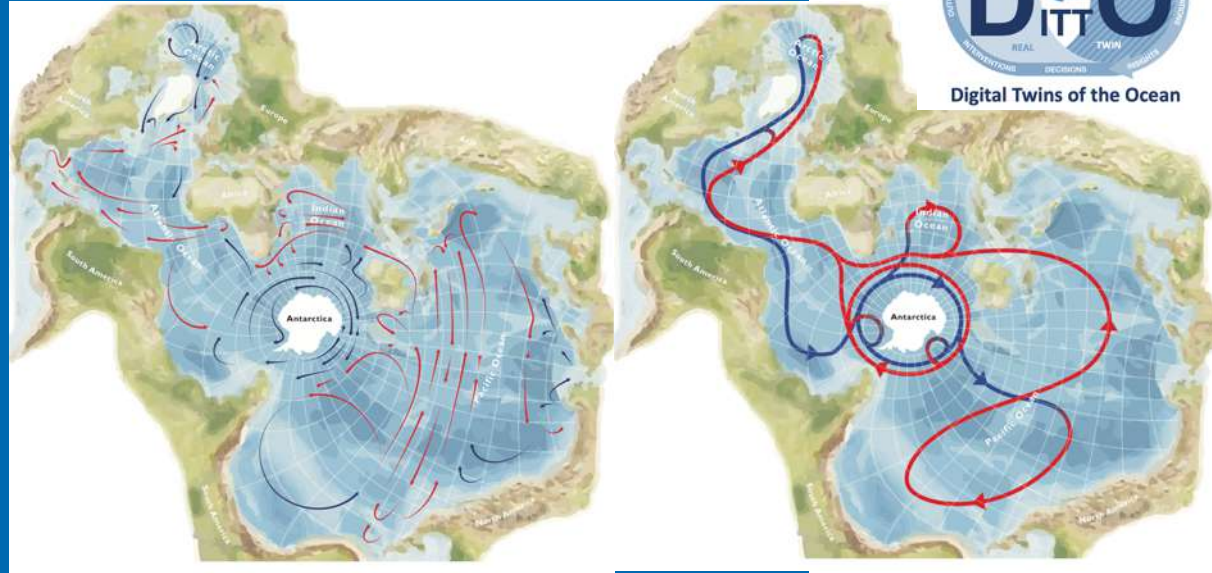


# “Digital Twins of the Ocean” Opportunities to connect science to society



Digital Twins of the Ocean



"Jamie Oliver, British Antarctic Survey"



2021 United Nations Decade  
2030 of Ocean Science  
for Sustainable Development

Martin Visbeck

GEOMAR Helmholtz Center for Ocean Research Kiel  
Kiel University, Germany



# Digital Twins of the Ocean



# Digital Twin



ons Decade  
cience  
able Development

## Observations



## Data



## Knowledge



# Ocean 5D – toward a ‘Digital Twin’ Ocean



Ocean5D delivers a powerful community based shared and interoperable digital-twin ocean. Ocean5D duct would allow all actors to interact with a wide range of **digital ocean information in a five-dimensional (5D)** manner.

The first dimension **time**, from the past, to the near real time present to predictions day to months ahead to scenarios of the future. Three **space** dimensions covering the Ocean basin from pole-to-pole and its coasts and ‘hinterland’ to the deep abyss. And the 5<sup>th</sup> dimension being **issue**.

Good examples include fish abundance, ocean heat wave, storm surge risk exposure, fishing potential, acidity, surface waves, currents, deep sea habitat, and sites for ocean extraction, protection and tourism.



# Digital Twins of the Ocean

## MISSION STARFISH 2030: RESTORE OUR OCEAN AND WATERS

*Healthy ocean and waters are taken for granted. Yet, they are in trouble and need to be restored. We call on all European citizens and policy makers to take responsibility for protecting and regenerating rivers, lakes, seas and ocean and demand urgent systemic change from our politicians and leaders.*

*Target 2: Marine and freshwater observation is streamlined and accessible to all via a digital twin of the ocean and all waters*

By 2030	Checkpoints for 2025
<ul style="list-style-type: none"><li>Global digital twin of all oceans and waters is operational</li><li>Global marine and freshwater observation is streamlined: all data collected is pooled centrally and made accessible to all</li><li>Global high-resolution ocean forecasting and regional ocean climate services are operational to support climate change adaptation at coastal scale</li><li>The European seabed is fully and coherently mapped in high-resolution</li><li>50 percent of DNA of life in our ocean and waters is fully sequenced and publicly available</li></ul>	<ul style="list-style-type: none"><li>European digital twin pilot of European oceans and waters is operational</li><li>European marine and freshwater observation is streamlined: all data collected by EU Member States is pooled centrally and made accessible to all.</li><li>The Copernicus programme deploys coastal-scale ocean forecasting and climate services</li><li>The North Atlantic Seabed is fully and coherently mapped in high-resolution</li><li>20 percent of DNA of life in our ocean and waters is fully sequenced and publicly available</li></ul>

# Digital Twin



ons Decade  
cience  
able Development

## Mission Starfish 2030: Restore our Ocean and Waters

Report of the Mission Board  
Healthy Oceans, Seas, Coastal and Inland Waters



# Digital Twins of the Ocean

## Background:

Many ocean communities are engaged in data collection and information delivery using digital means.

A recent example is that the preparation process for the **UN Decade of Ocean Science for Sustainable Development** has articulated one of the six societal outcomes to be a Transparent and Accessible Ocean with the goal: **“A transparent ocean whereby all nations, stakeholders and citizens have access to ocean data and information technologies and have the capacities to inform their decisions”**

# Digital Twin



Digital Twins of the Ocean

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# Digital Twins of the Ocean

## Background:

Many ocean communities are engaged in data collection and information delivery using digital means.

A recent example is that the preparation process for the **UN Decade of Ocean Science for Sustainable Development** has identified a 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.

# Digital Twin



Digital Twins of the Ocean

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## OCEAN DECADE Challenge Questions



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.



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.



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.



Generate knowledge, support innovation, and develop solutions to contribute to **equitable and sustainable development of the ocean economy** under changing environmental and social conditions.



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.



Expand **multi-hazard warning systems** for all biological, geophysical, and weather and climate related ocean hazards, and mainstream community preparedness and resilience.



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.



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.



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.



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.



2021  
2030 United Nations Decade  
of Ocean Science  
for Sustainable Development

### Decade programme

- Global or regional in scale
- Fulfills one or more of the Decade objectives.
- Long-term (multi-year), interdisciplinary and typically multi-national.
- Includes component projects, and enabling activities.

Proposal for an OceanDecade Global Programme  
January 2021

## Digital Twins of the Ocean - DITTO

Lead-PI: Martin Visbeck, GEOMAR, Kiel, Germany



### *Summary:*

DITTO will establish and advance a **digital framework** on which all marine data, modelling and simulation along with HPC capacities, AI algorithms and specialized tools including relevant best practices will form a globally shared capacity to access, manipulate, analyse and visualise marine information. It will enable users and partners to create ocean related development scenarios addressing issues such as green energy developments (renewable, non-renewable), mining impacts, fisheries and mariculture, marine protected area siteing, nature based solutions and ocean based tourism. Digital twins can quantify benefits and environmental change and provide powerful visualizations based on data and model derived knowledge. DITTO will empower ocean professionals including scientific users to create their own local or topical digital twins of 'their ocean issue' by using standard workflows.

# Digital Twins of the Ocean – DITTO

## *Program Proposal to the Ocean Decade*



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

DITTO will establish and advance a **digital framework**

on which all marine data, modelling and simulation along with HPC capacities, AI algorithms and specialized tools including relevant best practices will form a new globally shared capacity to access, manipulate, analyse and visualise marine information.

It will enable users and partners to **create ocean related development scenarios** addressing issues such as green energy developments (renewable, non-renewable), mining impacts, fisheries and mariculture, marine protected area siteing, nature based solutions and ocean based tourism.

Develop a comprehensive digital representation of the ocean.



# Digital Twins of the Ocean – DITTO

## Program Proposal to the Ocean Decade

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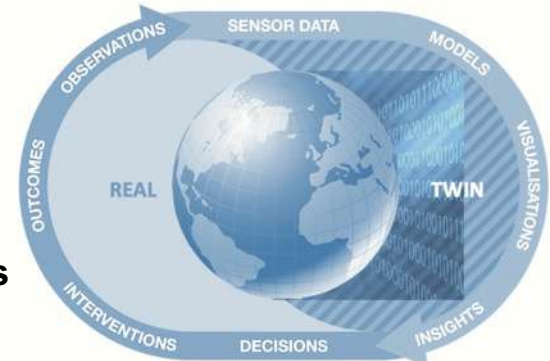
An **accessible ocean** with open and equitable access to data, information, and technology and innovation.

Develop a comprehensive digital representation of the ocean.



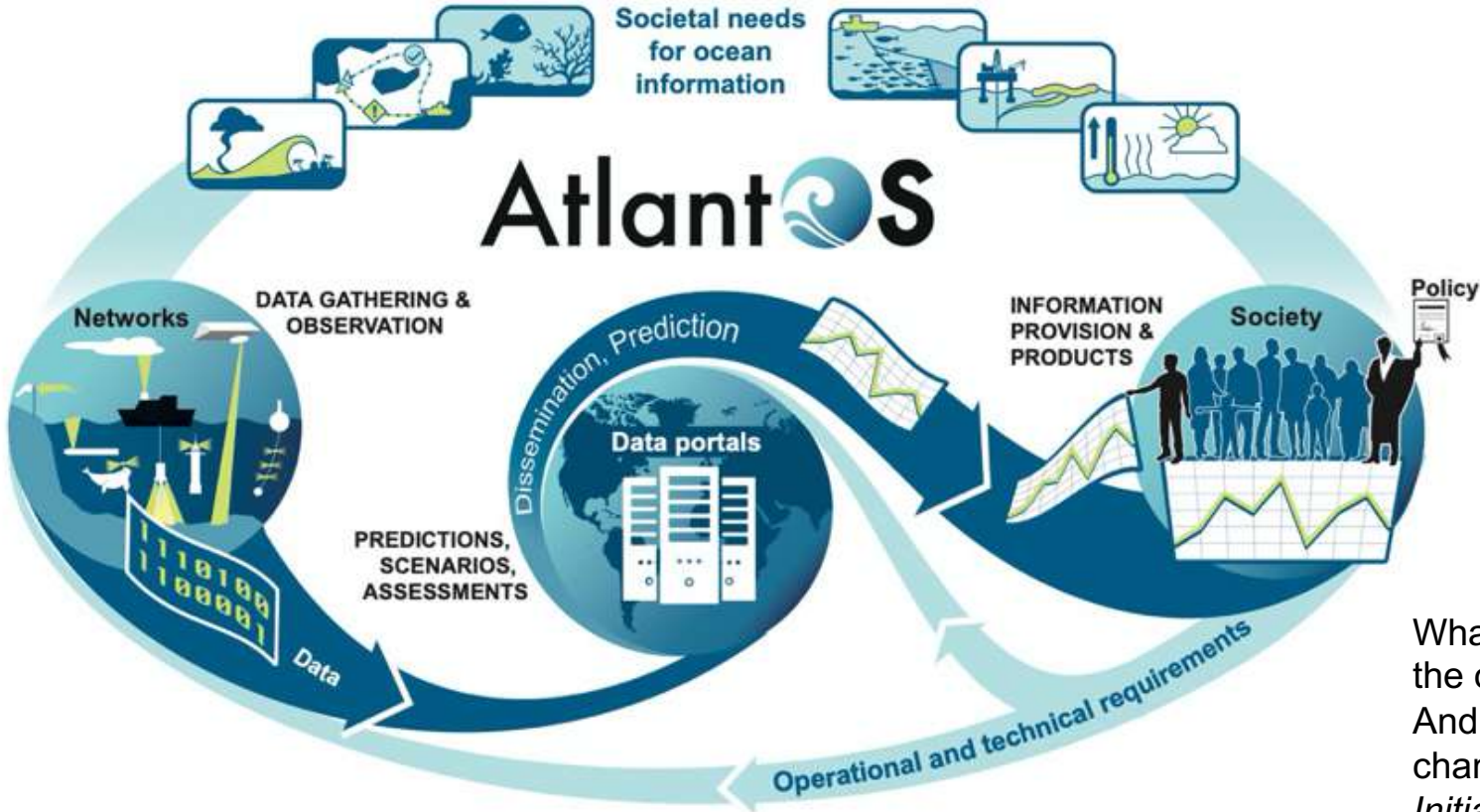
Ocean  
Information  
**supporting  
Services**

Ocean  
Information  
**assessing  
Interventions**



**Digital Twins of the Ocean**

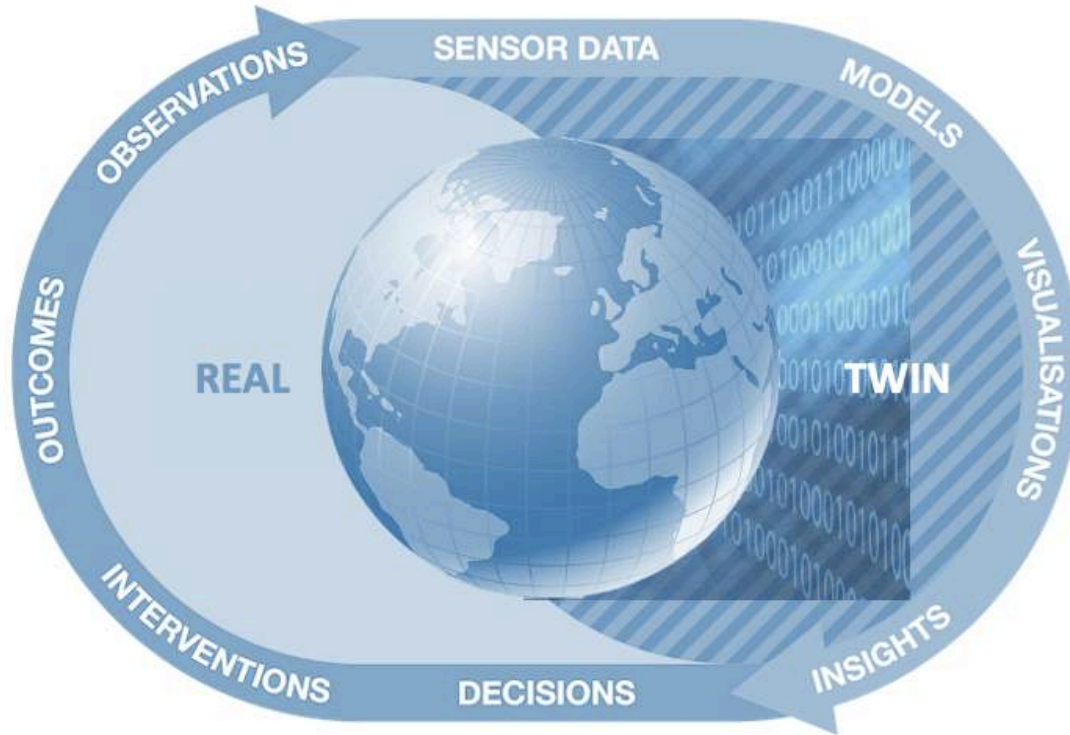
# Ocean Observation and Information Value Chain



Ocean  
Information  
supporting  
Services

What is the state of  
the ocean today?  
And how will it  
change tomorrow?  
*Initial Value Problem*

# Ocean Simulation Digital Twin Framework



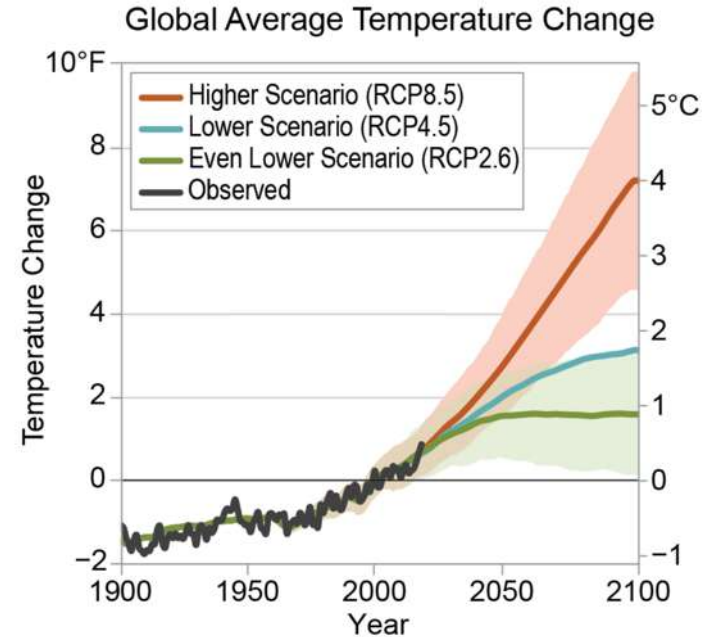
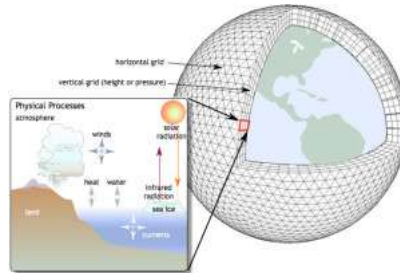
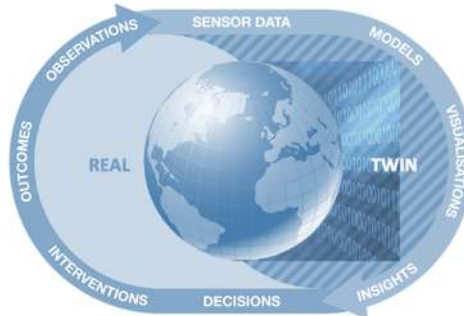
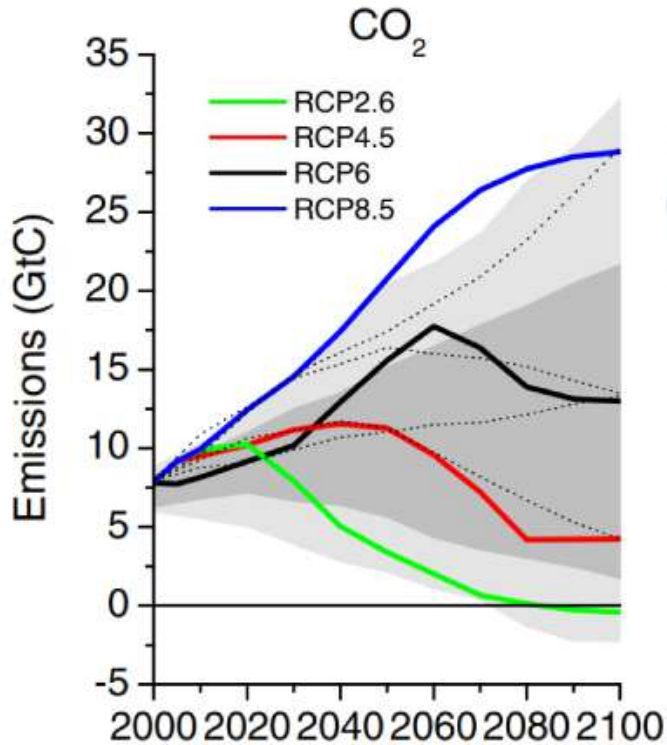
Ocean  
Information  
**assessing**  
**Interventions**

What – If Scenarios  
How will the ocean  
change if humans act?  
*Boundary Value Problem*

## Digital Twins of the Ocean

# Digital Twin ,Prototype‘

What would the global temperature look like if we put CO<sub>2</sub> in the atmosphere?



# Digital Twin ,Prototype‘

What is the most cost effective option to mitigate the coastal impact of sea level rise?

## Minimal Defense

Many communities have developed right along the ocean with only minimal natural defenses from a small strip of beach between them and the ocean.



## Natural

Natural habitats that can provide storm protection include salt marsh, oyster and coral reefs, mangroves, seagrasses, dunes, and barrier islands. A combination of natural habitats can be used to provide more protection, as seen in this figure. Communities could restore or create a barrier island, followed by oyster reefs and salt marsh. Temporary infrastructure (such as a removable sea wall) can protect natural infrastructure as it gets established.



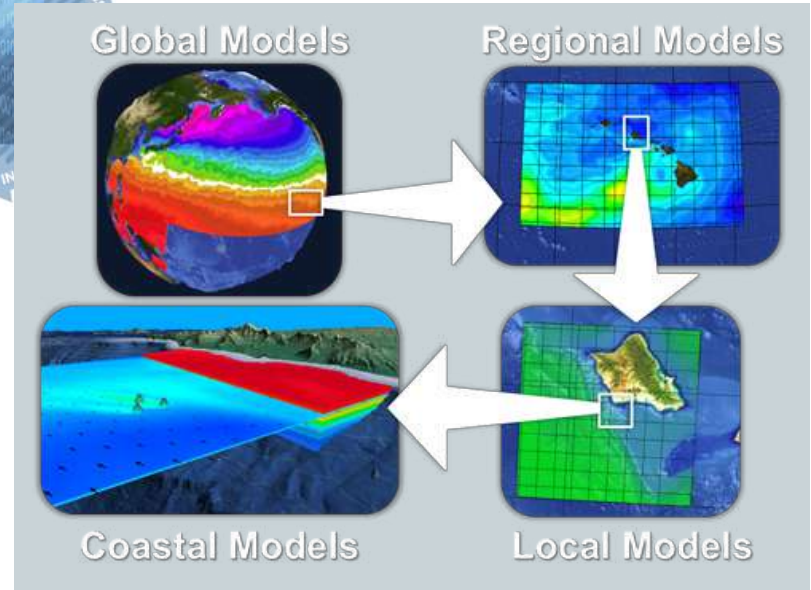
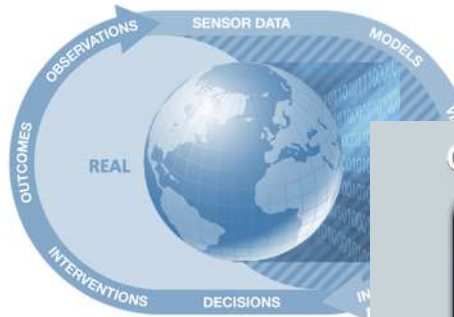
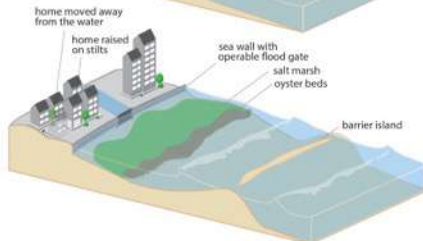
## Managed Realignment

Natural infrastructure can be used to protect built infrastructure in order to help the built infrastructure have a longer lifetime and to provide more storm protection benefits. In managed realignment, communities are moving sea walls farther away from the ocean edge, closer to the community and allowing natural infrastructure to recruit between the ocean edge and the sea wall.



## Hybrid

In the hybrid approach, specific built infrastructure, such as removable sea walls or operable flood gates (as shown here) are installed simultaneously with restored or created natural infrastructure, such as salt marsh and oyster reefs. Other options include moving houses away from the water and raising them on stilts. The natural infrastructure provides key storm protection benefits for small to medium storms and then when a large storm is expected, the built infrastructure is used for additional protection.







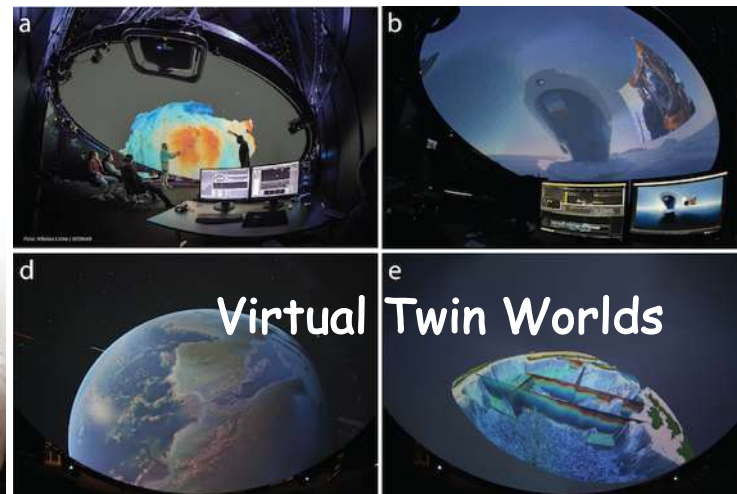
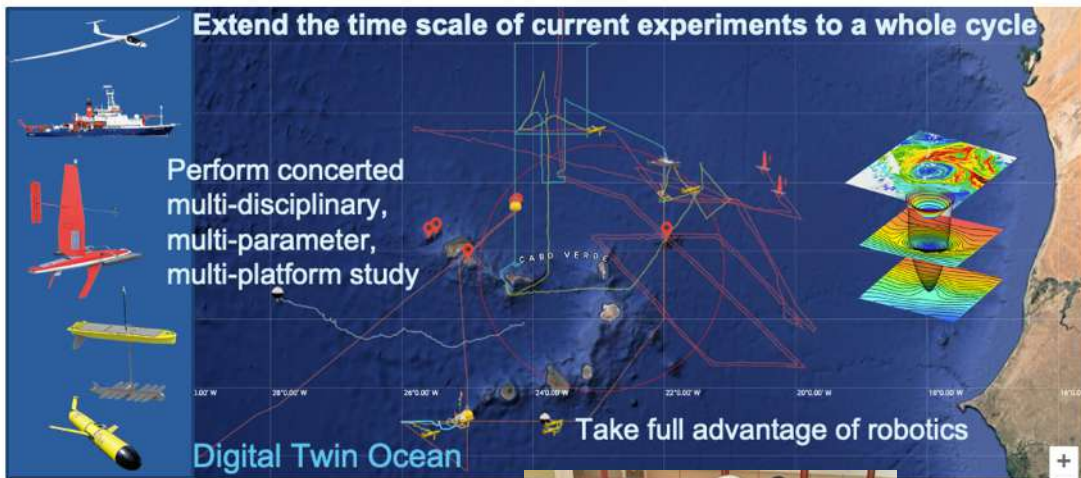
## Description

The Cape Verde Ocean Scape will provide a digital-twin for a small island developing country (Sao Vincente Island). It will assemble all data available already in EMODNet and facilitate the growth of biodiversity observations, data from robotic campaigns and if possible commercial (fishing industry and artisanal fishers) sources. It will allow the beauty of the region to be displayed, show the habitat and its diversity, but also support the region in its development of renewable energy, fresh water production, eco-tourism and engage in ocean literacy in the region.





# OCEANSCAPE EXPLORER Cape Verde



# Digital Twins of the Ocean – DITTO

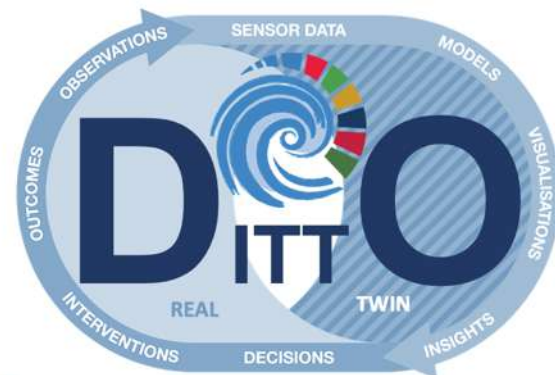
## Program Proposal to the Ocean Decade

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

DITTO will establish and advance a digital framework to explore ocean related development scenarios

40 Partners from around the world

Develop a comprehensive digital representation of the ocean.



### Digital Twins of the Ocean

