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INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (of UNESCO)

Thirteenth Intergovernmental Session of the IOC Sub-Commission for the Western Pacific (WESTPAC-XIII)
Virtual, 27-29 April 2021

Item 5 of the Provisional Agenda

ESTABLISHMENT OF NEW PROGRAMME/PROJECT AND/OR NEW WESTPAC WORKING GROUPS

United Nations Educational, Scientific and Cultural Organization · Intergovernmental Oceanographic Commission · Sustainable Development Goals

I. PROPOSED PROJECT/PROGRAMME (OR WORKING GROUP):
The 2nd Cooperative Study of the Kuroshio and Adjacent Regions (CSK-2)

II. PROPOSER (OR WORKING GROUP CHAIR) AND OTHER RECOMMENDED MEMBERS FOR THE PROJECT/PROGRAMME STEERING GROUP (WORKING GROUP) IF AVAILABLE:
Ken Ando, Xiaopei Lin, Cesar Villanoy, Akira Nagano, Dongliang Yuan, Kiyoshi Tanaka, Jae-Hak Lee, Masami Nonaka, Hanna Na, Adi Purwandana, Johan Wahyudi, Linlin Zhang

III. PROJECT/PROGRAMME TIMEFRAME:
(The maximum timeframe of the working group could be no more than two consecutive intersessional periods, no longer than four years)
2021-2024

IV. JUSTIFICATIONS FOR THIS PROJECT/PROGRAMME (OR WORKING GROUP):
The Kuroshio and other ocean currents in the western Pacific Ocean and adjacent marginal seas influence both the regional climate and weather, and culture of Asia. The heat transported by these ocean currents affects the regional climate of East Asia and also the basin-scale climate of the Pacific Rim region via atmospheric and oceanic teleconnections. The Kuroshio flows between a relatively eutrophic region on its coastal side and a relatively oligotrophic region on its open-ocean side. Owing to the complicated dynamics of the Kuroshio, biodiversity is high along its path, and regional fishery activity is related to its ecological characteristics. The recent papers by Hu et al. (2020) and Ando et al. (2021) and the book by Nagai et al. (2019) reveal the many scientific gaps that should be addressed in the next ten years. Fundamentally, there are two primary areas of concern: 1) systematic understanding of the Kuroshio and its impact on global and regional climate and weather, and 2) systematic understanding of the Kuroshio in relation to marine ecosystem variations linked partially to the effects of front dynamics, climate change and the direct impacts of anthropogenic coastal activities.

For additional information, please check in Section 1 and Section 2 of the draft Science Action Plan (SAP) of CSK-2 in the Annex.

V. PROJECT/PROGRAMME (OR WORKING GROUP) OBJECTIVES AND EXPECTED OUTPUTS/OUTCOMES:
Based on reviews of marine sciences and our current capability regarding marine science, discussion by the inter-sessional working group for CSK-2 developed under the Intergovernmental Oceanographic Commission (IOC) Sub-Commission for the Western Pacific (WESTPAC) has identified two major objectives for future Kuroshio study. The first is to achieve improved forecasts of regional weather and climate. The second is to manage better regional fisheries and aquaculture along the Kuroshio and adjacent regions, including local bays and estuaries. The first objective, which is mainly based on physical oceanographic and atmospheric observations, numerical modelling, and satellite datasets, will improve the ocean-atmosphere observation and forecasting system of coastal countries along the Kuroshio path. The second objective, which is based on sound science regarding the marine ecosystem, improved measurements of biological and biogeochemical parameters, and enhancement of observations along the Kuroshio, will lead to improved management of both fisheries from the open ocean in the Kuroshio region to coastal regions, and aquaculture in the bays and estuaries along the Kuroshio and in adjacent regions.

Considering the Kuroshio, during the UN Ocean Decade, one of the most important actions will be developing and operating a value chain mechanism to enrich our Kuroshio data from local to regional scales. At the scale of a bay or estuary, the local and local governments are the major stakeholders, while national interests and conflicts are the major concerns at the national scale. At the regional scale of the entire Kuroshio system, national interests will be more important in terms of disaster risk reduction achieved through improved regional weather and climate forecasting, and improved risk management of natural resources such as regional fisheries and aquaculture.

The regions we will focus on are 1) Kuroshio Current region; 2) Adjacent current regions; and 3) Adjacent coastal regions, but we will exclude potential areas eliciting any conflict. Expected scientific outputs are summarized by the titles of a) Kuroshio circulation as the western boundary current including contribution from eddies, b) Kuroshio and NEC–KC–MC variability including the ITF, c) Air-sea interaction at various scales along the Kuroshio, d) Impacts of Kuroshio on coastal phenomena in bays and estuaries, e) Nutrient and ecosystem changes along the Kuroshio, and f) Variations of linkages between fisheries/aquaculture and marine ecosystem/environmental changes. Expected societal outputs are also summarized by the titles of g) Societal applications of regional climate monitoring and forecasting, h) Societal application of regional/local ocean current monitoring and forecasting in bays and estuaries, i) Regional fisheries management, j) Local aquaculture management, and k) Marine environmental conservation.

The gaps to achieve these objectives are also identified in section 4 in the draft SAP. For additional information, please check in Section 1 and Section 3 of the draft Science SAP of CSK-2 in the Annex.

VI. TERMS OF REFERENCE OF THE PROJECT/PROGRAMME STEERING GROUP (OR WORKING GROUP):

Recalling the decision at its 10th Session (WESTPAC-X, Phuket, Thailand, 12–15 May 2015) setting-up an open-ended International Task Force on Feasibility Study of the Second Cooperative Study of the Kuroshio and Adjacent Regions (CSK-2), and the Recommendation SC-WESTPAC-XI.2 adopted at the 11th Session of WESTPAC (WESTPAC-XI, Qingdao, China, 21–23 April 2017) setting-up an Intersessional Working Group of the Feasibility Study on the Second Cooperative Study of the Kuroshio and Adjacent Regions (IWG-CSK2),

Based on the Recommendation SC-WESTPAC-XII.3 adopted at the 13th Session of WESTPAC (WESTPAC-XII, Manila, Philippine, 2-5 April 2019), continuing the Intersessional Working Group of the Feasibility Study on the Second Cooperative Study of the Kuroshio and Adjacent Regions (IWG-CSK2). The IWG-CSK2 has worked to 1) complete the review report of CSK and its related research projects; 2) develop a science plan of CSK-2 and its implementation strategy if feasible, while taking into account its societal and economic benefits to the Member States, and identified gaps for conducting CSK-2, considering the potential for future coordination with on-going relevant national and international projects such as CLIVAR and GOOS, the requirements of WESTPAC Member States, and capacities available for the implementation of the project, deliberating on a potential contribution of CSK-2 to the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), and 3) submit a report to the 13th Session of WESTPAC in 2021. The outputs are a) one review paper to be published in an international journal (see Annex-I), and one report concerning a science plan and strategy towards the implementation of CSK-2 (see Annex-II), in which the vital social, economic, environmental and cultural importance of Kuroshio and its adjacent region are also identified.

As shown in this document, the IWG-CSK2 proposes that the Sub-Commission establish a new programme on CSK-2, and form, in accordance with the following Terms of Reference, an International Steering Group (ISG) to guide the development and implementation of CSK-2.

Purpose:
The International Steering Group (ISG) will provide guidance and oversight, and make recommendations and report to the IOC Sub-Commission for the Western Pacific (WESTPAC) on the development and implementation of the CSK-2.

1. The function of the International Steering Group (ISG) of the CSK-2
   i. Review and provide inputs to the development of the CSK-2 Science Action Plan, and relevant strategic documents and guidelines;
   ii. Review the development progress on CSK-2, and recommend actionable strategies for engagement and resource mobilization to support the CSK-2 development and implementation;
   iii. Provide coordination and facilitate collaborations among relevant countries and their institutions in the developments and implementation of CSK-2;
   iv. Promote development of new CSK project(s), and ensure their outputs/outcomes to be in line with the CSK-2 objectives and relevant operational guidelines;
   v. Review and recommend endorsements of new CSK-2 project(s);
   vi. Promote and raise awareness on CSK-2, and engage its stakeholders into the development and implementation;
   vii. Plan, and organize annual ISC meetings, CSK-2 workshops and other relevant events,
   viii. Support communications, and provide information to the WESTPAC Office to enable its posting to the WESTPAC Website, and reporting or dissemination to IOC and other organizations;
   ix. Submit reports, and if needed, make recommendation to the Sub-Commission and/or its advisory group.

2. Composition and terms
   The ISG will consist of national representatives nominated by the WESTPAC member states who are willing to participate in the CSK-2. No more than three representatives could be nominated from each country with one preferably from national agency closely related to CSK, and 1-2 from CSK research or other relevant communities. Individual experts or other stakeholders could be invited, if deemed necessary. The WESTPAC officer and the Head of Office will serve as ex-officio members.

   The Sub-Commission will seek the nomination once every two years. The member of ISG shall serve a two-year term, and could be renominated for no more than three consecutive terms. The ISG will select two (2) co-chairs, and their terms will be two years and can serve no more than two consecutive terms. In case of resignation, inactivity or other issues affecting the work of ISG, his/her replacement(substitute) could be recommended by her/his country, and the substitute shall perform the required functions for the rest of the term.

   The roles of the co-chairs are to lead endorsement processes of new investigations for CSK2, plan meetings, draft report to the session, revise the SAP, develop sub-group, and invite experts and/or stakeholders for further development of CSK2.

3. Meetings
   The ISG will meet at least once per year to perform the functions. Specific sub-group may be established and mandated for conducting technical tasks as decided by the ISG. These technical working groups may meet as often as required by their members.

4. Secretariat
   The WESTPAC Office will assume the secretariat function at the regional level, acting as the primary coordination unit for the CSK-2 and the Secretariat for the ISG.

Decentralized secretariat support at the project level will be encouraged. These structures would have well-defined mandates that would be developed and cooperated with the WESTPAC Office.

The new project is intended to connect to a proposal to the Decade Programme from the region in the future.

VII. MAIN ACTIVITIES TO BE CARRIED OUT OVER THE PROJECT/PROGRAMME/WORKING GROUP TIMEFRAME:

In designing an action framework, ocean value chain processes are taken into account, as outlined in the Oceanobs'09 FOO (Lindstrom et al., 2012), in which the importance of adding value in the delivery of our ocean data and information to society and of feedback to marine experts to improve our science was clearly emphasized. In this chain, marine scientists must provide data and information in more actionable ways such that it is readily available to other ocean stakeholders. It is also expected that ocean stakeholders will co-design activities with marine scientists through dialogue and partnerships to develop actions that are best suited to achieving the stated goals. This idea is reflected in our action framework that is described in this section.

International Steering Group (ISG): The International Steering Group (ISG) will review, make recommendations and report to the IOC Sub-Commission for the Western Pacific (WESTPAC) on the development and implementation of the CSK-2. The ISC will comprise marine science experts, governmental officials, and ocean stakeholders. Facilitating Marine Scientific Research clearances will also be an important agenda for this committee.

Secretariats: Secretariat support is essential to the development and implementation of CSK-2. At the regional level, the WESTPAC Office will assume the secretariat function, acting as the primary coordination unit for the CSK-2 and the Secretariat for the CPG. Coordination of research activities, ship time, data and information management, capacity development, and literacy will be among major tasks during inter-sessional periods.

The Implementation Framework entails decentralized secretariat support at the project level. These structures would have well-defined mandates that would be developed with the WESTPAC Office. As some research activities will be performed at the national or institutional level, secretariats might be required at the national level to oversee coordination within each nation.

Actions (CSK2 investigtions): There are eleven (11) actions/activities, which compose the substances of the CSK-2, and names of the CSK2 investigations in parentheses. All information is as of March 2021.

1) Time-series observations of Kuroshio variability in the East China Sea (Hanna NA)
2) Philippine Rise Integrated Marine Environmental Research (Cesar VILLANOY)
3) Air-Sea Interaction in the Kuroshio Extension and its Climate Impact Phase II (Xiaopei LIN)
4) Assessment of Ocean Carbon Dynamics in the Sunda Shelf Region on dealing with Issues of Climate Change and Ocean Acidification (A'an Johan WAHYUDI)
5) The Circulation and Ecosystem Study in the Indonesian Seas under the Influence of the Western Pacific Variability (Adi PURWANDANA)
6) Mid-latitude air-sea interaction studies through the Climatic Hotspot2 project in Japan (Masami NONAKA)
7) Hybrid-Intelligence estimation and Prediction of Ocean Productivity in the Kuroshio current area of influence (Jae-Hak LEE)
8) Observations in the origin region of the Kuroshio (Akira NAGANO)

9) The dynamical and ecological interaction between the Kuroshio Current and coastal circulation (Kiyoshi TANAKA)
10) Ocean circulation in the Indonesian seas and its climate effects (Dongliang YUAN)
11) Subthermocline currents and eddies in the origin of Kuroshio - NEC-Kuroshio-MC –(Linlin ZHANG)

For additional information on the above, please check in Section 5 of the Draft Science Action Plan of CSK-2 in Annex.

Data System: A data and information system will be essential for the success of the CSK-2 in WESTPAC. Without data and information sharing among participants and contributors and without dissemination to all other stakeholders interested in the Kuroshio, it will be impossible to achieve the goals of the programme. This programme aims to contribute to the SDGs through the UN Ocean Decade. In the objectives of the UN Ocean Decade, it is strongly recommended to have a dialogue and communication among ocean stakeholders. One way is to deliver our data/information via Internet technologies. With the incorporation of an efficient data/information system within our programme, we will be able to deliver our message to all other stakeholders in the Kuroshio and adjacent regions. Based on the principles in section 7 in the draft SAP, distributed data management and dissemination system will be developed. The schematic of the data system is shown in the draft SAP.

Meetings: Regular CSK-2 workshop will serve as the main means of developing and implementing the CSK-2 programme. Workshops will allow discussions among participants, including Principal Investigators (PIs), and for further development of collaborations. They will also provide the opportunity to invite new potential PIs to join the CSK-2. Confirmation of data exchange and sharing with and dissemination to the public will also be performed at such events. In addition to annual workshops, bi-annual co-design/co-delivery workshops for the Kuroshio study will also be held in collaboration with ocean stakeholders. The bi-annual workshops are expected to support collaboration with ocean stakeholders, including funding agencies, the private sector, and the public, and to provide an opportunity for all ocean stakeholders to consider/act regarding the societal outputs of the CSK-2. Finally, compiling and submitting a report to the Advisory Group and WESTPAC Intergovernmental session will also be an important task for the ISC.

VIII. PROPOSED WORK PLAN AND BUDGET FOR MAY 2021 - MAY 2023:

Project/Programme/ Working Group	*Activities*	*Objectives*	*Expected outputs/outcomes*	*Date and Place*	*Funding required*	
					IOC	*Other sources(i.e., from national/international sources)*
CSK-2	ISC meetings	Coordination etc.	Report	Not determined yet	0	10K US$
	Stakeholders meeting	Develop Partnership	Partnership in official and/or offline	Not determined yet	0	10K US$
	Each observational and research activities	Research	Papers Data Summary information	Continuous	0	Depends on each Each Member state directly support
	Whole Data management	Data sharing	Data portal	Start design in May 2021	0	5K US$ for server

A research project fund at the national level is fundamental for the implementation of the CSK-2. Initially, some CSK-2 research activities will be supported by existing projects; however, PIs will need additional support to develop networks with other PIs, the data system, and stakeholders. Furthermore, in later stages, PIs will have to request continued funding for support if their outputs are considered to have the potential to realize the objectives of the CSK-2.

ANNEX-I

Science Action Plan (SAP) of CSK-2 (Draft version 2021)

Science Action Plan (SAP) of CSK-2

(Draft Version 2021)

Contents

1. Background and Objectives of CSK-2

1. Background

The Kuroshio and other ocean currents in the western Pacific Ocean and adjacent marginal seas influence both the regional climate and weather and the culture of Asia. The heat transported by these ocean currents affects the regional climate of East Asia and also the basin-scale climate of the Pacific Rim region via atmospheric and oceanic teleconnections. The Kuroshio flows between a relatively eutrophic region on its coastal side and a relatively oligotrophic region on its open-ocean side. Owing to the complicated dynamics of the Kuroshio, biodiversity is high along its path and regional fisheries activity is related to its ecological characteristics.

Recently, two review papers and one book focusing on Kuroshio research have been published, in which current scientific gaps are well described (Nagai et al., 2019; Hu et al., 2020; Ando et al., 2021). In the book by Nagai et al. (2019), the well-organized collection of papers clearly highlights the maintenance mechanisms of the marine ecosystem along the Kuroshio from the Philippines to the Kuroshio Extension (KE) from the multidisciplinary perspectives of physical, chemical, and biological oceanography, including fishery oceanography. The papers by Hu et al. (2020) and Ando et al. (2021) describe comprehensively the roles of western boundary currents in relation to both regional climate and marine ecosystems since the beginning of the North Pacific Ocean Circulation Experiment (NPOCE) in the lower latitudes of the western Pacific and the beginning of the Cooperative Study of the Kuroshio and Adjacent Regions (CSK) programme from the lower to mid-latitudes of the western Pacific, respectively. These recent publications reveal the many scientific gaps that should be addressed in the next 10 years. Fundamentally, there are two primary areas of concern: 1) systematic understanding of the Kuroshio and its impact on global and regional climate and weather, and 2) systematic understanding of the Kuroshio in relation to marine ecosystem variations linked partially to the effects of climate change and to the direct impacts of anthropogenic coastal activities.

2. Objectives

On the basis of reviews of marine sciences and on our current capability regarding marine science, discussion by the inter-sessional working group for CSK-2 developed under the Intergovernmental Oceanographic Commission (IOC) Sub-Commission for the Western Pacific (WESTPAC) has identified two major objectives for future Kuroshio study. The first is to achieve improved forecasts of regional weather and climate, and the second is to achieve better management of regional fisheries and aquaculture along the Kuroshio and in adjacent regions including local bays and estuaries. The first objective, which is based largely on physical oceanographic and atmospheric observations, numerical modelling, and satellite datasets, will lead to improvement of the ocean–atmosphere observation and forecasting system of coastal countries along the path of the Kuroshio. The second objective, which is based on sound science regarding the marine ecosystem, improved measurements of biological and biogeochemical parameters, and enhancement of observations along the Kuroshio, will lead to improved management of both fisheries from the open ocean in the Kuroshio region to coastal regions, and aquaculture in the bays and estuaries along the Kuroshio and in adjacent regions.

In 2015, the “Transforming our World: the 2030 Agenda for Sustainable Development” was adopted at the United Nations General Assembly (UNGA), and the 17 Sustainable Development Goals (SDGs) demonstrate the ambition of the agenda. Subsequently, the IOC/United Nations Educational, Scientific, and Cultural Organization (IOC/UNESCO) started preparations to respond in particular to SDG14, Life Under Water (Ocean), and proposed that the UNGA proclaim the UN Decade of Ocean Science for Sustainable Development (UN Ocean Decade) to support ocean matters. The Implementation Plan for the UN Ocean Decade was accepted at the 72nd UNGA. This plan identifies clearly that marine science is the basis for future human existence on earth, and that new marine science should be much more relevant to human society to be of service. It also expresses clearly that marine science experts should work with other stakeholders via co-design and co-delivery to achieve SDG14 by 2030.

Considering the Kuroshio, during the UN Ocean Decade, one of the most important actions will be to develop and operate a value chain mechanism for enrichment of our Kuroshio data from local to regional scales. At the scale of a bay or estuary, the local population and local government are the major stakeholders, while national interests and conflicts are the major concerns at the national scale. At the regional scale of the entire Kuroshio system, national interests will be more important in terms of disaster risk reduction achieved through improved regional weather and climate forecasting, and improved risk management of natural resources such as regional fisheries and aquaculture. Our best value from Kuroshio study will be based on how we prevent conflicts between stakeholders and benefit all stakeholders through open availability of Kuroshio data. Following the Framework for Ocean Observing (FOO; Lindstrom et al., 2012) of the Global Ocean Observing System, a value chain system after retrieval of observations will be needed for co-design/co-production/co-delivery with stakeholders of all levels. Therefore, continuous open dialogue among the various ocean stakeholders will be crucial.

The success of the CSK-2 will be evaluated based on the level of Kuroshio literacy[#1] of the ocean stakeholders, including the public. Kuroshio literacy is the basis on which all ocean stakeholders will be empowered to co-design/co-produce/co-deliver our programme, and higher literacy will inspire a greater level of action, particularly autonomous action by the public. Our ultimate objective is to elevate the level of literacy regarding the Kuroshio in society and to pursue "the science we need for the Kuroshio we want."

2. Regions of Focus

On the basis of societal impact and scientific importance, our primary region of focus

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[1] Kuroshio literacy is defined as gaining an understanding of what the Kuroshio is, how it behaves, and how it interacts with other bodies of water in terms of physical, chemical, biological, cultural, economic, and societal perspectives. It also highlights the importance of the mutual interaction between the Kuroshio and associated systems in our daily lives.

regarding the Kuroshio can be divided into three sub-regions: 1) the Kuroshio Current (KC)[#2] region, 2) adjacent currents and eddy active regions, and 3) adjacent coastal regions. In this regard, however potential areas eliciting conflicts will be excluded from our regions of focus.

1. <u>Kuroshio Current region</u>

The KC region covers the region of origin region of the Kuroshio, western boundary areas, the East China Sea KC region, areas south of Japan, and the KE region. The KC is the largest western boundary current and impacts global environmental issues including climate change and variation. The KC originates in tropical regions of the Pacific Ocean as a northward branch of the North Equatorial Current (NEC). As it flows northward, it has many interactions with the continental shelf, eddies (or unstable currents), turbulence at straits and sills, and atmospheric physical and chemical forcing. These forcing characterize the Kuroshio in the north. The return flow from north to south, meso-scale eddies, and water mass such as Subtropical Mode Water (STMW) play important roles in transporting heat and various oceanic memories that characterize the conditions of the origin of the Kuroshio. Considering the important role of the Kuroshio, it is necessary to consider the KC system in its entirety.

2. <u>Adjacent current regions</u>

The adjacent current regions include the Indonesian Throughflow (ITF), NEC, North Equatorial Counter Current (NECC), Midanao Current, Ryukyu Current, Subtropical Counter Current (STCC), Oyashio Current, and Tsushima Current. Oceanic phenomena in these regions are characterized by the direct oceanic impacts by and to the Kuroshio. The NEC bifurcates to the east of the Philippines into the KC and the Mindanao Current (MC), and the MC is further separated into the NECC and ITF. These bifurcated currents to the south affect the regional marine environment. The Kuroshio in the East China Sea (ECS) sends a branch to the northwest of Kyushu Island as the Tsushima Warm Current, which also affects regional weather and marine ecosystems. The Kuroshio flows out of the Tokara Strait and merges with the northward Ryukyu Current, and is enhanced by the regional recirculation associated with STCC. Interactions with mesoscale eddies are the key to understanding the behaviour of the Kuroshio meanders to the south of Japan, which impact regional fisheries. It is clear that understanding the Kuroshio is not sufficient to fully understand its impact on society.

3. <u>Adjacent coastal regions</u>

The adjacent coastal regions include straits, bays, estuaries, and the continental shelf of the

[2] Kuroshio Current represents focusing on its currents, while Kuroshio represents wider and ambiguous, including circulation system.

ECS. These regions have great societal importance because most anthropogenic activities are restricted to those coastal regions such as bays, estuaries, and straits. The regions facing the open ocean and close to the KC or adjacent currents are easily impacted by such currents because of their high speed, high variability and different biogeochemical conditions, which means that coastal ocean conditions and environments can change over a timescale of several days. Additionally, owing to the more complex topography near coasts and straits, the speed of the Kuroshio can generate areas of high turbulence, which can bring nutrient-rich waters from deeper layers that enrich the marine ecosystem and increase biodiversity. Thus, the high energy of the Kuroshio has considerable impact on the fisheries in the adjacent coastal regions.

3. Science and Societal Outputs

Science Outputs

3.1 Kuroshio circulation as the western boundary current including contribution from eddies

The Kuroshio, as the western boundary current of the North Pacific subtropical gyre, originates as a northward current that branches from the NEC in the region to the east of the Philippines, flows northward to the east of Taiwan, then north-eastward along the continental slope in the ECS, before proceeding to the south of Japan after passing through the Tokara Strait. After separating from the east coast of Japan, the current flows eastward as the KE (Fig. 1). Furthermore, owing to the narrow and intense characteristic of the current, the Kuroshio produces mesoscale and sub-mesoscale eddies via hydrodynamic instabilities. The Kuroshio is not uniform in terms of its volume transport and velocity along the path from its origin to becoming the KE because it

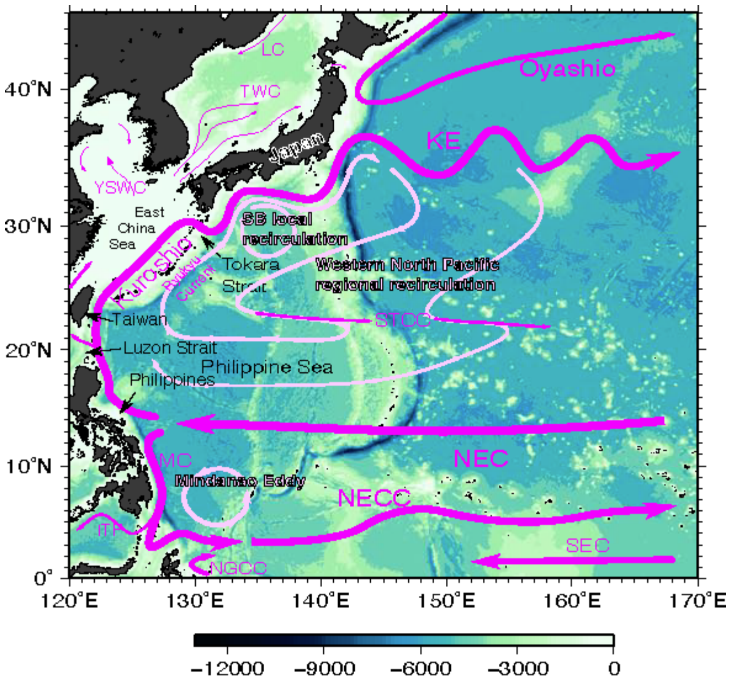

Figure 1. Schematic of the sea surface currents (magenta lines) and sub-circulations of the gyres (pink lines) in the western North Pacific.

has several branch currents (e.g., the Luzon Strait Loop Current and Tsushima Warm Current) and regional recirculations. The variations of the Kuroshio, its branch currents, and the mesoscale and sub-mesoscale eddies affect both the meridional transport of heat and freshwater and the supply of heat and material into the marginal seas, which can cause substantial variation in the marine environment.

In CSK-2, we will focus primarily on three aspects of the regional currents: (1) the region of origin of the Kuroshio, (2) the interaction between the KC/KE and mesoscale/sub-mesoscale eddies, and (3) the Kuroshio branch currents.

1. By resolving mesoscale and sub-mesoscale structures and seasonal–interannual variability, we will investigate how the NEC is concentrated into the Kuroshio and the Ryukyu Current System (RCS), from the area east of the Philippines to the region east of the southern Ryukyu Islands.
2. We will clarify the roles of multiscale eddy–eddy and eddy–mean flow interactions in both the formation of the Kuroshio large meander to the south of Japan and the decadal change between stable and unstable regimes of the KE.
3. We will reveal the spatiotemporal variations of the branch currents of the Kuroshio and their mechanisms.

3.2 Kuroshio and NEC–KC–MC variability including the ITF

In recent decades, based on in situ and remote sensing observations, considerable advances have been made in our understanding of the structure and variability of the currents in the origin area of the Kuroshio. Near the coast of the Philippines, the NEC bifurcates into the northward-flowing KC and the southward-flowing MC, and the entire system is referred to as the NEC–KC–MC (NKM) circulation system. Moreover, convergence of the MC and the New Guinea Coastal Current leads to the eastward-flowing NECC and the westward-flowing ITF, which transports fresher western Pacific Ocean water into the eastern Indian Ocean through the porous western boundary of the Pacific Ocean (e.g., Hu et al., 2020).

As part of the future CSK-2, we will focus on the following three scientific issues:

1) Multiscale variability of the NEC bifurcation, and the mechanisms that control the heat and transport of the NKM circulation system: Owing to changes in the monsoon and the variability associated with El Niño–Southern Oscillation (ENSO) events, the location of the NEC bifurcation and the NKM circulation system both show strong variability on seasonal, interannual, decadal, and longer timescales that have important consequences for the ocean circulation system and the global climate system. Owing to fluctuations propagating westward as Rossby waves, the NKM system shifts meridionally, inducing significant

anomalies in temperature near the thermocline and possibly affecting the sea surface temperature (SST).

2) The mechanisms of sub-surface counter current connectivity, their roles in relation to the climate, and the roles of eddies: Based on limited hydrographic measurements and theoretical dynamic analyses, several sub-surface counter currents such as the Mindanao Undercurrent, Luzon Undercurrent, North Equatorial Undercurrent, North Equatorial Subsurface Current and New Guinea Coastal Undercurrent have been discovered beneath the surface circulation. Recent intensive measurements by mooring arrays, Argo floats, and underwater gliders have confirmed the existence of these sub-surface counter currents and revealed their significant multiscale variability and importance with regard to inter-hemispheric water exchange. It is important to quantify nonlinearities in the sub-surface current linkage mechanisms. These undercurrents interact with the equatorial undercurrent system, such as the Equatorial Undercurrent and the Northern Subsurface Countercurrents, and with the Indonesian Throughflow in the sub-thermocline layers, potentially playing an important role in the Global Ocean Conveyer Belt and in climate variations.
3) Role of the ITF: The ITF, which plays an important role in the heat budget and freshwater balance of the low-latitude Indo–Pacific oceans, has influence on the dynamics and air–sea interactions in both oceans. Previous studies have highlighted that ITF transport is subject to strong interannual variation that is associated with ENSO and Indian Ocean Dipole (IOD) events. The role of the ITF in tropical and global climate systems is an active research subject.

3.3 **Air–sea interaction at various scales along the Kuroshio**

The Kuroshio is the unique warm western boundary current in the North Pacific, transporting considerable amounts of heat and moisture from the subtropics to mid-latitude regions. Its pathway can be identified easily by the warm SST relative to the surrounding water, forming a well-defined horizontal SST front. The KC–KE system is dynamical unstable, generating substantial mesoscale eddies in this region. Using high spatiotemporal resolution model simulations, the essential contributions of interactions between the mesoscale eddies and the atmosphere in modulating the Kuroshio and its front in the KE have been revealed, providing a new perspective for understanding western boundary current dynamics.

The pronounced SST gradient in the KE is crucial for maintaining lower atmospheric baroclinicity, and it excites fundamental influence on the mid-latitude climate by enhancing extratropical storm genesis and anchoring major storm tracks. Research on the low-frequency variation of the Kuroshio on long timescales has been facilitated by the improvement and compilation of long-term three-dimensional oceanic reanalysis datasets. Atmospheric variability associated with inter-decadal climatic variability in the Pacific, eg the Pacific Decadal Oscillation (PDO), has been regarded as the dominant forcing modulating SST in the KE, intensifying and controlling the location of the Kuroshio, and governing the stability of the KE. However, such linkages have considerable lag because PDO-related signals take several years to propagate from the central North Pacific to the KE. On the global scale, recent studies have demonstrated that Atlantic multi-decadal variability can simultaneously influence the SST in the KE region through inter-basin response of the atmospheric circulation. Other studies have emphasized the role of the oceanic nonlinearity in controlling the non-Sverdrup gyre circulation and the PDO variability and predictability. Despite the progress achieved in unravelling the roles of mesoscale eddies and fronts in terms of modulating atmospheric processes on various spatiotemporal scales, the questions of how these multiscale atmospheric processes might affect the oceanic processes in the KE and further modulate STMW remain challenging problems.

After comprehensive investigation as part of the CSK-2, the following two outputs are expected.

(1) Mesoscale air–sea interaction

One objective is to understand the local and remote influence of the Kuroshio and KE front and mesoscale oceanic eddies on the atmosphere and associated dynamics. It includes the different dynamics of the surface and upper-tropospheric atmospheric response to mesoscale SSTs, the impact of the Kuroshio front and eddies on mid-latitude weather systems such as storm tracks, and large-scale atmospheric circulations. Impacts of warm SST associated with the Kuroshio on extreme atmospheric events such as heavy rain/snowfall, heat waves and development of bomb cyclones and tropical cyclones are also important topic. Further, possible roles of aerosols in air-sea interactions in the Kuroshio and KE region should be also investigated. A second objective is to investigate how mesoscale and large-scale atmospheric responses have feedbacks on the ocean, including the kinetic energy and potential energy dissipation of oceanic eddies and also the mean state and low-frequency variability of the Kuroshio. As the KE region is the key region for STMW formation, it is also critical to establish whether mesoscale air–sea interactions can influence the subduction on high-frequency timescales that is responsible for the volume of the STMW.

(2) Inter-basin air–sea interactions

It remains to be determined whether major inter-decadal climatic variability, e.g., the PDO, Atlantic Multidecadal Oscillation (AMO), and North Pacific Gyres Oscillation, can influence oceanic processes in the Kuroshio and KE region and what might be the relative contributions of these climatic modes. Possible influence from the tropical climate modes should be also further investigated. Inter-decadal variation of the oceanic processes associated with these climatic modes can also influence the SST, mixed-layer depth, stratification, and subduction in the Kuroshio and KE region, which modulate the characteristics of the STMW. Given the enhanced SST warming trend observed along the Kuroshio and around marginal sea regions, influences of the warming climate on the climate system in the regions is also important topic.

In the tropical region, the western Pacific warm pool interacts with the Indian Ocean climate system through the Indonesian Throughflow, a.k.a. the oceanic channel, and the via the Walker circulation, a.k.a. the atmospheric bridge, due to its proximity to the maritime continent and to the Indian Ocean. Existing studies have focused on the atmospheric bridge processes. The study of the dynamics processes associated with the oceanic channel have just begun, which need more attention in the upcoming CKS-2 program. The exchange of water and heat through the oceanic channel is suggested to have long-lasting effects than the atmospheric bridge, the influence of which on the Kuroshio and its extension has yet to be disclosed.

3.4 **Impacts of Kuroshio on coastal phenomena in bays and estuaries**

The Kuroshio, as the western boundary current of the North Pacific, interacts with coastal circulations in adjacent bays and estuaries. Such interaction is noteworthy in two respects: ocean dynamics and marine ecology. The interaction with coastal circulation plays very important roles in the ocean dynamics of the Kuroshio and coastal circulations. In theoretical models, the behaviour of the western boundary current depends strongly on the relative intensity between viscosity and nonlinearity in the western coastal region, as indicated by the Reynolds number. In the real ocean, coastal viscosity and the non-linear behaviour of the Kuroshio are related to the generation and subsequent evolution of mesoscale and sub-mesoscale disturbances. Following the CSK project, viscous vorticity flux from the coast, enhancement of instability by bottom topography, and eddies accompanying the Kuroshio have been identified as playing essential roles in the formation of the Kuroshio large meander. Moreover, the mesoscale and sub-mesoscale disturbances that drive the coastal circulations are strongly controlled by coastal shape and bottom topography. For example, after becoming detached from the Kuroshio, sub-mesoscale streamers with high momentum are often captured in small bays where they cause drastic changes in the marine environment.

The other noteworthy role of the interaction between the Kuroshio and the coastal circulations is the maintenance of the marine ecosystems along the Kuroshio and in the coastal regions. For example, large amounts of nutrients and chlorophyll are transferred from the coast to the Kuroshio through such interaction (i.e., the mesoscale and sub-mesoscale disturbances), while the nutrient and chlorophyll distributions in coastal regions are also strongly controlled by the interaction (Fig. 2). The impact of the interaction between the Kuroshio and the coastal circulations on coastal marine ecosystems is a major concern with regard to regional fisheries.

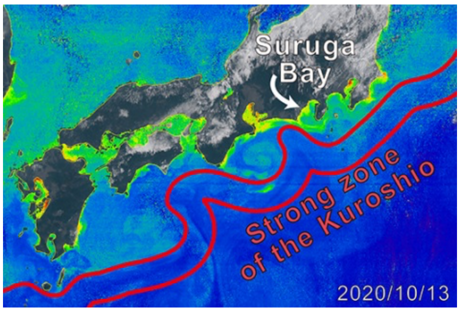

Figure 2. Surface chlorophyll-a south of Japan (warmer colors denote higher content), as derived from the Japan Aerospace Exploration Agency Himawari-Monitor and the Japan Coast Guard Ocean Report (Kaiyo-Sokuho).

Suruga Bay, which is the deepest bay in Japan's coastal waters, is a reasonable area in which to investigate the role of the interaction in terms of marine ecology for the following reasons: (i) coastal fisheries are well developed in and around the bay, (ii) the bay environment is strongly influenced by variation of the Kuroshio path, e.g., the large meander, and (iii) many research facilities such as university faculties of science and fisheries experimental stations are located there. Sakura shrimp, which represents the basis of the major fishery industry in the bay, is taken as a representation of the feasibility for study toward future ocean science because important and interesting fundamental mechanisms have been elucidated regarding shrimp ecology. One of the most important findings is that the shrimp ecology is critically controlled by coastal currents. For example, the large retention area, where the eggs and larvae of the shrimp remain in a nutrient-rich environment for a long period, is formed by a combination of the ocean currents and steep bottom topography.

The primary outcomes will be to improve understanding of the interactions between the Kuroshio and coastal circulations using state-of-the-art ocean circulation models and observations. A key point to consider is how well the numerical models are able to reproduce the mesoscale and sub-mesoscale disturbances. Obtaining in situ oceanographic observations with high resolution is also of paramount importance, and such programs will be conducted in collaboration with local stakeholders such as those involved in the fishery industry. Furthermore, the marine scientific outcomes will be of benefit to stakeholders living and working in coastal regions, and we will be able to expand/maintain such marine science activities in coastal seas along the

Kuroshio, which will meet the requirements of the UN Ocean Decade.

3.5 Nutrient and ecosystem changes along the Kuroshio

The Kuroshio and its adjacent regions/marginal seas exhibit large spatial gradients of nutrient concentration. As the Kuroshio originates in the warm tropical western Pacific, the initial nutrient concentration in the surface water is very low, which results in productivity dominated by nano- and picoplankton. However, the nutrient concentration of Kuroshio-influenced regions is enhanced by many processes, which include current boundaries, upwelling of and mixing with subsurface water, mesoscale eddies, exchange between the open ocean and marginal seas, and aerosol deposition. For example, interaction between the Kuroshio and the Oyashio creates a nutrient-rich region (i.e., the KE) that supports high productivity dominated by microplankton such as diatoms. Upwelling of subsurface water is a typical characteristic along the continental shelf edge of the ECS–Okinawa Trough. The subsurface Kuroshio water with high nutrient concentration is a major source of nutrients for the ECS and Yellow Sea shelf, which are among the most productive shelf seas, again dominated by diatoms. Additionally, nutrients from major rivers such as the Changjiang can be transported and mixed with Kuroshio water within the Okinawa Trough and then carried into the open western Pacific. Major eddy regions, such as those found east of the Luzon Strait, along the main Kuroshio pathway, and the KE, also exhibit substantial increases in nutrient concentration that often result in a major phytoplankton shift toward greater richness of diatoms. Aerosol deposition can be a major source of nutrients for the oligotrophic Kuroshio region, and Asian dust is particularly high in nutrients, including micronutrients such as iron. The contribution of aerosol nutrients is especially important during the cold seasons, and its region of influence extends over the larger Kuroshio region and beyond.

The major outputs from CSK-2 are anticipated to be as follows.

1). Quantification of the processes that enhance the nutrient concentration of the Kuroshio along its pathway.

2). Clarification of the responses of the Kuroshio nutrient concentration to global warming, which would further increase stratification of the ocean and further reduce ocean surface nutrient concentration.

3). Explanation of the effect of global warming on the spatial variation of the KE, which would greatly influence nutrient concentration.

4). Clarification of the increased impact on the Kuroshio region of anthropogenic activities in terms of nutrient input from rivers and aerosols.

5). Elucidation of the responses of productivity and phytoplankton community structure to spatial variations of changed nutrient inputs.

6). Increased ability to predict ecosystem changes in the Kuroshio region related to global changes on the decadal scale.

3.6 Variations of linkages between fisheries/aquaculture and marine ecosystem/environmental changes

The north Western Pacific Ocean is the most productive sea area globally, comprising oceanic waters where interactions of the western boundary currents (e.g., the Tsushima, Kuroshio, KE, and Oyashio currents) create zones of enrichment and concentration of biological processes. Among the regional oceanic areas, the Kuroshio is least productive owing to its lower nutrient concentration and plankton standing stock; however, the spawning and nursery grounds of many pelagic fish are found in the Kuroshio and KE areas. The KC plays an important role in determination of the fish community structure in the north-western Pacific by transporting eggs and larvae from low- to high-latitude regions. Furthermore, the KC also has considerable impact on the large marine ecosystems (LMEs) of the north Western Pacific, including the Yellow Sea, ECS, and South China Sea. The north Western Pacific region contributed almost one quarter of the global marine fisheries catch in recent years, provide unparalleled socioeconomic service considering the dense coastal population. Moreover, the LMEs of the north Western Pacific support an extraordinary level of biodiversity across all major species groups, ranging from zooplankton to marine mammals, exhibiting major ecological importance.

The KC exhibits substantial seasonal, interannual, and inter-decadal fluctuations in climate that impact the marine food web and regional fisheries. Climate-related changes include variation in stream flow (i.e., the KC and KE), SSTs sea level, water chemistry, ocean productivity, and diversity. The elemental scientific issue is to determine the response pattern to multiscale climatic variability from the individual level of key species to the fish community level. The Science Action Plan (SAP) of CSK-2 for fisheries focuses on research intended to improve understanding of potential risks to marine ecosystems, species, and communities; how best to forecast them; and how to identify ways to mitigate their impact. Cutting-edge technology and monitoring (such as e-DNA and modelling) are applied to track and project the impact of a changing climate on the marine resources and resource-dependent communities in this region.

The major areas of focus of CSK-2 will be as follows.

1) Responses of key species of the fish community at different spatiotemporal scales to multiscale climatic variability. Key species and the fish community structure are different in the LMEs and between subtropical and subarctic waters in the Kuroshio region. Therefore, it is important to establish the role of the KC in the determination of the latitudinal differences in fish community structure and their response to climatic variability.
2) Climatic impact on the distribution and migration of highly migratory species (e.g., tuna and

mackerel): Highly migratory species such as tuna and Japanese Spanish mackerel are important pelagic fish in this region with wide distribution from subtropical to subarctic waters. They experience different environmental conditions during their periods of migration. Further research on the impact of climate on the distribution and migration patterns of highly migratory species is crucial in relation to understanding fish population dynamics and management.

3) Kuroshio variability on the dynamics of the spawning grounds of small pelagic fish: Kuroshio waters are important spawning grounds for many species, particularly small pelagic fish such as sardine and mackerel. Variability of the KC (e.g., flow and temperature) can have considerable impact on the dynamics of the spawning grounds and recruitment success of small pelagic fish. Moreover, Kuroshio variation influences the growth and survival of the eggs and larvae of fish, and the success of their transportation to their nursery grounds in the Oyashio waters.
4) The recruitment process of Japanese eels in relation to the variability of the western boundary current: The spawning ground of Japanese eels is located to the west of the Mariana Island, and the transport of their larvae to coastal areas is largely affected by the NEC or the Kuroshio. Understanding the recruitment process from the spawning ground to the coastal waters is important for prediction of population dynamics and for proposing fisheries management strategies.
5) Multiple pressures on biodiversity of Kuroshio waters: The dispersion of organisms along the Kuroshio contributes to it having the highest biodiversity of the world's oceans. Biodiversity along the Kuroshio varies substantially between the low- and mid-latitude waters, representing the different responses to climate. Understanding the changes and differences in biodiversity is important for understanding the impact of climate-induced variability and for mitigating the effects on the key species and the marine ecosystem.

Societal Outputs

3.7 Societal applications of regional climate monitoring and forecasting

The Kuroshio and KE region are active areas of formation of mesoscale/sub-mesoscale oceanic eddies that are accompanied by considerable atmospheric variability as are shown in Section 3.3. Recent high-resolution observational and numerical studies have provided a breakthrough in the understanding of extratropical air–sea interaction in western boundary current regions. Thus, mesoscale air–sea coupling, which is not considered in current climate models, is potentially important for the prediction of extratropical cyclones and climatic extremes at sub-seasonal and seasonal timescales scales, as well as their response to climate projections.

The expected scientific outputs of CSK-2 are as follows.

1) Understanding finer resolution air–sea coupling in the Kuroshio region: The benefits of increasing the horizontal resolution of ocean models to resolve mesoscale eddies and sub-meso scale variability are increasingly recognized. Studies have shown that oceanic eddies in western boundary current regions not only affect local atmospheric precipitation and extratropical cyclones, but also modify the remote atmospheric large-scale circulation patterns. Increased resolution of atmospheric models is also necessary to accurately represent the narrow diabatic heating structure during cyclogenesis to correctly capture mesoscale air–sea interactions. Accordingly, to improve prediction of the mid-latitude climate system, not only must the resolution of oceanic and atmospheric models be refined, but the oceanic and atmospheric components must also be coupled at finer scale. Improved understanding and accurate prediction of the extratropical dynamic system calls for comparison of multiple models and increased numbers of ensemble members, which represents the goal for next-generation climate models, i.e., the High-Resolution Model Intercomparison Project of the 6th Coupled Model Intercomparison Project. Owing to limitations of computer resources, long-term global climate models capable of resolving atmospheric and oceanic small-scale processes currently remain unaffordable. However, regional high-resolution numerical simulations incorporating mesoscale atmospheric convection and mesoscale or even sub-mesoscale oceanic eddies could prove useful, particularly for study of regional weather systems and climatic extremes such as in the Kuroshio system.

2) Understanding regional climate variations via integrated observations: An integrated operational observational network for use in conjunction with numerical models and satellite observations will be developed. Together with traditional hydrographic and mooring measurements, new mobile platforms (e.g., Wave Gliders and Saildrones) will provide more efficient atmospheric and oceanic observations. Such integrated approaches, especially those involving in situ observations, could provide better overall understanding of the Kuroshio and its adjacent marginal seas, such as the multiscale variabilities of the Kuroshio, mesoscale and sub-mesoscale oceanic eddies, and their interaction with the atmosphere. Moreover, approaches designed to acquire observations of physical, biogeochemical, and ecosystem parameters along the Kuroshio path with high temporal resolution will elucidate the importance of physical processes on ecosystem changes associated with climate change and climatic variability. Accumulated in situ observations together with improved understanding of Kuroshio dynamics will markedly increase the simulation and prediction skill of present air–sea coupled numerical models.

3.8 Societal application of regional/local ocean current monitoring and forecasting in bays and estuaries

The objective is to present a clear vision for future ocean science in relation to the bays and estuaries adjacent to the Kuroshio, meeting the goals of the UN Ocean Decade. To achieve this objective, we have three principal outputs: forecasting of the coastal ocean using numerical simulation, monitoring the coastal ocean using in situ observations, and feedback through collaboration with stakeholders.

1) Forecasting of the coastal ocean: We are in an age when the use of high-resolution ocean general circulation models such as the Japan Coastal Ocean Predictability Experiment model of the Japan Agency for Marine-Earth Science and Technology for direct simulation of sub-mesoscale disturbances has commenced. Using state-of-the-art ocean circulation models that precisely and realistically reproduce the complex interactions between the Kuroshio and coastal circulations, coastal ocean variations will be understood and forecasted with particular focus on the interaction with the Kuroshio.

2) Monitoring the coastal ocean using in situ observations: Validation of ocean model simulations and advanced assimilation is necessary. The latest geostationary satellites (e.g., Himawari and the Geostationary Ocean Color Imager) can provide retrievals of SST, chlorophyll-a, and other parameters with reasonably high resolution. However, it should be noted that information on salinity and flow velocity and their depth-profiles is also necessary. Therefore, it is important to obtain in situ high-resolution observations in bays using conductivity–temperature–depth (CTD) and Acoustic Doppler Current Profiler instruments. One idea is to deploy a unique epochal CTD instrument designed for use during operation of fishing vessels. The CTD instrument needs only to be attached to a fishing net, and the data obtained are transferred automatically via Bluetooth to a cell phone (Fig. 3). It is important to note that data are acquired during each fishing operation and that they can be used to monitor the coastal ocean.

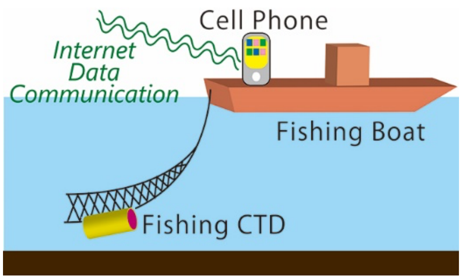

Figure 3. Schematic of deployment of an epochal CTD instrument.

3) Collaboration with stakeholders: To achieve the objectives of the CSK-2, synergistic collaboration with stakeholders such as those involved in local fisheries is essential. One reason is that frequent shipboard observations with high spatiotemporal resolution cannot be realized without their support. Another reason is that a future sustainable fisheries industry requires state-of-the-art ocean science.

As an example, the annual catch of Sakura shrimp in Sugura Bay has diminished rapidly since around 2000, reaching almost zero in the past few years (Fig. 4), which has resulted in unemployment and closure of fisheries businesses. A cooperative relationship has been established with members of the fisheries industry, and through understanding of the role of the Kuroshio with regard to Sugura Bay, possible scientific explanations for the problem concerning Sakura shrimp could be shared. Although further effort is required to resolve the problem, this represents a good example of the societal benefit of marine science.

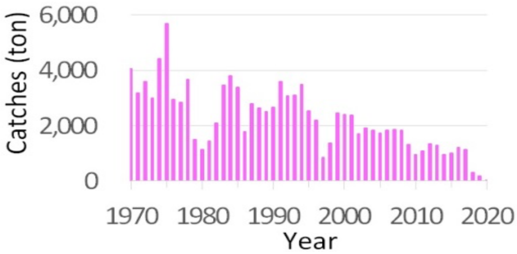

Figure 4. Annual catch of Sakura shrimp (information from the Shizuoka Sakura shrimp Fisheries Cooperative).

3.9 Regional fisheries management

The KC and its adjacent waters (i.e., the Yellow Sea, ECS, and South China Sea) have large impacts on the LMEs of the north Western Pacific, which provide unparalleled socioeconomic service considering the dense costal population. Many fish species such as tuna, Japanese eel, and Japanese Spanish mackerel are highly migratory species, and the stock is shared among the coastal countries in this region. However, because most countries in this region (except Japan and South Korea) have not established a workable stock assessment system, even for the fish stocks in their own Exclusive Economic Zone (EEZ), the stock status remains poorly understood for many fish species.

The SAP of CSK-2 for fisheries management focuses on improving the stock assessment level for migratory species and shared stocks, the main tasks of which are as follows.

1) Stock monitoring for highly migratory species such as tuna and Japanese Spanish mackerel: Unlike the countries of the International Council for the Exploration of the Sea, there is no long-term monitoring of the fish stocks in the KC. Species such as tuna, Japanese Spanish mackerel, and swordtip squid are distributed widely across the Kuroshio waters and undertake large seasonal migrations. Integrated monitoring of the spawning ground of these species by coastal countries is particularly important for understanding recruitment and for operation of stock assessment.
2) Fisheries data system for management: The task of sharing fisheries data is a considerable challenge for regional fisheries management. It might be necessary to establish a regional fisheries committee for the KC region, similar to the North Pacific Fishery Commission.
3) Management strategy for sharing regional stocks such as Japanese eel, mackerel, and common squid: Japanese eels represent a very important commercial species in this region,

but the stock has been facing collapse in recent years. A regional management programme is expected to have major importance with regard to the recovery and management of shared stocks such as eels.

4) Stock recovery plan for collapsed fish stocks: Chinese common squid, hairtail, and large yellow croaker are among the many species that have suffered over-exploitation in the LMEs of the north western Pacific. Climate change manifested as increasing water temperature appears to have enhanced the difficulty for fish stock recovery and management. Thus, it is urgent that fisheries management strategies be developed to aid the recovery of collapsed fish stocks and to mitigate the impacts of climate change.

5) Stock assessment method under limited data: Many fish species in this region are data-limited, i.e., there are no long-term time series data on age composition and fishing effort. Data-limited or data-poor methods are expected to be applied to stock assessment of typical coastal species in this region.

6) Costal fisheries management with special consideration of biodiversity conservation: Generally, the region of the western Pacific is extremely important for coastal and marine biodiversity and marine fisheries resources. Therefore, research on coastal and marine ecosystems is needed to improve support for better management of all living marine resources in the region.

3.10 <u>Local aquaculture management</u>

Globally, aquaculture production is increasing annualy and it reached 114.5 million tons (compared with 96.4 million tons of captured fish) in 2018 (FAO, 2020). Clearly, it could become the main supply of aquatic products for human consumption. There are diverse aquaculture species (e.g., fish, crustaceans, shellfish, and algae) and various aquaculture types (e.g., pond, indoor, cage, longline, and bottom) in the KC region and adjacent waters, which support most of the marine aquaculture production in the world. However, the organic and inorganic substances that form as by-products of aquaculture production represent sources of marine pollution. The suitable inshore sea areas for aquaculture were over-exploited with development of aquaculture, and the strengthening ecological protection policies also limited the further development of aquaculture. Good aquaculture practices with new technology such as Integrated Multi-Trophic Aquaculture (IMTA) and deep-water net cages are being introduced, together with more suitable species such as oceanic fish, which represent reasonable solutions for the current aquaculture problems in the KC area.

The KC transports warm water from the south to the north of the region and supports high production of small pelagic fish such as anchovy and sardine, which are important prey for larger fish and aquaculture species such as tuna. In this context, the warm water of the KC with abundant prey represents an area suitable for aquaculture. There are two aspects under consideration for resolving the aquaculture problems of self-pollution and limited space.

(1) Developing and expanding IMTA in suitable areas: IMTA has become well developed in some areas in China. It has been certificated as an efficient method for reducing the self-pollution of aquaculture; however, most aquaculture areas lack IMTA technology. Therefore, IMTA could be introduced to certain land-based and inshore areas based on diverse aquaculture species and types.

(2) Development of deepwater net-cage technology and suitable species: Aquaculture space is limited by ecological protection policies and large-scale aquaculture is fully developed in certain areas of the KC region. Deepwater net-cage technology, which is important for the expansion of aquaculture space and protection of the inshore environment, offers an opportunity for cultivation of other suitable species such as oceanic fish and squid.

4. Gaps for Implementation

4.1 Gaps in scientific outcomes

In this sub-chapter, based on reviews on previous studies and ongoing research projects with respect to the Kuroshio and adjacent regions, we consider the principal scientific gaps from the perspective of further development of regional climate and weather predictions and achieving SDG14, i.e., the conservation and use of the oceans, seas, and marine resources for sustainable development. What is lacking in terms of current Kuroshio research and knowledge regarding achievement of the goals is comprehensive understanding of the following: mesoscale and sub-mesoscale features of the large-scale circulations including the Kuroshio and surrounding current systems, variability of the Kuroshio and NKM system including the ITF, air–sea interaction, impacts of Kuroshio variation on coastal phenomena in bays and estuaries, ecosystem changes along the Kuroshio and through the ITF, and linkages between fisheries/aquaculture and the marine environment and ecosystems. To further develop regional climate and weather predictions and fisheries resource management in the western North Pacific region, more accurate monitoring and prediction of both the Kuroshio and the current systems in adjacent regions and their impacts on the atmosphere are required.

4.1.1 Knowledge gaps of the KC system

a. Knowledge gaps regarding the circulation features of the KC system

1) Blank regions of the KC system: With respect to the heat transport by the Kuroshio, in addition to the ECS Kuroshio, the north-eastward current flowing to the east of the northern Ryukyu Islands from Okinawa Main Island to Amami-Oshima Island, called the Ryukyu Current System (RCS), is of critical importance, i.e., the confluence of the RCS contributes

to the heat transport by the Kuroshio to the south of Japan and along the KE. However, the current system to the east of the Taiwan and the southern Ryukyu Islands, which is possibly the origin of the RCS, remains unclear because of high variability due to active mesoscale and sub-mesoscale eddies in the STCC. In particular, the transport of nutrients by the RCS makes a considerable contribution to the large nutrient transport by the Kuroshio to the south of Japan. Additionally, heat and materials are also transported by the mesoscale eddies. Clarification of the structure of the current system to the east of Taiwan and the southern Ryukyu Islands is required for accurate estimation of the transports of heat and materials. However, the area between 19°N and 25°N is not a target of ongoing intensive research projects. The transport processes of heat and materials across this region to the east of Taiwan and the southern Ryukyu Islands by the RCS and mesoscale eddies should be investigated in the future.

2) Finer temporal and spatial features of the Kuroshio: Along its path, the Kuroshio has several branch currents that influence adjacent marginal seas such as the ECS and South China Sea. The spatial scales of these branch currents are largely mesoscale or smaller. Additionally, fluctuations of the ECS Kuroshio are related to modification of the water mass properties and the influence of coastal regions. However, the spatiotemporal variation of the Kuroshio structure, which is related to the branching of the currents from the Kuroshio and the development of mesoscale and sub-mesoscale eddies through hydrodynamic instability, is not fully understood. As environmental changes in the marginal seas and bays are considered attributable to Kuroshio variations in the open ocean, monitoring of such changes of the Kuroshio is critically important. However, ship-based observations of the Kuroshio and adjacent current systems in the open ocean are currently conducted by only a limited number of institutions, although they could be further improved in future by adopting wide-swath altimeters and ocean radar systems. In the western subtropical North Pacific, there are a few repeat hydrographic observations such as the 137°E line and time series observations from the KE observatory site. Therefore, current Kuroshio research is based largely on satellite observations and reanalysis data. However, satellite-based data and Argo float data are too sparse to monitor the mesoscale (and smaller) features of the Kuroshio. Therefore, in situ high-resolution observations obtained in the Kuroshio area and adjacent regions using new observation platforms such as Wave Gliders and Saildrones, in addition to existing observation technologies such as research vessels and satellites, will be key to filling this gap.

3) Mid-depth and deep circulations adjacent to the Kuroshio: Past synoptic hydrographic transects and subsurface moorings have detected undercurrents such as the New Guinea Coastal Undercurrent, Luzon Undercurrent, Mindanao Undercurrent, Equatorial

Undercurrent, North Equatorial Subsurface Current and Undercurrent and Ryukyu Counter Current, which flow in the opposite directions of the surface currents of the Kuroshio and other western boundary and interior surface currents in the western North Pacific. Little is known about the mechanisms of their formation, connectivity, and roles in the climate systems. These subsurface counter currents and their variations might be related to upwelling of nutrient-rich deep water that is generally responsible for maintaining marine ecosystems. To understand the influences of the subsurface currents on such ecosystems, we need to monitor the variations of the currents. However, existing observation systems based primarily on satellites and Argo floats are insufficient for monitoring the variations of the subsurface currents.

b. Knowledge gaps regarding the NKM system variability including the ITF

1) Influence of subsurface waters in the NKM current system: The variability of the NKM current system in the region to the east of the Philippines is responsible for the latitude of the bifurcation of the NEC, and it has impact on the variations of the currents in downstream regions such as the KC, MC, and ITF. The properties of the water transported by the Kuroshio and MC, which are modified in the NKM region through local air–sea interaction and upwelling of subsurface water, affect the KE and ITF regions. Although modifications of the sea surface water in the region to the east of the Philippines via evaporation and precipitation variability (such as that associated with ENSO) have been studied, the influence from the subsurface layer has not yet been examined because of the difficulties in conducting measurements of vertical mixing and advection.

2) Role of the ITF in regional climate: The variation of the NKM current system is related to the convergence of the MC and the New Guinea Coastal Current, which is responsible for the variations in the NECC and the ITF. The ITF is the only oceanic connection that passes through so many complex channels between the Pacific and the Indian Oceans. It is a key link in the thermohaline circulation conveyor belt of the global ocean. However, it is unknown how the ITF transmits the interannual to decadal variations of the tropical Pacific to the Indian Ocean and what amounts of heat and freshwater are transported by the variations of the ITF. Moreover, although the ITF transport is driven in the inflow and outflow regions by the Asian monsoon, IOD, ENSO, and other atmospheric forcing, the mechanism in the region of the Indonesian archipelago remains to be clarified.

The implementation of CSK-2 will greatly improve our understanding of the multiscale variability of the NEC bifurcation and the mechanisms that supply heat and materials to the NKM circulation system. Understanding of the formation and connectivity of the undercurrent system, the coherences among the variations of these undercurrents on different timescales, and their influences on the variation of the downstream Kuroshio will also benefit from the CSK-2. Such information will also help the ocean and atmosphere communities to understand the role of the ITF in connecting the interannual to decadal variations of the tropical Pacific and Indian oceans, and its role in the heat budget and freshwater balance of the Indo–Pacific oceans.

c. Knowledge gaps regarding air–sea interaction in the Kuroshio and KE regions

1) Roles of eddies in the air–sea interactions in the Kuroshio and KE regions: A new perspective of subtropical western boundary currents is emerging. The air–sea interaction in mid-latitude regions is a response to the remarkably high SST and salient SST contrast in the Kuroshio and KE regions; however, unsolved issues remain. The difficulty for clarification of the climatic variability is attributable to the long timescales in comparison with the spatiotemporal coverage of existing observations. Additionally, as mesoscale eddies are known to play important roles in heat transport and air–sea interaction, observations should have sufficient spatiotemporal resolution to resolve mesoscale eddies.

2) Small-scale air–sea interaction: State-of-the-art numerical model simulations are generally used in most studies on climatic variability. However, detailed features such as the strength of small-scale air–sea coupling differ among the various models. This means that further comparisons are needed, especially in conjunction with supporting data from satellites with even higher resolution and other sources. For local atmospheric responses, modelling of the atmospheric boundary layer is crucially important. But, in situ observations of the atmospheric boundary layer over SST front and mesoscale eddies are still limited to validate the models. Validation of the remote atmospheric response to mesoscale and sub-mesoscale frontal structures of SST and further investigation of the underlying physical mechanisms rely on long-term high-resolution observations and multi-model comparisons. Recently, analysis of the feedback effect of small-scale air–sea interaction on the ocean has been reported; however, our current understanding of this phenomenon and its dynamics remains limited.

3) Precise estimates of CO_2 exchange and storage: Related to climate change, the mechanism via which the exchange of ocean CO_2 occurs across the air–sea interface remains unclear. The Kuroshio and KE regions are areas of intensive absorption of CO_2. In the KE region, atmospheric CO_2 (including anthropogenic CO_2) is absorbed in association with the formation of the STMW, which means that the STMW is the largest regional store of CO_2. However, the precise amounts of subducted and redistributed CO_2 remain subjects of contention.

4) Linkage of the Pacific warm pool to the Kuroshio: The Pacific Ocean warm pool, which is the region of origin of the Kuroshio and the ITF, is characterized as the warmest open-ocean water in the world. Owing to the active exchange of heat and freshwater at the air-sea interface, the impact of the variation of the areal extent, heat content, and location of the warm pool on regional and global climatic variability can be substantial over a broad range of timescales. Understanding the warm pool variability is important for improving regional weather and climate predictions and their environmental impact. The linkage between the Pacific warm pool and the Kuroshio region is not yet well known.

d. Knowledge gaps regarding the impacts on coastal environments

1) Distribution processes of heat and materials to coastal areas: Environmental problems in coastal regions such as red tides in surface waters and hypoxic zones in bottom waters are related to the supply of nutrients and water exchange between coastal regions and the open ocean. As the intrusion of Kuroshio subsurface water is one of the major sources of nutrients to coastal areas, which can lead to eutrophication, clarification of the nutrient transport by the Kuroshio is important for the prediction of the occurrences of red tides and hypoxic zones. Furthermore, identification of the origin of the materials and interactions between the Kuroshio and its adjacent marginal seas, and quantification of the material transport between them, have not been extensively performed. As described previously in section 4.1.1, the transport processes of materials (including nutrients) by the Kuroshio and particularly by mesoscale and sub-mesoscale branching currents remain to be elucidated in the future.

2) Dynamics of intrusion of Kuroshio water: Heat and material exchanges between the Kuroshio and the coastal/shelf circulation systems are considered associated with sub-mesoscale warm filaments detached from the Kuroshio. Furthermore, the heat and materials transported by these sub-mesoscale warm filaments and via vertical and horizontal mixing affect conditions such as the circulation and temperature in marginal seas and bays. In addition, bottom water intrusion would also occur when strong bottom stress induced by the energetic Kuroshio is present near the edge of the marginal seas or mouth of the bays. The dynamics of the intrusion of Kuroshio water attributable to such sub-mesoscale filaments and mixing remain unclear.

3) Impacts of climate change: The ecosystems in coastal regions are expected to be impacted directly on seasonal to decadal timescales by the effects of climate change on the Asian monsoon, IOD, ENSO, PDO, and variation of the Kuroshio; however, the impact remains largely unknown.

4.1.2 Knowledge gaps regarding ecosystem changes along the Kuroshio and in adjacent regions

a. Identification of missing nutrients and the impact on marine ecosystems

The LMEs in the north western Pacific, characterized by an extraordinarily high level of biodiversity across all major species groups ranging from zooplankton to marine mammals, are strongly affected by the Kuroshio. The mechanism of nutrient supply to the oligotrophic surface water in the subtropical region of the western Pacific Ocean to the south of the KE remains an open question, although it has been recognized that there are "missing nutrient sources." Several processes have been proposed as potential candidates for the missing nutrient sources, e.g., regeneration, upwelling driven by mesoscale eddies and meteorological events such as typhoons, aeolian inputs, and mixing by winter cooling and topography-induced turbulent flows. Identification of the missing nutrient sources will require physical observations with accuracy sufficiently high to allow quantitative discussion on the impact on ecosystem changes.

b. Effects of the Kuroshio and regional climate on fisheries/aquaculture

In addition to heat, salinity, and nutrients, the Kuroshio transports tremendous amounts of eggs and fish larvae, which have considerable effect on the ecosystems of the marginal seas in the western Pacific Ocean. Thus, the Kuroshio influences both the growth and survival of eggs and larvae in the spawning grounds and the transportation success to the nursery grounds such as in coastal regions and the Oyashio region.

The Kuroshio also prevents pollution by exchanging water between coastal and open-sea areas. Self-pollution associated with the activities of aquaculture is expected to be prevented by the Kuroshio. To improve management of fisheries/aquaculture in bays and estuaries along the path of the Kuroshio and in adjacent regions, more accurate forecasts of the risks to marine ecosystems, species, and communities are required. For this purpose, as marine ecosystems are influenced by the Kuroshio, the regional climate, and weather, further development of ocean, climate and weather prediction is needed and monitoring systems that are more accurate are required. As described above, the Kuroshio plays an important role in determining the fish community structure in the north-western region of the North Pacific by transporting eggs and larvae from low-latitude areas to high-latitude regions. However, the response of key species to the effects of climate change, such as the recruitment process of Japanese eels from their spawning ground to the coastal waters, is not sufficiently well understood to be incorporated in active decision-making processes.

c. Conservation of biodiversity and prevention of pollution

Associated with the existence of the LMEs, the biodiversity across all major species groups from zooplankton to marine mammals in the western North Pacific is extraordinarily high, possibly owing to the physical conditions in the Kuroshio and KE regions, which are known as "hot spots." The biodiversity in the western North Pacific varies markedly with latitude and is possibly a response to climatic variability. The diversity, distribution, and abundance of marine plants and animals are considered strongly related to the Kuroshio through turbulent nitrate mixing. The patterns of biodiversity response to fishing, population, warming, climate variability, Kuroshio variability and other physical stressors remain unclear, presenting considerable challenges to the development of biodiversity conservation and management strategies. Understanding marine biodiversity and distribution is important for sustainable development; however, the cause of the high biodiversity has yet to be elucidated satisfactorily.

4.2 Collaboration with modelling and satellite communities, and with related activities such as marginal sea projects within and beyond IOC/WESTPAC

Until the early 1990s, numerical modelling techniques and computer power were not sufficiently developed to make new findings, diagnoses and forecasts. In recent years, ocean general circulation models have become an important tool with which to obtain knowledge regarding present and future ocean conditions. However, collaboration between research groups using in situ observations and those using numerical modelling and data assimilation has not been undertaken actively. Although certain datasets might be effective in reproduction of the ocean state if assimilated into numerical models, problems might arise in determining whether such data might be suitable for assimilation. Moreover, while spatiotemporally uniform data such as altimeter-derived sea surface height are generally effective in data assimilation systems, it is unknown whether single-shot data with uneven spatial coverage obtained in intensive observation campaigns might be suitable for data assimilation purposes. In addition, quality of satellite altimetry data is generally worse in coastal areas. Conversely, using data assimilation methods, optimal observation plans that may be formulated might yet have to be implemented.

Satellite communities have used in situ observation data for calibration of satellite-derived parameters such as SST, ocean colour, and sea surface height. As the resolution of satellite observations will become higher, mesoscale (and smaller) features of the Kuroshio and eddies could be monitored in the future e.g. by wide-swath altimeter such as SWOT mission. Through combined use of satellite data and in situ data, we hope to reveal the mesoscale and sub-mesoscale currents that branch from the Kuroshio. However, traditional in situ observations such as those obtained by research vessels, moorings, and Argo floats cannot obtain high-resolution data, while satellite high-resolution data will be put to greater scientific use in the near future.

There are several related activities such as projects regarding ecosystems and fisheries in bays and estuaries along the Chinese, Japanese, Korean, and Philippine coasts. The research regions and targets that the CSK-2 addresses overlap those of other related projects. As the CSK-2 targets the Kuroshio and related offshore areas, collaboration with other marginal sea projects is expected to create synergistic effects. In such circumstances, mechanisms for information and data exchange will be important but they do not exist at present.

4.3 Data system

The information obtained by CSK-2 will represent a massive body of data that will have various types and formats. Furthermore, most processed data will have several process levels. Depending on the processes applied to the data, results based on such datasets, especially regarding mesoscale (or smaller) phenomena, might sometimes differ from those based on others. Currently, there is little information available about the datasets that could help users select appropriate data with which to conduct their analyses. As data processing tends to be rather complex, this issue is becoming increasingly serious and is related to the gaps in capacity development discussed in the next sub-section.

Methods of data management differ among the various member states and institutions. Data publication systems that member states and institutions adopt are varied and depend on the level of awareness, budgets and other factors of individual member states. In future, the most recent data assimilation technology should be used to construct data management systems that are dynamically consistent and allow easy analysis. Accordingly, data should be transferred into a certain system through which the data can be used in appropriate data assimilation systems. “Open access to data” under the IOC/International Ocean Data and Information Exchange (IODE) data policy (see Appendix-1) is a general rule adopted in the CSK-2. To encourage data collection, we should provide a grace period for research results to be published prior to publication of the data via websites. However, it must be recognized that delays in data publication caused by the “moratorium” could disadvantage forecasts of weather and regional climatic variability and ecosystem changes in the western North Pacific, and that disrupts the prevention and mitigation of associated damage.

The CSK-2 aims to obtain the decadal timescale variability of the Kuroshio and the surrounding current systems in addition to shorter timescale variabilities. This requires that data have uniform quality temporally, i.e., the quality of data collected at the beginning of the project must not be inferior to that of data observed 10 years later. Also, once data collection is stopped, we cannot restore them and reveal phenomena on timescales shorter than the gap, even if observations restart.

The existence of EEZs, which were not present in the CSK era of the 1960s and 1970s, is a complicating factor regarding obtaining and publishing data. An application for Marine Scientific Research clearance to conduct observations within the EEZ of a coastal state could take considerable time or permission might not be granted. Therefore, resolving the Marine Scientific Research issue is critical for achieving the scientific goals and for constructing an integrated observation system in the western North Pacific.

4.4 Gaps in multi-disciplinary observing systems

Understanding the structures of the circulations of the Kuroshio and its surrounding current systems, and the characteristics of the mesoscale and sub-mesoscale disturbances, will be fundamental to the design of an efficient monitoring system. However, there is currently no other long-term monitoring line for the Kuroshio except the Pollution Nagasaki line in the ECS by Japan Meteorological Agency (JMA), the repeated hydrography line along the 130°E section by the open cruise of the NSF of China, and along the 137°E line by JMA in the western North Pacific. These hydrographic lines are obviously insufficient to cover the entire variation of the Kuroshio from sub-mesoscale to regional scales. Although NPOCE had planned to deploy dozens of subsurface moorings in the western Pacific in recent years, those intended for the source region of the Kuroshio were cancelled owing to diplomatic issues. Moreover, the Tropical Atmosphere and Ocean/Triangle Transocean Buoy Network programme has cancelled almost all buoys in the western Pacific. Even though relatively more Argo floats are currently deployed in the western Pacific than ever before, their numbers remain inadequate for describing the mesoscale and sub-mesoscale phenomena of the Kuroshio and adjacent regions. Integrated and multidisciplinary approaches have also proven inadequate in the western North Pacific. Overall, observations in this region remain limited and a coordinated observation system for the Kuroshio has yet to be constructed.

For implementation of the CSK-2, an integrated operational observational network in conjunction with numerical models and satellite observations will need to be developed. Concurrent with traditional hydrographic and mooring measurements, new mobile platforms such as Wave Gliders and Saildrones will be used to provide more efficient atmospheric and oceanic observations. Such an integrated approach together with biological and biogeochemical monitoring could provide a better overall understanding of the Kuroshio and the adjacent marginal seas, such as the multiscale variabilities of the Kuroshio, mesoscale eddies, and their interactions with the atmosphere and fisheries. Moreover, approaches designed to acquire observations with high temporal resolution of physical, biogeochemical and ecosystem parameters along the Kuroshio path will illustrate better the importance of physical (ecosystem) processes on ecosystem (physical) changes associated with climate change and its associated variabilities. Accumulated in situ observations from various monitoring networks together with improved understanding of the physical and ecosystem dynamics of the Kuroshio will improve the simulation and prediction skill of present air–sea, physical–ecosystem and even ocean–land coupled numerical models.

4.5 Gaps in capacity development

The Kuroshio and its associated currents and water bodies extend beyond national boundaries, and a systematic approach to obtain observations will have to be based on the spatiotemporal scale of the process of interest and not limited by national jurisdictions. Large-scale observation programs are inherently complex because they involve coordination with different national authorities. Research collaborations between various academic institutions of different member states exist but at different levels of involvement that are determined by factors such as differences in research and technological capabilities, different awareness levels, and the scientific and socioeconomic priorities of each government authority. This results in research activities that might not be mutually beneficial to parties involved. To achieve the objectives of CSK-2, these gaps in capacity development will need to be addressed, and some related approaches are described in Chapters 6 and 8. The scientific goals of the programme will be more achievable if assistance to support capacity development is available both within each member state and within the study region. Such assistance could be in the form of graduate scholarships for young scientists, technical expert exchange, and support for research activities.

4.6 Strategy to fulfil these gaps via workshops/meetings

Through workshops/meetings, active exchange of scientific knowledge among scientists about the sub-mesoscale to regional-scale circulations in the western North Pacific and their variabilities, air–sea interactions, impacts on coastal environments, and ecosystem changes is essential to advance oceanography and to achieve social implementation of forecasts of weather and climate variability, and the conservation of biodiversity and prevention of pollution. In particular, given recent developments in the fields of numerical modelling and data assimilation, collaboration with modelling communities is critical to achieve social implantation of scientific knowledge. As most scientists participating in the CSK-2 are not developers of numerical models and not experts in the field of satellite observations, we should engage in discussion with scientists of the numerical modelling and satellite observation communities through regular ocean science meetings, such as the WESTPAC International Marine Science Conference. To collaborate with colleagues undertaking related activities such as marginal sea projects within and beyond IOC/WESTPAC, we should maintain continuous dialogue among the various CSK-2-related projects and related workshops and invite participants in the related projects to act as speakers. Moreover, it will be essential to elucidate the present and future ocean states to ocean stakeholders and decision makers via workshops and meetings. Already, members of the CSK-2 regularly hold workshops and make presentations in the language of the host country.

4.7 Strategy from process study to observing system

Based on the results obtained from the CSK-2, we will identify critical phenomena and locations that could play important roles in regional and global climatic variation and ecosystem changes in the western North Pacific and design an optimal observing system. First, in determining the locations for observation stations, we will examine the effectiveness of the observations and the representativeness of the sites by performing an observing system experiment or an observing system simulation experiment using assimilation technologies. Furthermore, we will also pay attention to the fact that an observation system could monitor extreme events such as extraordinarily strong typhoons that would be useful for mitigation of related damage. Second, for monitoring short- to long-term oceanic and atmospheric variations such as the PDO, the monitoring system should function continuously once installed. Therefore, we will examine the feasibility of a sustainable observation system by inviting operational bodies. Third, we will pay attention to synergistic effects by undertaking collaboration with existing and/or planed observation campaigns. Finally, we will examine whether the knowledge obtained from the observation system is useful in decision-making processes. The observation system should be improved continually as in the FOO concept.

5. Implementation Framework

To implement the CSK-2 successfully and to fill the gaps identified above, it will be crucial to develop effective framework for providing an enabling environment, and coordination among participating experts, institutions and member states, and for co-design/co-production/co-delivery with ocean stakeholders such as founders, Non-profit Organizations/Non-governmental Organizations, companies, educators, and citizens. Initial implementation framework is proposed below, although it will be subject to further changes or modifications based on recommendations by WESTPAC member states and/or by changes of the programme itself.

5.1 Action Framework

a. Outline

In designing an action framework, ocean value chain processes are taken into account, as outlined in the Oceanobs'09 FOO (Lindstrom et al., 2012), in which the importance of adding value in the delivery of our ocean data and information to society and of feedback to marine experts to improve our science was clearly emphasized. In this chain, marine scientists are required to provide data and information in more actionable ways such that it is easily available to other ocean stakeholders. It is also expected that ocean stakeholders will co-design activities with marine scientists through dialogue and partnerships to develop actions that are best suited to achieving the stated goals. This idea is reflected in our action framework that is described in this section.

b. <u>International Steering Group (ISG)</u>

The International Steering Group (ISG) will review, make recommendations and report to the IOC Sub-Commission for the Western Pacific (WESTPAC) on the development and implementation of the CSK-2. The ISC will comprise marine science experts, governmental officials, and ocean stakeholders. Facilitating Marine Scientific Research clearances will also be an important agenda for this committee. The draft Terms of Reference will be proposed at the IOC/WESTPAC intergovernmental session.

c. <u>Secretariats</u>

Secretariat support is essential to the development and implementation of CSK-2. At the regional level, the WESTPAC Office will assume the secretariat function, acting as the primary coordination unit for the CSK-2 and the Secretariat for the CPG. Decentralized secretariat support at the project level will be encouraged. These structures would have well-defined mandates that would be developed and cooperated with the WESTPAC Office. These structures would have well defined mandates that would be development with the WESTPAC Office. As some research activities will be performed at the national or institutional level, secretariats might be required at the national level to oversee coordination within each nation.

5.2 <u>Actions (CSK-2 projects)</u>

There are eleven (11) actions/activities, which compose the substances of the CSK-2. All information is as of March 2021 and subject to change. Names after each title in parenthesis are principal investigators.

1) *<u>Time series observations of Kuroshio variability in the East China Sea (Hanna NA)</u>*

   This project aims to obtain continuous time series of the Kuroshio variability at more than one latitude band in the ECS. A simultaneous observation along its path would help to understand the connectivity of the Kuroshio Current from its upstream to downstream and meridional transport of heat, material, etc., by the Kuroshio Current. Outcomes of this project could help to address environmental and social-economic challenges, such as weather and climate knowledge and services in the neighboring communities and countries. Seagoing experience for early career scientists, including undergraduate and graduate students, would be an excellent opportunity for outreach and education.

Year 2021: A total of four mooring lines with 75 kHz acoustic doppler current profilers (ADCPs) observing upper 500 m current velocities has been being maintained in the ECS since June 2020. Two of them are located at about 27°N, and the other two of them are at about 28°N. It was designed to observe the horizontal and vertical structures of the Kuroshio at two different latitudinal bands along the path of the Kuroshio in the ECS.

In June 2021, all four of them will be recovered to obtain one-year-long time series and re-deployed using T/V Kagoshima-maru of the Kagoshima University. Additionally, two current and pressure recording inverted echo sounders (CPIES) will be deployed if the COVID-19 situation becomes better so that all the scientists can join the cruise.

Year 2022: A week-long research cruise is planned for the maintenance of the moorings during June 2022 using T/V Kagoshima-maru. Additional instruments will be deployed if possible.

PI and contributors: Na, Hanna; Nakamura, Hirohiko; Nishina, Ayako; Min, Hong Sik; Kim, Dong Guk.

Funding Resources: National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2019R1C1C1010446), the Japan Society for the Promotion of Science (Grant-in-Aid for Scientific Research MEXT KAKENHI-JP20H05169).

2) *<u>Philippine Rise Integrated Marine Environmental Research (Cesar VILLANOY)</u>*

This project focuses on three objects. The first is a more detailed study of the Benham Bank and the biophysical mechanisms which can potentially support the natural productivity of the bank. The second is a wider area investigation including the eastern Luzon, Luzon Strait and the NEC Bifurcation area, where the interaction of the Kuroshio and the Luzon shelf and coastline produces areas of enhanced biological primary production as well as the role of mesoscale eddies. The third is a capacity building component for local government units and academic institutions along the eastern Luzon coast. The diversity of organisms found and their possible adaptation mechanisms to the extreme environment found in this project which may help us to understand the resilience of such species to changing environmental conditions. With the PRIMER and collaborations with other MS, more observations can be obtained that will help understand dynamics in the area and potential consequences to pelagic and benthic biological communities.

Year 2021: Organizational work will be prepared and several initial cruises will be conducted.
Year 2022: Cruises in the Bifurcation area and west of Luzon along Kuroshio path will be conducted.

PI and contributors: Cesar Villanoy; Rene A. Abesamis; Wilfred John E. Santiañez; Rachel June Ravago-Gotanco; Victor S. Ticzon; Fernando P. Siringan; Caroline Marie B. Jaraula, Deo Florence L. Onda; Laura T. David; Charina Lyn Amedo.

Funding Resources: Philippine Government

3) *Air-Sea Interaction in the Kuroshio Extension and its Climate Impact Phase II (Xiaopei LIN)*

This project aims to develop sustainable observation networks in the Kuroshio extension region; establish the theoretical framework of the multi-scale ocean-atmosphere interaction in the mid-latitudes, especially in the Kuroshio extension region, to provide a theoretical basis for understanding and predicting the global climate change; reveal the key physical processes in determining climate change and improve the understanding of ocean and climate predictability in the Western Pacific. The observation system will provide data support for revealing the multi-scale physical biological coupling, energy cascade and climate effects, as well as the deep-ocean carbon cycle and benefit the theoretical frameworks of the multi-scale ocean-atmosphere interaction in this region, in particular, meso-scale and submeso-scales.

Year 2021: Comprehensive work related to observations and numerical modeling will be built, including maintaining the Kuroshio Extension Mooring System, initializing the data QC procedure after a QC team is set up; building data sharing website; deploying a multi-disciplinary subsurface mooring in the KE region; setting up high resolution (earth system model (3km x 3km for both ocean and atmosphere) in the Western Pacific Ocean and provide open access model data to the community.

Year 2022: The mooring system maintenance and QC team will be continued. Additionally, a multi-disciplinary surface buoy will be deployed, providing data for carbon cycle and fishery related studies. The program also attempts to set up high resolution numerical model prediction system in the Western Pacific Ocean

PI and contributors: Lin Xiaopei; Chen Zhaohui.

Funding Resources: N/A

4) *Assessment of Ocean Carbon Dynamics in the Sunda Shelf Region on dealing with Issues of Climate Change and Ocean Acidification (A'an Johan WAHYUDI)*

The project aims to do the following assesement: the spatio-temporal variability of the carbonate system in relation to the issue of ocean acidification, including its physico-chemical drivers; the flux of particulate and dissolved organic carbon that contributes significantly to carbon burial and enrichment of coastal and continental shelf sediment; seagrass's carbon stock and sequestration as an ecosystem service useful for climate-change mitigation by means of reducing CO2 emissions through the natural capacity of marine vegetation. High-CO2 conditions have national and regional socio-economic impacts within the Maritime Continent, affect marine production and alter ecosystem services. This interdisciplinary study will contribute to regional action to deal with climate change as a global issue, help to understand natural carbon dioxide removal (NCDR) mechanisms.

Year 2021: Assessment of the spatio-temporal variability of the carbonate system in relation to the issue of ocean acidification, including its physico-chemical drivers; Development of the MRV method for carbon inventory, including carbon emission reduction from activities of the Conservation/Protection of Seagrass Ecosystem in Marine Protected Area; publications of related work.

Year 2022: Assessment of the flux of particulate and dissolved organic carbon that contributes significantly to carbon burial and enrichment of coastal and continental shelf sediment; publications of related work.

PI and contributors: A'an Johan Wahyudi; Patrick Martin; Hiroshi Ogawa; Hanif Budi Prayitno; Udhi Eko Hernawan.

Funding Resources: The Coral Reef Rehabilitation, Management Program - Coral Triangle Initiative (COREMAP-CTI) from the Indonesian Institute of Sciences (LIPI) for 2021–2022, the INSINAS research grant from the Ministry of Research and Technology/National Research and Innovation Agency of the Republic of Indonesia, LIPI, Nanyang Technological University, and the Atmosphere and Ocean Research Institute - University of Tokyo.

5) *The Circulation and Ecosystem Study in the Indonesian Seas under the Influence of the Western Pacific Variability (Adi PURWANDANA)*

This project aims to measure the circulation, material flux, biology, and ecosystem variability in the eastern Indonesian seas, i.e. eastern Sulawesi Sea, Maluku Sea, Lifamatola Passage, Halmahera Sea, Savu Sea, Timor Strait, and 133°E section. The survey will conduct CTD and ADCP measurements in eastern Indonesian seas. The objectives will be fulfilled through the cooperative surveys with the Institute of Oceanology, Chinse Academy of Science. The output of this collaborative surveys will help to understand the biophysical interactions of the eastern Indonesian seas, provide science-based of sustainable use and management of the coastal and marine ecosystem. In particular, the collaborative research will make a significant contribution to the third component of the Coral Reef Rehabilitation and Management Program – Coral Triangle Initiative (COREMAP-CTI) Project.

Year 2021-2022: Joint research cruise between Indonesian Institute of Sciences and IOCAS is conducted to make synchronous measurements in the eastern Indonesian seas e.g. eastern Sulawesi Sea, Maluku Sea, Lifamatola Passage, Halmahera Sea, Dao Strait, Timor Passage, Lombok Strait, Ombai Strait, Savu Sea, and Makassar Strait, including water masses, material flux, flow structure and variability, and transports across the survey sections; time series of temperature, salinity, currents, associated with tides, internal mixing, and interannual variations like ENSO and IOD; the partition of the lTF transport through the Makassar Strait and the Maluku Strait, and their variability at the interannual variability. Analyses are performed to understand the water mass formation inside the Indonesian seas, especially in the deep Indonesian seas; the physics of western Pacific-Indonesian sea interactions. Database and numerical modeling capability are constructed.

PI and contributors: Adi Purwandana; Mochamad Riza Iskandar; Mochamad Furqon Azis Ismail; Dongliang Yuan; Li Yao.

Funding Resources: The National Science Foundation of China (NSFC) Innovative Group Grant (41421005), NSFC funding 41720104008, 91858204, NSFC-Shandong Province United Project (U1406401), Center for Ocean Mega Science, Chinese Academy of Sciences, and the Chinese Academy of Sciences Strategic Priority Research Project: Western Pacific Ocean System

6) *Mid-latitude air-sea interaction studies through the Climatic Hotspot2 project in Japan (Masami NONAKA)*

The project aims to further the understandings of mid-latitude ocean-atmosphere interaction processes that span multiple spatio-temporal scales and interplay among them through tight collaborations of latest observational and numerical modeling tools. Also, based on the improved understandings, predictability of extreme weather (such as typhoons and bomb cyclones), of persistent atmospheric circulation anomalies that induce those extremes, projection of climate changes, and active roles of mid-latitude oceans in those phenomena will be investigated. The project will improve our understanding of air-sea interaction associated with mesoscale and frontal scale oceanic structure and variability and have implications for improving predictability of mid-latitude ocean, atmosphere and climate variability.

Year 2021: In situ observations in the Kuroshio to the south of Japan and STMW region will be conducted. In addition, numerical studies for from sub-mesoscale to basin scale oceanic variability and also atmospheric responses to those oceanic variability will be conducted.

Year 2022: In situ observations in the Tsushima warm current regions will be conducted. The numerical studies for air-sea interaction will be continued.

PI and contributors: Masami Nonaka

Funding Resources: Japan Society of Promotion of Science (JSPS) through Grants-in-Aid for Scientific Research in Innovative Areas 2205.

7) *Hybrid-Intelligence estimation and Prediction of Ocean Productivity in the Kuroshio current area of influence (Jae-Hak LEE)*

This project aims to estimate the variability of ocean primary productivity (PP) as precise as possible using various cutting-edge technologies; understand the PP related processes in detail to develop and/or improve marine ecosystem models; make better prediction of PP focusing seasonal to interannual variability by developing a hybrid-intelligence prediction system on top of coupled physical-biogeochemical dynamic models. International collaborations are crucial to achieve those goals, especially for field campaigns and could be counted as the fourth goal. The project will further the understanding on the fundamental biogeochemical cycles of nutrients and carbon in the Kuroshio region as well as marine ecosystem changes. Understanding seasonal to interannual, and inter-decadal variabilities of physical and biogeochemical variables is imperative to improve the predictability of ocean productivity change.

Year 2022: Setting-up the three monitoring sites and field surveys of adjacent area will be prepared according to the schedule of R/Vs of Korea. The duration of the campaign would be a month long. The continental shelf station in the East China Sea will be visited every season, four times in a year. In parallel with the observation and analysis, numerical experiments using global to regional marine system model (a coupled physical-biogeochemical model) will be carried out. Several hybrid-intelligence models for the estimation of ocean productivity and for the regeneration of past variability will also be tested.

Year 2023: Shipboard observations and long-term monitoring would be similar to 2022. Data processing and quality control algorithms for the autonomous robot observations will be developed. Satellite primary production algorithms will be improved by comparing with optimal primary productivity in-situ data. Machine learning model for the primary productivity will be developed and tested. The interaction mechanism between bacteria and primary producers are key subject. Microbial loop process by adding bacteria as a state variable will be implemented in marine ecosystem model. Implementation of machine learning data for the PP prediction using dynamic model reproduced and predicted data.

PI and contributors: Hyoun-Woo Kang; Choi Dong Han; Jang Chan Joo; Kim Dongseon; Kim Yong Sun; Kwon Minho; Lee Yeonjung; Min Hong Sik; Pak Gyundo; Park Jae-Hyoung; Park Geun-Ha.

Funding Resources: N/A

8) *Observations in the origin region of the Kuroshio (Akira NAGANO)*

This project aims to monitor the water mass modification to the east of the Philippines by the air-sea interactions and upwelling of the subsurface and to study the transportation of modified water by the currents to the East China Sea and the east of the Ryukyu Islands in terms of spatial scales from basin scale to submesoscale. The project will provide data for assimilation and improve the understanding of heat and materials redistribution in the western North Pacific and fundamentally important in the wide range of oceanography and also is informative for the construction of a sustainable and effective observation system of the Kuroshio to monitor the ecosystem changes in the Kuroshio and adjacent regions in addition to physical environment changes.

Year 2021: Initial observations are conducted in the region east of the Philippines by deploying a mooring buoy (Philippine Sea buoy, abbreviated as Ph buoy) at 13˚N, 137˚E in December 2016 and unmanned surface vehicles such as Wave Gliders in the northern edge of the western Pacific warm pool. The Ph buoy will be replaced in the research cruise by the R/V Mirai from May to June of 2021 (cruise PI is Dr. I. Ueki). In addition, wave Gliders and Argo floats around the Ph buoy will be deployed to measure atmospheric and oceanic variables related to sea surface turbulent heat flux. Saildrone observation will be carried out in the Kuroshio or Kuroshio Extension region.

Year 2022: During the research cruise by the R/V Mirai in December, a high-resolution atmosphere and ocean observations of a mesoscale cyclonic eddy will be carried out. During the research cruise by the R/V Mirai, an intensive observation around the Ph buoy site will be performed and the Ph buoy will be replaced.

Data plan: Data collected by the research cruises are sent to the Data Management Group of JAMSTEC and will be published within 2 years in the website "Data and Sample Research System for Whole Cruise Information in JAMSTEC" (DARWIN) (http://www.godac.jamstec.go.jp/darwin/e). Real-time data obtained by the mooring buoy are published in the web site of Research Institute for Global Change/JAMSTEC (the web site is scheduled for completion until March 2021).

PI and contributors: Akira Nagano; Iwao Ueki; Takuya Hasegawa

Funding Resources: Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (Grant Number: JP20K04072, JP20H02236, JP20KK0097).

9) *Dynamical and ecological interaction between the Kuroshio Current and coastal circulation (Kiyoshi TANAKA)*

This project aims to investigate interaction between the Kuroshio Current and coastal circulations using state-of-the-art, numerical ocean circulation models. Shipboard observations with ADCP (acoustic Doppler current profiler) and CTD (conductivity-temperature-depth) instruments and mooring observations with a variety of loggers are also conducted. Synergistic collaboration with local fishers (fishermen/women) is essential to provide the coastal observations with higher spatial and temporal resolution. This research will improve the understanding of dynamical and ecological interaction between the Kuroshio Current and coastal circulations and present a clear vision for future ocean science from the viewpoint of sustainable ocean science, meeting the goal of the UN Decade of Ocean.

Year 2021: Model development and validation. State-of-the-art, numerical ocean circulation models based on JCOPE model (JAMSTEC) and MRI.COM model (Japan Meteorological Agency) is developed. Emphasis is put on reproducing precisely and realistically the interaction processes between the Kuroshio Current and the coastal region around Suruga Bay, which is selected as a reasonable area in the CSK-2. Moreover, shipboard observations using ADCP and CTD instruments will be conducted. The system of the shipboard observation has been developed so that the instruments can be carried and assembled easily on an ordinary fishing boat. A variety of monitoring loggers are also planned to be deployed in the bay to record water velocity, temperature, salinity, and chlorophyll. Special emphasis is put on synergistic collaboration with stakeholders such as those involved in local fisheries.

Year 2022: Both the numerical modeling and the observation are continued. Moreover, a comparison between numerical and observational results will be made, which will provide important information for improving both the numerical modeling and the observational plan.

PI and contributors: Tanaka, Kiyoshi; Miyama Toru; Toyoda Takahiro, Kutsuwada Kunio and Takahashi Daisuke

Funding Resources: JSPS KAKENHI Grant Number 20H01968

10) *Ocean circulation in the Indonesian seas and its climate effects (Dongliang YUAN)*

This project aims to estimate the transport of the ITF and study the variability and dynamics of the Pacific-Indian Ocean exchange. The output of this study will contribute to the NEC–MC–ITF variability part of the Science Action Plan by understanding the transports, pathways, variability and dynamics of the Pacific-Indian Ocean exchange.

Year 2021: Conducting a joint cruise in the eastern Indonesian seas with PPII and RCO/LIPI, rotating moorings and CTD.

Year 2022: Conducting a cruise with the Indonesian research agency, maintaining the mooring arrays.

PI and contributors: Dongliang Yuan; Wang Zheng; Zhao Xia; Wang Jing; Yang Ya

Funding Resources: CAS Strategic Priority Research Project B; NSFC key projects; National Key Research and Development Program.

11) *Subthermocline currents and eddies in the NEC-Kuroshio-MC region – (Linlin ZHANG)*

This project aims to build a long-term continuous observation network in the origin area of the Kuroshio, especially in the area east of the Philippine coast. These observations including repeated CTD transects, glider transects and mooring time series will provide valuable dataset for research on the three-dimension structure, multi-scale variations and associated dynamics of the NEC-Kuroshio-MC system.

Year 2021: Conducting a cruise in the NKM area, deploying 3-5 moorings in the NMK area, carrying out CTD and glider measurements. Based on the mooring data collected in previous cruises and projects, to investigate the complex mesoscale variations (surface-intensified and subthermocline-intensified types) in the NKM area, describe their general features and associated dynamics. This work is collaborated with Cesar Villanoy.

Year 2022: Conducting another cruise; investigating the interaction between the surface/subthermocline currents and the complex mesoscale eddies; estimating the mass, heat and salinity transport due to eddies; exploring interannual variations of the currents and their relation with ENSO.

PI and contributors:Wang Fan; Zhang Linlin

Funding Resources: Strategic Priority Research Program of the Chinese Academy of Sciences and National Key Research and Development Program of China.

5.3 Timetable for annual and bi-annual workshops

Regular CSK-2 workshop will serve as the main means of the development and implementation of the CSK-2 programme (Fig. 5). Workshops will provide opportunities for discussions among participants, including Principal Investigators (PIs), and for further development of collaborations. They will also provide the opportunity to invite new potential PIs to join the CSK-2. Confirmation of data exchange and sharing with and dissemination to the public will also be performed at such events. In addition to annual workshops, bi-annual co-design/co-delivery workshops for Kuroshio study will also be held in collaboration with ocean stakeholders. The bi-annual workshops are expected to support collaboration with ocean stakeholders, including funding agencies, the private sector, and the public and to provide an opportunity for all of ocean stakeholders to consider/act regarding the societal outputs of the CSK-2. Finally, compiling and submitting a report to the Advisory Group and WESTPAC Intergovernmental session will be also an important task for the ISC.

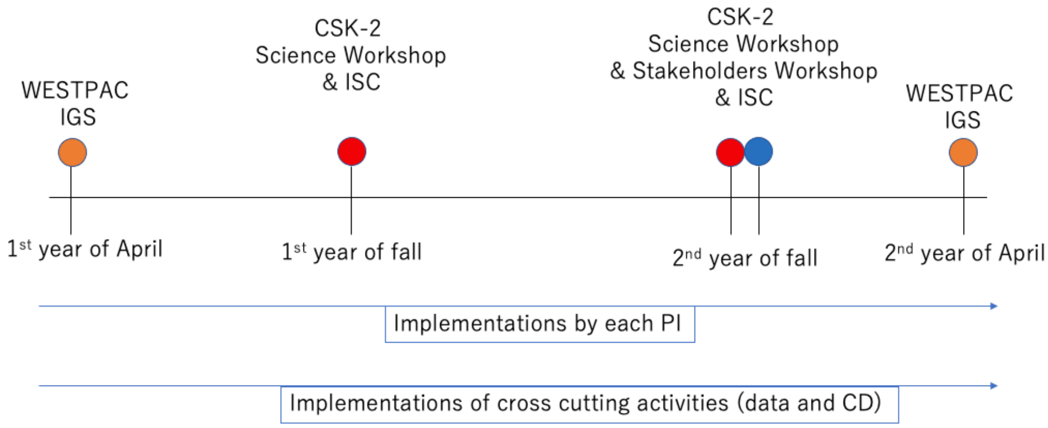

Figure 5. Timeline of CSK-2 workshops during an inter-sessional period of IOC/WESTPAC.

5.4 <u>Resources needed</u>

To implement the CSK-2, we will need several types of resource, as listed in the following.

a. <u>Secretariat and coordination</u>

The Secretariat support is critical for the smooth operation of the ISG and the CSK-2 as a whole. In addition to coordination and administrative tasks on a daily basis, outreach and capacity development will also constitute part of the secretariat work. In kind or in cash support will be required to maintain the secretariat function for the CSK-2 programme.

b. <u>CSK-2 project office, if needed</u>

The CSK-2 is foreseen to be underpinned by a wide range of projects and activities. The requirement for a project office function will depend on the ~~national~~ scale and magnitude of the CSK-2 project. If needed, a project office may be established as an effective link with the ISC, the WESTPAC Office and concerned parties.

c. <u>Research project fund of member states</u>

A research project fund at national level is fundamental for implementation of the CSK-2. Initially, some CSk-2 research activities will be supported by existing projects; however, PIs will need additional support to develop networks with other PIs, the data system, and stakeholders. Furthermore, in later stages, PIs will have to request continued funding for support if their outputs are considered to have the potential to realize to the objectives of the CSK-2.

6. Collaborations with Stakeholders

The success of CSK-2 hinges on the ability of the programme to address the needs of the stakeholders, which is a primary tenet of the UN Ocean Decade. The plan for the implementation of the UN Ocean Decade recognizes the need to find transformative solutions to problems affecting society that an understanding of the oceans could provide. Therefore, it is essential to identify stakeholders who will be sufficiently engaged to identify and find solutions to challenges they jointly face. Following the vision of the UN Ocean Decade, our stakeholders will mainly define the type of ocean we desire, and it will then be the role of the scientists to determine the science that is needed to achieve that goal. The engagement of stakeholders must be integral in all phases of the programme, from planning and execution to dissemination.

The stakeholders will include policy makers and national government agencies responsible for implementing ocean policies. Ultimately, policies must trickle down to local government, and engagement with government at the local level will be critical. Participation by funding agencies, scientists, economists, and social scientists as stakeholders will also be vital to ensure that policy decisions are based on sound science and evidence. The gauge for the success of policy implementation will ultimately be the response of the public. High-impact or transformative ocean policies will require transformative behavioural change by the public to be successful. Such change will likewise involve appropriate literacy to upgrade the understanding of the behaviour of our ocean environment and how it affects resources and dependent communities.

CSK-2 is an international programme to be undertaken under the framework of an intergovernmental body, requiring government endorsement and commitment. Initial national-level negotiations between government, funding institutions, and academic institutions will be needed to establish national programs as counterparts for the CSK-2. Concurrent meetings and workshops will have to be conducted to ensure that the activities of each individual country fall within the programme objectives, and to allow discussion of collaborative activities to avoid overlaps and to optimize the use of available resources.

Similar coordinating workshops at the regional level will also be necessary because multiple institutions and agencies from different countries are expected to be involved in the programme.

It is recognized that the goals might differ for individual member states because competencies, capabilities, resources, and relevant ocean issues and problems are not uniform throughout the region. Although there might be similar needs and problems, the approaches adopted to address these challenges might differ between member states. However, certain issues might be regional in scope and would therefore need region-wide solutions.

Opportunities for intergovernmental meetings include IOC/WESTPAC activities such as the WESTPAC International Marine Science Conference or other regional scientific meetings such as the Asia Oceania Geoscience Society and the Asia-Pacific Coral reef Symposium. National Marine Science Symposia are also potential venues for national coordination and meetings between national institutional partners.

Outreach programmes will be needed to engage stakeholders at the local level. This could be achieved by conducting outreach programs, public talks and seminars, and focused group discussions with local government and local communities, preferably conducted using the local language for greater exposure.

Information generated by the CSK-2 should be discussed with stakeholders, at international, national, or local level as appropriate, and translated into formats that could be used for drafting policy papers and the dissemination of such material to relevant decision makers.

7. Data System

A data and information system will be essential for success of the CSK-2 in WESTPAC. Without data and information sharing among participants and contributors, and without dissemination to all other stakeholders interested in the Kuroshio, it will be impossible to achieve the goals of the programme. This programme aims to contribute to the SDGs through the UN Ocean Decade. In the objectives of the UN Ocean Decade, it is strongly recommended to have a dialogue and communication among ocean stakeholders. One way to achieve is to have face-to-face meetings/conferences, but another way is to deliver our data/information via Internet technologies. With incorporation of an efficient data/information system within our programme, we will be able to deliver our message to all other stakeholders on the Kuroshio and adjacent regions. The development of such a synchronized data and information system should adhere to the following principles (Fig. 6).

Principles:

- Follow IOC/IODE data policy, and pursue "Findable, Accessible, Interoperable, and Reusable (FAIR)" policy.
- Data are obtained in situ and processed only after adequate quality control. Reanalysis, forecasting, and satellite-based data can be included.
- Quality control procedures should follow international standards, if relevant.
- Moratorium period for sharing/dissemination of data extends one year after acquisition.
- Aim to use common data formats for sharing and dissemination.
- Data provision should use the File Transfer Protocol or other simple protocol as a minimum function for sharing/dissemination.

The guidelines for the implementation are listed below:

- Data taken by project shall be managed by each PI in accordance with his/her country's relevant rules, and regulations.
- Required quality control shall be conducted by the appropriate PI.
- Only processed data shall be shared/disseminated by the PIs.
- Raw data shall be managed properly by each PI.
- Each PI will provide data to the National Oceanic Data Centre of each Member State.
- It is recommended that the OceanSITES data format of the netCDF be used, if applicable; otherwise, the netCDF data format is recommended.
- The CSK-2 global data portal will be established by one or more institutes/universities and its functions shall be to search all CSK-2 data and to provide access to related data system(s).
- The CSK-2 global data portal also will have functions to access existing data systems of modelling outputs and satellite datasets.
- It is also recommended that a local data portal be developed for each data system, possibly using the eXtensible Markup Language protocol.

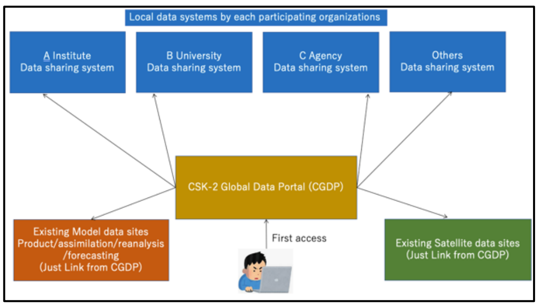

Figure 6. Schematic of the data system for the CSK-2.

8. Capacity Development and Kuroshio Literacy

From its area of origin to the KE, the KC extends over 6,000 km and moves past the EEZ of many countries. Associated interactions with marginal seas give rise to basin circulations that are influenced by Kuroshio variability. It traverses tropical and temperate latitudes and hosts a wide variety of ecosystems and habitats. The Kuroshio is a key component of the regional climate and thus it affects the economies of some of the most populous lands on the planet. The collaborative research that will be undertaken during the CSK-2 will hopefully shed light on some of the impacts of Kuroshio variability on our regional climate and improve its predictability on spatiotemporal scales that are directly relevant to how communities relate to the ocean and its resources.

Kuroshio literacy is defined as gaining an understanding of what the Kuroshio is, how it behaves, and how it interacts with other bodies of water in terms of physical, chemical, biological, cultural, economic, and societal perspectives. More importantly, it also highlights the importance of the mutual interaction between the Kuroshio and associated systems in our daily lives. However, Kuroshio literacy also requires basic understanding of marine science concepts, as well as knowledge regarding the interaction of the ocean with the atmosphere. Hence, efforts to enhance Kuroshio literacy go hand in hand with ocean literacy. UNESCO defines ocean literacy as "the understanding of our influence on the ocean and the ocean's influence on us. Ocean literacy is a way not only to increase the awareness of the public about the ocean, but it is as an approach to encourage all citizens and stakeholders to have a more responsible and informed behaviour toward the ocean and its resources. It is not just knowledge about the state of the ocean but a deeper understanding of our individual and collective responsibilities to take care of the ocean (https://legacy-oceanliteracy.ioc-unesco.org/)". In short, an ocean-literate individual is able to understand fundamental ocean concepts and principles, can communicate about ocean issues, and can make informed and responsible decisions that lead to appropriate actions regarding the ocean and its resources.

Programs to incorporate Kuroshio and ocean literacy are encouraged, and this can take many forms such as Massive Open Online Classes that target all levels of education (primary to tertiary), establishing virtual exhibits or museums, production of short audio-visual presentations for widespread distribution, developing materials for tri-media and social media exposure, and development of teaching aids to assist primary and secondary school teachers in the use of these aids. Considering the recent expansion of media, popular social media such as television broadcasts, YouTube, and other Internet-based platforms are suitable for widespread dissemination of information regarding the importance of the Kuroshio. In particular, advertising impressive messages through national/regional television broadcasts using local languages is effective at regional and local levels. Outreach programs and organized tours of research vessel whenever they visit ports of other countries is a wonderful opportunity for students and interested individuals to appreciate what it is like inside a research vessel, to see examples of the latest oceanographic instrumentation, and to learn about the experience of life onboard a research vessel from the scientists and crew.

Capacity development forms an integral part of the CSK-2 programme. Having a multinational collaborative program provides an perfect opportunity for graduate students to advance their knowledge and cooperation. Participation in the research activities of different research groups will provide exposure to different cultures, technologies, and operating procedures. IOC/WESTPAC could facilitate the development of and/or the exchange of information on training opportunities/programs through its various networks and comprehensive capacity development tools, including the Regional Network of Training and Research Centers on Marine Sciences (RTRCs). Regular scientific symposia to exchange results and ideas will be scheduled. Graduate student scholarships could be incorporated into individual research grants, and agreements between member states and institutions could include student and faculty exchanges to allow more effective interaction.

References (In this SAP, we should limit only to very major documents for SAP)

Ando, K., et al. (2021) Half-Century of Scientific Advancements Since the Cooperative Study of the Kuroshio and Adjacent Regions (CSK) Programme - Need for a new Kuroshio Research. Progress in Oceanography, https://doi.org/10.1016/j.pocean.2021.102513

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Abbreviations/acronyms

CSK - Cooperative Study of the Kuroshio and Adjacent Regions

CTD – Conductivity, Temperature, and Depth

ECS – East China Sea
EEZ – Exclusive Economic Zone
ENSO – El Niño–Southern Oscillation
FOO - Framework for Ocean Observing
IMTA – Integrated Multi-trophic Aquaculture
IOC - Intergovernmental Oceanographic Commission, UNESCO
IOD – Indian Ocean Dipole
IODE – International Oceanographic Data and Information Exchange
ISG – International Steering Group of the CSK-2
ITF – Indonesian Throughflow
KC – Kuroshio Current
KE – Kuroshio Extension
LME – Large Marine Ecosystem
MC – Mindanao Current
NEC – North Equatorial Current
NECC – North Equatorial Counter Current
NKM – North Equatorial Current, Kuroshio Current, Mindanao Current
NPOCE – North Pacific Ocean Circulation and climate variations Experiment of CLIVAR
PDO – Pacific Decadal Oscillation
PI – Principal Investigator
RCS – Ryukyu Current System
SAP – Science Action Plan
SDG - Sustainable Development Goal
SST – Sea Surface Temperature
STCC – Subtropical Counter Current
STMW – Subtropical Mode Water
UNGA - United Nations General Assembly
UN Ocean Decade - United Nations Decade of Ocean Science for Sustainable Developments (2021-2030)
UNESCO - United Nations Educational, Scientific, and Cultural Organization
WESTPAC – IOC Sub-Commission for the Western Pacific

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1: Co-leads of the Inter-sessional working group of IOC/WESTPAC
2: Drafting members of the zero-order SAP
3: Proposers and contributors to the Webinar Series for CSK-2 (see Appendix-4)
4: Authors and/or anonymous reviewers of the review paper for CSK-2 (see Ando et al., 2021)
5: Secretariat support and/or substantial support
6: Contribution of drafting the SAP version 2021.

Appendices

Appendix-1: IOC Oceanographic Data Exchange Policy (IOC resolution XXII-6: IOC Oceanographic Data Exchange Policy)

IOC Oceanographic Data Exchange Policy

Preamble

The timely, free, and unrestricted international exchange of oceanographic data is essential for efficient acquisition, integration, and use of ocean observations gathered by the countries of the world for a wide variety of purposes that include the prediction of weather and climate, operational forecasting of the marine environment, preservation of life, mitigation of human-induced changes in the marine and coastal environment, and the advancement of scientific understanding that makes this possible.

Recognizing both the vital importance of these purposes to all humankind and the role of the IOC and its programmes in this regard, the Member States of the IOC agree that the following clauses shall frame the IOC policy for the international exchange of oceanographic data and its associated metadata.

Clause 1

Member States shall provide timely, free, and unrestricted access to all data, associated metadata, and products generated under the auspices of IOC programmes.

Clause 2

Member States are encouraged to provide timely, free, and unrestricted access to relevant data and associated metadata from non-IOC programmes that are essential for application to the preservation of life, beneficial public use, and protection of the ocean environment, the forecasting of weather, the operational forecasting of the marine environment, the monitoring and modelling of climate, and sustainable development in the marine environment.

Clause 3

Member States are encouraged to provide timely, free, and unrestricted access to oceanographic data and associated metadata, as referred to in Clauses 1 and 2 above, for non-commercial use by the research and education communities, provided that any products or results of such use shall be published in the open literature without delay or restriction.

Clause 4

With the objective of encouraging the participation of governmental and non-governmental marine data-gathering bodies in international oceanographic data exchange and maximizing the contribution of oceanographic data from all sources, this Policy acknowledges the right of Member States and data originators to determine the terms of such exchange, in a manner consistent with international conventions, where applicable.

Clause 5

Use of IODE system: Member States shall, to the best practicable degree, use data centres linked to the World Data System and IODE's National Oceanic Data Centres, such as the World Ocean Database and the Ocean Biogeographic Information System, as long-term repositories for oceanographic data and associated metadata.

Clause 6

Member States shall enhance the capacity in developing countries to obtain and manage oceanographic data and information, and assist them to benefit fully from the exchange of oceanographic data, associated metadata, and products. This shall be achieved through the non-discriminatory transfer of technology and knowledge using appropriate means, including the IOC's Training Education and Mutual Assistance programme and through other relevant IOC programmes.

Definitions:

"Free and unrestricted" – non-discriminatory and without charge.

"Without charge" – at no more than the cost of reproduction and delivery, without charge for the data and products themselves.

"Data" – oceanographic observation data, derived data, and gridded fields.

"Metadata" – information about data describing the content, quality, condition, and other characteristics of the data.

"Non-commercial" – not conducted for profit, cost-recovery, or re-sale.

"Timely" – the distribution of data and/or products sufficiently rapidly to be of value for a given application.

"Product" – a value-added enhancement of data applied to a particular application.

Clause 5 was revised in 2019 by Decision IOC-XXX/7.2.1(II) of the Assembly at its 30th session, Paris, 26 June–4 July 2019

Appendix-2: Activity mapping and relations to proposed activities in 5.2 (as of March 2021)

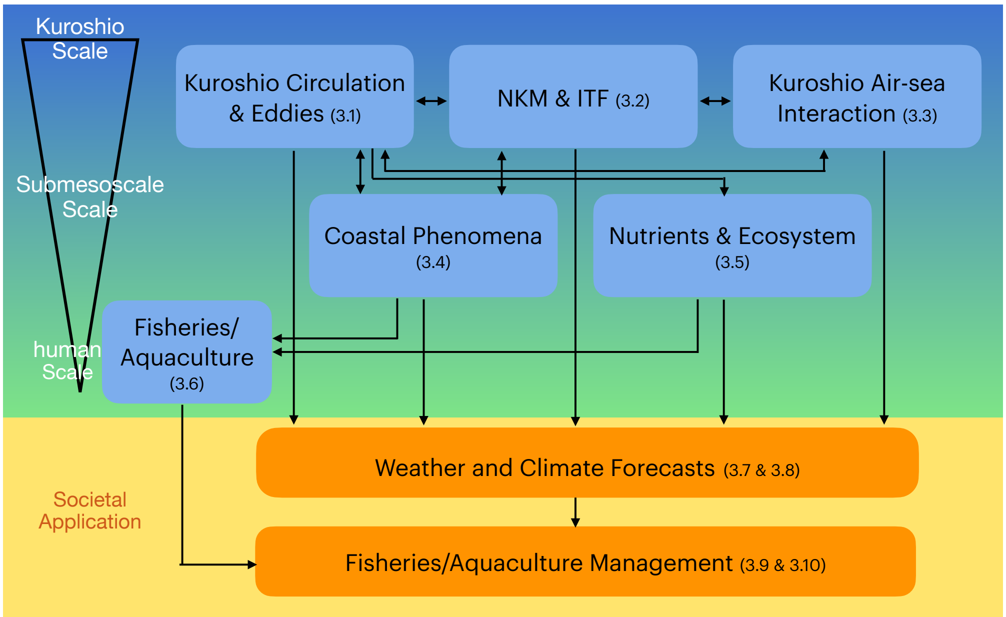

Table Correspondences between the expected outputs of the CSK-2 (3.1 and 3.2) and planned activities (5.2, titles are shortened)

Title of planned activities (section 5.2)	Outputs (Section 3.1 and 3.2)
5.2-1) Time series observations of Kuroshio variability in the East China Sea	3.1, 3.5
5.2-2) Philippine Rise Integrated Marine Environmental Research	3.1, 3.2, 3.5, 3.9
5.2-3) Air-Sea Interaction in the Kuroshio Extension and its Climate Impact Phase II	3.1, 3.3, 3.7, 3.8
5.2-4) Assessment of Ocean Carbon Dynamics in the Sunda Shelf Region	3.4, 3.5, 3.7
5.2-5) The Circulation and Ecosystem Study in the Indonesian Seas	3.2, 3.5, 3.9
5.2-6) Mid-latitude air-sea interaction studies through the Climatic Hotspot2 project	3.1, 3.3, 3.7, 3.8
5.2-7) Hybrid-Intelligence estimation and Prediction of Ocean Productivity	3.1, 3.5, 3.6, 3.9
5.2-8) Observations in the origin region of the Kuroshio	3.1, 3.2,3.3, 3.7
5.2-9) Dynamical and ecological interaction between the Kuroshio and coast	3.1, 3.4, 3.9
5.2-10) Ocean circulation in the Indonesian seas and its climate effects	3.2, 3.7, 3.8
5.2-11) Subthermocline currents and eddies in the origin of Kuroshio - NKM region -	3.2, 3.7, 3.8

These correspondences do show potential contributions to the outputs of CSK-2.

Appendix-3: Draft Terms of Reference (ToR) of the ISG

Please check the proposal, in which draft ToR is shown.

Appendix-4: Webinar series for CSK-2

Agendas of the Webinar sessions for the CSK-2 Science Plan

Date/time (Chinese Standard Time)		Speakers	Topic
2020-07-31 Chair: Ken Ando	14:00–14:20	K. Ando, C. Villanoy, X. Lin	Opening remarks
	14:20–15:00	DL. Yuan	Role of the western tropical Pacific Ocean, including its interactions with the marginal seas, in ENSO dynamics and global climate change
	15:00–15:40	XP. Lin	An integrated observation and service system in the Kuroshio Extension
2020-08-07, Chair: Cesar Villanoy	14:00–14:40	A. Hutahaean	The sources of organic carbon in the sediment of coastal environments in Indonesia
	14:40–15:20	A. Syhailatua	Role of the Indonesia Throughflow on marine life and the environment
	15:20–16:00	H. Na	Time series observations of Kuroshio variability in the East China Sea since 2015
2020-08-14 Chair: Xiaopei Lin	14:00–14:40	H. Saito	Observations of the structure and dynamics of the Kuroshio ecosystem under the CSK-2 project
	14:40–15:20	M. Nonaka	Observations of air–sea interaction in the Kuroshio regions: Climatic Hotspot 2 project in Japan
	15:20–16:00	A. Nagano	Observations in the origin region of the Kuroshio: A pilot study for construction of an observation system under the CSK-2 Project
2020-08-21 Chair: Ken Ando	14:00–14:40	C. Villanoy	Philippine Rise Integrated Marine Environment Research (PRIMER)
	14:40–15:20	PB. Wang	Impact of Kuroshio on harmful algal blooms (HABs) in Northeast Asia
	15:20–16:00	SJ. Hu	Is there a robust multi-decadal trend in low-latitude western boundary currents in the tropical Pacific Ocean?
2020-08-28 Chair: Xiaopei Lin	14:00–14:40	K. Tanaka	Toward understanding interaction between coastal circulations and the Kuroshio Current
	14:40–15:20	J-H. Lee	A KIOST CSK-2 project under development
	15:20–16:00	F. Wang Speaker: RC. Yu	Integrated Investigation in Indo-Pacific Convergent Centre (I3PCC): A proposal on regional cooperation program