

Two UN Decade Endorsed Actions:

COASTAL-SOS

(a project led by Minhan DAI)

Digital Twins of the Ocean (DITTO)

(a program led by Fei CHAI and Joanna STANEVA)

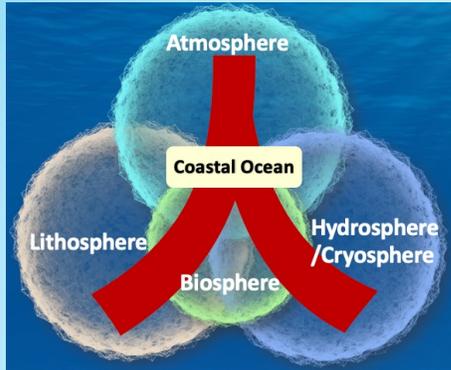
Dr. Fei CHAI

Chair Professor, Xiamen University

Professor Emeritus, University of Maine

OUTLINE

COASTAL-SOS



DITTO
Digital Twins of the Ocean

1

UN Decade

2

COASTAL-SOS

3

DITTO



2021
2030 United Nations Decade
of Ocean Science
for Sustainable Development



Coastal and Marine Ecosystem Stressors

Climate Change

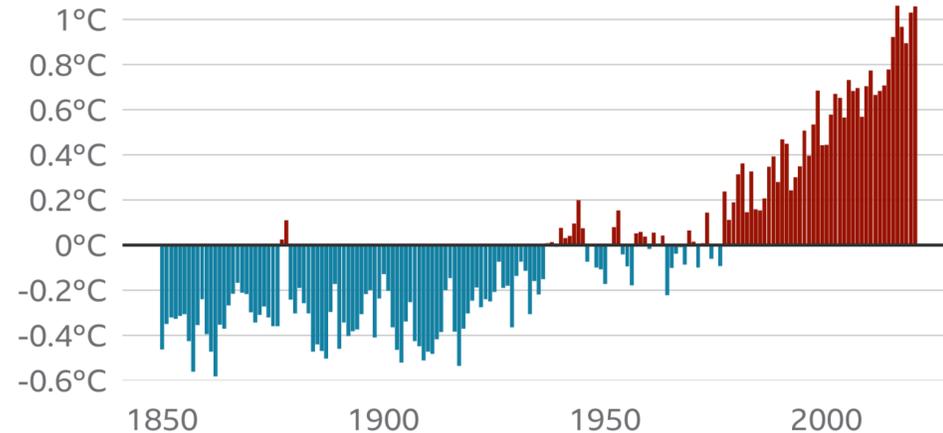
- Global warming
- Precipitation & runoff
- Sea-level rise
- Storms & extreme events
- Ocean acidification

Non-Climate

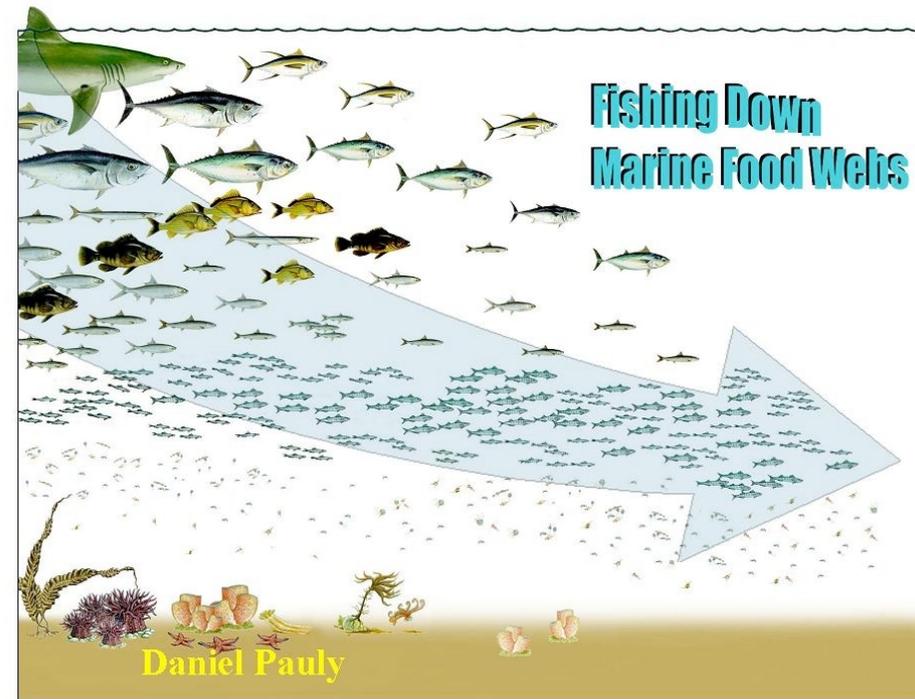
- Overfishing
- Eutrophication
- Loss of habitats
- Oil spill
- Land reclamation

The world is getting warmer

Annual mean land and ocean temperature above or below average, 1850 to 2020



Global Land-Ocean Temperature Anomaly



Coastal and Marine Ecosystem Stressors

Climate Change

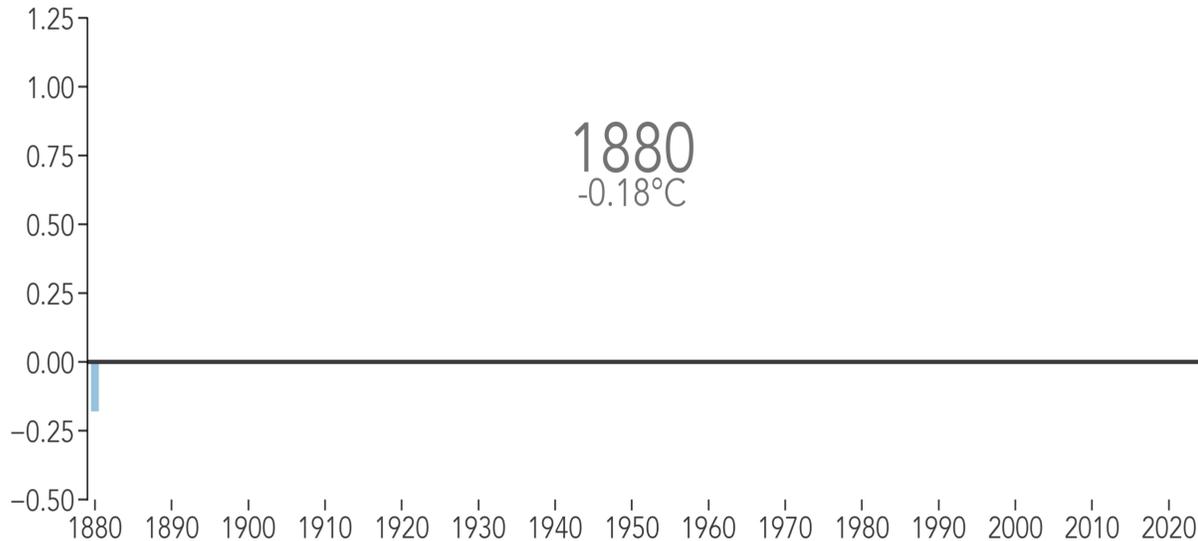
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Non-Climate

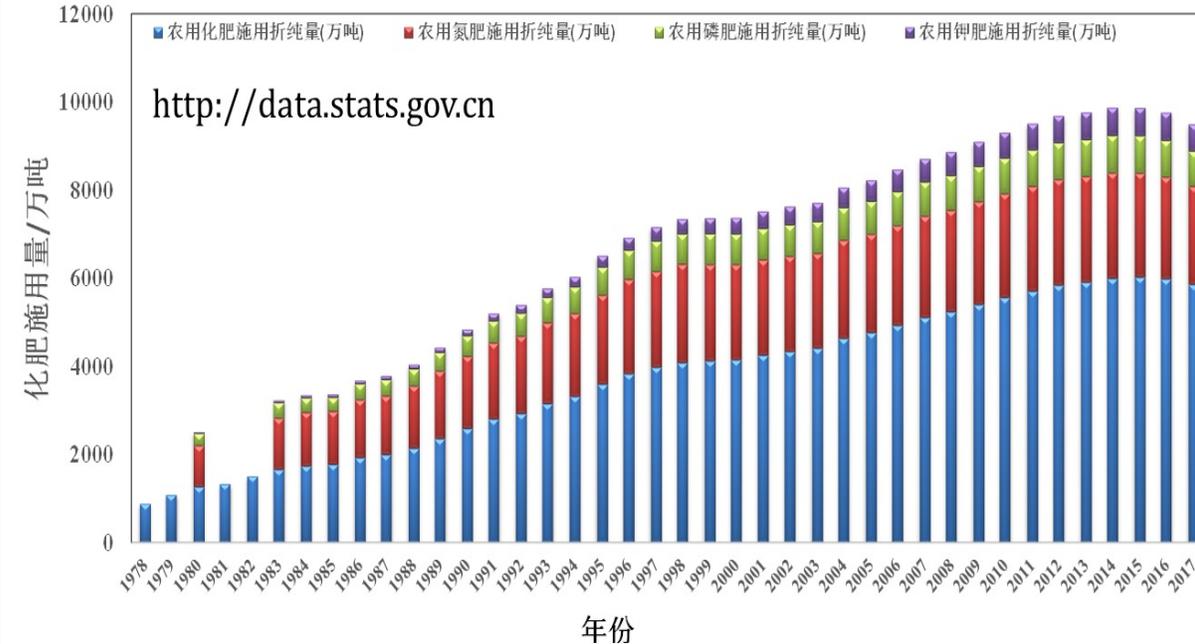
- Overfishing
- Eutrophication
- Loss of habitats
- Oil spill
- Land reclamation

2024 Was the Warmest Year on Record

Global Temperature Anomaly (°C compared to the 1951-1980 average)



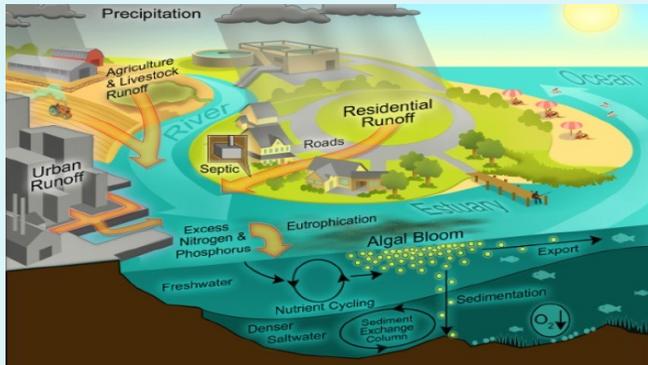
Fertilizer consumption in China (1978-2017)



Coastal ecosystem hazards:

Large scale, wide influence and hard to restore

Eutrophication



- Acidification
- Algal bloom



- Hypoxia
- Red tide



Pollution

- Heavy metal



- Petroleum



- Persistent Organic Pollutants



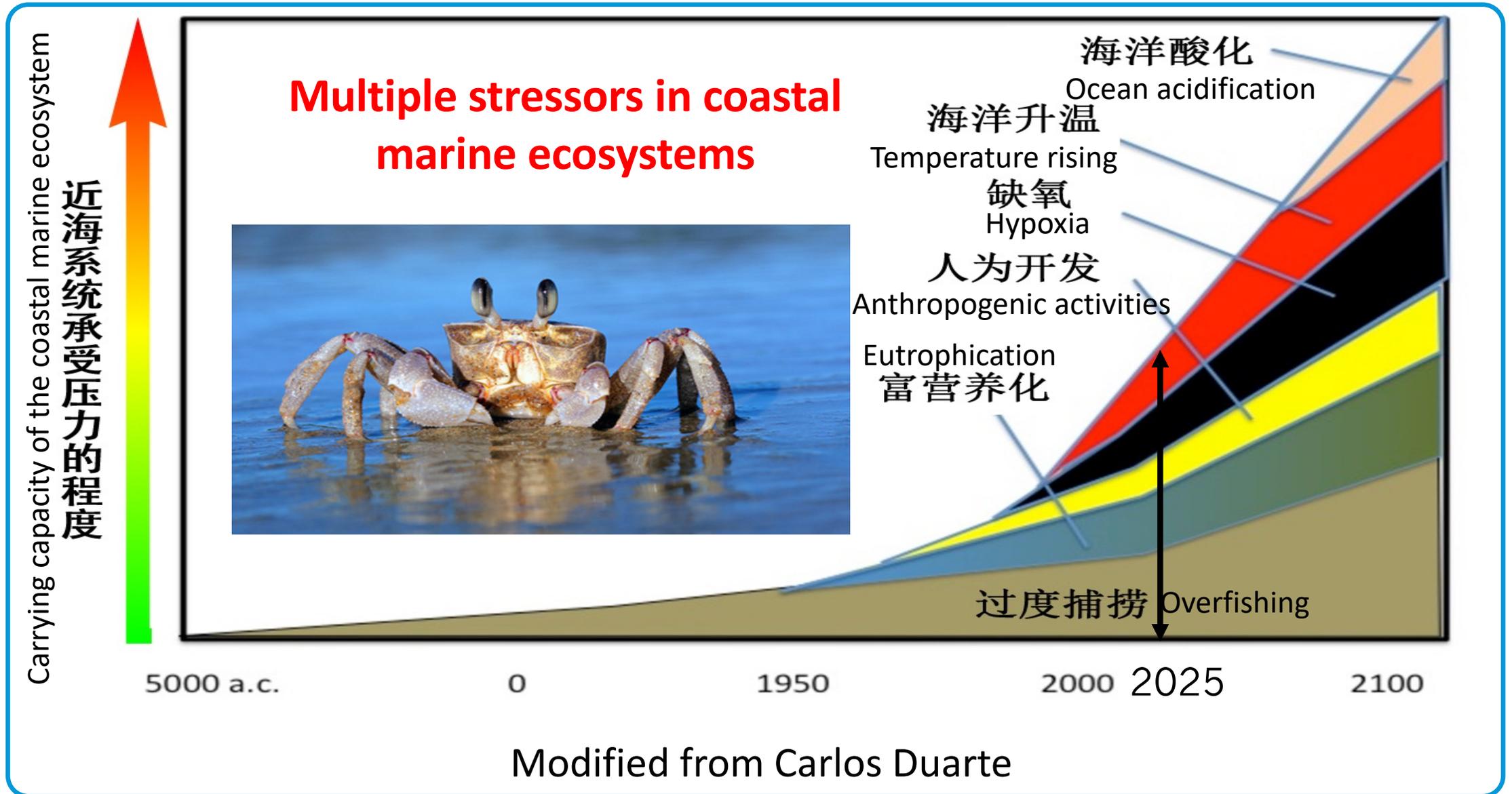
Over aquaculture



Fishery resources degradation



Future trends of ecosystem disasters in coastal area



Modified from Carlos Duarte

Coastal-SOS:

**Coastal Zones Under Intensifying Human Activities and
Changing Climate:**

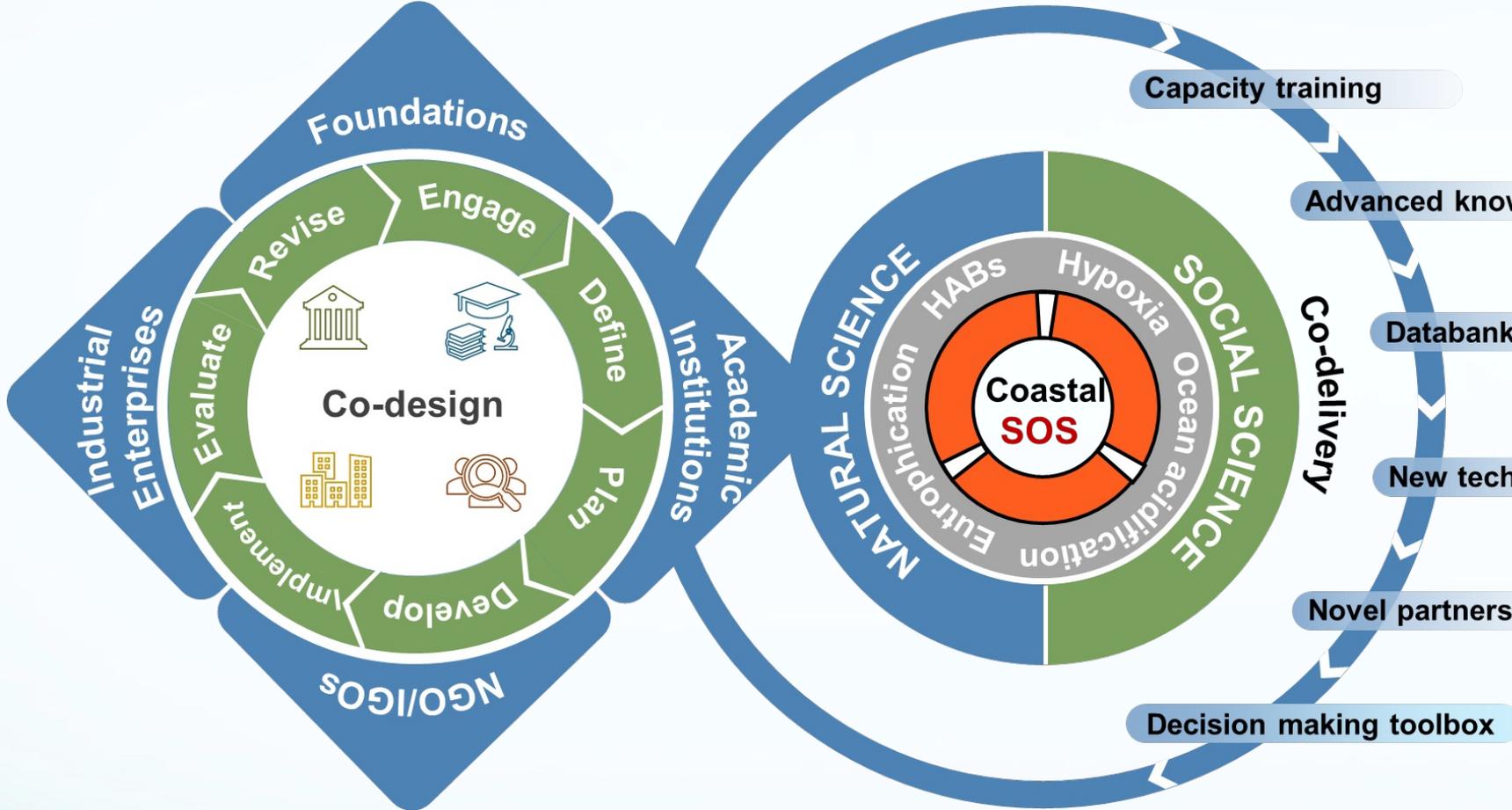
**A Regional Project Integrating Science, Management
and Society to Support Ocean Sustainability**

(A Project endorsed by The UN Decade)

Minhan Dai, Fei Chai & many others

Xiamen University

Project Overview



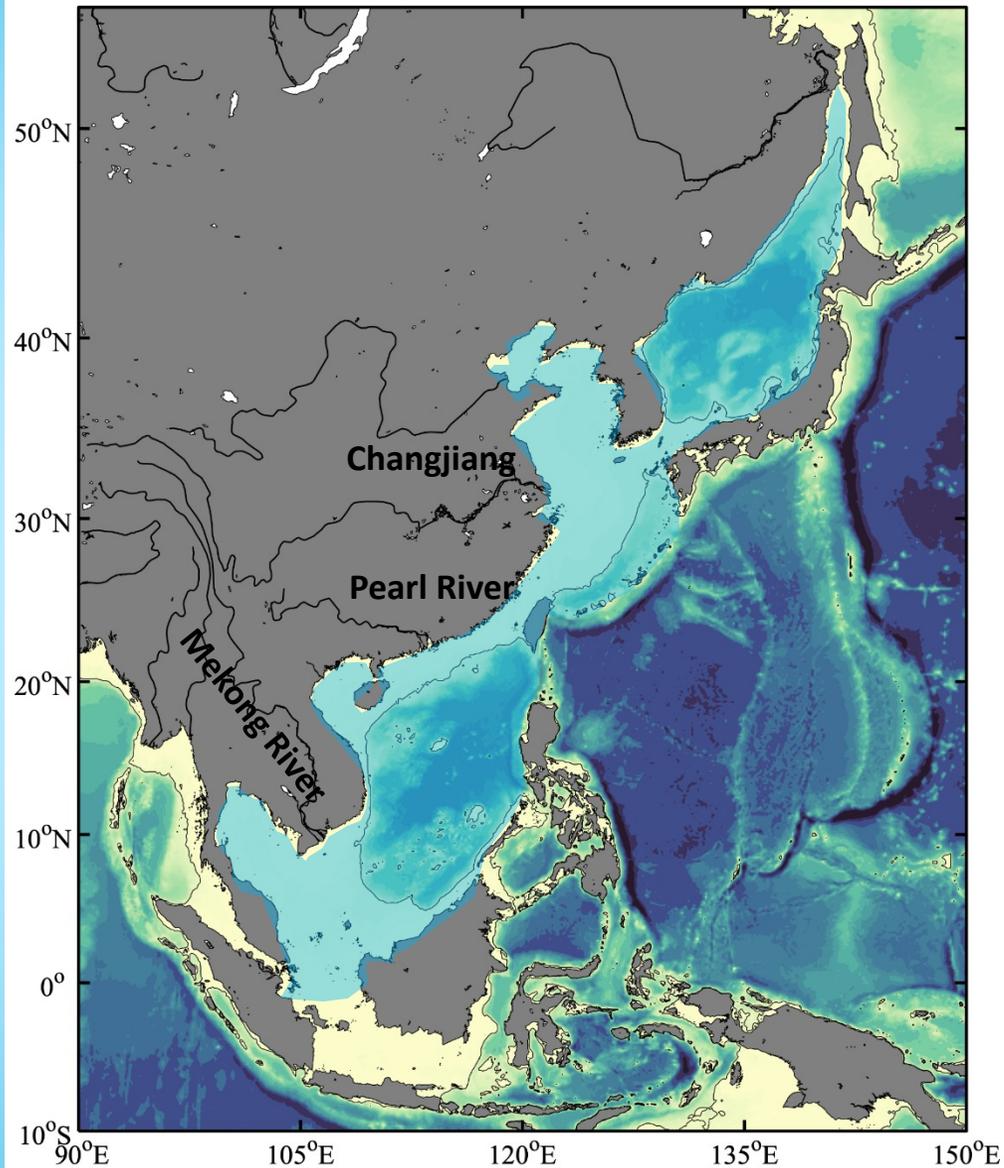
- Capacity training
- Advanced knowledge
- Databank
- New technology
- Novel partnership
- Decision making toolbox

Proposed by:



- 10 Academic Institutions
- 6 Business Enterprises
- 3 Foundations
- 4 NGOs & Inter-Gov. Organizations

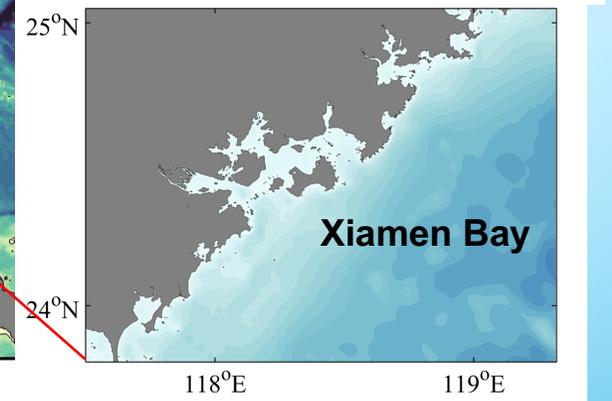
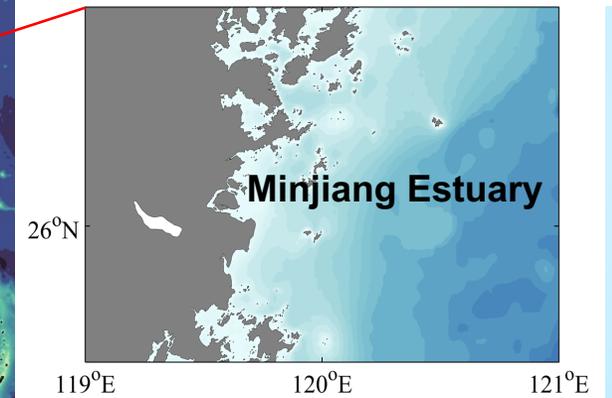
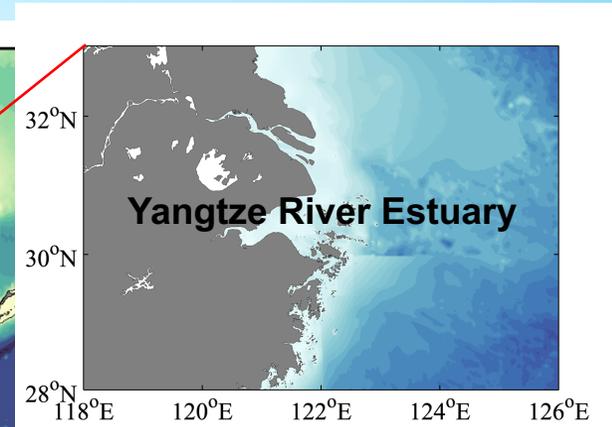
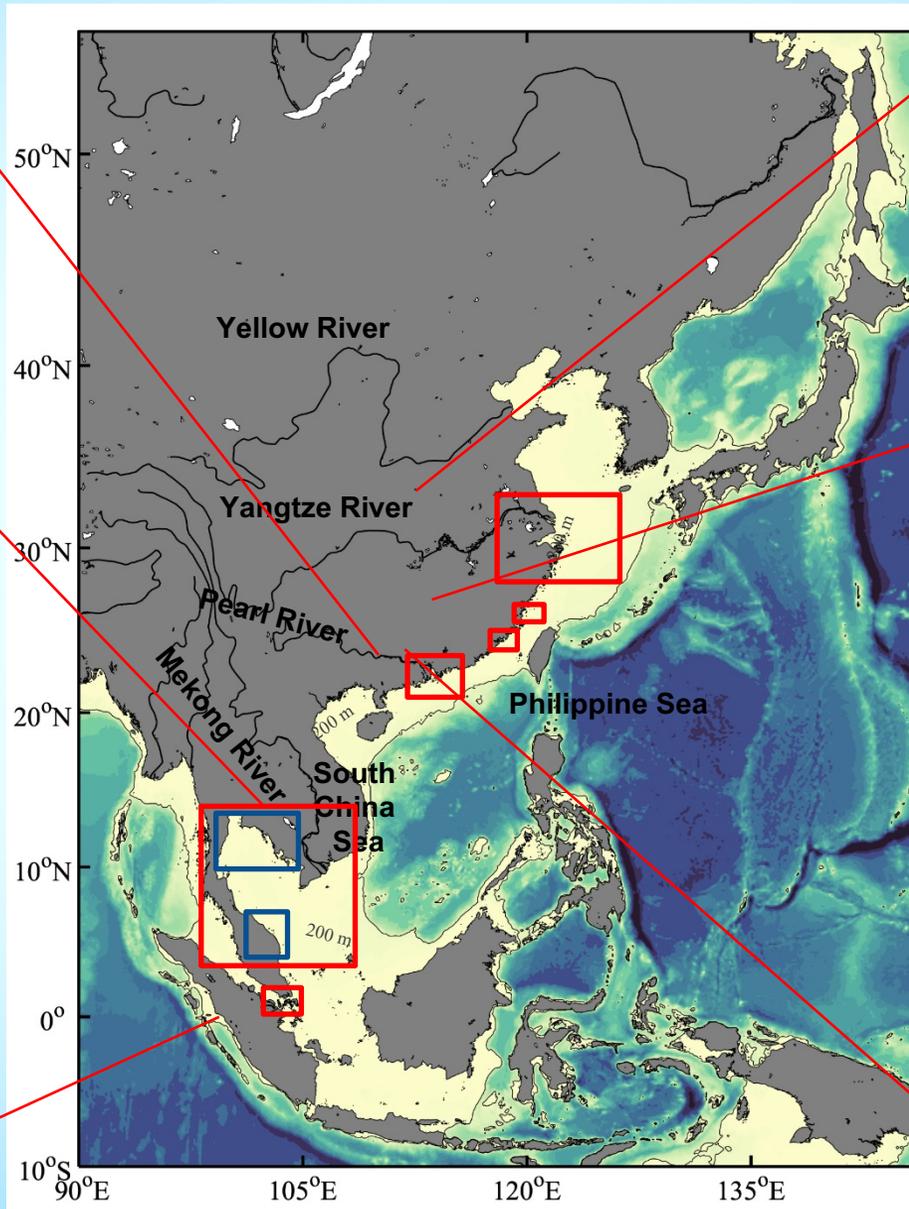
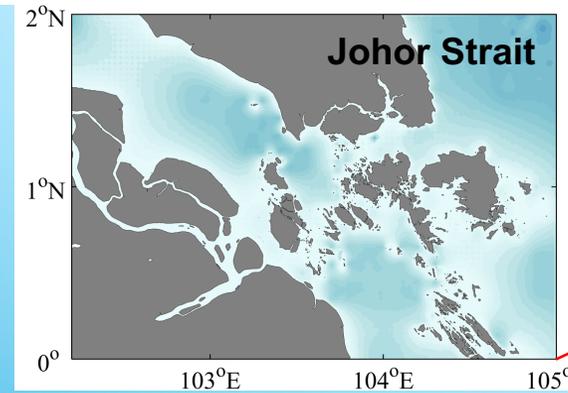
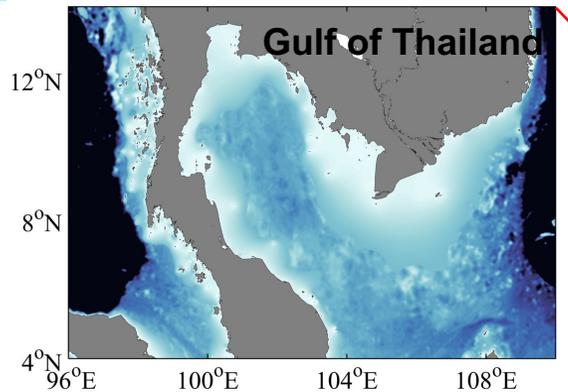
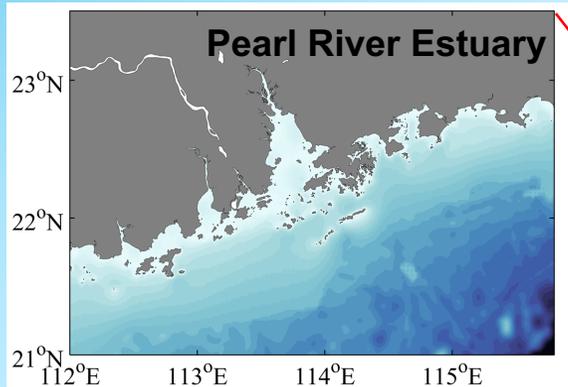




▶ East Asian seas

- 7 million km²
- Fed by world's longest rivers such as the Changjiang and Mekong River
- 1/5 world's population
- Major seafood exporters
- World's largest expanses of coral reef, mangrove & seagrass

Costal-SOS Six Model Coastal Systems



Costal-SOS Six Model Coastal Systems

A novel strategy of cross-sectoral partnership among leading academic institutions, industrial enterprises, non-profit foundations, NGO/IGOs to incorporate co-design with a goal to achieve shared objectives.

A problem-driven and solution-oriented observational network and data platform that for all six model coastal systems, and a coupled numerical models that has diagnostic and predictive capabilities.

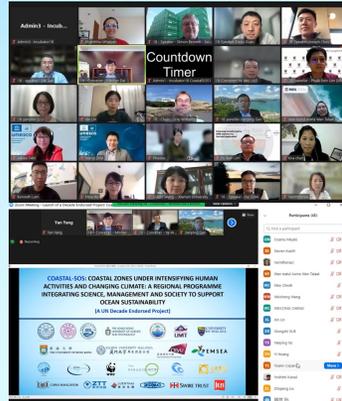
A decision-making support system and toolbox aided by numerical modelling and the **Digital Twin Ocean** initiative that will result in integrated coastal management and ecosystem conservation practices.

Progresses



October 2021

COASTAL-SOS was **officially endorsed** as a project of the United Nations Decade of Ocean Science for Sustainable Development.



November 2021

COASTAL-SOS successfully held **its launch session** during the UN Ocean Decade Regional Kickoff Conference for the Western Pacific.

Executive Director



Yawei Luo

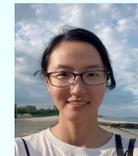


Hongmei Chen

Project Officer



Yongqi Liu



Yan Yang

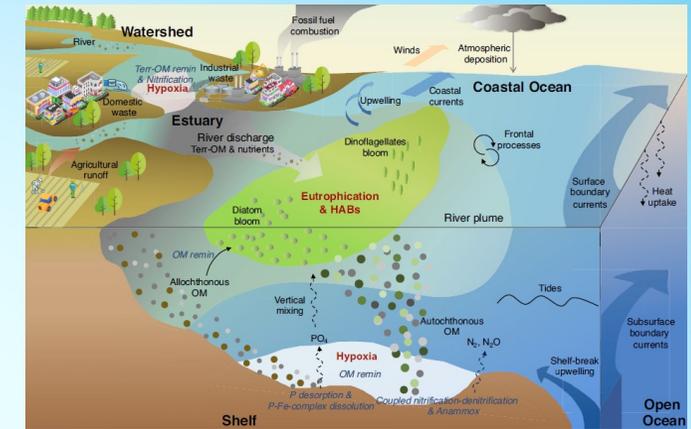
January 2022

The **International Project Office** for COASTAL-SOS was settled at the State Key Laboratory of Marine Environmental Science (MEL), Xiamen University.



July 2022

The **website and newsletter** will continually disseminate project-related initiatives, events, and activities, providing efficient information services to relevant stakeholders.



February 2023

Publish the **invited review** on Coastal Eutrophication & Hypoxia in Cambridge Prisms: Coastal Futures.

Office Coordinator



Chawalit Charenpong



Chalermrat Sangmanee

July 2025

The **Thailand International Project Office** for COASTAL-SOS was settled at Thailand with DMCR and CU, etc.

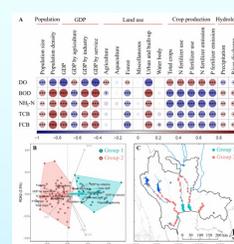
May 2024

Completed the **pre-research project** of the Coastal-SOS Xiamen case.

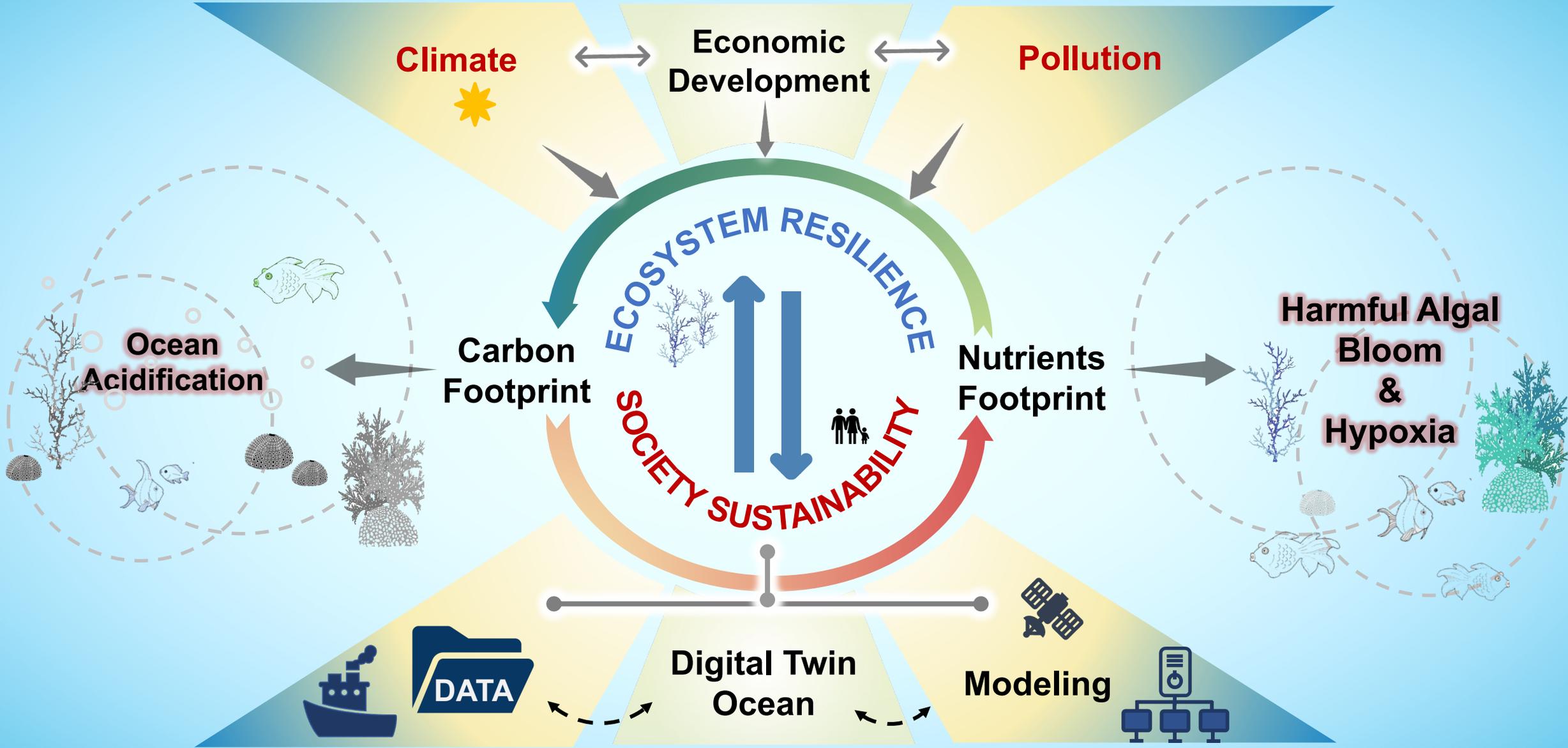


May 2025

Publish the **research progress** on Impact Factors of Water Quality in Thailand's Major Rivers.



Research Framework



COASTAL-SOS Funders & Sponsors

Since 2022, multiple research funds to COASTAL-SOS have been granted by the following agencies. Supported by these funds, the implementation plans are progressing in an orderly manner.



**National Key R&D
Program of China**

Funding Agencies	Project Names
Xiamen University	Coastal-SOS Project Office
Xiamen Ocean Development Bureau	Coastal-SOS: Xiamen Case Study
China Oceanic Development Foundation	Coastal-SOS project related activities
Chinese Academy of Sciences	Policy recommendations on the sustainable development of human-coastal ocean nexus
Tencent Co.	Blue Carbon Ecosystem Assessment, Restoration and Accounting
Ministry of Science and Technology of PRC	Tipping points, resilience and reconstruction of plankton ecosystem in typical marine areas of China

Related project: Blue Carbon Ecosystem Assessment, Restoration and Accounting (BLUE-CARE)



Tencent 腾讯

- Focus on the carbon cycles of typical **seagrasses** and **salt marshes** in China
- Develop methodologies for **accounting carbon sinks and credits** of these ecosystems
- Select two demo sites to perform **seagrass restoration**
- The carbon credits will be used for Tencent's **blue carbon trading**



Group photo of BLUE-CARE team



Group photo of spring survey, 2023



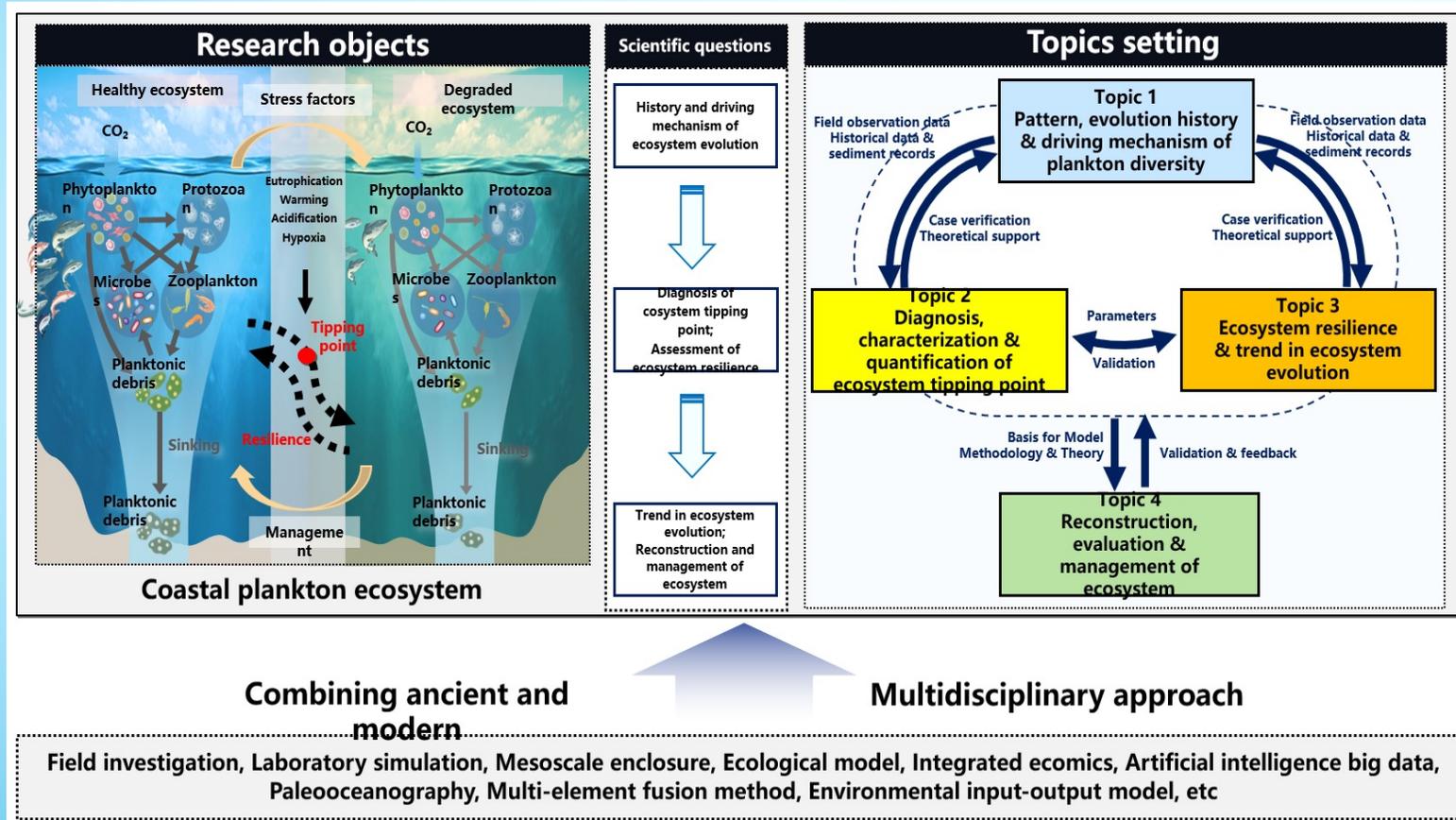
China National Radio news about BLUE-CARE



CCTV news about BLUE-CARE seagrass restoration

Related project: Tipping points, resilience and reconstruction of plankton ecosystem in typical marine areas of China

National Key R&D Program of China



Project Overview

- Focus on the plankton ecosystems in the **Yangtze River Estuary** and the **Pearl River Estuary**
- **Integrate and synthesize** data from various resources
- Characterize and quantify **the system's tipping points**
- Develop the **prediction model** of system evolution trend
- Put forward **management strategies** for sustainable development

Related project: Policy recommendations on the sustainable development of human-coastal ocean nexus



中国科学院
CHINESE ACADEMY OF SCIENCES

Project Outline

Compare environmental resources & social-economic development characteristics of four typical coastal systems in China

Identify key drivers of evolutionary processes and pattern changes in human-coastal ocean nexus

Explore tipping point and resilience mechanisms in coastal systems

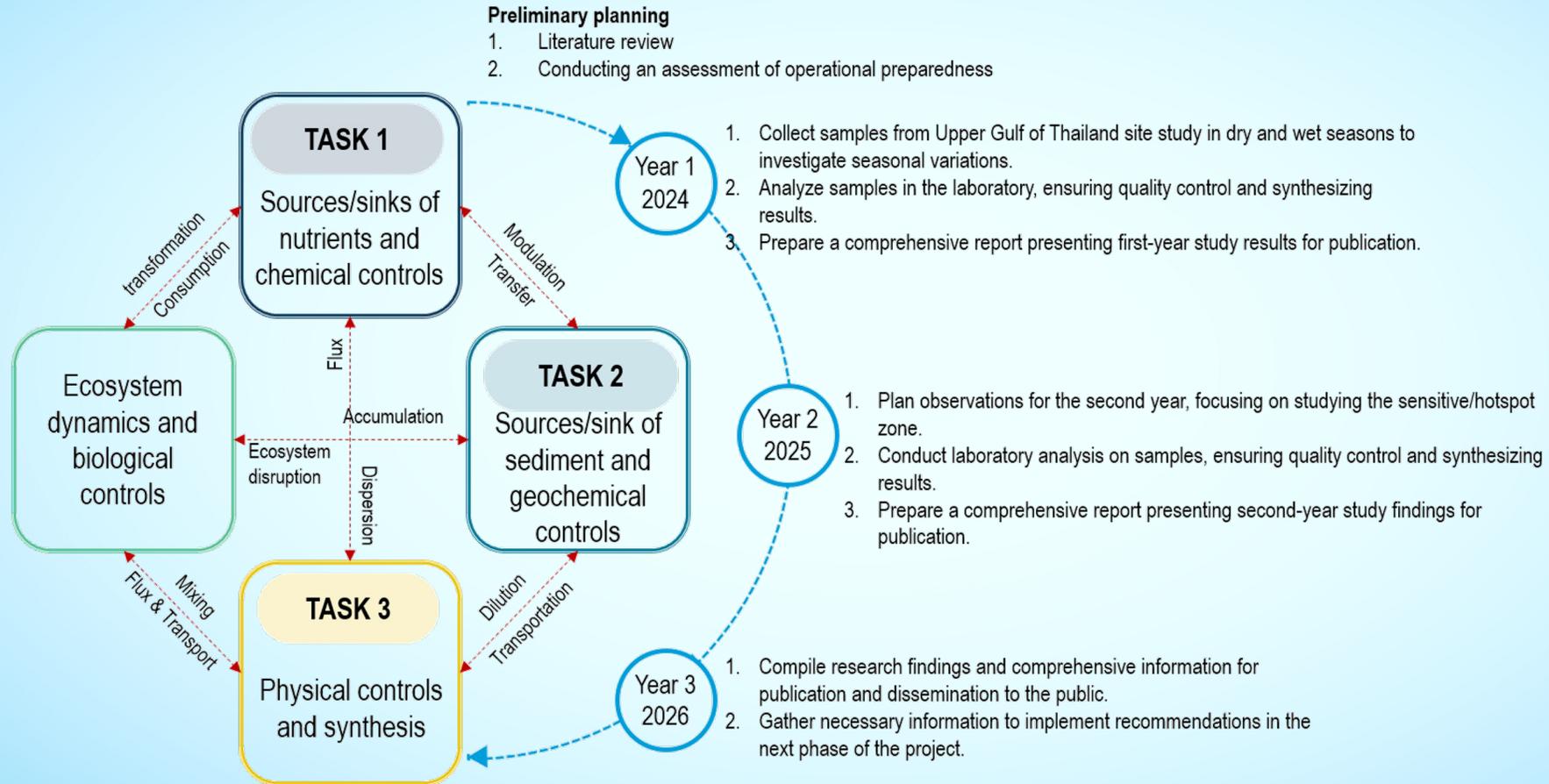
Compare China's coastal systems with international regions, e.g., the Baltic Sea, the Gulf of Thailand, and the Chesapeake Bay



Group photo at the launch meeting

COASTAL-SOS Thailand: 1st phase between 2024-2026

“Study on anthropogenic and climate change impacts on coastal deoxygenation in the inner gulf of Thailand in support of the Coastal-SOS program endorsed by United Nations for the decade of action for sustainable development”



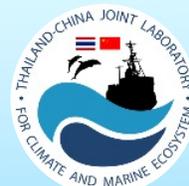
Domestic and International collaborators



2021-2030 United Nations Decade of Ocean Science for Sustainable Development



2021-2030 UN OCEAN DECADE ENDORSED PROJECT COASTAL-SOS

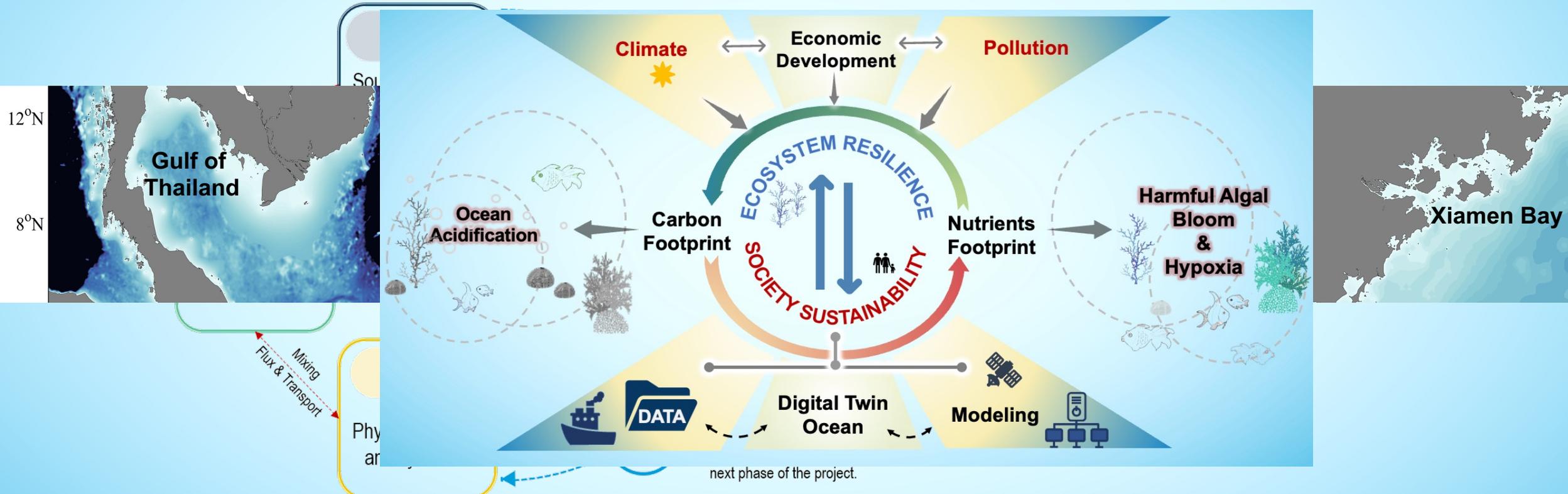


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Preliminary planning

1. Literature review
2. Conducting an assessment of operational preparedness



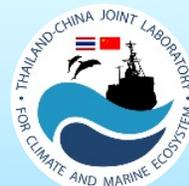
Domestic and International collaborators



2021-2030 United Nations Decade of Ocean Science for Sustainable Development



2021-2030 UN OCEAN DECADE ENDORSED PROJECT COASTAL-SOS





Digital Twins of the Ocean and its applications

DITTO and the UN Ocean Decade



The science we need for the ocean we want

Challenge 8:

Through multi-stakeholder collaboration, develop a comprehensive **digital representation of the ocean**, including a dynamic ocean map, which provides free and open access for exploring, discovering, and visualizing past, current, and future ocean conditions in a manner relevant to diverse stakeholders.

OCEAN DECADE 10 Challenges

The infographic displays 10 challenges in a 2x5 grid. Each challenge is represented by a circular icon and a text box. The challenge 'Develop a comprehensive digital representation of the ocean' is highlighted with a red border.

- Challenge 1:** Understand and map land and sea-based sources of **pollutants and contaminants** and their potential impacts on human health and ocean ecosystems, and develop solutions to mitigate or remove them.
- Challenge 2:** Understand the effects of multiple stressors on ocean ecosystems, and develop **solutions to protect, monitor, manage and restore ecosystems and their biodiversity** under changing environmental conditions, including climate.
- Challenge 3:** Generate knowledge, support innovation, and develop solutions to optimise the role of the ocean to contribute to **sustainably feeding the world's population** under changing environmental and social conditions.
- Challenge 4:** Generate knowledge, support innovation, and develop solutions to contribute to **equitable and sustainable development of the ocean economy** under changing environmental and social conditions.
- Challenge 5:** Enhance understanding of the **ocean-climate nexus** and use this **understanding** to generate solutions to mitigate, adapt and build resilience to the effects of climate change, and to improve services including improved predictions and forecasts for weather, climate, and the ocean.
- Challenge 6:** Expand **multi-hazard warning systems** for all biological, geophysical, and weather and climate related ocean hazards, and mainstream community preparedness and resilience.
- Challenge 7:** Ensure a sustainable **ocean observing system** that delivers timely data and information accessible to all users on the state of the ocean across all ocean basins.
- Challenge 8:** Develop a comprehensive **digital representation of the ocean**, including a dynamic ocean map, through multi-stakeholder collaboration that provides free and open access to explore, discover, and visualize past, current, and future ocean conditions.
- Challenge 9:** Ensure comprehensive **capacity development and equitable access to data, information, knowledge and technology** across all aspects of ocean science and for all stakeholders regardless of geography, gender, culture, or age.
- Challenge 10:** Ensure that the multiple values of the ocean for human wellbeing, culture, and sustainable development are recognised and widely understood, and **identify and overcome barriers to the behaviour change** that is required for a step change in humanity's relationship with the ocean.



Digital Twins of the Ocean - DITTO



Opportunities to connect science to society

<https://ditto-oceandecade.org>

Co-Chairs



Fei Chai



Joanna Staneva

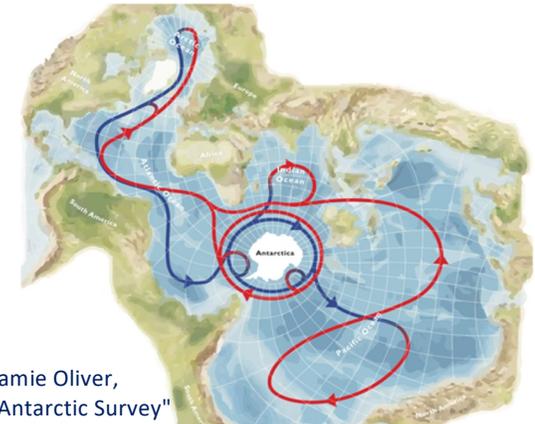
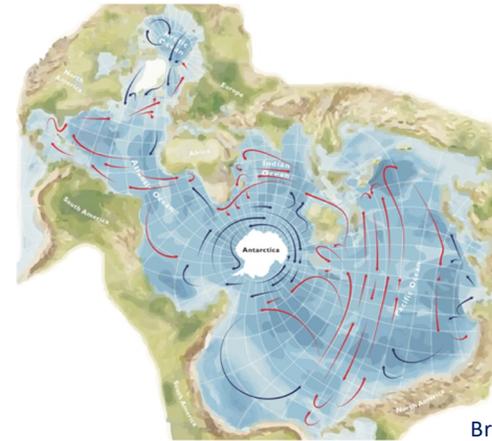
Vice-Chairs



Swadhin Behera



Marina Tonani



"Jamie Oliver, British Antarctic Survey"



Marine Knowledge at the Fingertips of our Communities:
Designing Digital Twins of the Ocean

Digital Twins of the Ocean - DITTO

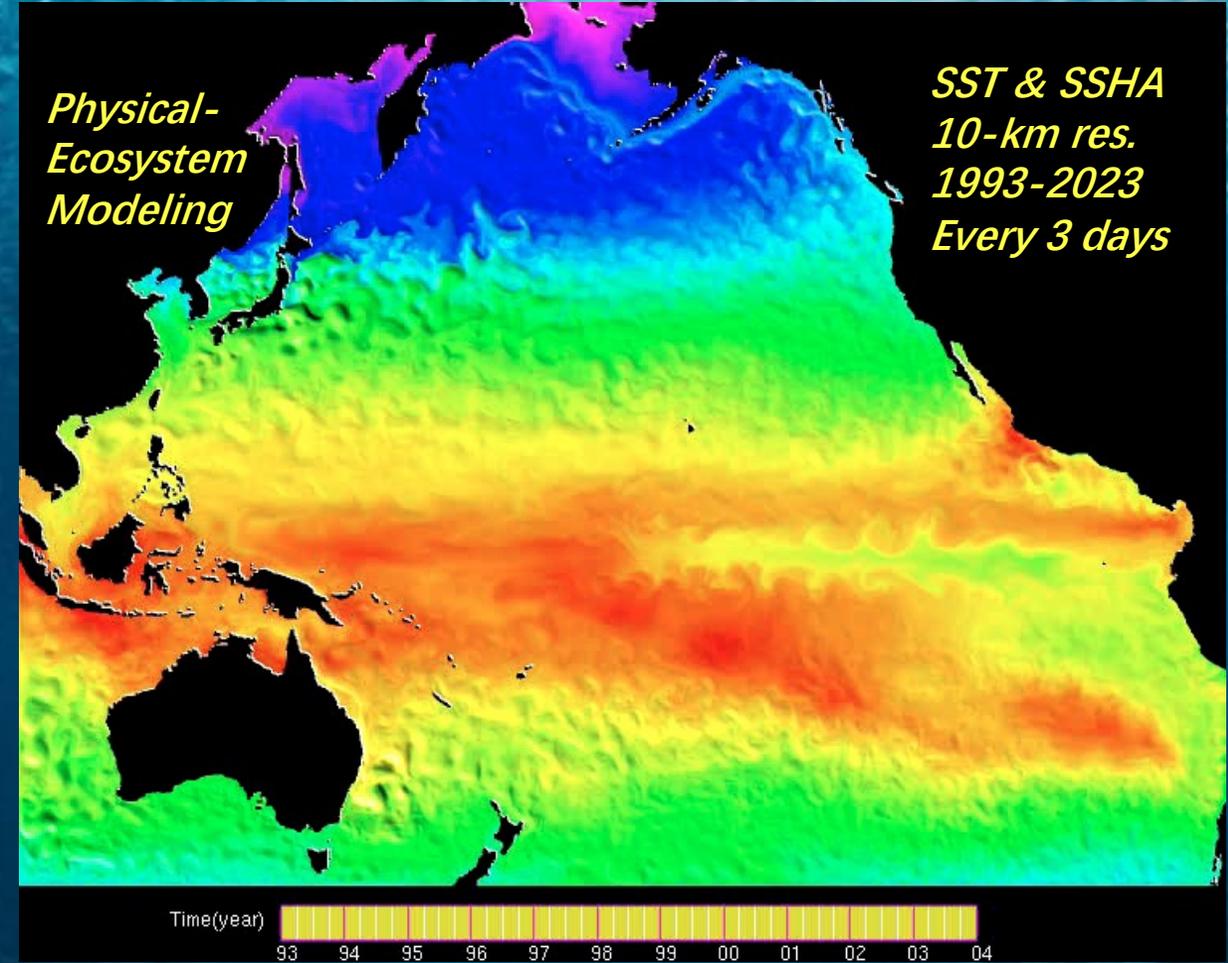


An **accessible ocean** with open and equitable access to data, information, and technology and innovation.



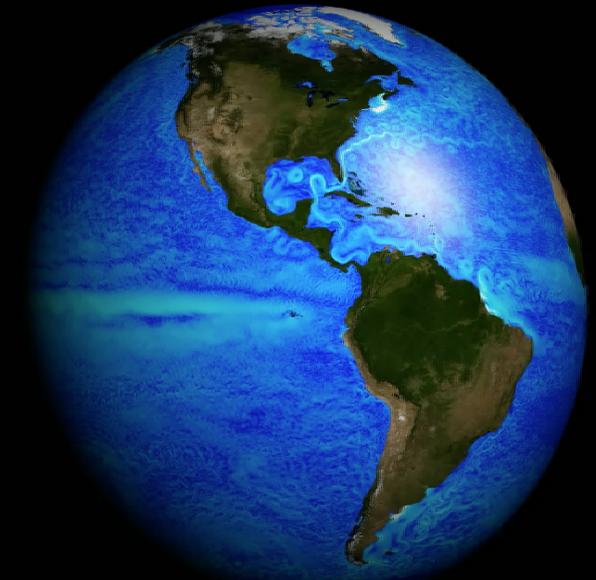
- **DITTO** is a **virtual** representation of the **real** ocean and have a two-way connection between **real** and **virtual** ocean
- **DITTO** enables users to address **‘What now’**, **‘What next’**, and **‘What if’** questions based on shared data, models and knowledge.
- **DITTO** empowers ocean professionals, citizen scientists, policymakers, and different stakeholders to visualise and explore ocean data, model results and information, **easily!**

Ocean Observations and Models



Digital Twin Ocean

- A digital framework connecting data-modeling-visualization (*real vs. virtual*)
- New tools and technologies to access and analyze *big data* (ML, AI, and HPC)
- It enables *users* and partners to create and develop different *scenarios*
- Establishing a new globally shared and *easy-to-use* platforms for different communities and general public



Courtesy of Estimating Circulation and Climate of Ocean (ECCO) by JPL & MIT.

DITTO Engagements



DITTO Summit 1st, London, UK, May 2022;

DITTO Summit 2nd, Xiamen, China, November 2023

DITTO Summit 3rd, Yokohama, Japan, November 2026

ditto-oceandecade.org



Participants
450 / 76 (overseas)

Diversity
19 nations/reg., 118 inst.

Oral presentations (keynotes)/Posters
116 (12) / 71

15 topic sessions



International Digital Twins of the Ocean Summit 2023

November 9-12, Xiamen

Co-Chairs: Fei Chai and Martin Visbeck

Initiated by: DITTO

Organisers: Fujian Ocean Innovation Center

MEL
近海海洋环境科学国家重点实验室 (厦门大学)
State Key Laboratory of Marine Environmental Science (Xiamen University)

22 domestic institutions + **13** international organizations + **7** sponsors

Co-Organizers



Premier Sponsor Tencent 腾讯 | 腾讯云

Co-Sponsors Lenovo SSTP 浅海科技 申盾云科技 OneSoft 创壹软件



International Digital Twins of the Ocean Summit 2023
2023 年 数字 孪生 海洋 国际 峰会

We ditto the Ocean

We ditto the Ocean

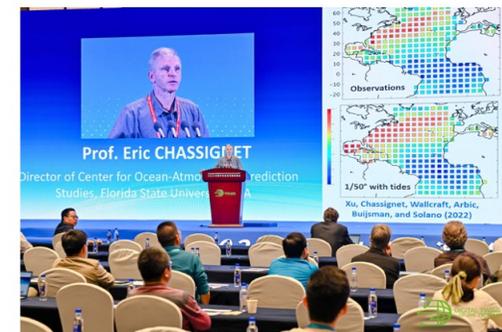
DITTO Summit 2023

We ditto the Ocean

DITTO Summit 2023



12 Keynote Speeches

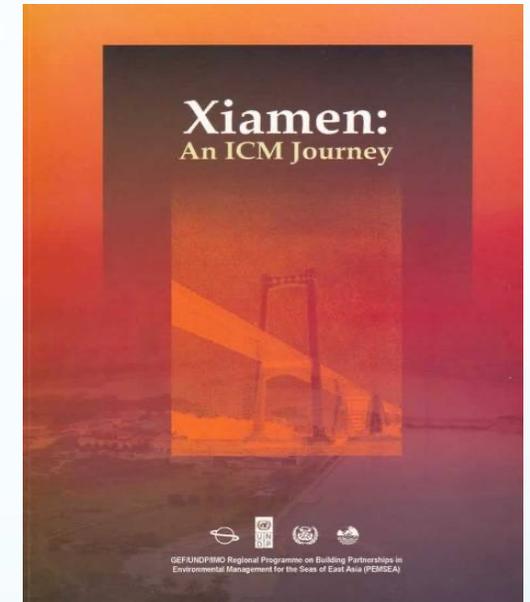
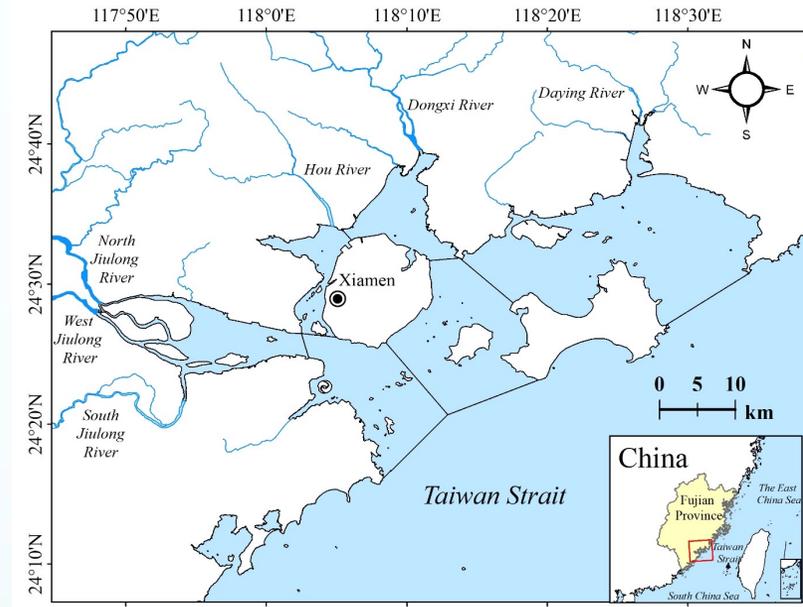


Case Study 1 : Xiamen Bay

A rapid urbanization region benefited from implementation of integrated coastal management (ICM)

Snapshot of Xiamen

- Population: ~5.16 million (2021)
- Land area: 1699 km²
- Sea area: 390 km², Coastline: 234 km
- One of the five SEZs in China since 1980
- ICM demonstration site since early 2000
- The **7th largest** container port in China.
The **13th largest** port in the world
- Regional Pilot City for National Marine Economic Innovation and Development.



Xiamen: An ICM Journey (Second Edition), PEMSEA, 2006
<http://www.pemsea.org/publications/integrated-coastal-management>



九龙江口-厦门湾观测体系



- Multi Source Remote Sensing
- Microsatellites

- Unmanned aerial vehicle (UAV) Remote Sensing

- Shore base station
- Video monitoring

- Buoy
- Ship base
- Seabed base

sky

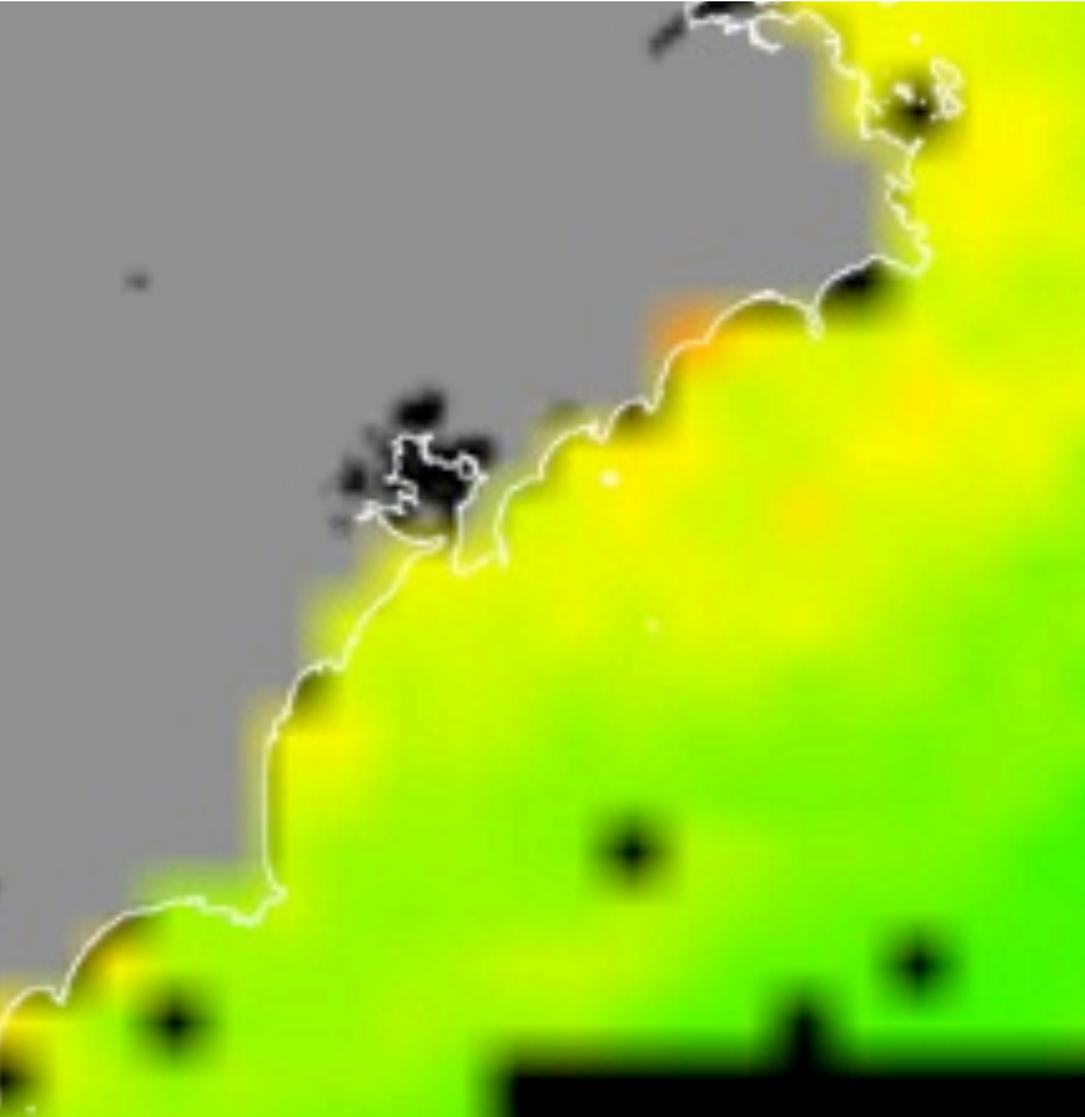
air

land

sea

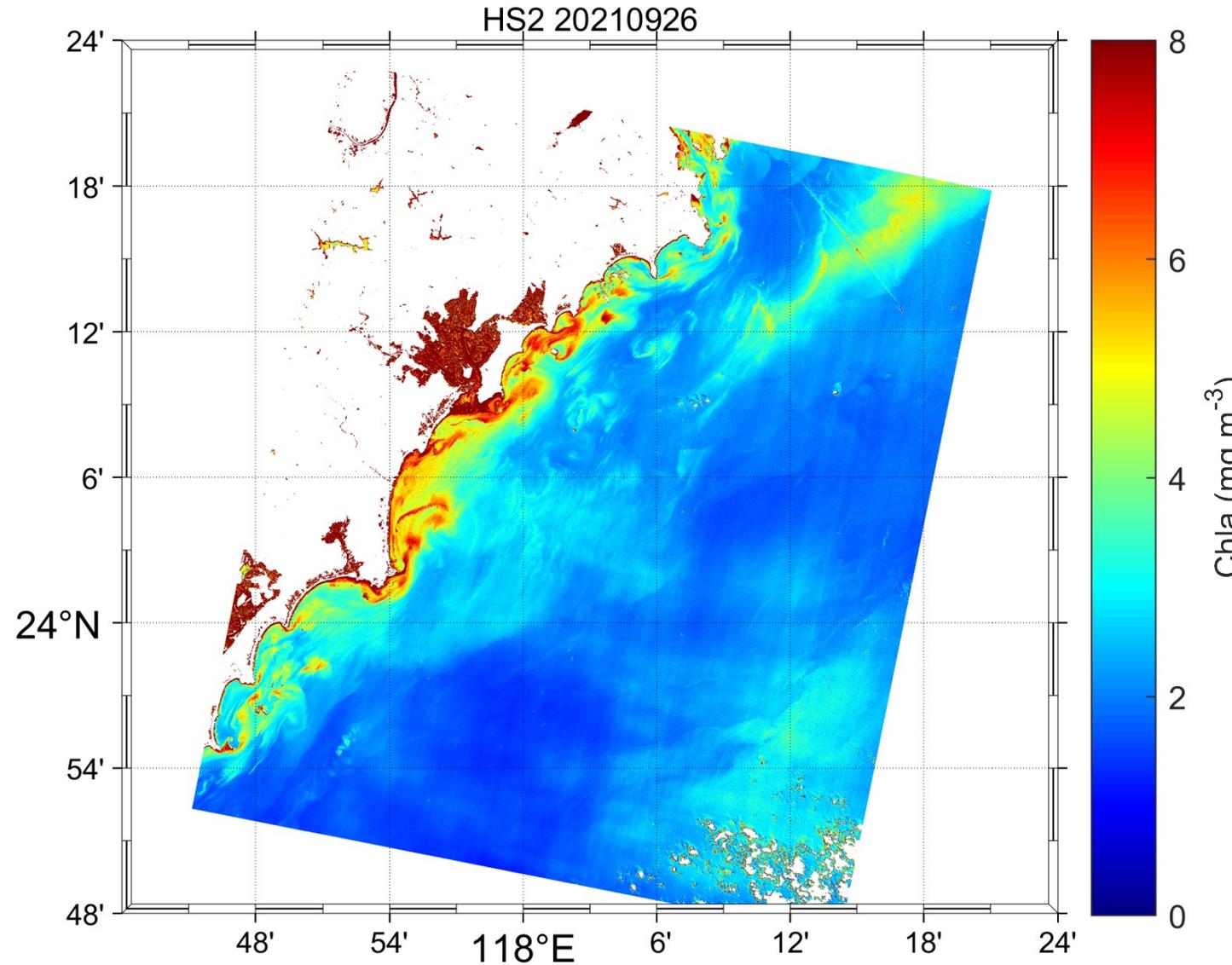
Comparison with larger satellites

MODIS (Chlorophyll, 500m)



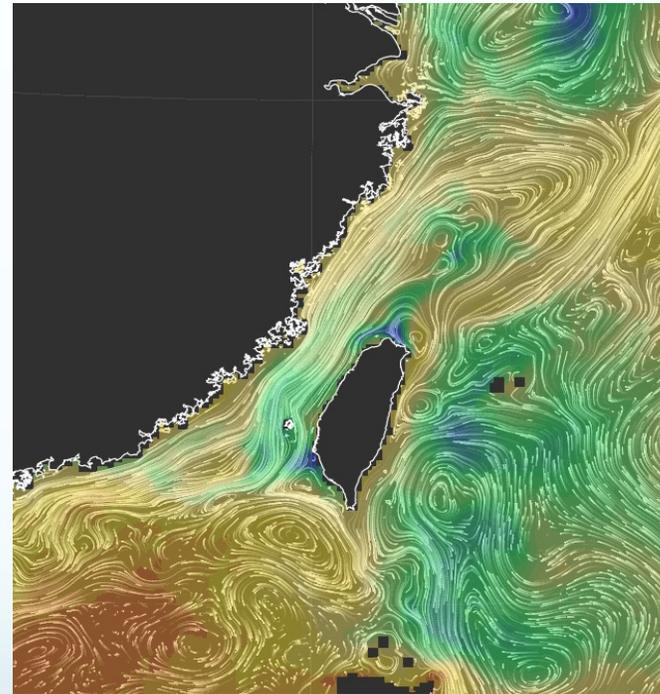
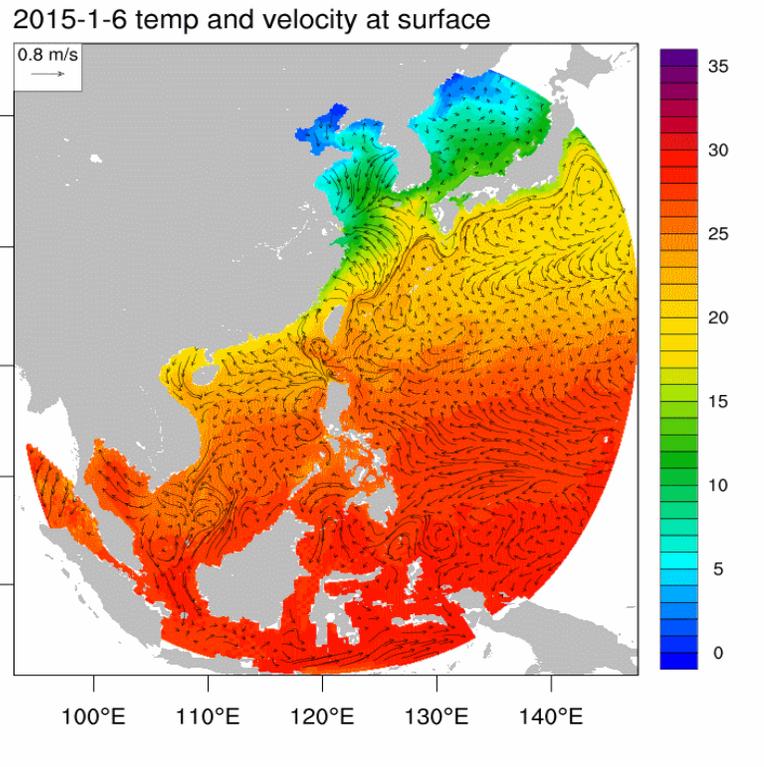
Courtesy of Zhong-Ping LEE

HiSEA-2 (Chlorophyll, 20m)

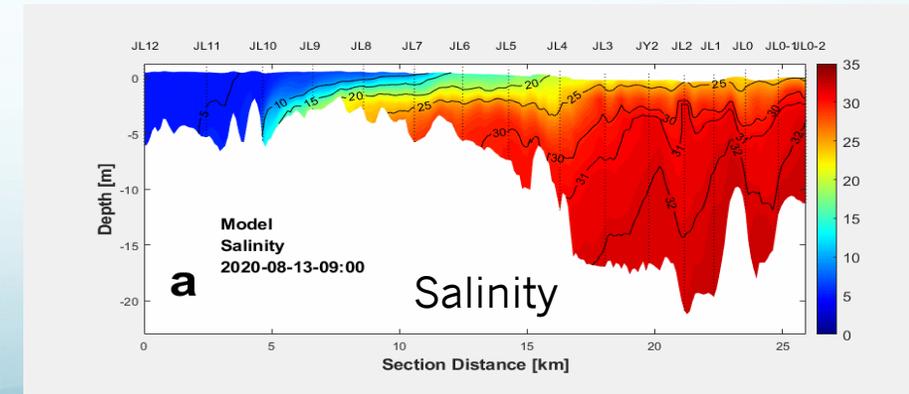


Multiple Scales of Numerical Models

The current and SST for the
northwestern Pacific Ocean and the Taiwan Strait



Xiamen Bay
modeled surface salinity



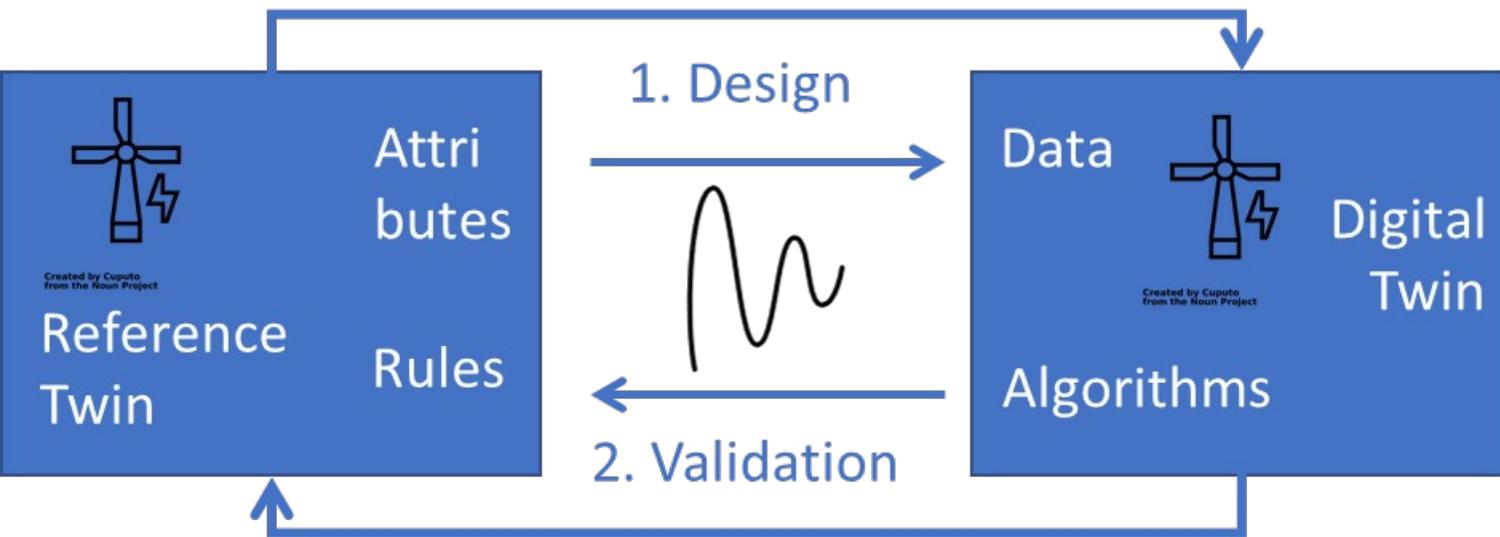
DITTO for Xiamen Bay

VS_UE51_01_XM_SZT_01 (64-bit Development PCD3D_SM6)



Digital twin for offshore wind systems (led by EU and Norway)

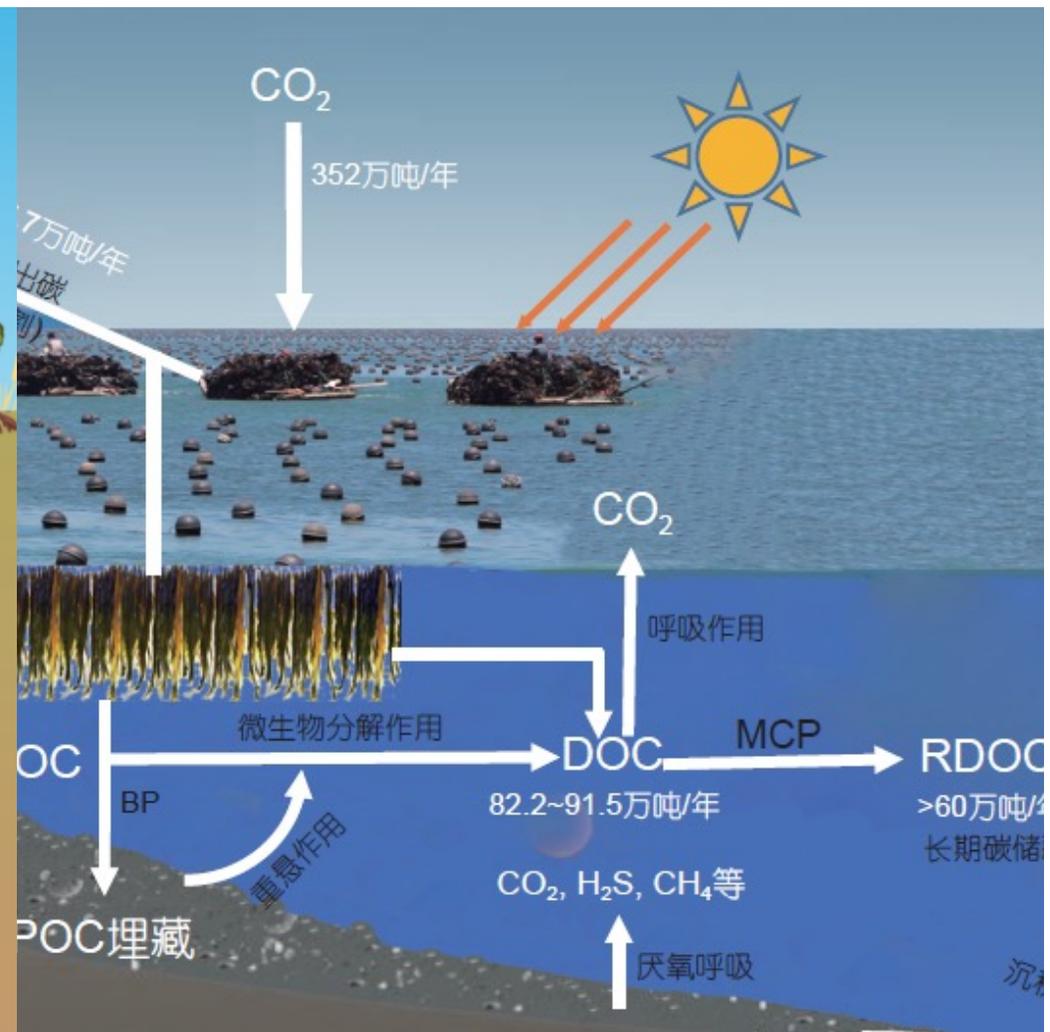
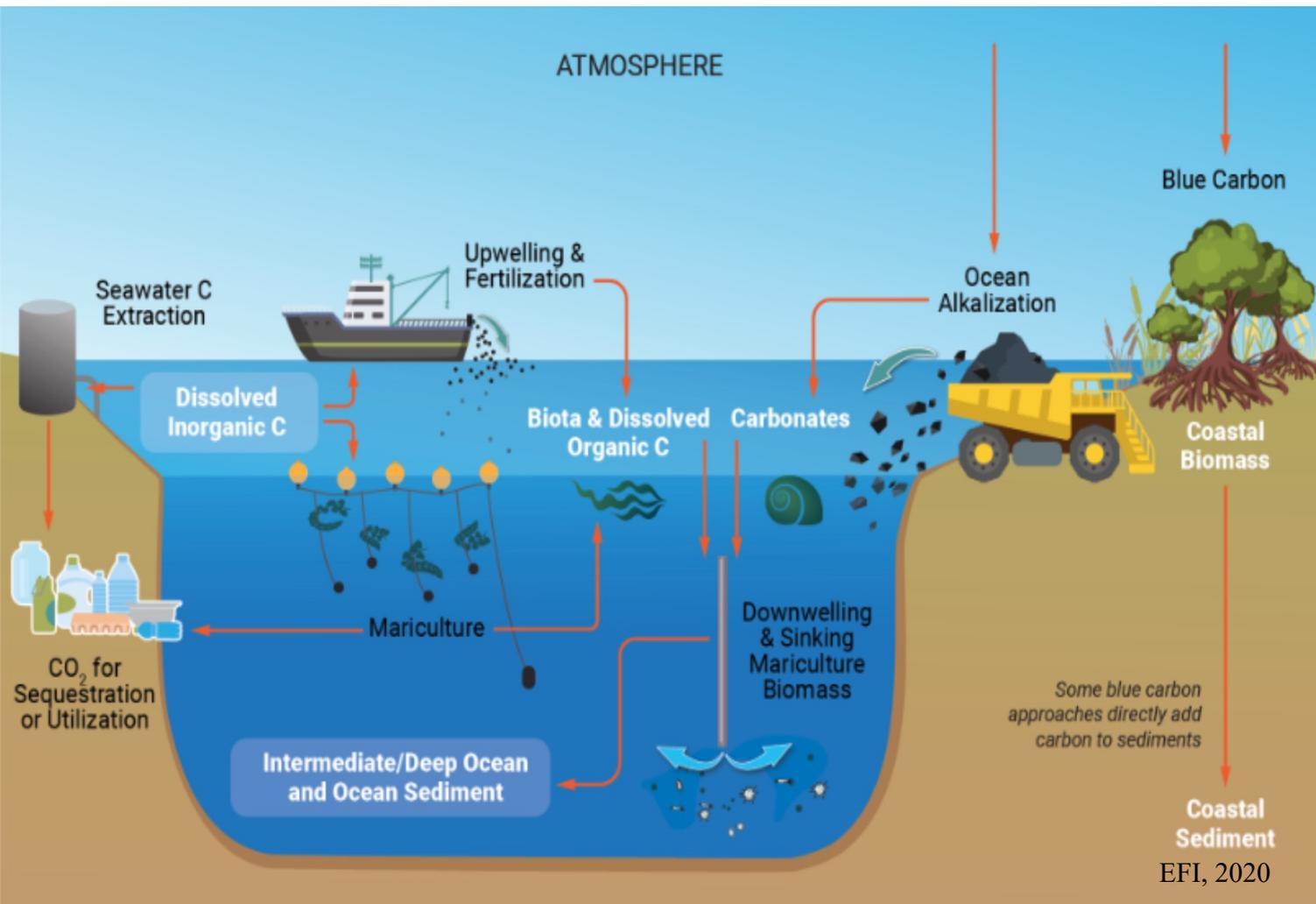
3. Decisions, actions: taking the right decisions?



4. Monitoring, control: Is it going right?



Ocean-based Carbon Dioxide Removal (CDR) Methods



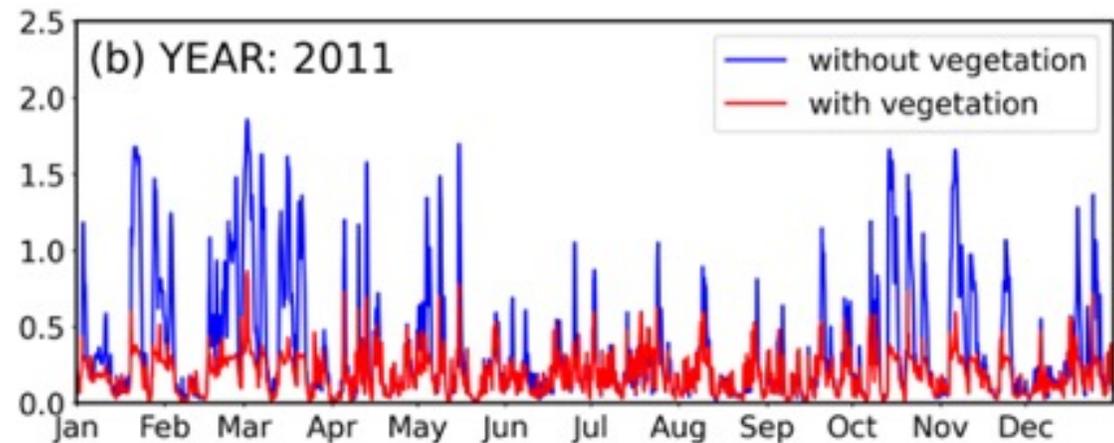
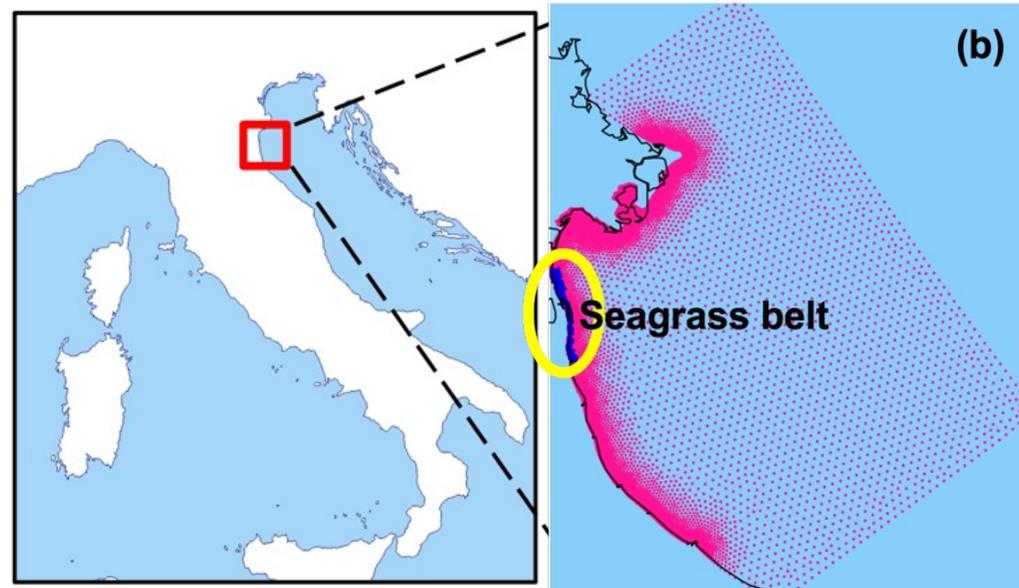
Using observations and physical-biogeochemical models and DITTO to test different CDR methods.

Coast Predict (led by Nadia Pinardi at Uni. Of Bologna): Digital Twin for Nature Based Solutions

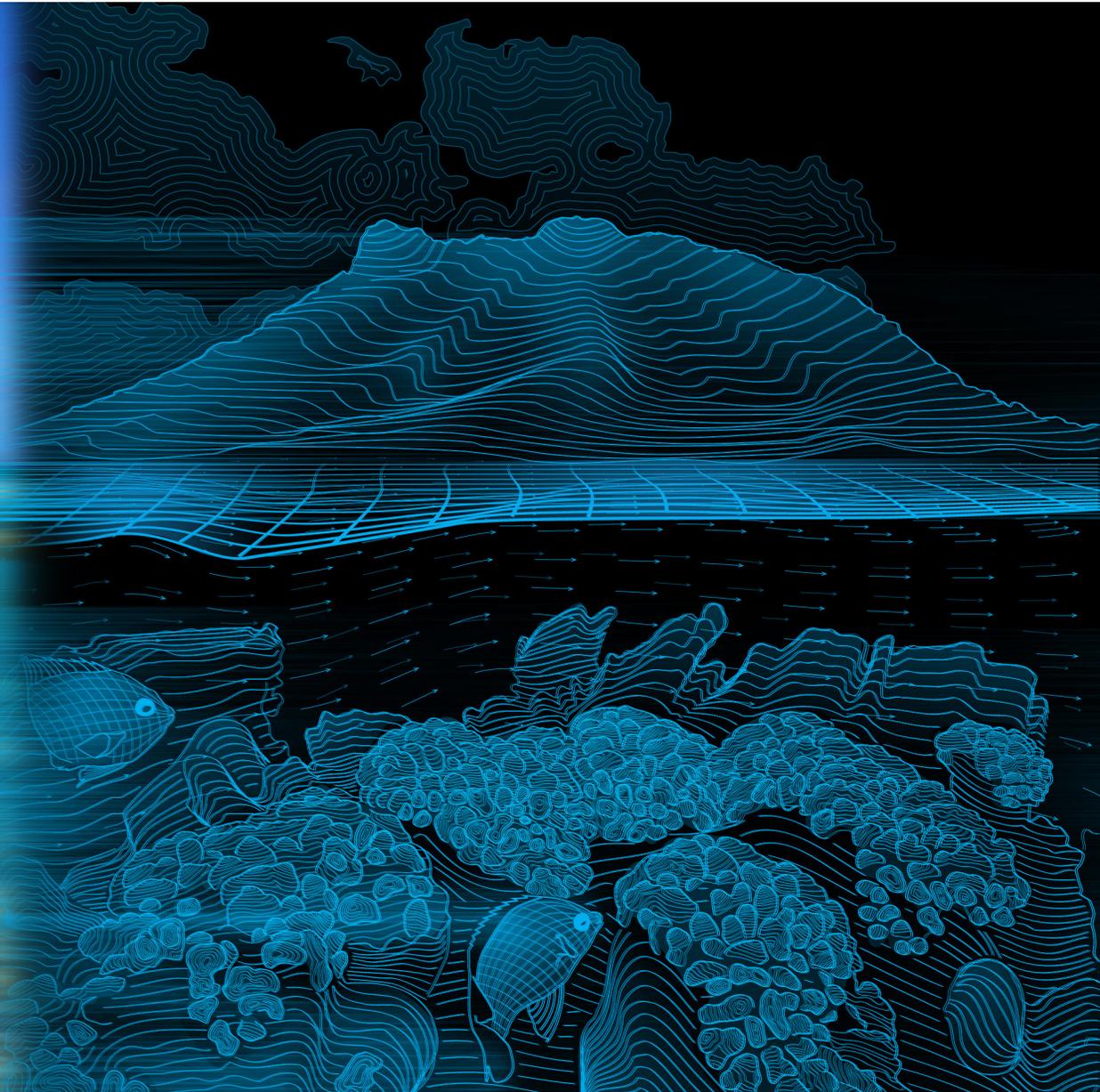
Are seagrass meadows
capable of attenuating waves?



Umesh et al., Sc. Total Env., 2022



Digital Twin of Coral Reef (led by Anne Cohen at WHOI)



Summary

OUTLINE

1

UN Decade

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COASTAL-SOS

3

DITTO

1. So many UN Decade actions (over 700)
Half way to the end (2021-2030)
2. Programs and projects need to have better coordination and support
3. Leaders are needed and to be trained
4. Engaging different communities and the latest technology (DITTO) & AI
5. Connecting coastal ocean with people
6. International collaborations
7. Ocean beyond 2030 (OceanObs'29)