



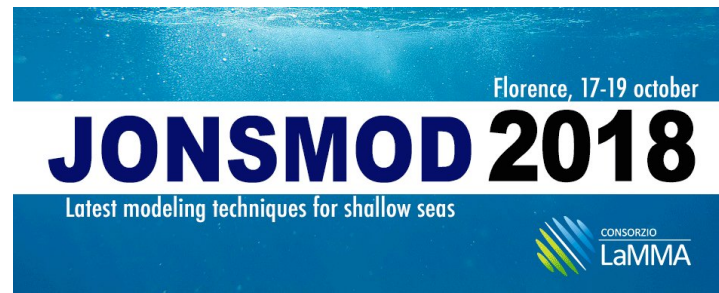
CADEAU



Integration of the Italian water quality dataset and a model downscaling of the Mediterranean CMEMS: the CADEAU coastal service

S. Querin (squerin@inogs.it), G. Bolzon, G. Cossarini, V. Di Biagio, S. Salon, C. Solidoro, A. Teruzzi

OGS - National Institute of Oceanography and Applied Geophysics, Trieste, Italy



ISPRA

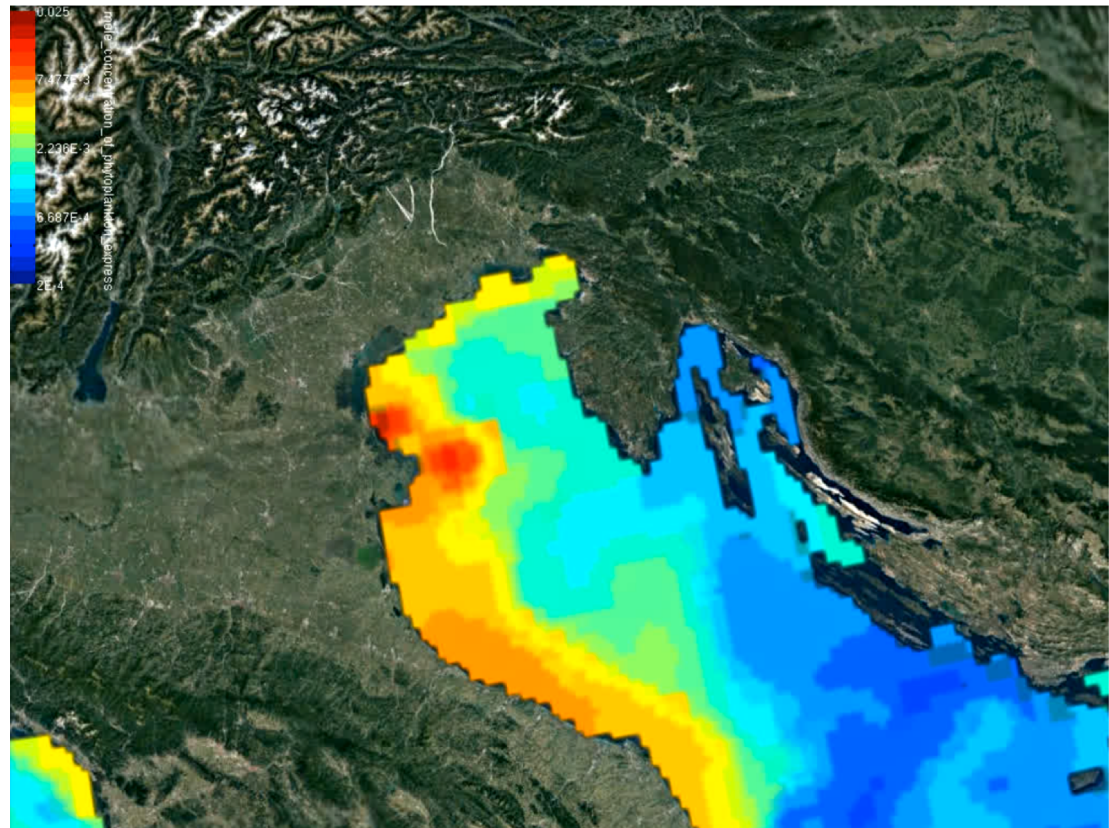
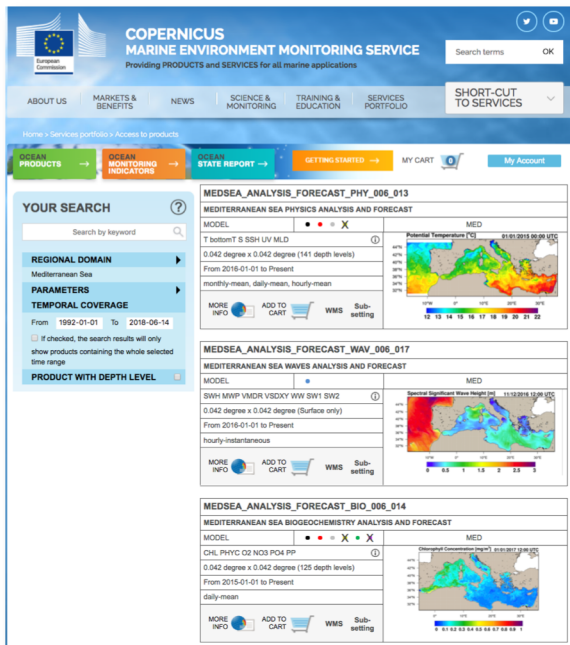
Istituto Superiore per la Protezione
e la Ricerca Ambientale

Downscaling of the CMEMS MED SEA service in the northern Adriatic

CMEMS Mediterranean Sea:

daily forecast service for the state of the sea with horizontal resolution of ~ 4.5 km

On line catalogue (open and free) of the products for the **physical** and **biogeochemical** variables and for **surface waves**



PROBLEM: for many coastal applications, the resolution ($1/24^\circ$) is not enough

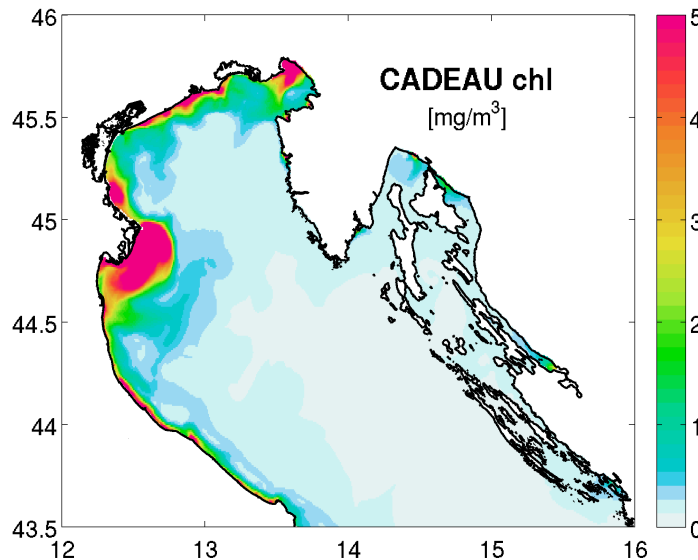
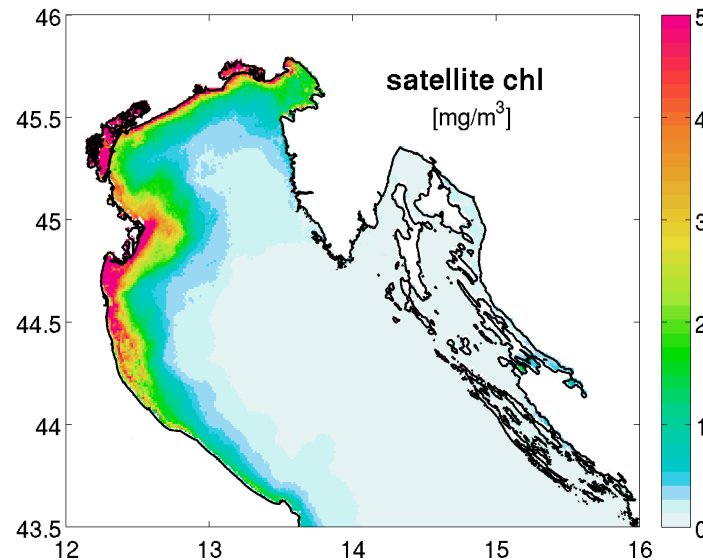
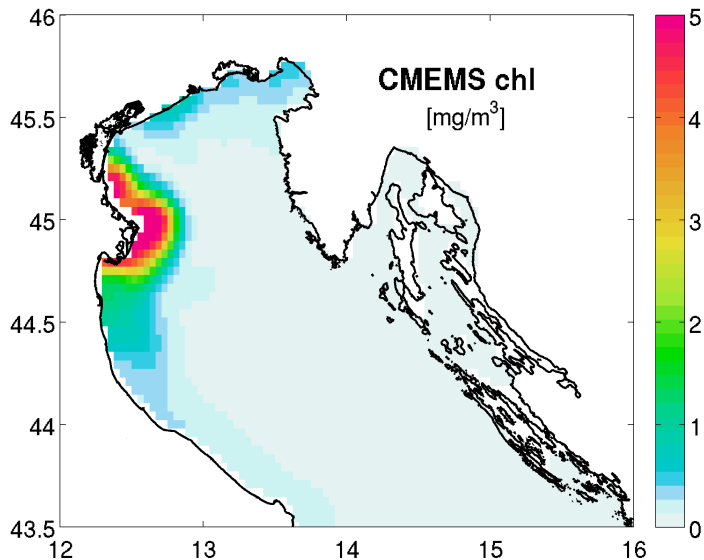


What can I "see better"?



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Comparison between the **CMEMS** model, the **CADEAU** model and **satellite** data

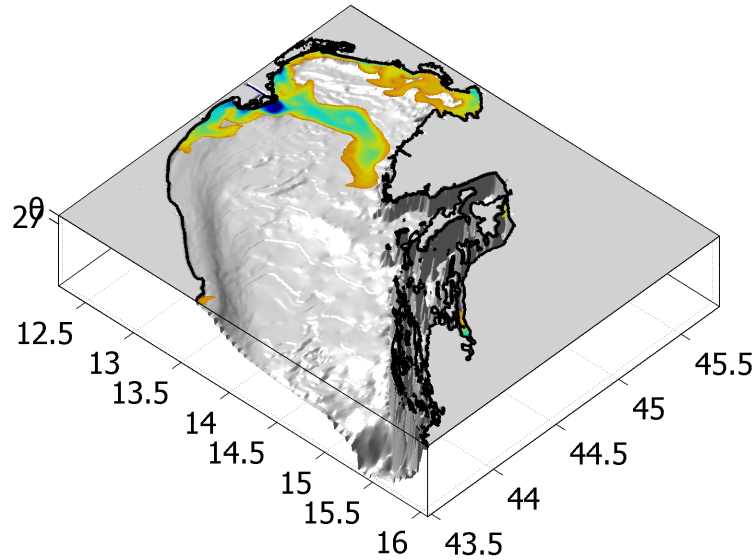


surface chlorophyll

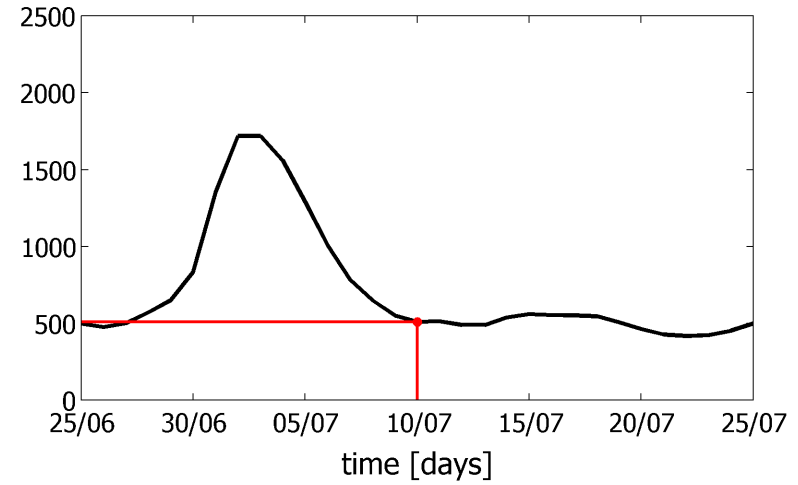
10-14 June 2017

The northern Adriatic: a complex system...

salinity
36 PSU

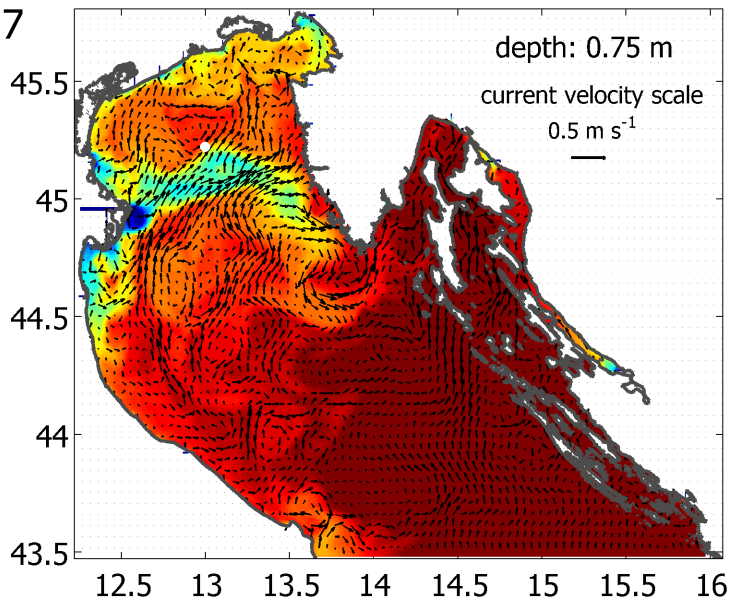


Po river discharge [m^3s^{-1}]

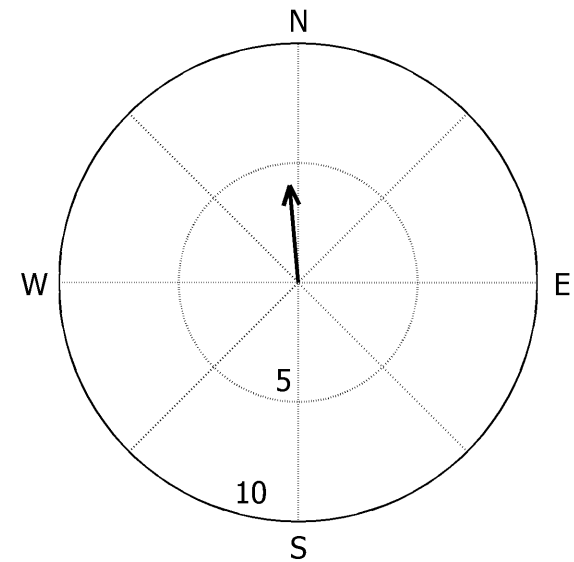


salinity and currents

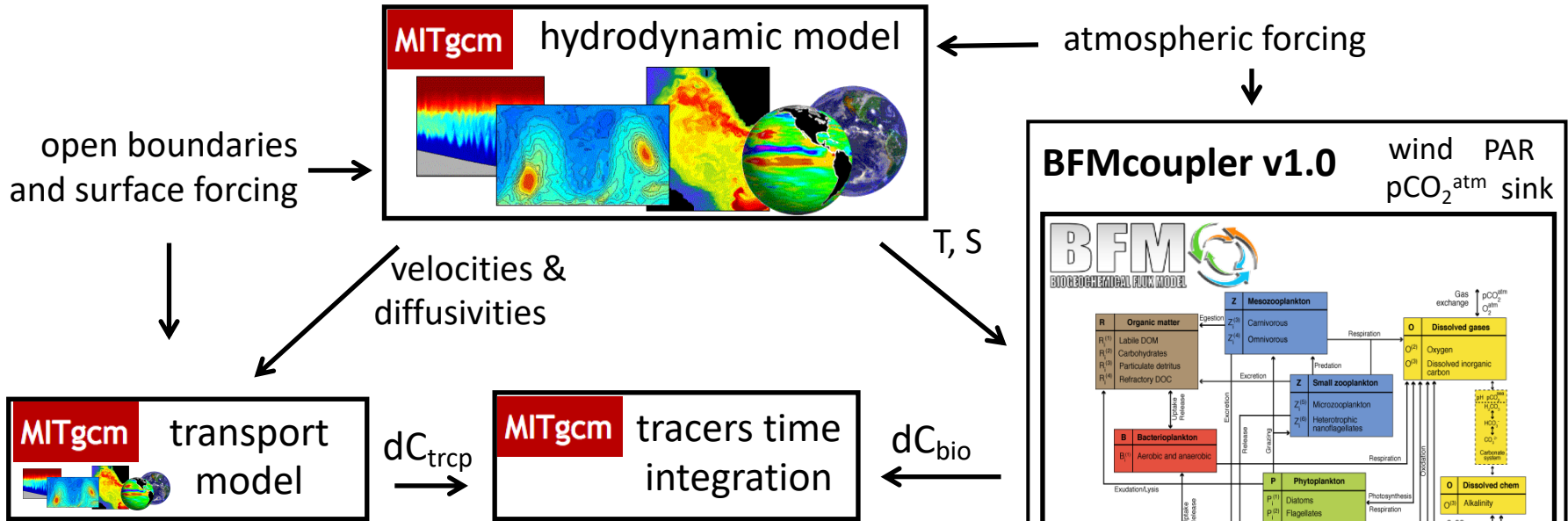
10/07/2017



wind [m s^{-1}]



CADEAU system based on the **coupled MITgcm-BFM** model with **1/128°** resolution (**~700 m**)



[Cassarini et al., 2017]

MITgcm: "state-of-the-art" hydrodynamic model
BFM: official biogeochemical model of the CMEMS Med-MFC community

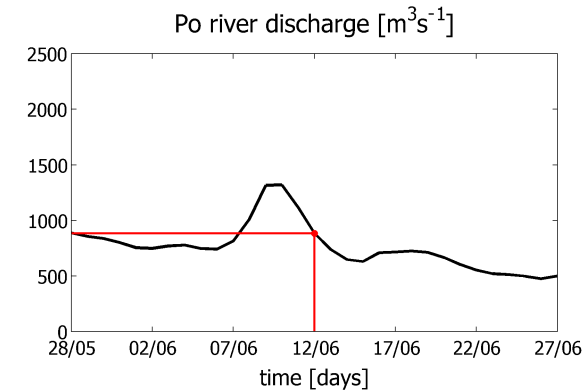
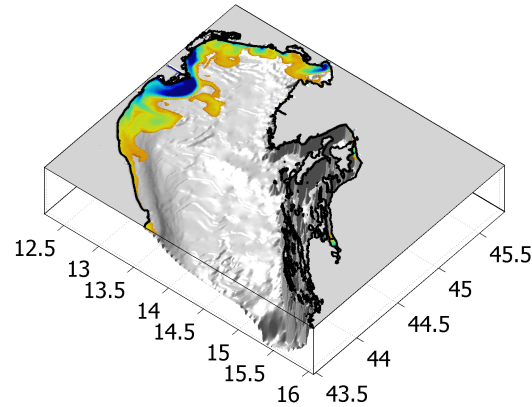
BFMcoupler v1.0: new online coupling (**possible two-way feedback**), modular approach, optimized integration schemes, open source

3DVAR-BIO/NUDGING: assimilation of surface chlorophyll and **coastal data of nutrients/chlorophyll**

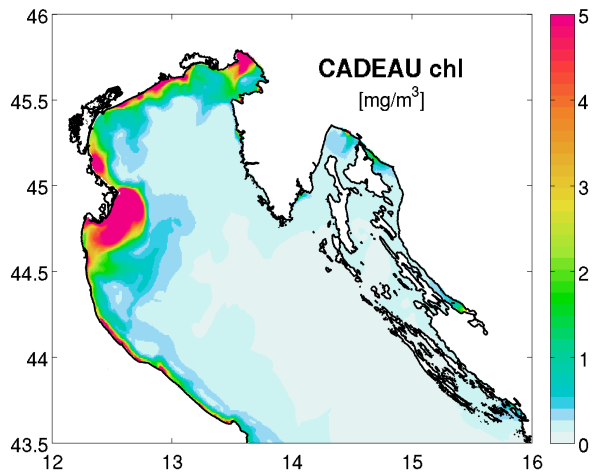
3DVAR-BIO/NUDGING
 (surface chlorophyll, coastal data)

Interaction between hydrodynamic and biogeochemical processes:
remarkable **spatial** and **temporal variability!**

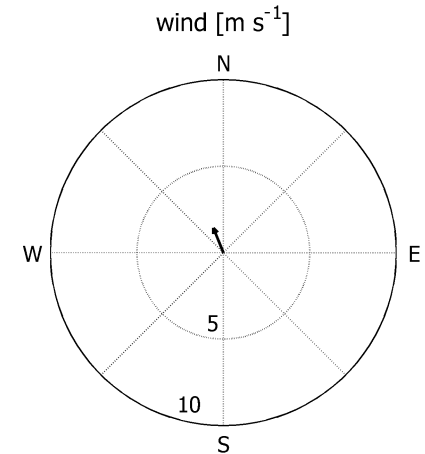
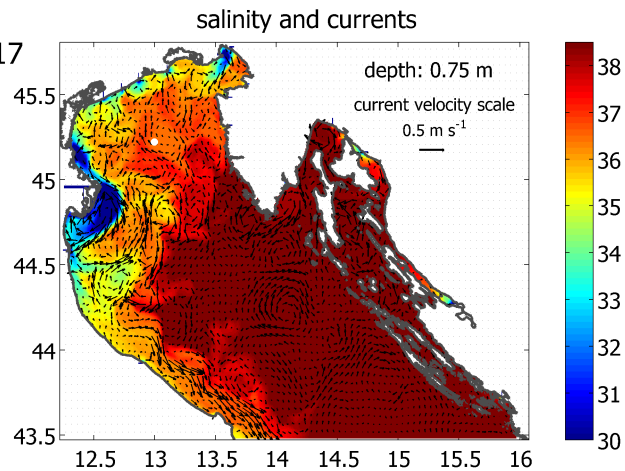
salinity
36 PSU



surface chlorophyll
10-14/06/2017



12/06/2017

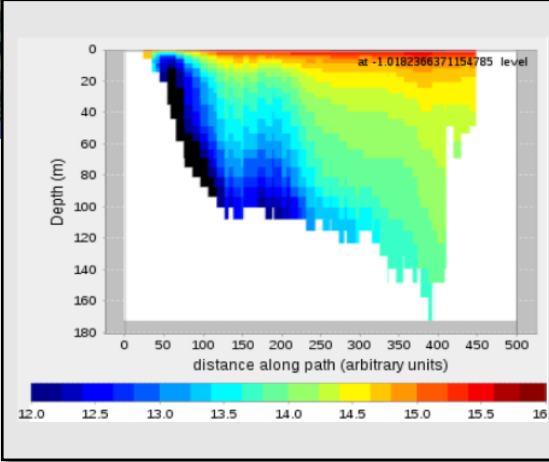
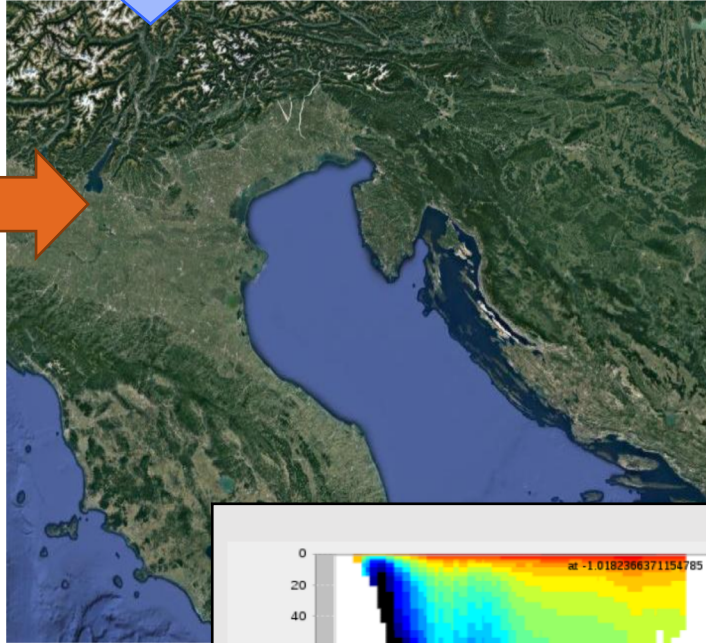


A "recipe" for a good simulation (2/5)

River run-off: ARPAE, ARPA-FVG, climatologies [Janekovic et al., 2014]

Atmospheric forcing:
ECMWF, COSMO I2
arpae
emilia-romagna

- Nutrient input from:**
- ✓ **RIVERS:** EU-FP7 project Perseus, D4.6
-
- ✓ **VENICE LAGOON** [Solidoro et al., 2006]
 - ✓ **ATMOSPHERE** [Ribera d'Alcalà et al., 2003]
 - ✓ **BOTTOM REMINERALIZATION** [Giordani et al., 2002; Bertuzzi et al., 1997]
 - ✓ **SEWAGE DISCHARGES AT SEA:** ISPRA-UWWTP

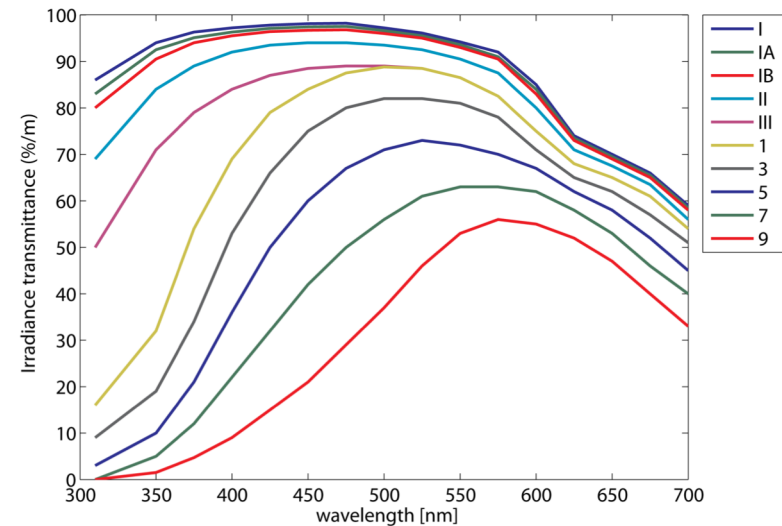


Boundary conditions for the southern open boundary (*nesting*) for physical and biogeochemical variables:
CMEMS

1. Jerlov water type

Jerlov [1976] discretized his observations into a set of five typical **oceanic** spectra and nine typical **coastal** spectra

| Jerlov Water Type | Examples |
|-------------------|--------------------------------------|
| I | Open Pacific |
| IA | Eastern Mediterranean, Indian Ocean |
| IB | Western Mediterranean, Open Atlantic |
| II | Coastal waters, Azores |
| III | Coastal waters, North Sea |
| 1 | Skagerrak Strait |
| 3 | Baltic |
| 5 | Black Sea |
| 7 | Coastal waters, dark |



2. Choice of the albedo

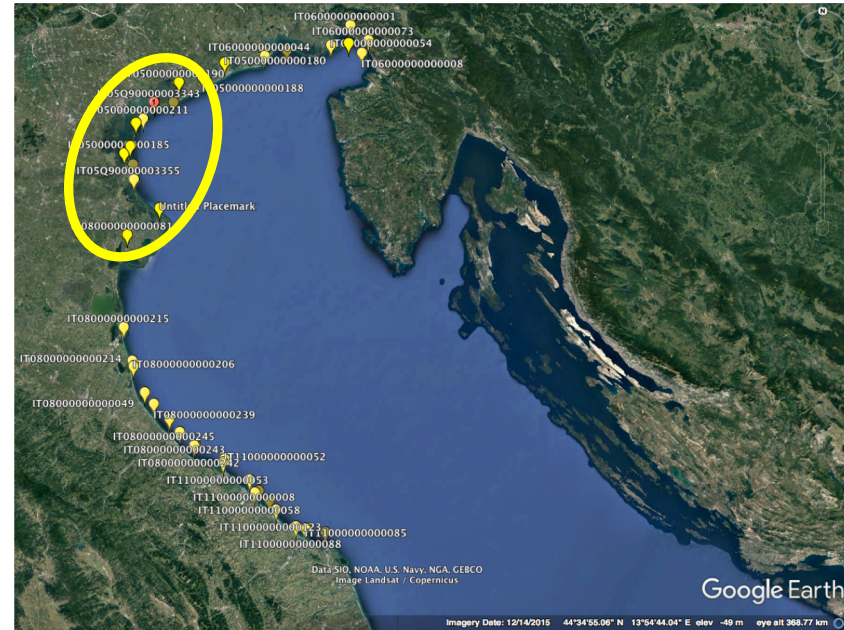
3. **Direct/diffuse** short wave radiation from atmospheric models: **same standard?**

4. **Spectral models** of light absorption

5. **Feedback** from **biogeochemical models**

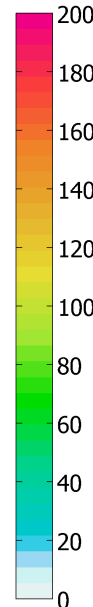
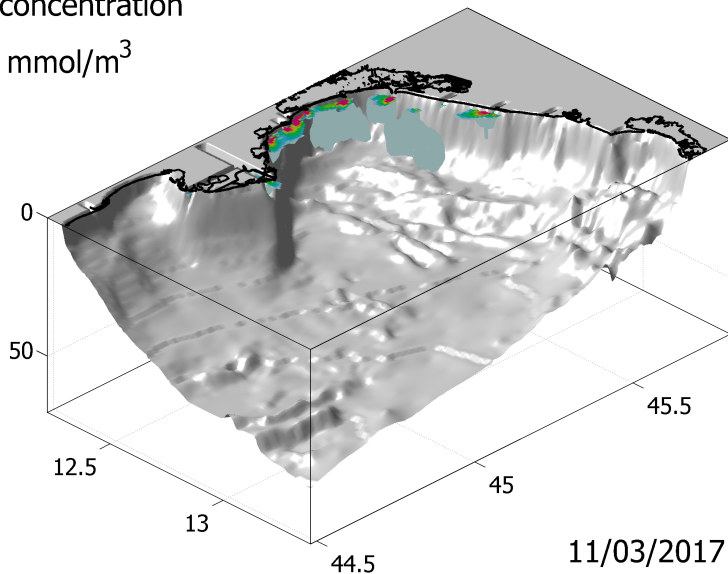
Simulation of **coastal sewage discharges**:
bottom flux of nitrate and phosphate
 (ISPRA dataset)

Bathing waters case study (Chioggia):
 12 sources of “*escherichia coli*”



tracer concentration

10 mmol/m³



first order decay law [Chan *et al.*, 2013]

$$k(z, t) = (k_b + k_s S(z, t)) \theta^{T-20} + k_I I(t) e^{-e_t z}$$

z (depth)

t (time)

$$k_b = 0.8$$

$$k_s = 0.017$$

$$k_I = 0.086$$

$$e_t = 0.5 \text{ (higher transparency)}$$

$$\theta = 1.07$$



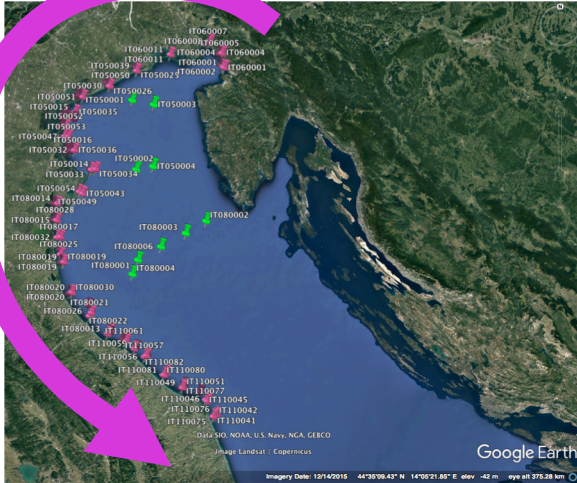
Bathing waters Directive (2006/07/CE)

| Indice di cross-correlazione tra la presenza del plume e la misura di Enterococchi intestinali | | | | | | | | | | | | |
|--|---------|--------|-----------|-------------------|-----------------------------|--------------------------|-------------------------|----------------------------|-----------------------|-----------------|---------|------|
| | Eraclea | Jesolo | Cavallino | Laguna di Venezia | Bocca di Porto Venezia Lido | Bocca di porto Malamocco | Bocca di porto Chioggia | Chioggia Brondolo (Brenta) | Rosolina Mare (Adige) | Isola Albarella | Foce Po | Goro |
| IT005027008001 | | | | | | | | | | | | |
| IT005027008002 | | | | | | | | | | | | |
| IT005027008003 | | | | | | | | | | | | |
| IT005027008004 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.82 | 0.96 | 0.97 | 0.84 | 0.84 | 0.87 | 0.94 |
| IT005027008010 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.59 | 0.85 | 0.55 | 0.47 | 0.47 | 0.56 | 0.63 |
| IT005027008005 | 0.16 | 0.16 | 0.2 | 0.17 | 0.24 | 0.25 | 0.57 | 0.82 | 0.18 | 0.18 | 0.19 | 0.3 |
| IT005027008006 | 0.51 | 0.49 | 0.5 | 0.49 | 0.51 | 0.58 | 0.22 | 0.83 | 0.22 | 0.27 | 0.19 | 0.47 |
| IT005027008007 | 0.32 | 0.49 | 0.27 | 0.5 | 0.56 | 0.24 | 0.19 | 0.9 | 0.3 | 0.13 | 0.13 | 0.13 |
| IT005027008011 | 0.38 | 0.8 | 0.32 | 0.66 | 0.7 | 0.3 | 0.24 | 0.76 | 0.31 | 0.24 | 0.25 | 0.43 |
| IT005027008008 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.71 | 0.58 | 0.94 | 0.36 | 0.3 | 0.3 | 0.32 |
| IT005027008009 | 0.21 | 0.51 | 0.25 | 0.35 | 0.51 | 0.23 | 0.24 | 0.95 | 0.38 | 0.23 | 0.23 | 0.24 |

| Indice di cross-correlazione tra la presenza del plume e la misura di Escherichia coli | | | | | | | | | | | | |
|--|---------|--------|-----------|-------------------|-----------------------------|--------------------------|-------------------------|----------------------------|-----------------------|-----------------|---------|------|
| | Eraclea | Jesolo | Cavallino | Laguna di Venezia | Bocca di Porto Venezia Lido | Bocca di porto Malamocco | Bocca di porto Chioggia | Chioggia Brondolo (Brenta) | Rosolina Mare (Adige) | Isola Albarella | Foce Po | Goro |
| IT005027008001 | 0.19 | 0.65 | 0.73 | 0.99 | 0.68 | 0.2 | 0.98 | 0.98 | 0.98 | 0.98 | 0.19 | 0.19 |
| IT005027008002 | 0.65 | 0.86 | 0.96 | 0.86 | 0.94 | 0.51 | 0.92 | 0.85 | 0.85 | 0.85 | 0.36 | 0.4 |
| IT005027008003 | 0.29 | 0.55 | 0.3 | 0.6 | 0.66 | 0.54 | 0.31 | 0.53 | 0.52 | 0.52 | 0.55 | 0.31 |
| IT005027008004 | 0.59 | 0.43 | 0.6 | 0.53 | 0.76 | 0.82 | 0.61 | 0.57 | 0.31 | 0.22 | 0.21 | 0.21 |
| IT005027008010 | 0.58 | 0.32 | 0.2 | 0.33 | 0.39 | 0.34 | 0.18 | 0.53 | 0.09 | 0.03 | 0.01 | 0.01 |
| IT005027008005 | 0.12 | 0.12 | 0.13 | 0.13 | 0.18 | 0.21 | 0.14 | 0.69 | 0.13 | 0.13 | 0.03 | 0.1 |
| IT005027008006 | 0.34 | 0.66 | 0.51 | 0.74 | 0.73 | 0.38 | 0.28 | 0.54 | 0.1 | 0.11 | 0.07 | 0.07 |
| IT005027008007 | 0.63 | 0.48 | 0.42 | 0.46 | 0.48 | 0.2 | 0.09 | 0.55 | 0.11 | 0.05 | 0.08 | 0.05 |
| IT005027008011 | 0.54 | 0.78 | 0.29 | 0.6 | 0.64 | 0.24 | 0.18 | 0.71 | 0.21 | 0.2 | 0.22 | 0.19 |
| IT005027008008 | 0.21 | 0.8 | 0.26 | 0.45 | 0.22 | 0.25 | 0.22 | 0.34 | 0.23 | 0.21 | 0.2 | 0.13 |
| IT005027008009 | 0.21 | 0.8 | 0.43 | 0.61 | 0.65 | 0.39 | 0.37 | 0.24 | 0.06 | 0.09 | 0.08 | 0.07 |

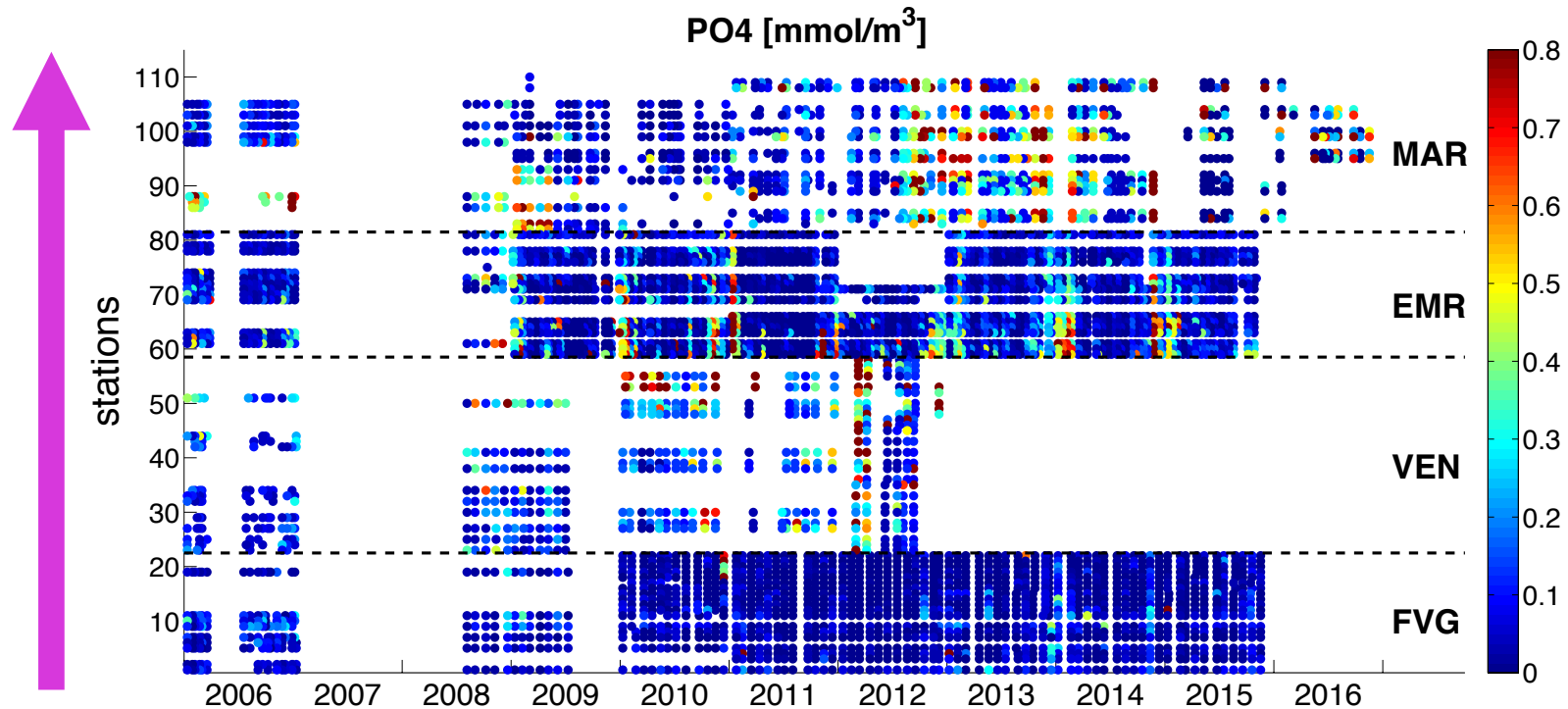
Cross-correlation index between the bacterial pollution measured in bathing waters and the tracer content

A "recipe" for a good simulation (4/5)



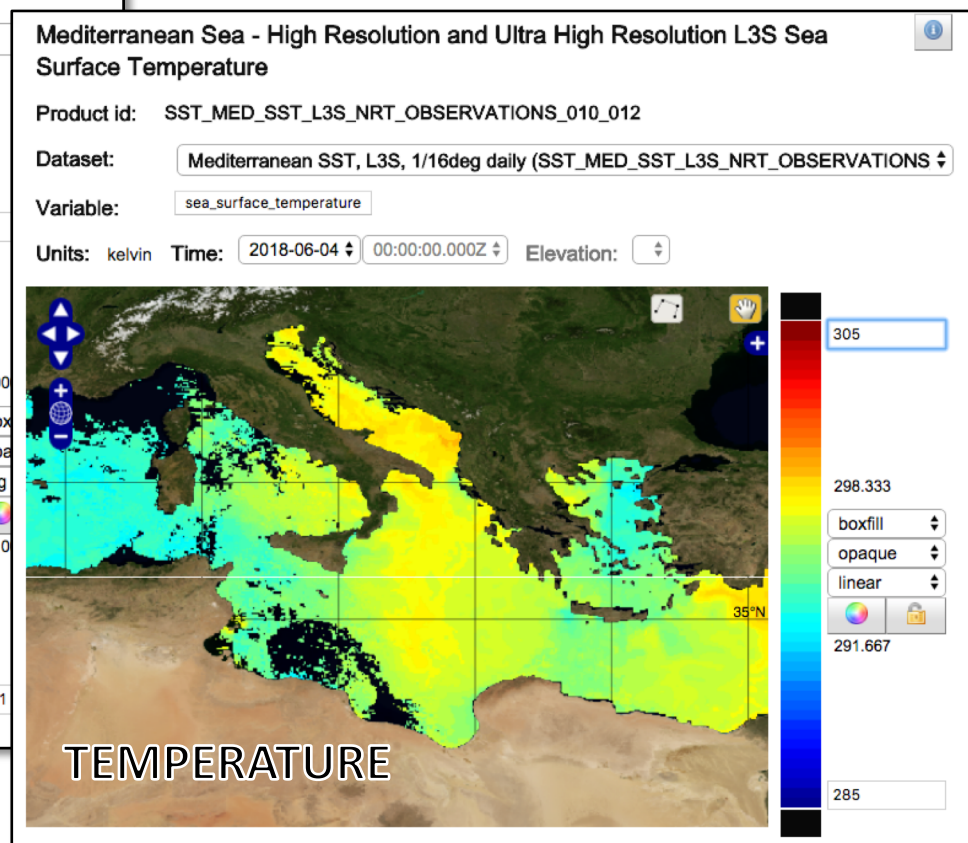
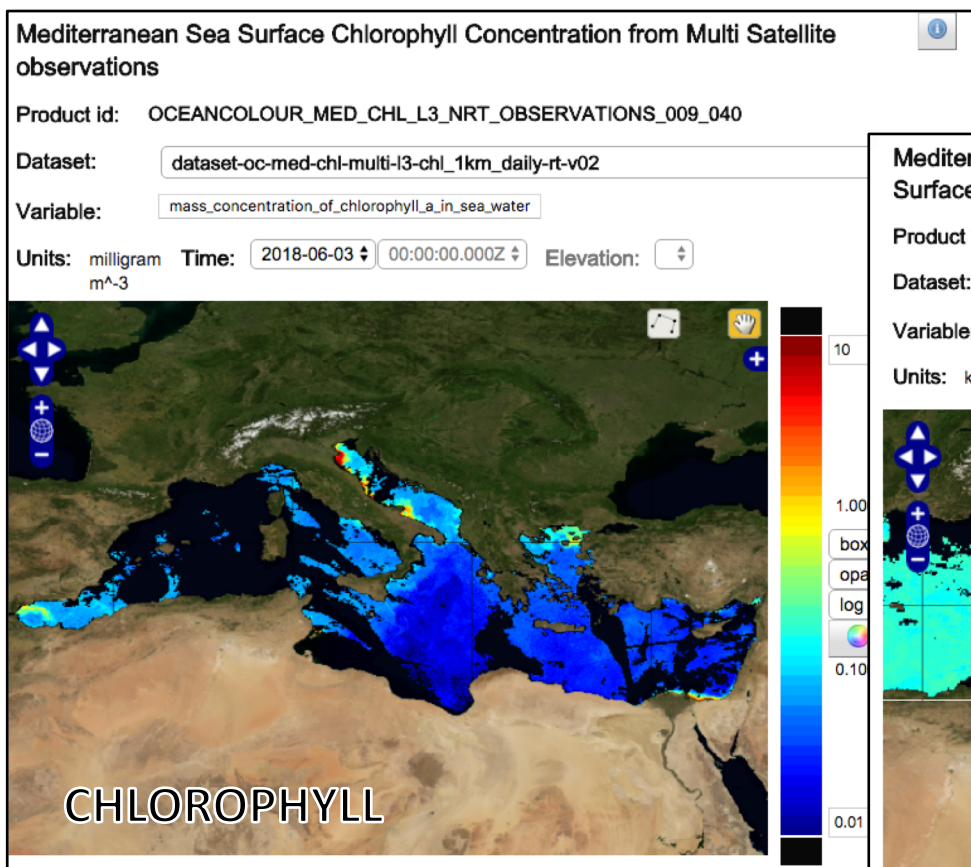
In-situ experimental data (ISPRA stations)

- ✓ **coastal data** (EIONET/SOE dataset)
- ✓ **transects** (EIONET/SOE dataset)
- ✓ usefulness in numerical simulations:
validation and assimilation
- ✓ contribution from modelling:
integration and interpretation

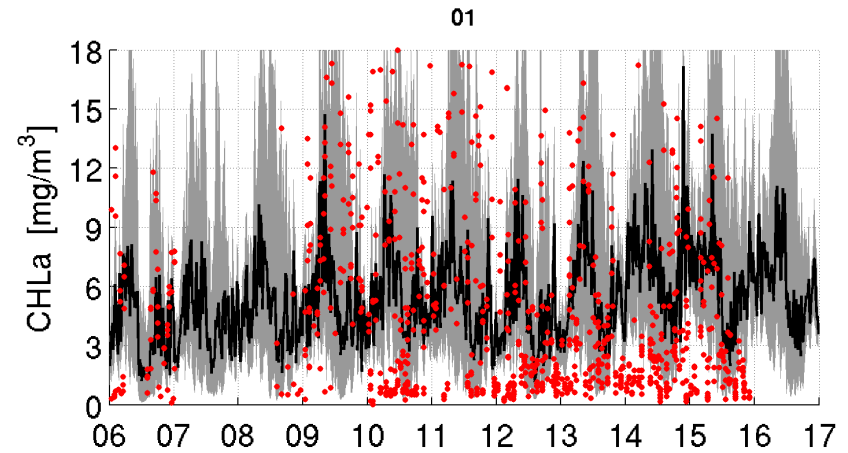
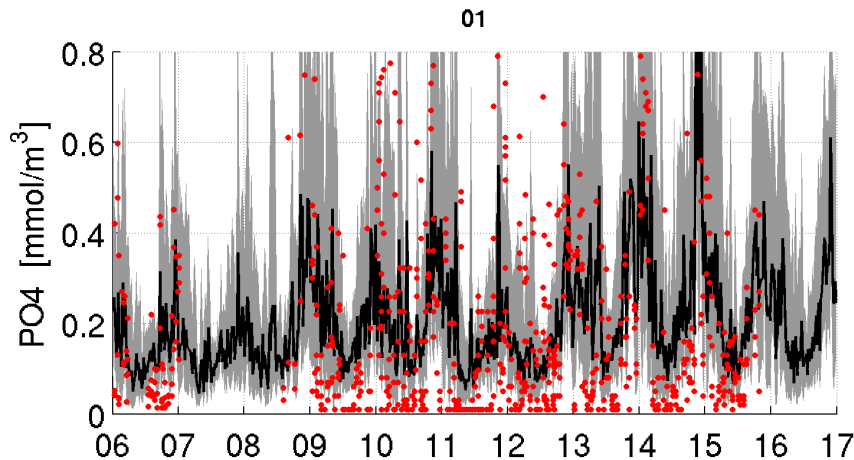
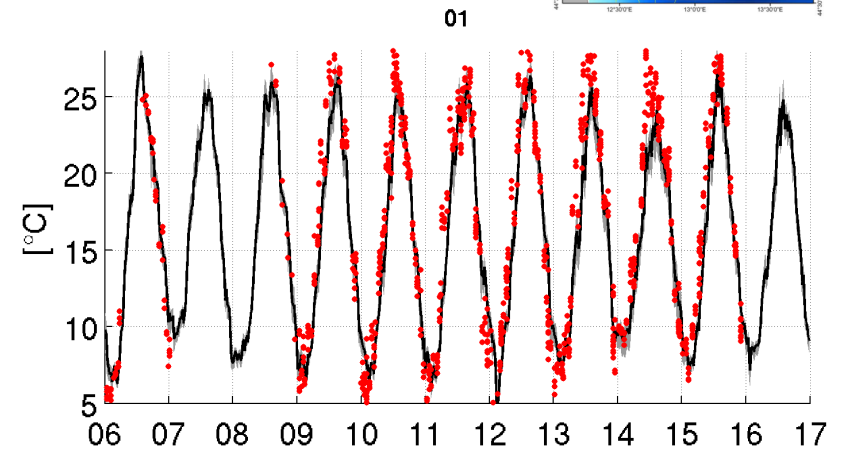
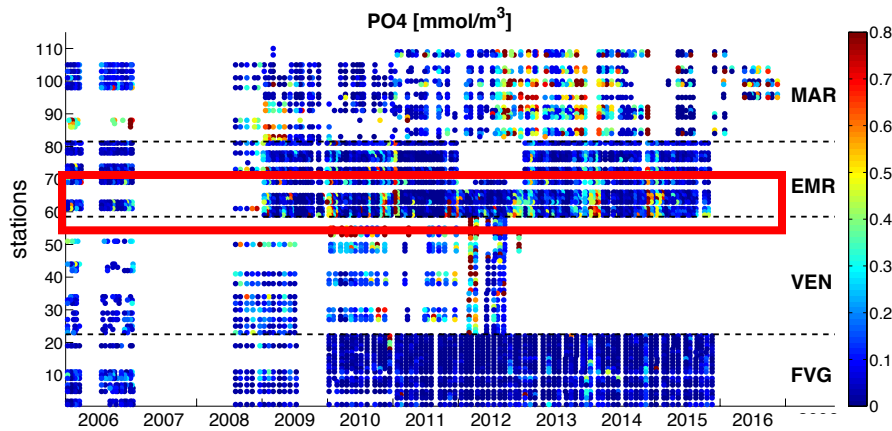
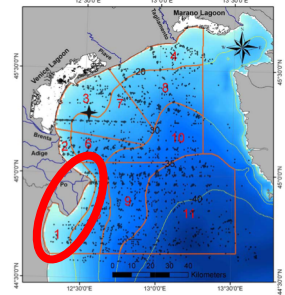


A "recipe" for a good simulation (5/5)

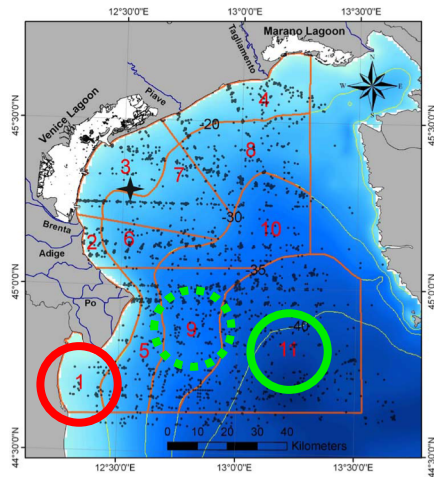
High resolution, up to 1 km (and even more...), satellite observations provided by the new generation **Sentinel satellites managed by **ESA**. Dataset available from the CMEMS system.**



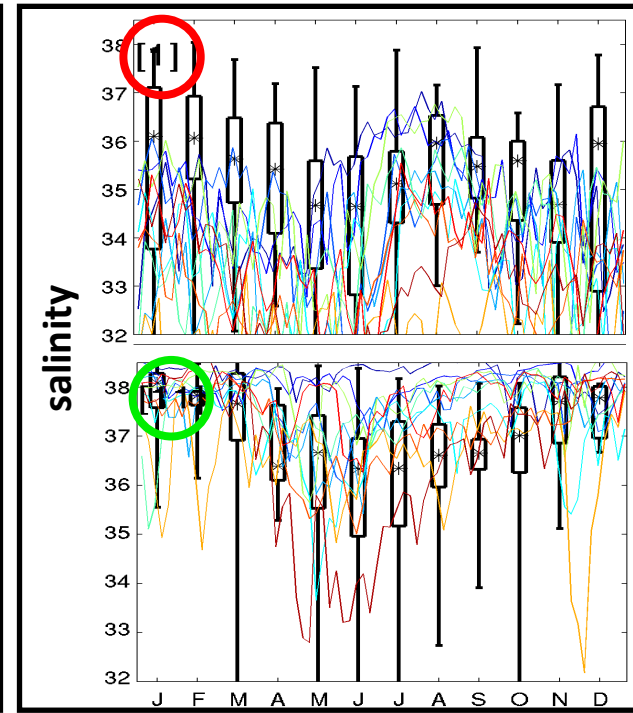
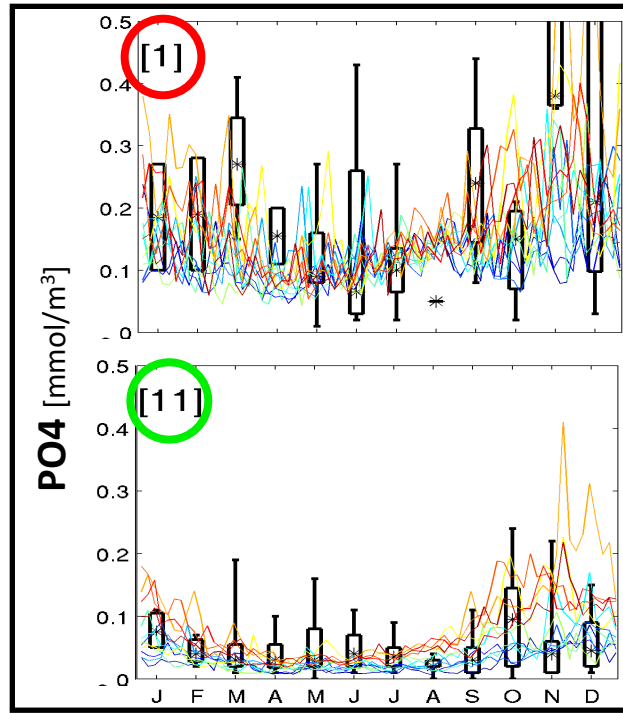
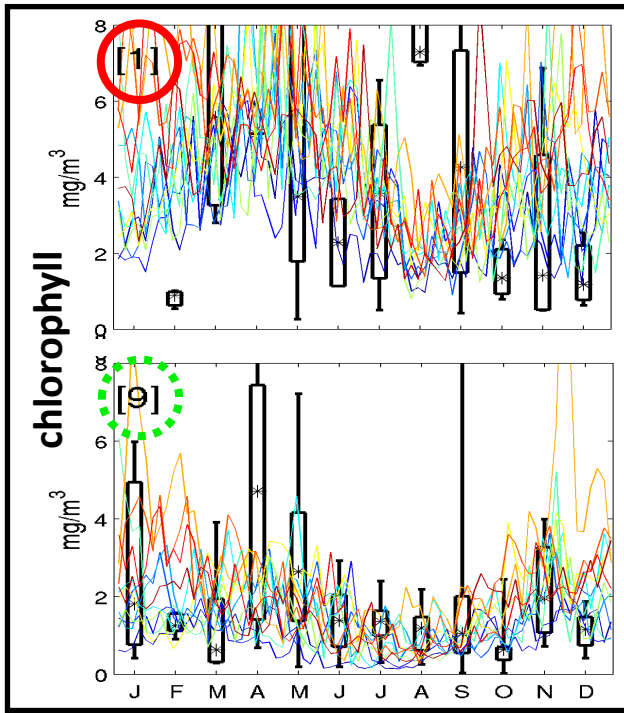
Time series 2006-2016: comparison with the ISPRA dataset



Results are consistent with the northern Adriatic climatologies [*Solidoro et al., 2009*]

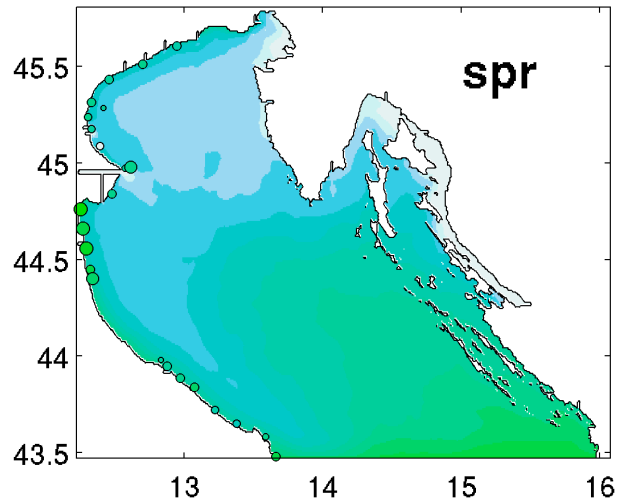


Northern Adriatic characterized by remarkable coast – open sea gradients

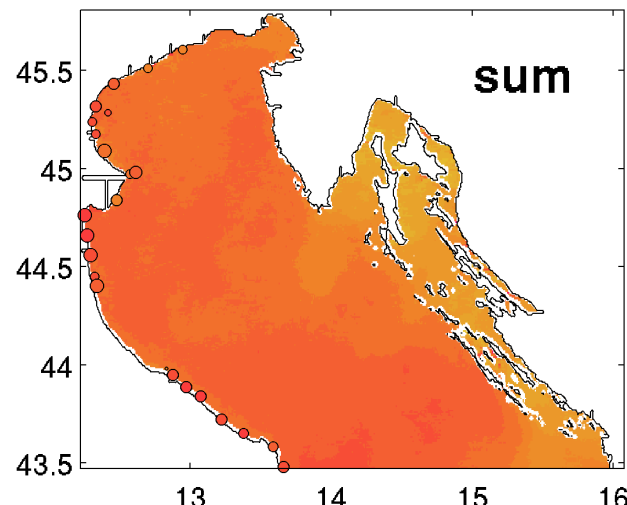
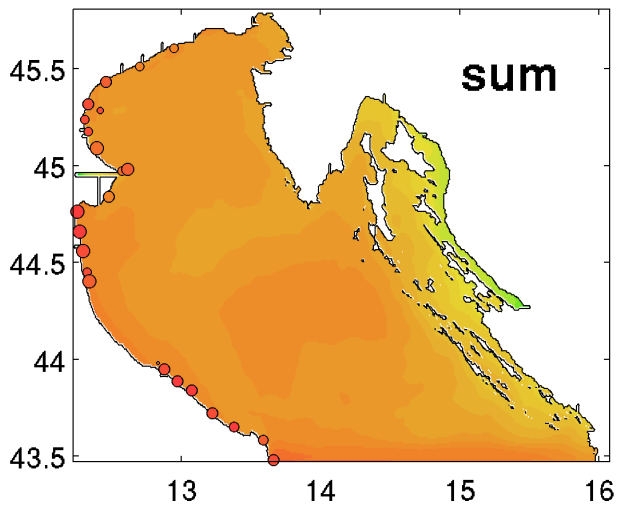
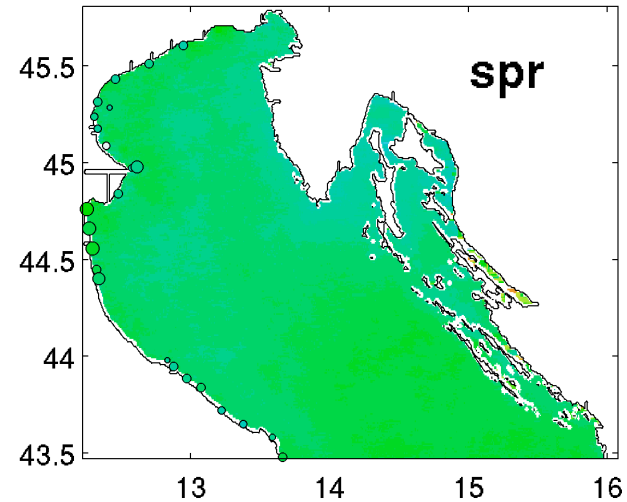


Sea surface temperature maps (seasonal averages)

Model (without assimilation)



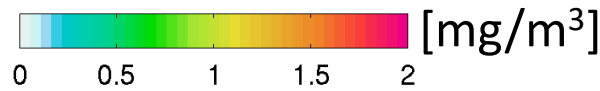
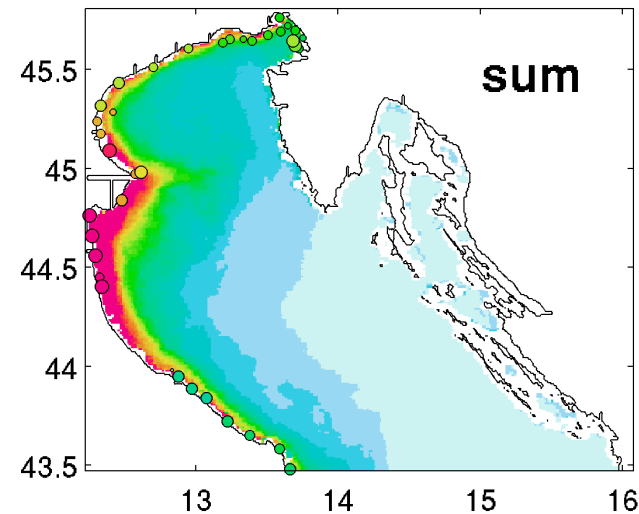
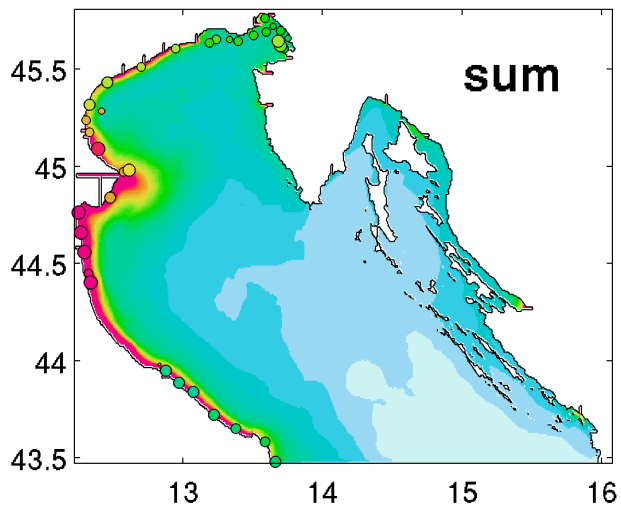
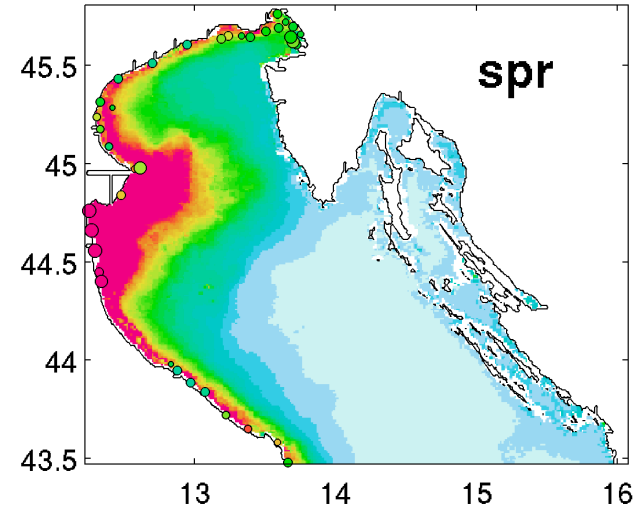
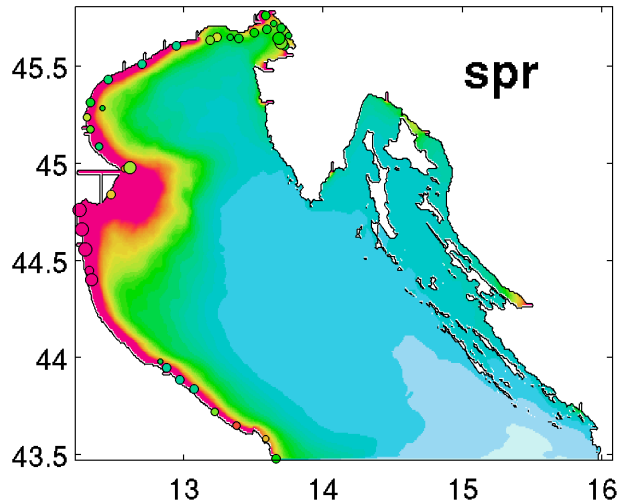
Satellite



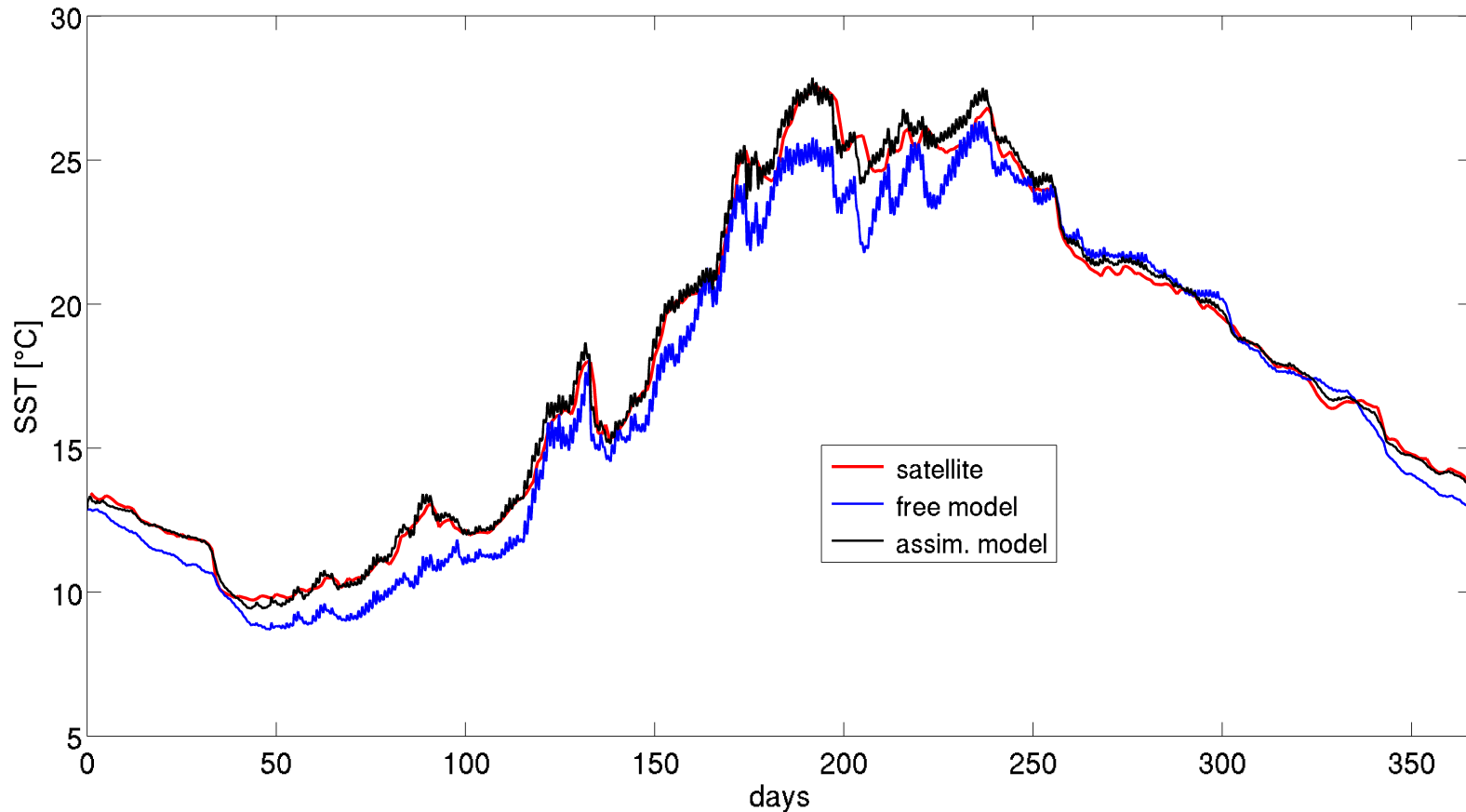
Surface chlorophyll maps (seasonal averages)

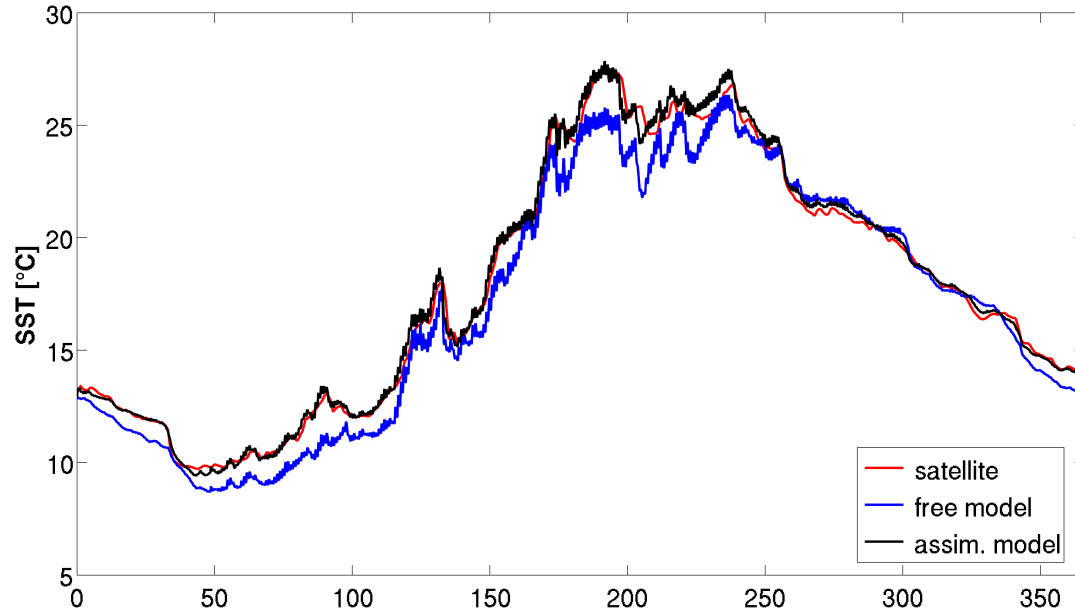
Model (without assimilation)

Satellite

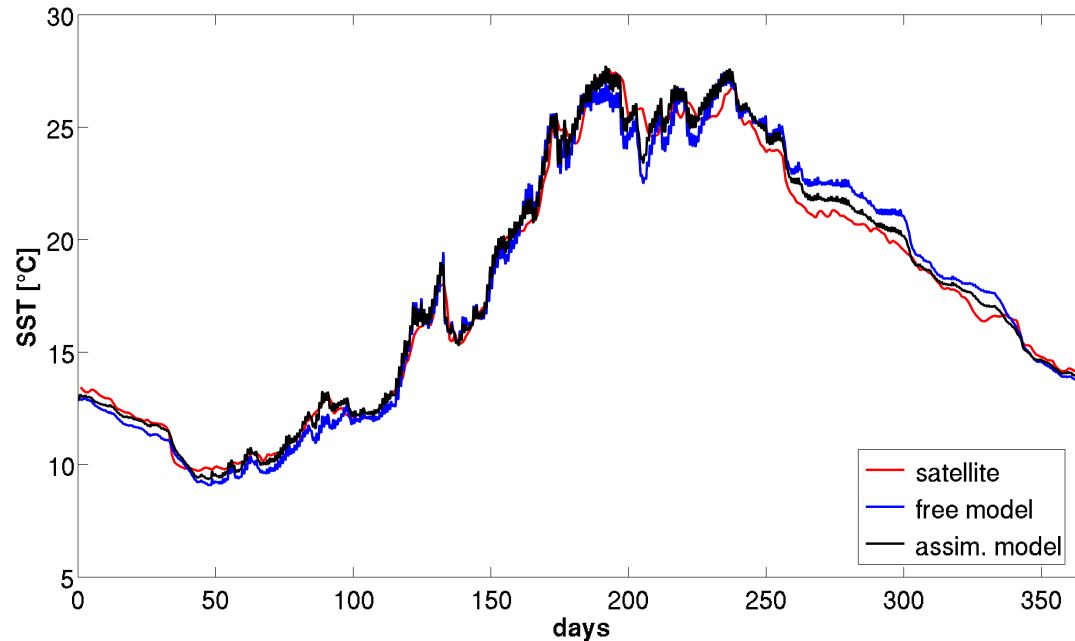


Surface temperature (SST) time series for **2012** (basin scale average):
observed data (satellite - CMEMS) and model without and with
 assimilation (nudging: MITgcm-RBCS [*Adcroft et al.*, 2013])





reference run



lw radiation × 1.1

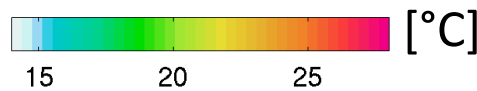
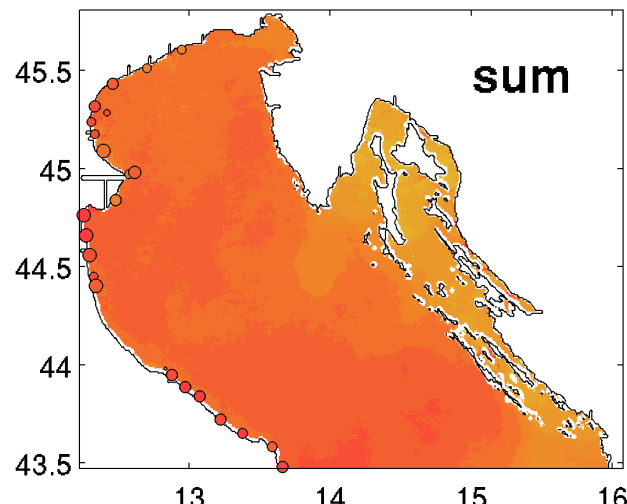
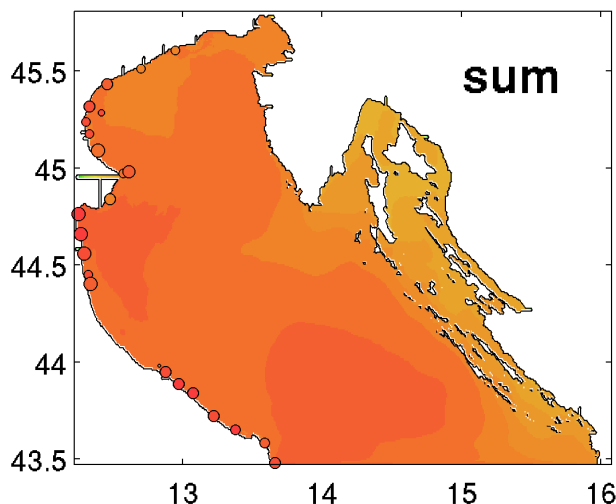
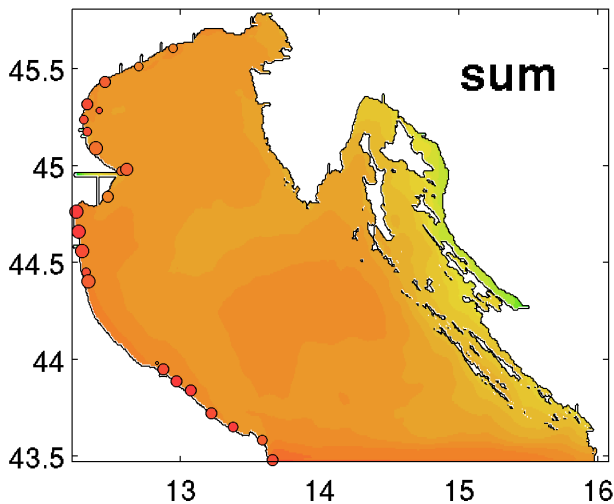
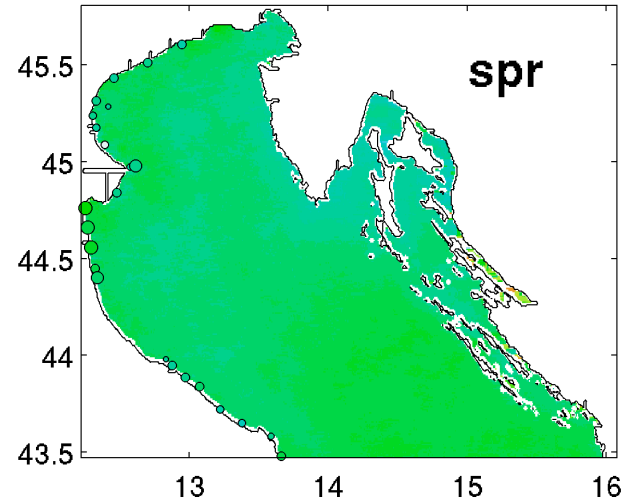
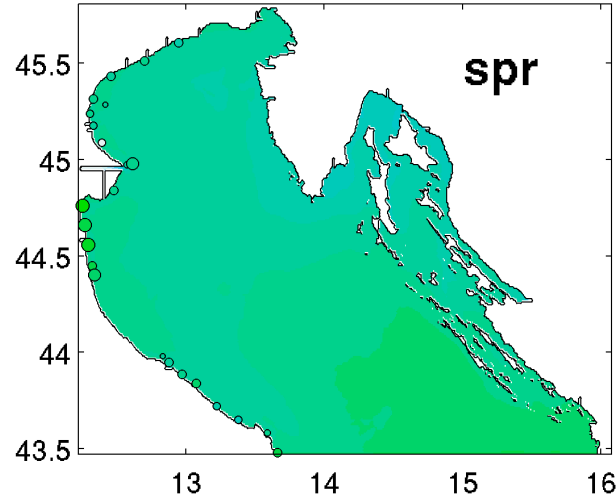
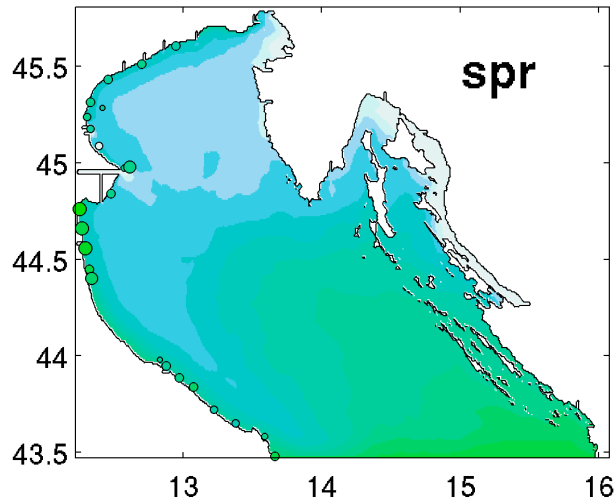
effect on **basin average SST** when changing the **downward longwave radiation** by **10%**

Sea surface temperature maps (seasonal averages)

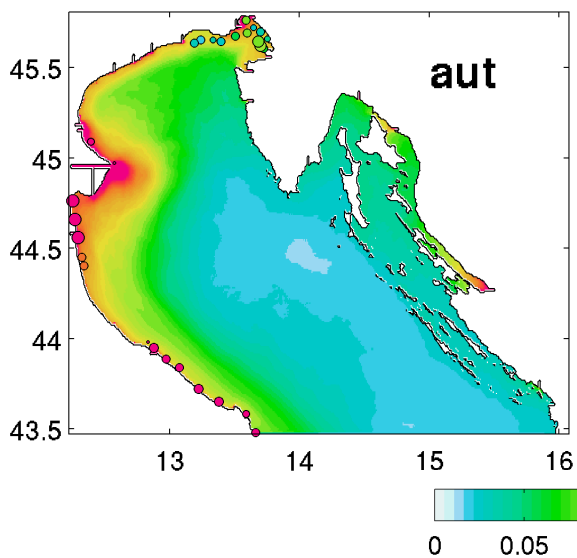
Model (no assimilation)

Model (assimilated)

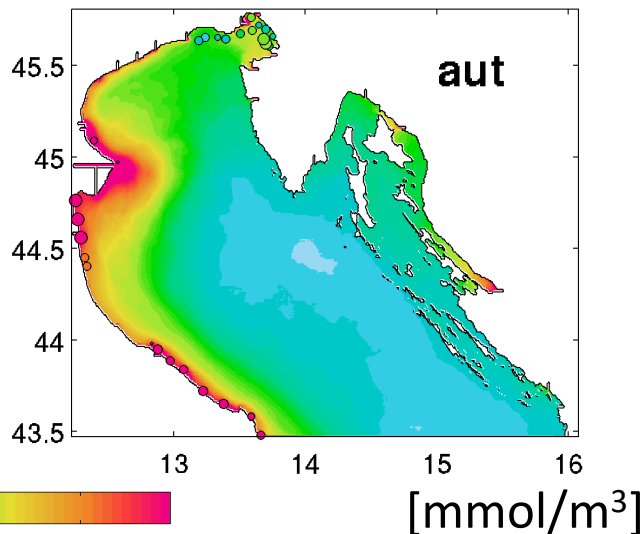
Satellite



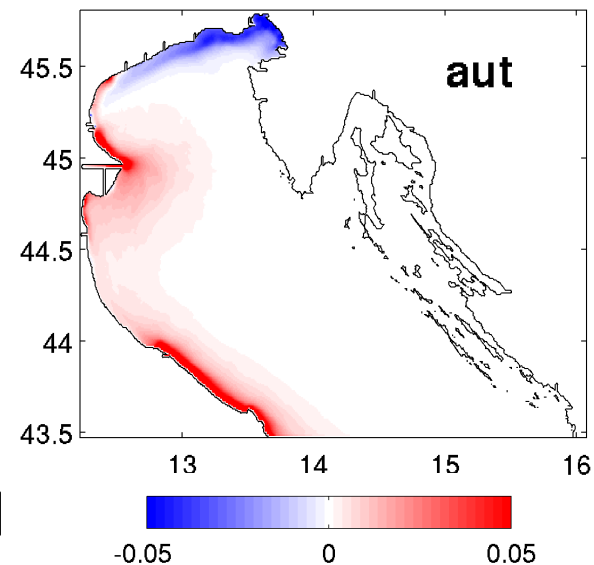
PO4 (no assimilation)



PO4 (assimilated)

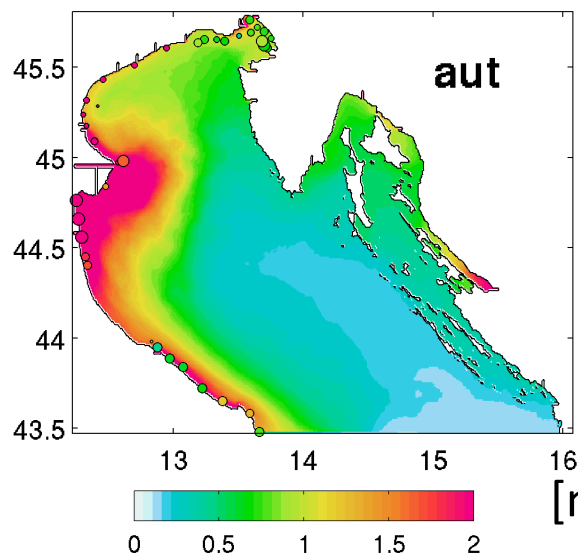


PO4 (anomaly)

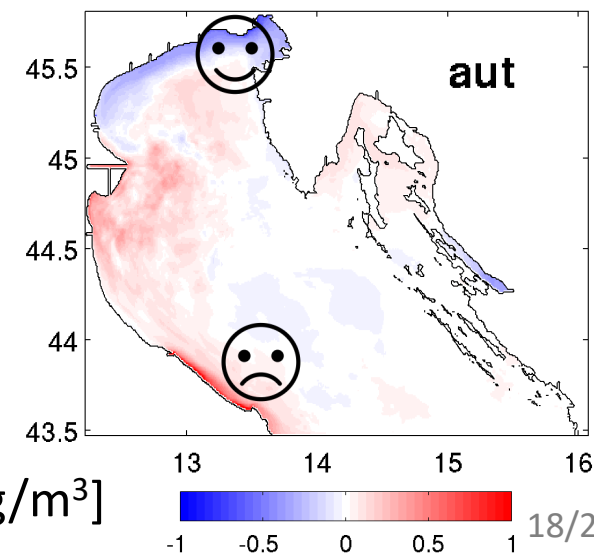


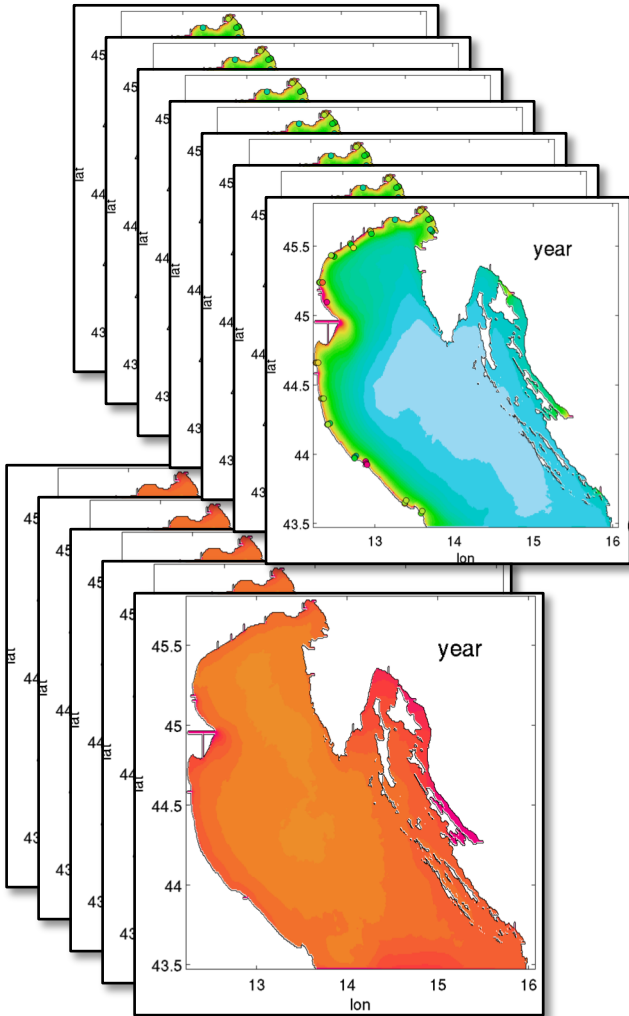
CHL (assimilated)

effect of nutrient assimilation on chlorophyll concentration



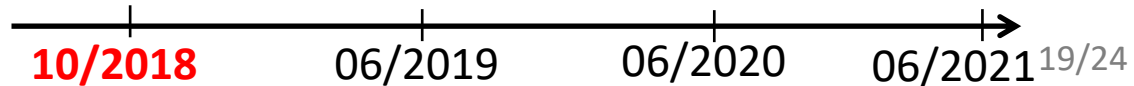
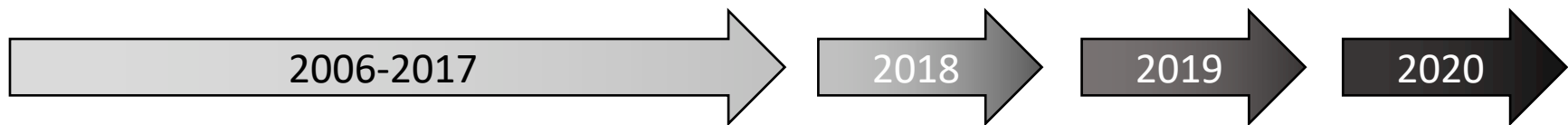
CHL (anomaly)

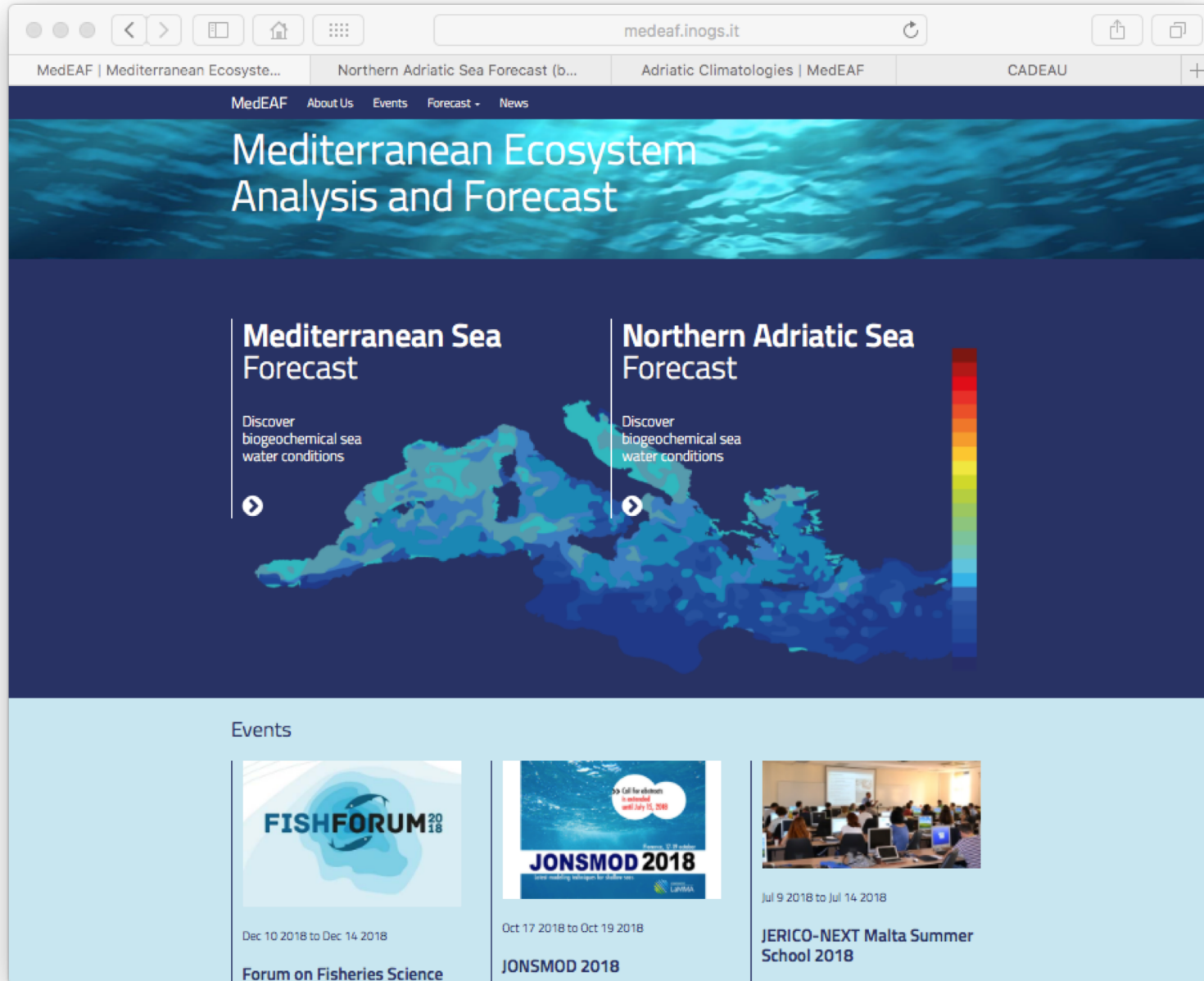




High-resolution (~700 m) physical-biogeochemical model corroborated and integrated with experimental observations and satellite data:

- ✓ **2006-2017 reanalysis** → reconstruction of the recent oceanographic/ecological state of the northern Adriatic (reference to evaluate changes);
- ✓ **annual simulations** from 2018 to 2020 → bulletin of the state of the sea for the previous year and derived products;
- ✓ **simulated variables:** nitrate, phosphate, ammonia, chlorophyll, primary production, oxygen, DOC...
- ✓ **derived variables:** TRIX, impact index...
- ✓ <http://www.bio.isprambiente.it/cadeau/>



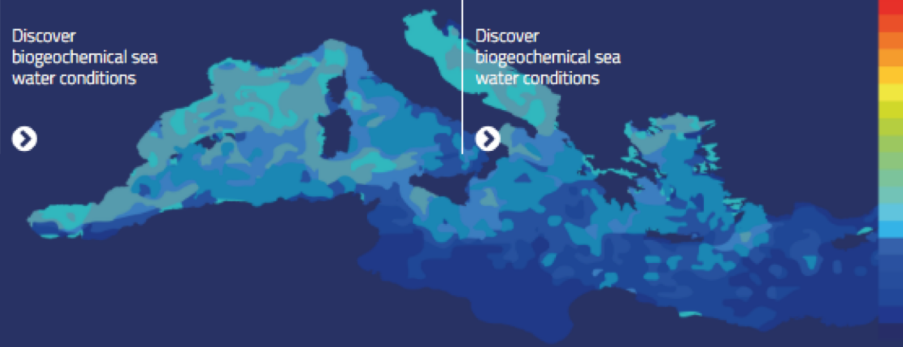


The screenshot shows a web browser window with the URL medeaf.inogs.it. The browser tabs include "MedEAF | Mediterranean Ecosyste...", "Northern Adriatic Sea Forecast (b...", "Adriatic Climatologies | MedEAF", and "CADEAU". The website header features navigation links: "MedEAF", "About Us", "Events", "Forecast -", and "News".

Mediterranean Ecosystem Analysis and Forecast

Mediterranean Sea Forecast




Discover biogeochemical sea water conditions

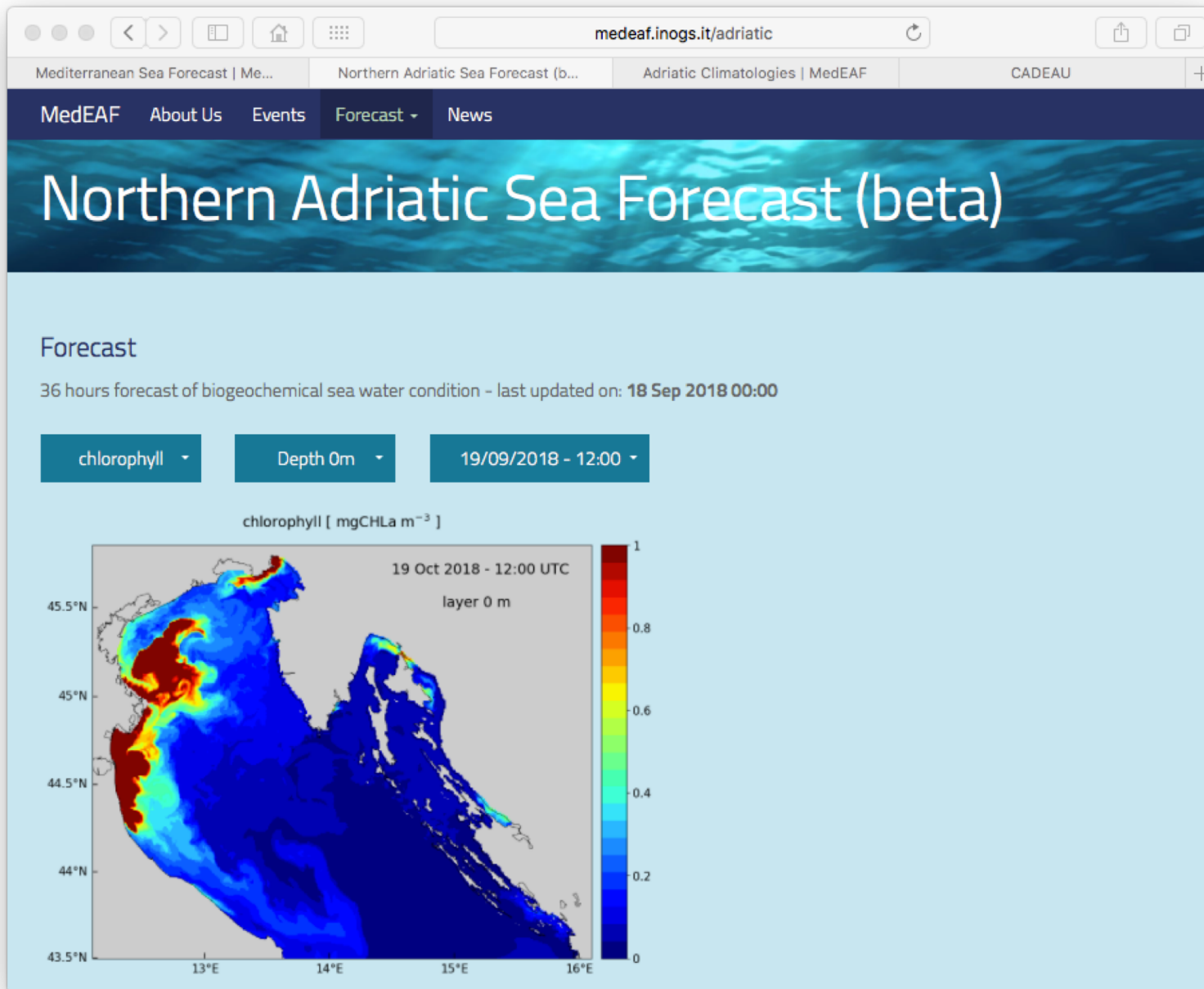


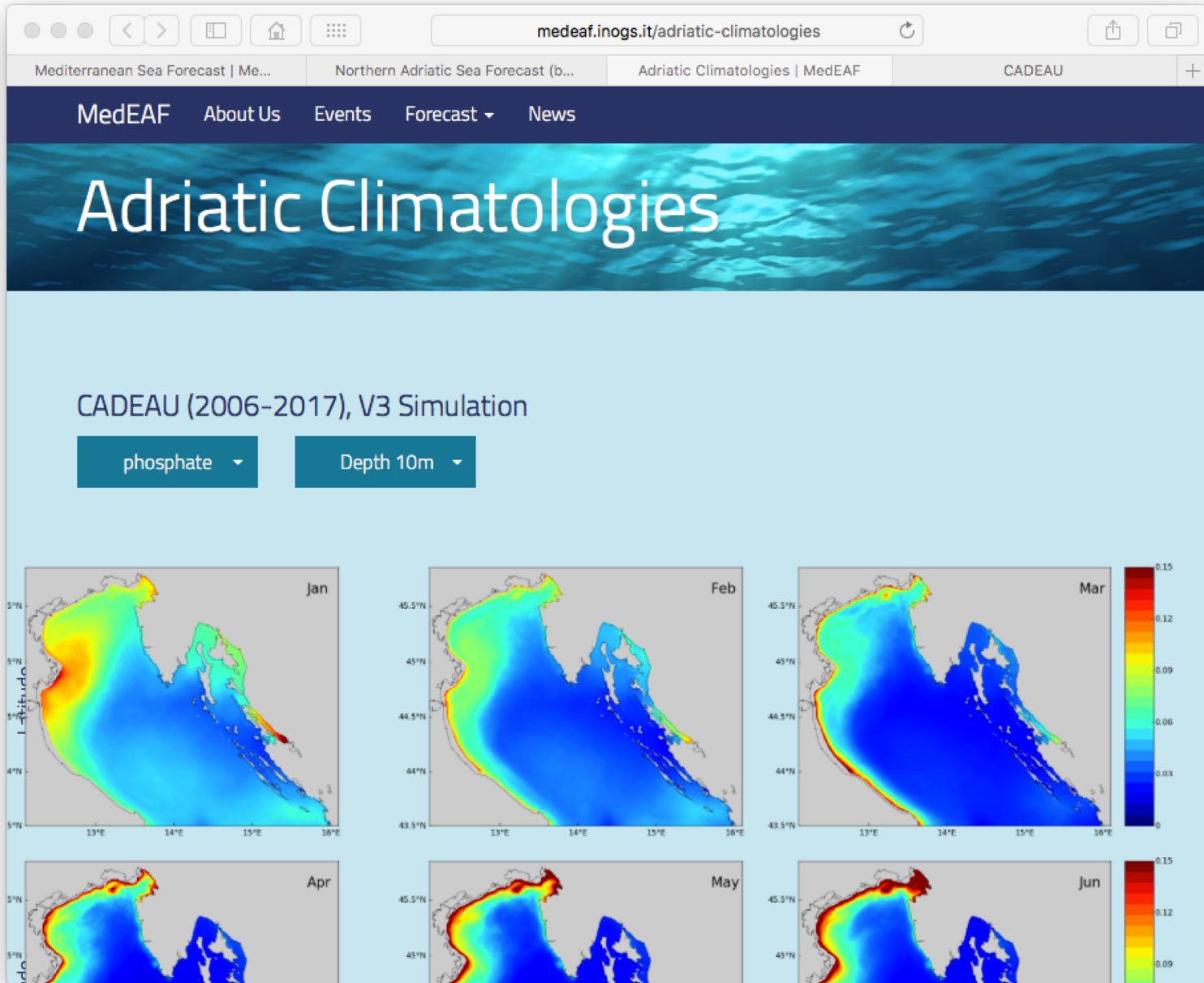
Northern Adriatic Sea Forecast

Discover biogeochemical sea water conditions

Events

| | | |
|--|---|--|
|  <p>FISHFORUM²⁰¹⁸</p> <p>Dec 10 2018 to Dec 14 2018</p> <p>Forum on Fisheries Science</p> |  <p>JONSMOD 2018</p> <p>Oct 17 2018 to Oct 19 2018</p> <p>JONSMOD 2018</p> |  <p>Jul 9 2018 to Jul 14 2018</p> <p>JERICO-NEXT Malta Summer School 2018</p> |
|--|---|--|





TO DO LIST (a lot of good intentions...)

- ✓ insert **tides**
- ✓ insert **Venice** and **Grado-Marano lagoons**
- ✓ **validation** of CADEAU products following CMEMS quality metrics

Reanalysis

- ✓ implementation of **variational assimilation schemes** (3DVarBio [*Teruzzi et al., 2014*])
- ✓ **update** the reanalysis

Forecast

- ✓ **real time** Po data (ARPAE) + earth system model
- ✓ more meteorological models (“**ensemble**” runs)

