director and Science Leadership Team (Table 4) to advance establishment of the Challenge and development of the Research and Business Plans.

Table 4. Interim *Deep South* Challenge Director and Science Leadership Team.

Role	Name	Organisation/Expertise
Director	Dr Rob Murdoch	NIWA, GM Research
Challenge Manager	Richard Nottage	NIWA, New Zealand Climate Change Centre Manager
Science Leader Engagement	Dr Rhian Salmon	Victoria University of Wellington, science education and public outreach
	Prof Dave Frame	Victoria University of Wellington; climate modelling, policy, engagement
Science Leader Vision Mātauranga	Darren Ngaru King	NIWA, climate science, Māori engagement
Science Leader Impacts	Dr Daniel Rutledge	Landcare Research, climate impacts and modelling
	Dr Andrew Tait	NIWA, climate impacts and modelling, end-user networks
Science Leader Modelling	Dr Sam Dean	NIWA, regional climate modelling, global climate modelling, sea-ice dynamics
Science Leader Processes & Observations	Dr Pat Langhorne	University of Otago, sea ice, Antarctic climate
	Dr Marcus Vandergoes	GNS Science, paleoclimate observations
	Dr Mike Williams	NIWA, physical oceanography, ice-ocean interaction
NZARI Director	Prof Gary Wilson	University of Otago, Antarctic science, paleoclimate

Collaboration Agreement: A 'Collaboration Agreement for the Co-funding Parties to the *Deep South* National Science Challenge' has been drafted and is currently being negotiated by the Parties (see attached). This agreement sets out the terms under which the Parties shall establish and operate the Challenge and comply with the National Science Challenge Investment Contract. The agreement includes:

- Mission, objectives, domain and scope definitions for the *Deep South*;
- roles and responsibilities of the Parties, Host, Governance Board (including a Terms of Reference), Director and Science Leadership Team, and guiding principles for the operation of the Challenge;
- financial management, funding definitions, allocation processes and subcontracting arrangements;
- Intellectual Property policies and principles, communication principles, a dispute resolution process, and a conflicts of interest policy and process for the *Deep South*;
- provisions for changes to the Challenge membership, reviews, and termination.

Governance Board: The Parties have established an independent Chair (approved by MBIE) and Governance Board for the *Deep South*. The Governance Board will report to the NIWA Board and will operate under the principles and Terms of Reference outlined in the Collaboration Agreement. Members of the Board include:

- **Roger France** (Chair) – professional company director (Chief Financial Officer for Allied Farmers Co-operative Ltd and Freightway Holdings Ltd; was a member of the Management Board of Pricewaterhouse Cooper; currently a director of Air New Zealand, Fisher & Paykel Healthcare Corporation and Orion Health Group; former director for the Fonterra Co-operative Group; appointed to the Council of the University of Auckland in 2001, Chancellor from 2009-2012).
- **Rob Fenwick** – businessman and company director aligned to sustainable development (current Chair Antarctica New Zealand and New Zealand Antarctic Research Institute, and director of NEXT Foundation and Sir Peter Blake Trust; formerly deputy Chair TVNZ, Chair of St Johns Ambulance and Landcare Research; co-founder of Living Earth Ltd).
- **Bruce Mapstone** – significant management experience and knowledge of climate and marine science (former Chief CSIRO Marine and Atmospheric Research, Chief Executive of the Antarctic Climate and Ecosystems Cooperative Research Centre, Chief Executive for the Centre for Australian Weather and Climate Research).
- **Rebecca Mills** – well-regarded sustainability strategist (strategist for central/local government on sustainability, energy, climate change, water and waste strategy and policy, public/private partnerships and governance; led plans for energy developments with Contact Energy, Mighty River Power, Belvedere waste to energy plant (London), Tripcock Point Masterplan (London), Thames Gateway Bridge (London), Tairua Marina and Wairakei Geothermal Power Station; one of two UK representatives on ESPACE (European Spatial Planning Adapting to Climate Events) project team to shape planning for climate change adaptation at a global level.
- **John Morgan** – Chief Executive of NIWA, *Deep South* host organisation.
- **James Palmer** – expertise in government policy and planning, and economics (Deputy Secretary Strategy, Ministry for the Environment, responsible for strategy development across the natural resources sector, including climate change and ocean management; former Director Strategy, Systems and Science Policy at the Ministry for Primary Industries and Director Strategy at the former Ministry of Agriculture and Forestry; former Chief of Staff to the Minister of Agriculture, Forestry, and Fisheries, and Senior Private Secretary to the Deputy Prime Minister).
- **Sir Mark Soloman** – professional director and Māori tribal leader of Ngāi Tahu and Ngāti Kuri decent (Kaiwhakahaere (Chair) of Te Rūnanga o Ngāi Tahu; director of Te Ohu Kaimoana (Māori

Fisheries Trust), Chair of the New Zealand China Council; former director Museum of New Zealand Te Papa Tongarewa).

- **Chris Kelly** – expertise in management and the primary production sector (former Chief Executive of Landcorp Farming Limited; current director of the Crown Irrigation Investment Company, Pengxin NZ Farm Management Limited and FarmIQ; Chair of AgriOne (a joint venture between Lincoln and Massey Universities) and Kahne Animal Health).
- **Tania Simpson** – professional director, expertise in social policy, environment, economic development and Treaty-related matters, and is of Tainui, Ngāi Tahu and Nga Puhi descent (Member of the Waitangi Tribunal, a director of Oceania Group, Mighty River Power, AgResearch, the Reserve Bank of New Zealand; a Trustee of Te Reo Irirangi o Maniapoto Trust, Kōwhai Trust and Tui Trust).

Given that NIWA will also be hosting the *Sustainable Seas* Challenge, and the strong linkage between *Sustainable Seas* and the *Deep South* (ocean drivers of climate; impacts of climate on ocean resources; common interests of Māori, communities, planners, regulators and industry), it is proposed that the first seven members listed above be common to the Governance Board of both Challenges.

Kāhui Māori: This panel has been formed to provide independent advice and council on the responsiveness of the Challenge to Vision Mātauranga, and assist with Māori engagement. The Kāhui Māori will specifically provide guidance to the Director and Science Leadership Team, although may also provide input into the Governance Board if required. See section 3.2 (Programme 2: Vision Mātauranga) for a list of the proposed Kāhui Māori members.

Independent Science Panel: This panel has been formed primarily to provide the Board with independent science advice and input into the science strategy and priorities of the *Deep South*, and help with assessments of science quality and performance. The panel will also be available to the Science Leadership Team for independent advice and review. Members of the Panel, along with their expertise and affiliations, are provided in Table 5, and the composition of the Panel covers the breadth of science covered by the Challenge.

Director: The Director will report to the *Deep South* Governance Board, and will oversee the management of the Challenge. The Director is responsible for the development and implementation of the Research Plan in accordance with the National Science Challenge Investment Contract and the Collaborative Agreement between the Parties to the Challenge. The Science Leadership Team will support, and be Chaired by, the Director. It will be the responsibility of the Director, through this support, to provide recommendations to the Governance Board associated with research priorities and strategy, annual budgets and the allocation of Challenge funds, alignment of external resources, and membership of the Science Leadership Team. The Director will also oversee all reporting and contract requirements, subcontracting, peer-review processes, performance management of the Challenge Manager, and promote stakeholder relationships, outreach and incorporation of Vision Mātauranga within the *Deep South*. This position will be a fixed term (0.5 FTE after establishment phase) employee of NIWA, and performance will be based on the recently finalised Position Description. Two suitable applicants have been interviewed and appointment of the Director is expected by the end of December. The new Director will be expected to commence in the role in late January 2015.

Table 5. Independent Science Panel (provisional members).

Programme	Panel Member	Organisation	Expertise
Chair	<u>Dr David Wratt</u>	Vice Chair Working Group I, IPCC, Adjunct Professor NZ Climate Change Research Institute, Companion Royal Society New Zealand	Applied climatology and the science of climate change. Regional implications for climate impacts and adaptation.
Engagement	<u>Susanne Moser</u>	Director, Susanne Moser Research and Consulting	Interdisciplinary Research, Productive Science-Policy Interaction and Effective Communication for Social Change.
Vision Mātauranga	<u>Prof. Linda Tuhiwai Smith</u>	Pro-Vice Chancellor Māori, Waikato University	Māori development; kaupapa Māori research, research methodologies; research and indigenous peoples; operational strategy; iwi relationships.
ESMP	<u>Prof Bryan Lawrence</u>	University of Reading, Professor of Weather and Climate Computing	25 years atmospheric sciences and computational sciences. Helped establish the UK and European strategies for climate modelling and data handling.
PO	<u>Dr Nathan Bindoff</u>	Professor of Physical Oceanography and Climate Change and Ocean Processes program leader, University of Tasmania	Ocean climate and the earth's climate system, focus on understanding the causes of change in the oceans.
I & I	<u>Dr Francis Zwiers</u>	Director, Pacific Climate Impacts Consortium, University of Victoria, Canada	Application of statistical methods to the analysis of observed and simulated climate variability and change.

Science Leadership Team: This team will consist of the Science Leaders of each Challenge Programme, the NZARI Director and the Challenge Manager, and will support the Director. The Science Leadership Team will meet at least quarterly (with indirect costs covered by their member organisations) to review and plan Challenge activities, and will operate through a consensus process. Responsibilities of the team, together with the Director, will include:

- Ensuring the development and on-going review of the Challenge research strategy and activities.
- Development of the research priorities for any Request for Proposals (RfP) for the allocation of *Deep South* funds.
- Identification and coordination of hui, meetings and workshops and ensuring the participation of Māori, industry, local and central government and communities in the Challenge activities.
- Ensuring that the Challenge is giving effect to Vision Mātauranga.
- Allocation and monitoring of resources within the Challenge, including co-funding, consistent with the Challenge priorities. This will include resources provided by Parties to the Challenge.
- Ensuring that the Parties, and other science providers through appropriate sub-contracting, maintain and commit the appropriate capability, and have adequate project management systems in place to enable planning, monitoring and evaluation of science quality, relevant technology transfer, and IP and data management.

- Assessing Challenge performance, addressing any research delivery issues, and implementing science reviews as appropriate, including benchmarking performance of the different projects, and stopping or scaling down projects.
- Provision of any material required under the MBIE contract for reporting and reviews.
- Developing and implementing a transparent reprioritisation process in response to any change event that would affect the ability of the Challenge to meet its Objective and Mission. Such change events could include, but not be limited to, review results, capability loss, or significant changes in national strategy, Challenge funding levels, or logistical support for the research.
- Advising the Governance Board of any proposed changes to the parties to the Collaborative Agreement.
- Developing a strategy to guide dissemination and promotion of Challenge activities through appropriate Challenge level communication media and outreach, and community engagement within *Deep South*.

Challenge Manager: The Challenge Manager will provide operational and administrative support to the Director. This will include, but not be limited to, subcontracting, organisation of meetings and workshops and associated documentation, stakeholder management, contract management, budget and project management, reporting and reviews and maintenance of the *Deep South* website (see www.deepsouthchallenge.co.nz). Richard Nottage (see CV), has been appointed to this 0.5 – 0.8 position, and also provides connection to the New Zealand Climate Change Centre as its Project Manager.

Science Leaders: Science Leaders will be established for each of the *Deep South* Programmes, and chosen based on their knowledge and expertise, stakeholder networks, research track record, and ability to lead and manage large multi-disciplinary/multi-organisational projects. The responsibilities of the Science Leaders will be to:

- Provide input into the development of the Challenge research priorities and strategy, including Vision Mātauranga
- Lead and coordinate research projects in the spirit of the principles of the *Deep South* Collaboration Agreement, including development and coordination of proposals in response to Challenge RfPs, and collaboration with Māori and stakeholders
- Review and report quarterly to the Science Leadership Team on the publications, new products and services, collaborations, co-funding, key research achievements and progress towards the Challenge Objective and Mission
- Advise the Director of any issues associated with the delivery or performance of the Challenge research projects or related activities, including capability needs, that will affect the performance of the Challenge
- Interact with other Challenge Science Leaders to ensure research coordination across the Challenge, and minimise the creation of silos
- Prepare material required for MBIE reporting or reviews, and maintain science quality.

Expressions of interest for the Science Leader roles have been sought, and appointment of the permanent Science Leaders and establishment of the Science Leadership Team is planned for early February 2015.

Management arrangements

The Collaboration Agreement and sections above outline much of the management arrangements for the Challenge. Individual organisations with projects funded through the Challenge will be required to implement their own project management systems, and NIWA will use its project management system (Oracle) to manage subcontracts and activities of the multiple research providers involved, including reporting, timelines and performance monitoring. Systems for communication and coordination of

research teams, both within the Challenge and across the wider research community, will be developed over the coming months by the Director and Governance Board (e.g., the established website is currently a source of information and has a regular online newsletter for informing subscribers). Other aspects of communication and engagement are covered within the Engagement Programme.

6.2 Financial management

In general, the Parties will endeavour to maximise the amount of Challenge funds used to support the *Deep South* research projects and related activities. Principles that will guide financial management within the Challenge, however, will include:

- *Host*: NIWA as the Challenge host, will be responsible for, and cover, the costs of managing the National Science Challenge Investment contract with MBIE, and the administration and sub-contracting of Challenge funds. NIWA has well established financial and project management systems (Oracle based), to manage and monitor the Challenge funding envelope, that meet company audit standards. Based on these systems, it will provide reports on expenditure against budget to the Director, who shall report financial information no less than quarterly to the *Deep South* Board.
- *Minimizing administration/management costs*: the Parties to the Challenge already have in place governance, management and administration systems that can meet the needs of the Challenge, and they will be expected to provide and share these services as required at their cost (e.g., legal services, project management and finance systems, IT support or office space, communications, general administration etc.). NIWA will not change overheads on administration services or the Director.
- *Governance Board costs*: Remuneration rates for members of the Governance Board are based on standard rates for Crown Directors. The total cost of the Board is not expected to exceed \$100K per annum.
- *Director, Manager and Science Leadership Team costs*: the salary and direct costs of the Director and Challenge Manager will be covered by *Deep South* funding. Direct costs (travel and accommodation) for the Science Leaders will be covered by *Deep South*, along with up to 0.2 FTE of time commitment.
- *Full cost funding*: all projects and activities are expected to be fully costed, including any cost of capital. In principle, funds will not be used to fund capital expenditure, and any required capital equipment is to be provided separately by the Parties and participants in the Challenge.
- *Co-funding*: is expected to be secured and managed via the participants in the Challenge.
- *Sub-contracting*: appropriate sub-contracts, consistent with the purpose and principles of the Collaboration Agreement, will be negotiated by NIWA with each organisation receiving Challenge funds. Payment of the funds will be based on invoices received from subcontractors.
- *Mapped Ministry Contracts*: The Ministry has mapped two existing research contracts (*Ross Sea Climate and Ecosystems* and *Climate Change Impacts & Implications* (CCII)) with NIWA into the *Deep South* Challenge funding envelope. These contracts will be unaffected by being mapped and remain in place until their contract end dates. While the objectives of the *Ross Sea Climate and Ecosystems* contract fall out of scope for the *Deep South*, the CCII Programme will become an integral part of the Challenge.

Budget

The Proposed budget for *Deep South*, based on the detailed research and related activity priorities within each of the Challenge Programmes, governance and management, and known co-funding, is shown in Table 6. The funding envelope for *Deep South* until 30 June 2019 (\$24M excluding GST) is based on the MBIE funding allocation outlined in their letter 8 May 2014.

Establishment Budget

Deep South has received \$450K to advance through the establishment phase of *Deep South*. This has been used to establish the Governance Board, Director and Challenge Manager, direct costs for Science Leadership Team meetings, hui, science meetings and stakeholder workshops, establishment of a *Deep South* Challenge website, and administration.

Funding Allocation

Prior to each financial year the Director shall prepare, and submit to the *Deep South* Board for approval, a budget for the use of the Challenge Funds. The indicative annual budget for the Challenge out to 30 June 2019 is provided in Table 6. The budget shall provide for:

- *Administration Funding* – to cover the Challenge administration and management costs, including salary costs of the Director and Challenge Manager, any operational management, stipends paid to the *Deep South* Board Chair and members, as well as general administration costs, travel, accommodation, event management, promotions and other agreed direct costs (e.g., direct costs associated with the Independent Science Panel and Kahui Māori).
- *Project Funding* – this includes research funding for approved research or related activities, administered by way of subcontracts on a full cost funding model (i.e., includes staff salaries, direct costs and indirect costs at the standard overhead rate of the subcontracted organisation according to its internal policies and practices). Project funding will also be used to support management and leadership of the Challenge by the Science Leadership Team.

Table 6. Indicative *Deep South* Challenge budget, 2014 – 2019 (all figures \$000, excl. GST). Note that aligned co-funding is likely to be an underestimate, as this has yet to be fully negotiated by the Parties; final allocations across Programmes are expected to vary slightly once full project proposals have been through peer-review; administration is currently around 5%.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	14-15	15-16	16-17	17-18	18-19	
Governance	100	100	100	100	100	500
Challenge Director, Manager and Administration	345	250	250	250	250	1345
Project and related activity						
Engagement	100	420	420	420	420	1780
Impacts & Implications	0	250	1000	1400	1400	4050
Vision Mātauranga	140	565	565	565	565	2400
Earth System Modelling & Prediction	275	1020	1020	1020	1020	4355
Processes & Observations	275	1230	1230	1230	1230	5195
Contestable	235	935	935	935	710	3750
Science Leadership	125	125	125	125	125	625
Total Project Funding	1150	4545	5295	5695	5470	22155
Challenge Total	1595	4895	5645	6045	5820	24000
Aligned co-funding						
CRI	1690	1690	1690	1690	1690	8450
University	100	100	100	100	100	500
Total	1790	1790	1790	1790	1790	8950

Project Funding Allocation

Two project funding streams will be used to allocate Challenge resources. The first, approximately \$935K per year, will be contestable and used to support Innovation Seed Projects (following the processes and criteria in section 4.1. The remaining project funds will be used to support large multi-disciplinary/multi-organisational projects within the Programmes following the ‘negotiated’ approach used to date. Based on the projects and priorities, and associated research leaders, as identified in the five year work plan of the Research Plan above, full research proposals suitable for peer-review will now be sought seeking detailed information on research methods, research teams and budgets, along with other relevant supporting information. Funds will be allocated across the Programme projects based on the indicative budget in Table 4, and projects may be funded for up to a four year term. Further funding of projects would be subject to meeting research priorities, performance and any input from Challenge and/or MBIE reviews. The Director/Science Leadership Team will be responsible for the call for proposals and their assessment. The assessment criteria that will be used, in addition to appropriate peer-review, will be based on those listed in section 4.1. The final recommendations from the Science Leadership Team will be provided to the Governance Board for their approval. Note that the negotiated approach to date has already prioritised potential projects based on fit to the Challenge research priorities and strategy, Vision Mātaraunga, collaboration, pathway to implementation, research quality and stretch, science team track record, co-funding and support, alignment with existing research and international linkages.

Co-funding

Co-funding will be an essential component of the *Deep South*, and necessary if the Challenge is to achieve its Mission. There are two types of co-funding:

- *Party aligned co-funding*: The Parties have agreed to align their own funding to the Challenge as co-funding. They have also agreed that alignment of funding to the Challenge means that the use of the funds by the Party aligning the funds will be based on the priorities of the Challenge as specified in the Research Plan. While these aligned funds will be retained and used by the owning Party, approval to recognise such funds and associated supported activities as co-funding to the Challenge will be sought from the Board. Each Party will be required to submit a plan for the use, and a report on the supported activities, of co-funding via the Director on an annual basis. This will be essential to aid planning and prioritisation of the research projects and related activities.
- *Commercial co-funding*: This includes any funding received by a Party from other organisations for work related to the objectives and priorities of the Challenge. Parties receiving such co-funding will report on it to the Director and NIWA as the Challenge Contractor.

Party aligned co-funding, both cash and in-kind, is significant and expected to grow (see budget amounts above). Commercial co-funding is expected to be closely aligned to technology transfer within the Challenge, and also expected to grow as the Challenge evolves. This is difficult to quantify at this stage, although the Department of Conservation has indicated that co-funding for measurement campaigns in the Subantarctic region is under consideration. Co-funding will be managed by the Party that receives it.

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