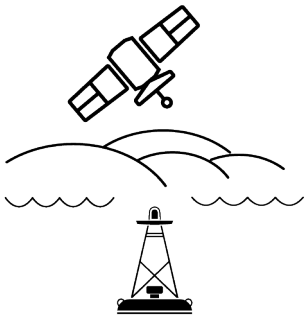
Asia-Pacific Economic Cooperation

Australian Government

Workshop on Building Regional Earth and Marine Observing Systems to Safeguard APEC Resources and Communities

26-30th September 2016, Australia

(26th September Sydney, 27-30th September Canberra)



TECHNICAL REPORT

EXECUTIVE SUMMARY

This report provides the recommendations and outcomes from the Workshop on *Building Regional Earth and Marine Observing Systems to Safeguard APEC Resources and Communities* ('The Workshop'). The Workshop was held in Sydney and Canberra in September 2016.

The Workshop participants agreed that earth and marine observation systems can support and benefit economic and environmental sustainability in the Asia Pacific Economic Cooperation (APEC) region. In particular, it was emphasised that such observations facilitate key APEC objectives instilled in the Bogor Goals of inclusive growth and prosperity, and technical cooperation and inclusive growth (see *Workshop Statement (page 5)*).

Together, the participants analysed and prioritised the potential future direction of earth and marine observations in the APEC region. The most important regional challenges and priorities included: emergency forecasting, preparedness and management, coastal health and hazards, food security, and water security.

Noting the outcomes of these discussions, and the in spirit of cooperation and collaboration in the region, the following policy priorities were identified to enhance earth and marine observing systems in the APEC region:

- facilitate and share in-situ data among economies
- fully utilise satellite data across the APEC region, including the currently available Landsat and Data Cube (Australia) systems; and in the future, the Sentinel/Copernicus Hub.
- fully utilise the overlap of geostationary satellites in the APEC region
- downscale climate projections to space and time scales relevant for decision making across APEC member economies
- engage other APEC member economies in the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM)
- encourage shared investment across APEC member economies in detecting and diagnosing the El Niño-Southern Oscillation
- encourage innovation to lower the cost of sensors and other observing platforms
- facilitate the transfer of knowledge and capacity building of earth and marine observation communities across APEC member economies
- target the enhancement of existing observing networks
- assist in the economic valuation of the economic benefits of earth and marine observing
- work in APEC Working Groups and Chief Science Advisors and Equivalent (CSAE) fora to raise the awareness of earth and marine observing systems to relevant policy makers. This would assist in promoting the end-use benefits of earth and marine observations to meet economic and societal needs underpinned by high level policy objectives. The objectives are contained in the United Nations Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction 2015-2030, Tsukuba Communique of the G7 Science and Technology Ministers' Meeting (2016), and the Joint Declaration on Harnessing the Data Revolution for Climate Resilience

The Workshop participants would like to extend their thanks to APEC, the Policy Partnership on Science Technology and Innovation (PPSTI), and the Australian Government for facilitating this Workshop, and they look forward to future engagement to further enhance earth and marine observation systems.

1 Introduction

The *Building Regional Earth and Marine Observing Systems to Safeguard APEC Resources and Communities* Workshop was held in Canberra 27-30 September 2016 drew together over 40 technical experts and policy makers across 14 APEC member economies, and included representatives from small and medium-sized enterprises (SMEs) and universities and observers from the Pacific Islands.

As part of the Workshop activities, on the 26 September 2016, international participants undertook a site visit to the Sydney Institute of Marine Science and were given demonstrations of institutional and commercial products derived from earth and marine observing and attended a presentation by Assoc. Prof. Lin Lin Ge from the University of New South Wales) on the use of radar imaging to improve disaster preparedness and response.

Participants then travelled to Canberra to participate in discussions regarding opportunities and priorities for innovative, efficient and effective use of satellite and in-situ earth and marine observation systems to benefit the APEC region.

The purpose of this report is to inform APEC via its representatives of the Policy Partnership on Science, Technology and Innovation of the opportunities of earth and marine observing information to safeguard resources, communities and livelihoods in the Asia-Pacific region, to identify ways to improve regional cooperation in earth and marine observing towards end use benefits to all economies, and a pathway to achieve this.

2 Statement of Workshop Outcomes and Priorities

STATEMENT FROM THE *WORKSHOP ON BUILDING REGIONAL EARTH AND MARINE OBSERVING SYSTEMS TO SAFEGUARD APEC RESOURCES AND COMMUNITIES*

The following statement intends to inform APEC members, their ministers, and their broader economies of the benefits that regional earth and marine observing systems can offer, and to identify the priorities that can assist in building stronger regional observation systems.

Earth and Marine Observing Systems & the APEC Region

The participants of the Workshop on *Building Regional Earth and Marine Observing Systems to Safeguard APEC Resources and Communities* recognised the importance of earth and marine observation systems in supporting economic and environmental sustainability in the APEC/Asia-Pacific region. In particular, such observations facilitate primary APEC objectives instilled in the Bogor Goals of inclusive growth and prosperity, and technical cooperation.

Earth and Marine Observation Systems

Earth and marine observing systems provide economies with data, products, and services derived from monitoring observations of the environmental, climate, and anthropogenic impacts on our land, coastal and oceanic environments. These observing systems benefit the APEC region by:

- safeguarding and building the resilience of communities and their livelihoods against the impacts of climate change and natural disasters;
- providing greater regional food, water, and energy security;
- stimulating economic growth through innovation via the implementation of a new or significantly improved product or process, new marketing methods, or new organisational methods in business practices, workplace organisation or external relations;
- building human capital, through the enablement of data access, and its related product development;
- improved protection of natural resources, including the environment; and
- providing opportunities for gender equity in science, technology, engineering and mathematics based industries involved in the earth and marine observation communities.

Addressing APEC & Global Priorities

The Workshop noted and supported APEC and PPSTI's role in implementing and complementing international and individual economy agreements and statements, including, but not limited to, the United Nations Sustainable Development Goals, The Sendai Framework for Disaster Risk Reduction 2015-2030, and the Tsukuba Communique of the G7 Science and Technology Ministers' Meeting (2016).

The Potential of Building Stronger Earth and Marine Observation Systems

The Workshop recognised the potential of enhancing earth and marine observation systems in:

- building human capacity across the APEC region to utilise earth and marine observing systems to enhance growth, prosperity, and technical cooperation;
- increasing research-industry collaboration within and across economies in the APEC region;
- better aligning earth and marine observing systems with the current and future requirements of APEC member economies; and
- addressing knowledge gaps that are currently constraining the enhancement of growth and prosperity in the APEC region.

Policy Priorities for the APEC Region

Based on the sharing of experiences and best practices of the APEC member economies at this forum, the participants present to PPSTI, other APEC Centres, and their individual economies the following immediate priorities to enhance earth and marine observing systems in the APEC region:

- facilitate and share in-situ data between economies
- fully utilise satellite data across the APEC region, including the currently available Landsat and Data Cube (Australia) systems; and in the future, the Sentinel/Copernicus Hub.
- fully utilise the overlap of geostationary satellites in the APEC region
- downscale climate projections to space and time scales relevant for decision making across APEC member economies
- engage other APEC member economies in the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM)
- encourage shared investment across APEC member economies in detecting and diagnosing the El Niño-Southern Oscillation
- encourage innovation to lower the cost of sensors and other observing platforms
- facilitate the transfer knowledge and capacity building of earth and marine observation communities across APEC member economies
- target the enhancement of existing observing networks
- assist in the economic valuation of the economic benefits of earth and marine observing
- work in APEC Working Groups and Chief Science Advisors and Equivalent (CSAE) forums to raise the awareness of earth and marine observing systems to relevant policy makers. This would assist in promoting the end-use benefits of earth and marine observations to meet economic and societal needs underpinned by high level policy objectives. The objectives are contained in the United Nations Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction 2015-2030, Tsukuba Communique of the G7 Science and Technology Ministers' Meeting (2016), and the Joint Declaration on Harnessing the Data Revolution for Climate Resilience.

The Principles and Aspirations of Earth and Marine Observations Systems

in the APEC Region

Noting the spirit of cooperation and collaboration in the APEC region, member economies are encouraged to recognise, endorse and/or work together to achieve the following overarching principles and aspirations:

- the need to sustain adequate earth and marine observation systems in the APEC and Pacific region.
- that the sharing of earth and marine observation infrastructure will enable region-wide benefits of science to the common good and peace of the APEC region.
- that individual economies have specific needs in regards to earth and marine observations that can be resolved through increased collaboration and cooperation across the APEC region, and through the building of capacity through training.
- that increased consideration of policies can facilitate economic growth through innovative use of accessible data for the benefit of end-users.
- the financial benefits to economies and their small to medium enterprises in gaining access to data collected from earth and marine observation systems.
- the need for future actions in APEC to support and develop the collaborative potential of current earth and marine observing fora in the region.
- the involvement and support from relevant APEC fora, including but not limited to, PPSTI, the APEC Business Advisory Council, APEC Ocean and Fisheries Working Group, the APEC Emergency Preparedness Working Group, the Chief Science Advisors and Equivalents.

The Workshop participants would like to extend their thanks to APEC, PPSTI, and the Australian Government for facilitating this Workshop, and they look forward to future engagement to further enhance earth and marine observation systems.

3 Earth and Marine Observations – an introduction

Earth and marine observation is the gathering of information about planet Earth's physical, chemical and biological systems via remote sensing technologies (satellites) and in-situ surveying techniques.

Owing to the magnitude of the topic, this Workshop focused on a subset of earth and marine observations:

- Land/Earth: observation of land masses (earth) via in-situ observations and Earth observing from space (remote sensing by satellites).
- Marine (coastal and oceanic): coastal and oceanic observations by both in-situ (buoys, argo floats, gliders, moorings) and remote sensing (from space via satellites, drones, aerial surveys).

Earth and marine observation includes the collection, analysis and presentation of data.

Earth and marine observations include:

- numerical measurements taken by a thermometer, wind gauge, ocean buoy, altimeter or seismometer;
- photos, videos and radar or sonar images taken from ground or ocean-based instruments;
- photos and radar images taken from remote-sensing satellites; and
- decision-support tools based on processed information, such as maps and models.

Earth and marine observations have a broad and ever increasing range of applications, for example:

- forecasting weather;
- tracking biodiversity and wildlife trends;
- measuring land-use change (such as deforestation);
- monitoring and responding to natural disasters, including fires, floods, earthquakes and tsunamis;
- managing natural resources, such as energy, freshwater and agriculture;
- addressing emerging diseases and other health risks; and
- predicting, adapting to and mitigating climate change.

The collection and use of earth and marine observations have a cumulative value (Figure 1). Each link in the chain presents various opportunities for economies, SMEs, and universities to be involved in innovative collection methods and use of the observations for various societal benefits.

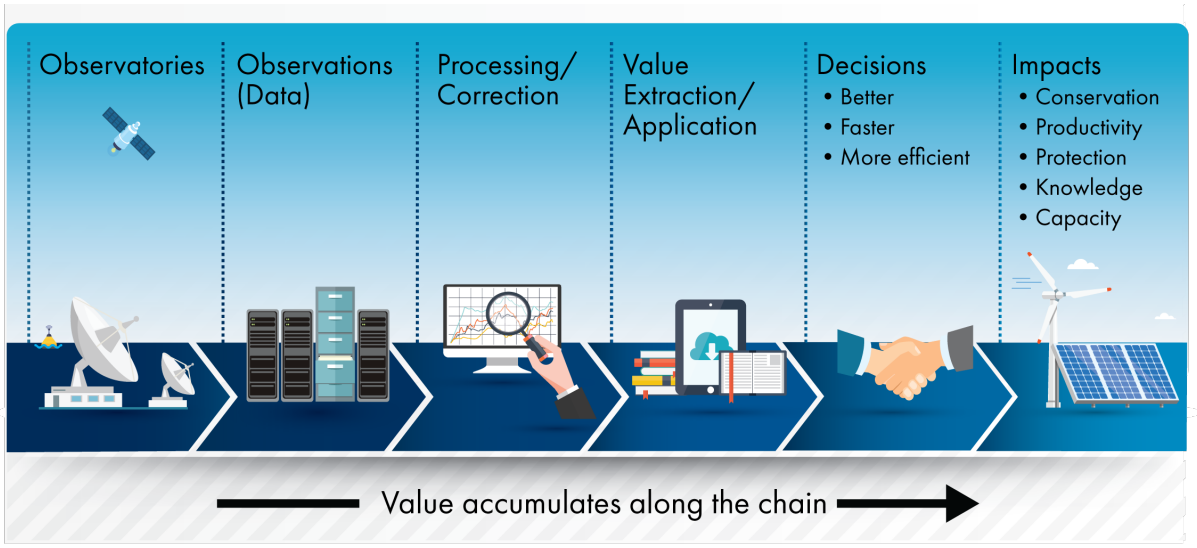


Figure 1: Earth and Marine Observing Value Chain

Technological advances have resulted in a rapid increase in the collection and storage of data. Data are turned into information for end users at various points in the value chain.

With this increase in methods and ways to collect and use data, two important questions remain:

- where should collection efforts be focused? It is costly to collect, measure and analyse everything, in addition to the ongoing costs associated with research infrastructure maintenance and human capital required to gather the data;
- what questions are most important for earth and marine observing to answer?

4 Relevance of Earth and Marine Observations to APEC Policies and Other Development Goals

The participants of the Workshop noted that earth and marine observation information had useful, direct application relevant to the interests of the APEC Policy Partnership on Science Technology and Innovation, Emergency Working Group, and Food Security, and many other sectoral APEC Committees that emphasise economic and technical cooperation.

On a broader scale, earth and marine observations have been highlighted in numerous international Instruments, and non-binding Statements, Communiques and Declarations, of which APEC member economies are prominent advocates and supporters, including:

- The United Nations Sustainable Development Goals
- The Sendai Framework for Disaster Risk Reduction 2015-2030
- Tsukuba Communique of the G7 Science and Technology Ministers' Meeting (2016)
- Joint Declaration on Harnessing the Data Revolution for Climate Resilience

5 Synthesis of Observation System Framework Discussions & Development

The Workshop reviewed the requirements for enhancing earth and marine observations across the APEC region using an agreed Framework (Figure 2). The Framework was designed to ensure that all efforts are focussed on priority SDGs for the region, and in Social Benefit Areas where broad coordination and collaboration were most likely to benefit the APEC region.

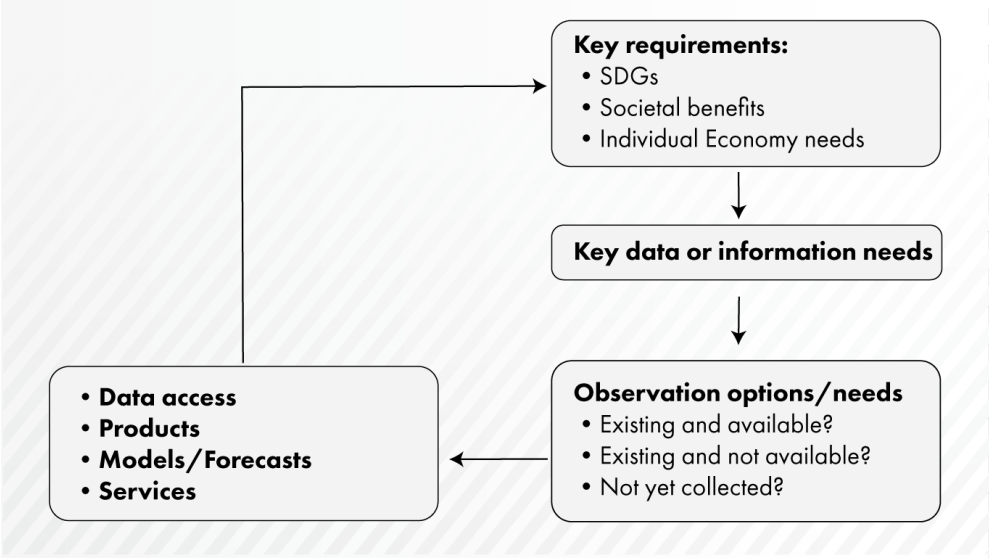


Figure 2: Framework of Review

Following a first order analysis of societal benefits where earth and marine observations were an important input to meeting various SDGs, Workshop participants prioritised four thematic areas for more detailed evaluation.

These themes were:

- Coastal Communities
    - Coastal health and livelihoods
    - Coastal hazards
- Water Security
- Food Security

5.1 APEC Coastal Communities

More than 40% of the population of all the APEC member economies live within 150km of the coast. Coasts are critical to economic health and large populations who live, work and play in coastal waters. Ensuring coastal water quality is good, landforms/coasts remain stable and use planning is well informed underpins numerous economic sectors (e.g. aquaculture, fisheries, tourism and recreation, maritime transport, infrastructure, urban planning). Rapid population growth and industrialization of coastal areas over the last 50 years throughout the APEC region, has escalated the pressures and impacts on coastal waters: agricultural pollution (e.g. sediments, nutrients, pesticides), urban development (e.g. chemical and

biological pollutants, coastal transformation), industrialisation (e.g. mining and process waste, land degradation), overfishing (e.g. loss of livelihoods), harmful algal blooms (toxic food, habitat loss, unsafe environment), introduced marine pests (biodiversity loss, emergent diseases) and climate change (inundation, erosion, glacial melting). The cumulative impacts of these pressures are a significant risk to the prosperity and health of hundreds of millions of people in both developed and developing APEC member economies. Observations facilitate understanding of the nature, extent and dynamics of the impacts caused by these pressures. They also enable the development of effective measures to reduce these impacts by informing evidence-based ecosystem health assessments.

Advances over the last decade in satellite-based remote sensing have allowed many relevant variables to be measured using the existing constellation of satellites. However, in-situ and ship-based monitoring remain essential to coastal observations and are deployed in some, but not all, APEC member economies. Cost and having sufficient capacity to deploy and maintain technologies are two of the major barriers to having an integrated earth and marine observing system throughout the Asia-Pacific. Individual APEC member economies are developing new sensor packages useful to coastal monitoring and ensuring they remain affordable will increase the likelihood of their widespread diffusion to other APEC member economies. New technologies like remotely operated and autonomous underwater and aerial vehicles will also extend the spatial and temporal coverage of coastal observations. Affordability and ease of use will be critical to their adoption throughout APEC member economies.

5.2 Coastal health and livelihoods

5.2.1 Key information needs

Numerous parameters can be used as measures of coastal health and productivity. Workshop participants agreed the suite of essential variables identified by the UNESCO-IOC Global Ocean Observing System Coastal Panel provided the basis for comprehensive coastal observations data and information management systems. Taking a regional approach to prioritising key measures for monitoring will enable the benefits of cooperation and collaboration (increased critical mass, greater data availability, easier information and technology transfer). These diverse data can feed numerous stakeholder driven data products, services and models to enable governments, industry and other end users to maintain coastal health while increasing prosperity and ensuring continuity in the way of life for coastal populations.

Observing programs generate the most value when they are sustained. Funding for ocean observing and terrestrial climate studies is fragile within the APEC region, often funded on a project-by-project basis. Programmatic funding promotes long-term planning and increases the likelihood of stakeholder co-investment because there is more certainty that data streams/products that have been integrated into their operations and decision-making will be ongoing. Funding for weather observations is often more secure but cost constraints limit improvements (adoption of cutting edge technologies and extending geographic coverage) and development of value added products from weather data.

5.2.2 Products and Services

APEC member economies are at the cutting edge of efforts to develop techniques for analysis of large geospatial data sets (e.g. The "Australian Geoscience Data Cube"), integrated and relocatable physical – biogeochemical – ecological modelling suites, and innovative decision support tools such as Environmental Report Cards and Simulation models. In concert these provide the basis for examining historical changes in systems and understanding the individual and cumulative impacts of stressors, and provide managers and the community with a ready way to explore and understand complex technical data. Data products such as these have proven useful for stakeholders in coastal systems in several APEC member economies and transfer of these methods APEC-wide will magnify their value.

5.2.3 Gaps and opportunities for APEC collaborations

Adoption of data standards and harmonisation of methods and guidelines is improving throughout the APEC member economies but it is not yet complete. When done, there will be more seamless transfer of data and data tools. Industry, government and communities would also profit from increased integration of calibration/validation from individual economies into regional scale datasets. This would also improve the local relevance of information and data products derived from regional/global models. This is not currently the case for some of the APEC member economies and improved downscaling would greatly benefit their governments and industries.

5.3 Coastal Hazards (Sea-level rise, inundation, storm surge, tsunamis)

Economic development within the APEC member economies is closely tied to the coastal zone, in part, due to the increasing densities of population centres in coastal areas. These coastal communities are particularly vulnerable to coastal erosion, the long-term inundation threat of sea level rise, and to the additional episodic risk of wave inundation, storm surge, and tsunamis. Additionally, coastal economies are vulnerable due their dependence upon the sea for transportation, tourism, and resource production. Understanding and being able to predict these coastal hazards is necessary for emergency, disaster and health risk mitigation and response, as well as infrastructure and national security planning.

Timely access to earth and marine observation data, and open sharing of that information between economies, is required to develop the level of understanding required to improve risk assessments and generate local, national and regional mitigation strategies and plans.

5.3.1 Key information needs

The accurate prediction of inundations due to both episodic events (waves, tsunami, storm surge) and long-term change (sea-level rise) requires integration of earth and marine data from a variety of platforms and sources: satellite and airborne/shipboard remote sensing (land use, water level, elevation, infrastructure distribution, bathymetry, precipitation); in-situ observing platforms (ocean surface currents, wave height, water level, stream flow, rainfall, water table elevation, land subsidence); and numerical modelling (wave field, surface circulation, atmospheric pressure and wind).

5.3.2 Products and Services

APEC member economies have a wide range of capacity with respect to the analysis, distribution, and consumption of hazard and risk information. Coastal communities require both near-term and long-range forecasts of inundation potential. Those forecasts must include assessments of vulnerability based on current and anticipated future use of coastal land, distribution of critical infrastructure, and the uncertainty of the hazard prediction. Forecasts must be distributed to communities with sufficient lead-time to allow action, and in modes that are easily consumed and understood by the general public.

5.3.3 Gaps and opportunities for APEC collaborations

Some member economies have highly mature observation systems (water level stations, wave buoys, LIDAR, multi-beam bathymetry, satellite-derived digital elevation models), forecast products (wave inundation, tsunami inundation, sea level rise projections), and advanced data quality control and access policies that allow for data to be accessible to all. The capacity transfer of observing, modelling, and data management capabilities, and the integration of observing system outputs among economies, is a clear opportunity to advance the economic value of earth and marine observing within APEC.

5.4 Water Security

Participants at the Workshop on Building Regional Earth and Marine Observing Systems to Safeguard APEC Resources and Communities agreed that inland and coastal water resource management and water security is a key issue in the APEC region. Sustained access to acceptable quality water is important for all APEC economies. There are many ways to address water security, including monitoring salinity caused by coastal intrusion and evaporation, monitoring the disturbance of the water regime caused by erosion and land compaction, monitoring the contamination of ground resources to tackle sanitation and health, and managing competing priorities for water. These competing priorities are within the context of requirements for population, hydropower, irrigation, drinking water, water for livestock, environmental ecosystems, climate change and extreme events. Managers and decision makers require integrated detection, monitoring and assessment tools that provide information on these issues

This issue is also being addressed by Sustainable Development Goal 6, to ensure availability and sustainable management of water and sanitation for all, and Goal 15, to protect, restore and promote sustainable use of terrestrial ecosystems including wetlands, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

5.4.1 Key data and information requirements

There are many information products from earth and marine observing systems that can support the management of water security in the APEC community. These products are available from a variety of surface-based and space-based platforms including in-situ (grab samples to autonomous instrumentation), airborne (drone to high altitude aircraft), space-based (satellites), and include:

- precipitation
- evapotranspiration
- soil moisture
- ground water recharge
- water scarcity and floods
- runoff
- lake/reservoir levels
- water quality of rivers, lakes, estuaries and coastal and marine waters (including coral reef waters), HABs, point and diffuse sources of pollution and nutrients
- vegetation height and Digital Elevation Models via Lidar measurements (can be expensive)
- Digital Elevation Models (DEM) using high resolution satellite Synthetic Aperture Radar data and altimeters
- shallow water bathymetry
- marine parks, sanctuaries and monuments assessments

Other datasets and techniques that complement products from earth and marine observing systems to support the management of water security issues include:

- Population and livestock statistics
- Measurement and modelling of catchments and rivers, estuaries, deltas and coastal waters including hydrodynamic and biogeochemical modelling.

- Point and diffuse sources of pollution and nutrients
- Weather forecasts (both 3-5-7 day forecasts and seasonal)
- Numerical models and analysis

5.4.2 Gaps and opportunities for APEC collaborations

The gaps identified were:

- capacity building in all aspects of the earth observation to informed decision making levels;
- data access: open access and transboundary data access are key
- observation systems: access to high spatial and temporal earth and marine observing data streams (optical, temperature, SAR, passive microwave) such as now produced for the (South East Asian, Australia, New Zealand, Pacific Island States) region by the European Space Agency and the United Stage Geological Survey (the Sentinel series of satellite and the Landsat series of satellites) distributed though the Australian Copernicus-Sentinel collaborative ground segment; the Indian, Chinese, Vietnamese, Japanese and Korean satellite programs; and the US satellite programs of NASA and NOAA.
- access to detailed, correct digital elevation models
- transboundary information on river water quality and quantity (and reservoirs and lakes within those river systems); potentially harmful algal blooms.

There are opportunities for APEC member economies to:

- benefit from high resolution (10 m) weekly and (300 m) temporal (daily) satellite data for water levels and water quality; and for the 300 m data Water Surface Temperature
- benefit from improved digital elevation models (DEMs) for managing water resources across catchments
- detect, monitor and assess water bodies that are transboundary in nature
- benefit from improved weather forecast accuracy, particularly seasonal forecasts; and
- improve expertise in all aspects of the value chain, from data observations (including data-data fusion to modelling and model data fusion to integrated data analysis and model-data assimilation.

5.5 Food security

The Workshop participants agreed that food security is a key issue in the APEC region. Throughout the APEC community, sustainable food security is a fundamental requirement. Ensuring the quality and quantity of food production from year to year is becoming increasingly important in the face of population growth, increasing intensity of natural disasters and weather fluctuations that arise from climate change, and with growing competition for land including from urbanisation. Food security also relies on healthy coastal and ocean environments for the management of aquaculture fisheries and wild stocks.

This issue is also being addressed by Sustainable Development Goal 2, to end hunger, achieve food security and improved nutrition and promote sustainable agriculture.

5.5.1 Key data and information requirements

The key products derived from Earth and Marine Observing systems that are required for addressing food security in the APEC community are considered to be:

- land use and land use change;
- extent of cropped areas;
- annual production/projection; and
- water quality and bio pests.

These products are based on satellite observations of land, coastal areas, and ocean. Complementary data and statistics on fisheries stocks and projections in wild catch and aquaculture are also required.

5.5.2 Data analysis and modelling requirements

Several types of modelling and analysis tools are required to transform the satellite observations to information products that are of value to the end user. These capabilities include:

- crop models,
- downscaled climate and weather models,
- fisheries models,
- resource allocation models and frameworks,
- satellite data analysis tools,
- water resources/availability models, and
- linkages between food and water security, biosecurity and pest control.

5.5.3 Gaps and opportunities for APEC collaborations

There are opportunities for APEC member economies to:

- benefit from access to high resolution (10m) and temporal (daily) satellite data;
- benefit from access to 3- day weather information and accurate longer term (seasonal) outlooks;
- address human and equipment capacity gaps as knowledge expertise is required across all elements of the value chain;
- improve data sharing e.g. data policies/standards/consistency; and
- improve sharing of knowledge in global and regional crop monitoring and forecasting methods and systems.

6 Priorities

From the analysis of gaps and opportunities emerging across the four thematic areas, a shortlist of high priority follow-on activities for earth and marine observation in the APEC region were identified as (in no particular order):

- facilitate and share in-situ data among economies
- fully utilise satellite data across the APEC region, including the currently available Landsat and Data Cube (Australia) systems; and in the future, the Sentinel/Copernicus Hub.
- fully utilise the overlap of geostationary satellites in the APEC region
- downscale climate projections to space and time scales relevant for decision making across APEC member economies
- engage other APEC member economies in the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM)
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7 Priorities: Time and Cost/Benefit

The table below briefly outlines what were identified by Workshop participants as to the likely time vs cost outlook of the various priorities.

These were not comprehensively discussed at the Workshop, however, and are indicative factors to consider in the next step towards greater collaboration, cooperation and implementation of earth and marine observation systems across the APEC region.

Longer term	• Exploiting overlap of geostationary satellites in the APEC region • Climate projections, downscaled • Valuing the economic benefits of earth and marine observing	• Detecting and diagnosing ENSO • Innovation to lower the cost of sensors and platforms
Shorter term	• APEC-wide access to in-situ data • Fully exploiting satellite data APEC-wide, current (Landsat/Data Cube) • Engagement of other APEC member economies in GEOGLAM • Transfer of knowledge and capacity building across APEC member economies	• Fully exploiting satellite data APEC-wide, future (Sentinel/Copernicus Hub) • Targeted enhancement of observing networks
	Lower cost/benefit	Higher cost/benefit

8 Opportunities for APEC Collaboration

To ensure the continuation of this project, various ideas for future collaboration with APEC Groups and Centres were identified. This is not an exhaustive list, however it highlights the general areas upon which some Earth and Marine Observing Workshop participants would like to engage in further discussion.

8.1 Capacity Development

The effective use of earth and marine observations (and associated analytical approaches) to improve and manage coastal health across the region will require investment in capacity development across a number of technical areas. As we have a number of institutions in APEC member economies with very strong capacity, we recommend the development of a dedicated capacity development program within APEC. This should include training to use freely available satellite derived data (current and new missions) to the deployment and maintenance of *in situ* and roving technologies (both marine and terrestrial).

8.2 Data Access and Conversion into Meaningful Data Products and Information

A fundamental principle of earth and marine observations is the sharing of data. The systems we seek to understand and manage do not recognize national boundaries and the global earth and marine observing community has made significant progress over the last decade through sharing data, information and models. We encourage all APEC member economies to support the principle of cooperation in sharing all environmental data.

8.3 Regional Innovation Hubs for Technology Development and Diffusion

The sharing of technological breakthroughs and methodological innovation has underpinned significant advances within APEC member economies. This progress can be accelerated by appointing and funding several Key APEC Centres focussed on developing and adapting observing technologies for priority observations. In addition to technical and technological innovation and diffusion, they would be charged with acting as reference agencies to improve QA/QC on a regional scale.

9 The Workshop: Expert Presentations

The Workshop methodically approached the task of analysing the requirements and opportunities of earth and marine observations in the APEC region. Presentation slides are available from the website, www.earthmarineobserving.org.

9.1 Setting the Scene (Plenary)

The Workshop began with a scene-setting plenary chaired by Dr Sue Barrell of the Australian Government's Bureau of Meteorology. This panel included Mrs Jane Urquhart, the Head of Science and Commercialisation Policy at the Australian Government's Department of Industry, Innovation and Science, who emphasised the importance of government-researcher-industry collaboration and asked participants to work towards real and tangible outcomes for the APEC region.

Ms Rowena Thomson, Director of the Strategy Branch at the Australian Government's Department of Foreign Affairs and Trade (DFAT), discussed the importance of earth and marine observation systems integrating with business facilitation, technical cooperation, and trade and investment liberalisation in APEC member economies. Ms Thomson cited the examples of the Blue Economy Aquaculture Challenge and eReefs initiative, which were borne of public, NGO and private partnerships to better manage marine resources. Ms Thomson noted that innovative outcomes similar to eReefs could specifically assist in increasing emergency pre-preparedness in the Pacific by better predictive technologies and alleviate the impact of drought in Papua New Guinea through the use of climate data.

Mr Nathan Eaton, the Principal Consultant of NGIS, speaking on behalf of the Spatial Industries Business Association, introduced the perspective of SMEs in the earth and marine observing community. Mr Eaton emphasised the exponential increase in innovation that was possible given new technologies in satellite and in-situ data gathering. It was discussed that data analysis and its output to the end-user was where earth and marine observations could add economic and societal value in APEC region. The example of the Coastal Risk Australia website highlighted the importance of communicating the data collected in a useful and meaningful way, and it was noted that the website had received over 3 million visits. Mr Eaton outlined the potential for earth and marine observing systems in facilitating real time warnings for loss of forest cover, precision agriculture, sea level rise action in the Pacific and other community engagement across all APEC member economies.

Dr Steve Rintoul, an Australian Academy of Science Fellow, and Team Leader of the Australian Government's Commonwealth Scientific and Industrial Research Organisation (CSIRO) Marine and Atmospheric Research Centre, and Antarctic Climate and Ecosystems Cooperative Research Centre, stressed the importance of ocean observations and their critical role in researching the global climate system. Dr Rintoul noted the advancements in ocean observations in recent years but told participants that a 'revolution' was needed in innovative ocean observing to keep pace with the needs of climate science.

Recognising the value of earth and marine observations for all APEC member economies, participants resolved to draw together the various technical expert opinions to identify opportunities for the increased use, and enhancement of, earth and marine observations in the APEC region.

9.2 Frameworks of Earth and Marine Observations (Session 1)

Technical experts from earth and marine observation institutions introduced the global frameworks and partnerships within which observations in the APEC region were collected.

Dr Stuart Minchin, the Australian principal of Group of Earth Observation (GEO), member of the GEO Asia/Oceania Caucus and Chief of Environmental Geoscience at the Australian Government's Geoscience Australia, introduced the framework of earth (satellite) observations. GEO and its collaborative 'System of Systems' (GEOSS) aims to inform and progress society across eight fields: biodiversity and ecosystems; disaster resilience; energy and mineral resources management; food security and sustainable agriculture; infrastructure; health; sustainable urban development; and water management.

In discussing GEO's 103 member countries, Dr Minchin noted that Pacific Islands were not amongst the membership, despite the challenges these small nations face from climate-induced coastal erosion, sea level rises and other impacts. GEO members benefitted from the open sharing of data, and receive an estimated $2.1 billion in annual economic benefit stemming from this shared data. It was highlighted that GEO contributes to the achievement of the United Nations Sustainable Development Goals (SDGs) through the provision of Earth observations and geographic information. This was explicitly mentioned in the UN General Assembly Resolution A/Res/70/1 *Transforming Our World: The 2030 Agenda for Sustainable Development* (art 76), which states:

> We will support developing countries, particularly African countries, least developed countries, small island developing States and landlocked developing countries, in strengthening the capacity of national statistical offices and data systems to ensure access to high-quality, timely, reliable and disaggregated data. We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including earth observation and geospatial information, while ensuring national ownership in supporting and tracking progress.

Dr Minchin noted that the APEC region had much to gain from greater investment and innovation in the earth and marine observation area.

Mr John Gunn, the Chief Executive Officer of the Australian Institute of Marine Science presented in his capacity as co-chair of the Global Oceans Observing System (GOOS). Mr Gunn noted the increasing importance of ocean observations, and highlighted the recent G7 Science and Technology Ministers' Tsukuba Communique. The Communique stated that to achieve SDG 14 to conserve and sustainably use the oceans seas and marine resources for sustainable development, along with other relevant SDGs, that the G7:

> Support the development of a global initiative for an enhanced, global, sustained sea and ocean observing system, developing new technologies and integrating new physical, biogeochemical and biological observations while sustaining critical ongoing observations and ensuring full co-ordination with existing mechanisms.

Mr Gunn stated that collaborations must increase between nations in order to ensure early warnings were in place for ocean-related hazards, and to grow and sustain the global Blue Economy. It was noted that international collaborations were improving under the GOOS Regional Alliances, and that the APEC region had much to gain from sharing coastal and ocean observations. There was not currently the right level of observation accessibility,

capacity and support to assist developing economies in the APEC region. In order to achieve SDG 14, ocean observation coverage and the capacity to use those data would need to improve. Mr Gunn cited the Tropical Pacific Observing System as an example, noting that only 20% of the necessary observations had been put in place. Using enhanced public-private partnerships to deliver earth and marine observation's predicted social benefits would be best achieved at a regional level, however the end users' needs must first be accurately identified.

The participants considered the global and regional frameworks, and an emphasis on the Pacific Islands became central to the discussion. The problems of Pacific Island nations' participation in such fora was a result of small population and capacity.

It was further highlighted that many economies shared and accessed satellite data, but were hesitant to share in-situ ocean data that were collected within exclusive economic zones or territorial seas. Such hesitation hindered regional knowledge of coastal issues, particularly those associated with climate change. It was noted that government departments who made data available in regards to climate and ocean-based risks were lowering the risk of business investments by making the data freely accessible.

Interoperability standards were also discussed, and it was noted that regional alliances should ensure that data are admissible when measured against SDG indicators.

9.3 Management, Decision-Making & Opportunities (Sessions 2, 3, 5.2 & 6)

9.3.1 Regional Applications of Observational Data (Session 2)

The various regional applications of earth and marine observations were demonstrated by technical experts from the economies of the United States, Japan, Chile and China.

Mrs Zdenka Willis, Director of the United States Integrated Ocean Observing System (US-IOOS) Program at the National Oceanic and Atmospheric Administration cited examples of how ocean observations gathered by various means can assist in mitigating the impacts of natural disasters and climate change. For example observations assisted the US shellfish industry by measuring the rate of ocean acidification in shellfish growing areas. Echoing the importance of the G7 Tsukuba Communique and the OECD's Ocean Economy 2030, Mrs Willis highlighted the critical role observations will play in future efficiency commerce and trade on the world's oceans, and how 'public good science' can assist in broader economic gains.

Dr Ken Ando, Group Leader of the Ocean-Atmosphere Interaction Research Group at the Japanese Agency for Marine-Earth Science and Technology (JAMSTEC), gave an overview of the freely available data and samples collected on various JAMSTEC cruises. Data-sharing, and integration of these data, was emphasised as being important in providing societal benefits across the APEC region.

Dr Gaston Vidal, the Head of the Environment Department at the Instituto de Fomento Pesquero in Chile, highlighted the importance of observation data for the Chilean aquaculture industry. In recent years the industry has been impacted by increased toxins in their aquaculture regions. Dr Vidal emphasised the importance of both satellite and in-situ observations in managing the crisis, and hoped that networks could be further enhanced to improve their knowledge of the outbreaks in toxins.

Professor Liu Jianbo, the Deputy Director of the Institute of Remote Sensing and Digital Earth at the Chinese Academy of Sciences, outlined the different observing systems assisting Chinese authorities in the areas of meteorology, vegetation cover and emergency management.

Dr Kim Juniper, of Ocean Networks Canada, discussed Canada's cabled observatory system in the Northeast Pacific Ocean. Ocean Networks Canada serves various sectors including: networking seafloor and land-based earthquake sensors into an early-warning network that detects P-waves, locates epicentres and sends alerts to civil authorities; experimental HF radar installation to detect incoming near-field tsunamis generated by earthquakes in the Cascadia subduction zone off Vancouver Island; a collaborative 'sandbox' approach for development of tsunami inundation models using a high performance computer facility; a marine mammal alert system that combines real-time hydrophone data and vessel location information to issue alerts with the aim of avoiding vessel-whale collisions and disturbance of marine mammal activities due to vessel noise; real-time sea state information and forecasting for critical coastal navigation routes used by passenger ferries, oil tankers and container vessels; and water quality information in coastal areas for ocean health and habitat monitoring. Ocean Networks Canada is developing various partnerships to extend real-time ocean observing to Canada's Arctic and Atlantic coasts, by adding new infrastructure and networking existing observing platforms.

9.3.2 Observational Data and Decision-Making (Session 3)

The various ways in which earth and marine observations can assist with decision-making were demonstrated by technical experts from the economies of Malaysia, Australia, and New Zealand.

Mr Raja Bidin Raja Hassan, the Special Departmental Coordinator at the Southeast Asian Fisheries Development Centre/Marine Fishery Resources Development and Management Department in Malaysia, presented the application of remote sensing technology for purse seine fisheries in Malaysia waters. Remote sensing observations are currently used to identify potential fishing zones of pelagic fisheries, and to verify the proper implementation of various fisheries-based regulations.

Ms Alexis McIntyre, of the Australian Government's Geoscience Australia, introduced the applications of satellite observation data and information products to support hazard risk assessment and mitigation in Papua New Guinea. Using satellite images of drought-affected areas of PNG, Geoscience Australia and (DFAT) have developed hazard and risk information products for improved agricultural management. This project recognised the limitations of data availability, and limited and slow internet access, a common issue of least developed economies, and instead provides appropriately sized products according to IT/technical capabilities, for ease of use and analysis. The project highlighted the importance of observations being practical to the on-the-ground situation in many APEC regions, and noted that the work supported the objectives of the Sendai Framework for Disaster Risk Reduction 2015-2030.

Dr Barb Hayden, Chief Scientist Coast and Oceans at the National Institute for Water and Atmospheric Research (NIWA) in New Zealand, introduced Riskscape, an online tool for disaster risk reduction. Riskscape is designed to improve decision making by understanding the'possible impacts of natural hazards on specific areas using local data and modelling'.

Various observation datasets are used for real-time (e.g., earthquakes) and modelled hazard scenarios (e.g., tsunami, storm surge, winds, floods) that are matched to asset inventories (e.g., building and infrastructure attributes) to determine their vulnerability. This, in turn, is validated using post-hazard observational data. Datasets are complemented with citizen-based science, such as residents' photographs of coastline inundation to determine the impact of king tides on the Auckland coastline. Riskscape assists in hazard preparedness and prioritising emergency and economic responses prior to and during times of natural disaster.

9.3.3 Challenges and opportunities through collaborations (Session 5.2)

The opportunities that earth and marine observations could present to APEC member economies were demonstrated by technical experts from the economies of Singapore and Australia.

Dr Liong Shie Yui, Deputy Director at the Tropical Marine Science Institute at the National University of Singapore, presented on the impacts of climate change on food security in relation to rice yields. Soil and cultivar (rice) data were used across Vietnam and Singapore to create climate models that better projected rice crop yield. Such models are important to the two regions which share economic and food security issues. It was noted that higher resolution and downscaled observation data could assist in planning for future impacts of climate change.

Dr Lyndon Llewellyn, the Research Program Leader of Data and Technology Innovation at the Australian Institute of Marine Science, discussed Australia's priorities in marine observation data production and usage. Dr Llewellyn noted that improving discoverability, accessibility, and usability of datasets, and increasing interoperability and standards, had been identified as broad priorities. It was highlighted that growth in observational data usage would be driven by end-user needs, private sector business interests, and the growth of new technologies involved in the 'Internet of Things'.

Mr Vance Hum, the Vice-Chair of the APEC PPSTI Innovation sub-group and the president and CEO of IM Systems Group presented on linkages between economies and SMEs. IM Systems is an SME engaged in many programs for the US government and international organisations. IM Systems Group employs over 300 scientists and consultants in providing expertise in improving disaster resilience environmental monitoring and inclusive innovation. Some of these programs include the Environmental Response Management Application, which assists stakeholders in visualising environmental information relevant to oil spills, natural disasters and hazardous material releases. Working in conjunction with NOAA, IM Systems assists in capacity building amongst response workers and have a coverage across all coastal US states and territories.

Dr Kim Juniper, Chief Scientist of Ocean Networks Canada at the University of Victoria, introduced the work of the university, which 'operates world-leading ocean observatories for the advancement of science and the benefit of Canada'. The university has a focus on innovative and commercialised technologies and end-user applications, including the use of integrated technologies to monitor seismic activities off the Canadian coast and its potential impact on natural resources.

9.3.4 Opportunities at the Coastal Interface (Session 6)

Professor Peter Steinberg, Director and CEO of the Sydney Institute of Marine Science in Australia, introduced the opportunities that coastal observing presents to the APEC region. Using Sydney Harbour as an example, Prof Steinberg explained how ocean observations focus on the coast to reveal such risks as sediment and water quality, contamination risks, flooding, and coastal erosion. The outcomes of analysing these observations included real-time monitoring of erosion, land use planning, and community engagement and communication.

Dr Tommy Moore, the Secretariat of the Pacific Regional Environment Program and Pacific Islands Global Ocean Observation System, discussed opportunities for Pacific Islands at the coastal interface. Dr Moore identified the priority areas for the Pacific Islands region: coastal inundation and safety at sea; ocean acidification and impacts of climate change on coastal ecosystems; water quality; and biodiversity. Collaborations building on the work by NIWA, the Australian Integrated Marine Observing System (IMOS) and the Pacific Integrated Ocean Observing System, were discussed.

Dr Andy Steven, the Research Director of the CSIRO Coastal Development and Management Program, discussed how observations can be used in services and produced to better inform coastal decision-making. Dr Steven noted that the value in data lies in its quality and verification, rather than solely the exercise of collecting data. The need to reuse, repurpose, rescale and blend marine and earth data was emphasised along with the need to also collect socio-economic data. In relation to the specific coastal domain, Dr Steven stated that there were various components of the observation data chain that needed improving and linking, including: more efficient and effective observations; data assimilation and process understanding; model coupling and orchestration; ecosystem models; management strategy evaluations; and data access and effective communication. Dr Steven identified GEOSS work in Blue Planet, AcuaPacifico, and eReefs mechanisms, and stated that the APEC region supported a large range of coastal ecosystem services and livelihoods that were intertwined with carbon stocks and sequestration rates.

Mr Chris Ostrander, the Assistant Dean at the School of Ocean and Earth Science and Technology at the University of Hawaii, and the United States' Pacific Integrated Ocean Observing System (Pac-IOOS), emphasised the value of coastal ocean observations in the APEC region. Mr Ostrander began with the premise that while global observing systems collected data for large scientific questions, an ordinary citizen's interest in earth and marine observations extended only as far as they could see a direct and immediate impact of those data on a decision they need to make. Both, seemingly divergent, concepts should be taken into consideration when planning policies. It was stated that APEC member economies had made significant deployments in observational equipment such as wave buoys, in recognition of dangerous coastal waves particularly in the Pacific. In terms of the economic value of observing systems, Mr Ostrander cited a 10:1 investment return on the 14 buoys deployed by Pac-IOOS, and that complex 'super' users of Pac-IOOS data gave a 20:1 return to the economy on the annual investment.

In noting the plethora of applications in the APEC region, participants discussed what the most valuable datasets might be, acknowledging that various sensitivities existed in some areas. It was recognised that instead of focusing on the data that would be reluctantly shared or politically problematic, participants expressed the desire to find common ground upon

which economies could facilitate data sharing and capacity building to achieve observations that were valuable to economic prosperity and regional security.

The needs of various end-users were again raised. It was noted that end-users didn't necessarily want the data, per se, they wanted a product that had already analysed the data. The conduits between observational data and a valuable data 'product' were identified as governments, collaborative programs, and SMEs. This highlighted the importance of including SMEs in the future planning of regional observational projects, and of building developing regions' capacity to translate data into end-user friendly products.

The identification of what various end-users needed in terms of natural resource management, mitigating natural disaster impacts and other potential uses of observational data became a priority for discussion. It was agreed that participants would define a clear set of requirements and priorities to maximise the effectiveness of data collection, extraction and supply to APEC member economies (see *4. Building a Framework*).

9.4 Opportunities for Gender Equity in Earth and Marine Observations (Session 5.1)

To better define what collaborations and opportunities could ensure that gender equity in the earth and marine observation community was addressed, participants heard a presentation by Dr Marguerite Evans-Galea on gender equality in science, technology, engineering and mathematic (STEM) disciplines. It was highlighted that even though rhetoric of equality existed in various policies, the reality was that the numbers did not reflect equality. Participants noted various examples from their individual economies and underscored the importance of both ensuring bias did not exist in the engagement and promotion of women in the workplace, and that building the capacity of women in STEM in developing economies was of critical importance.

10 Workshop Participant List:

Dr	Ken	Ando	JAMSTEC, Japan
Dr	Sue	Barrell	Bureau of Meteorology, Australia
Dr	Richard	Brinkman	Australian Institute of Marine Science, Australia
Dr	Le Van	Chinh	Ministry of Science and Technology of Viet Nam, Viet Nam
Mr	Michael	Cook	Department of Industry, Innovation and Science, Australia
Dr	Arnold	Dekker	CSIRO, Australia
Mr	Nathan	Eaton	NGIS Australia, Australia
Miss	Rose	Filipovic	Department of Industry, Innovation and Science, Australia
Ms	Tricia	Frake	Department of Industry, Innovation and Science, Australia
Mr	John	Gunn	Australian Institute of Marine Science, Australia
Dr	Barbara	Hayden	National Institute of Water & Atmospheric Research (NIWA), New Zealand
Dr	Alex	Held	CSIRO, Australia
Miss	Indi	Hodgson-Johnston	Integrated Marine Observing System, Australia
Mr	Vance	Hum	IMSG, United States
Ms	Louise	Jansen	Department of Industry, Innovation and Science, Australia
Dr	Kim	Juniper	Ocean Networks Canada, Canada
Ms	Grace	Kaue	Papua New Guinea Department of Justice & Attorney General
Dr	Boris	Kelly-Gerreyn	Bureau of Meteorology, Australia
Ms	Camila	Lagunas	Undersecretariat for Fisheries and Aquaculture, Chile
Ms	Agnes	Lane	Bureau of Meteorology, Australia
Dr	Adam	Lewis	Geoscience Australia, Australia
Dr	Adam	Lewis	Geoscience Australia, Australia
Dr	Shie-Yui	Liong	Tropical Marine Science Institute, National University of Singapore, Singapore
Prof	Jianbo	Liu	Institute of Remote Sensing and Digital Earth, CAS, China
Dr	Lyndon	Llewellyn	Australian Institute of Marine Science, Australia
Ms	Emma	Luke	Department of Industry, Innovation and Science, Australia
Dr	Vicente	Malano	Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA-DOS), Philippines
Dr	Stuart	Minchin	Geoscience Australia, Australia
Mr	Tim	Moltmann	Integrated Marine Observing System (IMOS), Australia
Dr	Tommy	Moore	Secretariat of the Pacific Regional Environment Programme
Dr	Van Quan	Nguyen	Institute of Marine Environment and Resources, Viet Nam Academy Of Science And Technology, Viet Nam
Mr	Chris	Ostrander	University of Hawaii, United States
Ms	Shannon	Owen	Australian Academy of Science, Australia
Ms	Namrata	Pingle	Department Of Industry, Innovation And Science, Australia
Dr	Matthew	Purss	Geoscience, Australia
Mr	Raja Bidin	Raja Hassan	SEAFDEC/MFRDMD, Department of Fisheries, Malaysia
Dr	Stephen	Rintoul	CSIRO and Antarctic Climate and Ecosystems Cooperative Research Centre, Australia
Dr	Antonio	Robles-Kelly	CSIRO-Data61, Australia
Mr	Jonathan	Ross	Geoscience, Australia
Prof	Peter	Steinberg	Sydney Institute of Marine Science, Australia
Dr	Andy	Steven	CSIRO, Australia
Mr	Gregory	Stuart	Australian Bureau Of Meteorology, Australia
Mrs	Jane	Urquhart	Department of Industry, Innovation & Science, Australia
Mr	Gaston	Vidal	Instituto De Fomento Pesquero, Chile
Dr	Kelly	Wade	Australian Institute of Marine Science, Australia
Mr	Wan Mohd Nazri	Wan Daud	Malaysian Meteorological Department, Malaysia
Mrs	Zdenka	Willis	U.S. IOOS, United States