Enhancing Marine Geospatial Data with Digital Twin of the Met-Ocean Environment

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   - Supporting UN Sustainable Development Goals (SDGs)
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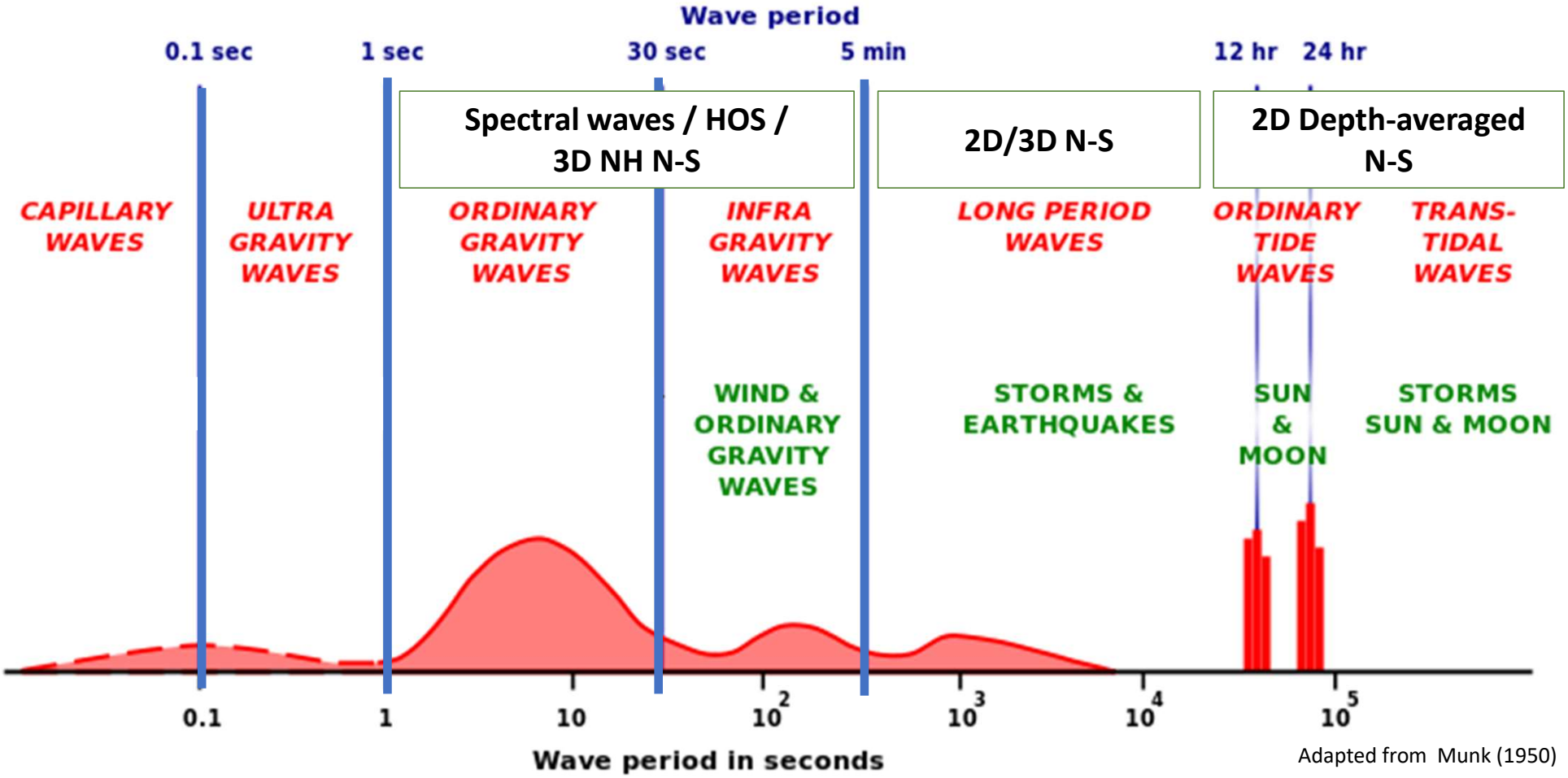
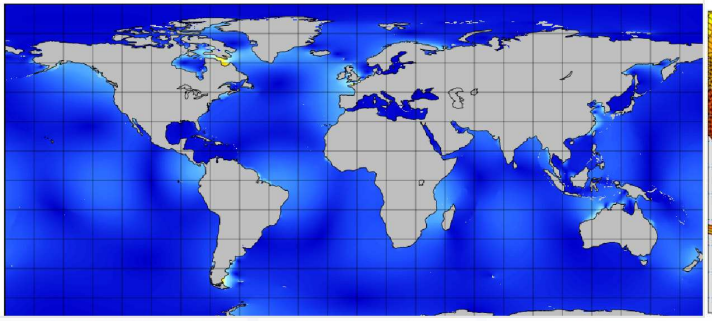
Scales of the Met-ocean Environment

Environment can be described by the superposition of waves of different time and length scales

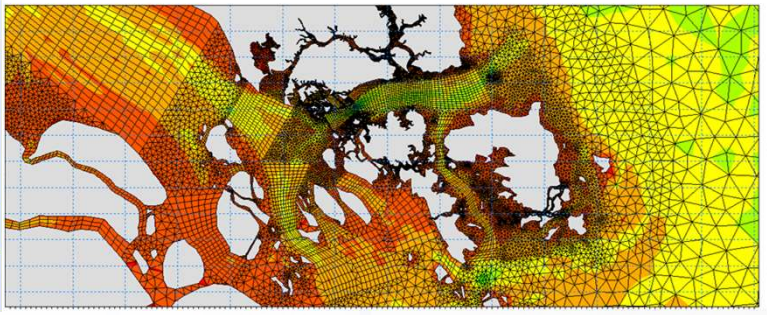


Adapted from Munk (1950)

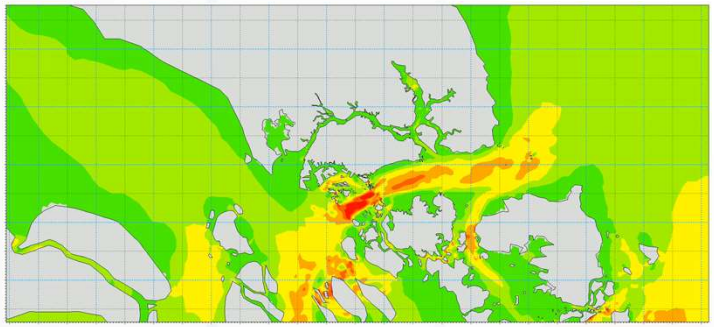
Scales of the Met-ocean Environment

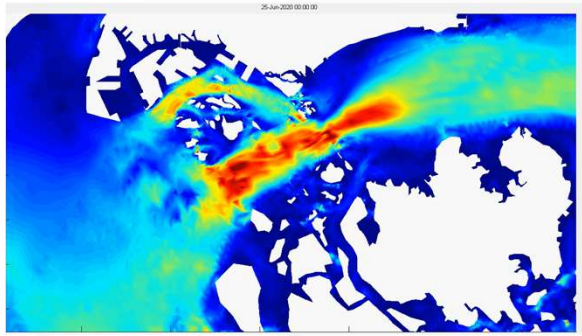


Sea surface height amplitudes (M2)

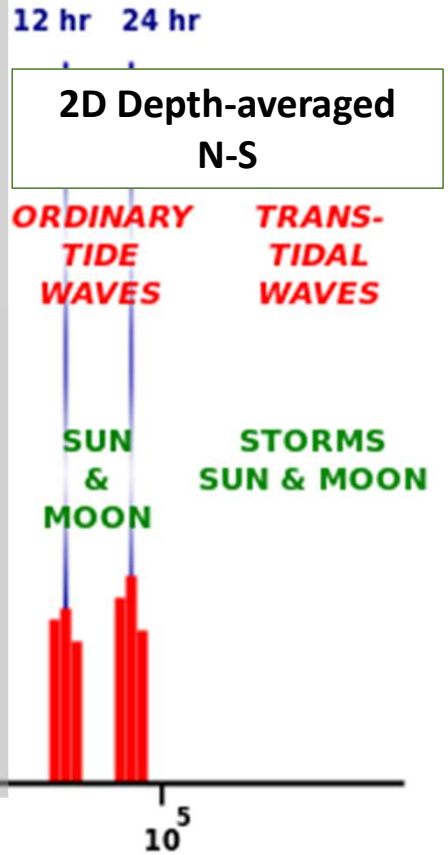


Computational domain and Bathymetry





Current speeds in the SG straits



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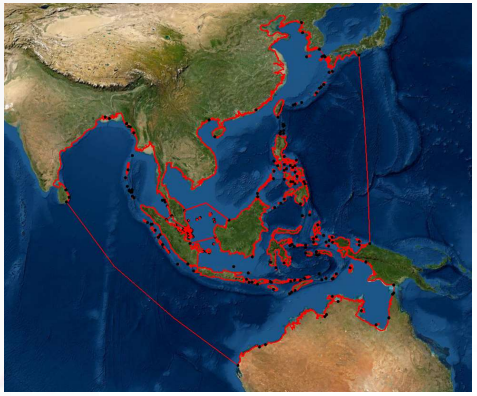
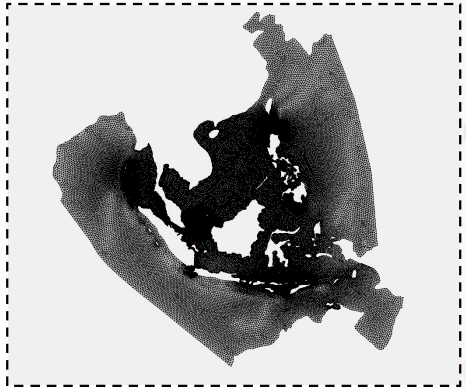
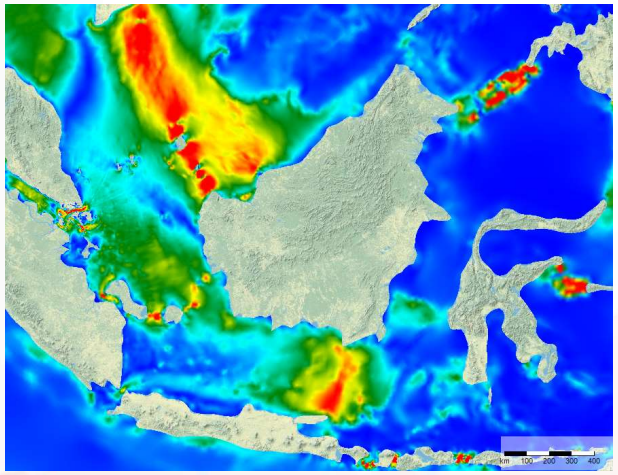




Domain of the extended region

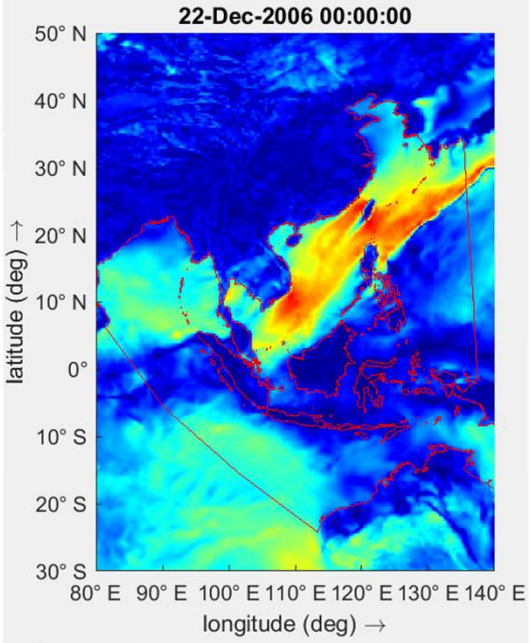


Current speeds in the extended region

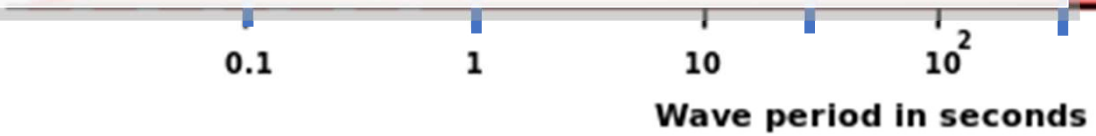
2D/3D N-S

LONG PERIOD WAVES

STORMS & EARTHQUAKES



Wind and atmospheric pressure from ERA5 (ECMWF)



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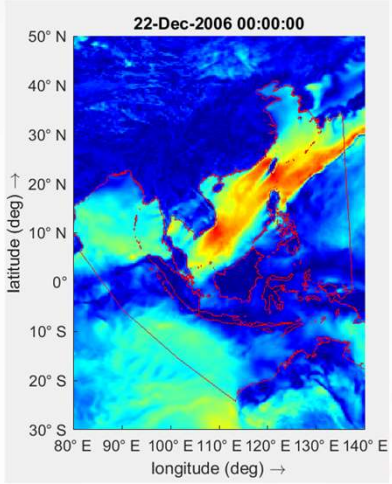
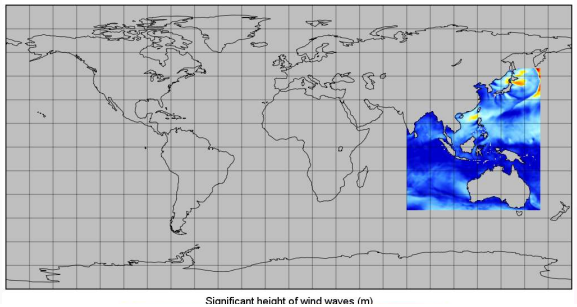
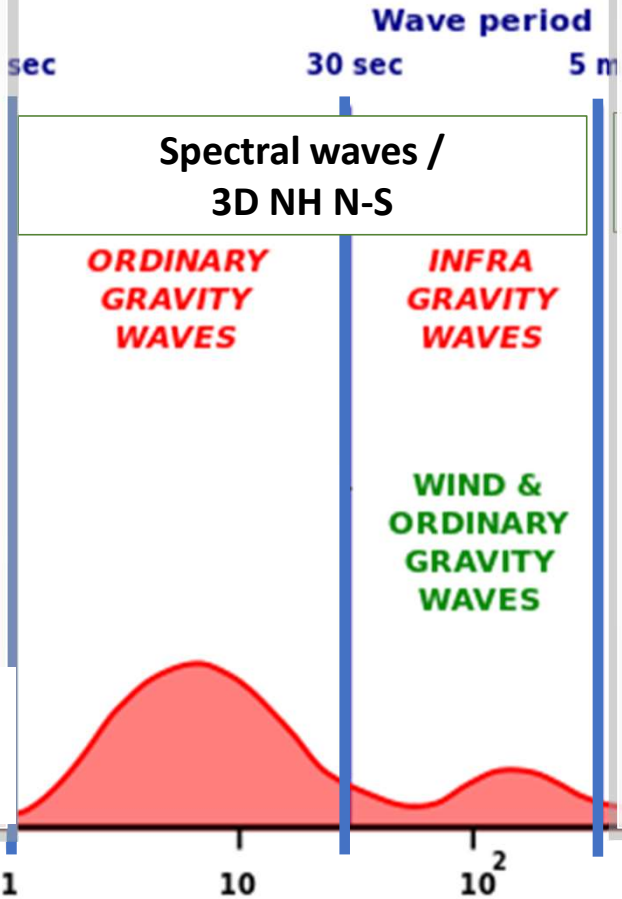
Scales of the Met-ocean Environment

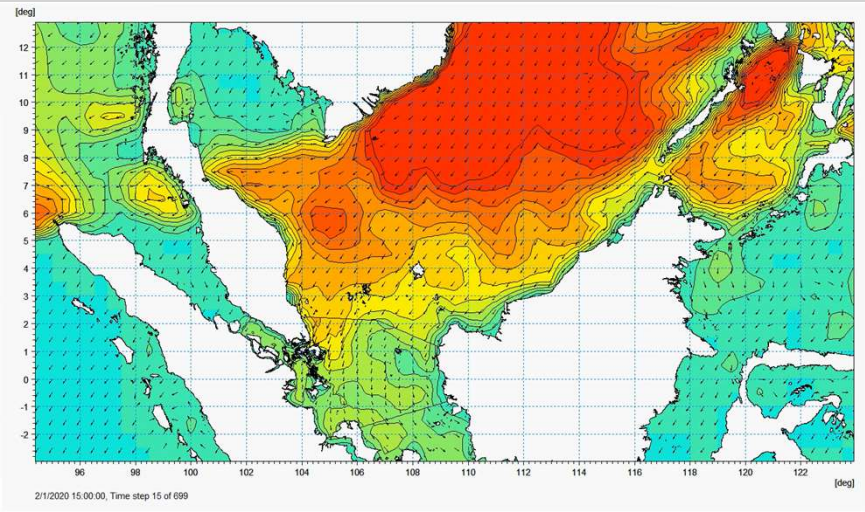
Wind from ERA5



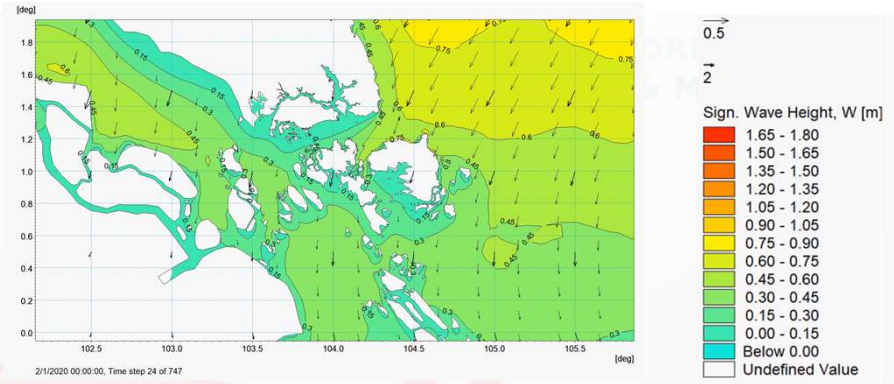


Spectral energy from ERA5 / Larger scale spectral wave model





Downscaled wave + winds applied on local domain
Wind-waves in the SG straits

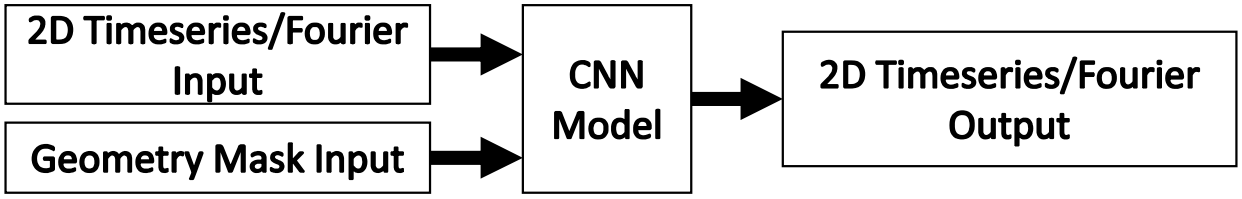


Adapted from Munk (1950)

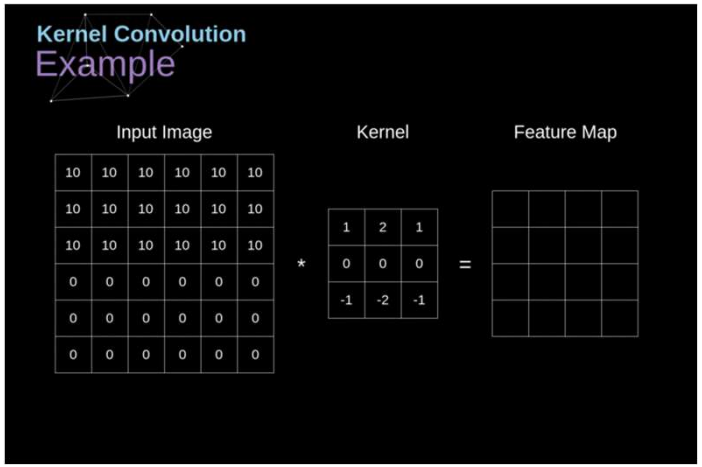
Data-driven models for hydrodynamic and wave environments

A data-driven version of the physics model for **currents** and **waves**

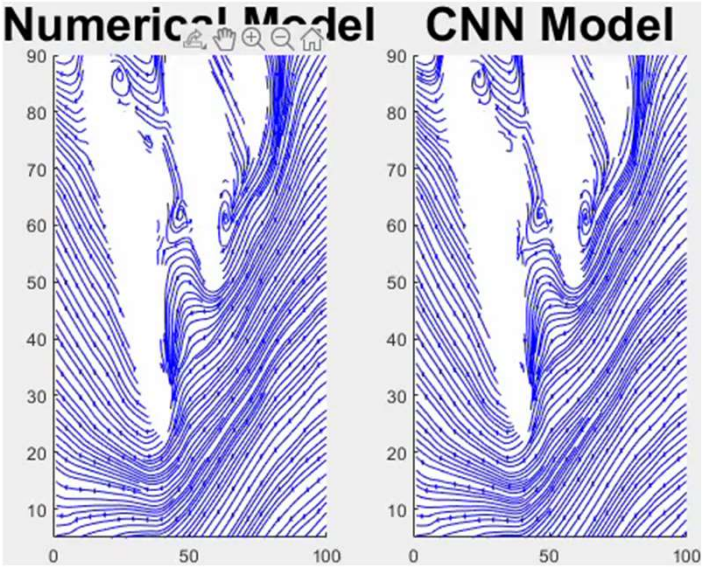
- Efficient forecasting of met-ocean environment
- Computationally much less demanding
  - Limited bandwidth and lack of computational resources on board



- Accurate prediction of complex flows
  - Prediction of timeseries was within 5% of relative error.
  - Excellent R^2 value for timeseries and its amplitude and phase



From: towardsdatascience.com/gentle-dive-into-math-behind-convolutional-neural-networks



Defining the Digital Twin of Met-ocean Environments

GLOBAL MODELS AND DATA

WIND WAVES (reanalysis, hindcast, forecast)

ATMOSPHERIC FORCING (reanalysis, hindcast, forecast)

Ocean Model (reanalysis, hindcast, forecast)

REGIONAL MODELS
(South-east Asia, parts of Antarctica, Oceania, up to Japan, Korea)

Atmospheric Model *WRF*

Wind-Wave Model *WW3*

Ocean Circulation and Storm Surge Model *NEMO*

LOCAL MODELS
(Singapore Strait)

Atmospheric Model *WRF*

Wind-Wave Model *SWAN, DELFT-WAVE MIKE SW*

Hydrodynamics Model *DELFT-3D MIKE 3/21 FM*

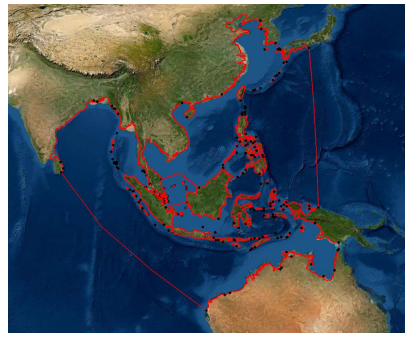
DATA ASSIMILATIONS

OBSERVATIONS
- Satellites
- Gauges
- Moorings
- Ships
- Gliders

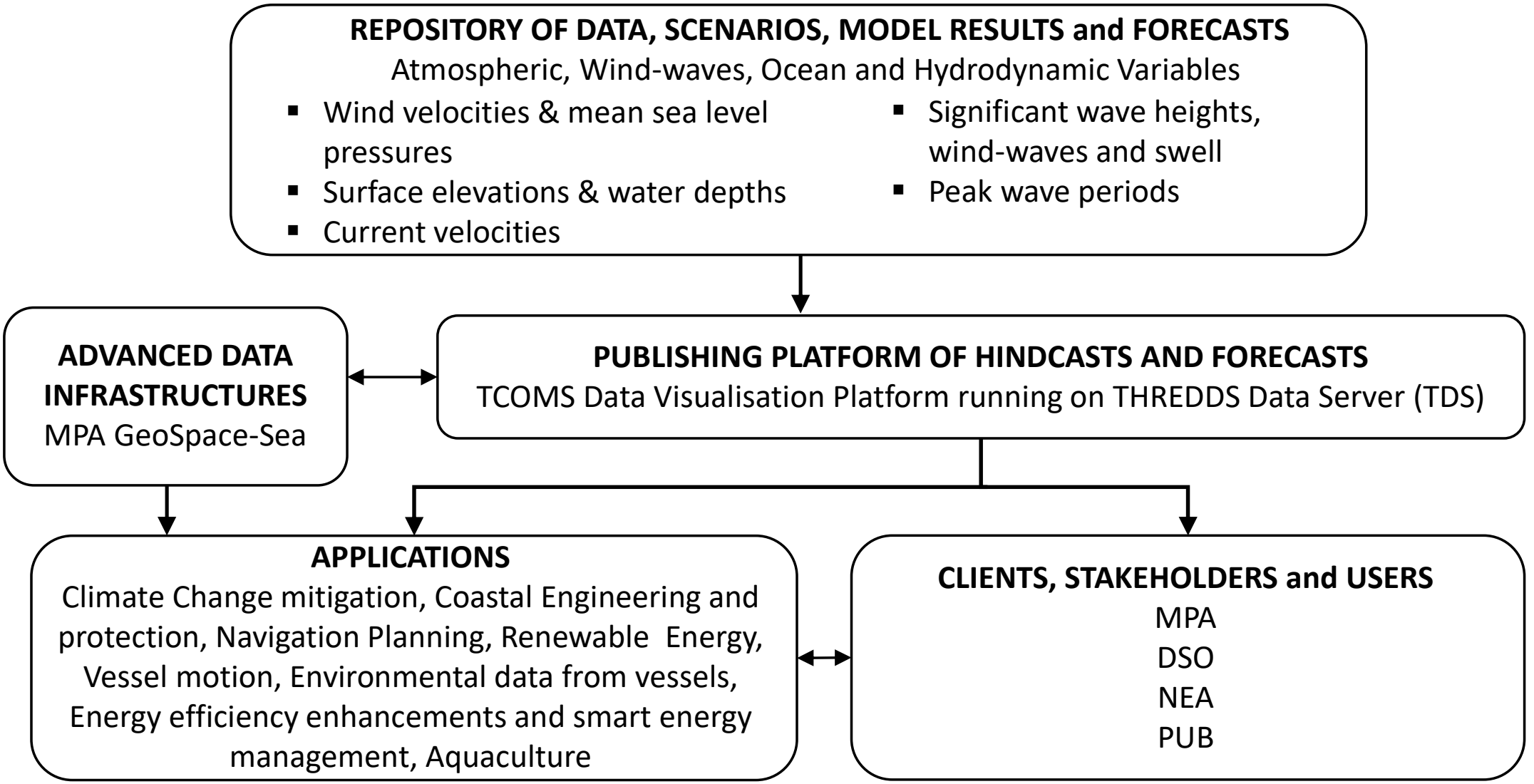
REPOSITORY OF DATA, SCENARIOS, MODEL RESULTS and FORECASTS

Atmospheric, Wind-waves, Ocean and Hydrodynamic Variables

- Wind velocities & mean sea level pressures
- Surface elevations & water depths
- Current velocities
- Significant wave heights, wind-waves and swell
- Peak wave periods



Defining the Digital Twin of Met-ocean Environments



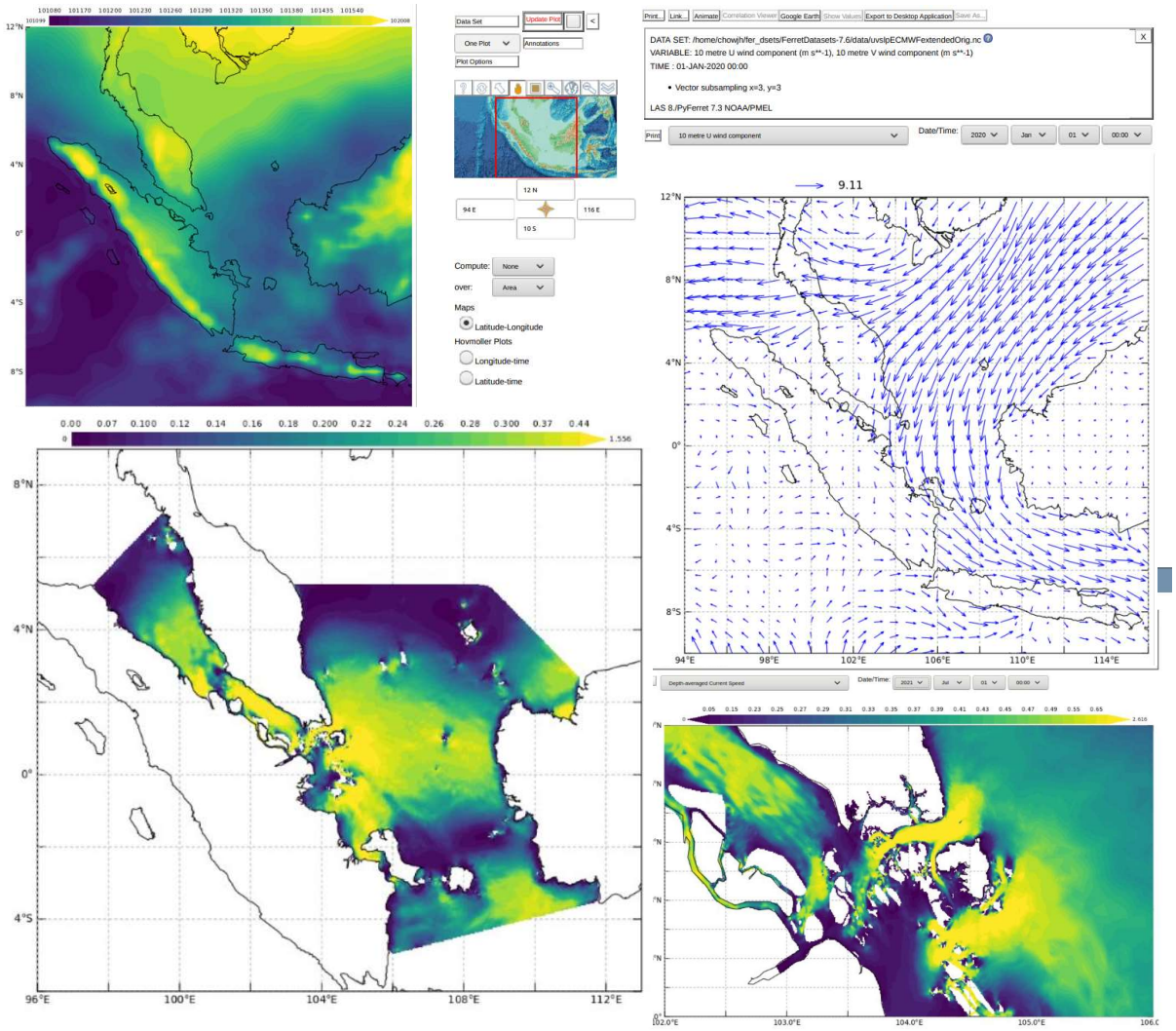
Digital Met-ocean Visualization Platform

Objective & Applications

- Develop a basic visualization framework for disseminating accurate information on the met-ocean conditions to maritime stakeholders
  - Wind
  - Currents
  - Waves
- Incorporation of information into the navigation and control systems
- Enhancement of MASS performance and other smart maritime solutions

Implementation

- Live Access Server enables efficient data product access and customized NetCDF downloads
  - Platform for viewing of forecasted data overlay on map



Data Formatting with NetCDF

Network Common Data Form (NetCDF) as the **optimal format for interoperability** between systems:

- Portable, scalable, appendable, sharable

Packing standards of NetCDF data

- u-velocity range of -4.6798 to 7.8869 m/s
- Can be represented by range of int16:
- -32,768 to 32,767
- -32,768 allocated to NaN values
- Apply **offset** and **scaling**

scale_factor = 1.9175867732353235E-4; (double)

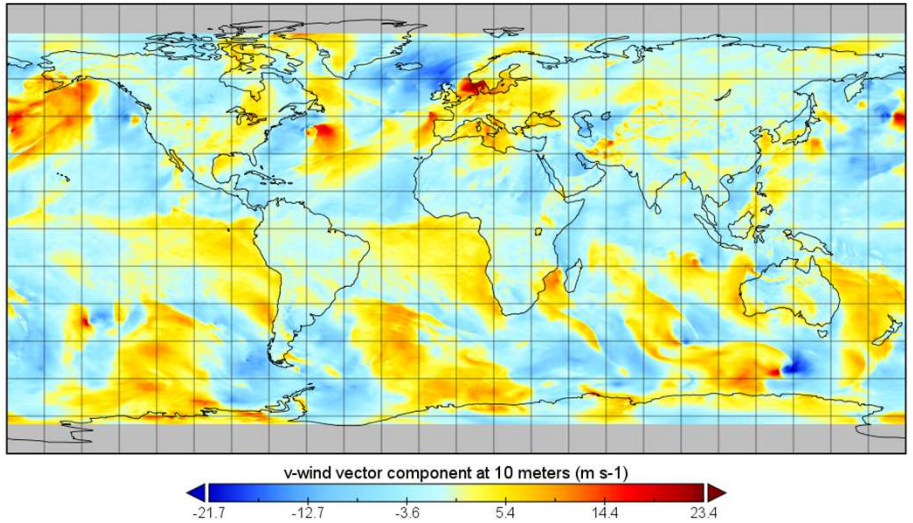
add_offset = 1.6035202588645445; (double)

- Results: 20 GB (Float)→ 4 GB (int16) packed

Name	Long Name	Type
CCMP_RT...	CCMP_RT_Wind_...	Local File
latitude	latitude	1D
longitude	longitude	1D
nobs	number of obser...	Geo2D
time	Time of analysis	1D
uwnd	u-wind vector co...	Geo2D
vwnd	v-wind vector co...	Geo2D

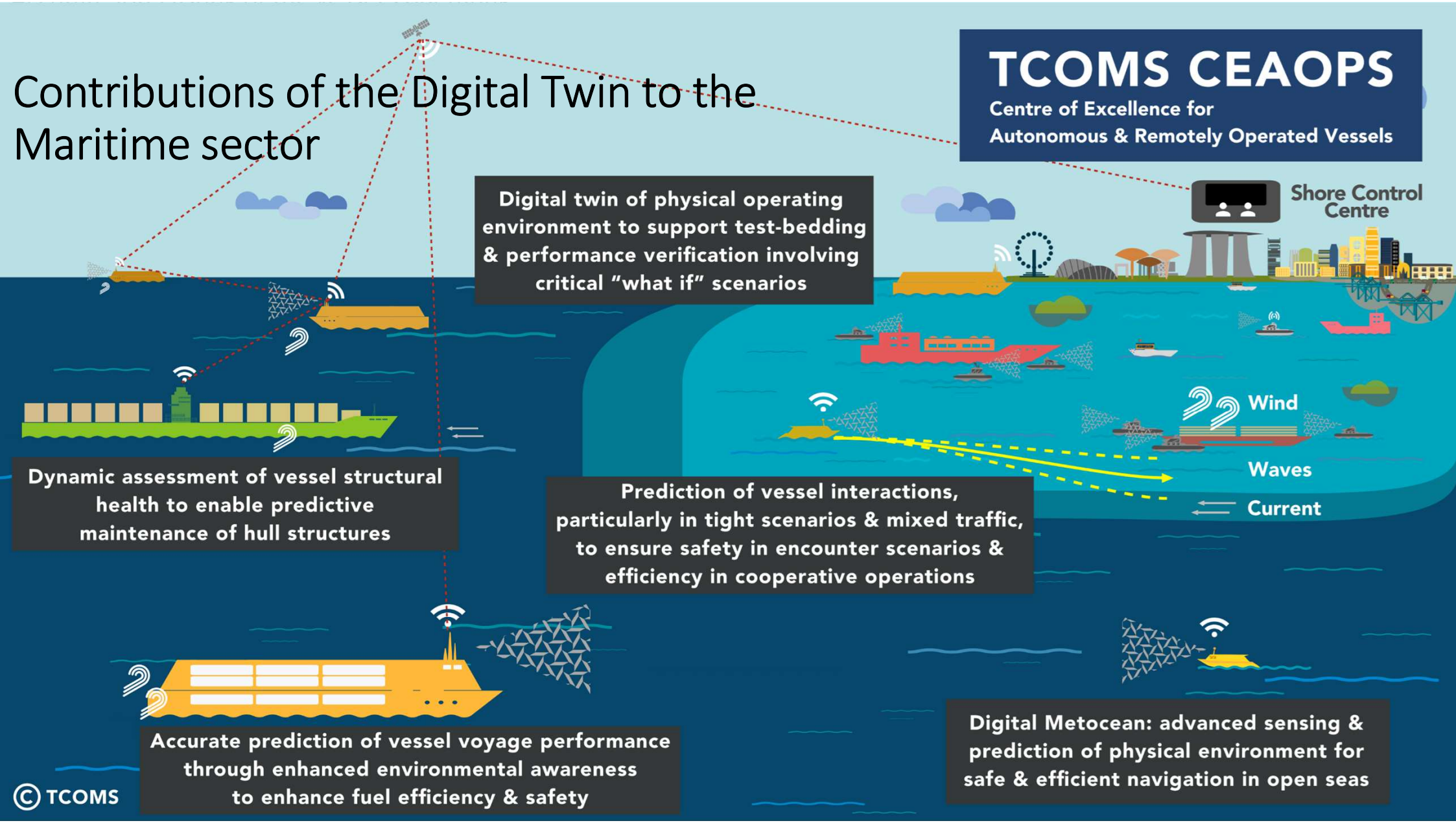
	260.75	260.8125	260.875	260.9375
-6.3125	18.3	18.5	18.7	18.9
-6.25	18.4	18.6	18.8	19.0
-6.1875	18.5	18.7	18.9	19.1
-6.125	18.6	18.8	19.0	19.2
-6.0625	18.7	18.9	19.1	19.3
-6.0	18.8	19.0	19.2	19.5

v-wind vector component at 10 meters



Adapted from https://coastwatch.gitbook.io/satellite-course/

Contributions of the Digital Twin to the Maritime sector



Further Applications of Geo-spatial Met-ocean data

- Forward predictions of met-ocean variables in the long-term based on current trends
  - ➢ Impact of ocean changes on the climate
- Testing of mitigation strategies through models to optimise outcomes

- Testing of development project configurations to minimise environmental impacts
  - ➢ Transport of sediments and contaminants

Real-time marine geospatial data in supporting UN Sustainable Development Goals (SDGs)

Balancing economic activities with the long-term sustainability

- Analysis of tidal current over a domain to identify sites through statistics
- Testing of configurations to optimise energy outputs
- Environmental impact considerations

- Maintain marine biodiversity by environmental conservation and climate change mitigation efforts
- Met-ocean data enables setting up of the legal framework for the conservation and sustainable use of oceans and their resources

Summary

- High resolution real-time marine geospatial data of the met-ocean environment of various scales can be obtained from numerical & data-driven models, with assimilated data from past observations, enables the digital twin

- Marine geospatial data efficiently disseminated on visualization platforms, accessible by stakeholders and allowing collaborators to develop advanced data infrastructures

- Resulting contributions to the maritime sector in various ways, and blue economy opportunities supporting UNSDGs

End of Presentation – Questions & Answers