
ANTONIO NAVARRA
THE CLIMATE CHALLENGE

Who we are

The Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (Fondazione CMCC) **is a non-profit research institution**. CMCC's mission is to **investigate and model our climate system and its interactions with society** to provide reliable, rigorous, and timely scientific results, which will in turn **stimulate sustainable growth, protect the environment, and develop science driven adaptation and mitigation policies** in a changing climate.

Offices

Partners

UNIVERSITÀ DEL SALENTO

UNIVERSITÀ DEGLI STUDI DELLA Tuscia

uniss
UNIVERSITÀ DEGLI STUDI DI SASSARI

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

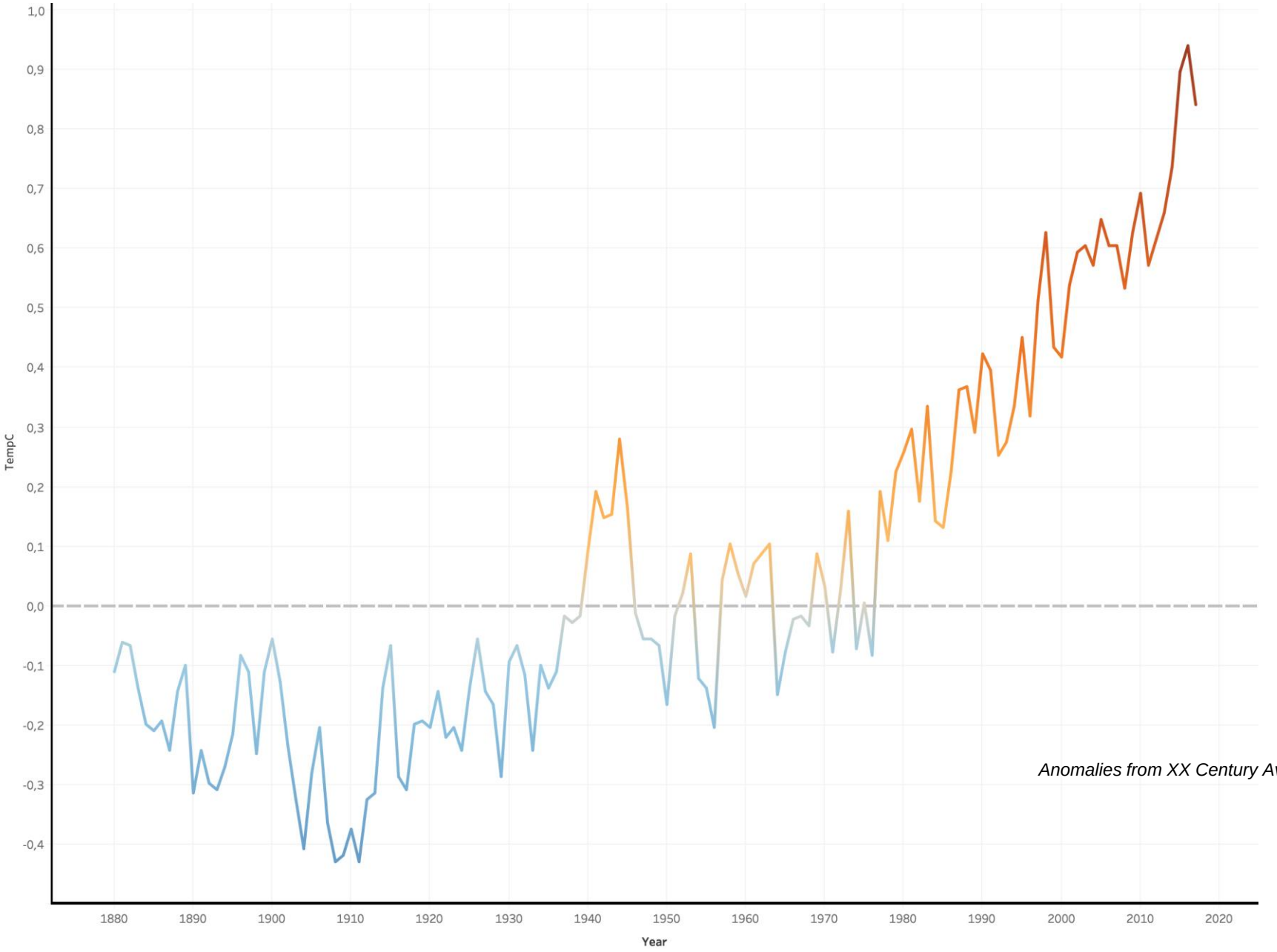
POLITECNICO MILANO 1863

Università Ca'Foscari Venezia

RESOURCES FOR THE FUTURE

CIRA
Centro Italiano Ricerche Aerospaziali

Global Surface Temperature



The CMCC–CM2 model

Atmosphere
Community Atmosphere Model
CAM5.3 (1°x1° - 0,25°x0,25° - 30 -46 v. lev.)

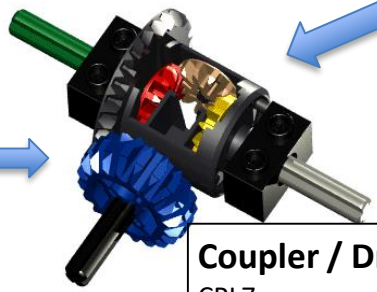
Land / Vegetation
Community Land Model
CLM4.5 (1°x1° - 0,25°x0,25°)

River routing
River Transport Model
RTM (0.5°x0.5°)

30 min.

30 min.

30 min.



Coupler / Driver
CPL7

30 min.

1.5 hrs

Ocean
Nucleus for European Modelling of the Ocean
NEMO 3.6
(1°x1° - 0,25°x0,25 - 50 v. lev.)

Sea Ice
Community Ice Code
CICE4 (1°x1° - 1/4°x1/4°)

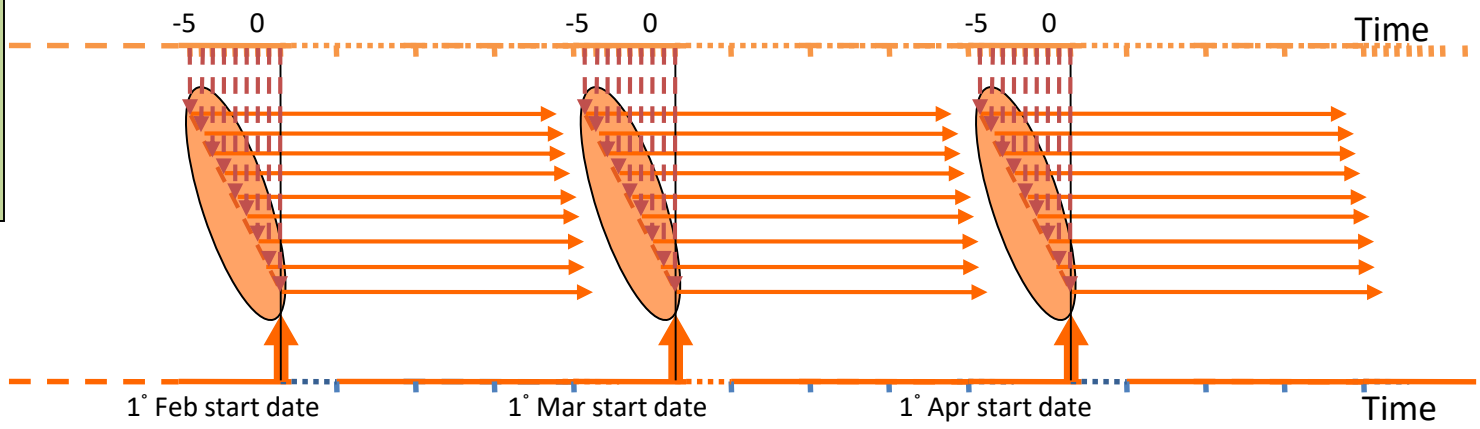
SEASONAL

The ensemble forecast production

Day lag every 12 hours

OFF LINE interpolated Atmosphere IC from ECMWF (ERA interim) operational analysis

OFF LINE CLM4.5 forced with ECMWF and NCEP atmospheric forcing to Land Surface



OFF LINE assimilated OCEAN ANALYSIS

- 3 perturbations for the land surface
- 9 perturbations for the atmosphere
- 8 perturbations for the ocean

216 ICs

50 forecast members

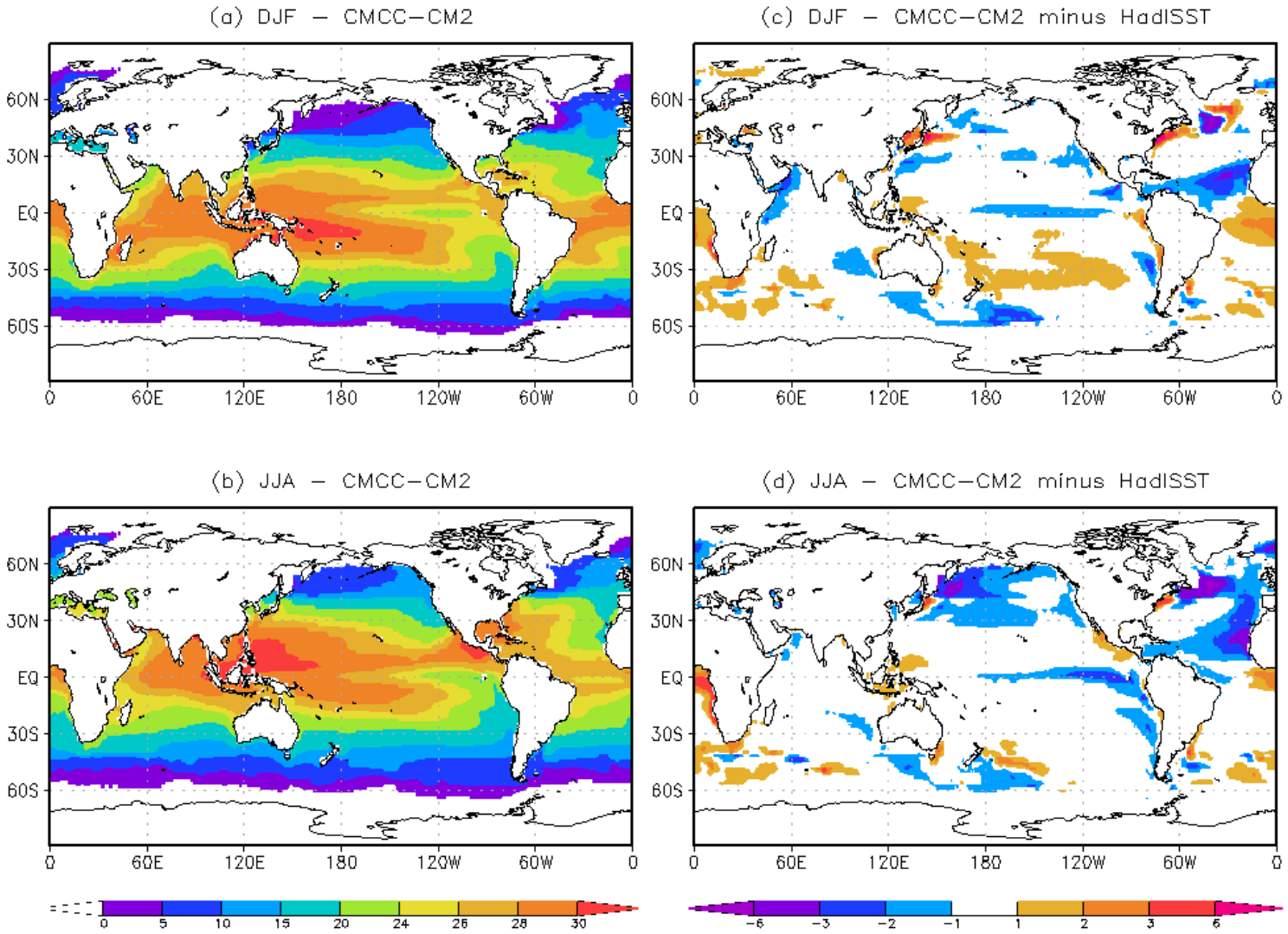
40 re–forecast members 1993–2016

CMIP

		CMCC-CM2-SR5	CMCC-CM2-HR4	CMCC-CM2-VHR4	CMCC-ESM2-SR5	CMCC-ESM2-HR5	
		Climate model Standard - CAM5 Atm(1° x 1°) Ocn(1° x 1°)	Climate model High Res. - CAM4 Atm (1° x 1°) Ocn (¼° x ¼°)	Climate model Very High - CAM4 Atm (¼° x ¼°) Ocn (¼° x ¼°)	Earth system Standard - CAM5 Atm(1° x 1°) Ocn(1° x 1°)	Earth system High Res. - CAM5 Atm(1° x 1°) Ocn(¼° x ¼°)	
Deck 1001 yrs (control= 500, amip=36, 1%=150, 4x=150 + hist=165)		**1001 yrs**	**1001 yrs**	–	**2002 yrs** (conc & esm)	**315 yrs** (1% and hist)	
MIPs	HighResMIP (AMIP=100; CPL-CTRL=100; CPL-Trans=100)	–	**300 yrs**	**300 yrs**	–	–	
	DCPP-C + DCPP-A	**1500 yrs**	–	–	–	–	
	C4MIP (use DECK and ScenarioMIP)	–	–	–	–	–	
	LS3MIP	–	–	–	**500 yrs**	–	
	LUMIP	–	–	–	**500 yrs**	–	
	OMIP (CORE-II protocol - NO Atm)	–	**300 yrs**	–	**300 yrs**	–	
	ScenarioMIP (SSP5-8.5, SSP3-7.0, SSP2-4.5, SSP1-2.6 -> 85 yrs each)	**340 yrs**	–	–	**680 yrs** (conc & esm)	**85 yrs** (only SSP5-8.5)	
	GMMIP (amip-hist=145 x 3 members)	**435 yrs**	–	–	–	–	
	SIMIP (use DECK and ScenarioMIP)	–	–	–	–	–	
	CORDEX (use DECK and ScenarioMIP)	–	–	–	–	–	
Total		**2076+1500=3576**	**1601**	**300**	**3982**	**400**	**9859**

Current climate simulation

DJF and JJA mean SST for CMCC-CM2 and differences with HadISST



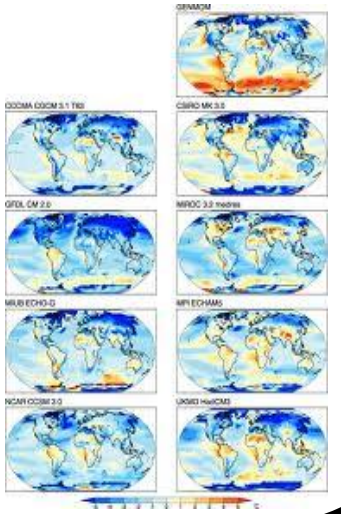
Cherchi et al. 2018

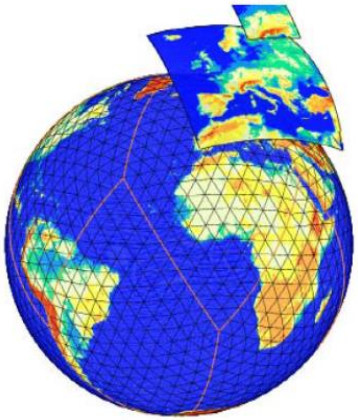
From Climate to Impacts

Climate data from GCMs/ESMs

Downscaling (statistical/dynamical)

Models for impact assessment

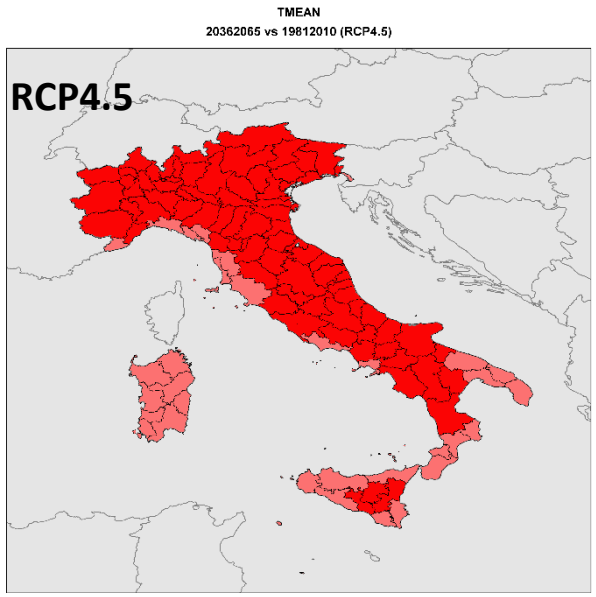


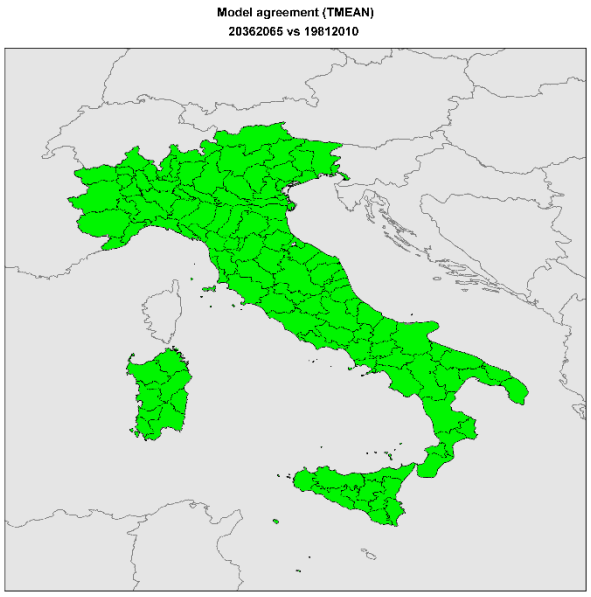


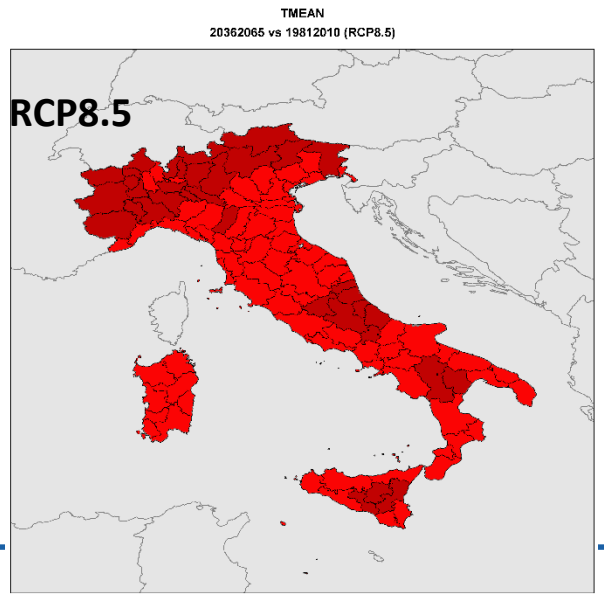
- Agriculture
- Forest and fires
- Water cycle
- Coastal Zones
- Tourism
- Health
- .....

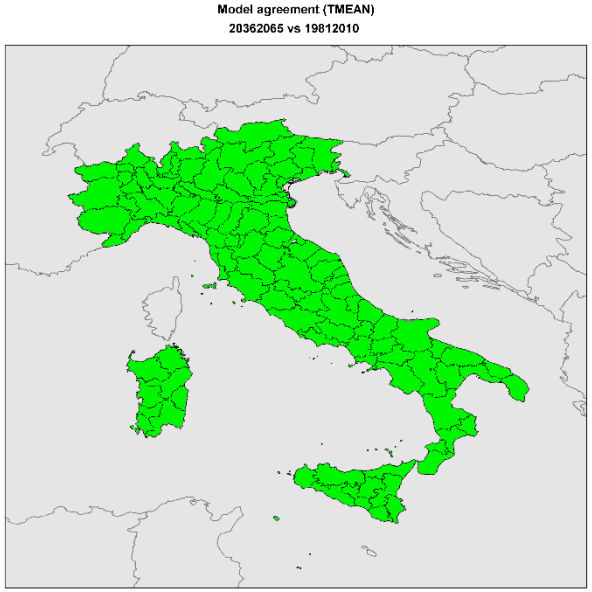
- Economic analyses
- Climate change mitigation
- Climate risk reduction or prevention
- Adaptation to Climate Change

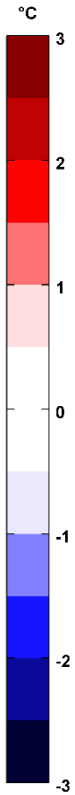
Data projection on Italy (NUTS3): mean temperature

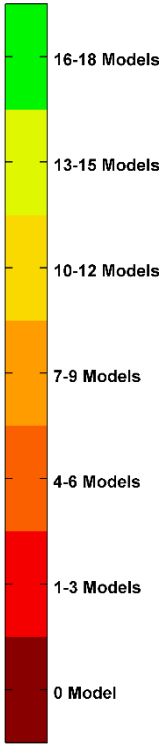






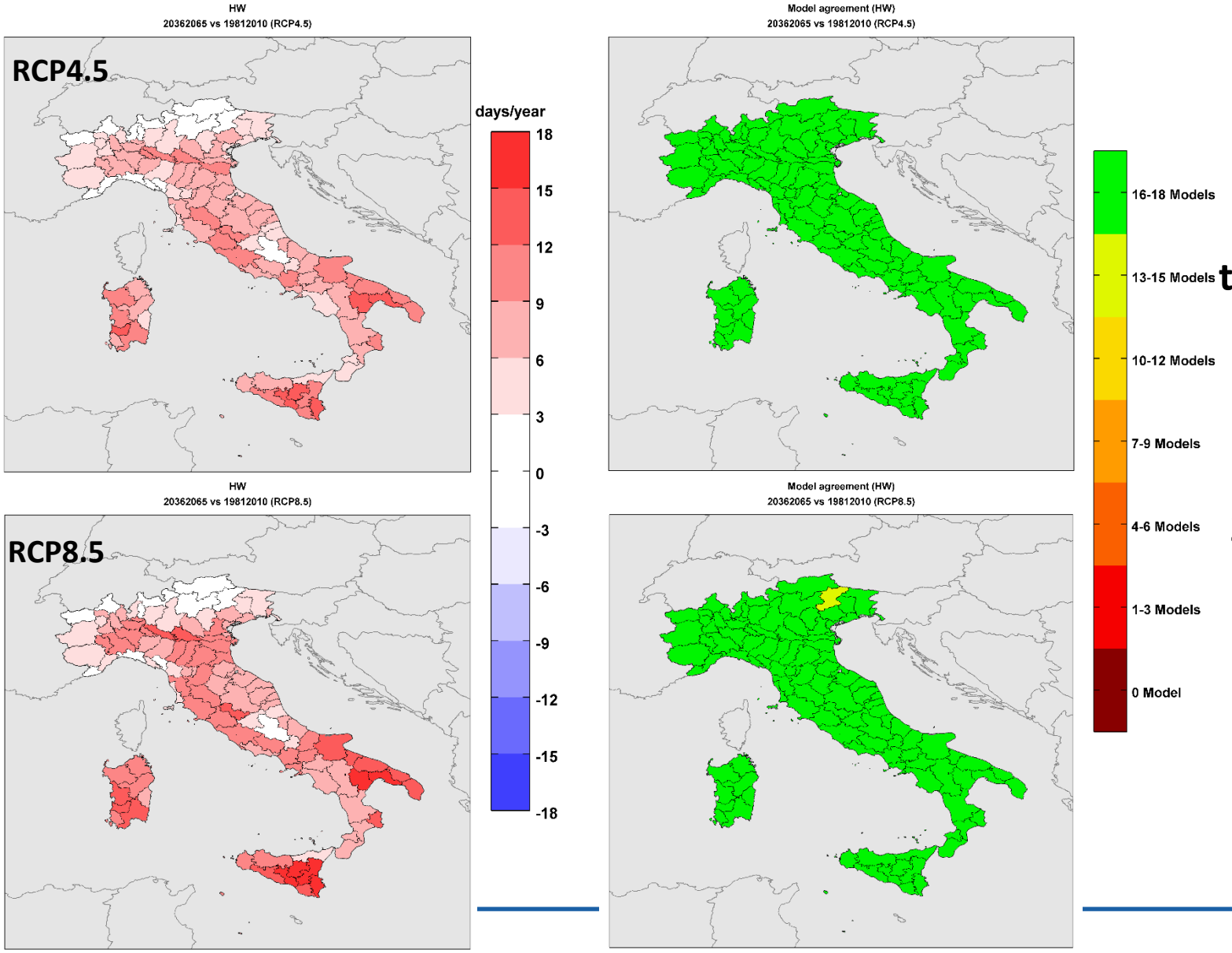






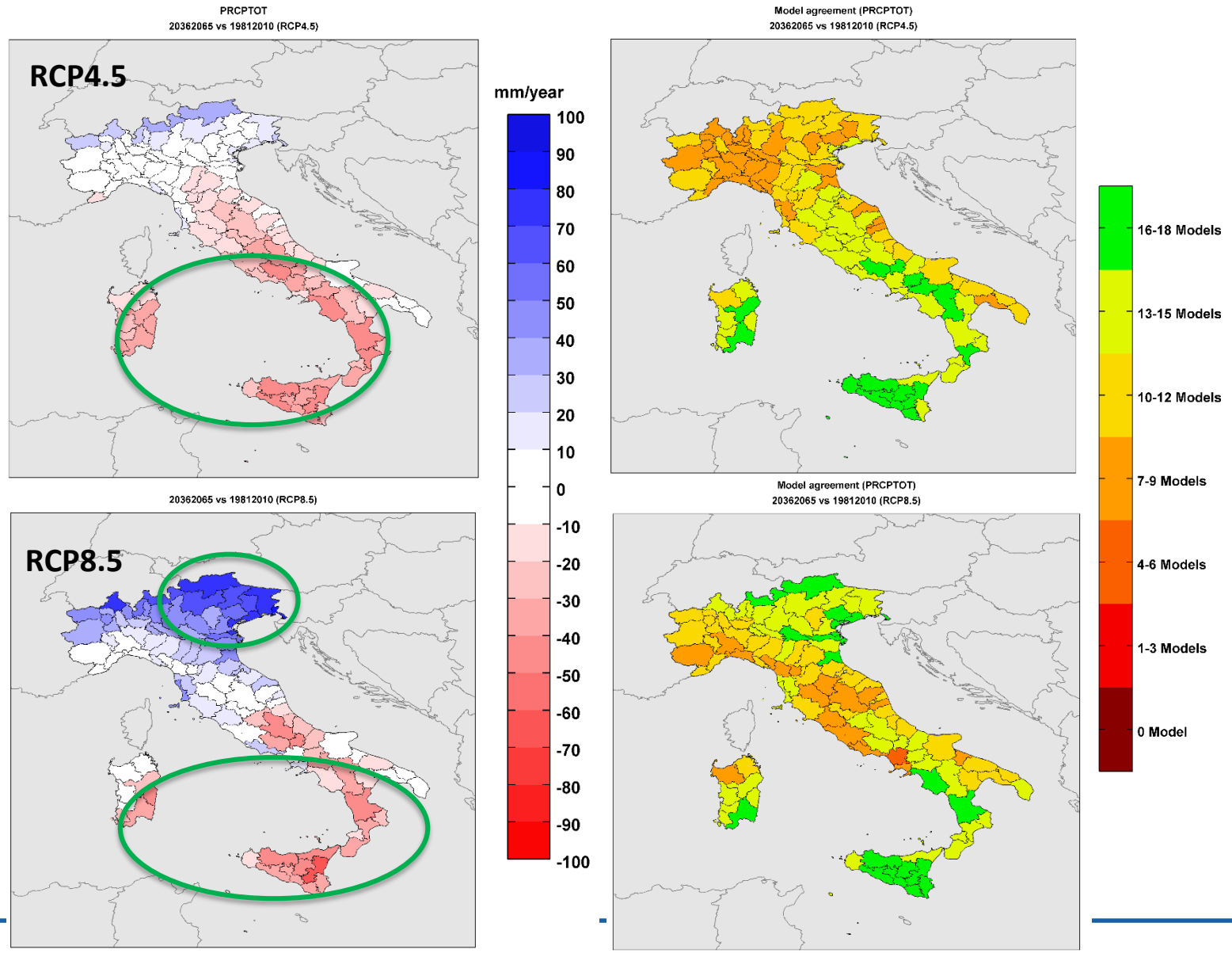
Variation of daily mean temperature: 2036-2065 vs 1981-2010

Data projection on Italy (NUTS3): number of days with maximum temperature over 35°C



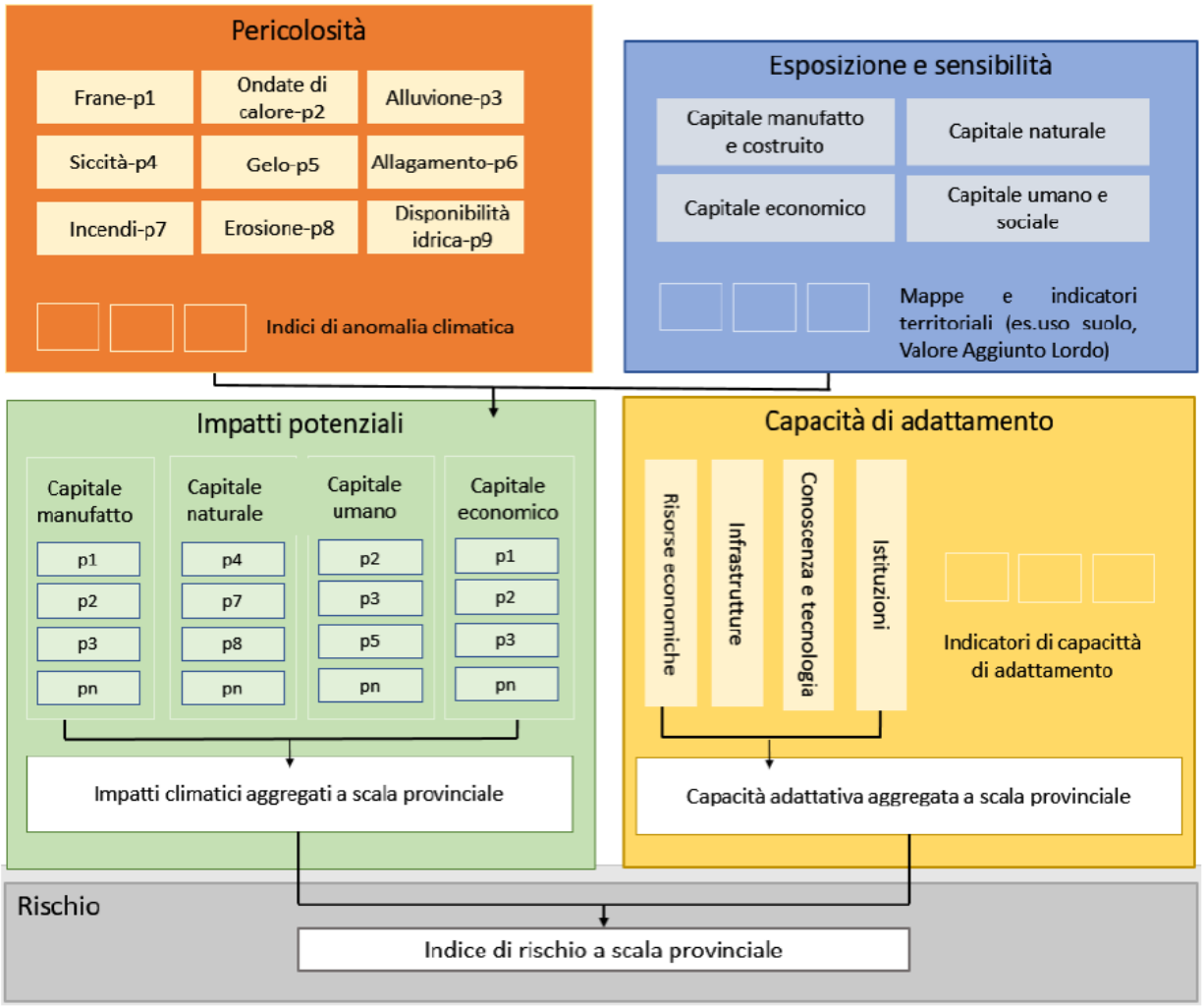
Variation of the number of days with maximum temperature over 35°C: 2036-2065 vs 1981-2010

Data projection on Italy (NUTS3): annual precipitation



Variation of annual precipitation: 2036-2065 vs 1981-2010

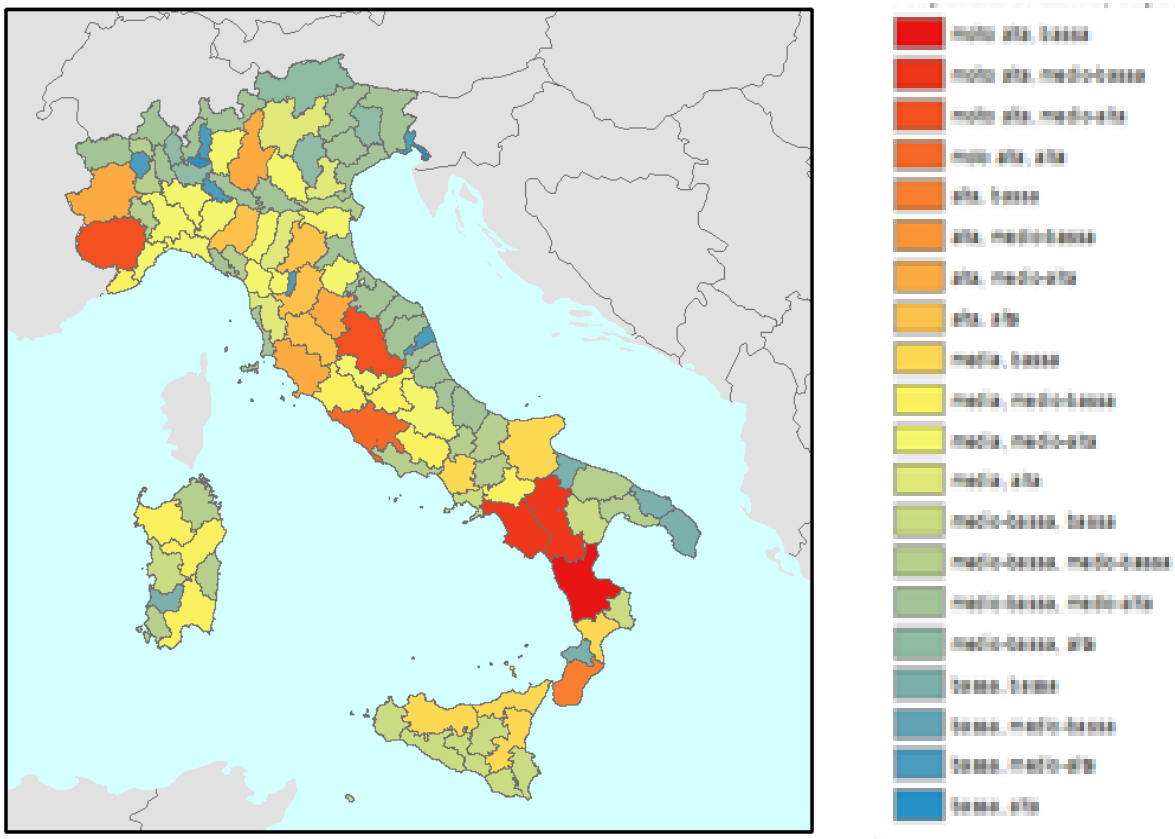
Knowing the impacts



The NAP presents a **risk index at provincial scale**, which takes into account both the expected impacts and the adaptation capacity of each province.

Knowing the impacts

The final outcome of this analysis is a risk map at provincial scale, where the impacts (ranked from low to very high) are related to the adaptation capacity (from high to low)



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Ocean Predictions and Applications
Big data challenge

THE OCEAN ACTIVITIES AT CMCC

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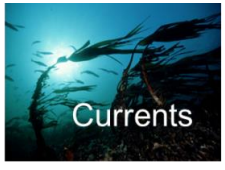
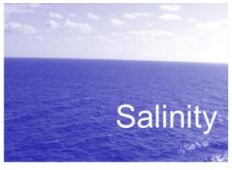
PAST	→	PRESENT	→	NEAR FUTURE	→	FAR FUTURE
REANALYSES 10 to 45 years	→	**REAL-TIME** Daily, hourly	→	**FORECAST** 2 to 10 days	→	**SCENARIOS up to 100 years**





GOFS16: A GLOBAL OCEAN FORECAST SYSTEM AT EDDY RESOLUTION

The Global Ocean Forecasting System GOFS16

Mesh:

Tripolar grid [180ºW-180ºE; 78ºS-90ºN] with 1/16º (6.9 km) horizontal spacing at the equator (increasing poleward to ~2 km) and 98 vertical levels with partial step

Grid size: 5762 × 3963 × 98 points

Bathymetry:

ETOPO2 for the deep ocean, GEBCO for the continental shelves, BEDMAP2 for Antarctica region

Atmospheric Forcing:

Operational NCEP analyses and forecasts; bulk CORE formulation

Land river runoff:

Monthly climatology from Dai et al. 2009 + Antarctic freshwater fluxes (Jacobs et al. 1992)

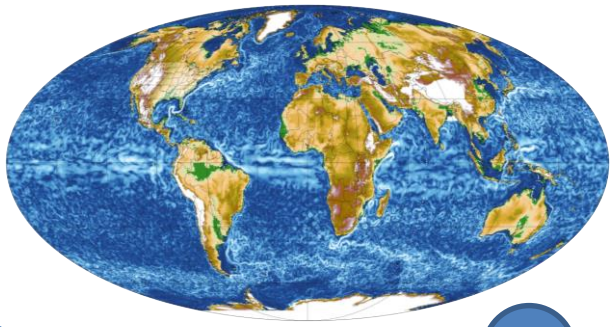
GOFS16

NEMO v3.4

Circulation Ocean Modeling System coupled to LIM2 EVP sea ice model (Iovino et al. 2016)

Data Assimilation Scheme

OceanVar (Storto and Masina, 2016): three-dimensional variational (3Dvar) data assimilation scheme with updates from multiple data sources and nudging schemes for surface temperature and sea ice concentration



Assimilated Observations:

In-situ T/S profiles from CMEMS In-Situ TAC: XBT, CTD, Argo, moorings, marine mammals (roughly 3º × 3º resolution)

Along-track satellite altimetry observations from CMEMS SL TAC: Jason-2, Altika, CryoSat2 (~1/4º resolution)

SST data from Metop-A/AVHRR and GCOM-W/AMSR-2 (up to ~ 3-4 km resolution), **SSS relaxation** toward NOAA 1/4º Analyses (15 days)

Sea ice concentration satellite data processed by NCEP

Operational Chain:

The chain consists of daily cycle of a **7-day-long forecast, initialized by a former (daily) analysis.** At each cycle, the chain starts one day back, assimilates all observations available for that day and runs nowcast and forecast afterwards.

Products:

1-day ASYS, 1-day SIMU, 7-days FCST for **3D** Temperature, Salinity, Currents and **2D** SSH, Sea Ice Thickness, Concentration and Drift

Time series: from 2017-ongoing

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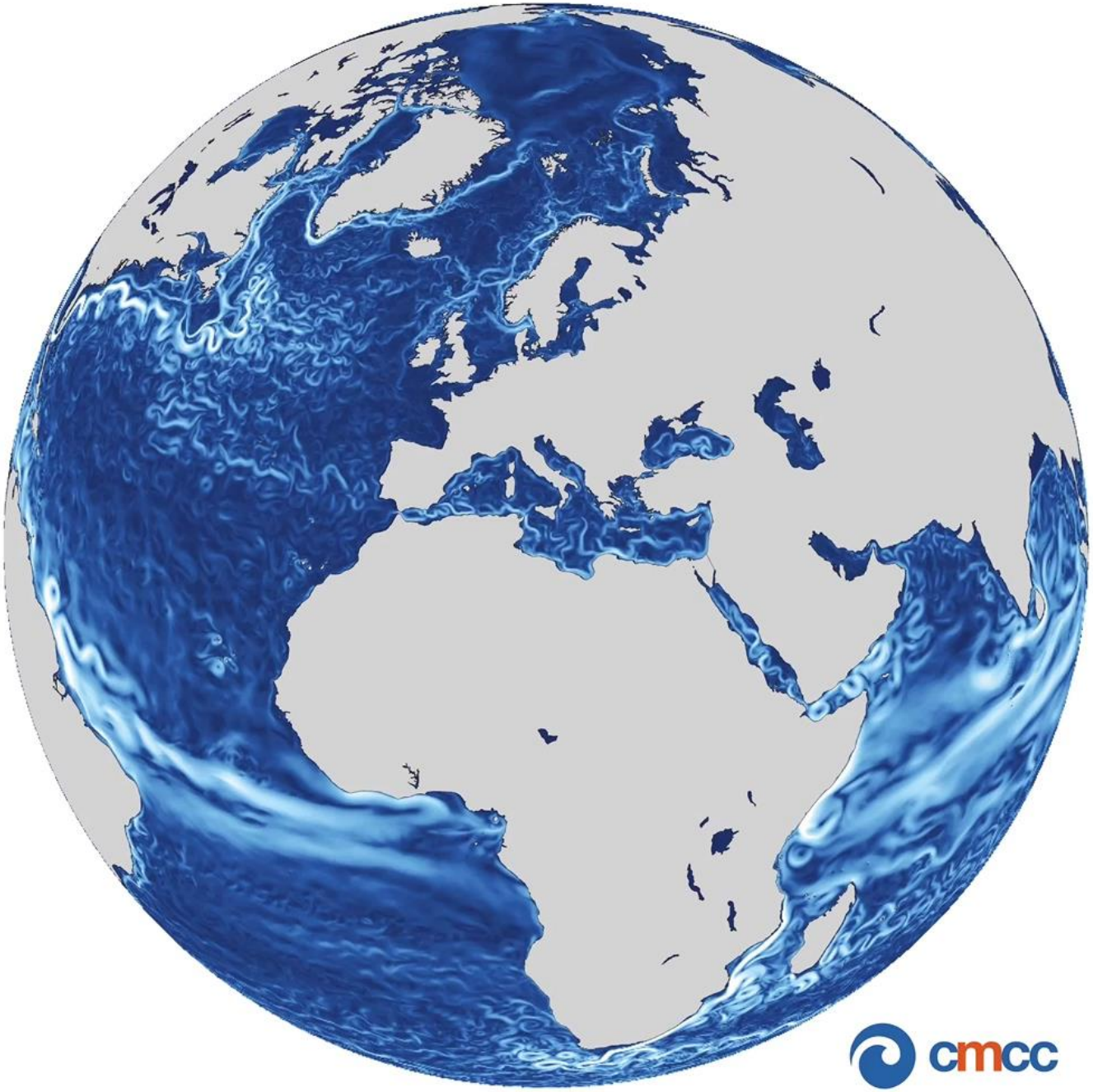
Iovino et al., A 1/16º eddying simulation of the global NEMO sea-ice–ocean system, Geosci. Model Dev., 9, 2665-2684, 2016.
Storto and Masina, C-GLORSv5: an improved multipurpose global ocean eddy-permitting physical reanalysis, Earth Syst. Sci. Data, 8, 679-696, 2016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The Mediterranean and Black Sea systems in the frame of Copernicus Marine Environment and Monitoring Service

Med-MFC Physics Analysis and Forecast System

Lateral Boundary conditions in the Atlantic:
Daily NRT analyses and forecasts from **CMEMS GLO-MFC** @ 1/12° horizontal resolution, 50 vertical levels

Land river runoff:
39 major rivers with annual mean discharge >**50 m³/s**
Climatological monthly mean values from PERSEUS dataset

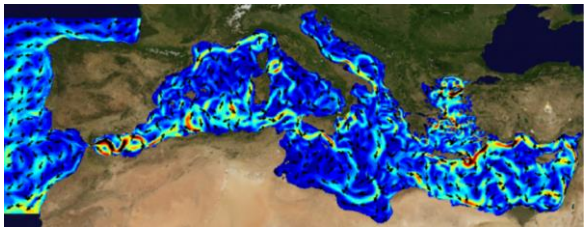
Atmospheric Forcings:
ECMWF 1/8º atmospheric fields **6 hours** time resolution (3hrs for the first 3 days of forecast)

Data Assimilation: 3DVar

SLA Satellite and T/S InSitu observations are jointly assimilated using a 3DVAR assimilation scheme with a daily assimilation cycle.

Non-solar heat flux correction is achieved through satellite **SST nudging**

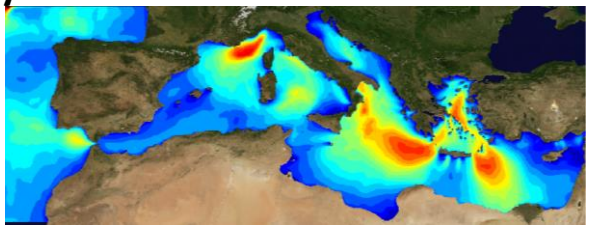
Ocean General Circulation Model (OGCM) based on NEMO code v3.6



Hor. Res. = 1/24º (~4.5 km)
Vert. Res. = 141 z* vertical levels

2-way hourly coupling
(Cd, UV, T)

Spectral Wave model WaweWatch-III (WW3) v3.14



Hor. Res. = 1/24º (~4.5 km)
30 freq. bins, 24 directional bins

Output hourly and daily mean analysis + 10 days forecast:

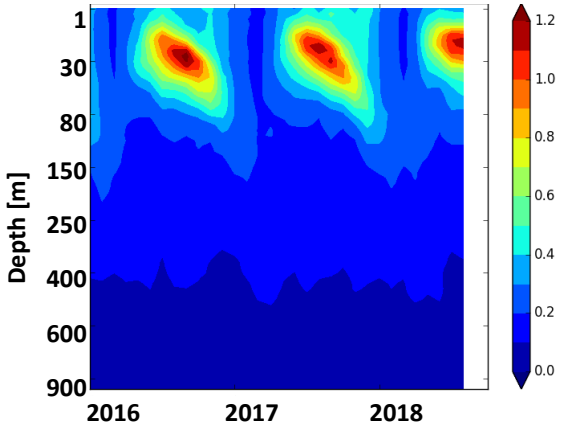
3D: T, S, UV

2D: SSH, MLD, T bottom

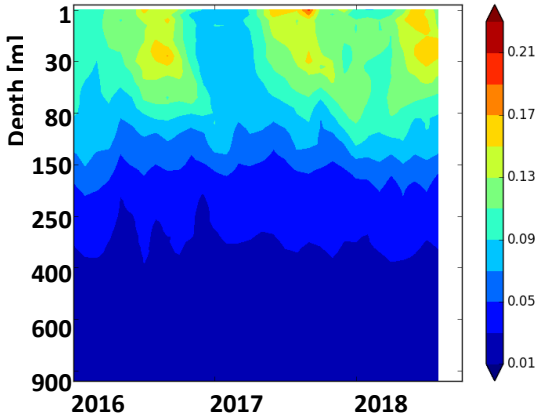
http://marine.copernicus.eu/

Vertical, Temporal and Spatial variability of T, S, SLA RMS misfits

Temperature RMS misfits [°C]

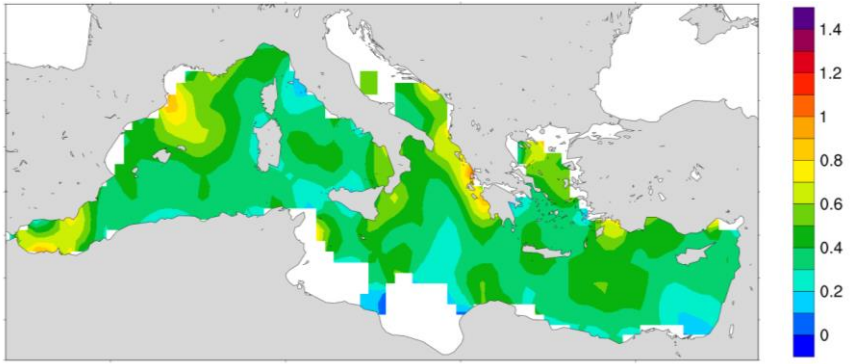


Salinity RMS misfits [PSU]

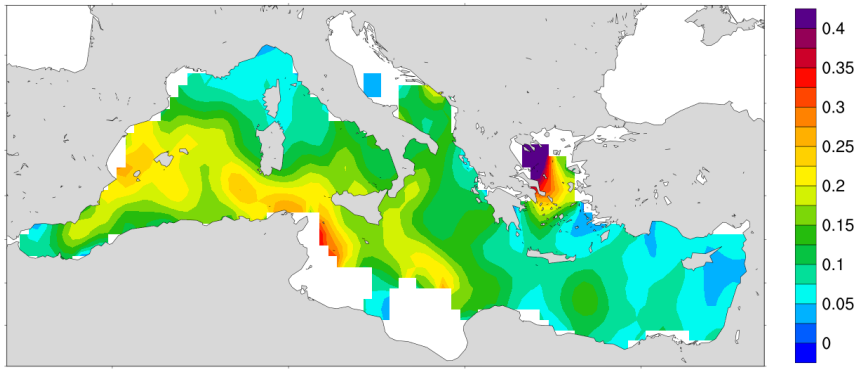


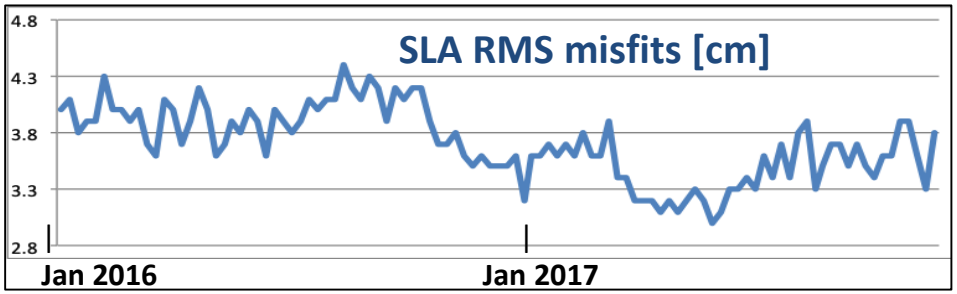
- Larger error during summer
- Larger error at thermocline, which decreases at lower layers

Temperature RMS mifits at 8m [°C]



Salinity RMS mifits at 8m [PSU]





BS-MFC Physics Analysis and Forecast System

Atmospheric Forcing

ECMWF 1/8º forecast/analysis fields time resolution: 3/6 hrs: mean sea level pressure, cloud cover, 2m relative humidity, 2m air temperature, 10m zonal and meridional wind components
GPCP precipitation (climatological monthly mean)

Assimilated Observations

Along track satellite SLA from CMEMS SL-TAC, for all available satellites: Jason 2/2N/3 , Cryosat2, AltiKa, Sentinel3
Sea Surface Temperature SST L4 from CMEMS SST TAC
Vertical profiles of ARGO T and S from CMEMS In-Situ TAC

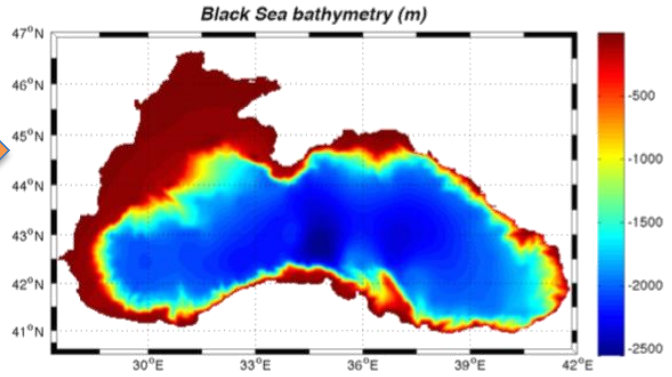
Black Sea Near Real Time System

NEMO v3.4

Circulation Ocean Modeling System
1/36x1/27 horiz. res.
31 vert. levels

Data Assimilation

3DVar Satellite and InSitu observations are jointly assimilated using a 3DVAR assimilation scheme with a daily assimilation cycle. Non-solar heat flux correction is achieved through satellite SST nudging



Initial Conditions: T/S January monthly climatology

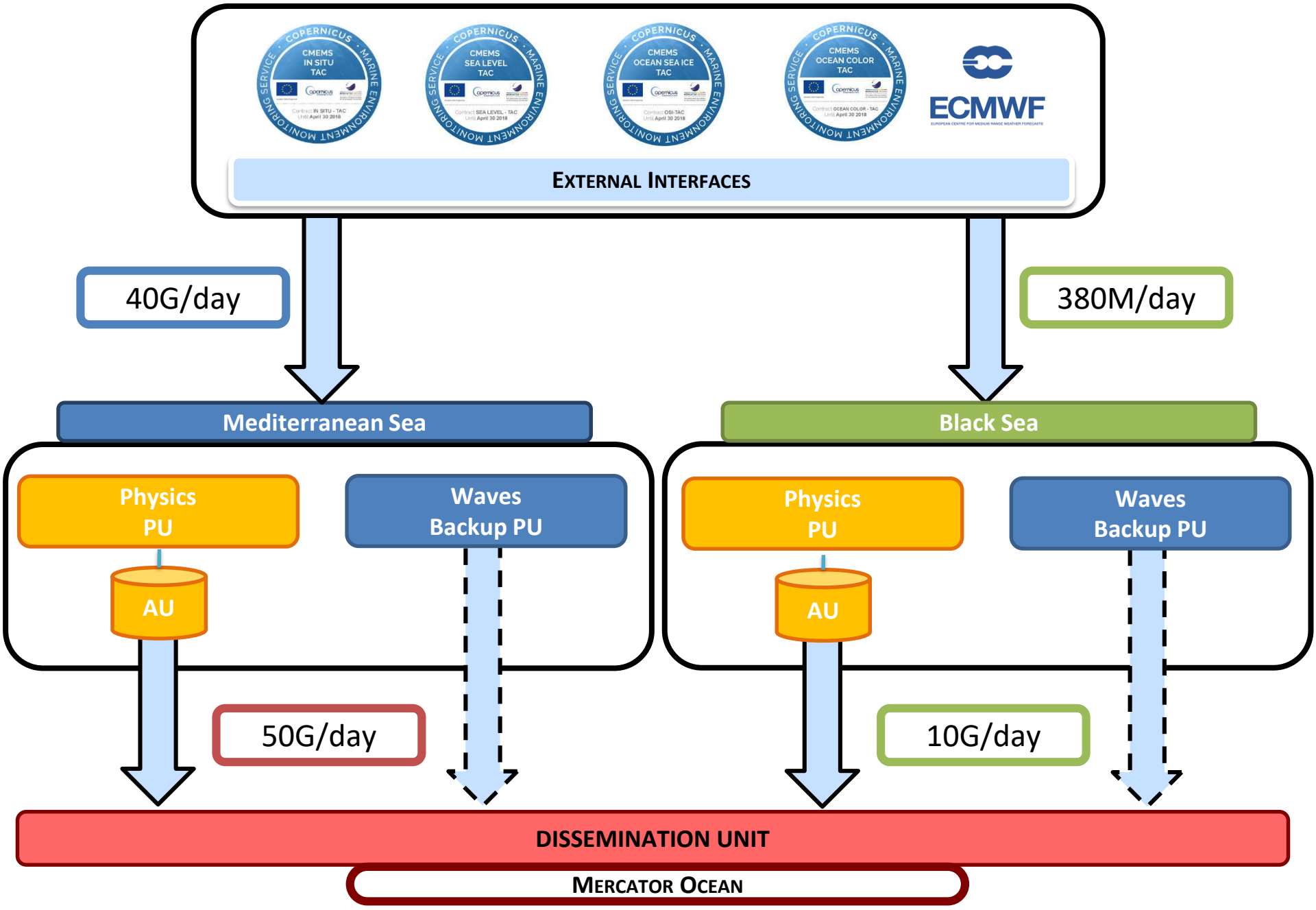
Surface Boundary Condition
The Bosporus Strait is modeled as water volume flux and provided as surface boundary condition, calculating a steady state barotropic transport as in Stanev et al. (2000) and Peneva et al. (2001)
Land river runoff: river runoff input from SESAME project database (climatological monthly mean)

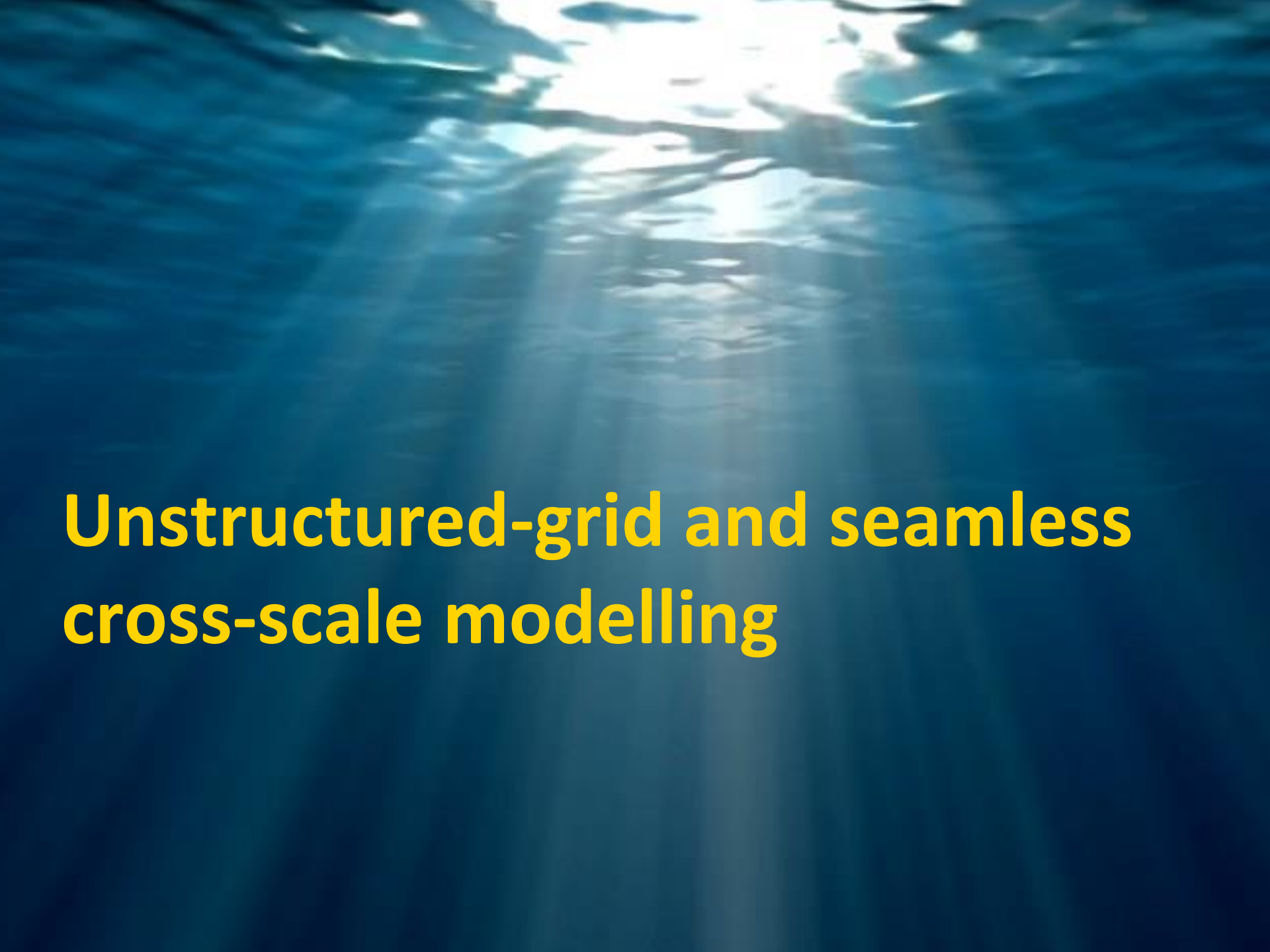
Products

3/14-day ASYS, 1-day SIMU, 10-day FCST for
3D: Temperature, Salinity, Currents
2D: SSH, MLD, Bottom Temperature
Temporal frequency: Daily and Hourly averages
Time series: from 2016-ongoing

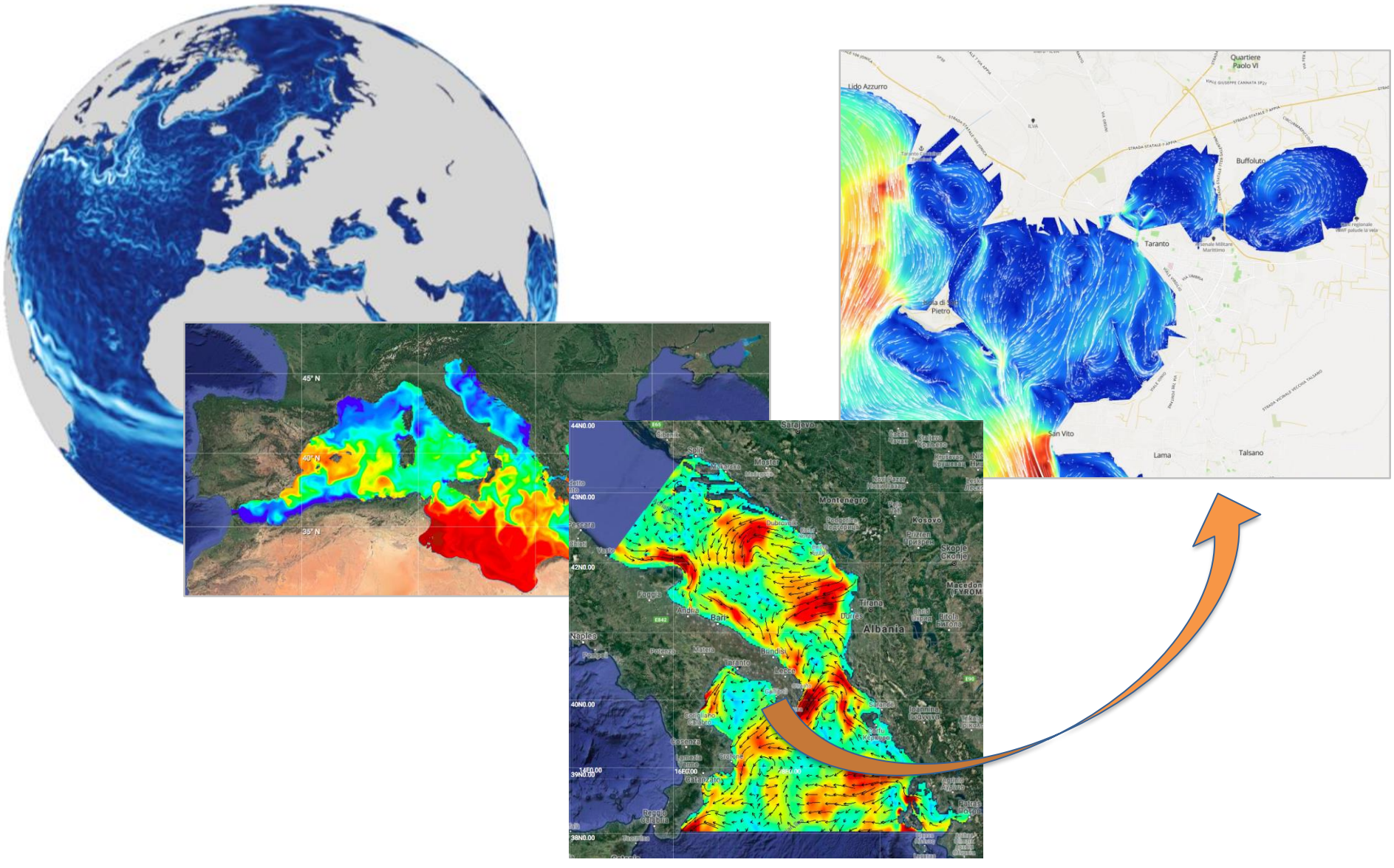
COPERNICUS · MARINE ENVIRONMENT MONITORING SERVICE
CMEMS BLACK SEA MFC
Contract CMEMS MFC BS
Until 31 March 2021

European Commission
COPERNICUS
MARINE ENVIRONMENT MONITORING SERVICE
Providing PRODUCTS and SERVICES for all marine applications


CMEMS IN SITU TAC
CMEMS SEA LEVEL TAC
CMEMS OCEAN SEA ICE TAC
CMEMS OCEAN COLOR TAC
ECMWF
EXTERNAL INTERFACES
40G/day
380M/day
Mediterranean Sea
Black Sea
Physics PU
Waves Backup PU
AU
Physics PU
Waves Backup PU
AU
50G/day
10G/day
DISSEMINATION UNIT
MERCATOR OCEAN


Unstructured-grid and seamless
cross-scale modelling

FROM THE GLOBAL TO THE LOCAL SCALES



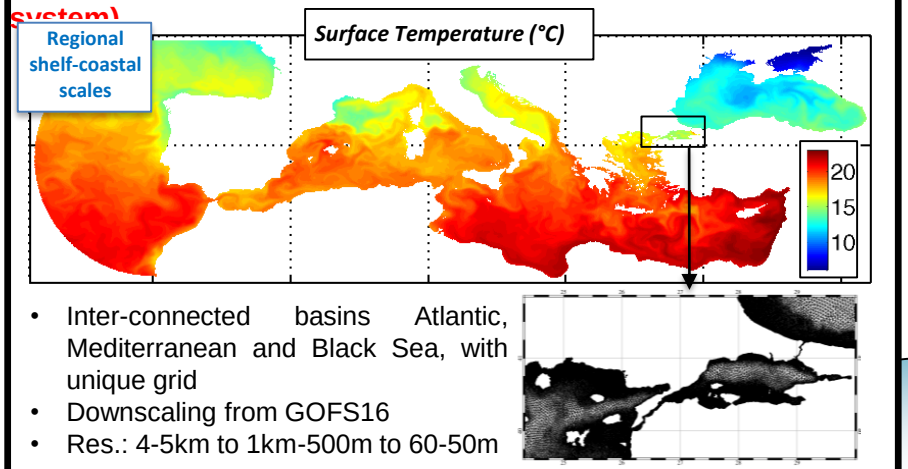
Unstructured-grid and seamless cross-scale modelling

Nowdays, numerical modelling system based on **unstructured-grid** codes and **seamless cross-scale** approach needs a treatment of large amount of data both to be ingested and then produced.

SHYFEM, 3D fully baroclinic finite element model (Umgiesser et al., 2004)

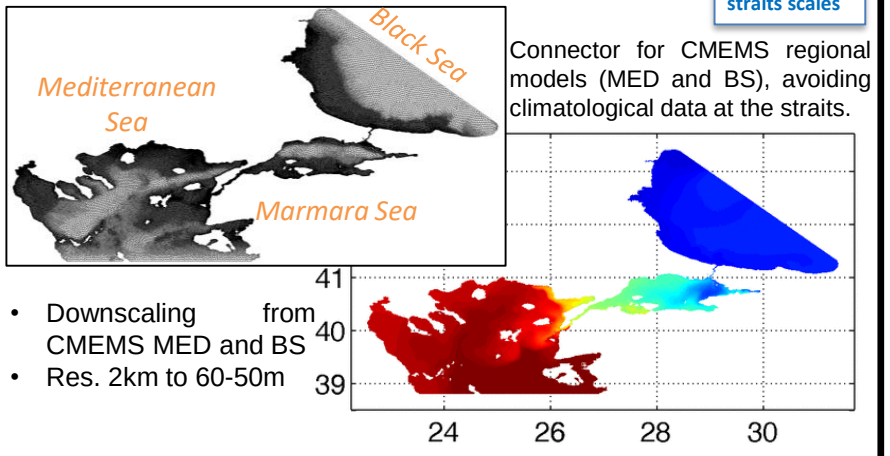
Designing Operational Forecasting Systems

U-MEDBS (Unstructured-grid MEDiteranean and Black Sea system)



- Inter-connected basins Atlantic, Mediterranean and Black Sea, with unique grid
- Downscaling from GOFS16
- Res.: 4-5km to 1km-500m to 60-50m

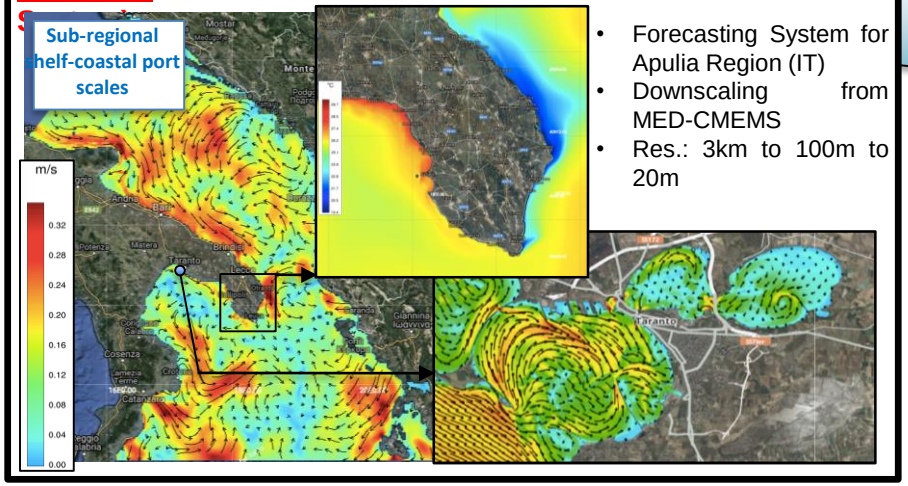
U-TSS (Unstructured-grid Turkish Strait System)



Connector for CMEMS regional models (MED and BS), avoiding climatological data at the straits.

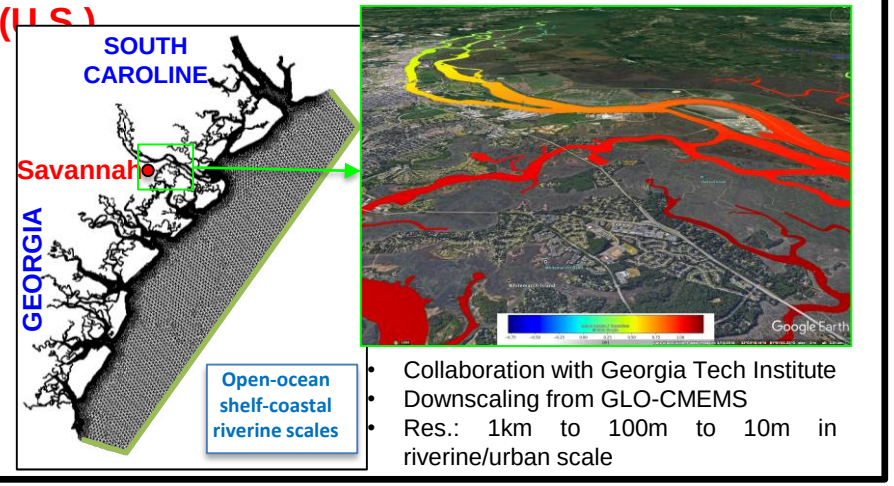
- Downscaling from CMEMS MED and BS
- Res. 2km to 60-50m

SANIFS (Southern Adriatic Northern Ionian Forecasting System)



- Forecasting System for Apulia Region (IT)
- Downscaling from MED-CMEMS
- Res.: 3km to 100m to 20m

Georgia coasts and Savannah urban area System (U.S.)

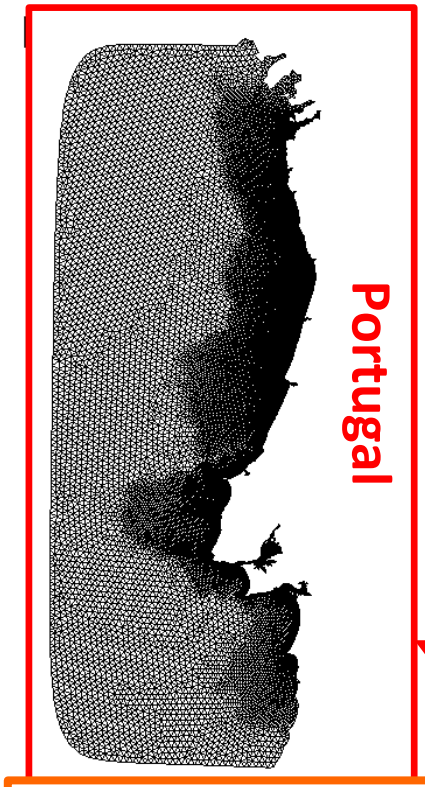


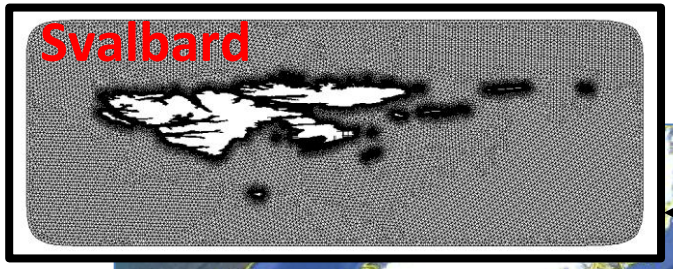
- Collaboration with Georgia Tech Institute
- Downscaling from GLO-CMEMS
- Res.: 1km to 100m to 10m in riverine/urban scale

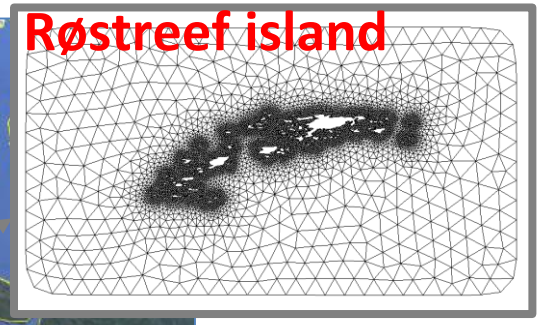
Unstructured-grid and seamless cross-scale modelling

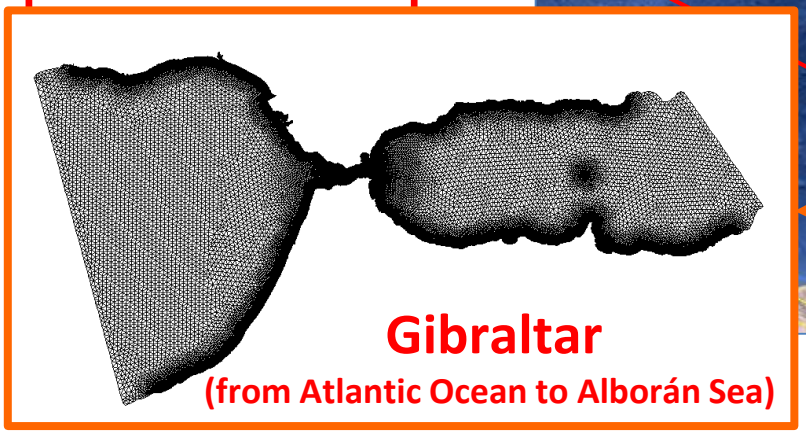
Nowdays, numerical modelling system based on **unstructured-grid** codes and **seamless cross-scale** approach needs a treatment of large amount of data both to be ingested and then

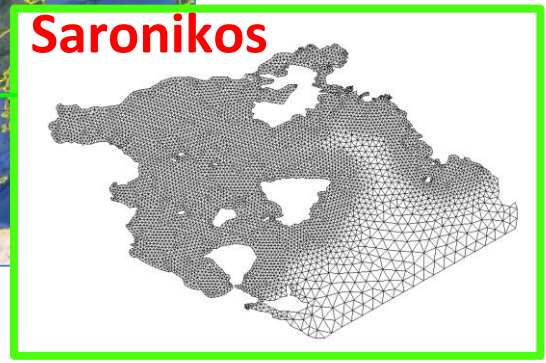
Experimenting Relocatable capabilities









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