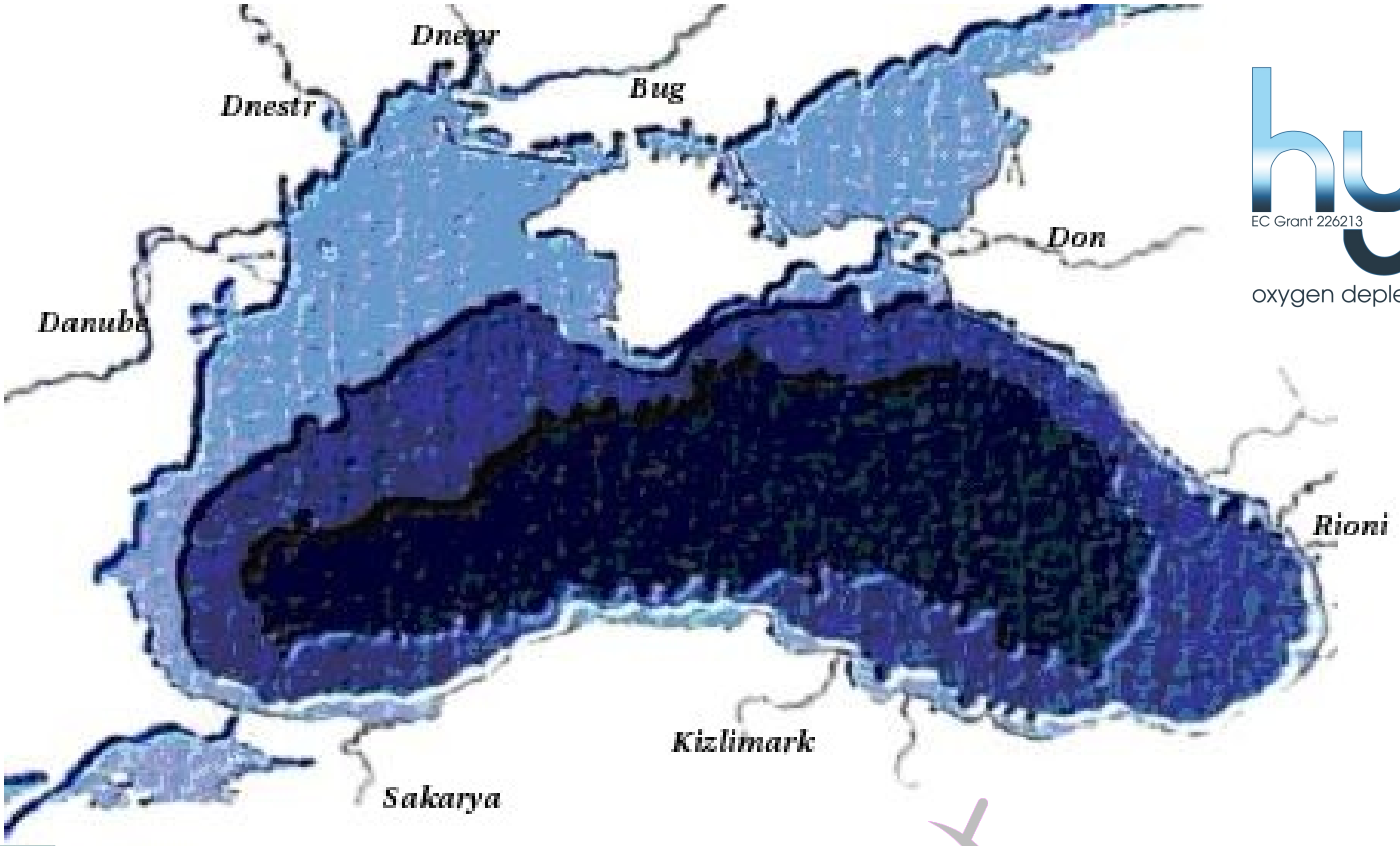
Sensitivity of the Oxygen Dynamics in the Black Sea North Western Shelf to physical and biogeochemical processes : 3D model approach



hypox
EC Grant 226213
In situ monitoring of oxygen depletion in hypoxic ecosystems

Université de Liège

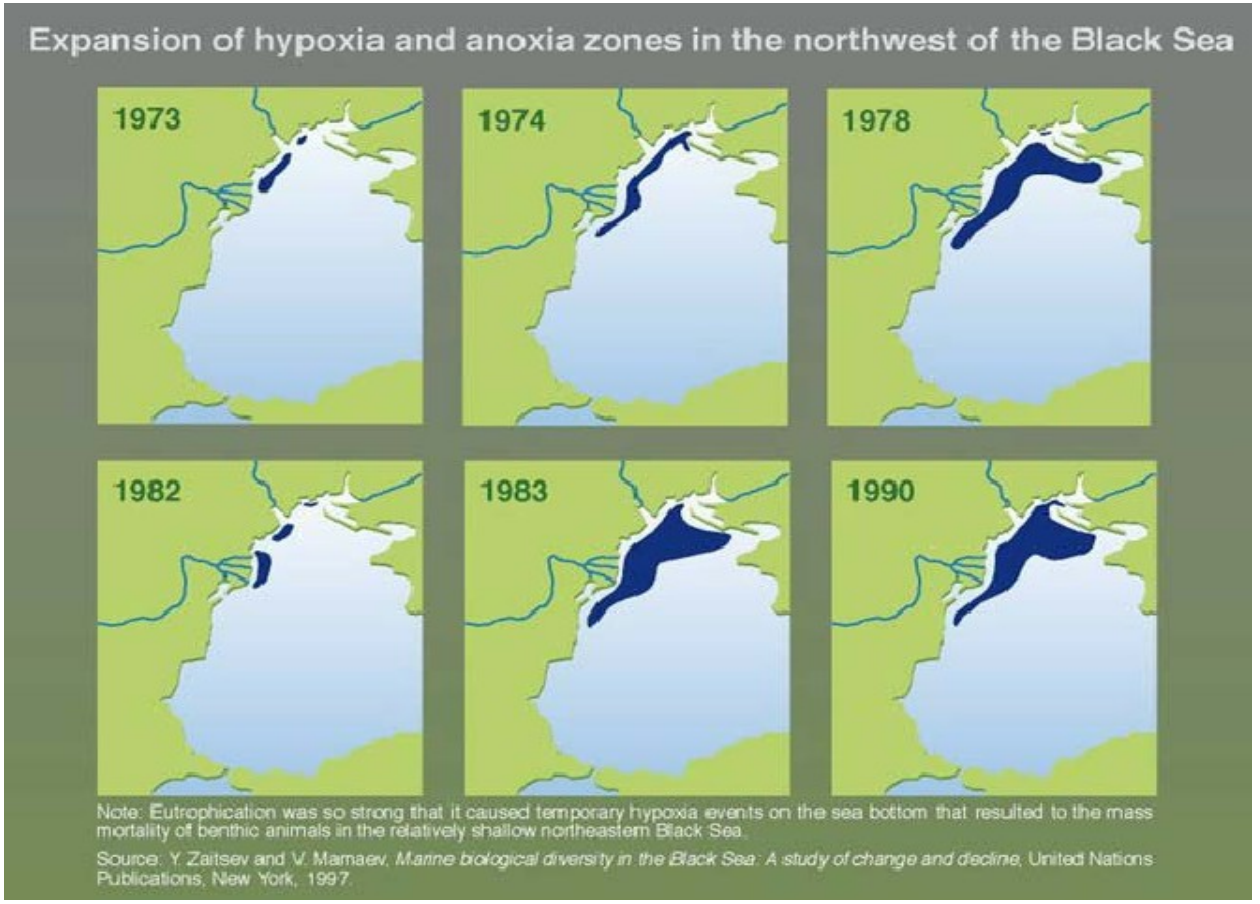
MARE
INTERFACULTARY CENTER FOR MARINE RESEARCH - LIEGE UNIVERSITY

GHER
GeoHydrodynamics and Environment Research

FNRS

Capet Arthur, Grégoire M, Beckers, JM.,Joassin P., Soetaert K., Meysman F.

Introduction



Which are the main process driving **spatial** , **seasonal** and **interannual** variability?

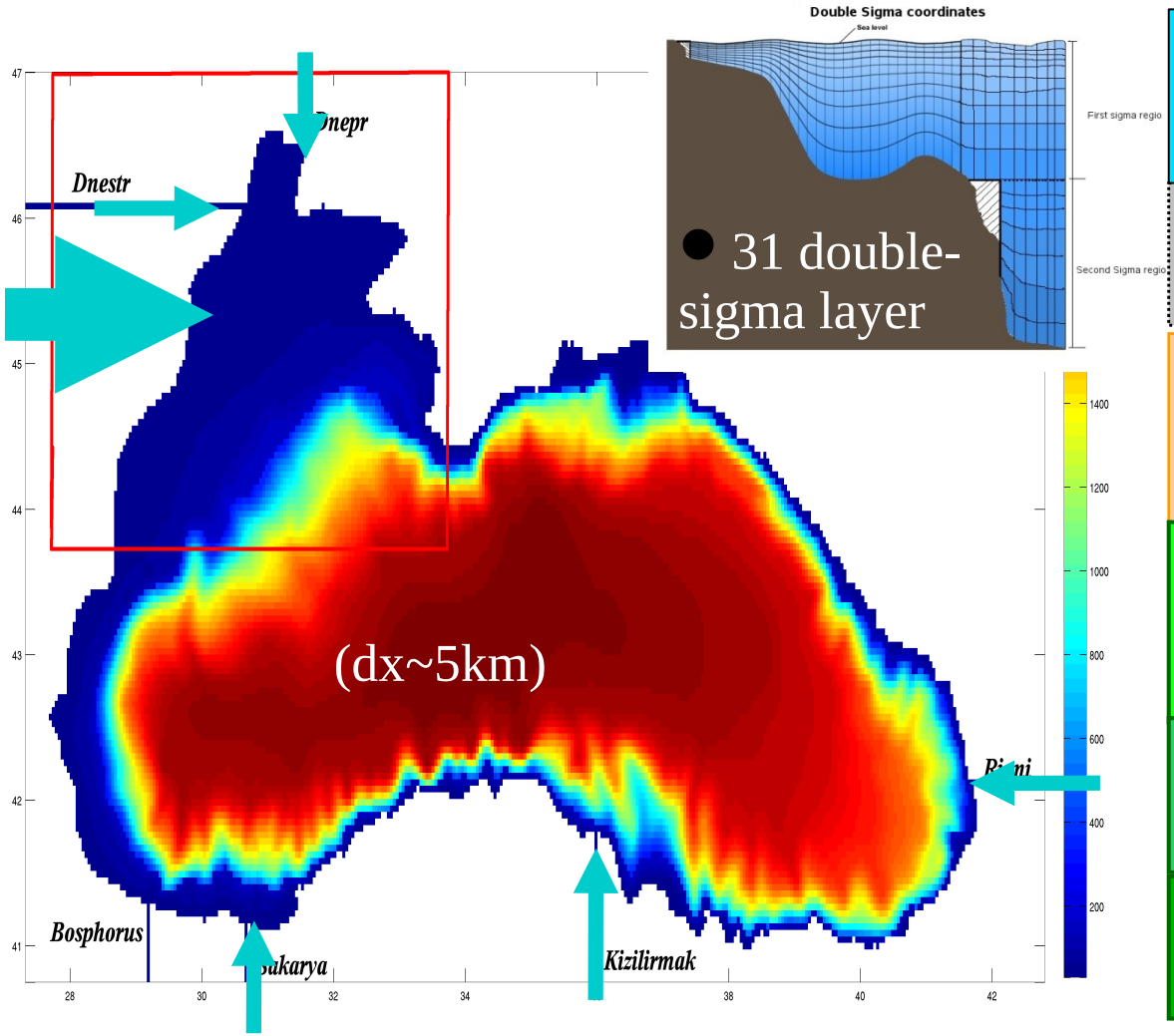
Outline

- Model description.
- Climatological annual cycle:

  Detailling the various processes acting in the bottom oxygen variations.
- Spatial variability.
- Interannual variability.
- Conclusion

Model Description

The Model



Monthly RIVERS fluxes and nutrients flows (from L. Wolfgang & A. Cociasu)

6h-atmospheric forcings from ECMWF (1.125°). (from ERA40)

36 States variables

Physics (5)
Currents, T°, Salinity,
Surface elevation, Turbulence

Oxygen and Dissolved Inorganic Carbon (2)

Inorganic nutrients (5)
SiO,NO3,NH4,PO4,"Reducers"

3 Phytoplankton (6) (free C/N)
Diatoms,Flagellates, Small Flagellates

Zooplankton (2)
Micro-, Meso-.

Gelatinous zooplankton(2)
Omnivorous , Carnivorous

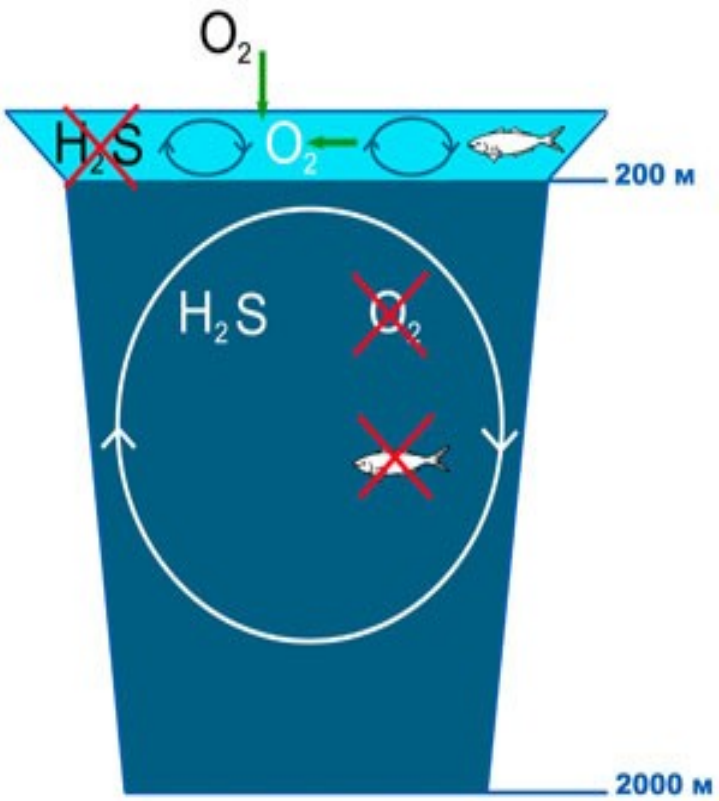
Detrital matter (8)
Particulate, Semi-labile and Labile forms
Silicious Detritus, Aggregates

Bacteria(1)

Model's Specificity

- No data assimilation : Necessity to construct specific Bosphorus representation to ensure conservation of volume and total salt content.

- Anoxic waters : The biological model explicitely includes anoxic chemistry trough the use of a variable 'Oxygen demanding Units', as a proxy for reducers acting in the anoxic zone.



- Sediments compartiment

- Light absorption scheme

Benthic Model

sedimenting variables
(POM, Diatoms)

W_{POC} is given by aggregation model

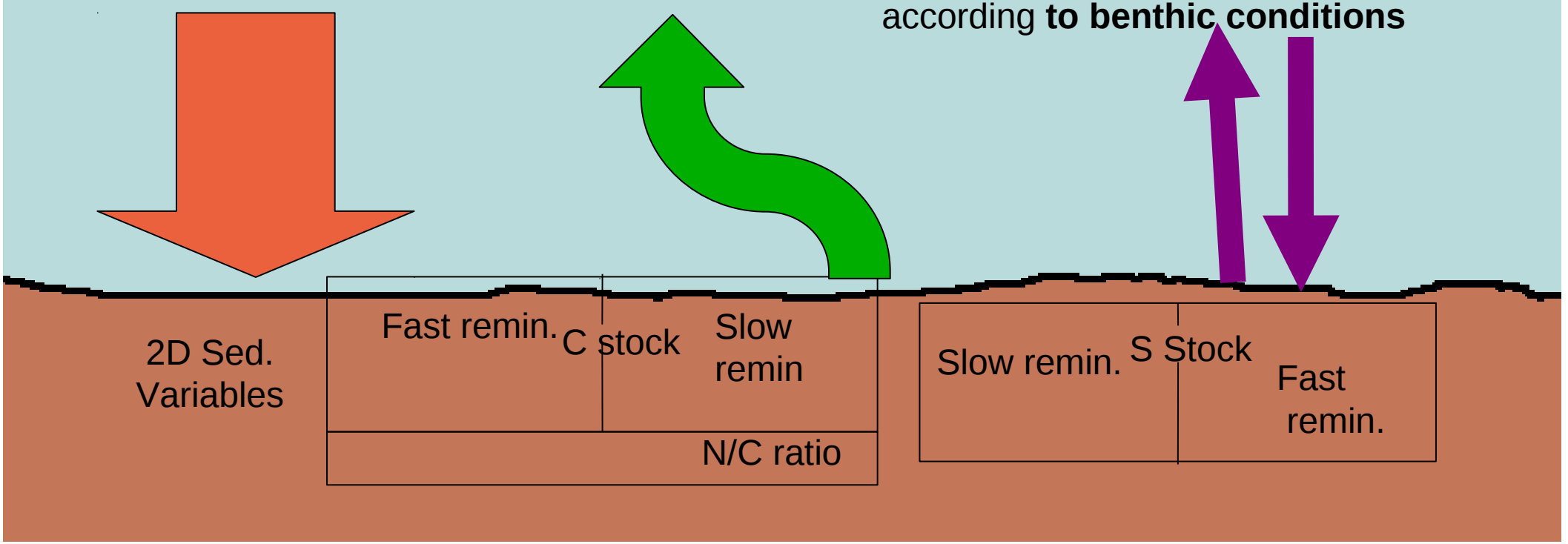
Resuspension
in particulate form

due to bottom stress from **currents** and (mainly) **waves**.

Benthic remineralisation

Remineralised content (in mmolC/m²/s)
= [fast C stock] . K_{fC} . f(T°)
+ [slow C stock] . K_{sC} . f(T°)

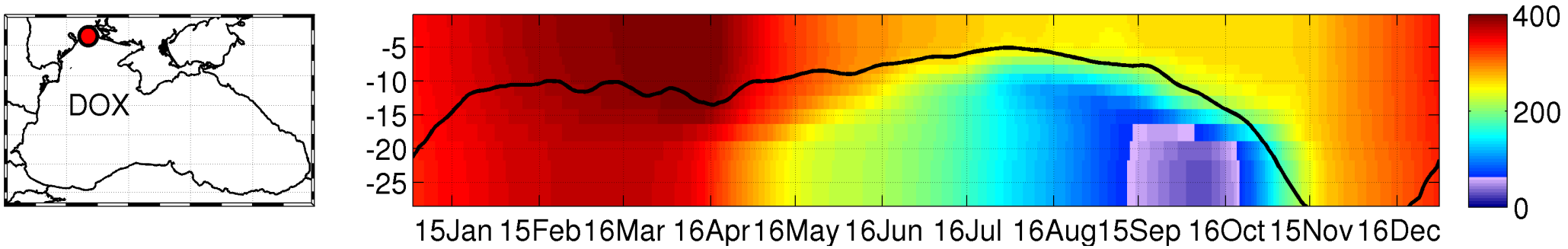
Calibrated functions compute from Cmin and Nmin, the fluxes of **Oxygen**, **ODU, DIC, Ammonium**, **Nitrate, Silicate,** according **to benthic conditions**



Climatological Annual Cycle

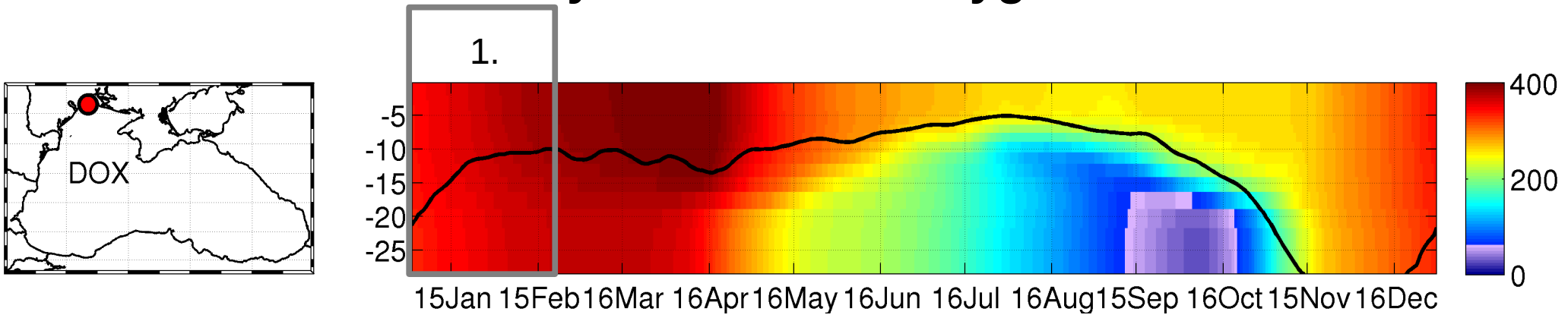
detailling the various processes acting in the bottom oxygen variations.

The annual cycle of bottom oxygen concentration



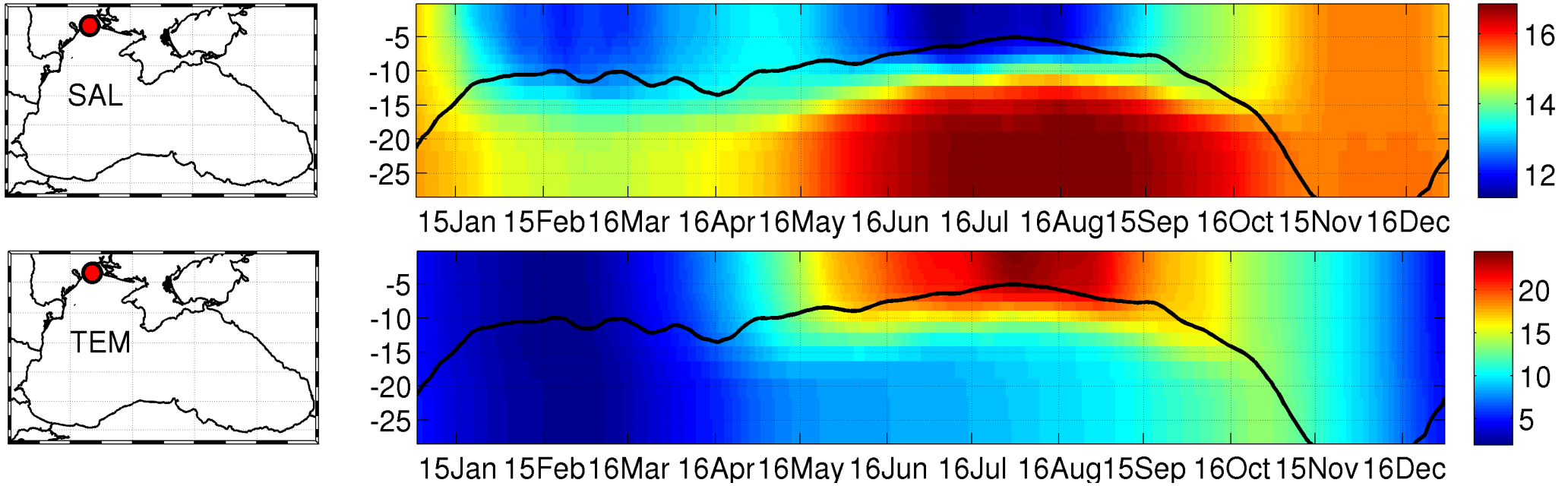
- Climatological (2001-2009) Oxygen profile.

The annual cycle of bottom oxygen concentration



1. Beginning of the stratification

- Well mixed water column.
- Stratification is due to river plume and then thermocline



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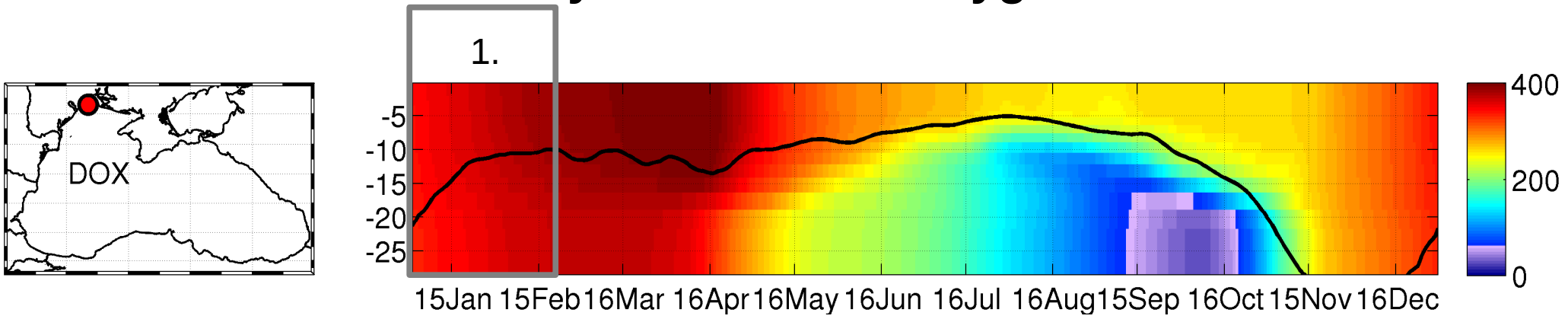

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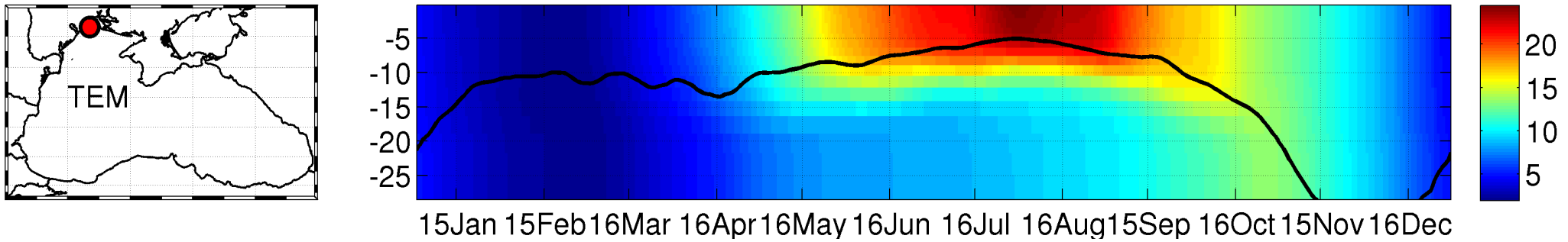

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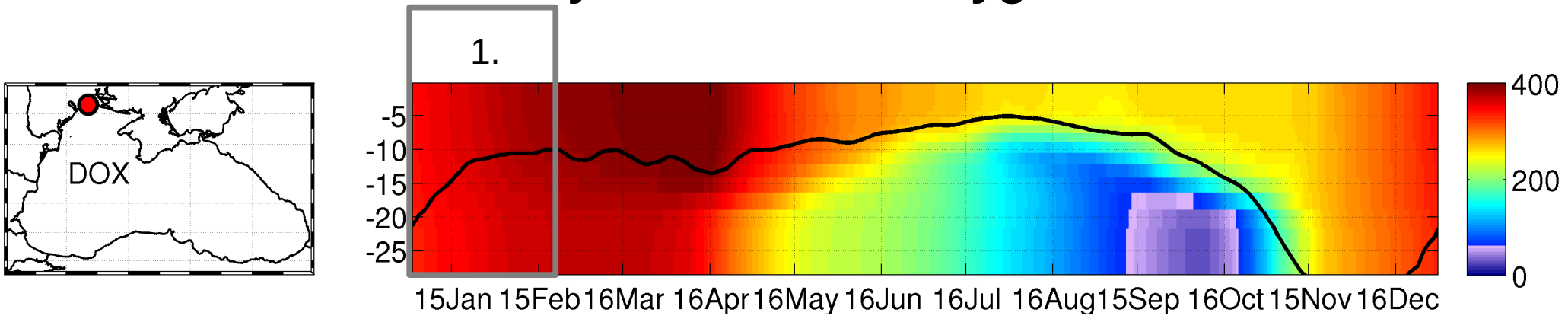
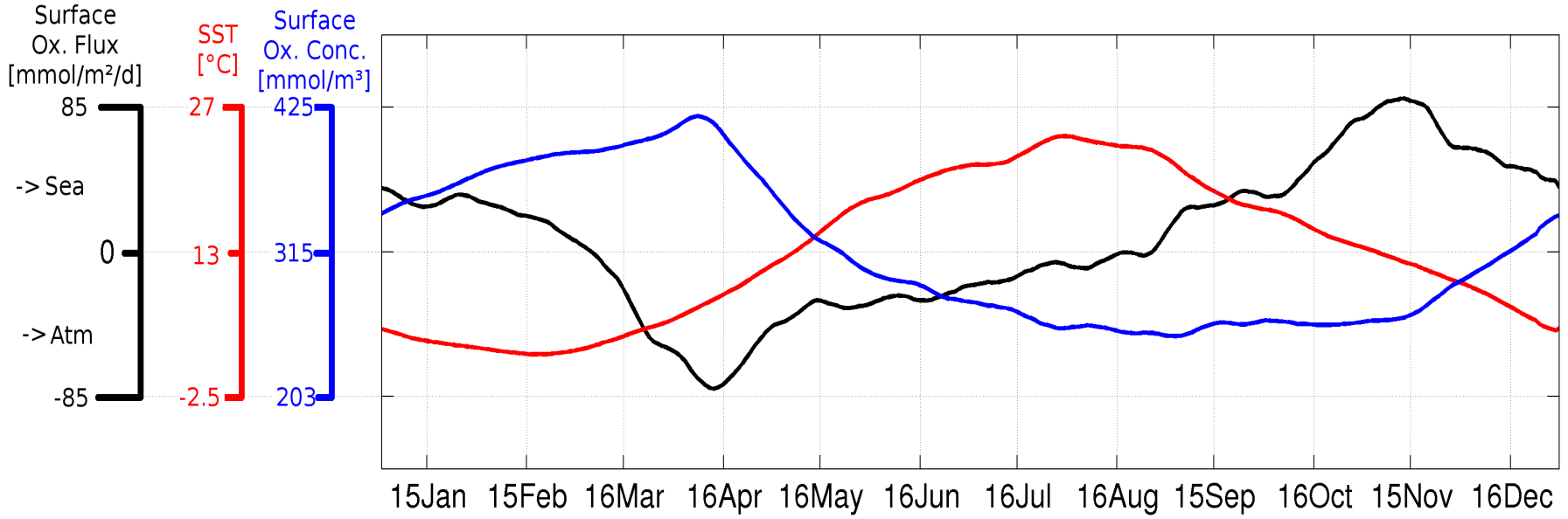


1. Beginning of the stratification

- Well mixed water collumn.
- Stratification is due to river plume and then thermocline.
- Until beginning of March, surface Oxygen flux is positive.

That is before SST lowers Ox. Solubility and before the start of Spring Blooom.



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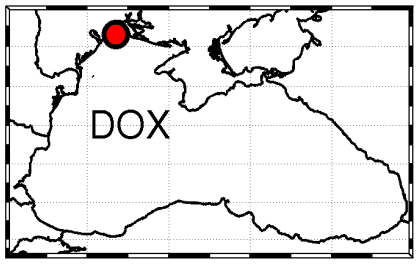
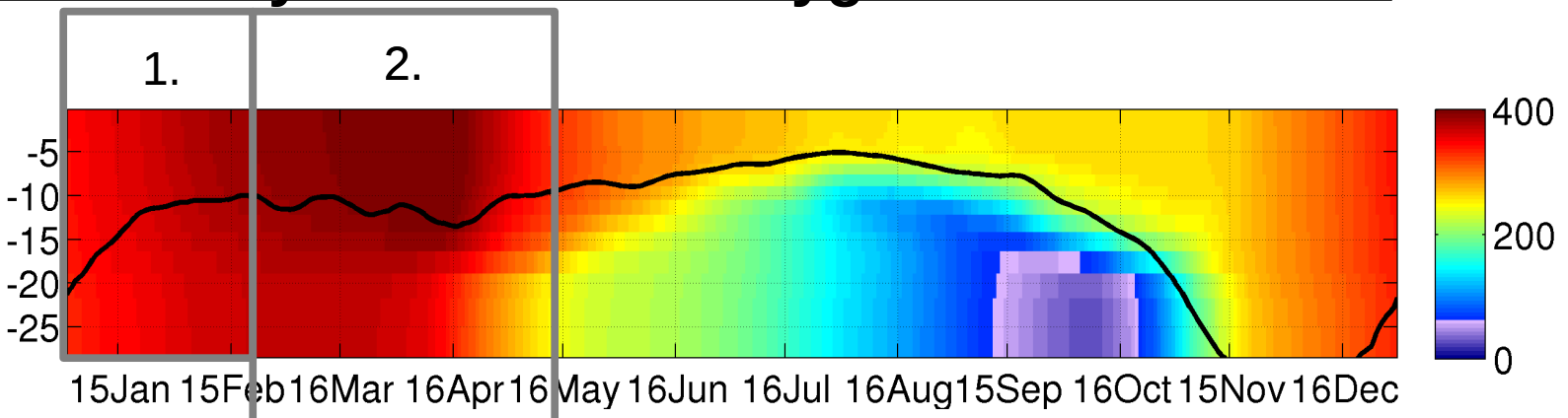
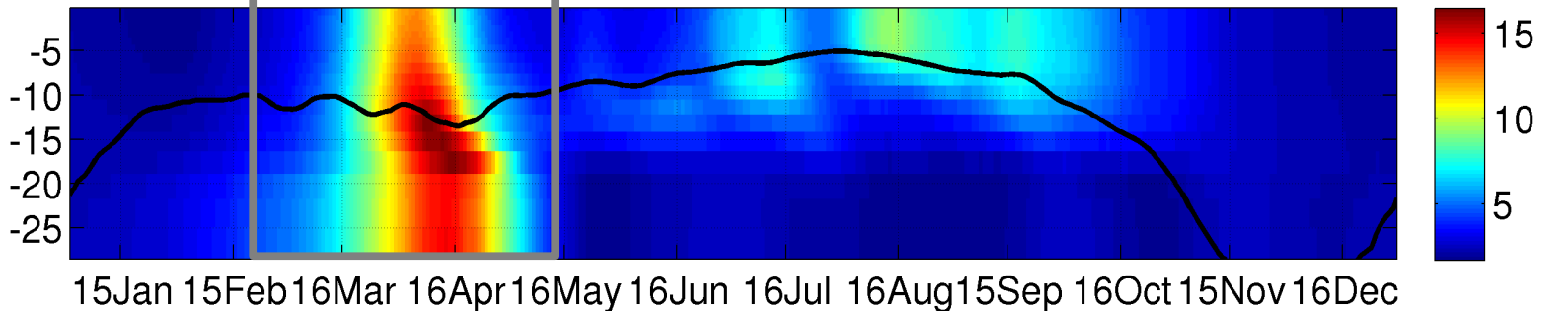




2. Spring Bloom

- The spring bloom starts around March, peak in April and end in May.

Chlorophyll [mg/m³]



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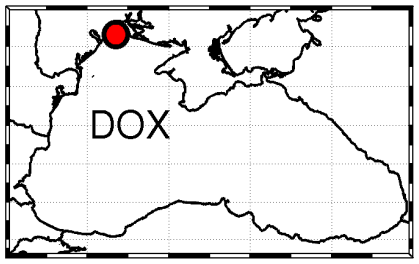

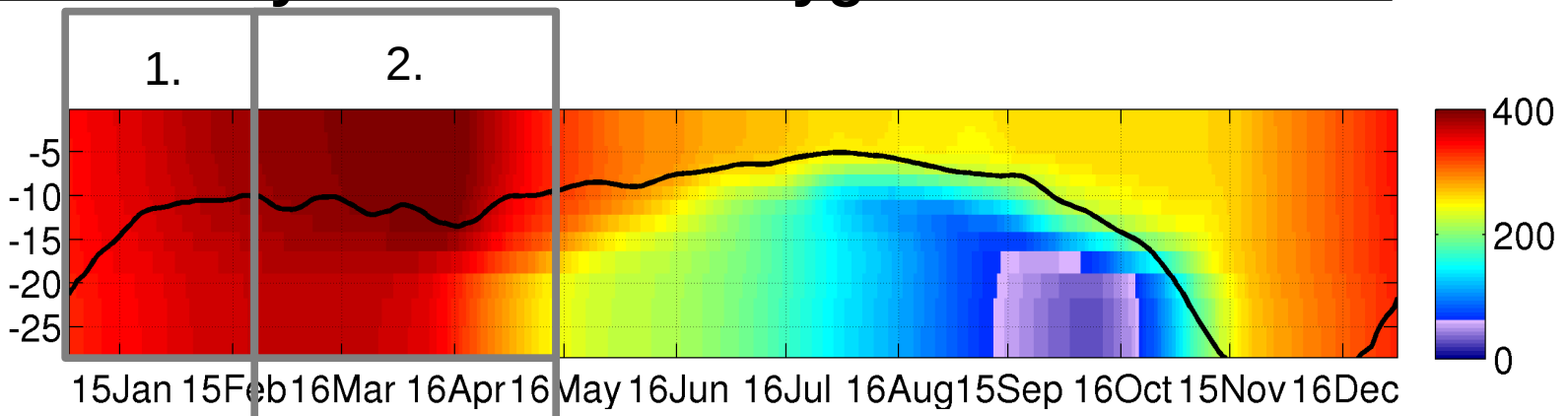

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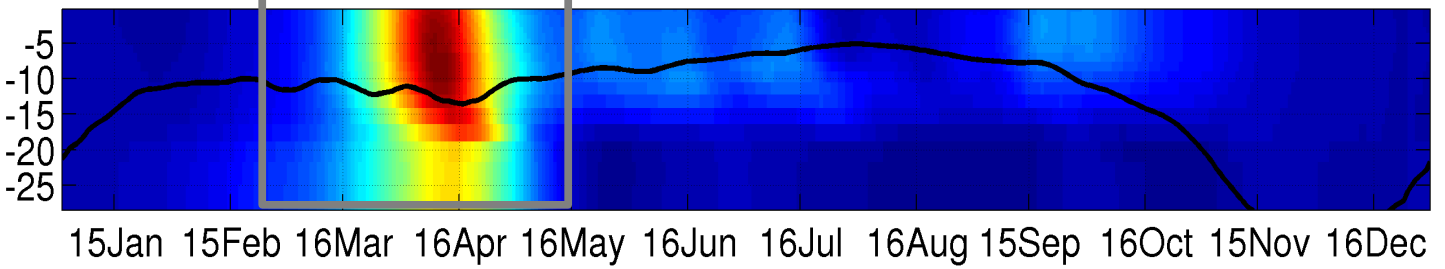
- Spring bloom is mastered by the sedimentating Diatoms group.

Diatoms [mmolC/m³]



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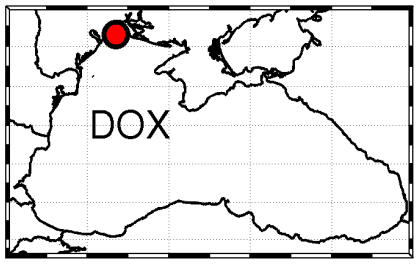

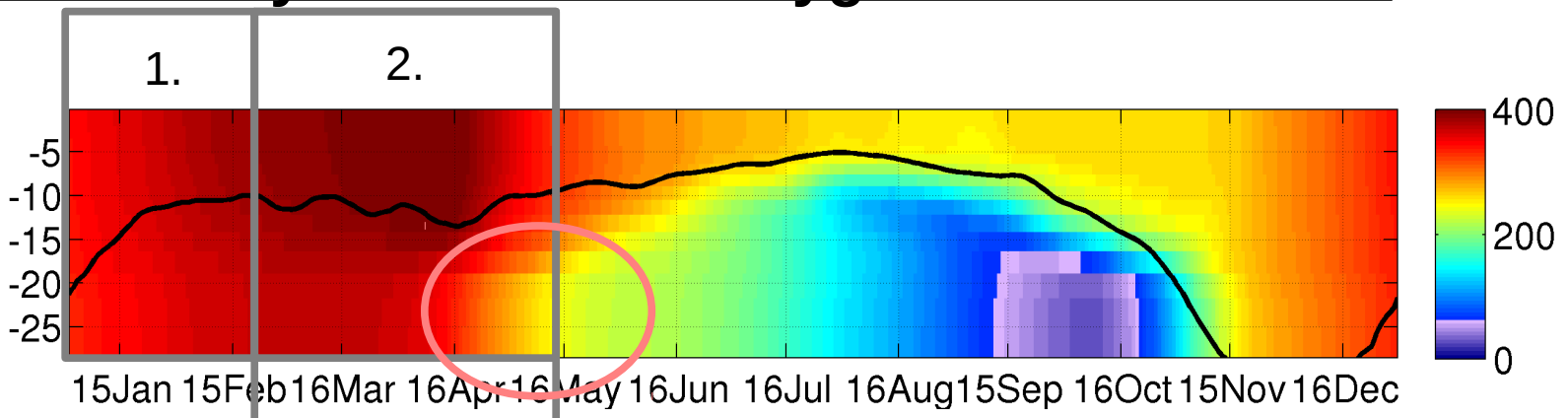

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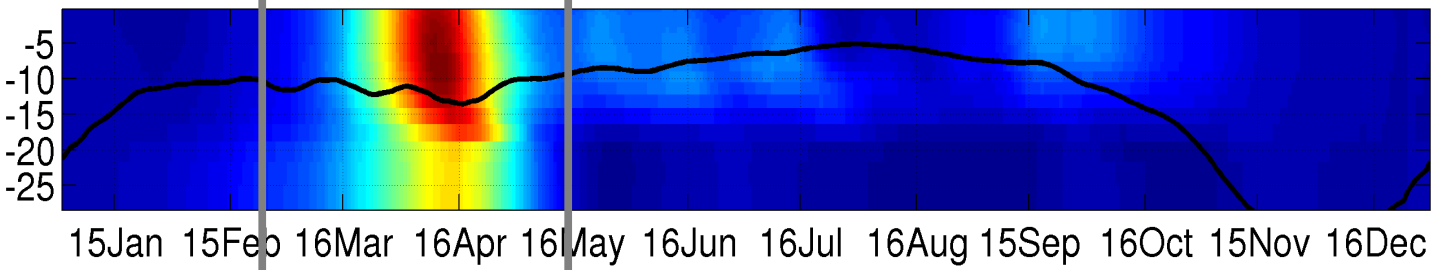
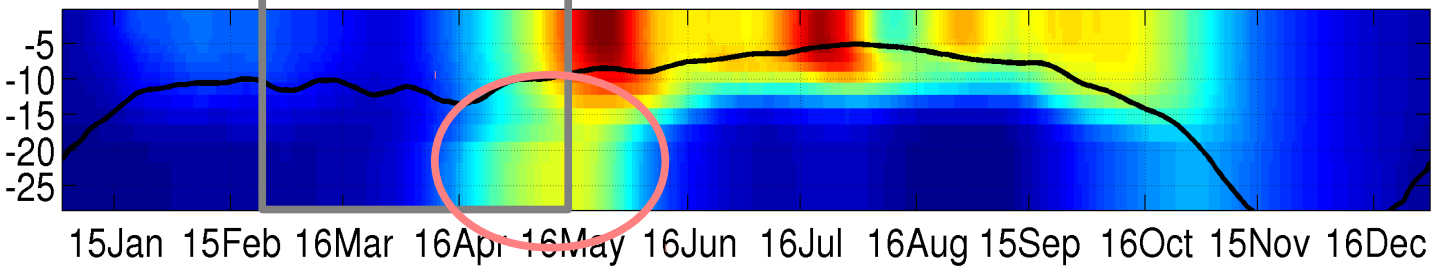
- Spring bloom is mastered by the sedimentating Diatoms group.
- It trigger a first bacterial activity, cause of the first drop in bottom Oxygen.

Diatoms [mmolC/m³]



Bacteria [mmolC/m3]



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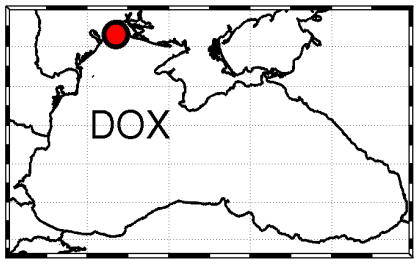
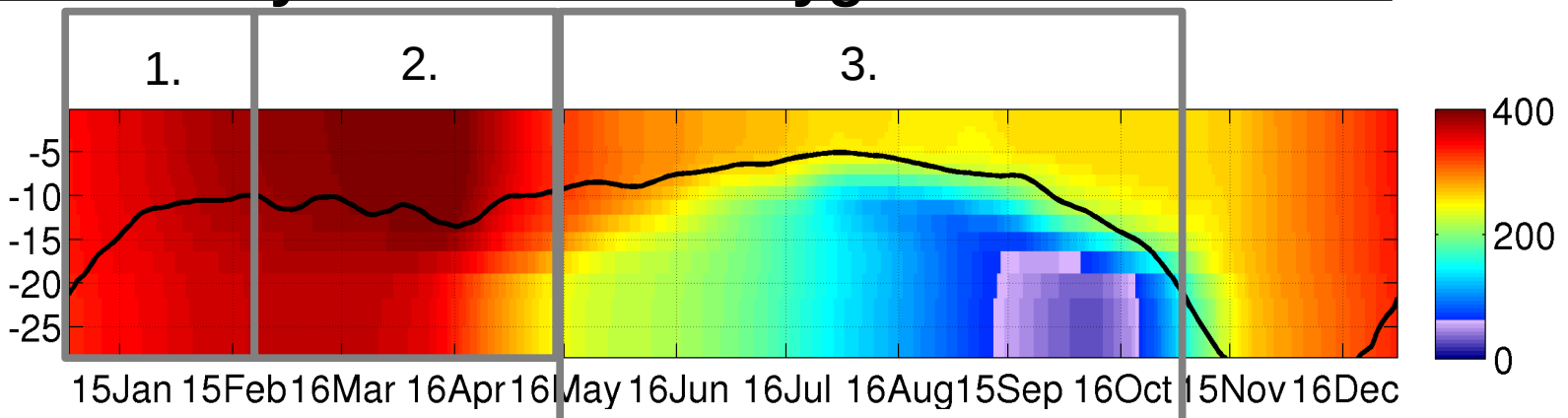
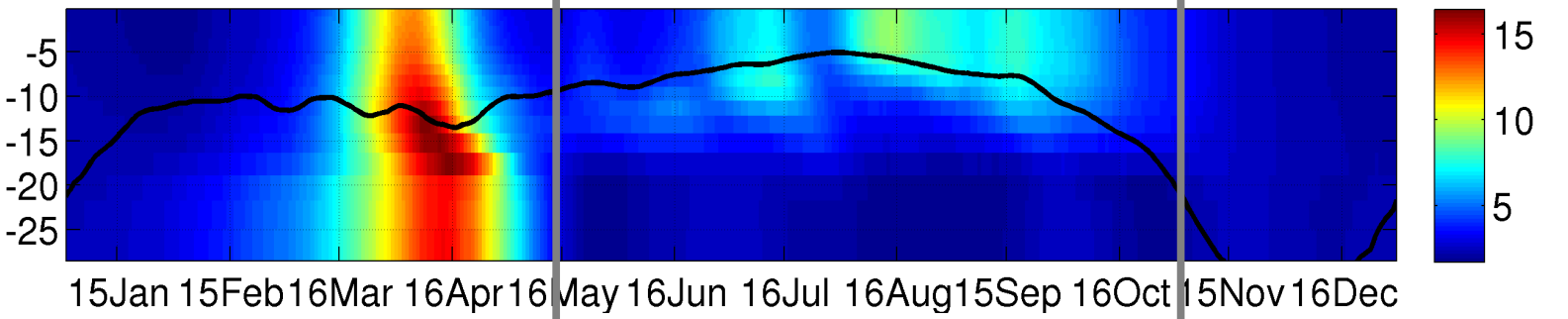




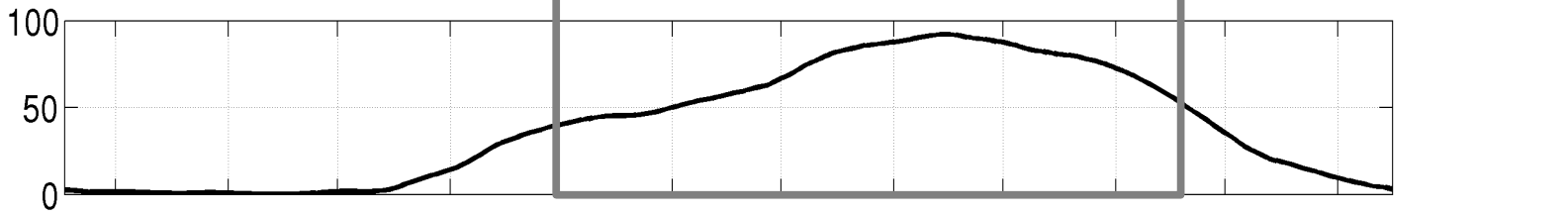
3. Sediment activity

- Starting from spring bloom and when wave induced bottom stress start to lower, organic matter start to accumulate in the sediments.
- A second marked increase occur in July with the onset of the summer bloom.

Chlorophyll [mg/m³]



Fast C stock [mmolC/m²]



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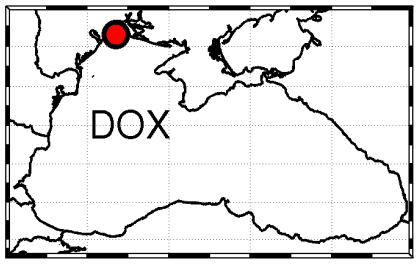

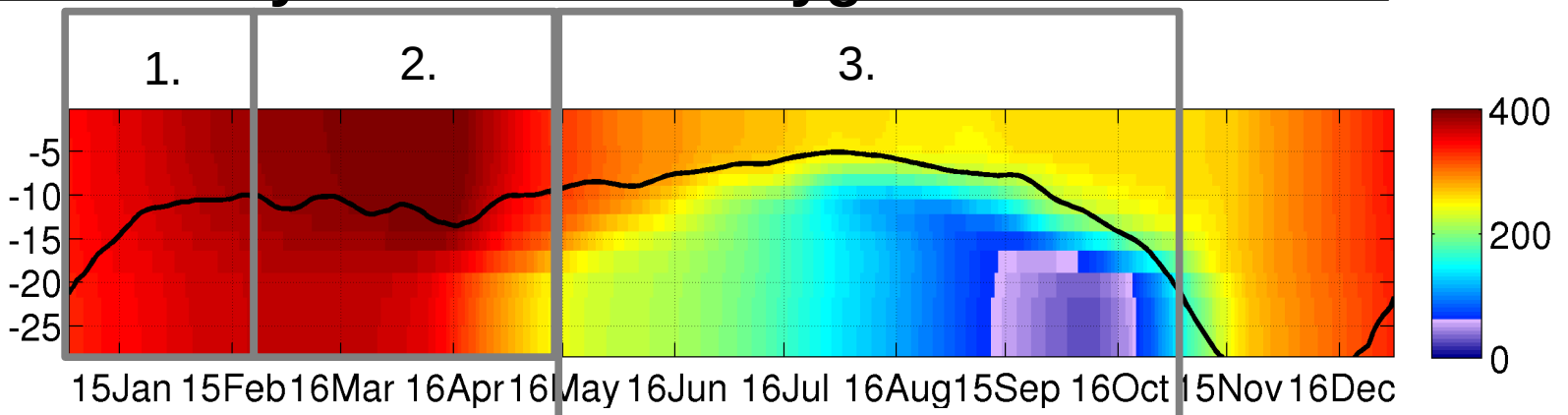

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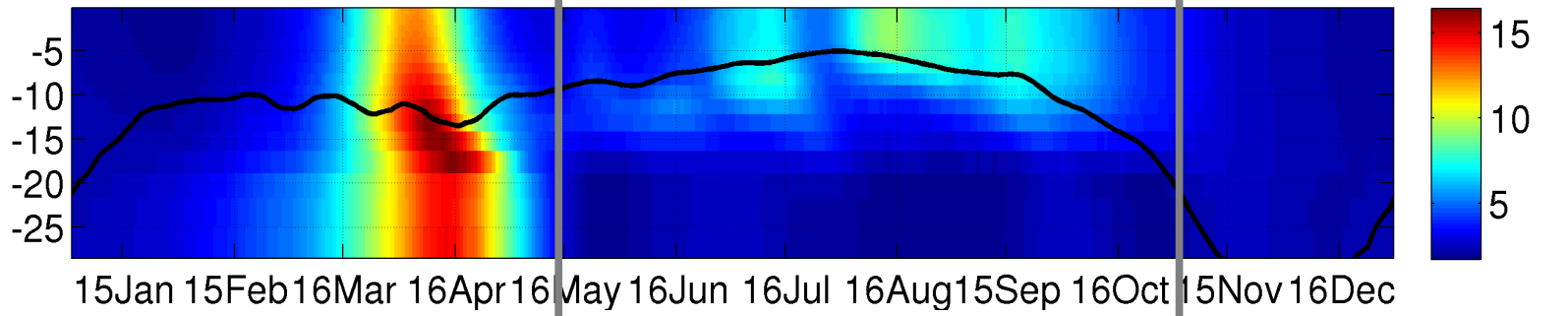

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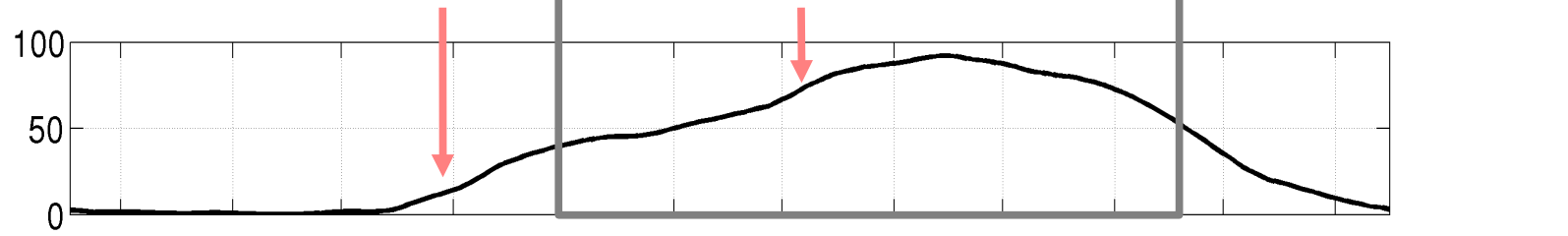

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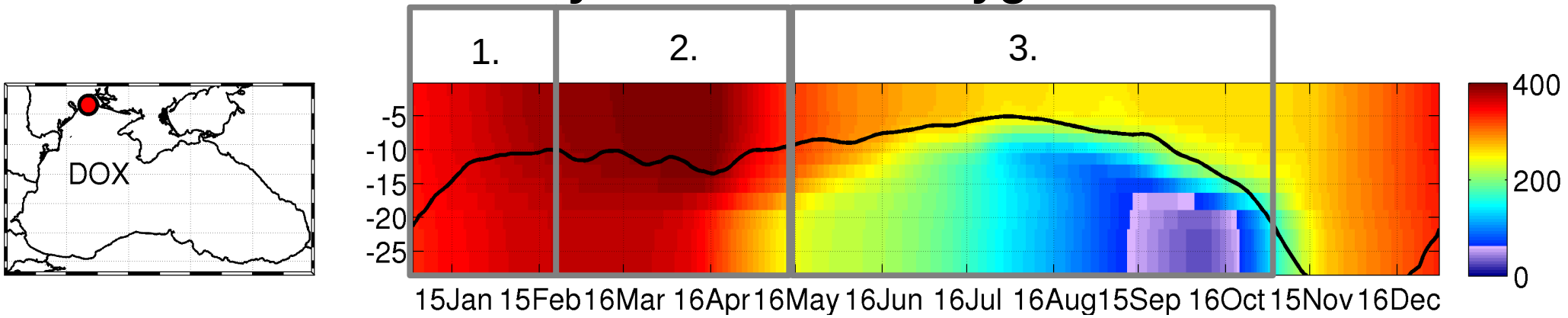
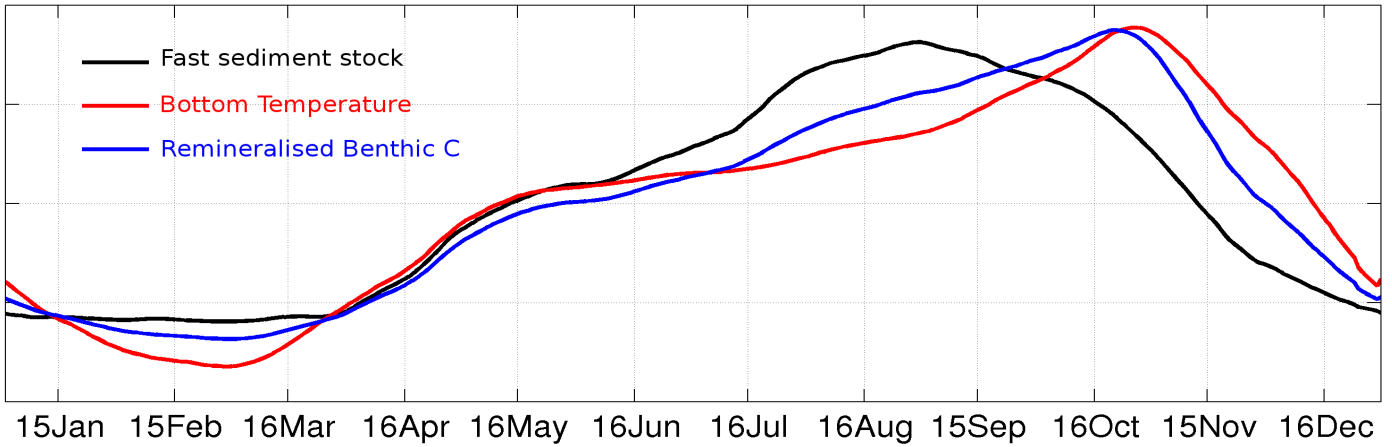


3. Sediment activity

- Benthic Remineralisation depends on sediment organic content but is modulated by bottom Temperature.



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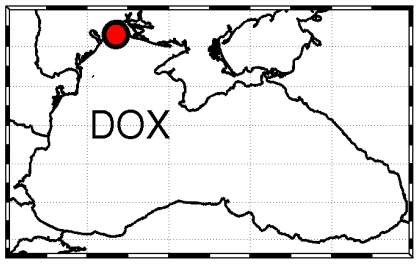
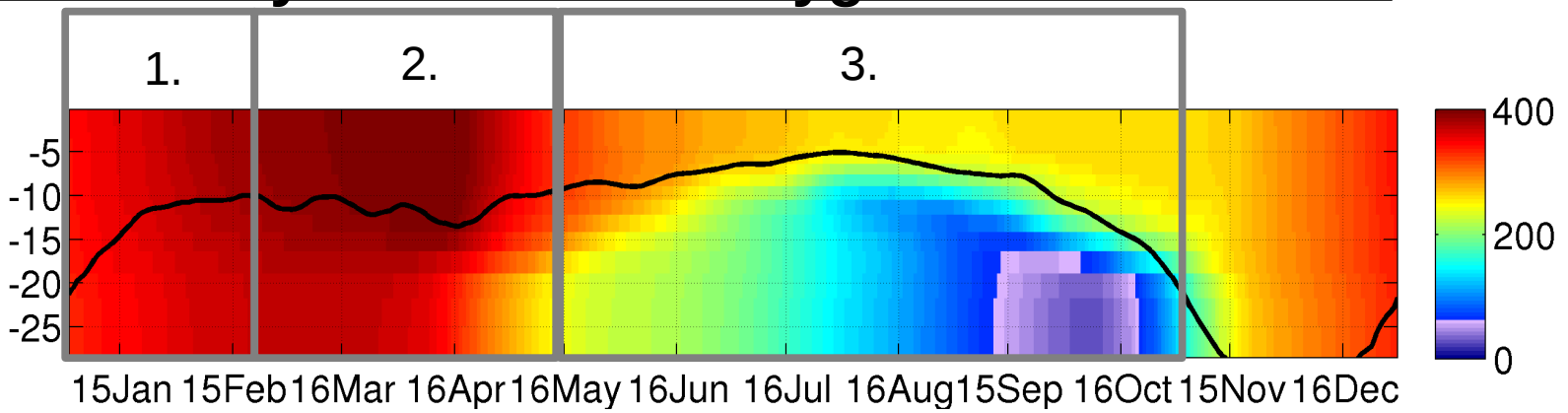
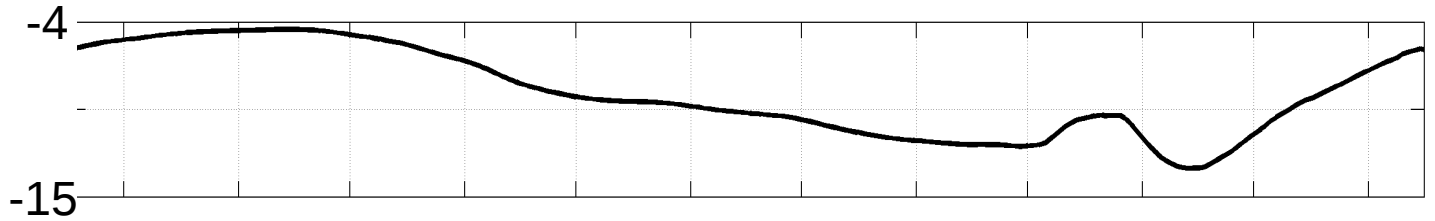




3. Sediment activity

- **Benthic remineralisation** has a direct effect on bottom oxygen concentration trough :
  - **Downward Oxygen fluxes**.
  - When hypoxic conditions settles **ODU (H2S) is released**, and causes further oxygen consumption in the water collumn.

Benthic Ox. Fluxes [mmol O /m²/d]



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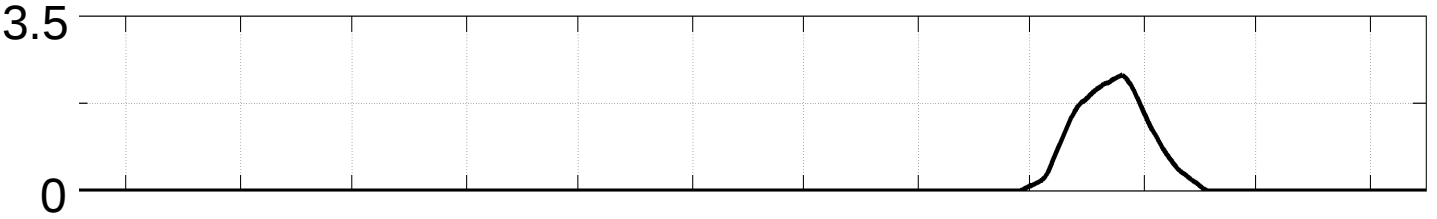

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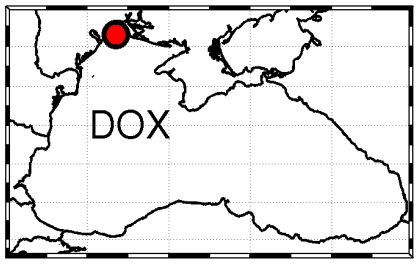

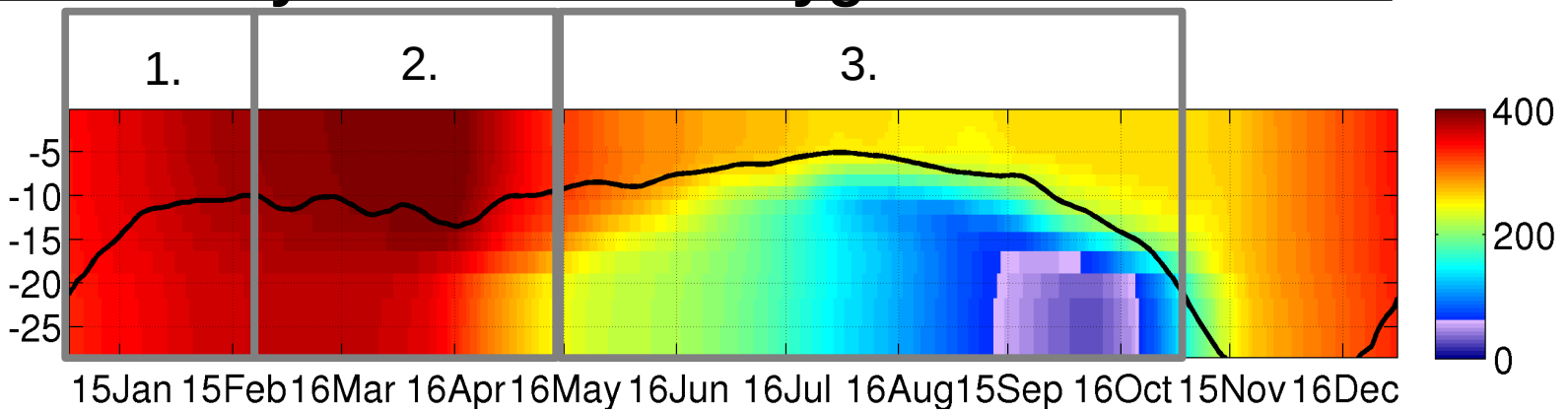

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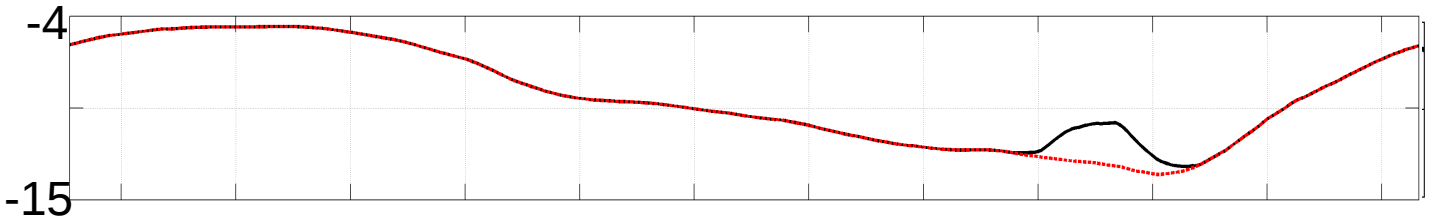

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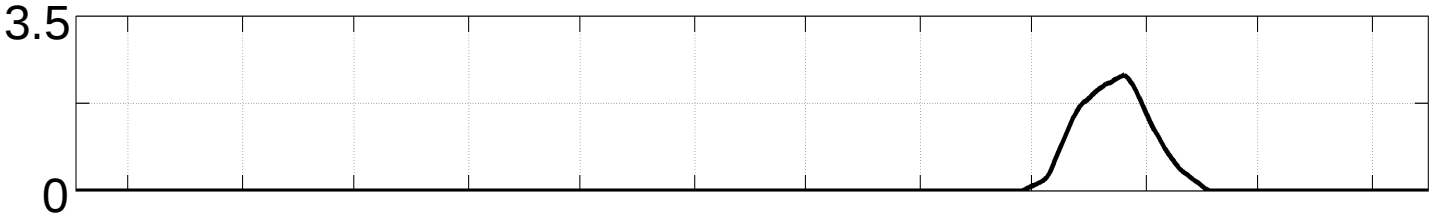

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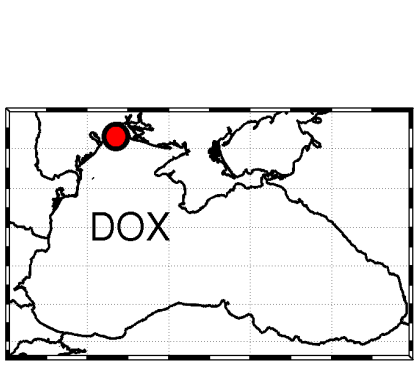

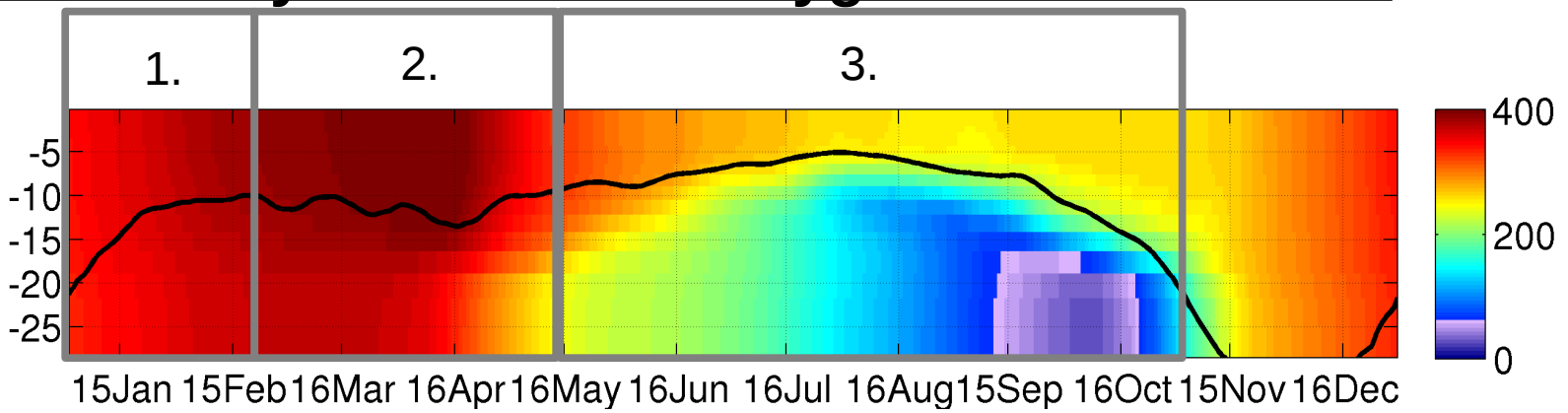

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  - **Downward Oxygen fluxes**.
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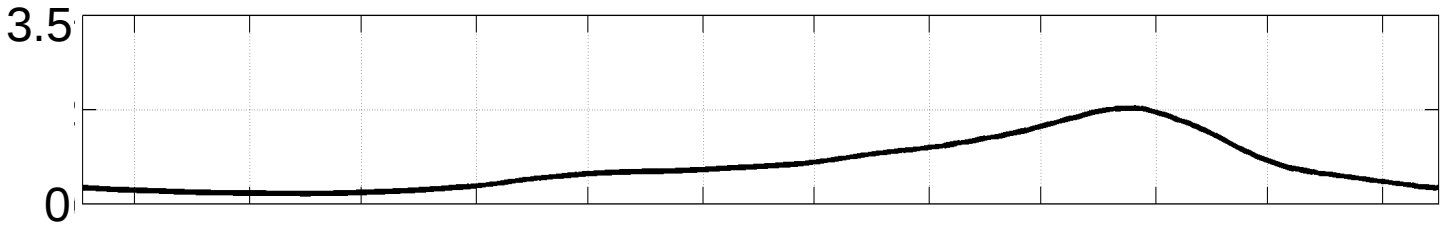
  - **Ammonium released** by the remineralisation of the benthic organic N content further lead to oxygen consumption trough **nitrification** in the water collumn.

Benthic NH4 Fluxes [mmol N /m²/d]



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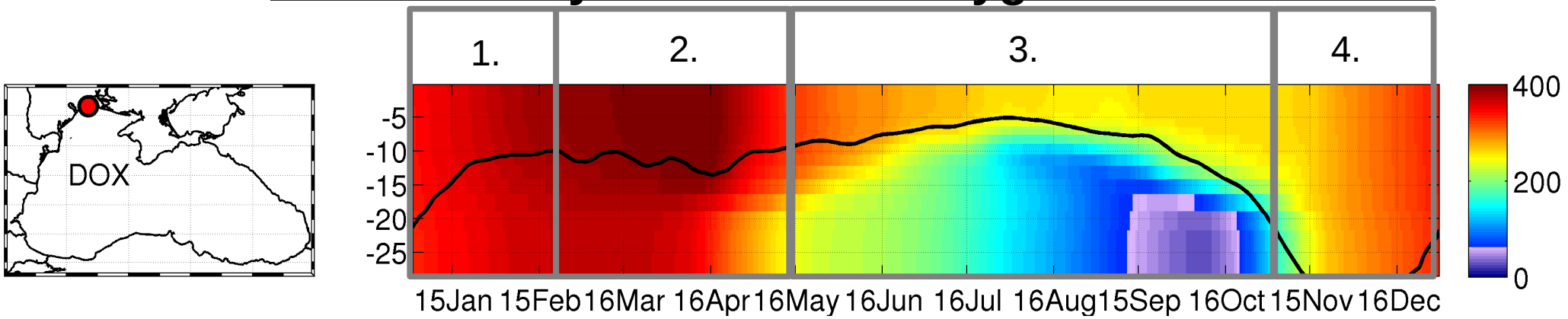
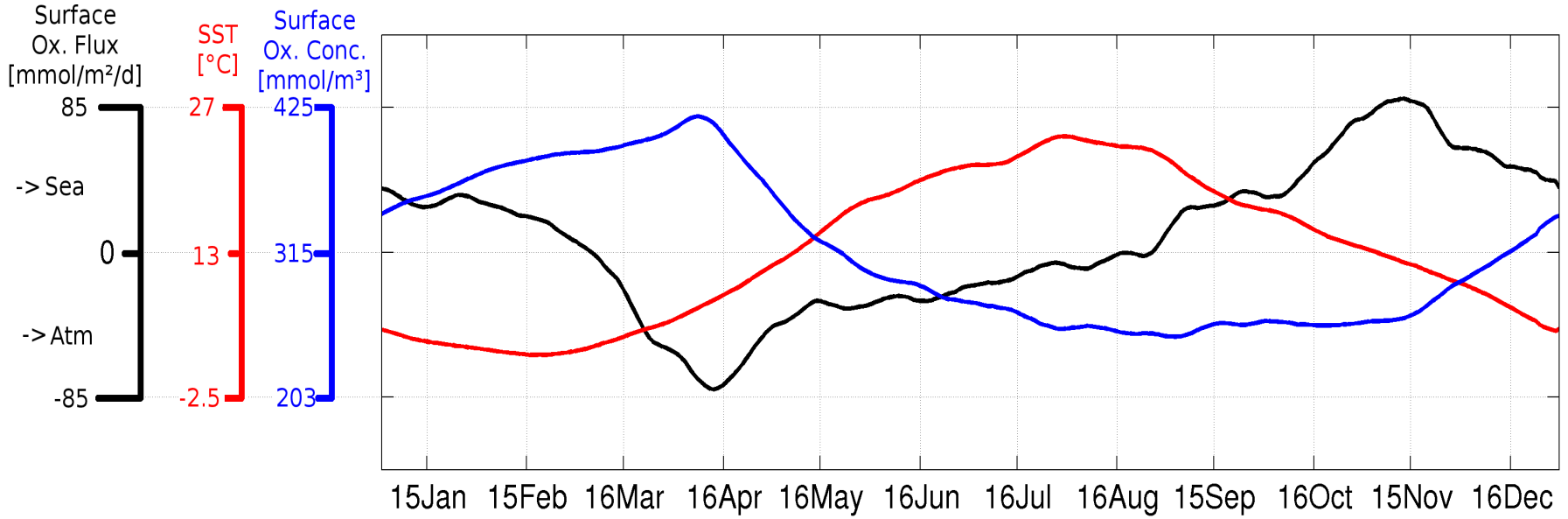


4. Thermocline breakdown

- In October, lowering SST and strong winds **enhance the mixed layer depth**.
- The **fast sediment stock is emptied** by remineralisation and resuspension.
- **Incoming surface oxygen** fluxes maintain the surface concentration trough the mixing period with underlying deoxygenated waters.
- Surface oxygen concentration only to rise when the mixing is complete and lowered SST increase the oxygen solubility.



Oxygen Climatological Annual Cycle

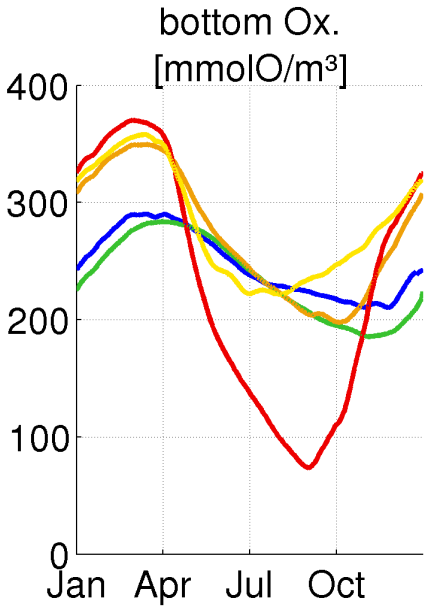
- Nov → March : Mixed water column and positive surface fluxes
- March-May : Spring bloom trigger pelagic remineralisation
- May-October : Accumulation in sediments and rising bottom temperature cause benthic remineralisation. Oxygen consumption trough :
    - Downward oxygen fluxes.
    - Release of H2S (during hypoxia).
    - Nitrification of released Ammonium.

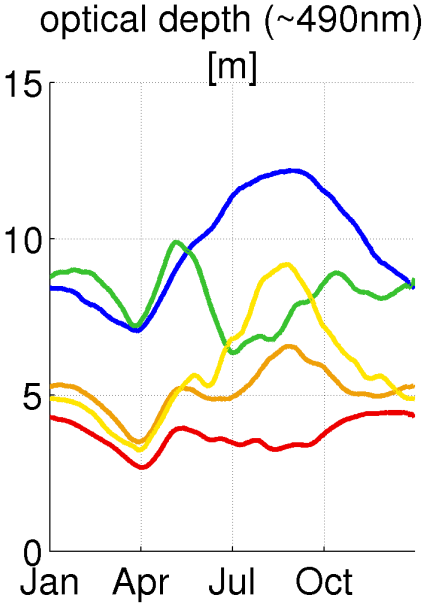
Surface concentration is maintained by surface fluxes.

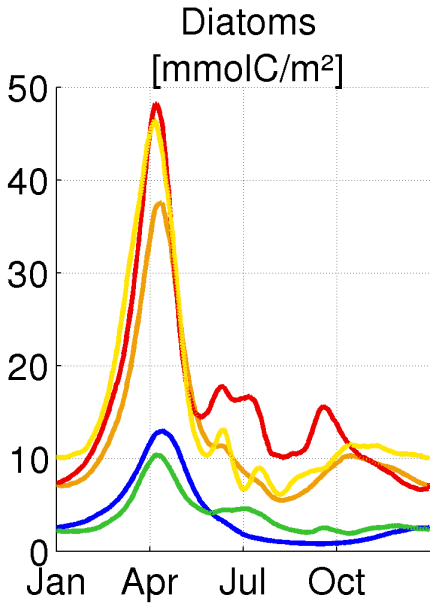
- November : Thermocline breakdown → ventilation

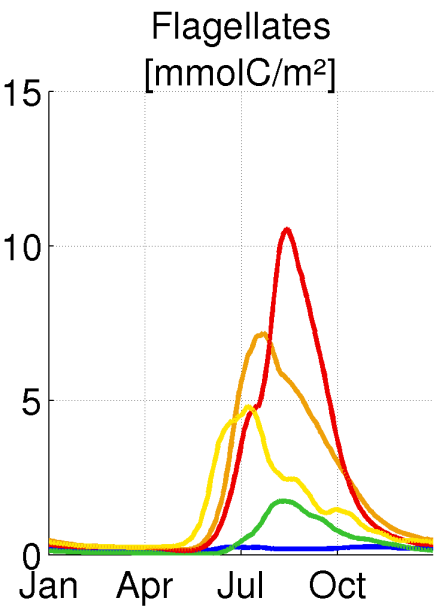
Spatial variability

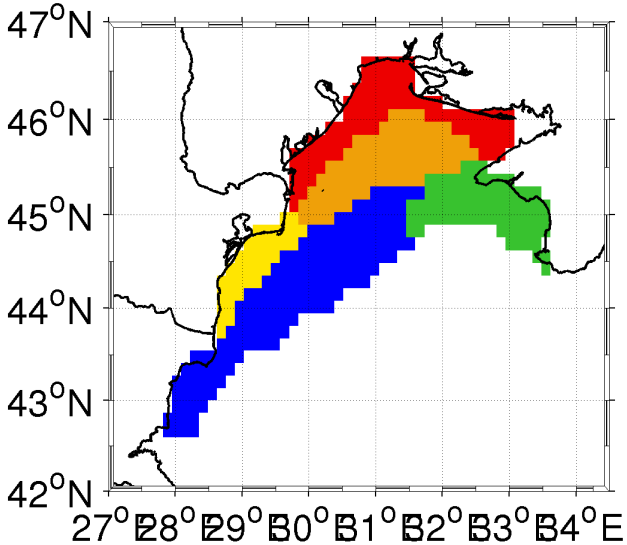
Spatial variability

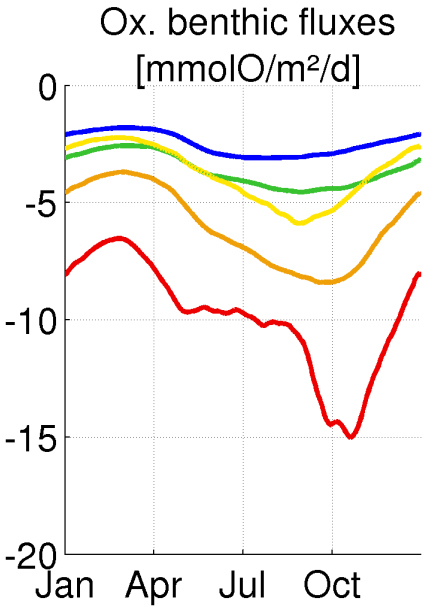


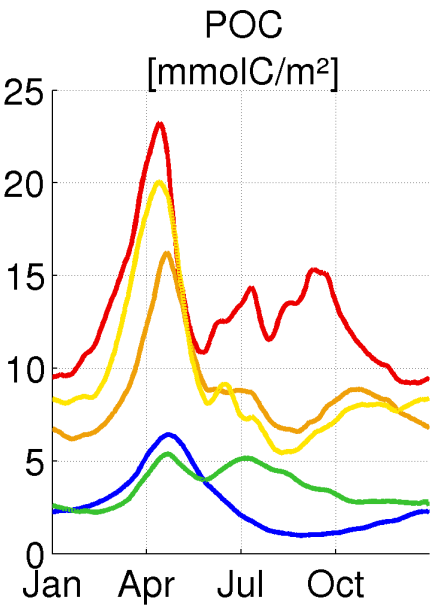


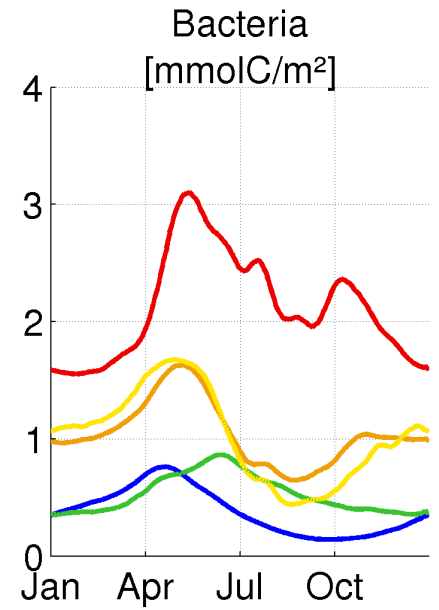






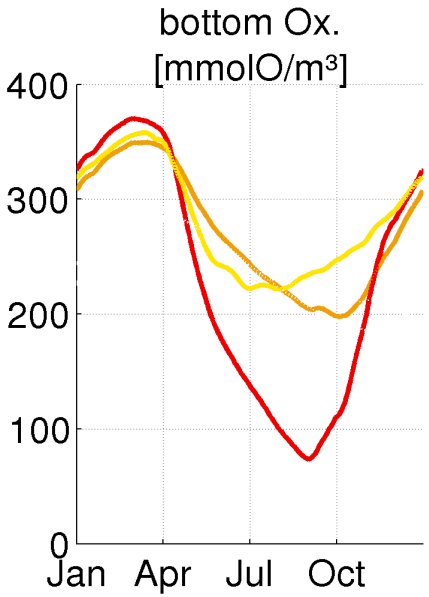


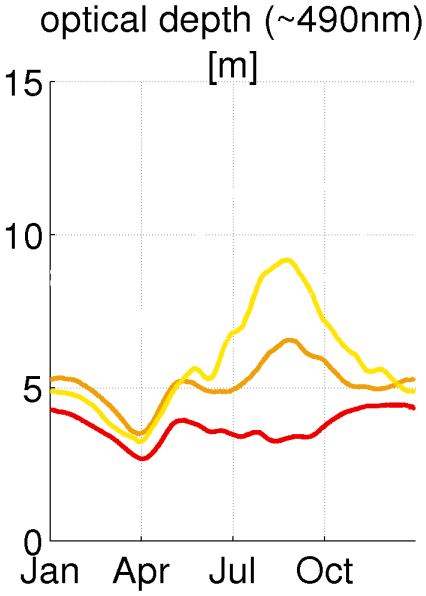


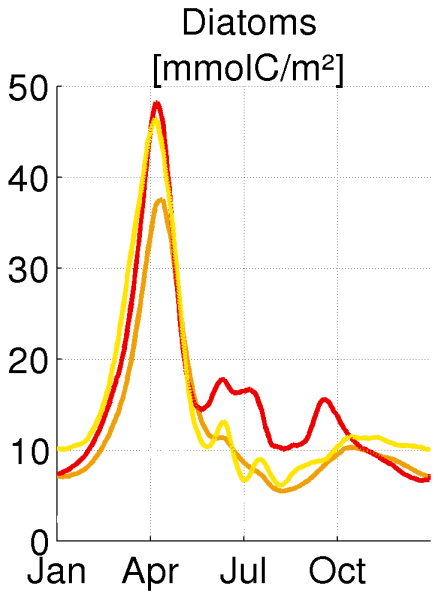


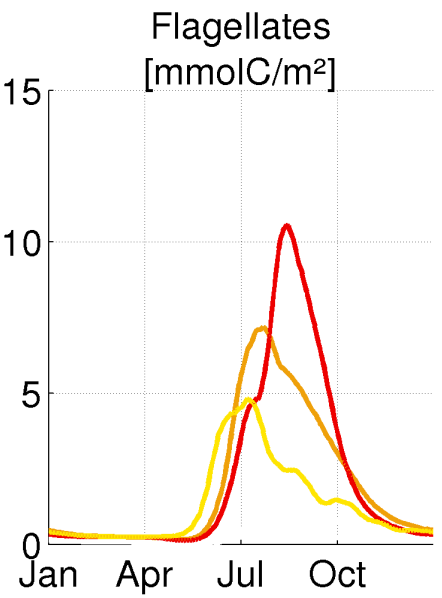
Spatial variability

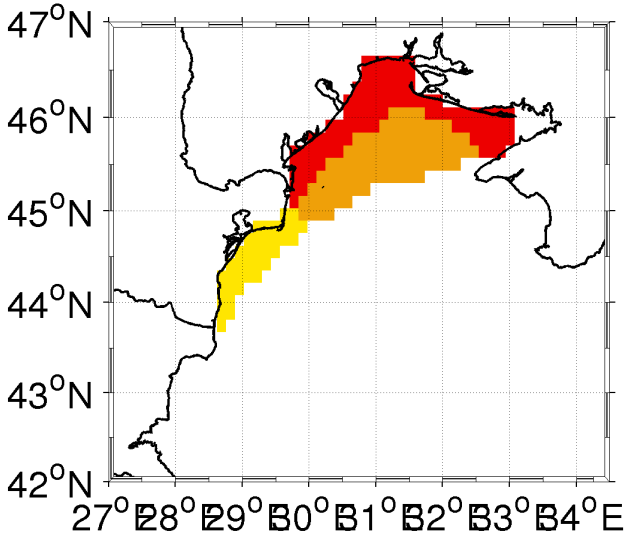
Northern shelf

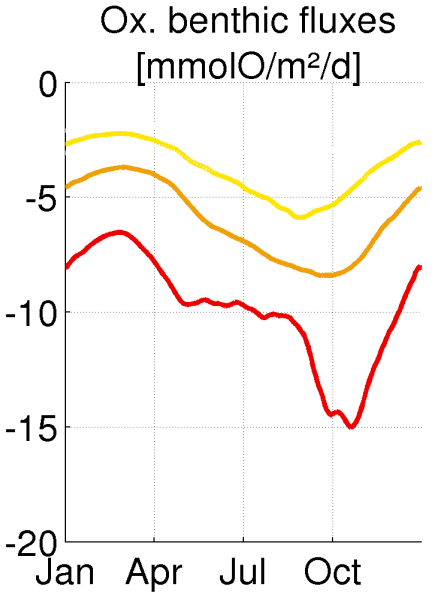


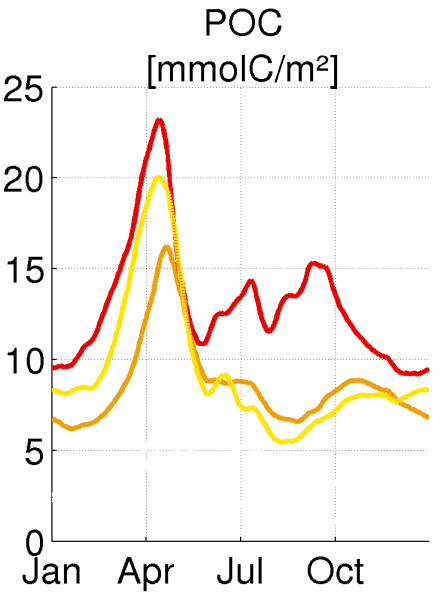


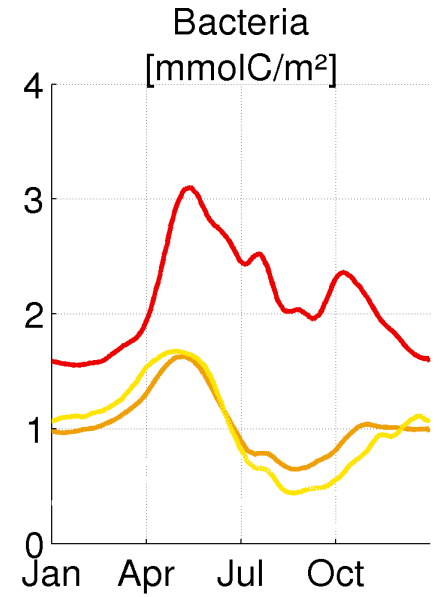




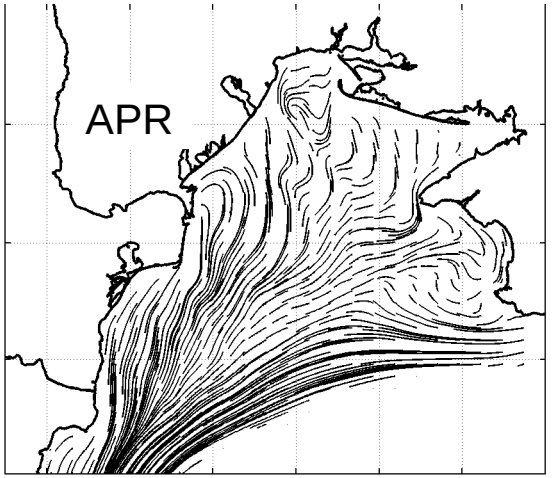


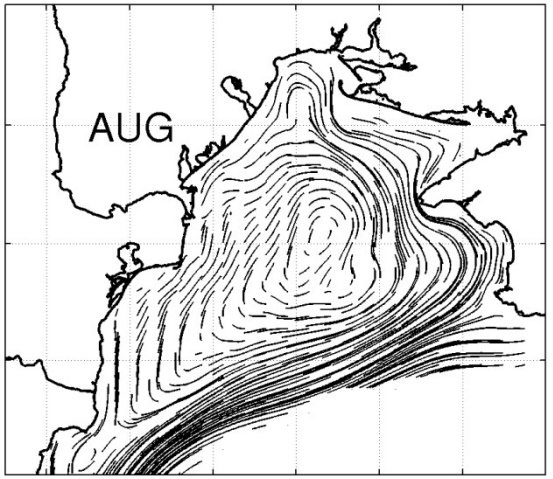


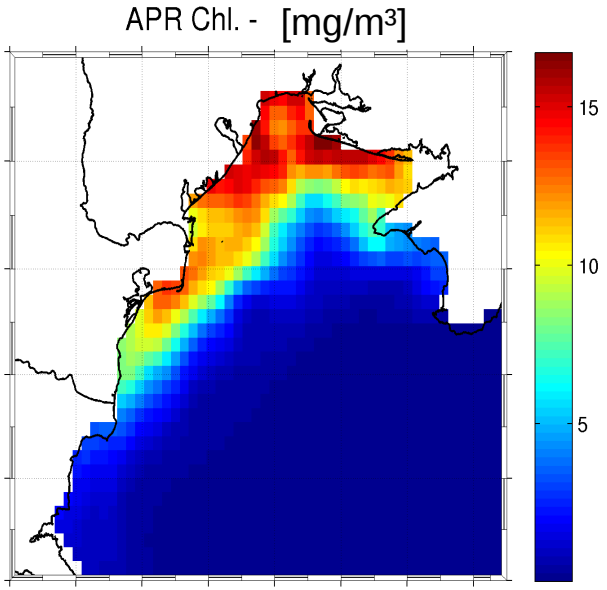


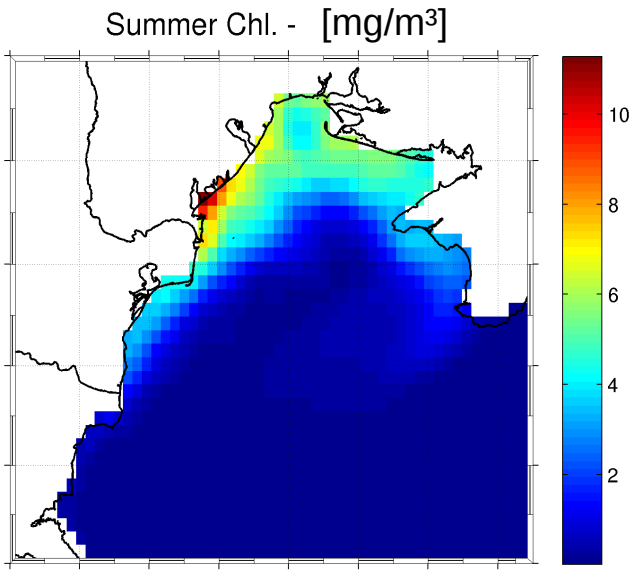


Spatial variability



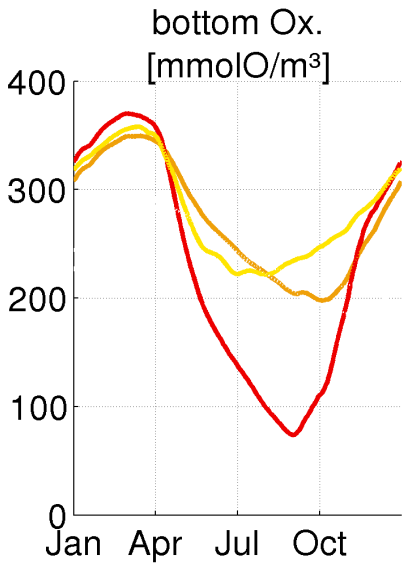


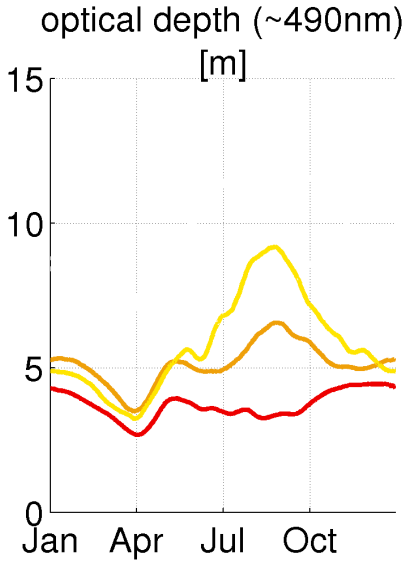


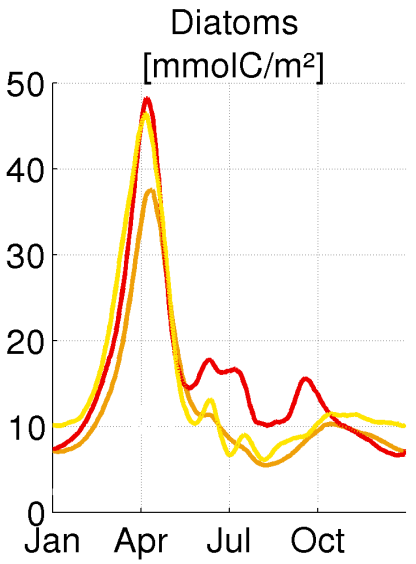


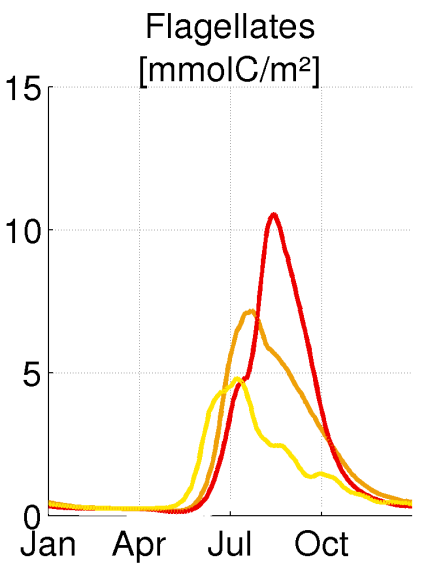
Spatial variability

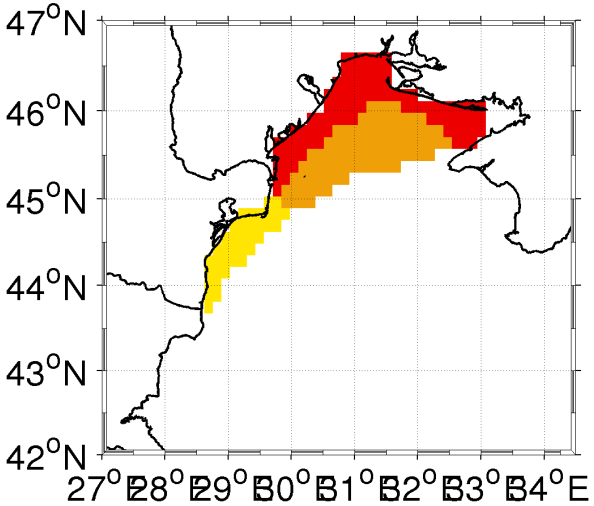
Northern shelf

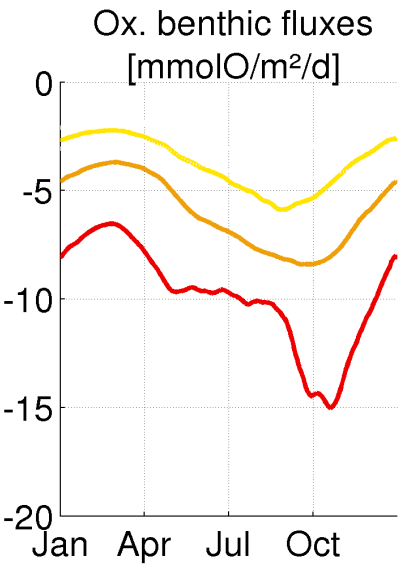


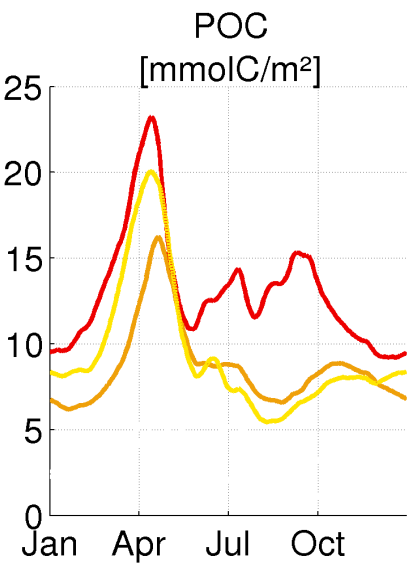


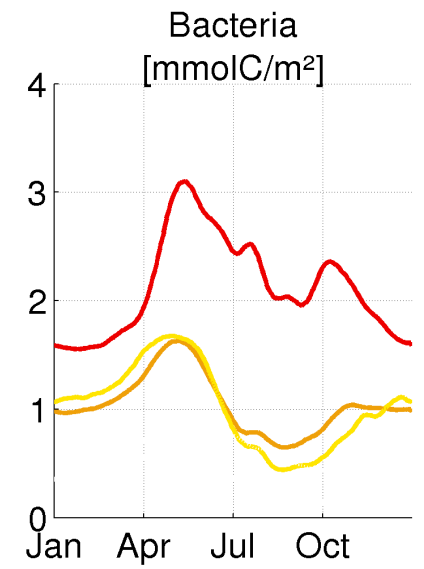




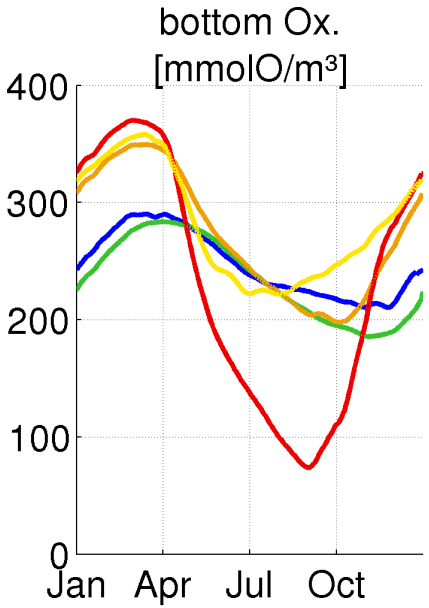


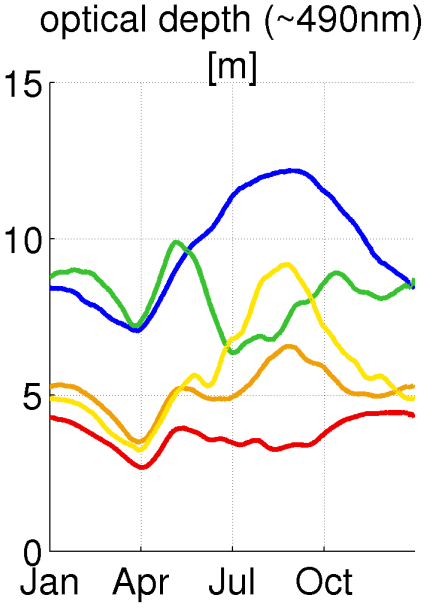


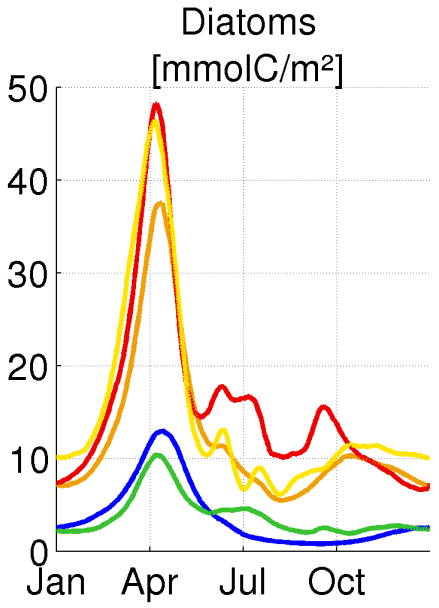


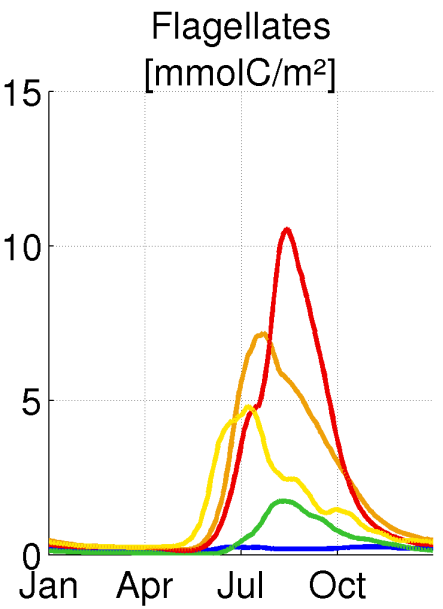


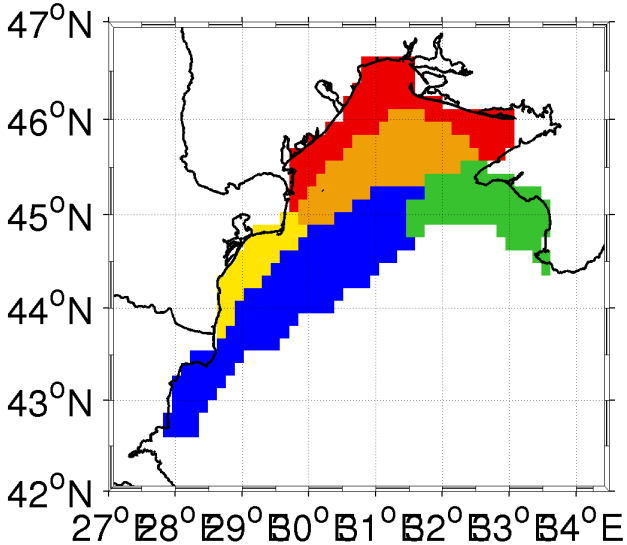
Spatial variability

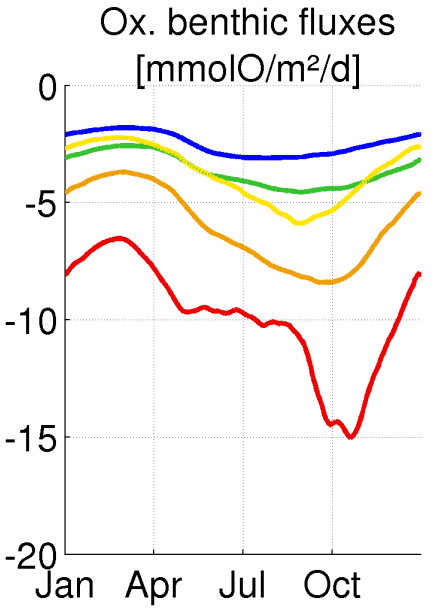


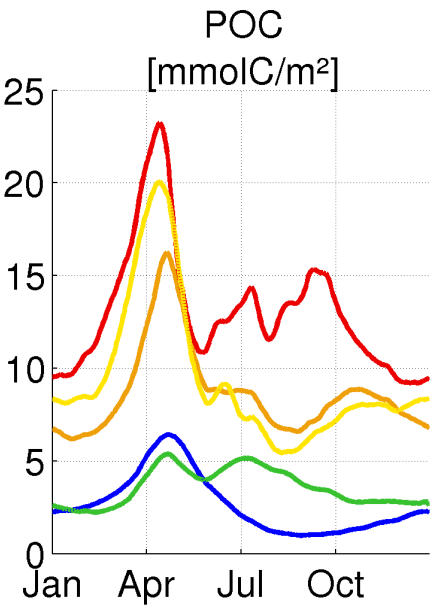


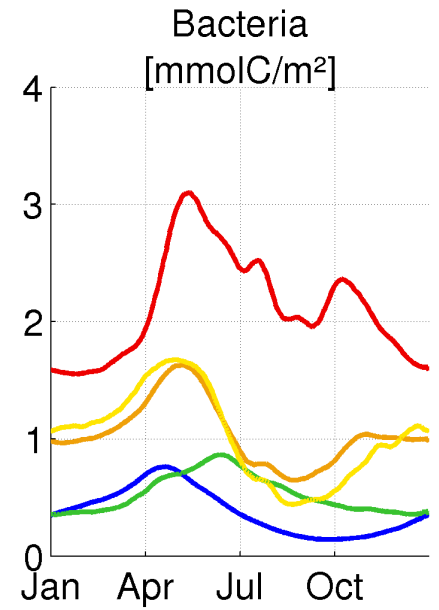






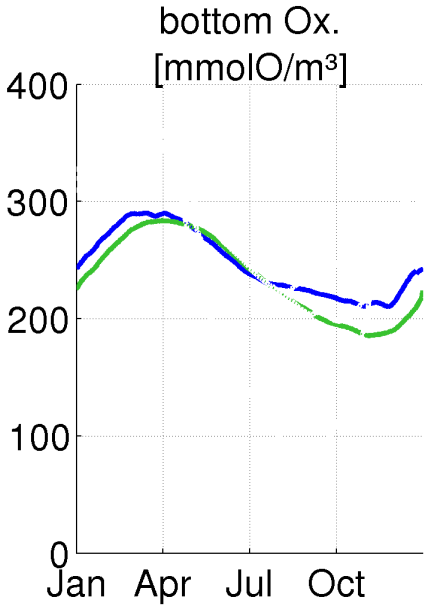


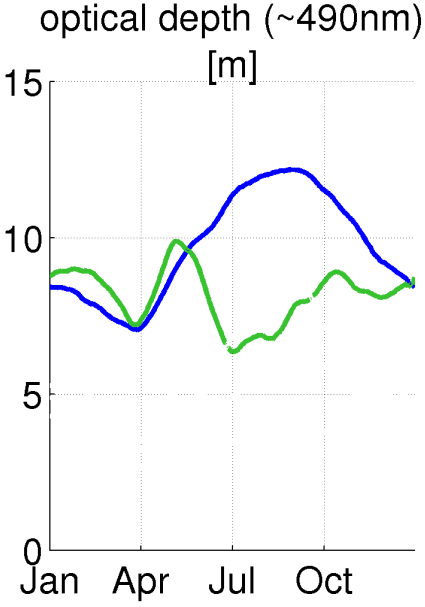


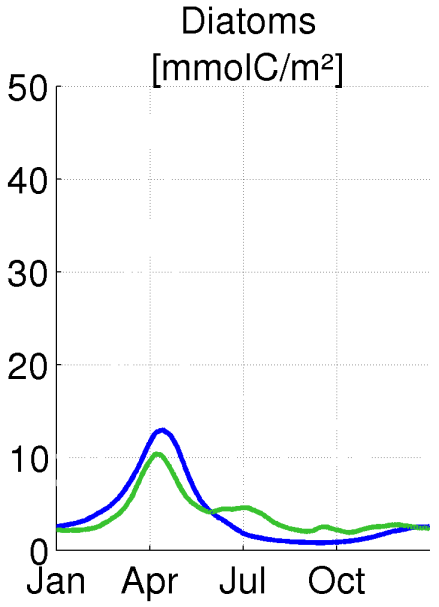


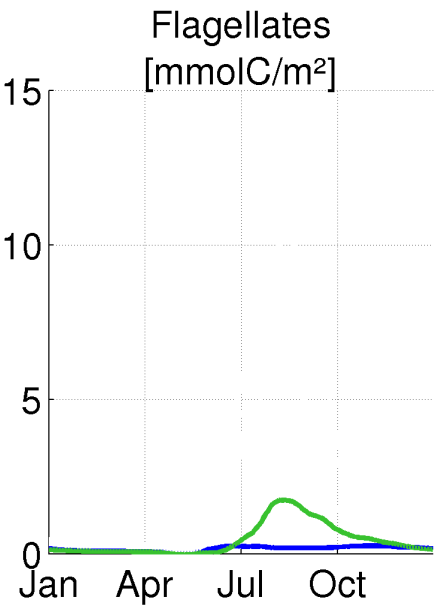
Spatial variability

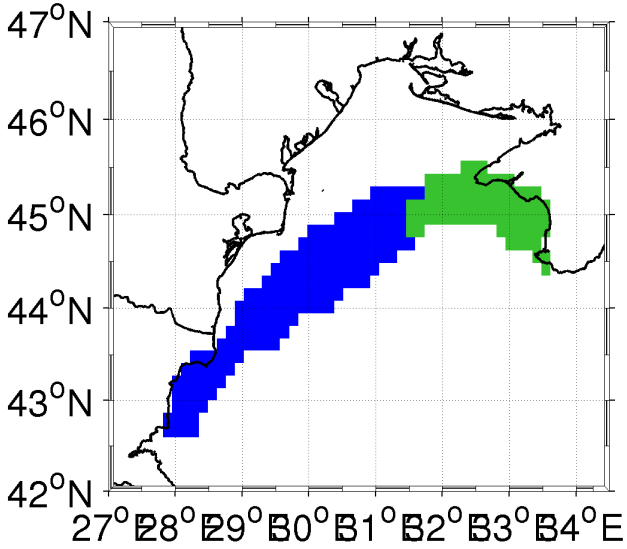
Southern shelf

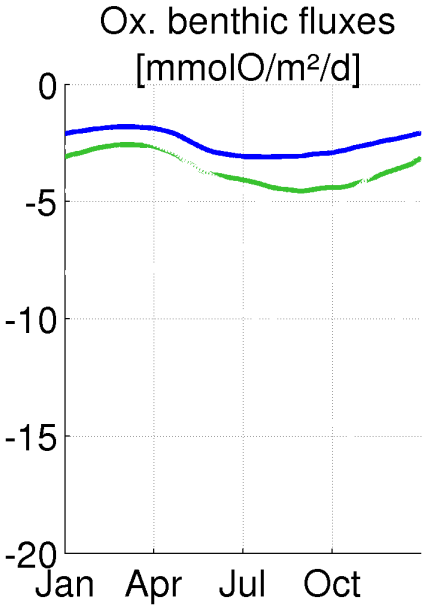


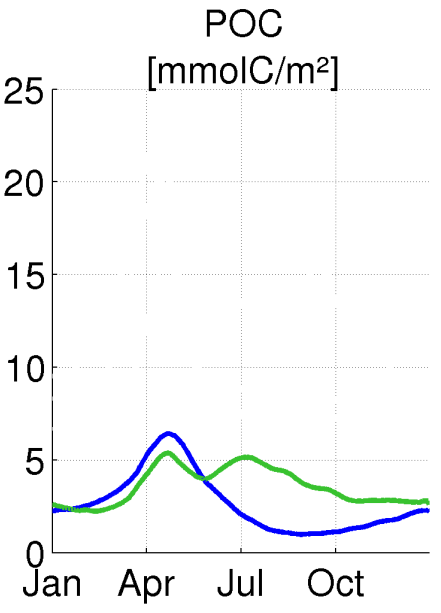


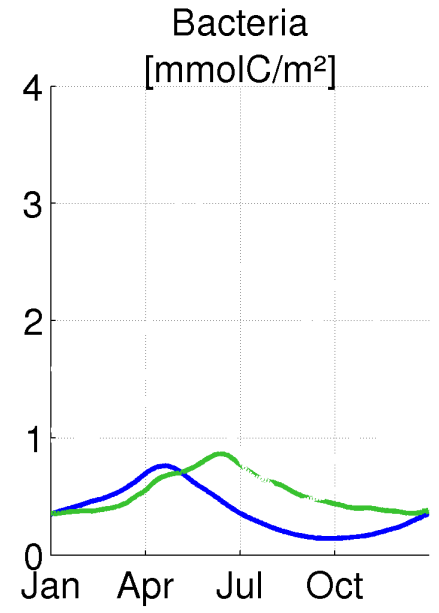




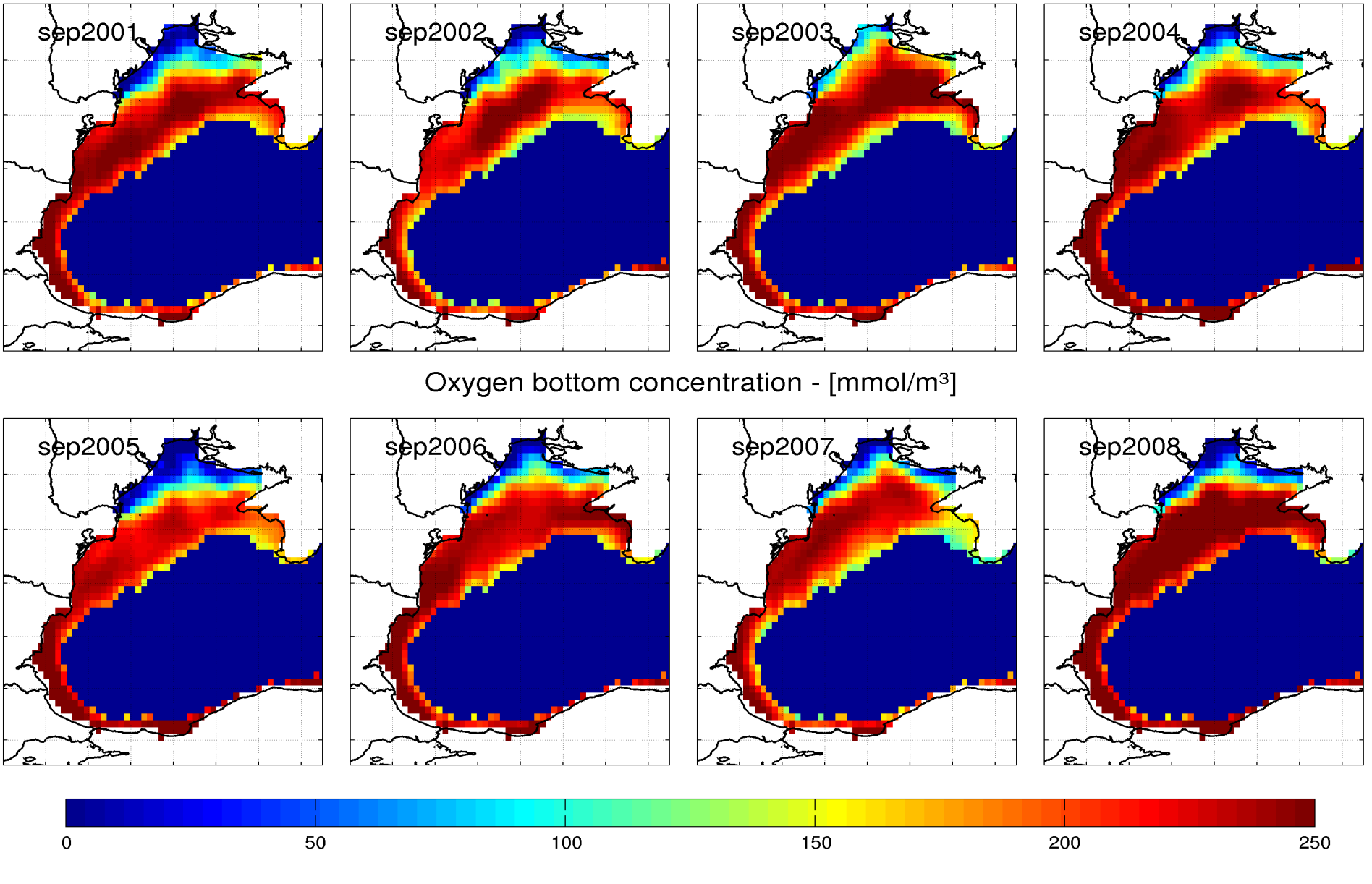




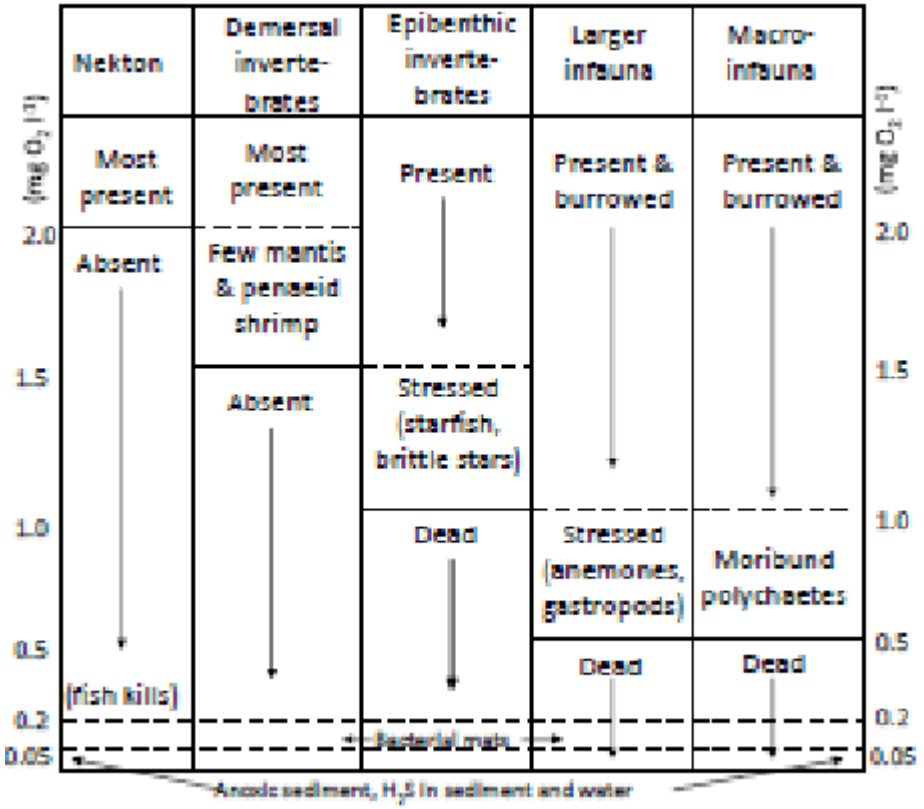




Interannual variability



Interannual variability

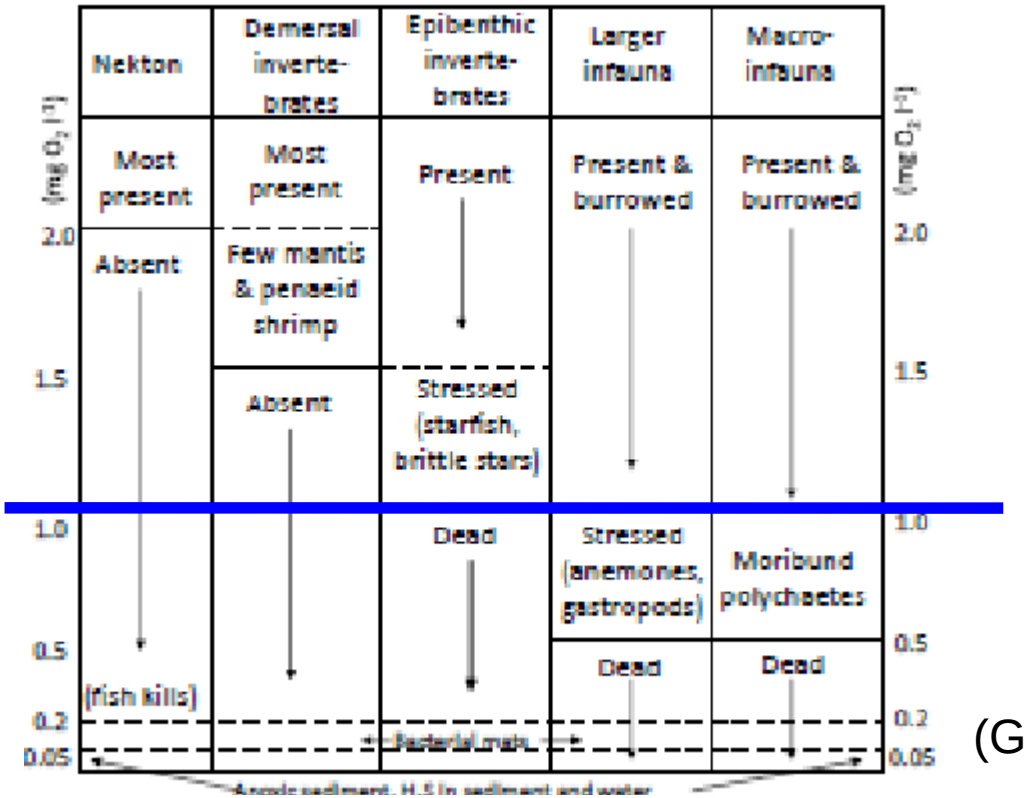


- Various species are effected differently from low Oxygen conditions.

→ The Study of hypoxia should be species specific.

(Gray et al. MEPS 2002)

Interannual variability



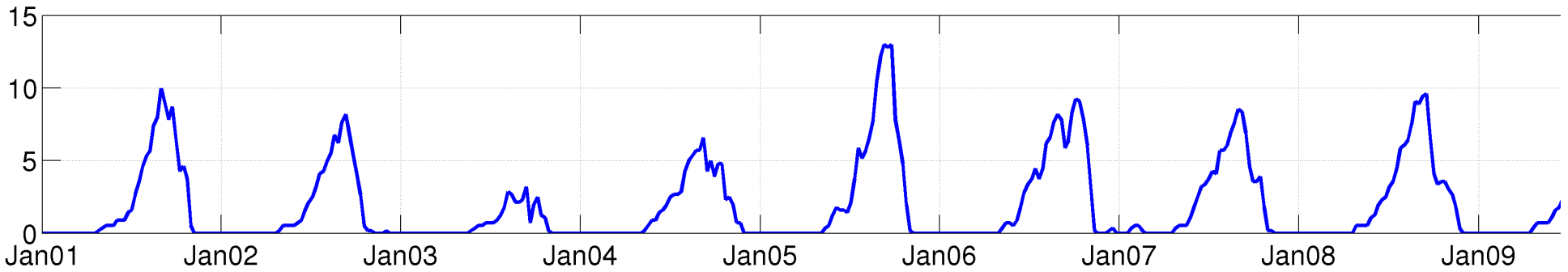
- Various species are effected differently from low Oxygen conditions.

→ The Study of hypoxia should be species specific.

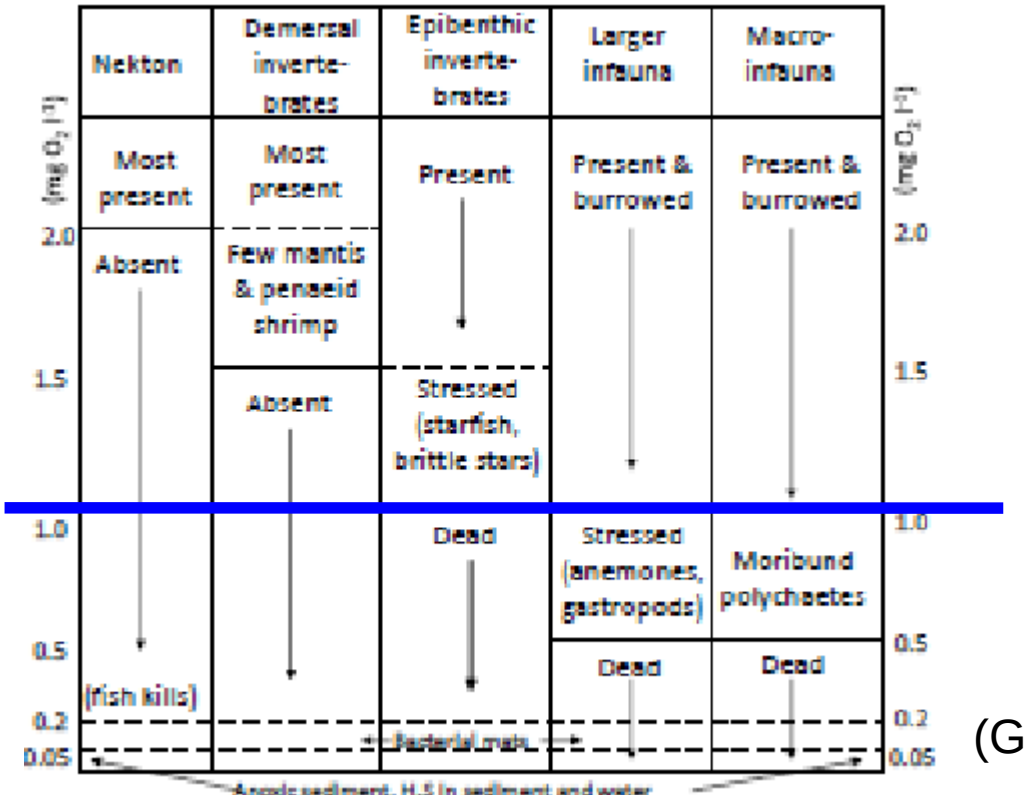
- A fixed threshold allows to compute statistics.

(Gray et al. MEPS 2002)

NW shelf area under Hypoxic conditons (< 62 mmolO/m³)



Interannual variability



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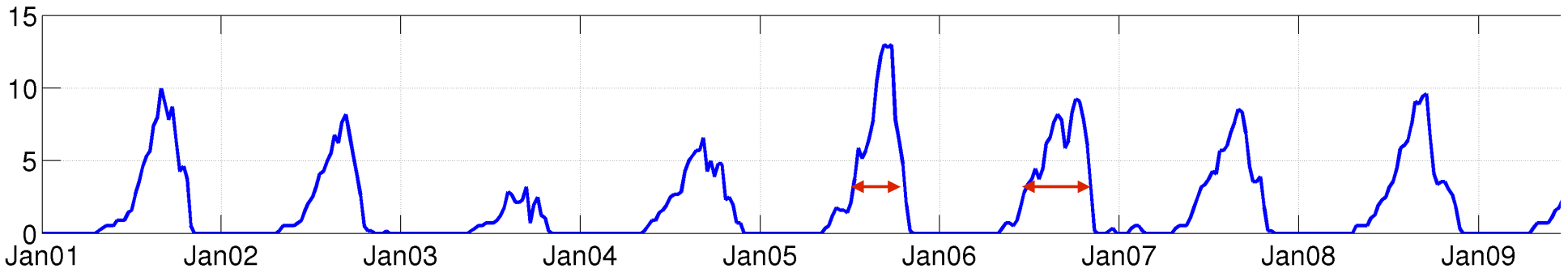
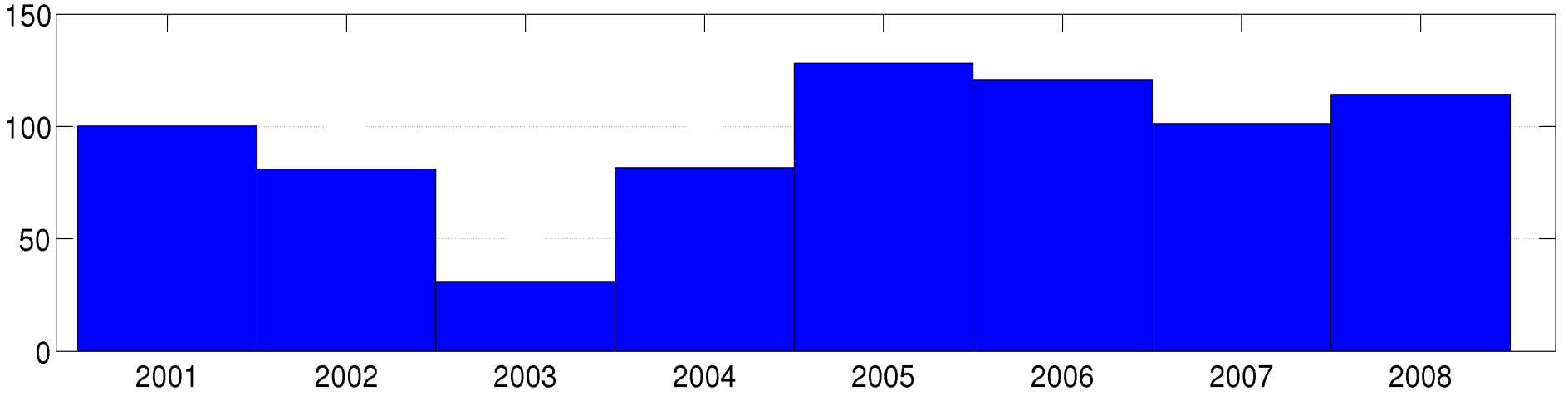
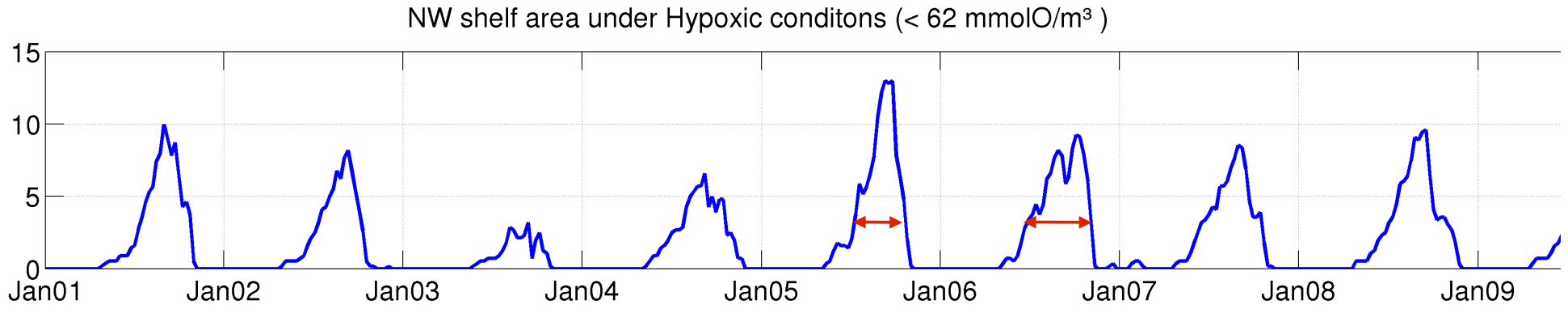


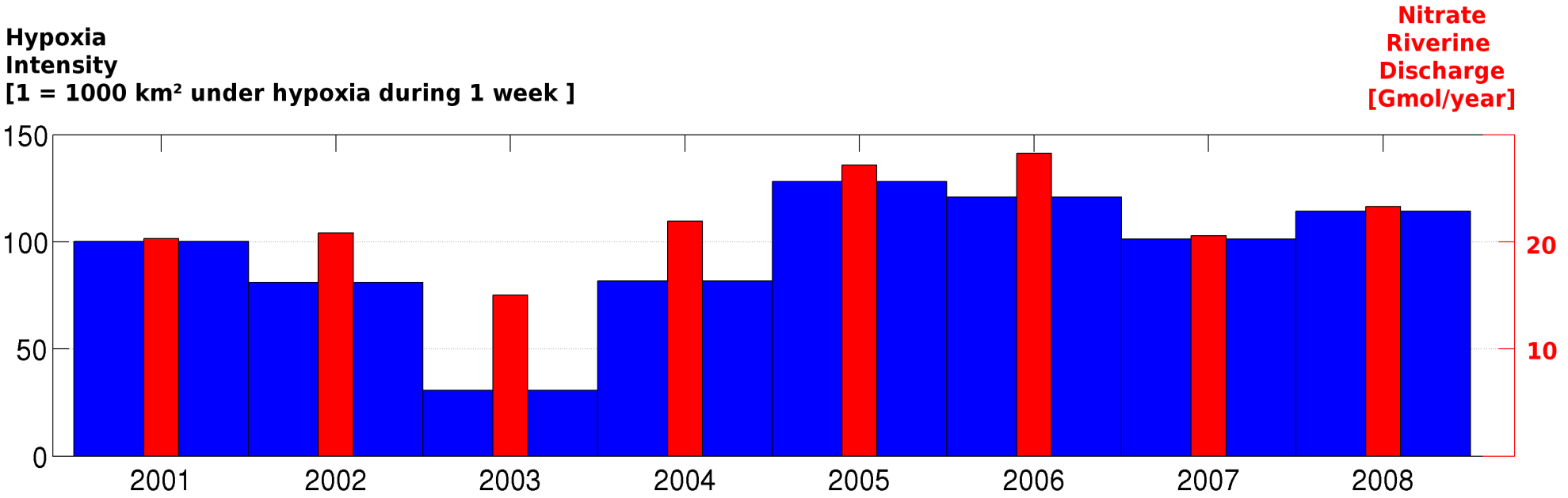
Interannual variability

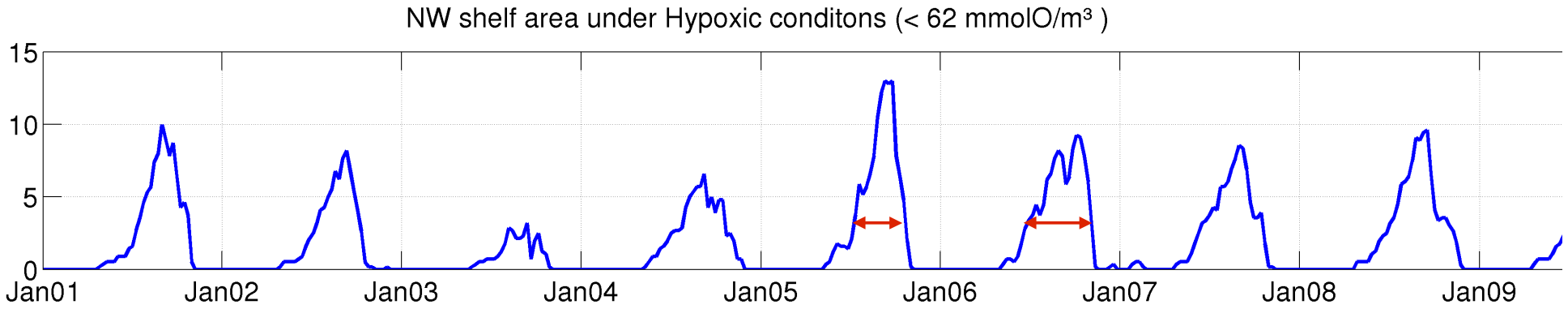
Hypoxia
Intensity
[1 = 1000 km² under hypoxia during 1 week]





Interannual variability





Conclusions : 1

- Seasonal Hypoxic events occur each year on Black Sea North western.
- Seasonal variability results from :
    - Stratification cycle, bottom temperature, resuspension preventing sedimentation.
- Spatial variability mainly results from :
    - Distance to river mouth.
    - Seasonnal Motion of the river plume (circulation inversion from cyclonic to anticyclonic) .
- Interannual variability relates well with Nitrogen river discharge. Additional process modulates this relationship.
- The model allows to represent simultaneously the numerous processes intervening in the oxygen budget and their interaction on seasonnal and interannual scales.

Conclusions : 2

Oxygen Climatological Annual Cycle

- **Nov → March** : Mixed water column and positive surface fluxes
- **March-May** : Spring bloom trigger pelagic remineralisation
- **May-October** : Accumulation in sediments and rising bottom temperature cause benthic remineralisation. Oxygen consumption trough :
    - Downward oxygen fluxes.
    - Release of H2S (during hypoxia).
    - Nitrification of released Ammonium.

Surface concentration is maintained by surface fluxes.

- **November** : Thermocline breakdown → ventilation

Spatial variability