Future of Research **Use Cases**

REANNZ

Thank you to the contributors and participants that took part in the Future of Research workshop discussions. The insights shared were hugely valuable for the development of these use cases. The discussion during the workshops also covered a large range of topics, shared challenges and solutions relevant to the sector and we appreciate everyone’s time and contribution.

David Eyers
Associate Professor
University of Otago

Greg Rossiter
Technology & Digital Services Director
AgResearch

Helena Rattray
Researcher - Social systems
ESR

Linda Moore
Principal Policy Advisor
Ministry of Business, Innovation and Employment

Mallory Ross
Scientist
AgResearch

Mik Black
Professor
University of Otago

Richard Newcomb
Professor, Chief Scientist
Plant & Food Research NZ

Simon John Holdaway
Professor, Associate Deputy VC Research
University of Auckland

Warrick Johnston
General Manager
Technology & Innovation
NIWA

Winston Seah
Professor of Network Engineering
Victoria University of Wellington

Dr. Robert Hickson
Guest Speaker
Day One Futures

Amber McEwen
Host
REANNZ CEO

Gabrielle Hine
Organizer
REANNZ

Taryn Hopkins
Assistant/Facilitator
REANNZ

Hannah Edwards
Assistant/Facilitator
REANNZ

May 2022

These use cases imagine data-intensive research 10+ years ahead. As such, they are not predictive, but speculative, and based on ideas and suggestions from a working group. The increasing role complex data sets and analytics will play in research, science, and technology can though be confidently anticipated.

The use cases look at a variety of research fields and activities, but not always at the same point in time and dates are deliberately vague. They share the theme of greater interdisciplinary, and in some cases transdisciplinary, research, often involving international partners. Edge computing, where more analysis is undertaken as a distributed rather than centralised process, is also a theme.

REANNZ's (or a successor's) role in the use cases is intentionally absent because the cases are intended to stimulate thinking about what its role and others in the sector roles could be. With the pace of technological development, and the skills needed to adopt new technologies, REANNZ's functions are likely to change so that it can better facilitate access to the capabilities and infrastructure that research and education organisations, and individual researchers, will need.

There are six use cases covered in this paper that cover a wide range of different research collaborations; as such, they reflect the broad nature of research undertaken in Aotearoa.

The future use cases are:

1. Creating a digital volcano
2. An underwater visual and acoustic observatory
3. Weaving knowledge systems for healthy communities
4. Deep chemistry
5. A global disaster sensing network
6. Taking omics out to the farm

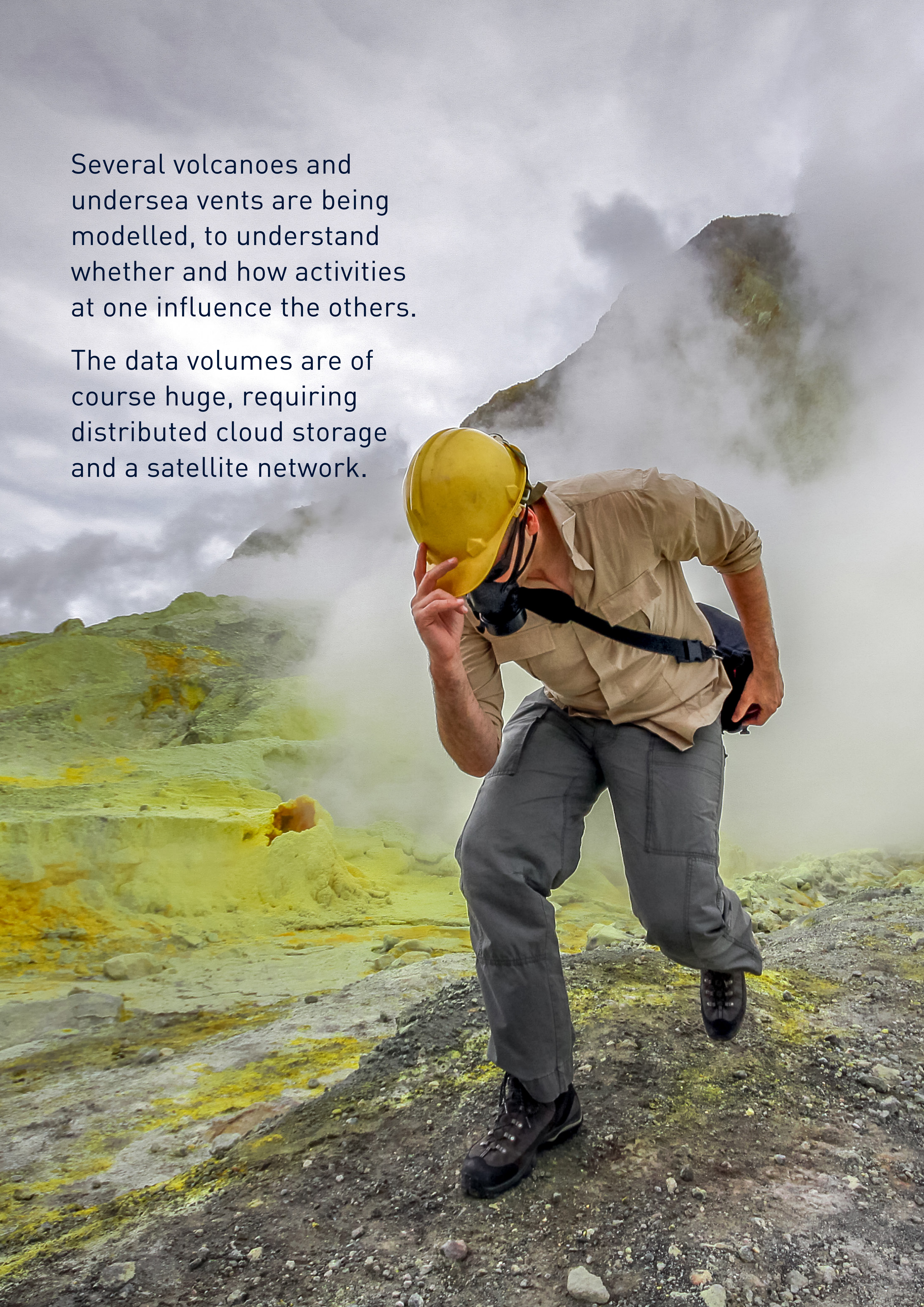
Thank-you to the contributors who gave up their time to help define these use cases. We now look forward to working further with our membership and the sector to understand how the REANNZ high speed data network needs to evolve over the coming years to support these varied use cases.

Ngā mihi,

Amber McEwen
Chief Executive Officer

Several volcanoes and undersea vents are being modelled, to understand whether and how activities at one influence the others.

The data volumes are of course huge, requiring distributed cloud storage and a satellite network.



CREATING A DIGITAL VOLCANO /

Volcanoes across Aotearoa have been monitored for decades, although it is difficult to predict when eruptions will occur. To improve the understanding of volcano dynamics an advanced sensor array has been installed in and around Whakaari/White Island.

This is enhancing the collection of real-time monitoring of seismic, chemical, temperature, and acoustic information. Satellite and other imaging data are also being used to track changes in the physical structure of the volcano. All this data is being used to develop a more unified digital version of the volcano.

Being one of the most accessible, active small volcanoes in the ring, Whakaari/White Island provides an excellent choice to a realistically simulate a volcano. Detailed digital predictive models of physical systems, have until recently focussed on man-made objects or systems (such as vehicles, buildings, and farming systems). A virtual Whakaari/White Island will enable a better assessment and prediction of eruption risks by modelling in much greater detail how the volcano's activity responds to changing physical and chemical conditions.

The research will also improve our understanding of other volcanoes along Pacific Ring of Fire. It is part of an international collaboration, the digital Pacific Ring of Fire research programme, involving Japan, China, and the US.

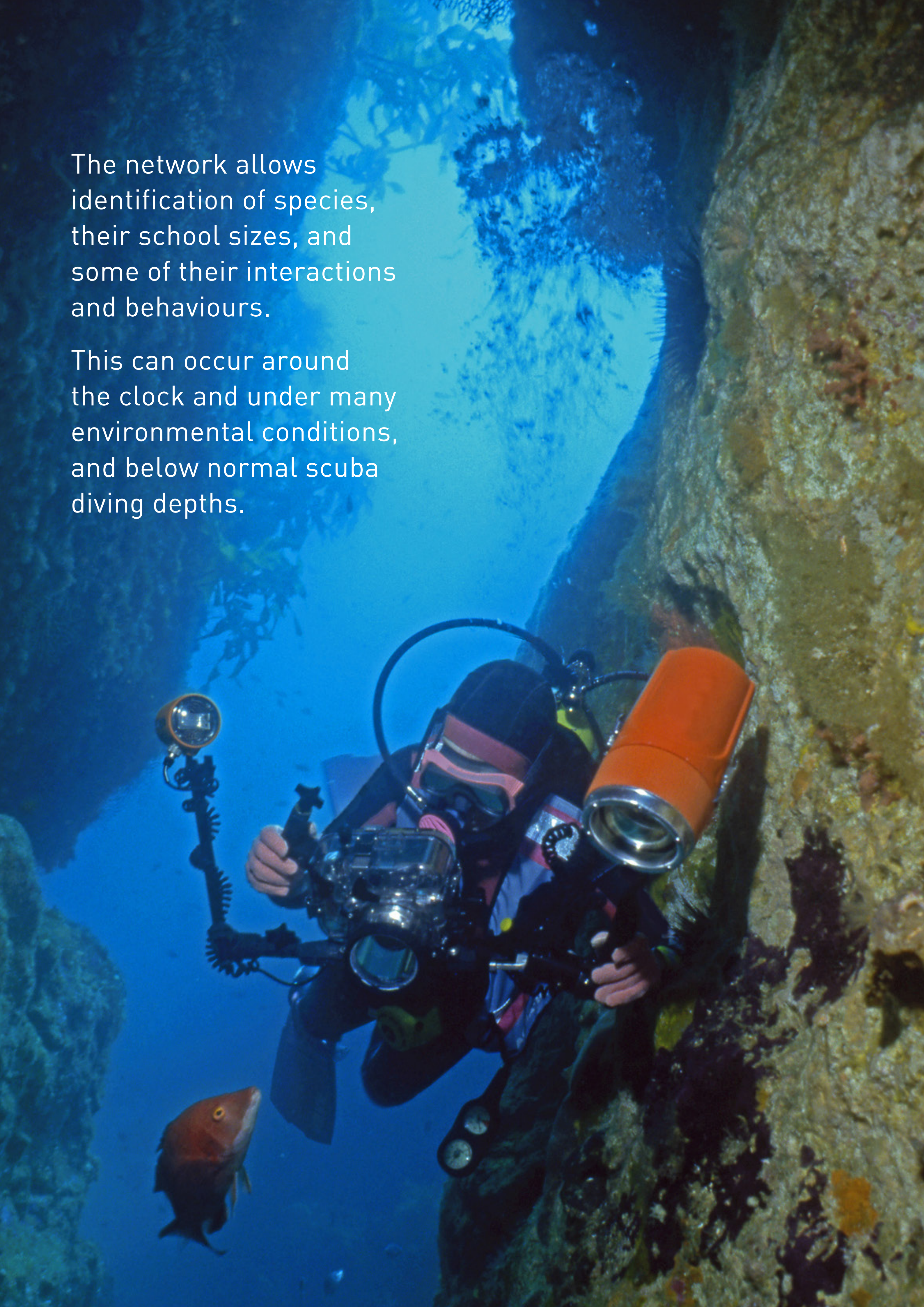
Several volcanoes and undersea vents are being modelled, to understand whether and how activities at one influence the others.

The data volumes are of course huge, requiring distributed cloud storage and a satellite network.

But as the programme progresses, and technology improves, it is anticipated that localised data processing by the sensors will continue to identify the most essential data streams and just share those.

The network allows identification of species, their school sizes, and some of their interactions and behaviours.

This can occur around the clock and under many environmental conditions, and below normal scuba diving depths.



AN UNDERWATER VISUAL AND ACOUSTIC OBSERVATORY /

The ability to extract meaning from data at the source, rather than sending very large data streams back to the lab, is opening up new avenues of research.

A visual and acoustic underwater observatory network around the Poor Knights Islands is being used to study associations and interactions between fish species.

A library of acoustic sounds, collected over the years and categorised with the help of citizen scientists, can be used to identify species with a high degree of accuracy. When combined with sonar, cameras, and small semi-autonomous submersibles, individual species can be tracked and monitored remotely for extended periods. Observations can be made beyond normal scuba diver depths, and under turbulent and murky sea conditions. Undersea life can now be studied with the same level of detail as many terrestrial communities.

The network allows identification of species, their school sizes, and some of their interactions and behaviours. This can occur around the clock and under many environmental conditions, and below normal scuba diving depths.

The audio-visual 3D grid allows precise localisation of animals in the water column. Twenty fish and crustacean species can be identified with high degrees of accuracy using machine learning to analyse acoustic profiles in real time. When there is acoustic uncertainty camera data can often be used to confirm species. Individual fish are also electronically tagged so that their social interactions, and some physiological conditions, can be tracked as well.

Rather than beaming all the data back to laboratories, analyses are conducted on-site using intelligent edge computing, allowing the network to be tasked with locating particular species and behaviours as they happen. Scientists can be alerted on nearby vessels or, via satellite, back at their labs. The behaviours can then be observed in real time, and the system records them for later study too.

Examples of research questions include how often do Blue Maomao form mixed species schools, with what species, and under what conditions?

The project is a partnership between research organisations, local visual effects and gaming firms, and the BBC Studios Natural History Unit, which has long helped adapt new techniques for field deployment.

None were more important than the other, but they needed to work together to produce the kete the community wanted.

The technical challenge was in enabling different data sets to have common structures and formats so that an integrated health map could be produced.

Mt Hikurangi, East Cape
Credit: Matt Crawford

WEAVING KNOWLEDGE SYSTEMS FOR HEALTHY COMMUNITIES /

Health care on the east coast has evolved from focusing on "How sick am I?" to "How healthy is my community?" Defining and assessing the latter required a transdisciplinary approach. This was led by local hauora Māori healthcare providers, building on a whanau-centred approach.

Coming to a common view of what a healthy community looked like from that community's perspective, and in particular persuading researchers and government officials of that approach, was the hardest step.

Physical, cultural, environmental, economic, and political factors all need to be taken account of. Some involve measurement, and others require decentralising power and control. At one of the early workshops a kuia commented that it was like weaving a kete with different plants. None were more important than the other, but they needed to work together to produce the kete the community wanted.

The technical challenge was in enabling different data sets to have common structures and formats so that an integrated health map could be produced. Data sets that are being combined range from: satellite data of physical and atmospheric conditions, granular local environmental and biodiversity data, dietary, biophysical, and mental health data. Along with information on the traditions and activities that brought, or bring, meaning and pleasure to the those in the community.

Data sovereignty is of course a fundamental component for such projects. Even for the more detailed satellite imagery, which provides information on sites and structures of special cultural importance. As data management and security has evolved, the community is able to control access and use, even when storage and processing is not local or even within Aotearoa New Zealand. This enables them to utilise the latest data systems and processes so protections are easy to adjust as the evolving demands and needs of the project change.

Telehealth sessions in the region are now less about simply providing a physical diagnosis and treatment plan, but more about facilitating individual and whānau discussions about causes, implications and actions. Assessing health at a community level means that there isn't a single metric to aim for. Instead, there are a set of baselines beyond which there are different preferences between individuals and families.

Critically, much of the work is being led from within the community. This is not just for ensuring data is properly managed and appropriately used, but to also build capabilities and skills locally, which is one of the factors included in assessing community health and wellbeing.

Health status isn't seen as the end point, but one of the preconditions for how the community can flourish in a variety of ways.

The community is already looking ahead now that they have a better view on current contributors to health. Through modelling various future environmental and social scenarios they are becoming better informed about what they need to protect collectively and what they may need to change to create new community kete.

The potential of black smokers, those deep hydrothermal vents rich in metals and minerals, has shifted from being viewed as a mineable resource to being part of a chemistry and biochemistry lab.

DEEP CHEMISTRY /

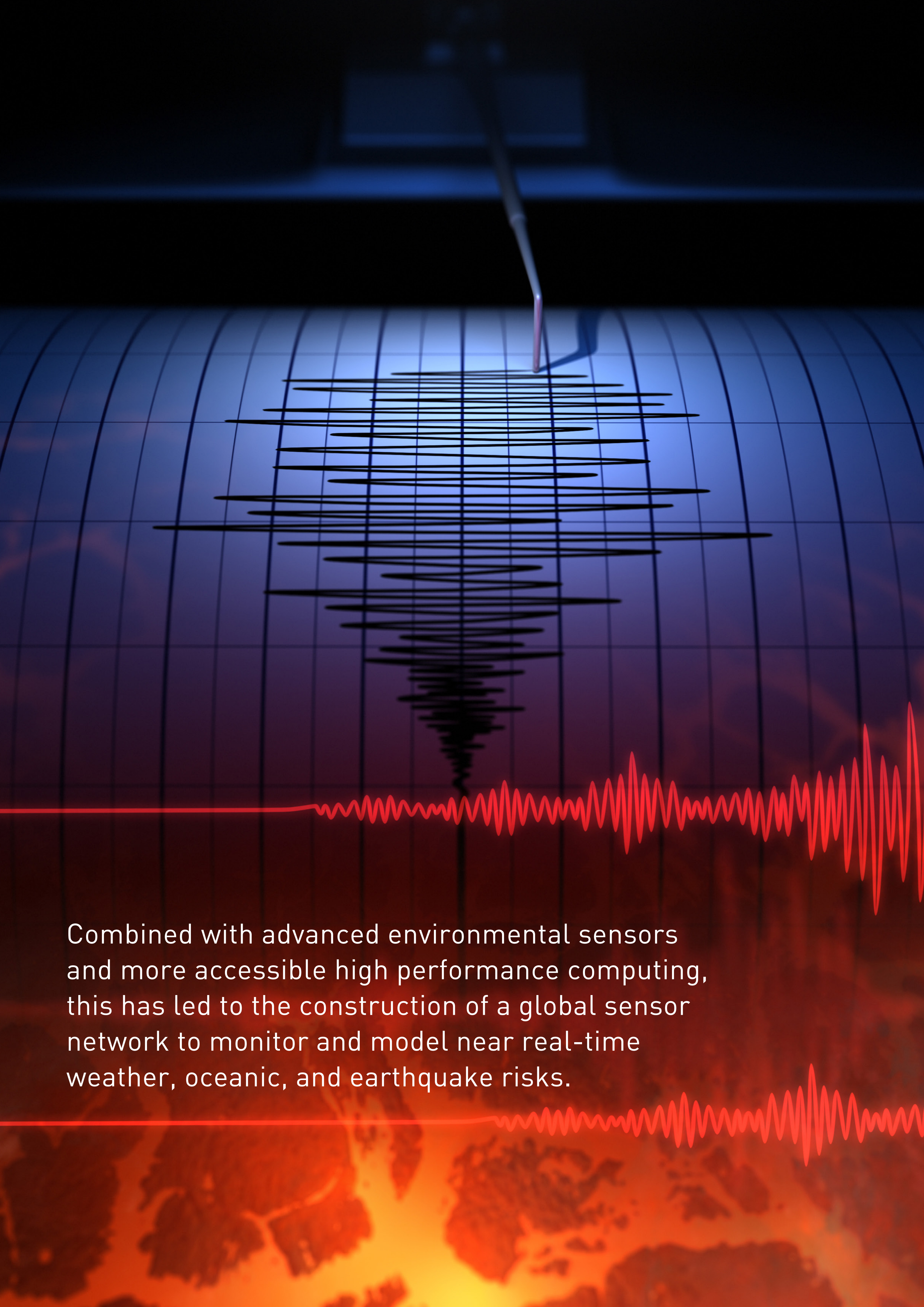
The potential of black smokers, those deep hydrothermal vents rich in metals and minerals, has shifted from being viewed as a mineable resource to being part of a chemistry and biochemistry lab. High pressure chemistry has been used to predict and synthesise some new compounds in traditional labs. High pressures can change the activity of some compounds by activating electrons and orbitals in new ways.

The Brothers Volcano in the Kermadec's takes such chemistry to a deeper level. With black smokers ranging from 1,500 to 1,800 metres below sea level, the pressures lie between 151 and 181 atmospheres.

In a joint venture involving New Zealand and international scientists, the US National Science Foundation, BASF and IBM Research, a series of small automated labs are being deployed down that pressure gradient. Each is the size of a fridge. Phase 1 of the research programme has just commenced and involves detecting short- and longer-lived small compounds. Sampling is to be done directly from the vents, and from microbial colonies growing on the vents. Results are relayed by satellite to researchers.

Phase 2 will involve conducting some simple standard chemical reactions to see if they behave differently at such pressures. And to see if novel compounds can be formed under those conditions.

Phase 3, development of a terrestrial high pressure automated chemical synthesis platform, is expected to begin once data analyses are complete, and a machine learning model based on vent compounds has been developed to guide synthesis stages. Commercial production of specific high-value chemicals and compounds can then commence.



Combined with advanced environmental sensors and more accessible high performance computing, this has led to the construction of a global sensor network to monitor and model near real-time weather, oceanic, and earthquake risks.

A GLOBAL DISASTER SENSING NETWORK /

“Disaster science” is now a global endeavour. Modelling at the quantum level is now practical and reliable, making detection and interpretation of very subtle environment changes feasible.

Combined with advanced environmental sensors and more accessible high performance computing, this has led to the construction of a global sensor network to monitor and model near real-time weather, oceanic, and earthquake risks.

The network is complimented by a citizen science and partner data portal, allowing the public and companies (such as mining and shipping companies) to contribute their observations and data.

The Global Environmental Risk Consortium oversees the network. Made up of government representatives, researchers and research organisations, engineering and information technology companies, and non-governmental organisations, the consortium administers and curates the data from member countries, international waters, and satellites. It also negotiates access to the cloud-based high performance computing needed to run the models and simulations.

At local levels, most of the sensor noise is automatically filtered out by self-learning artificial intelligence systems before being shared with the network. Specific signals and patterns in the data streams can be flagged to initiate on-demand computing runs. Given the demand on computational time, redundant or irrelevant processing is able to be killed promptly, and often autonomously, so that resource use is optimised.

The greater sensor sensitivity and improved models allow some earthquakes to be forecast minutes, or sometimes hours before, permitting early warnings to be issued.

Low-orbit satellite swarms enable data collection and communications to and from any point in New Zealand and the Pacific.

Simplified continuous modelling of key parameters is performed on-site so plant and animal performance can be assessed at a glance in the field or lab in real-time. More detailed high performance modelling is undertaken nightly in the cloud via satellite uplinks.

TAKING OMICS OUT TO THE FARM /

Over the last decade the multi-omics and system biology approach to agriculture has developed the knowledge, tools, skills, and the infrastructure, to develop sophisticated physiological and molecular models for how some key pasture species respond to environmental conditions and stresses under controlled environments.

Now the challenge is to test how those models hold up under real field conditions. While very large and complex "data lakes" were needed to develop the models, post-model information requirements have been able to be reduced to relatively smaller smarter "data ponds." However, the connectivity of a more diverse range of in-farm sensors and monitoring stations has shifted rather than reduced the analytical, computational, and other infrastructure requirements. And, overall, the data requirements are orders of magnitude greater compared to simpler laboratory experiments.

Six combinations of new ryegrass and clover cultivars, developed for improved drought tolerance and reduced methane production, are being tested across a hill country farm with several soil types. Soil nutrient and water content, above and below ground temperatures, humidity and solar radiation are all continuously monitored. Diversity and abundance of soil and leaf microbial species are determined daily using automated samplers and sequencers. Specific plant molecular and physiological responses are also regularly measured in-situ using portable sequencing, chemical and imaging platforms.

Simultaneously, the performance and production of a low carbon emission sheep breed is being tested on the plant cultivars. This too involves measuring gene and protein expression in the animals, and their gut microbiome. As well as monitoring animal behaviour and their emissions.

Simplified continuous modelling of key parameters is performed on-site so plant and animal performance can be assessed at a glance in the field or lab in real-time. More detailed high performance modelling is undertaken nightly in the cloud via satellite uplinks. Researchers are automatically alerted when there are significant or unexpected deviations to the models, or particular conditions are reached.

In parallel, the soil types and plant combinations are repeated in controlled climate rooms, so the field conditions can be mimicked as closely as possible, more detailed molecular studies undertaken, and the results compared. The underlying models can then be adjusted to better reflect field observations, and tested further.

The is part of a broader collaborative research programme with The Netherlands, Denmark, and Ireland, who are conducting similar trials with different plant species. The ambition being to develop a more generalisable model for pastures.

REANNZ