



The  
Ocean

Oceans are not digital  
Digital is the way we look at the Ocean



Digital  
Twin

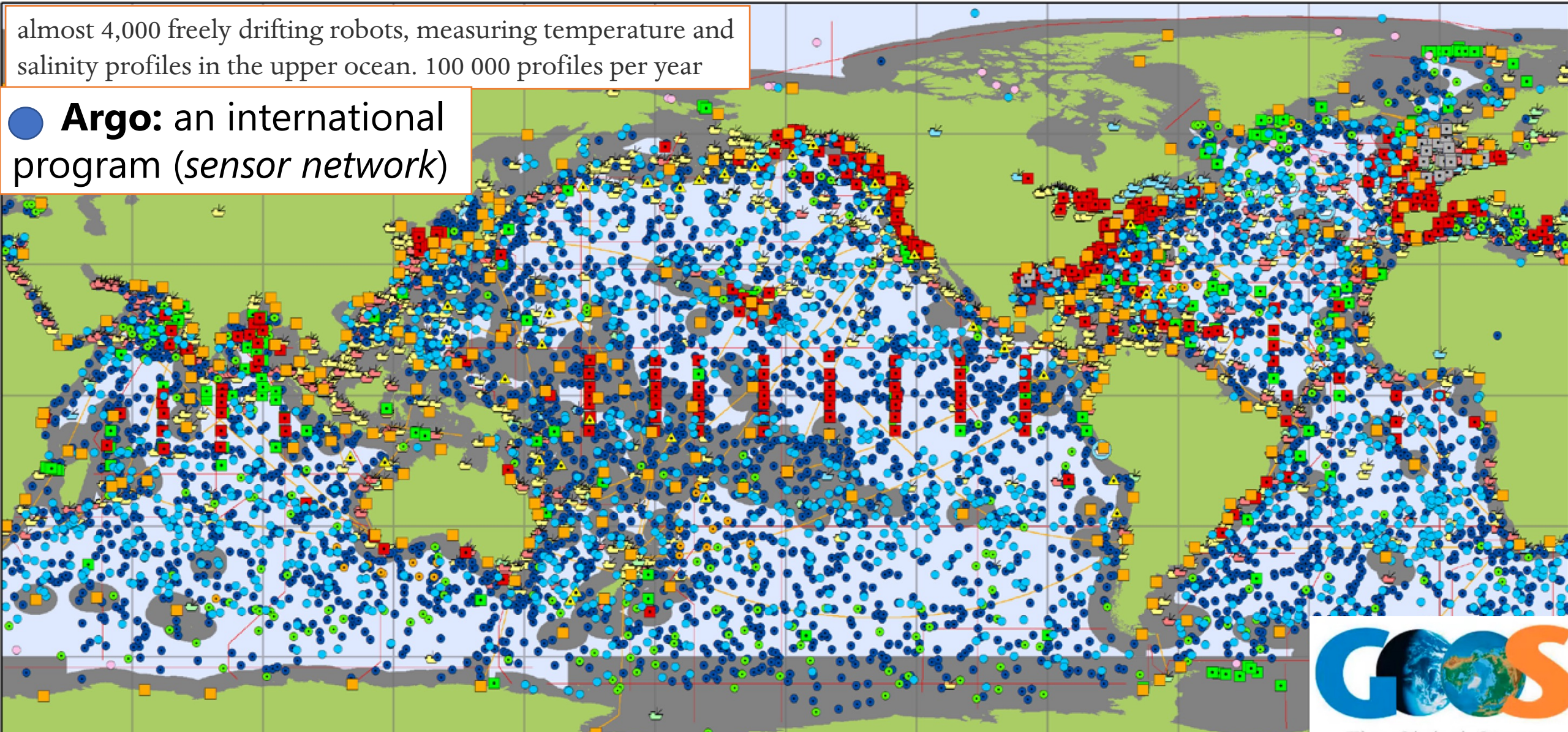


# Ocean as a complex system. Let's start from DATA

Network of sensors: physical, biochemical, buoy, satellites, underwater autonomous systems, etc.

almost 4,000 freely drifting robots, measuring temperature and salinity profiles in the upper ocean. 100 000 profiles per year

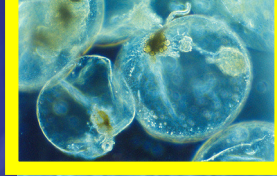
● **Argo**: an international program (*sensor network*)





**Yangtze discharge captured by GOCI/COMS9**

Geostationary COMS satellite: **turbid plume of resuspended sediment originating from the discharge of the Yangtze River.**



**ISRO's OCM Sensor Captures Extensive Noctiluca Bloom**

North-western Arabian Sea experiences an outbreak of *Noctiluca scintillans* algal blooms  
**Oman**

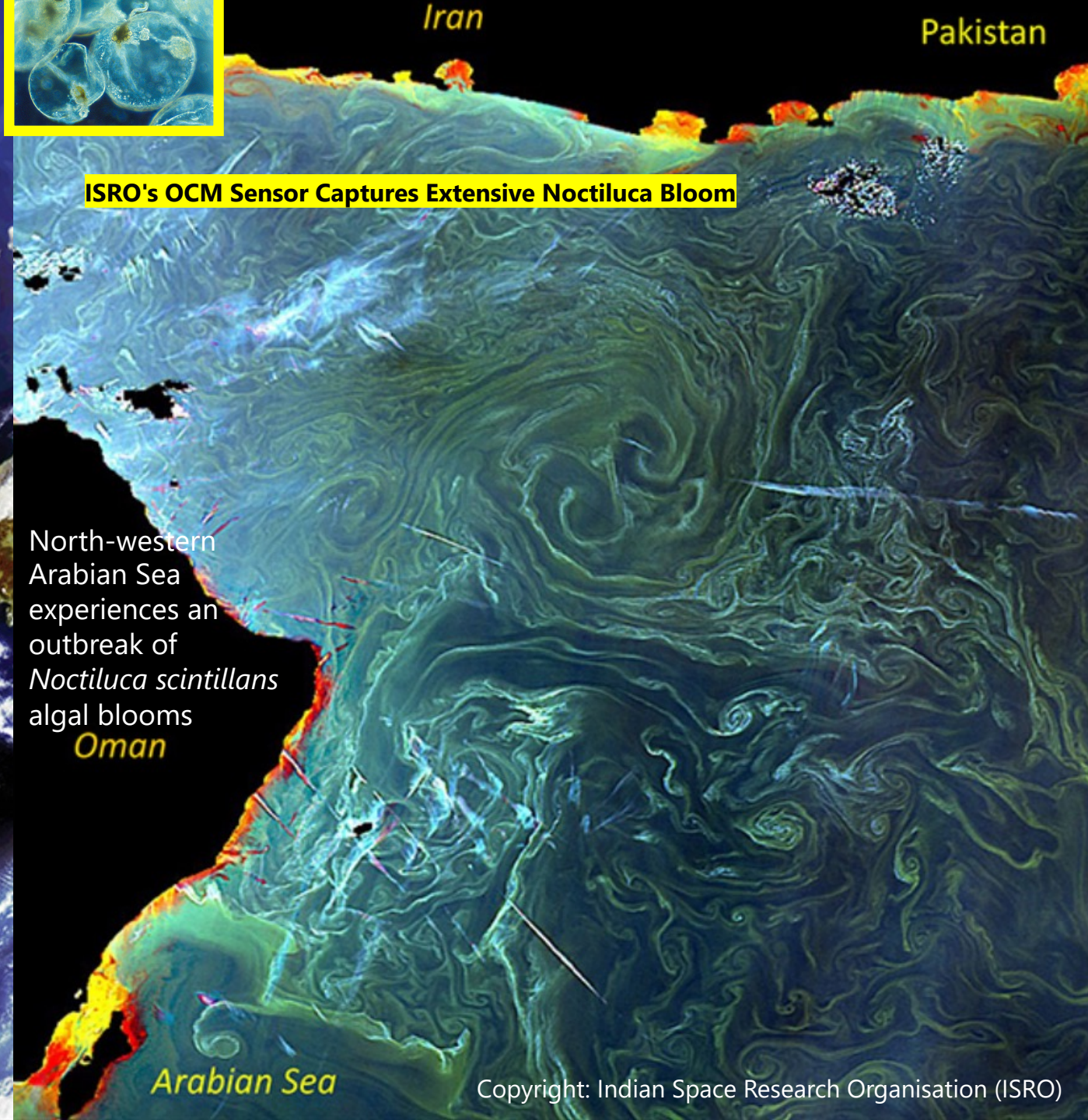


Image provided by Dr. Yu-Hwan Ahn, KORDI (Korea Ocean Research and Development Institute).



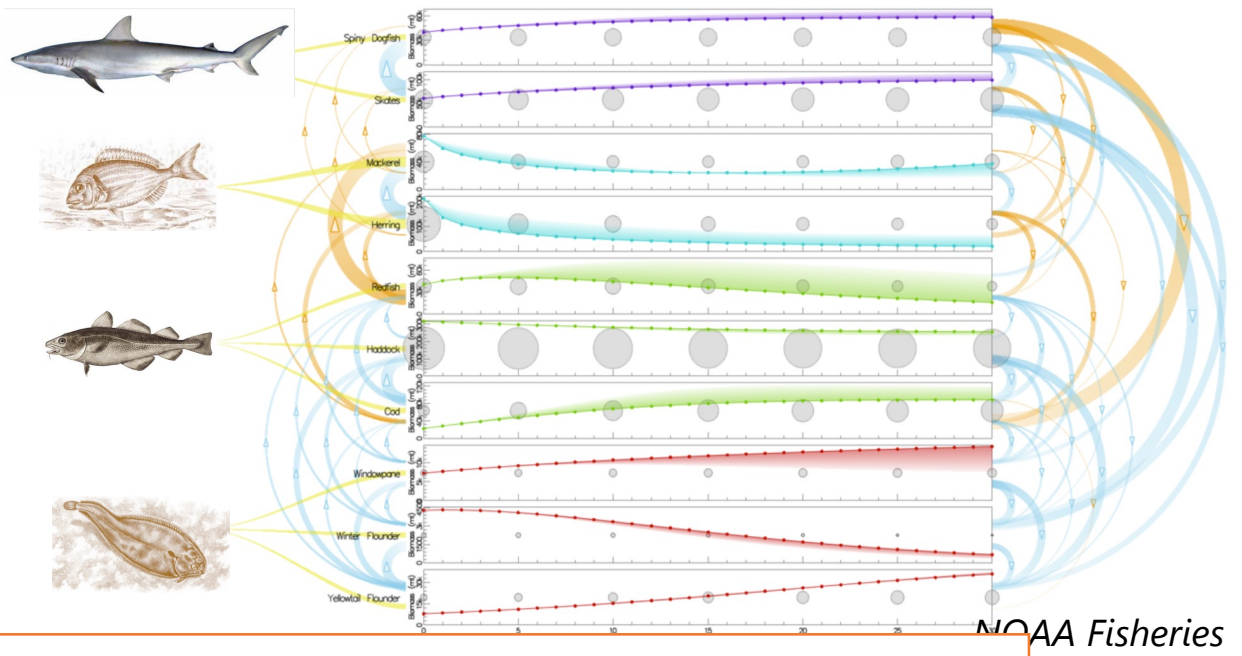
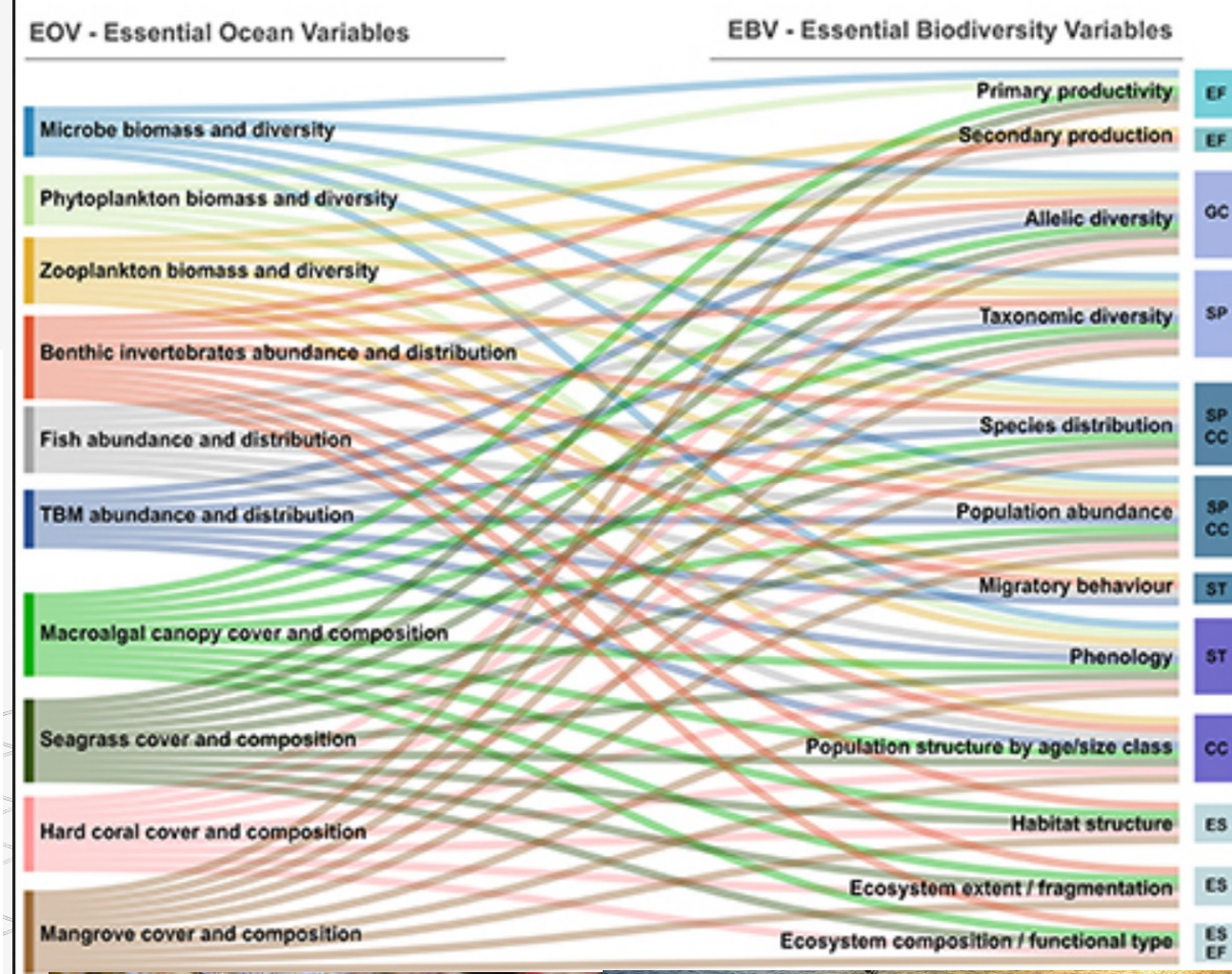
# Ecosystem models need also other data and relations

Multi-species model: effects of fishing on different species and interactions between species (predation or competition). The changes in fisheries extend to other species even if they are not directly affected by fisheries.

## Conceptual relationship between EOVs and EBVs

**Essential Ocean Variables** microbes, phytoplankton and zooplankton, higher trophic levels (benthic invertebrates; fish; marine turtles, birds, and mammals), and habitat forming species

**Essential Biodiversity Variables** population, species, habitat structure, etc.

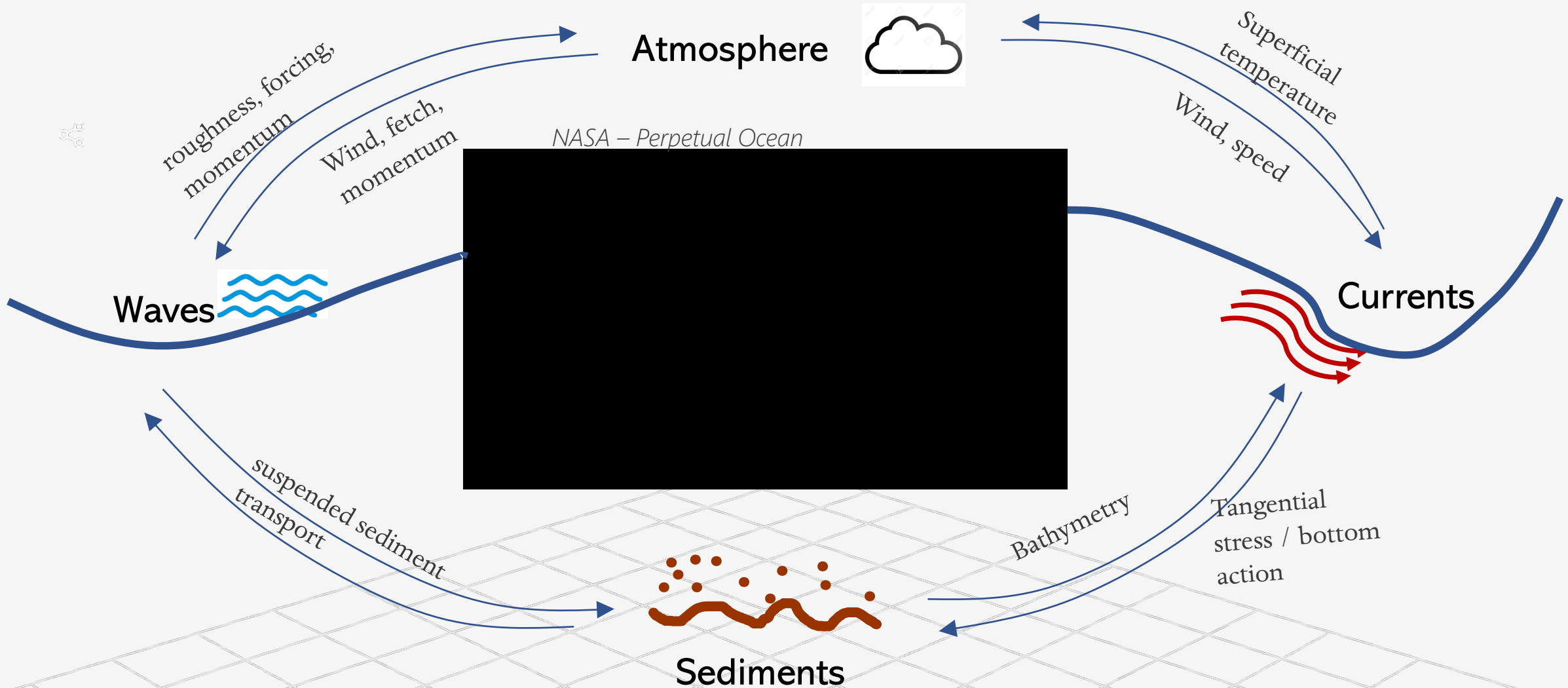


Biogeochemical and ecosystem parameters sensors



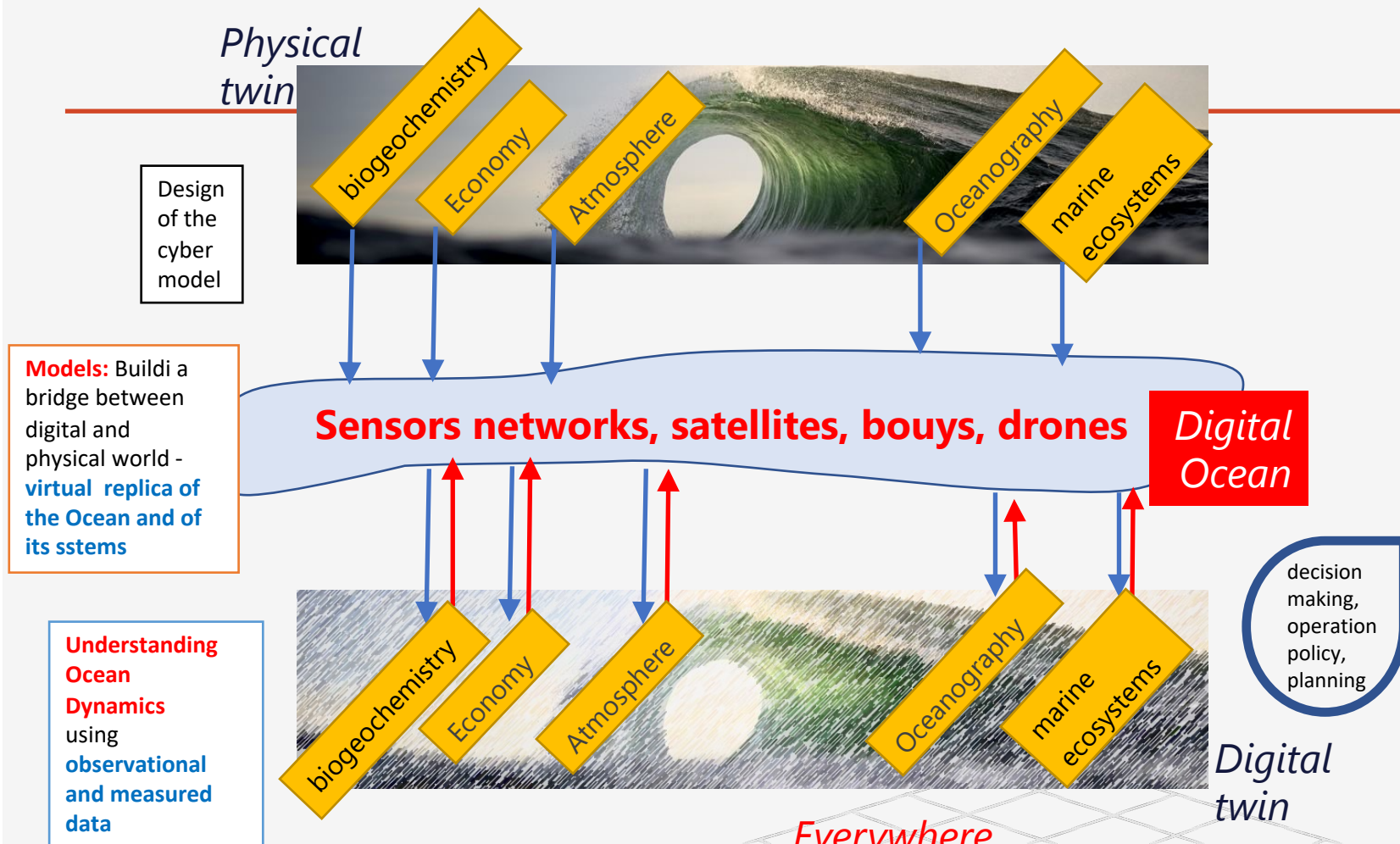
Muller-Karger, Front. Mar. Sci., 27 June 2018

# Mathematical models and Data





# The Ocean Digital Twin (ODT)



- ❑ Good ocean conservation and management of marine habitat ecosystems, safeguarding productivity and biodiversity
- ❑ Increased awareness and understanding of the dynamics, interactions and evolution of seas and oceans and their role in our well-being and survival
- ❑ Knowledge-based decision-making processes, increase the efficiency and sustainability of maritime activities
- ❑ Sharing, availability, viewing and use of data

**Artificial Intelligence =**  
*Machine Learning (ML)* +  
*Big Data* +  
*High Performance Computing (HPC)*

*Everywhere computing for distributed ML*

Algorithmic, computational, physical, biogeochemical, and technological innovations, drawing together elements of computational fluid dynamics, statistics, meteorology, oceanography, ecology and computer science

