Oceans and Society

Oceans and Society:
Blue Planet

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FOREWORD

BARBARA J. RYAN

"The sea, once it casts its spell, holds one in its net of wonder forever"
Jacques Cousteau

Oceans cover more than 70 percent of the Earth's surface, represent 99 percent of the planet's living space by volume and sustain life for nearly 50 percent of its entire species. The ocean works for us twenty-four hours a day, seven days a week, all year round, by producing much of the oxygen we breathe, absorbing the carbon that we create, recycling the water we drink and providing the majority of all the protein we eat. Whereas "only" 50 percent of the world population lives within 50 miles of the coast, we are all dependent on our coasts and ocean for our food, health, recreation and livelihood. Oceans and society are intricately and inextricably linked. Although humans benefit tremendously from the life-sustaining services the oceans provide, we need to increase awareness and understanding that our everyday actions impact on the ocean and its resources, and, therefore, on every one of us.

The Group on Earth Observations (GEO) is a voluntary, international, intergovernmental partnership dedicated to providing leaders in government, science, industry and civil society with accurate and timely Earth observation data and information to enable informed decision-making about the environmental challenges described above. GEO Member governments include 89 nations and the European Commission, and 67 Participating Organisations comprising international bodies with an interest or mandate in Earth observations. The GEO community is creating a Global Earth Observation System of Systems (GEOSS) that will link Earth observation resources worldwide across multiple Societal Benefit Areas, including water.

"Oceans and Society: Blue Planet" is an exciting new GEO initiative designed to:

- Raise public awareness of the role of the oceans in the Earth system, of their impacts (positive and negative) on humankind and of the societal benefits of ocean observations;
- Coordinate the various marine initiatives within GEO and develop synergies among them; and
- Advocate for and advance the establishment and maintenance of a global observing network for the oceans.

To manage our oceans and maintain ocean health and productivity, decision makers need clear, relevant, and up-to-date information. Citizens are both hungry to know, and eager to be involved actively in supporting, ocean policy and management. Scientists have the responsibility to provide the necessary building blocks for making intelligent choices and instituting good governance. We cannot do this important work without numerous national and international partnerships, collaborations and networks, and this is where the GEO "Oceans and Society: Blue Planet" initiative can play a vital role.

Sound decision-making requires that scientific knowledge be shared with society and, ultimately, with the various national and international political institutions. This book aims to provide this broader audience with information on the relevant elements of ocean observations and scientific research, as well as examples of the multiple ways in which oceans benefit society. In so doing, it is my hope that this book will contribute to bridging the existing gaps between oceans and society.

Barbara J. Ryan
Director GEO Secretariat

PREFACE

TREVOR PLATT

This book is a contribution to the activities of GEO, an intergovernmental body dedicated to developing the societal benefits of observing the Earth, either directly (*in situ*) or through the use of remote sensing. GEO is structured around nine societal-benefit areas; within each a series of Tasks is established to accomplish the overall Work Plan.

Although the oceans play important roles in each of the nine societal-benefit areas, marine affairs were initially less prominent in GEO than they deserved to be because there was no mechanism to link all of the ocean-related activities. While "green" is the colour associated with environmental responsibility and respect for planet Earth, Earth is, in fact, a "blue" planet. Exercising knowledge-based stewardship requires up-to-date information about the ocean, as well as the land and atmosphere. Therefore, it was important that, in setting its agenda, GEO recognise the importance of oceans in the Earth system.

The Partnership for Observation of the Global Oceans (POGO) lobbied strenuously over several years to stimulate a greater prominence for oceans within GEO. In May 2011, POGO submitted to the GEO Work Plan Symposium the prospectus for a new umbrella Task that would integrate and coordinate all the marine initiatives then active in GEO, as well as a number of new ones. The plan was adopted by GEO and the new Task "Oceans and Society: Blue Planet" was born, with the following mission:

The "Oceans and Society: Blue Planet Task" of GEO seeks, through the mobilisation of expert knowledge to:

- Raise public awareness of the role of the oceans in the Earth system, of their impacts (good and bad) on humankind and of the societal benefits of ocean observations;
- Coordinate the various marine initiatives within GEO and develop synergies between them; and
- Advocate and advance the establishment and maintenance of a global observing network for the oceans.

Already at the kick-off Symposium, held in Ilhabela, Brazil in November 2012, enthusiasm for Blue Planet was very strong; the new Task was definitely responding to a need. The Symposium marked the first time that all marine facets of GEO had been represented in the same room. It was an unprecedented opportunity to develop synergies among the different elements, and those who took part really felt that they had attended a landmark event.

Participants and organisers resolved to write a book showing the scope and applications of observing the ocean. This book, arising from the meeting, goes beyond mere conference proceedings. It illustrates the breadth and vitality of Earth observation in the ocean arena. It should provide a reference point, not just for marine scientists, but also for all those concerned with operational oceanography and stewardship of marine resources. The book provides an overview of the value of Earth observation in the marine sphere, from scientific advances to societal applications. It is a rich spectrum.

The Ilhabela Symposium would not have been possible without the support of the Canadian Space Agency (CSA). CSA had been funding GEO-related international programmes (SAFARI, Societal Applications in Fisheries and Aquaculture of Remote-sensing Imagery, and ChloroGIN, Chlorophyll Globally Integrated Network) for some five years; both programmes are now important elements of Blue Planet.

As Blue Planet emerged as the most significant activity in Earth observation for marine applications, CSA readily agreed to a revised funding plan that supported the Ilhabela Symposium. I am most grateful to Yves Crevier for his help in bringing this about and I hope the book will show that it was a wise decision.

Sophie Seeyave (POGO), Keith Alverson (IOC/GOOS), Boram Lee (WMO) and Douglas Cripe (GEO) helped steer the Blue Planet proposal through the approval stages at the GEO Work Plan Symposium and I thank them all. In Canada, I am grateful to Venetia Stuart (IOCCG) and Li Zhai (BIO) for their help in planning the Symposium. Shubha Sathyendranath has contributed at every stage in the evolution of Blue Planet. Milton Kampel was a wonderful local host in Brazil.

Samy Djavidnia played a vital role in helping to structure the outcomes of the Symposium, including the editing of the book, in which he was assisted by Sophie Seeyave, Vikki Cheung and Michael Ott. Albert Fischer (IOC/GOOS) presented the results of the Symposium to the GEO Plenary meeting that followed and thus helped build credibility for the fledgling Task. I thank Barbara Ryan, the new Director of GEO, for finding the time to attend the Symposium in her demanding schedule and

so contribute to building confidence in Blue Planet. It was highly gratifying that so many people willingly helped in various ways to make the Symposium an undoubted success, including as authors of the chapters in this book. I am indebted to each of them.

Trevor Platt
Blue Planet Task Leader
and POGO Executive Director

PART I

INTRODUCTION

CHAPTER ONE

THE BLUE PLANET INITIATIVE

SAMY DJAVIDNIA, SOPHIE SEEYAVE
AND TREVOR PLATT

Our society faces a number of crucial challenges. Climate change is one of the biggest threats; sustainable management of our diverse ecosystems to enable mitigation and adaptation to these changes is imperative. Although we are accustomed to thinking that "green" is associated with environmental responsibility and protection of our Earth, Earth is in fact a "blue" planet, covered three quarters by water. As such, we need to be aware of, and understand what is happening to, both parts of the Earth's ecosystem: water as well as land. Understanding and conservation of the marine ecosystem are such essential components of global economic growth and prosperity, that the concepts and objectives of "sustainable development" make sense only if the ocean is fully incorporated.

GEOSS is a global, coordinated, comprehensive and sustained "system of observing systems" for observing the Earth on all relevant scales. Its main objective is to provide decision support tools to a wide variety of users in nine Societal Benefit Areas (SBAs). Although GEOSS is intended to cover all aspects of Earth observation, and, in this way, introduces new capabilities for monitoring and providing data on environmental processes, the Ocean component is considered a horizontal Task which spans all nine of the SBAs: Biodiversity, Ecosystems, Climate, Weather, Water, Disasters, Health, Energy and Agriculture.

The new GEO 2012–2015 Work Plan adopts a strategic target-driven structure, based on the following three pillars: 1) Infrastructure; 2) Institutions and Development, and; 3) Information for Societal Benefits. The "Information for Societal Benefits" pillar focuses on the information, services and end-to-end systems needed to support decision making across the nine SBAs. Within this pillar, the "Oceans and Society: Blue Planet" Task implements programmatic actions aimed at:

- Providing sustained ocean observations and information to underpin the development, and assess the efficacy, of global-change adaptation measures.
- Improving the global coverage and data accuracy of coastal and open-ocean observing systems.
- Coordinating and promoting the gathering, processing and analysis of ocean observations.
- Establishing a global ocean information system by making observations and information, generated on a routine basis.
- Developing a global operational ocean-forecasting network.
- Providing advanced training in ocean observations, particularly for developing countries.
- Raising awareness of biodiversity issues in the ocean.

The Blue Planet Task is a comprehensive initiative with six main Components:

- C1: Sustained Ocean Observations;
- C2: Sustained Ecosystems and Food Security;
- C3: Ocean Forecasting;
- C4: Services for the Coastal Zone;
- C5: Climate and Carbon;
- C6: Developing Capacity and Societal Awareness.

The Task Components are led primarily by the Partnership for Observation of the Global Oceans (POGO), the Committee on Earth Observation Satellites (CEOS), the Global Ocean Observing System (GOOS), the Global Ocean Data Assimilation Experiment (GODAE) OceanView, and the Coastal Zone Community of Practice (CZCP).

The first effort to bring all of these different ocean (and freshwater) observing elements together was the Kick-Off Symposium in Ilhabela, São Paulo, Brazil, which took place from 19–21 November 2012. The Symposium highlighted each of the Task Components through special sessions on their programme elements and addressed a broad range of themes. The objectives of the Symposium were to:

- Learn about the diverse on-going activities;
- Better coordinate the ocean-related Tasks within GEO;
- Speak with a common voice to GEO member nations and participating organisations at the subsequent GEO Plenary in Foz do Iguaçu, Brazil;

- Raise awareness of societal benefits of ocean observations in the broader community, targeting, in particular, policymakers, and funding agencies;
- Seek new avenues for enhancing implementation of ocean observation systems; and
- Promote capacity-building globally, particularly in developing countries.

The Symposium brought together a total of 68 participants from 24 countries, comprising leaders and representatives of various international organisations and networks, research scientists and postdoctoral and graduate students. The Symposium offered the opportunity for participants to become familiar with the full scope of the "Oceans and Society: Blue Planet" Task, to develop synergies and to plan future activities. It also helped distil a clear and strong message about the way forward from the ocean community to the 2012 GEO IX Plenary (held in Foz do Iguaçu, Brazil, immediately following the Symposium). The meeting turned out to be a landmark event in the development of marine work within GEO.

This book, based on the aforementioned GEO themes and marine-related Tasks discussed at the Symposium, summarises the proposed current and future actions needed to further develop and implement the Blue Planet agenda.

This book, as was the Symposium, is structured around the Task Components, though the number of Components has grown from four to six as the Task has continued to evolve. Chapter 2 provides the GEO and GEOSS context in which the Blue Planet is embedded. Parts II to VII each comprise a number of chapters covering various aspects of each Task Component. Neither the Symposium nor the book are an exhaustive overview of the wealth of projects that are being undertaken worldwide in ocean observations and marine ecosystem and fisheries management. Rather, they are a first attempt to bring some of these projects together under a common umbrella, with the hope of entraining others as the Task evolves.

As the Blue Planet concept gathers momentum, the need for ocean indicators to provide information to citizens and society becomes fundamentally important. A shift to a paradigm under which we are able to deliver "ocean-type services" in support of all nine SBAs of GEO is required. To accomplish this, we need to listen to, and work closely with, users across the globe. This will entail a new approach, where cooperation and coordination become increasingly important, and where ocean science meets society to address issues of relevance to citizens in all nine SBAs.

The Blue Planet has recently launched its website (http://www.oceansandsociety.org), where more information on the Task can be accessed, its products downloaded and ideas both promoted and shared.

We hope this book will provide stimulating material and attract both scientists and non-experts to the field of ocean observation and marine ecosystem management. Finally, we anticipate that the book will be a valuable resource for national and international stakeholders within the marine community, including policymakers, scientists, and operational and environmental managers.

CHAPTER TWO

GEO, GEOSS AND THE 2012–2015 WORK PLAN

DOUGLAS CRIPE

In 2002, the World Summit on Sustainable Development, held in Johannesburg, South Africa, called for the integration of global observations through strengthened cooperation and coordination among global observing systems and research programmes, to help address the challenges articulated in its Plan of Implementation. These challenges included understanding the Earth system in order to enhance human health, safety and welfare, alleviate human suffering, protect the global environment and achieve sustainable development. Likewise, the summary of outcomes of the G8 Summit held in Evian, France (2003) called for strengthened international cooperation on global observation of the environment.

Following three Earth Observation Ministerial Summits (Washington DC, 2003; Tokyo, 2004; Brussels, 2005), GEO was created in 2005 as a non-binding intergovernmental partnership, with a commitment to respond to these calls through the establishment of a comprehensive, coordinated, and sustained Global Earth Observation System of Systems (GEOSS), to deliver data and information for informed decision making. GEOSS is designed to be a distributed system of systems, building on current cooperation efforts and coordination mechanisms among existing observing and processing systems, while encouraging and accommodating new components. The development of GEOSS, guided by a 10-Year Implementation Plan, is being achieved through improving and coordinating observation systems, advancing broad and open data policies and practices, fostering increased use of Earth observation data and information and building capacity. GEOSS encompasses all areas of the world and covers *in situ*, airborne, and space-based observations. Through the inclusion of a broad range of user communities, including managers and policymakers, scientific researchers and engineers, civil society,

governmental and non-governmental organisations and international bodies, GEOSS is delivering information needed for informed decision-making in nine Societal Benefit Areas: Agriculture, Biodiversity, Climate, Disasters, Ecosystems, Energy, Health, Water and Weather.

Membership in GEO is open to all Member States of the United Nations. It also welcomes, as Participating Organisations (subject to approval by GEO Member States), governing bodies of the UN Specialised Agencies and Programmes, as well as intergovernmental, international and regional organisations with a mandate in Earth observation or related activities. Today, GEO counts 90 Member States and 67 Participating Organisations from across the globe, including both developed and developing nations. The main decision-making body is the full GEO Plenary, which comprises of Members and Participating Organisations and meets annually.

In its strong advocacy for broad and open data policies, GEO has established Data Sharing Principles to which its Member States and participating organisations adhere: full and open exchange of data and data and products available with minimal time delay and at minimum cost (i.e., free of charge or cost of reproduction for research and development use). The GEO Portal provides a user interface with the GEOSS Common Infrastructure (GCI), designed to facilitate the sharing of observation data and information products. The GEONETCAST system ensures that those with limited or no internet access also can have access to an increasing proportion of these data.

The GEO Work Plan provides the agreed framework through which to engage the GEOSS 10-Year Implementation Plan. It is a living document, updated annually, that represents the compendium of activities carried out, on a voluntary basis, by the Members and Participating Organisations towards the implementation of GEOSS. Specific gaps being targeted by activities of the GEO Work Plan include the uncertainty over continuity of observations, large spatial and temporal gaps in specific data sets, limited access to data and associated benefits in the developing world, inadequate data integration and interoperability, lack of relevant processing systems to transform data into useful information, inadequate user involvement and eroding or limited technical infrastructure in many parts of the world.

The activities or “Tasks” of the Work Plan are organised into three major areas according to the key objectives of GEOSS implementation to which they contribute:

- Infrastructure: the physical cross-cutting components of an operational and useable GEOSS, including interoperable observing, modelling and dissemination systems;
- Institutions and Development: describing "GEO at work" and the community's efforts to ensure that GEOSS is sustainable, relevant and widely used, with a focus on data sharing, resource mobilisation, capacity development, user engagement and science and technology integration;
- Information for Societal Benefits: the information, tools and end-to-end systems that will be made available through GEOSS to support decision-making across the nine SBAs.

In Summary: The Global Earth Observation System of Systems (GEOSS) is a coordinating and integrating network of Earth observing and information systems, to which Members States and Participating Organisations of GEO contribute on a voluntary basis, to support informed decision making for society, including the implementation of international environmental treaty obligations.

PART II

SUSTAINED OCEAN OBSERVATIONS

CHAPTER THREE

INTERNATIONAL COORDINATION OF SATELLITE OBSERVATIONS OF THE OCEAN

KERRY ANN SAWYER

Introduction

An improved understanding of the ocean system – weather, climate, ecosystems, natural resources, bathymetry and natural and human-induced hazards – is essential to better predict, mitigate, and adapt to, the expected changes to the oceans and their impacts on society, at both local and global levels. Earth observation data and derived information provide the evidence necessary for informed decision making. These support the science that underpins strategy development for local and global environmental decision making, and for monitoring progress on all geographical scales. Producing better information on the ocean environment has become a worldwide priority. International partnerships and coordination are essential to achieving this goal, because no country can monitor the vast expanse of the oceans by itself and understanding the complexities of the oceans requires global programmes and combined expertise. There are a number of key international coordination mechanisms for space-based ocean observations, including: the GEO Global Earth Observation System of Systems (GEOSS); the Global Climate Observing System (GCOS); the International Ocean Colour Coordinating Group (IOCCG); the Group on High Resolution Sea Surface Temperature (GHRSST); and the Committee on Earth Observation Satellites (CEOS). The focus of this chapter will be on CEOS and the roles it plays in international coordination of satellite observations of the ocean.

International Cooperation

Bringing space-based sensors, ground-based data analysis systems and skilled experts together requires a well-coordinated international effort and

a strong commitment from space agencies. CEOS is dedicated to international collaboration among space systems and Earth observation missions and addresses the needs of the ocean community. CEOS Agencies strive to address critical scientific questions and to develop national satellite programmes with common standards and systems that can provide data to the international community, avoiding unnecessary overlaps between the different Agencies' satellite missions. CEOS ensures technical coordination among Agencies on issues concerning the usability of Earth observation data acquired by diverse systems, including coordinated access to data, inter-calibration of multiple sensors and coordination of multi-mission blended products.

CEOS, established in 1984, is an international body uniquely capable of coordinating the broad spectrum of space-based Earth observation activities. CEOS participants include government organisations that develop and operate civil Earth observation satellites (Members) and other coordinating groups and scientific or governmental organisations that support CEOS's mission (Associates). The three primary objectives of CEOS are:

1. To optimise the benefits of space-based Earth observation through cooperation of CEOS Agencies in mission planning and in the development of compatible data products, formats, services, applications and policies.
2. To aid both CEOS Agencies and the international user community by, among other things, serving as the focal point for international coordination of space-based Earth observation activities, including GEO and entities related to global change.
3. To exchange policy and technical information to encourage complementarity and compatibility among space-based Earth observation systems currently in service or development and the data received from them, as well as address issues of common interest across the spectrum of Earth observation satellite missions.

CEOS has a three working-level mechanisms to achieve the objectives listed above: CEOS Virtual Constellations; CEOS standing Working Groups; and CEOS *ad hoc* Working Groups.

CEOS Virtual Constellations typically consist of multiple space- and ground-based systems that operate together in a coordinated manner to meet a common set of observational requirements in a well-defined thematic Earth observation domain to meet societal needs. These Virtual Constellations (VCs) demonstrate the value of collaborative partnerships in addressing key observational gaps and sustaining routine collection of

critical observations. There are seven CEOS VCs, of which four include marine elements: Ocean Colour Radiometry (OCR-VC); Ocean Surface Topography (OST-VC); Ocean Surface Vector Wind (OSVW-VC); and Sea Surface Temperature (SST-VC).

CEOS Working Groups typically address topics such as calibration and validation of space-based instruments and ground-based processing, common data processing standards, capacity building and data sharing, and facilitating the implementation and exploitation of time series of Essential Climate Variables (ECVs). The joint CEOS and Coordination Group for Meteorological Satellites (CGMS) Working Group on Climate (WGClimate) plays a key role in the coordination of satellite ocean observations in monitoring the oceanic ECVs and will be discussed in more detail below.

Ad hoc Working Groups are created to undertake a particular activity in support of a short-term objective. The CEOS Carbon Task Force (CTF) was established to coordinate the response from space agencies (the *Carbon Observations from Space*) to the GEO Carbon Strategy Report. This response will address the potential of space observations to monitor pools and fluxes of carbon in the ocean, land and atmospheric domains, in the context of climate change, and will provide a basis for systematic carbon observations from space and reporting of progress towards satisfying society's need for carbon information.

CEOS is deeply committed to GEO and to implementing GEOSS. This commitment is reflected in the large scale and broad scope of CEOS Agency resources allocated on a best efforts basis annually to GEO activities, including the Blue Planet Task, the Virtual Constellations and the GEO Carbon Strategy Report.

CEOS, a Participating Organisation in GEO and the "space component of GEO", established the concept of Virtual Constellations in 2006 in order to harmonise efforts among space agencies to deploy Earth observation missions, to close emerging data gaps and to contribute to GEOSS, which includes *in situ*, remotely sensed, and space-based observations. The information below, which outlines the four Virtual Constellations, is directly quoted from the *CEOS Virtual Constellations Process Paper* (updated November 2013).

The CEOS Constellation for Ocean Colour Radiometry (OCR-VC)

The objective of the OCR-VC is to provide a time series of calibrated aquatic radiances at key wavelengths from ocean colour satellite sensors.

Well-calibrated aquatic radiances enable the estimation of many optical, biological, biogeochemical and ecological properties of Earth's aquatic environments. Activities include on-orbit and vicarious calibration, data validation, merging of satellite and *in situ* data, product generation, as well as development and demonstration of new and improved applications for scientific and management purposes.

The CEOS Constellation for Ocean Surface Topography (OST-VC)

The objective of the OST-VC is the implementation of a sustained, systematic capability to observe the topography of, and the significant wave height on, the surface of the global oceans ranging from basin-scale to mesoscale. The OST-VC focuses on global sea level rise, the role of the oceans in climate, and operational oceanography.

The CEOS Constellation for Ocean Surface Vector Winds (OSVW-VC)

The objective of the OSVW-VC is the implementation of a sustained, systematic capability to observe the wind field at the surface of the oceans from basin-scale to mesoscale. It focuses on the role of ocean surface wind fields in operational oceanography and meteorology, such as in supporting improvements in operational marine warnings and forecasts through the use of ocean surface vector winds from satellite scatterometry (together with significant wave height, SWH, from the OST-VC). OSVW also characterises the OSVW field for use in climate-quality data records and facilitates research related to the influence of wind forcing on the circulation of the oceans.

The CEOS Constellation for Sea Surface Temperature (SST-VC)

The objective of the SST-VC is the development and improvement of SST products, including the SST Essential Climate Variable. SST-VC seeks to develop and implement metrics for SST services, products and users, to improve calibration and validation of the relevant instruments, and to develop training activities for satellite SST practitioners. The SST-VC serves as the formal link between CEOS and GHRSST.

Links to Societal Benefits: Climate and Carbon

GCOS has identified 48 ECVs that must be routinely monitored to meet requirements set forth under the United Nations Framework Convention on Climate Change (UNFCCC) and to contribute to the reports of the Intergovernmental Panel on Climate Change (IPCC). The *2010 GCOS Implementation Plan (GCOS IP-10), 2011 Satellite Supplement to the GCOS Implementation Plan*, and the *2012 CEOS Response to the GCOS Implementation Plan* provide detailed information on the ECVs as well as identifies the Actions that CEOS Space Agencies are undertaking to observe and monitor the ECVs.

Table 3-1: ECVs where satellite observations can make a significant contribution to coordinated outputs for monitoring of ECVs

Domain	Essential Climate Variables
Atmospheric (over land, sea, and ice)	Surface wind speed and direction; Precipitation; Upper-air temperature; Upper-air wind speed and direction; Water vapour; Cloud properties; Earth radiation budget (including solar irradiance); Carbon dioxide; Methane and other long-lived greenhouse gases; Ozone and Aerosol properties, supported by their precursors.
Oceanic	Sea-surface temperature; Sea-surface salinity; Sea level; Sea state; Sea ice; Ocean colour.
Terrestrial	Lakes; Snow cover; Glaciers and ice caps; Ice sheets; Albedo; Land cover (including vegetation type); Fraction of absorbed photosynthetically active radiation (FAPAR); Leaf area index (LAI); Above-ground biomass; Fire disturbance; Soil moisture.

The CEOS Working Group on Climate was created in 2009, and became a joint Working Group with CGMS in 2013, to coordinate and encourage collaborative activities among the CEOS Space Agencies and CGMS Meteorological Agencies in the area of climate monitoring. One of the main foci of the WGClimate is to facilitate the implementation and exploitation of ECVs through the coordination of the existing activities in the area of climate monitoring currently being undertaken by CEOS and CGMS Agencies. One of the key external stakeholders and partners of CEOS and CGMS is GCOS, with which WGClimate works very closely.

Because satellites routinely observe the entire Earth, whether circling the globe in polar orbits or focussing on a single region from geostationary orbits, they provide data and measurements to support the consistent

monitoring of ocean-related ECVs. The OCR-VC, OST-VC, OSVW-VC, and the SST-VC are working very closely with the CEOS-CGMS WGClimate to develop a space-based climate information strategy, and especially to provide critical information on changes in global sea level, ocean surface vector winds, ocean colour, and SST.

Table 3-2: Overview of oceanic products that are being developed by satellite sensors

ECV	Global Product	Satellite Sensor Type
Sea Surface Temperature	Integrated SST analyses based on satellite and *in situ* data records	Infrared, Microwave
Sea Level	Sea level global mean and regional variability	Microwave
Sea State	Wave height, wind speed and direction and other measures of sea state	Altimeter
Sea Ice	Sea-ice concentration, extent, edge, supported by thickness and drift	Microwave, Visible Imager, Radar, Lidar, Synthetic Aperture Radar, Altimeter
Ocean Colour	Ocean radiometry, chlorophyll-*a*	Multispectral Visible Imager

Some of the key initiatives in ECV and climate data record (CDR) generation currently being undertaken by the four ocean-themed VCs include:

- SST-VC: generation of ECVs and CDR in collaboration with established requirements of the National Oceanic and Atmospheric Administration (NOAA) Climate Data Record Program, the European Space Agency's Climate Change Initiative (ESA CCI) Requirements, and GHRSST.
- OCR-VC: generation of ECVs and CDR in collaboration with the IOCCG.
- OST-VC: collaborating with the International Ocean Surface Topography Science Team in developing sea-level products and future mission planning.
- OSVW-VC: very operationally focused and is currently addressing the needs of the operational marine forecasting community in acquiring quality wind speed and direction data on a routine basis.

CEOS established the CTF in 2009 to coordinate the response from space agencies to the GEO Carbon Strategy Report, the *CEOS Response to the GEO Carbon Strategy*, and to:

- Take into account information requirements of both the UNFCCC and IPCC and consider how future satellite missions will support them;
- Take account of, and be consistent with, the GCOS Implementation Plans and the GEO 2012–2015 Work Plan;
- Help define the next generation carbon observing missions for individual agencies; and
- Provide a basis for systematic observation and reporting of progress towards satisfying society's need for carbon information.

The CEOS Response, which is to be released in early 2014, will address the three major domains – atmosphere, land, and oceans – and their interrelationships. Each domain chapter will include a number of Actions and Recommendations for CEOS Agencies. Some of the proposed Actions and Recommendations related to the ocean domain include: ensuring the continuity of satellite missions with adequate and sustained on-board calibration and validation operations; ensuring the high spatial resolution observations of the often turbid coastal water for analysing phytoplankton blooms; and encouraging space agencies to develop and validate products that include the ocean carbon pool.

Conclusion

CEOS is engaged in the analysis of Space Agency contributions to monitoring marine ECVs, to develop and implement space-based climate information strategies (the *CEOS Response to the GCOS IP* and the *CEOS Response to the GEO Carbon Strategy*) and especially to provide critical information on changes in global sea level, ocean surface vector winds, ocean colour, and SST, and to identify the role of the oceans in the carbon cycle and how best to define a strategy for the next generation of CEOS Agency satellite missions to meet society's needs for carbon information. CEOS is dedicated to international collaboration among space systems and Earth observation missions. It provides the multilateral coordination that enables achievement of CEOS Agency goals and addresses the needs of the ocean community.