OCEANS AND THE LAW OF THE SEA: REPORT OF THE SECRETARY-GENERAL – PART II (2016)

CONTRIBUTION OF WMO

EXECUTIVE SUMMARY

The World Climate Research Programme (WCRP), continues to coordinate the Coupled Model Intercomparison Experiment Project (CMIP), now in its 6th phase, to better understand past, present and future climate changes arising from either natural, unforced variability or in response to changes in radiative forcing in a multi-model context. Among the Grand Science Challenges addressed by WCRP, "Regional Sea Level Change and Coastal Impacts" addresses the need for integrated interdisciplinary approach for quantitative understanding of regional to local sea level variability, to foster the development of sea level predictions and projections for coastal zone management. The Grand Challenge on "Understanding and Predicting Weather and Climate Extremes" invigorates community-wise efforts to improve understanding, assessment and prediction of weather and climate extremes, such as coastal storms. [A/RES/70/235, para 187]

The latest analysis of observations from the WMO Global Atmosphere Watch (GAW) Programme shows that atmospheric CO2 reached 143% of the pre-industrial level in 2014, primarily because of emissions from combustion of fossil fuels and cement production, deforestation and other land-use change. The main sinks for CO2 emissions from fossil fuel combustion are the oceans and terrestrial biosphere. Uptake of CO2 by the ocean leads to ocean acidification (see *WMO Greenhouse Gas Bulletin* 2014). [A/RES/70/235, paras 18, 172]

Recognizing the growing need for data and research related to understanding of greenhouse gas budgets on enhanced temporal and spatial scales to support implementation of the COP 21 agreement and provision of climate services, the 17th WMO Congress adopted a resolution on the implementation of the Integrated Global Greenhouse Gas Information System (IG3IS). The implementation of IG3IS relies on the globally harmonized observations of GHGs and will require the development of high resolution and complex observing systems, modelling tools and data assimilation techniques, entailing collaboration with organizations and institutions that address the carbon budget of biosphere and ocean. [A/RES/70/235, paras 18, 172]

The Coastal Inundation Forecasting Demonstration Project (CIFDP) is a multi-hazard warning system that promotes an integrated approach in the enhancement and delivery of early warnings, no matter what the causes for coastal inundations are, in line with the concept of impact-based forecasting and the UN Sendai Framework for Disaster Risk Reduction (DRR). The CIFDP is currently underway in four sub-projects (Bangladesh, Dominican Republic, Fiji and Indonesia), three of which are in urban coastal settings. Substantial progress to date has been made in each of these CIFDP sub-projects since 2013. [A/RES/70/235, para 187]

The 17th WMO Congress reiterated the importance to address ship security and piracy, and prevention of vandalism to data buoys, requesting the Secretary-General to organize a second WMO-IMO high level meeting in 2016/2017 to safeguard the buoys at sea, and further urged Members to follow recommendations of the Data Buoy Cooperation Panel (DBCP) Technical Document No. 41, *Ocean Data Buoy Vandalism – Incidence, Impact and Responses*. [A/RES/70/235, para 259]

INTRODUCTION

WMO is the authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources. The Oceans provide essential natural resources to human beings, and regulate the global climate. WMO contributes to oceans-related issues through the observation and monitoring of the ocean and climate; research on the climate and Earth systems; development and delivery of services for disaster risk reduction, including marine hazards; provision of science-based information and tools for policymakers and the general public at regional and global levels.

WMO continues strengthening the global observing systems through implementation of the WMO Integrated Global Observing System (WIGOS) and WMO Information System (WIS), and observing networks with partners. The WMO-ICSU-IOC-UNEP Global Climate Observing System (GCOS) serves the requirements of Members for comprehensive, continuous, reliable climate data and information, for climate monitoring, research, projections and assessments, to provide climate information and to promote sustainable development. The IOC-WMO-UNEP-ICSU Global Ocean Observing System (GOOS) improves its capabilities in climate- and ocean-related services, and recognizes the importance of coastal observations and links to products for societal benefits.

WMO, jointly with IOC-UNESCO and ICSU, coordinates the World Climate Research Programme (WCRP), which takes major challenges in climate research that reflect the complexity and interactions among the major components of the planet – ocean, atmosphere, land and ice. The WCRP Grand Challenges focus on those high-priority research, in close partnership with IOC and other national and international entities; the WCRP Grand Challenges on Regional Sea Level Change and Coastal Impact, as well as on Understanding and Predicting Weather and Climate Extremes (e.g. coastal storms). The Global Atmosphere Watch (GAW) continues its contribution on the latest trends and atmospheric burdens of the most influential, long-lived greenhouse gases, and has published its implementation plan 2016–2023.

WMO continues its collaboration with IMO and IHO for coordinated and standardized metocean information, forecasts and warning services for safety of life and property at sea, improved marine environment and sustainable management of natural resources, with due focus on Polar Regions. WMO through the work of the Marine Meteorology and Oceanography Programme coordinates and implements the Coastal Inundation Forecasting Demonstration Project (CIFDP) among others, to protect livelihoods and support the sustainable development of coastal communities.

WMO contributes to the global development agenda through its programmes and initiatives. The 17th World Meteorological Congress established new Small Island Developing States programme to consolidate WMO actions and activities for improved weather and climate services in SIDS and Member Island Territories. In the context of the Third World Conference on Disaster Risk Reduction to develop the Sendai Framework for DRR, WMO with multiple stakeholders in the UN system and beyond advocated to substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments, including for marine hazards, by 2030. WMO advocated also the established of an International Network for Multi-hazard Early Warning Systems (IN-MHEWS), and is now working extensively on engaging interested stakeholders, partners and organizations to develop and facilitate IN-MHEWS.

DEVELOPMENTS RELATING TO INTERNATIONAL SHIPPING ACTIVITIES

1. WMO continued to work with the International Maritime Organization (IMO) and the International Hydrographic Organization (IHO) for the provision of marine safety information services in the context of the World Wide Met-Ocean Information and Warnings Service (WWMIWS) and the Global Maritime Distress and Safety System (GMDSS). Work is being undertaken to fully review the Manuals and Guides which provide the standards, recommended practices and guidance for services in the marine sector, principally WMO-No. 558 and WMO-No. 471, and in particular on the role of the Metarea Coordinators, as outlined in the IMO Resolution A.1051 (27). In this regard, WMO governing bodies have called further on Members to support the

introduction of competency standards into marine forecasting and support the compliance to these standards within their National Meteorological and Hydrological Services and to introduce impact-based services into the marine sector, whilst ensuring that services continue to meet requirements outlined in the International Convention for the Safety of Life at Sea (SOLAS). Met-Ocean Forecasting services are also promoted in alignment with the WMO services delivery strategy and roadmap for marine services, including compliance with the future seamless Global Data-processing and Forecasting Systems (GDPFS), and its updated manual. [A/RES/70/235, para 145]

MARINE SCIENCE AND TECHNOLOGY

Marine science, observations and services

2. WMO is collaborating with partner organizations such as the IOC of UNESCO to further develop, optimize and maintain in complement to satellite observations and remote sensing technology, *in situ* marine meteorological and oceanographic (metocean) observing networks in support of applications such as weather forecasting and operational meteorology, the monitoring, understanding and prediction of climate variability and climate change at various time scales, ocean forecasting and marine services activities, the protection and sustainable development of the ocean and marine environment, and the efficient management of marine resources, including disaster risk reduction in coastal regions. In face of evolving requirements and advances in observing technology, and in response to GCOS requirements in particular, the WMO and the IOC of UNESCO through JCOMM are revising observing network implementation targets and addressing the means to reach those targets in the most cost-effective way.

3. Today's global ocean observing system relies on composite observing networks comprising meteorological and oceanographic satellites, coastal high frequency radars, and thousands of observing platforms in the global ocean and coastal regions, including drifting and moored data buoys, ice buoys, profiling floats, sub-surface ocean gliders, surface wave gliders, tide gauges, Tsunameters, and voluntary observing ships. Assuring sustainability of metocean observing systems and the required exchange of the collected data on free and unrestricted basis is also critical for addressing the user requirements, and particularly those for disaster risk reduction.

4. The 17th World Meteorological Congress reiterated the importance to address ship security and piracy, and prevention of vandalism to data buoys, requesting the Secretary-General to organize a second WMO-IMO high level meeting in 2016/2017 to safeguard the buoys at sea, and further urged Members to follow recommendations of the Data Buoy Cooperation Panel (DBCP) Technical Document No. 41, *Ocean Data Buoy Vandalism – Incidence, Impact and Responses*. [A/RES/70/235, para 259]

5. Collaboration with the maritime industry is critical to maintain the ocean observing arrays as it provides opportunities for making observations from ships, or for deploying or servicing autonomous observing platforms at sea. While good progress was made since the beginning of the century to complete the global ocean observing systems (two third completed), much efforts remain to be made to reach the implementation targets for some of the observing networks.

6. The GCOS-GOOS- WCRP Ocean Observations Panel for Climate (OOPC) is charged with delivering requirements for the Ocean Component of GCOS (Global Climate Observing System), the physics variables for GOOS (Global Ocean Observing System), and observations for the World Climate Research Programme (WCRP) in addition to scientific advice to the Joint WMO-IOC Commission for Oceanography and Marine Meteorology (JCOMM). Following the adoption of the work plan for 2013–2018 as a framework to inform engagement with partners and focusing panel activities around priority system evaluations, OOPC-19 was held 6-8th April 2016 in Esporles, Majorca overlapping with the JCOMM Observations Coordination Group. Main focus, the GCOS Implementation Plan, and a coherent approach and the development of Variable/Network Specification Sheets, particularly focussed on the articulation of missions and targets for networks. [A/RES/70/235, para 256]

7. WMO and IOC/UNESCO jointly coordinate through JCOMM global efforts to implement operational ocean forecasting services. A Marine Service Ad Hoc Working Group has been established since the 17th World Meteorological Congress to assess the work and future direction of WMO marine meteorology activities, including examining links to JCOMM, the cooperation between WMO, IOC/UNESCO, IMO and IHO and identifying positive engagement mechanisms with all relevant partners/stakeholders (both within WMO and externally) for improved service delivery in marine meteorology, whilst taking into account the needs of users beyond mariners.

SUSTAINABLE DEVELOPMENT OF OCEANS AND SEAS

Scientific information and assessments to support decision-making

8. A significant body of oceanographic research of direct benefit for decision-making in climate related risks is spearheaded and coordinated by the WMO-IOC/UNESCO-ICSU co-sponsored World Climate Research Programme (WCRP).[1] Through its scientific leadership to consolidate global and regional efforts to understand the dynamics, the interaction and the predictability of the coupled ocean-atmosphere system, significant improvement has been made in understanding climate variability and changes, as well as the benefit of society and the environment in which we live – such as predictive experiments for the future state of climate system and project how it will evolve under different emission scenarios.

9. WCRP continues to coordinate the Coupled Model Intercomparison Experiment Project (CMIP) that is one of the foundational elements of climate science, to better understand past, present and future climate changes arising from either natural, unforced variability or in response to changes in radiative forcing in a multi-model context. The 5th phase of CMIP (CMIP5, 2010–2013) provided essential dataset to support research compiled in the Report of IPCC entitled "Climate Change 2013: The Physical Science Basis"[2] (September 2013). The 6th phase, CMIP6[3], is structured to address three broad scientific questions in support of the WCRP Grand Scientific Challenges[4]: (1) how the Earth System respond to forcing; (2) the origins and consequences of systematic model biases; and (3) modality to assess future climate changes given climate variability, predictability and uncertainties in scenarios.

10. In support of decision making, WMO through WCRP supports climate science that underpins planning for future, and provides reliable source for metocean-climate services. Development of scientific methods for treatment of uncertainty in climate-related decision-making is one of key subjects of research conducted by WCRP; a WCRP Grand Science Challenge on "Regional Sea Level Change and Coastal Impacts"[5] addresses the imperative need for integrated interdisciplinary approach to establish quantitative understanding of regional to local sea level variability, to foster the development of sea level predictions and projections that are of increasing benefit for coastal zone management. The Grand Challenge on "Understanding and Predicting Weather and Climate Extremes" [6] invigorates community-wise efforts to improve understanding, assessment and prediction of weather and climate extremes, such as coastal storms. [A/RES/70/235, para 187]

11. WCRP and the Prince Albert II of Monaco Foundation (FPA2) are jointly promoting a Polar Challenge with a Prize money award of 500,000 Swiss francs to the first team able to complete a 2000km continuous mission under the sea-ice with an autonomous underwater vehicle in the Arctic or Antarctic. The start of the competition was formally announced at the Arctic Science Summit Week in March 2016. This challenge aims to promote innovation towards a cost-effective, scalable and sustainable monitoring system for the polar oceans.

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1 See http://www.wcrp-climate.org/.
2 See http://www.ipcc.ch/.
3 See http://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6.
4 See http://www.wcrp-climate.org/grand-challenges.
5 See http://www.wcrp-climate.org/grand-challenges/gc-sea-level.
6 See http://www.wcrp-climate.org/grand-challenges/gc-extreme-events.

SMALL ISLAND DEVELOPING STATES

12. The 17th World Meteorological Congress (Geneva, 25 May – 12 June 2015) approved Resolution 5.3(2)/1 (Cg-17) to create a Programme for WMO Small Island Developing States (SIDS) and Member Island Territories. The new Programme will consolidate existing WMO activities to support improved weather and climate services in SIDS and Member Island Territories, with a view to increase their resilience to extreme weather events and other adverse climate change impacts. Through the Partnership established at the 3rd International Conference on Small Island Developing States in Samoa (1–4 September 2014), WMO aims at implementing the "Samoa Pathway" for: (1) improved delivery of weather and climate information services; (2) enhanced human and technical capacities at national and regional climate centres; (3) increased range of products and services delivery to stakeholders; (4) South-South/ North-South Cooperation fostered; and (5) expansion of the infrastructure required for weather and climate research and services.

CLIMATE CHANGE AND OCEANS

Mitigating the impacts of climate change

13. Carbon dioxide is the single most important anthropogenic greenhouse gas in the atmosphere.[7] It contributes ~65% to radiative forcing by long-lived greenhouse gases (LLGHGs) since pre-industrial time (1750). It is responsible for ~83% of the increase in radiative forcing over the past decade and ~82% over the past five years. The pre-industrial level of ~278 ppm represented a balance of fluxes between the atmosphere, the oceans and the biosphere. Observations at the marine and terrestrial ground based stations contributing to the Global Atmosphere Watch (GAW) Programme of WMO are used to assess globally averaged levels of CO_2 in the lower atmosphere. The sites (about 120) are operated by WMO Members.

14. The latest analysis of observations from the WMO GAW Programme shows that atmospheric CO_2 reached 143% of the pre-industrial level in 2014, primarily because of emissions from combustion of fossil fuels and cement production, deforestation and other land-use change. The globally averaged CO_2 mole fraction in 2014 was 397.7±0.1 ppm. The increase in global annual mean CO_2 from 2013 to 2014 of 1.9 ppm is smaller than the increase from 2012 to 2013, but close to the average growth rate for the past decade (~2.06 ppm yr^{-1}) and larger than the average growth rate for the 1990s (~1.5 ppm yr^{-1}). The smaller growth rate in 2014 compared to previous years is most likely related to the larger annual uptake of CO_2 by the terrestrial biosphere in tropical and subtropical regions. The average increase in atmospheric CO_2 from 2004 to 2014 corresponds to ~44% of the CO_2 emitted by human activity with the remaining ~56% removed by the oceans and the terrestrial biosphere. The mean CO_2 growth rate from 2014 to 2015 based on NOAA's globally averaged marine surface data was 2.99 ppm, exceeding the previous year's growth rate as well as the average growth rate for the past decade.[8] CO_2 concentrations recorded in the northern hemisphere (Mauna Loa Observatory) and southern hemisphere (Cape Grim and Casey Station) reached the 400ppm mark in 2015 and 2016, respectively. This jump in CO_2 was probably driven by increased emissions from fossil fuels as well as the impact of the recent El Nino, which reduced the capacity of plant life and other terrestrial systems to absorb CO_2.[9]

15. The main sinks for CO_2 emissions from fossil fuel combustion are the oceans and terrestrial biosphere. Uptake of CO_2 by the ocean leads to ocean acidification. The *WMO Greenhouse Gas Bulletin* No. 10 published in 2014 includes a section on ocean acidification and trends in ocean pCO_2. This section was jointly produced by the International Ocean Carbon Coordination Project of

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7 See *WMO Greenhouse Gas Bulletin* no. 11, 9 November 2015 (http://library.wmo.int/pmb_ged/ghg-bulletin_11_en.pdf).

8 See the National Oceanic and Atmospheric Administration's Trends in Atmospheric Carbon Dioxide (http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html#global_growth).

9 See WMO's Press Release (18 May 2016) "CO2 breaches milestone, drives warming" (http://public.wmo.int/en/media/news/southern-hemisphere-breaches-co2-milestone).

the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the Scientific Committee on Oceanic Research, and the Ocean Acidification International Coordination Centre of the International Atomic Energy Agency with support from WMO. According to the Bulletin during the last two decades ocean water acidity expressed as pH decreased by 0.0011–0.0024 units per year, and the amount of CO_2 dissolved in seawater (pCO_2) increased by 1.2–2.8 µatm per year for time series from several featured ocean stations. [A/RES/70/235, paras 18, 172]

16. WMO/GAW has been a long-time sponsor of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) Working Group on The Atmospheric Input of Chemicals to the Ocean (WG 38). WG 38 has published numerous studies related to the impact of atmospheric deposition of anthropogenic nitrogen to the ocean. Recent work includes a major summary paper on the current understanding of the impact of atmospheric nitrogen deposition on marine biogeochemical cycling and an upcoming article on comparing observation and model-based estimates of atmospheric nitrogen deposition to the ocean. WG 38 is also embarking on two new activities approved by GESAMP at its 42nd session (31 August to 3 September 2015, Paris): (1) an investigation of the changing atmospheric acidity and the oceanic solubility of nutrients, and (2) an investigation of the impact of ocean acidification on fluxes of non-CO_2 climate-active species. Workshops to initiate these activities will be held simultaneously in Norwich, UK in February 2017.

17. To ensure better coordination of CO_2 observations between atmospheric and ocean communities a special session on measurements of dissolved greenhouse gases and related ocean tracers was held at the 18th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases, and Related Measurement Techniques (GGMT-2015), on 13–17 September, 2015 in La Jolla, California. Requirements for network compatibility and recommendations for QA/QC procedures and ocean observations were reviewed.

18. Some atmospheric gases, like water vapour and CO_2, absorb and re-emit infrared energy from the atmosphere down to the surface. As the atmospheric concentration of CO_2 increases, water vapour and clouds act as fast feedbacks. The strong water vapour feedback means that for a scenario considering doubling of CO_2 concentrations from pre-industrial conditions, water vapour and clouds globally lead to an increase in thermal energy that is about three times that of LLGHGs. [10] The impact of water vapour in a changing climate is an area of uncertainty that the GAW Programme will take into consideration. The infrastructure for observations and applications of this focal area within GAW has not been defined yet.[11]

19. Recognizing the growing need for data and research related to understanding of greenhouse gas budgets on enhanced temporal and spatial scales to support implementation of the COP 21 (Paris) agreement and provision of climate services, the 17th World Meteorological Congress adopted a resolution on the implementation of the Integrated Global Greenhouse Gas Information System (IG^3IS). The implementation of IG^3IS fundamentally relies on the globally harmonized observations of GHGs and will require the development of high resolution and complex observing systems, modelling tools and data assimilation techniques. The Congress requested WMO Members to support the development, improvement and modernization of networks for observations of GHGs and co-emitted species; to ensure respective data submission within the period of time required to support IG^3IS; to cooperate on development of modelling tools for inverse modelling and anthropogenic greenhouse gas flux attribution; and to collaborate with organizations and institutions that address the carbon budget of biosphere and ocean. The working group tasked with the development of an IG^3IS implementation plan produced a draft concept paper. The concept was presented to major stakeholders, policy makers and user groups, and is to be approved by WMO 68th Executive Council. [A/RES/70/235, para 172]

20. WMO acknowledges that climate engineering covers a wide spectrum of technologies, each

[10] See *WMO Greenhouse Gas Bulletin* no. 11, 9 November 2015 (http://library.wmo.int/pmb_ged/ghg-bulletin_11_en.pdf).

[11] See GAW Implementation Plan 2016-2023: Research Enabling Services. (http://www.wmo.int/pages/prog/arep/gaw/documents/IPFinalDraftMay11.pdf).

with a different level of complexity, uncertainty and associated risk. The 17th World Meteorological Congress considered the issues related to climate engineering and agreed with a conclusion of the Commission for Atmospheric Sciences (CAS) that further research is needed to adequately understand the potential feasibility, the effectiveness and risks associated with various climate engineering techniques. Congress requested CAS to identify the gaps in scientific understanding on climate engineering and appropriate research to address such gaps in the form of a science assessment. The Congress further requested CAS to coordinate its contribution to such an assessment in close cooperation with IMO, IOC/UNESCO, IPCC, WCRP and other relevant international, academic and science bodies. WMO is of the opinion that the future could require a UN-wide framework to govern these activities as consequences could be global and irreversible, involving the atmosphere, land and oceans.

21. At its 42nd session, GESAMP agreed to establish a new working group (WG 41) on marine geoengineering under the lead of IMO with support from IOC/UNESCO and WMO and co-chaired by independent experts. The goal of the WG is to carry out an assessment of a wide range of marine geoengineering approaches for their potential environmental and socio/economic impacts on the marine environment (and the atmosphere where appropriate) as well as their potential scientific practicality and efficacy for climate mitigation purposes. The WG held its first workshop at IMO Headquarters, London, UK, 23-25 May 2016 in order to gather experts, review the current state of knowledge, and discuss the methodology and approach to the assessment. The final peer-reviewed report, to be completed by January 2018, is intended to assist the Parties of the London Convention and London Protocol to determine which marine geoengineering activities might be listed in Annex 4 of the Protocol and consequently regulated.

Adapting to the impacts of climate change

22. The Coastal Inundation Forecasting Demonstration Project (CIFDP) is a multi-hazard warning system that promotes an integrated approach in the enhancement and delivery of early warnings, no matter what the causes for coastal inundations are, in line with the concept of impact-based forecasting and the UN Sendai Framework for Disaster Risk Reduction (DRR). Implementation will demonstrate how integrated coastal inundation forecasting and warnings can be improved and effectively coordinated by the National Meteorological and Hydrological Services (NMHSs). The CIFDP is currently underway in four sub-projects (Bangladesh, Dominican Republic, Fiji and Indonesia), three of which are in urban coastal settings. Substantial progress to date has been made in each of these CIFDP sub-projects since 2013. [A/RES/70/235, para 187]

ACRONYMS

CIFDP	Coastal Inundation Forecasting Demonstration Project
CMIP	Coupled Model Intercomparison Experiment Project
GAW	Global Atmospheric Watch
GCOS	Global Climate Observing System
GHG	Greenhouse gas
GMDSS	Global Maritime Distress and Safety System
GOOS	Global Ocean Observing System
IAEA	International Atomic Energy Agency
ICSU	International Council for Science
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IOC/UNESCO	Intergovernmental Oceanographic Commission of UNESCO
IPCC	Intergovernmental Panel on Climate Change
JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
OOPC	Ocean Observations Panel for Climate
SIDS	Small Island Developing States
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WWMIWS	World-Wide Metocean Information and Warning Service