

COPERNICUS MARINE 8th GENERAL ASSEMBLY

• Blue Ocean: models 2023 achievements and 2024 plans

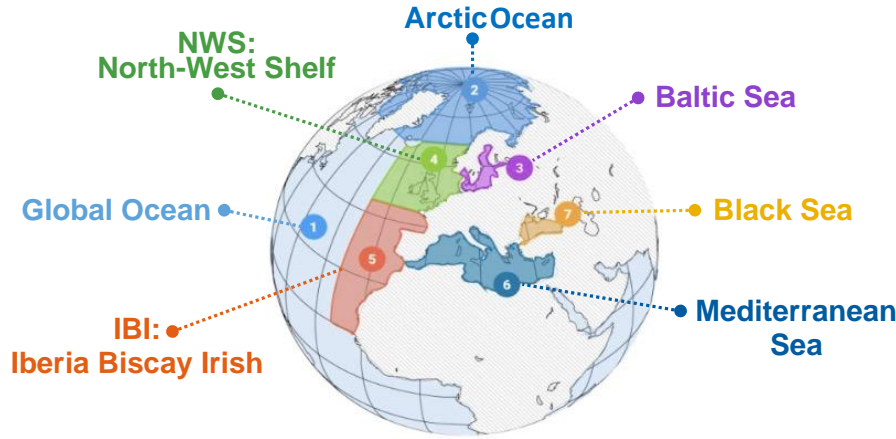




● Ocean Modeling Systems

- Numerically simulate the space-time scales that characterize the ocean → ability to accurately represent the various phenomena that are resolved, and to parameterize those scales of variability that are not resolved
- Apply state-of-the art ocean models and assimilation methods ingesting observations to improve the models' solution
- Produce short-range ocean forecasts, boundary and initial conditions to extend the predictability of regional, local & coastal subsystems
- Provide ocean analyses and reanalyses for improved understanding of the oceans, assessments of the ocean variability, indicators and trends

7 Monitoring & Forecasting Centers



- Temperature
- Salinity
- Currents
- Sea Level
- Mixed Layer Depth
- Waves:

Sig. height	Wind waves
Period	Pr. swell
Directions	Sr. swell

**Multi
Year**

Reanalysis: last decades

Interim: up to m-1

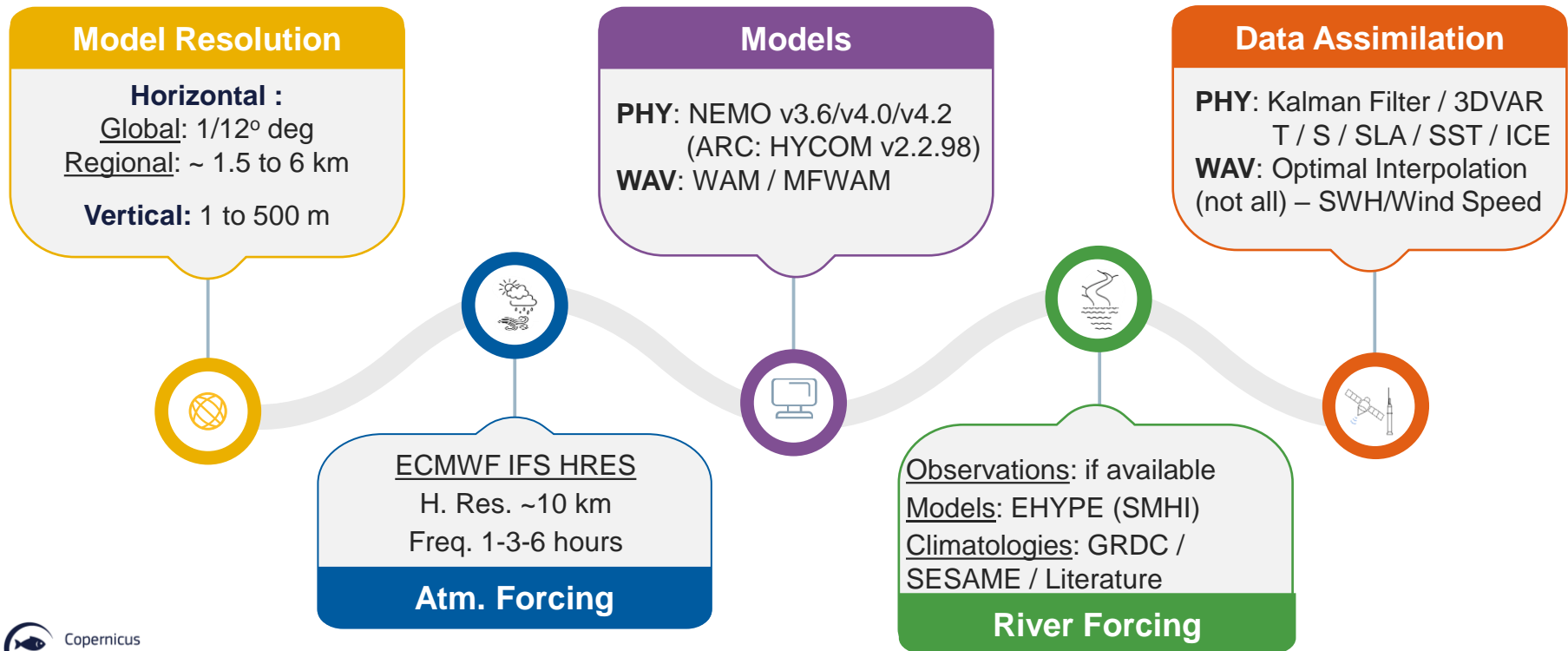
**Near Real
Time**

Analysis: - 2 years

Forecast: 10 days

- Monthly mean
- Daily Mean
 - Hourly Mean
 - Hourly Inst. (waves)
 - < 1hour

Near Real Time Models' Characteristics



Multi-Year Time Models' Characteristics

Model Resolution

Horizontal :

Global: 1/12° to 1/5°
Regional: ~ 2 to 12 km

Vertical: 1 to 500 m

Models

PHY: NEMO v3.6 – v4.0
(ARCTIC: HYCOM)
WAV: WAM / MFWAM / WWIII

Data Assimilation

PHY: Kalman Filter / 3DVAR
T / S / SLA / SST / ICE
WAV: Optimal Interpolation
(not all) – SWH / Wind speed

ECMWF ERA5
H. Res. ~25 km
Freq. 1 hour

Atm. Forcing

Observations: if available
Models: EHYPE (SMHI)
Climatologies: GRDC /
SESAME / Literature

River Forcing

PHY: From 1993
(MED:1987)
WAV: From 1980/1993
(BLK: 1950)

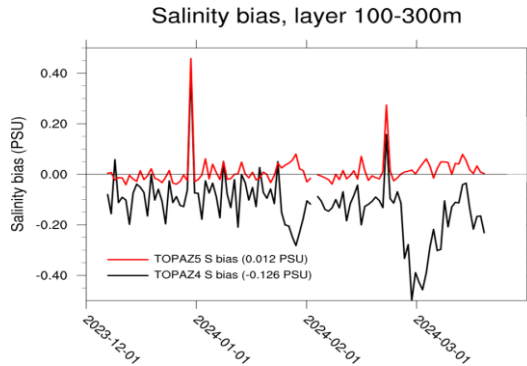
Time Series

Major Achievements 2023

ARC PHY Analysis & Fcst (NRT)

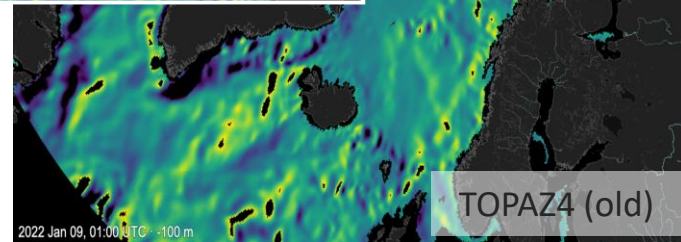
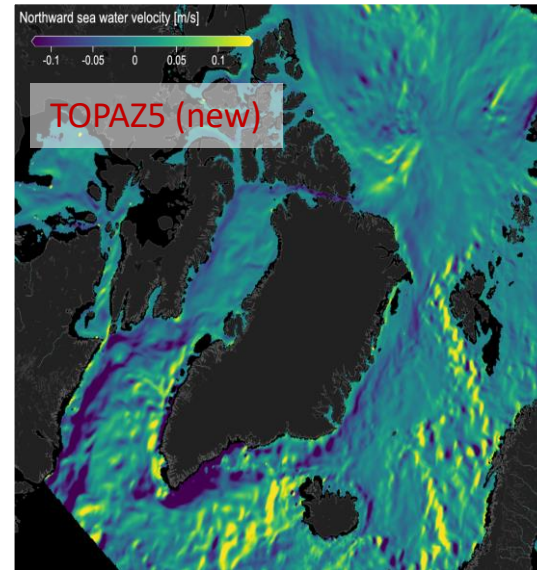
- Complete update of the modelling system
 - From HYCOM v2.2.37 to v2.2.98 including: (i) 6 km and 50 hybrid layers, (ii) lat. BDY from GLO, (iii) updated river clim., (iv) ESMF coupler, (v) new bulk flux formulae (vi) GEBCO
 - Data assimilation with MSS from CNES/CLS 2022

Improved water masses
Atlantic Water



TOPAZ5 (new)
TOPAZ4 (old)

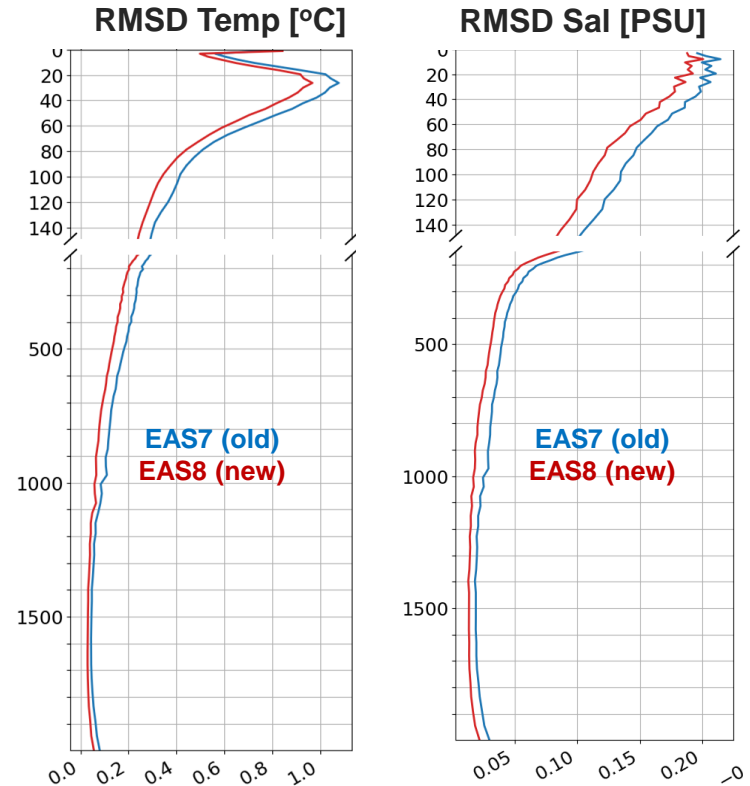
Better defined currents at depths
Northwards velocity at 100 m



Temperature & Salinity validation wrt in-situ Overall reduction of the error

Major Achievements 2023 MED PHY Analysis & Fcst (NRT)

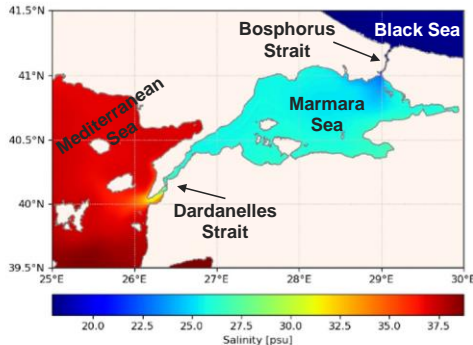
- Complete update of the modelling systems
 - From NEMO 3.6 to 4.2 including: (i) updated BDY, (ii) updated bulk formulae, (iii) increased time step
 - From WWIII 3.16 to 6.07
 - OASIS Coupler
- Updated Data Assimilation
 - New EOFs
 - Assimilation of in-situ obs in the Atlantic box



Major Achievements 2023

BLK PHY Analysis & Fcst (NRT)

Extension of the domain in the Marmara Sea



- Based on the U-TSS unstructured grid model
- 1/160° (500m)
- BDY to the BLK-PHY

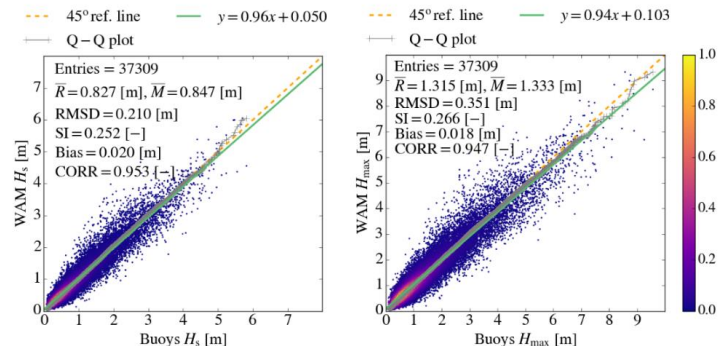
It will provide the missing link for the Southern European seas

Major Achievements 2023

MED WAV Analysis & Fcst (NRT)

- Delivery of maximum crest height and crest-to-trough height (H_{max})
- LATEMAR method more accurate than Janssen (ECMWF) approach for the Med Sea for H_{max} estimation

Validation of H_s and H_{max} against buoys in 2021
Overall metrics for H_{max} are relatively poorer than those obtained for H_s , but still in line with the literature



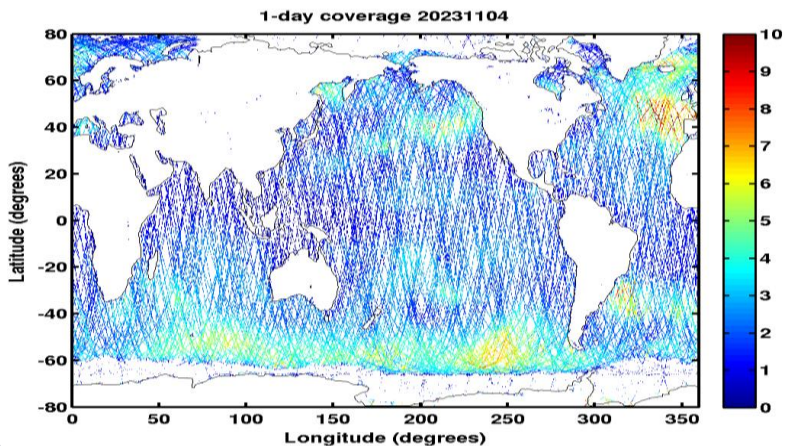
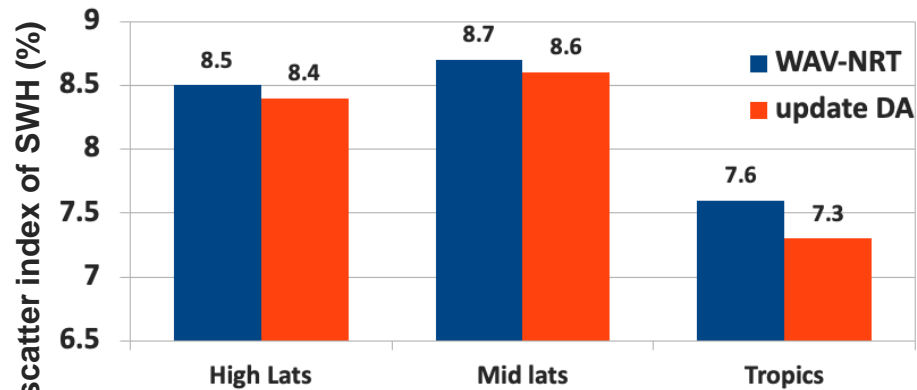
Major Achievements 2023

GLO WAV Analysis & Fcst (NRT)

- 6-hourly current forcing
- Updated assimilation
 - Improved data coverage for SWH altimetry including SWOT-nadir and HY2B

SWH Scatter index comparison with H2C & H2D: Nov 2023

Slight improvement of SWH estimate in all ocean basins particularly in the tropics



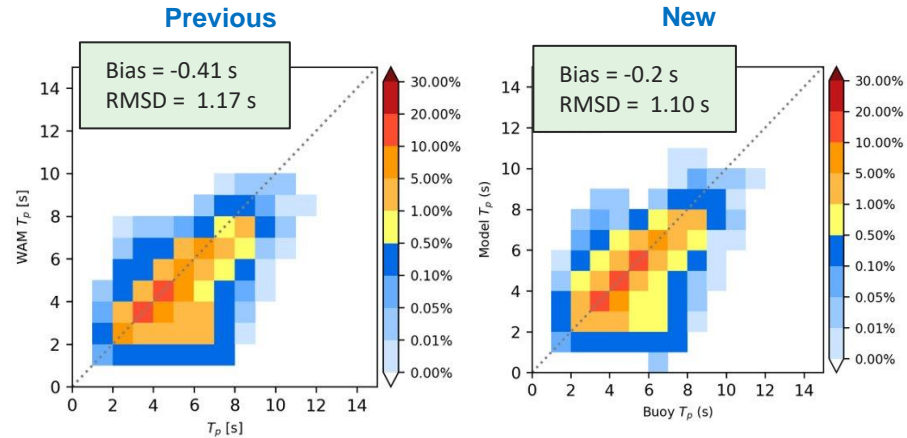
Major Achievements 2023

BAL WAV Analysis & Fcst (NRT)

- **Upgraded model system** WAM v4.6 to 4.7
- **Included new ST4 physics source term** for improved dissipation of wind generated waves
- **Improved coastal archipelago area**
 - by updating the grid-obstruction fields
 - by including new bathymetry dataset

Validation of Peak Period
2 years buoy observation in Gulf of Finland

Slightly improved model results
Ready for tighter coupling with the ocean model



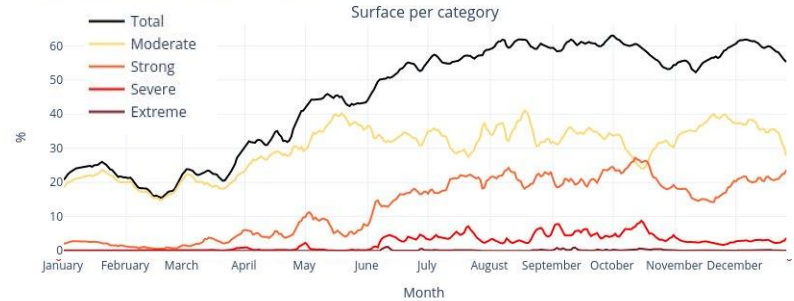
Major Achievements 2023: GLO PHY MY interim time series extensions

Improvement of the global PHY MY product to facilitate ocean reporting activities

- Since 2023: a continuous global reanalysis product available **from 1993 up to 4 months before real-time**, updated each month
- The product is used for **OSR contributions** analysing El Nino 2023/2024, and the North Atlantic Marine Heat Wave of 2023
- The WAV MY product is also updated in **interim mode** since November 2023

North Atlantic MHWs in 2023 Surface by category

Surface - glorys12 (2023-01-01 - 2023-12-26)
Surface of the studied area: 43599348.0 km² | Depth: 0.49m

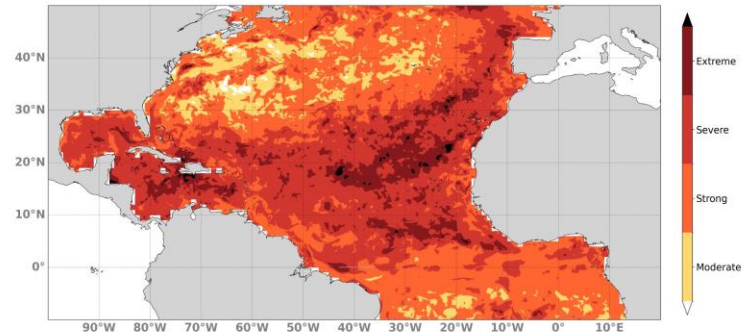


MERCATOR
OCEAN
INTERNATIONAL

Highest MHW Category - glorys12

Time period: 2023-01-01 - 2023-12-26 | Depth: 0.49 m | Climatology: 1993-2022

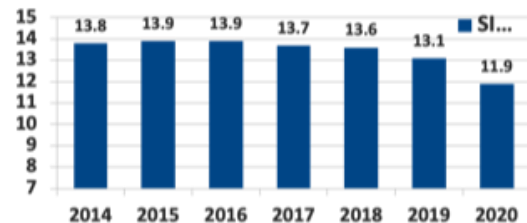
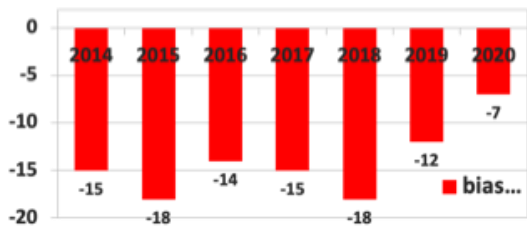
Copernicus
Marine Service



Validation of SWH with independent HY2-A&B
Significant improvement after 2019 thanks to more
Assimilated data from altimetry

Major Achievements 2023 IBI WAV Reanalysis (MY)

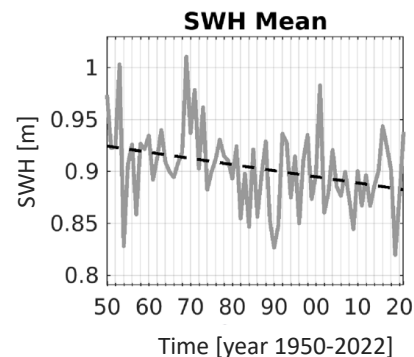
- **Increased resolution**
 - 2.5 km / spectral resolution (36 dir.)
- **Spectral assimilation** (Envisat, S1, CFOSAT)



Major Achievements 2023 BLK WAV Reanalysis (MY)

- **Timeseries extension since 1950**

- Period: 1950-2022 (INT: -1M)
- Output: 1-hourly
- Resolution: ~2.5 km
- Forcing: ERA5
- Assimilation: wave height and wind speed from Jason



Significant wave height trend
yearly basin-wide averages and linear trend
from 1950 to 2022

NRT Systems' planned evolutions in 2024



Model resolution/domain

- Extension of the BLK domain to the Azov Sea
- Towards NEMO v4.2 (All)



PHY/WAV Models

- Assimilation 5Hz Altimetry data (All)
- Improved assimilation schemes (BLK-PHY)
- Assimilation of new observational data (MED-PHY & ARC-WAV)
- Forced by GLO-PHY HF currents at 6h (GLO-WAV)



Data Assimilation

- Use of EFAS runoff (IBI-PHY, MED-PHY, BLK-PHY)
- Major upgrade of the online coupled system (BAL-PHY & BGC)
- Wave terms (Langmuir mix, Stokes drift, wave breaking) (ARC-PHY)
- 2nd forecast cycle (BLK-WAV)
- Extended forecast to 10 days (BAL-PHY & WAV)



Forcings & Coupling



Forecast Availability



● Multi-Year Systems' planned evolutions in 2024

● New reanalysis:

- **IBI-PHY:** *new system (ECFLOW / NEMO 3.6 / SAM2V2) at 1/36°*
- **BLK-PHY:** *upgraded systems at 1/40 ° covering 1993 to present*
- **BAL-WAV:** *new WAM system and covering 1980 to present*
- **BLK-WAV:** *improved coupling between PHY-WAV (sea surface currents and heights) covering from 1950*

● Longer time series:

- **Backward extension up to 1977:** ARC-WAV
- **Backward extension up to 1980:** GLO-WAV, BAL-PHY & BAL-BGC
- **Backward extension up to 1985:** MED-WAV
- **Production of interim close to NRT:** GLO-PHY & -WAV



● Take home Messages

Continuous effort to:

- Improve the systems accuracy by including modeling upgrades, assimilating new and higher resolution (space and time) observations
- Improve dependencies between PHY / WAV / BGC and with external forcings
- Increase the model data quality
- Increase the consistency and the availability of the Blue Ocean products offer
- Deliver extended time series (Backward & Forward)

