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**Sapropel S1 Deposition Event:
Modelling Perspectives**

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Sapropel S1 Deposition Event: Modelling Perspectives

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most of the material can be found in *Bianchi et al. (2006)*

OBJECTIVE

The objective of this work is to investigate, by means of a one-dimensional numerical ecosystem model, the role of stagnation and enhanced productivity for the deposition of S1, trying to gain insight on the dynamics of the development of anoxic conditions in the water column and at the sea-floor.
S1 is the most recent sapropel in the succession of organic carbon-rich layers found in normal Neogene sedimentary sequences. Different theories have been invoked to explain the deposition of this peculiar layer.

OUTLINE

- Background
- The Numerical Model
- Model Results
- Conclusions

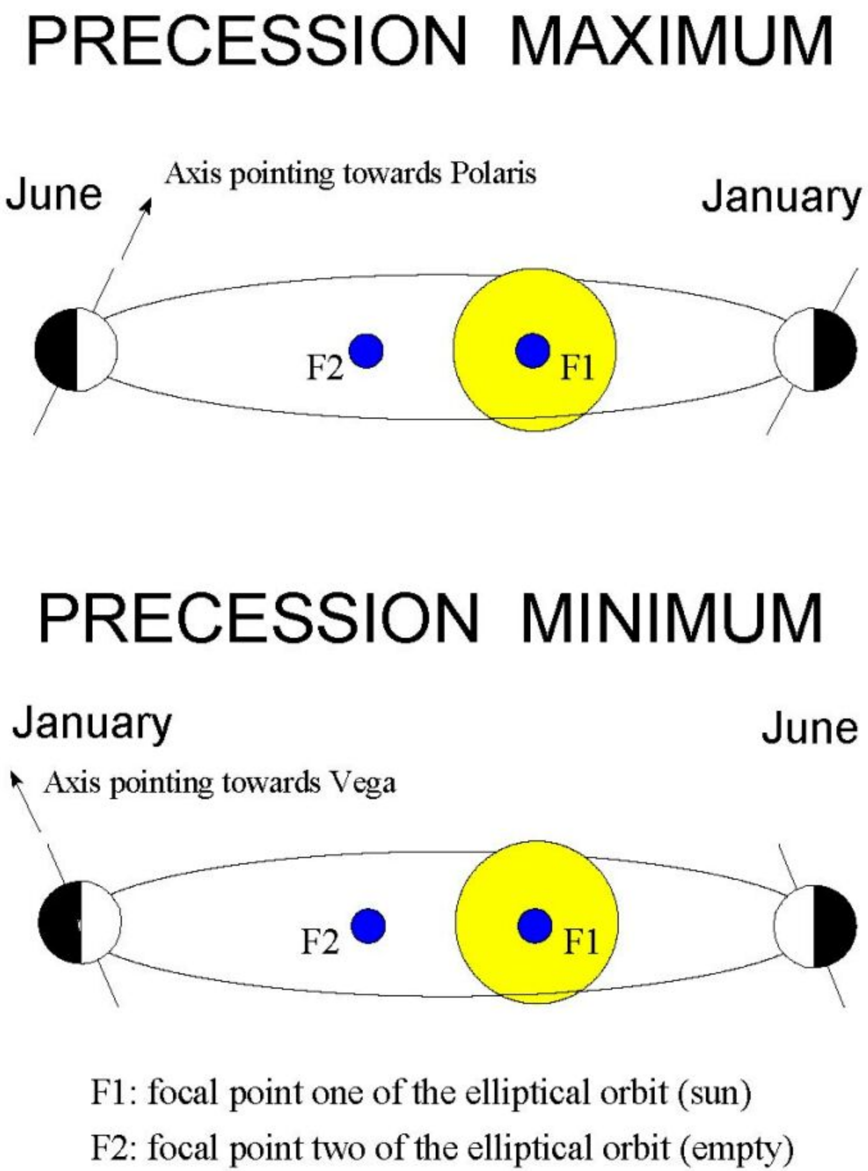
BACKGROUND

•**Sapropel**: cyclic (orbitally driven) occurrence of dark carbon-rich sediment layers with an organic carbon content greater than 2%.

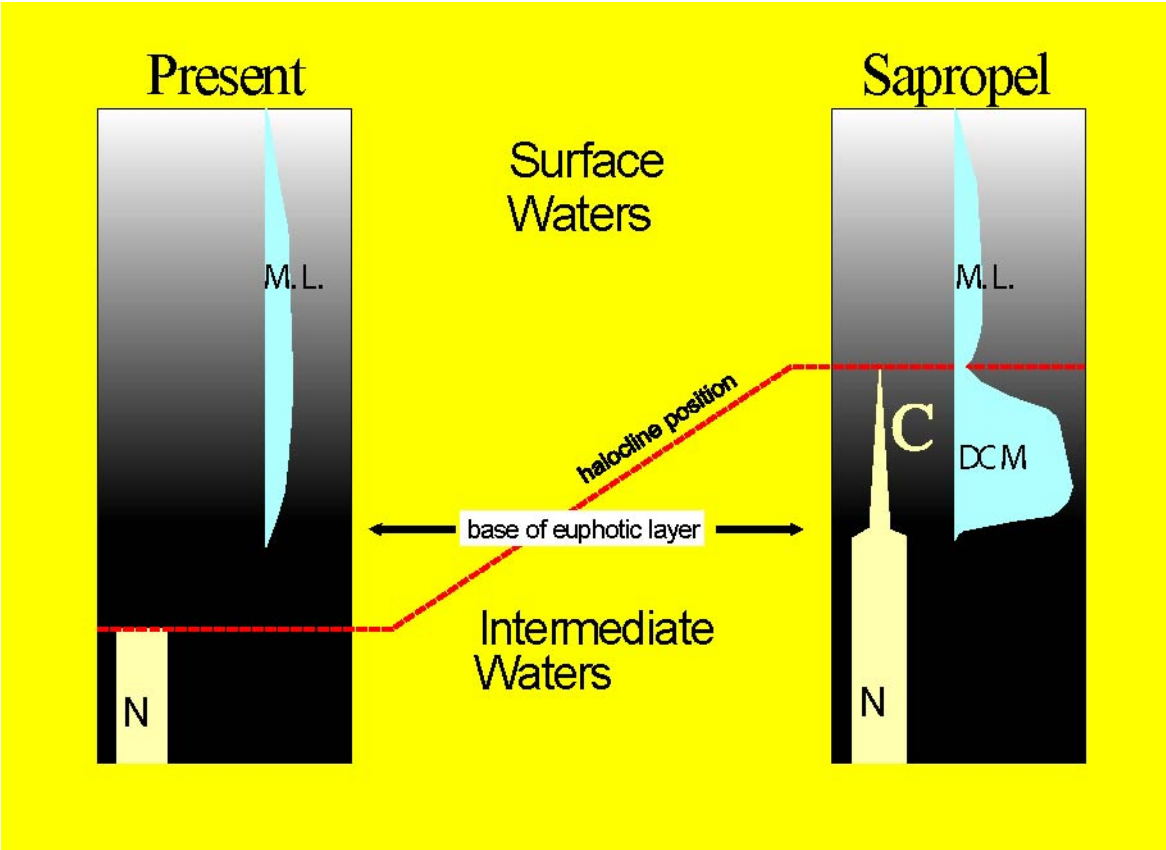
•**Sapropel S1** (the most recent) was deposited during the Climatic Optimum interval of the Holocene (9500-6000 years BP).

•In this period **increased precipitation and river runoff** determined the freshening of the surface layers at a basin scale.

•The occurrence of sapropels has been linked to **anoxic bottom waters** induced by **increased productivity and/or decreased deep water ventilation**. A 200-years interruption found within S1 seems to indicate the rapid transition from anoxic to oxic bottom conditions (Rohling et al., 1997).



During precession minima, the northern hemisphere experiences enhanced summer insolation and reduced winter insolation. The seasonal insolation contrast and the thermal gradient between ocean and continental regions are considerably higher during a precession minimum than today. Therefore the monsoonal circulation is also enhanced.

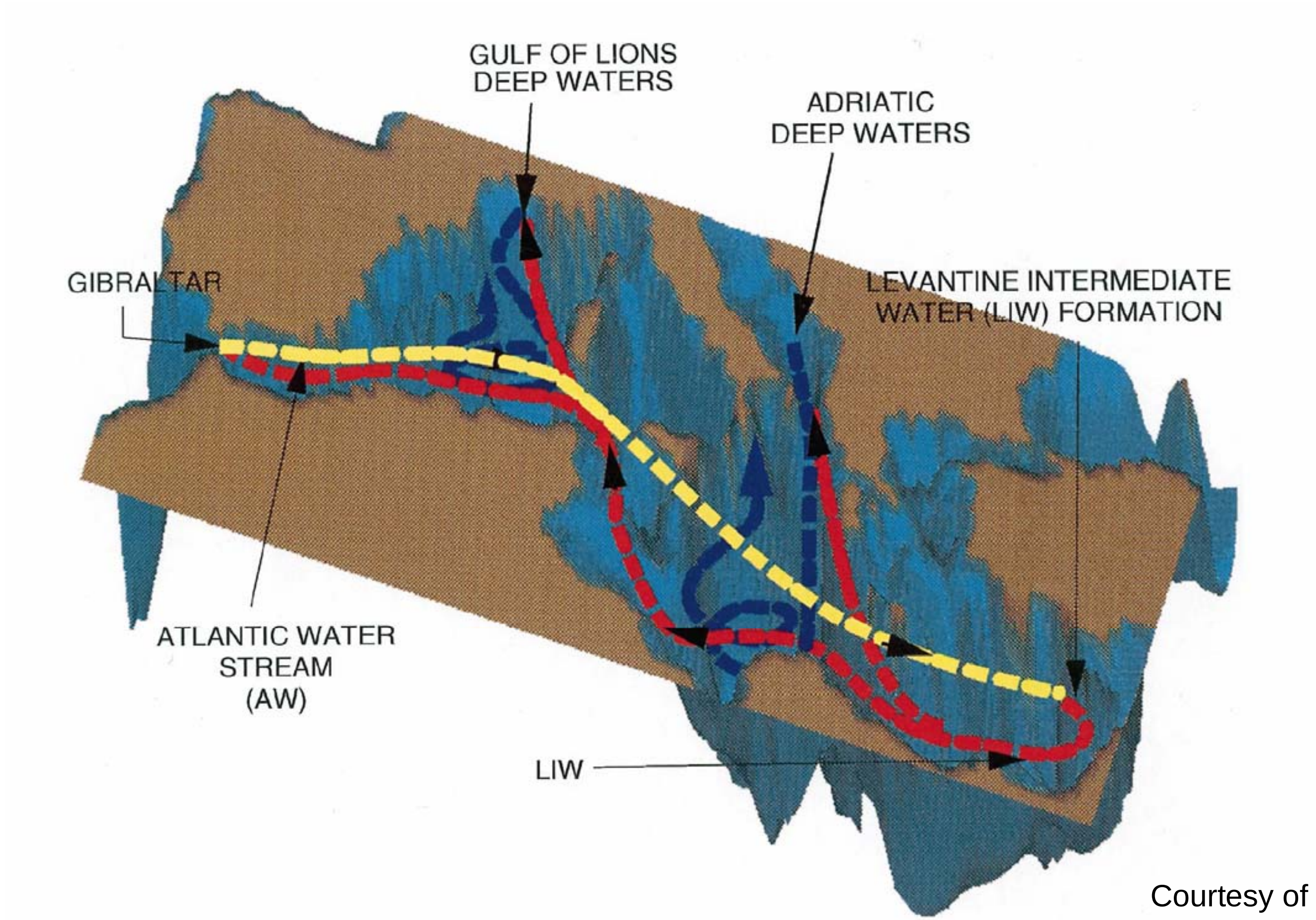


Difference in the depth of the surface to intermediate water interface between the present and times of sapropel deposition, relative to the depth of light penetration. N indicates nutrients, C indicates consumption of nutrients for photosynthesis, DCM stands for Deep Chlorophyll Maximum, and M.L. for Mixed Layer.

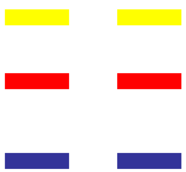
At the same time the formation of a less saline surface layer preventing dense-water formation could provoke the halting of oxygen ventilation in the deep layers.

Rohling, E.J. (2001), *The dark secret of the Mediterranean - a case history in past environmental reconstruction*

Schematic of the Mediterranean Sea thermohaline circulation



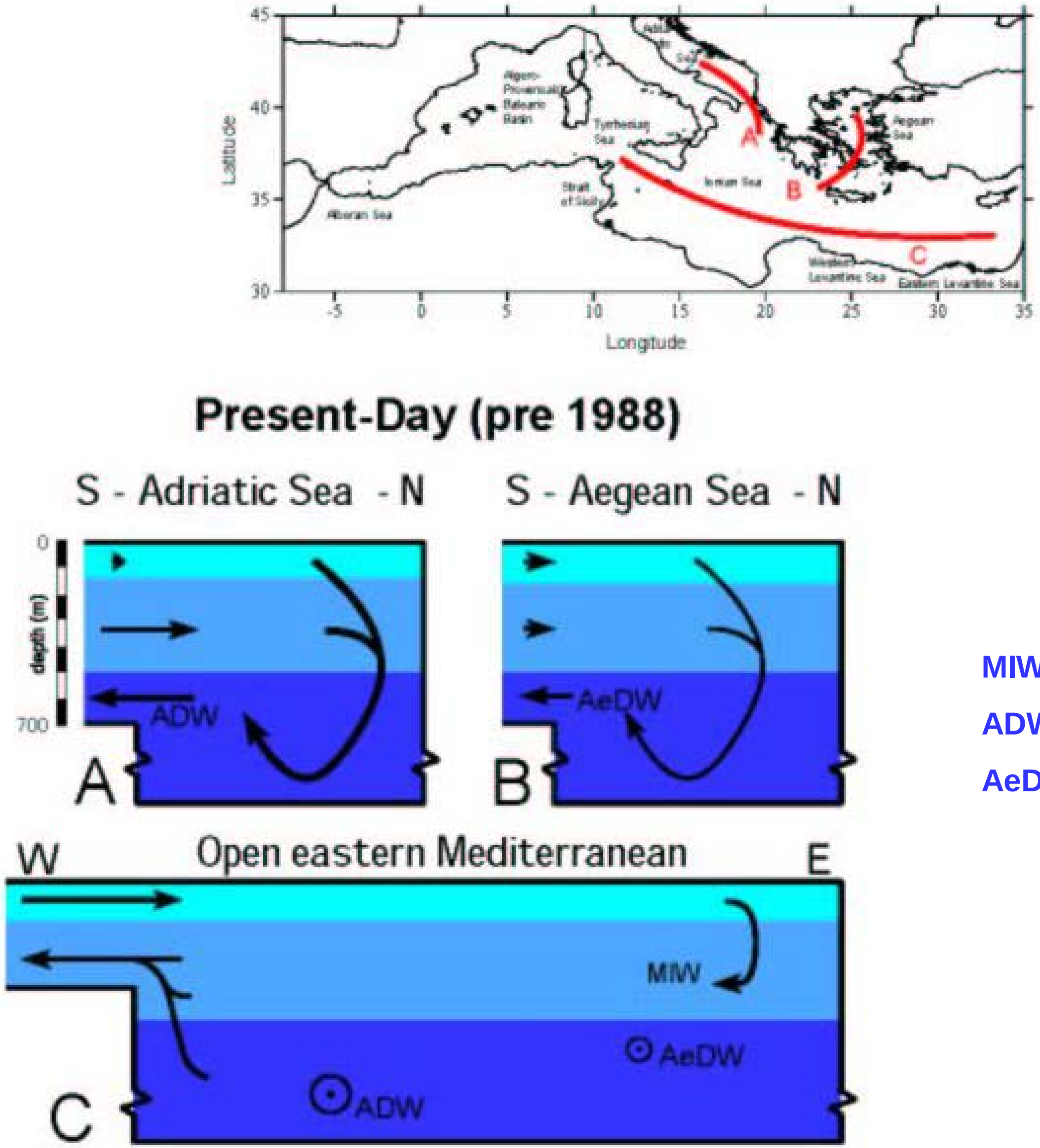
Courtesy of *Pinardi and Masetti, 2000*



Surface water mass circulation forced by Gibraltar Atlantic inflow

Intermediate water mass circulation forced by LIW

Meridional vertical circulation forced by deep water formation processes

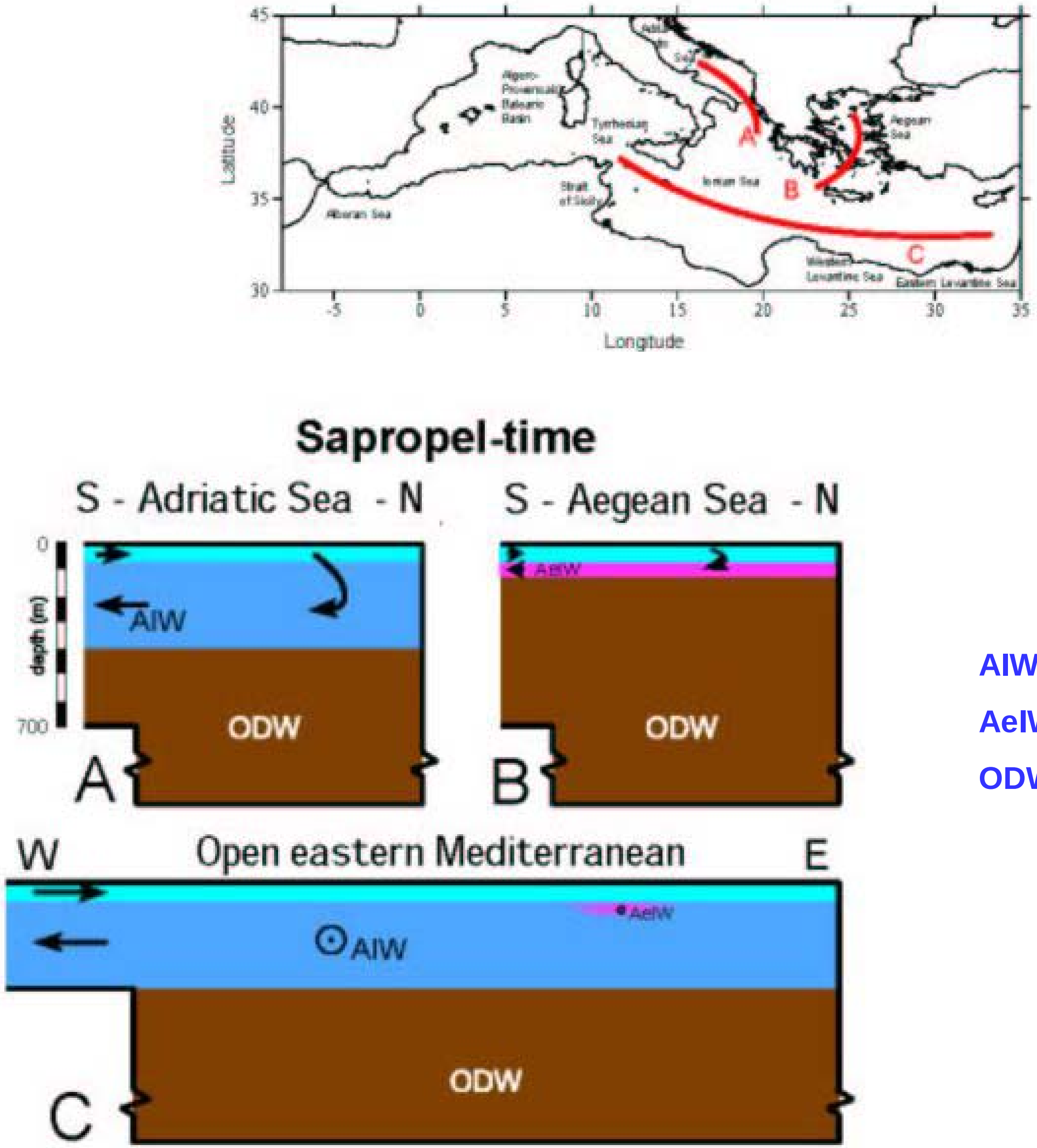


MIW, Mediterranean Intermediate Water

ADW, Adriatic Deep Water

AeDW, Aegean Deep Water

Rohling, E.J. (2001), *The dark secret of the Mediterranean - a case history in past environmental reconstruction*

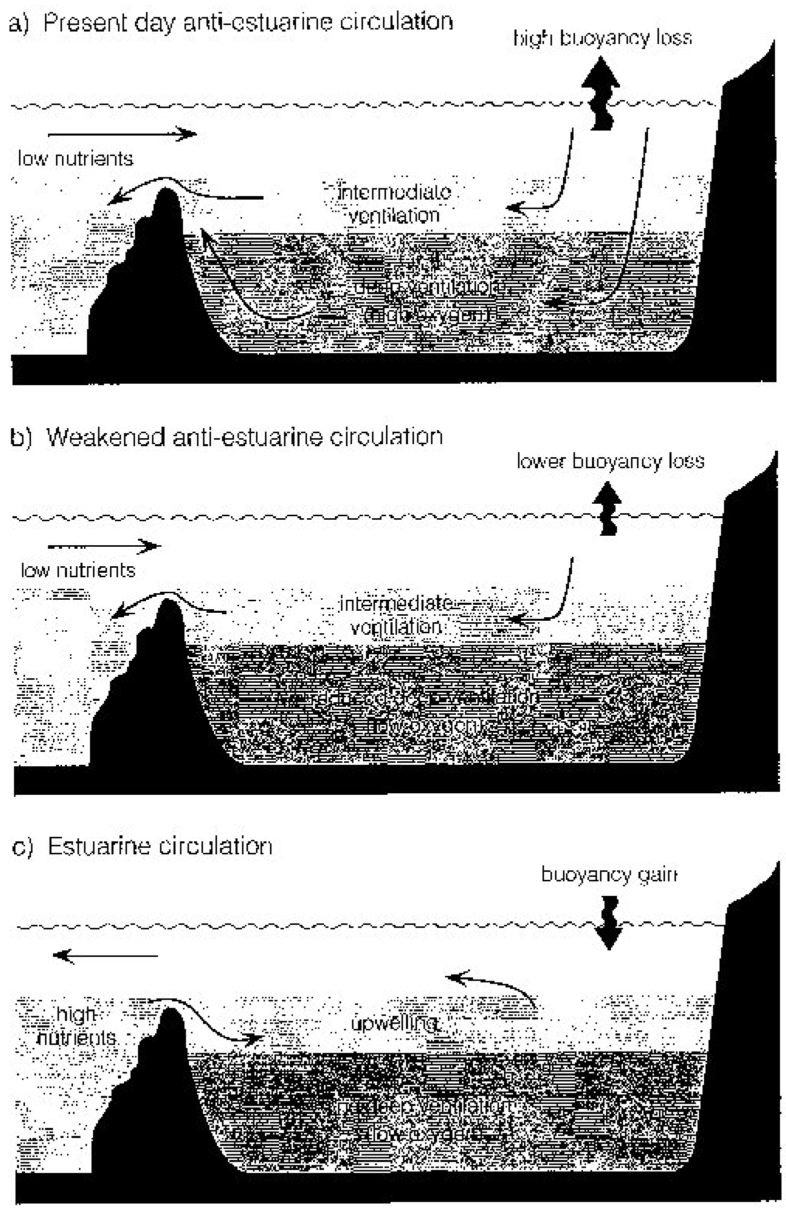


AIW, Adriatic Intermediate Water

AeIW, Aegian Intermediate Water

ODW, Old Deep Water

Rohling, E.J. (2001), *The dark secret of the Mediterranean - a case history in past environmental reconstruction*



Both circulations allow sapropel formation

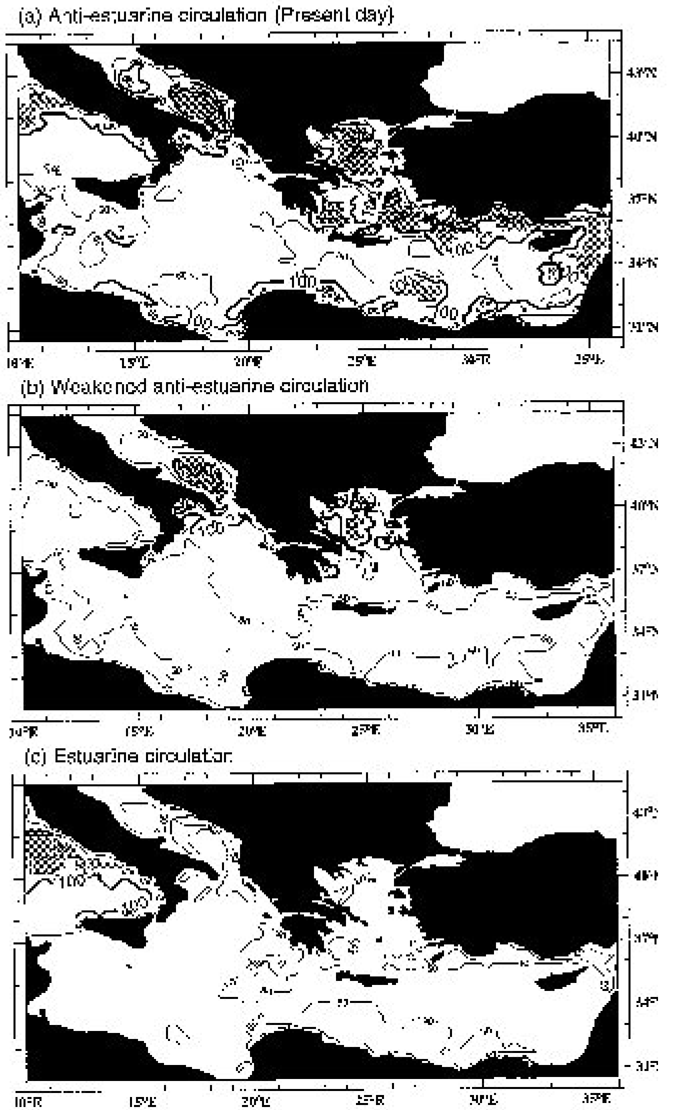


Figure 4. Maximum depth of winter convective overturni (m) in the the different GCM integrations. The shaded re gions indicate convection beyond 100 m in the model. Note that there is significantly reduced convective overturning in the estuarine case, particularly in the Adriatic.

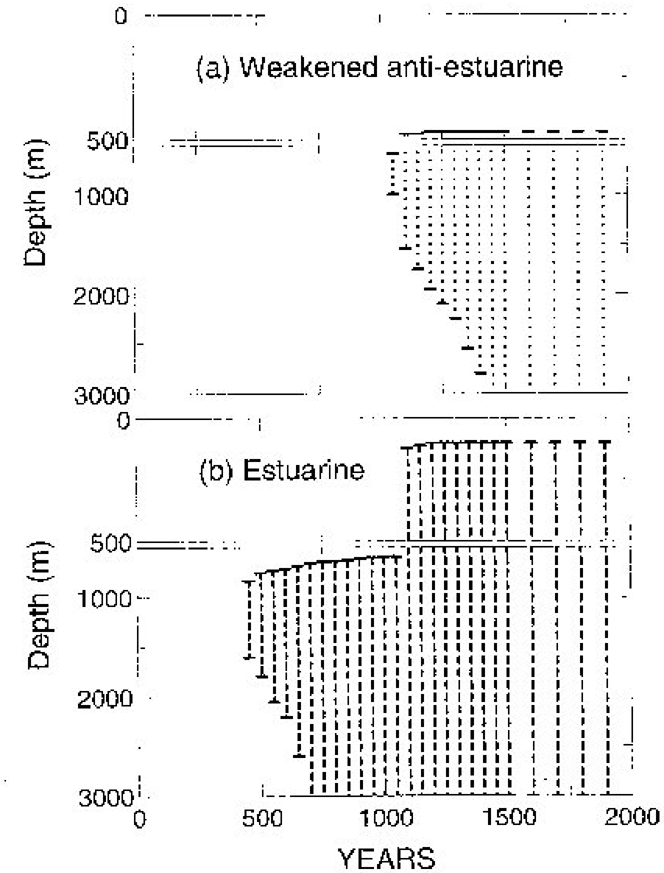


Figure 7. Time series showing the vertical extent of anoxia, defined by concentrations lower than 0.06 mol O_2 m^{-3} for (a) weakly anti-estuarine and (b) estuarine circulations. Note the expanded vertical scale above 500 m.

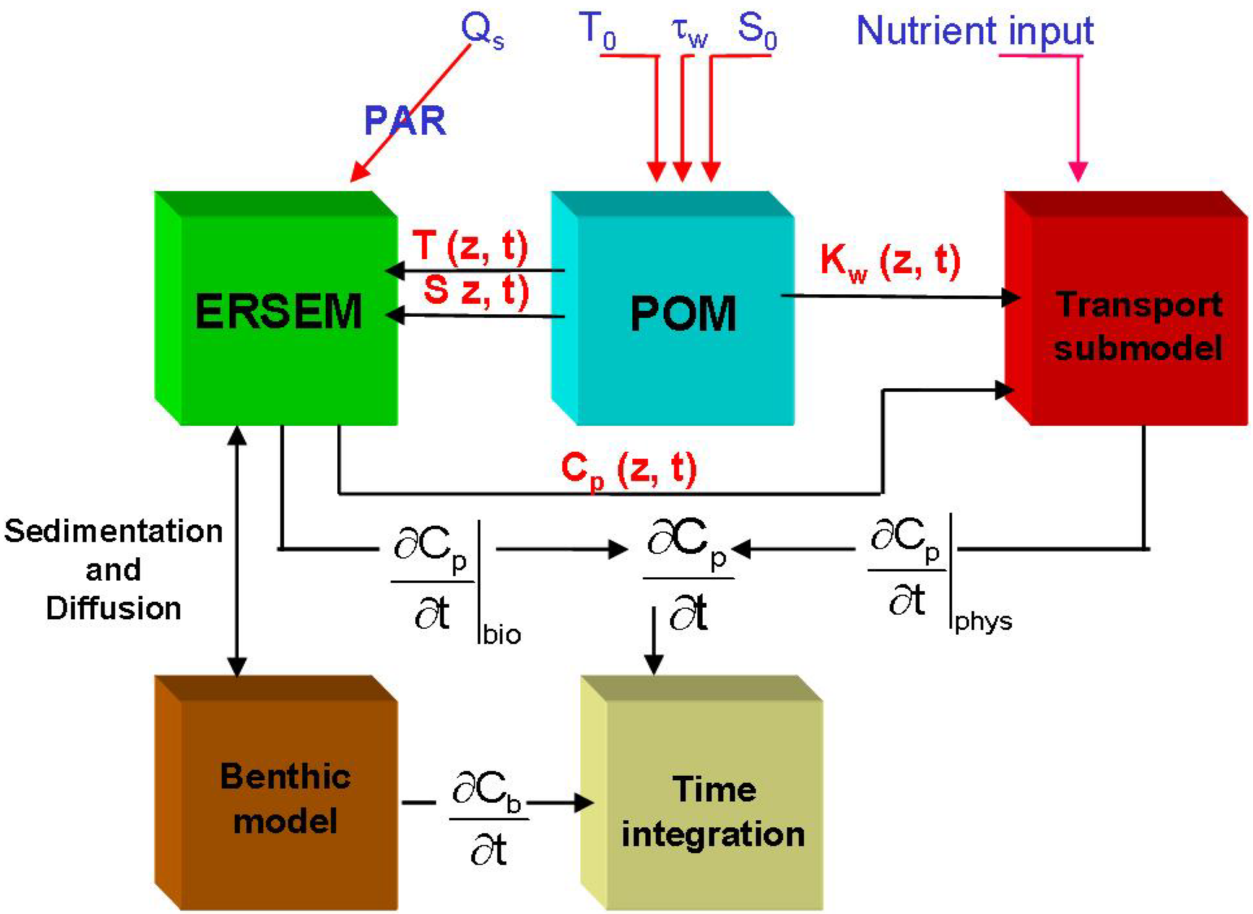
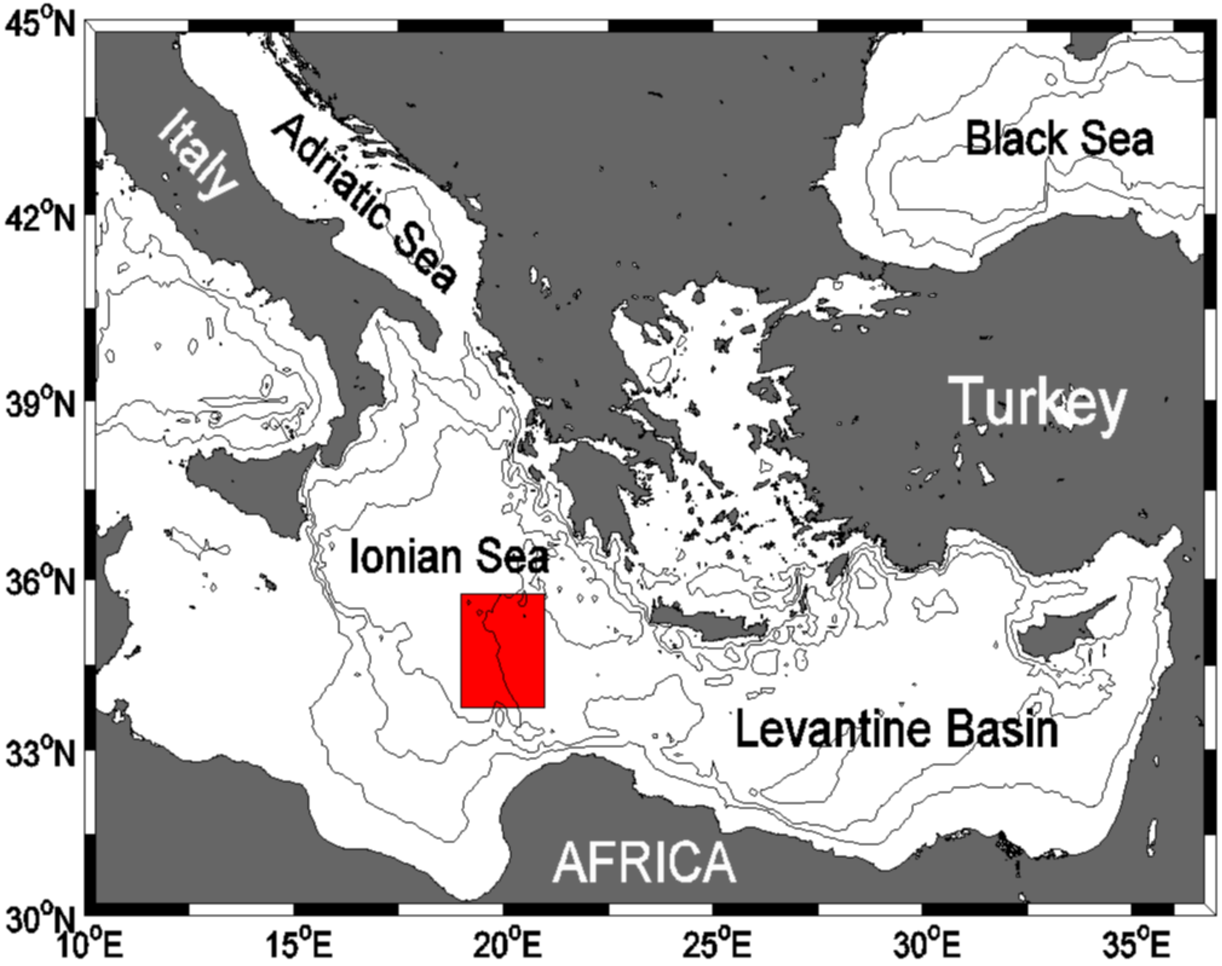


Fig 1 - Schematic of MEM-1D structure and submodels

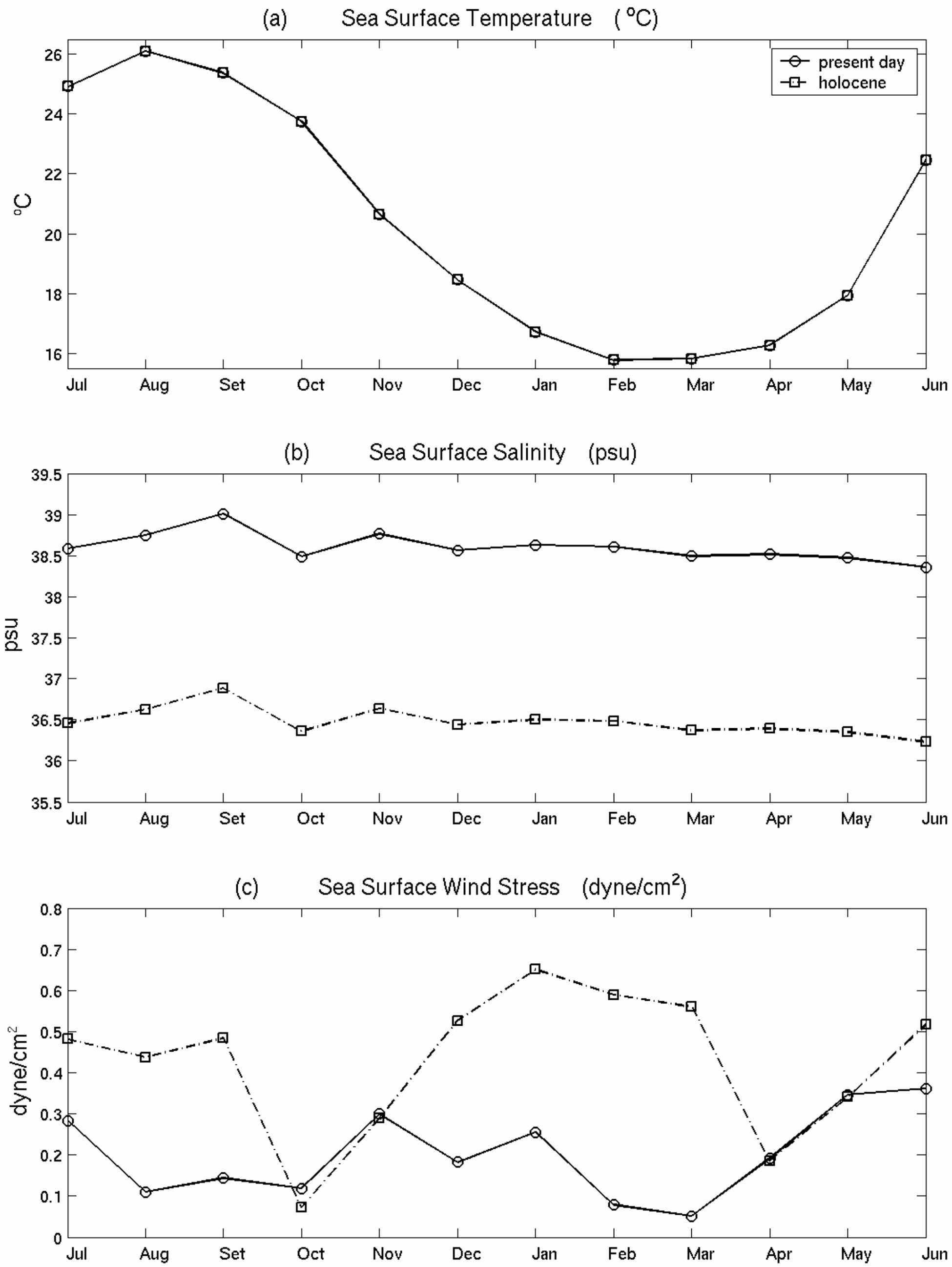
Area of implementation of the model



THE ONE-DIMENSIONAL ECOSYSTEM MODEL IMPLEMENTATION

Physical profiles are diagnostically imposed from the simulations of Myers et al. (1998) for the present day and for the Holocene.

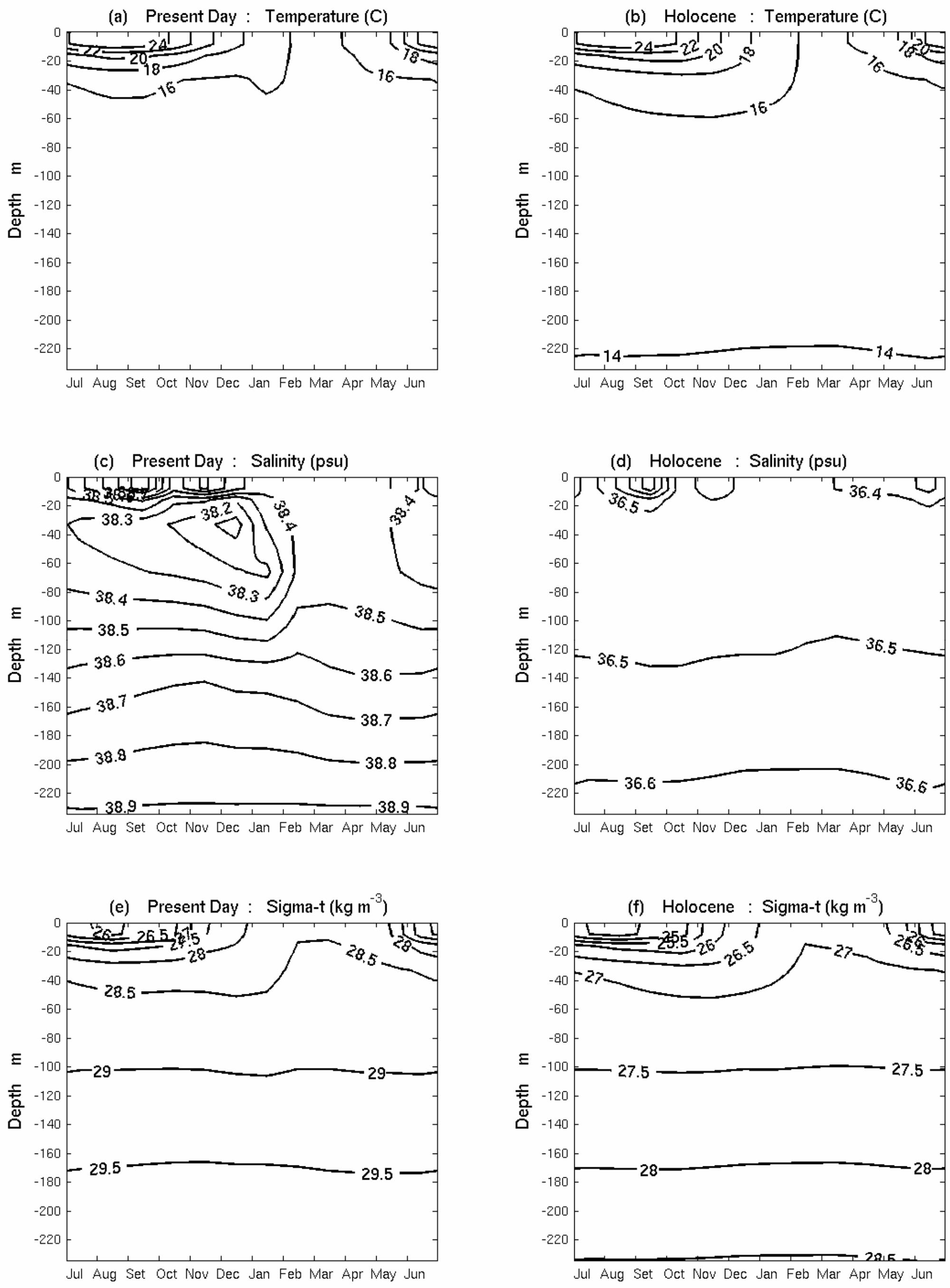
Seasonal cycle of SST, SSS and Wind Stress for the present-day and Holocene physical conditions over the area of implementation of the model.



SSS reconstruction from Kallel et al. (1997)

Paleowinds from Dong and Valdes (1995)

Seasonal cycle of Temperature, Salinity and Sigma-t profiles for the present-day (left) and Holocene (right) physical conditions.



THE ONE-DIMENSIONAL ECOSYSTEM MODEL IMPLEMENTATION

Physical profiles are diagnostically imposed from the simulations of Myers et al. (1998) for the present day and for the Holocene.

The different depth of reventilation (Myers et al., 1998) is parameterized as follows:

Present day → Oxygen relaxation to the initial profile from the surface to the bottom

Holocene → Oxygen relaxation to the initial profile from the surface to 500 *m* depth

The hypothesis of enhanced productivity is tested using three different boundary conditions:

Present day Ionian Sea → No nutrient fluxes at the surface

Reconstruction 1 → Surface PO4=0.03 *mmol m-3*, other nutrients in Redfield Ratio

Reconstruction 2 → Surface PO4=0.04 *mmol m-3*, other nutrients in Redfield Ratio

Main experiments

Six main experiments have been carried on to test the role of oxygen reventilation and enhanced productivity:

Now Low: Present day physics, reventilation (to the bottom) and nutrients

Now 1: Present day physics and reventilation (to the bottom), nutrient Reconstruction 1
Now 2: Present day physics and reventilation (to the bottom), nutrient Reconstruction 2

Holo Low: Holocene physics and reventilation (to 500m), present day nutrients

Holo 1: Holocene physics and reventilation (to 500m), nutrient Reconstruction 1
Holo 2: Holocene physics and reventilation (to 500m), nutrient Reconstruction 2

Productivities fall within a wide range (from 120 *mgC m-2d-1* for present day nutrients to 2000 *mgC m-2d-1* with the Reconstruction 2).

Little ecosystem sensitivity to the different physical conditions between present day and Holocene.

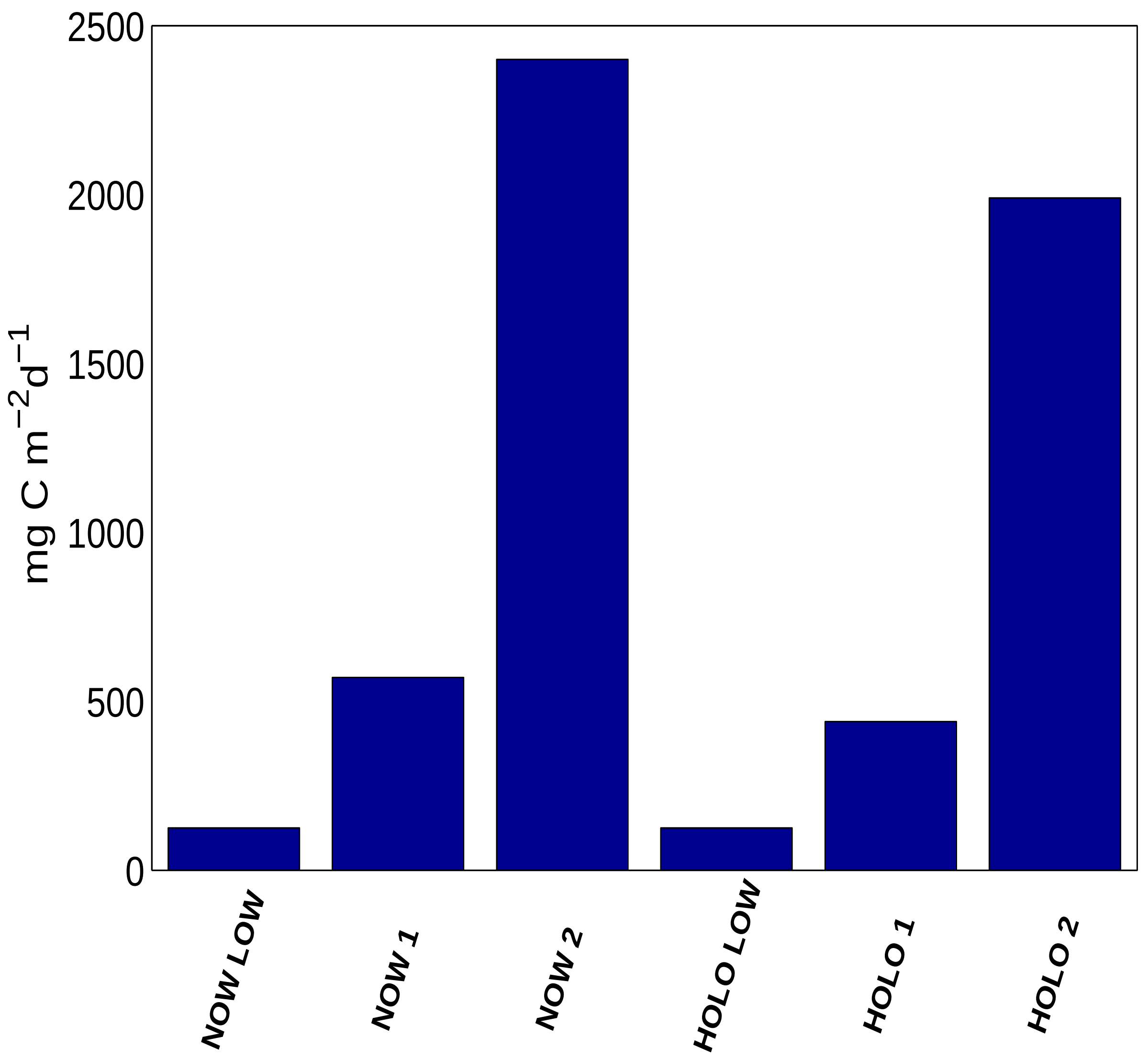
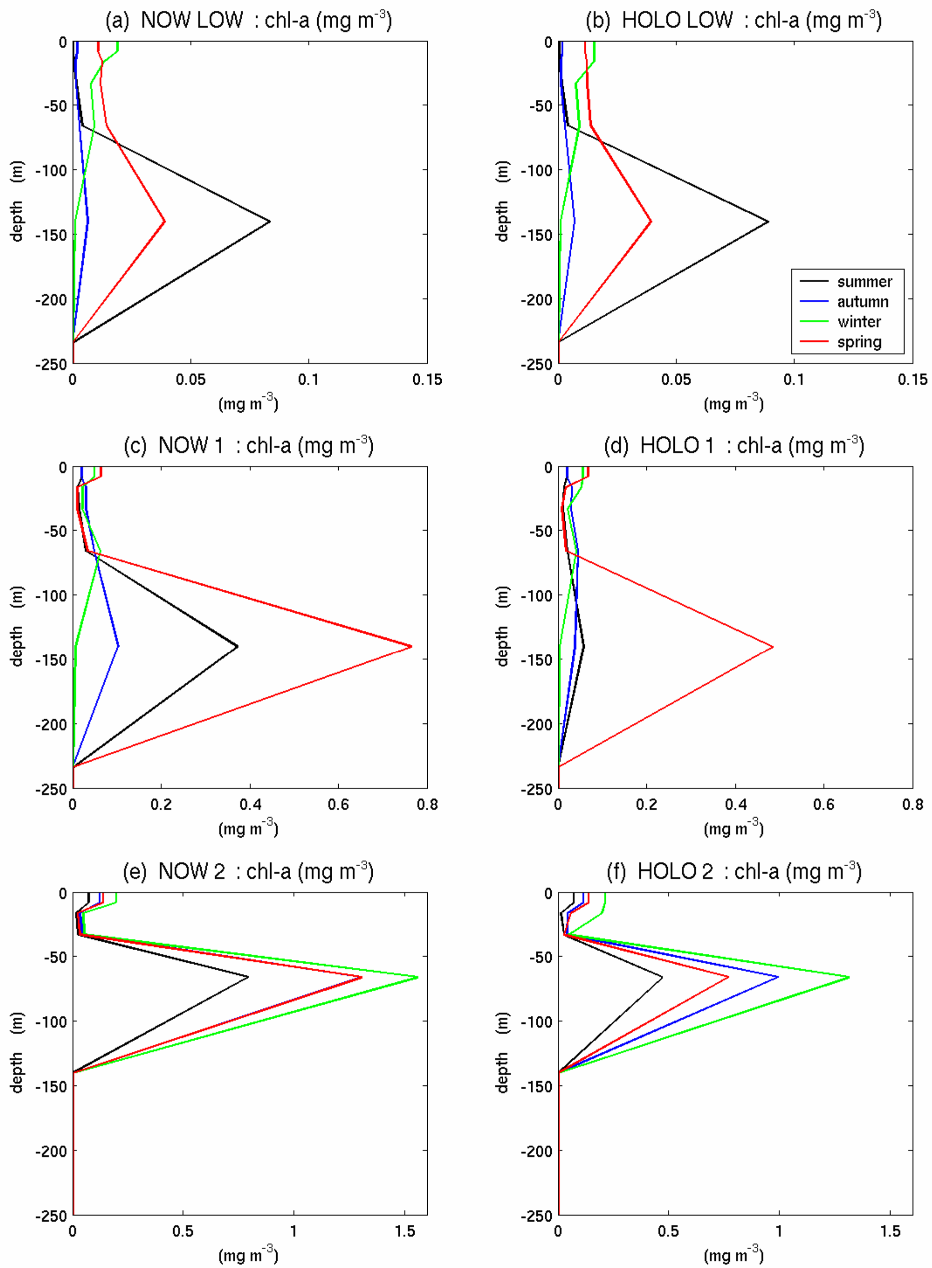


Fig 3 – Annual primary productivities (*mgC* m^{-3} d^{-1}) for the main experiments



Summer DCM at 140m

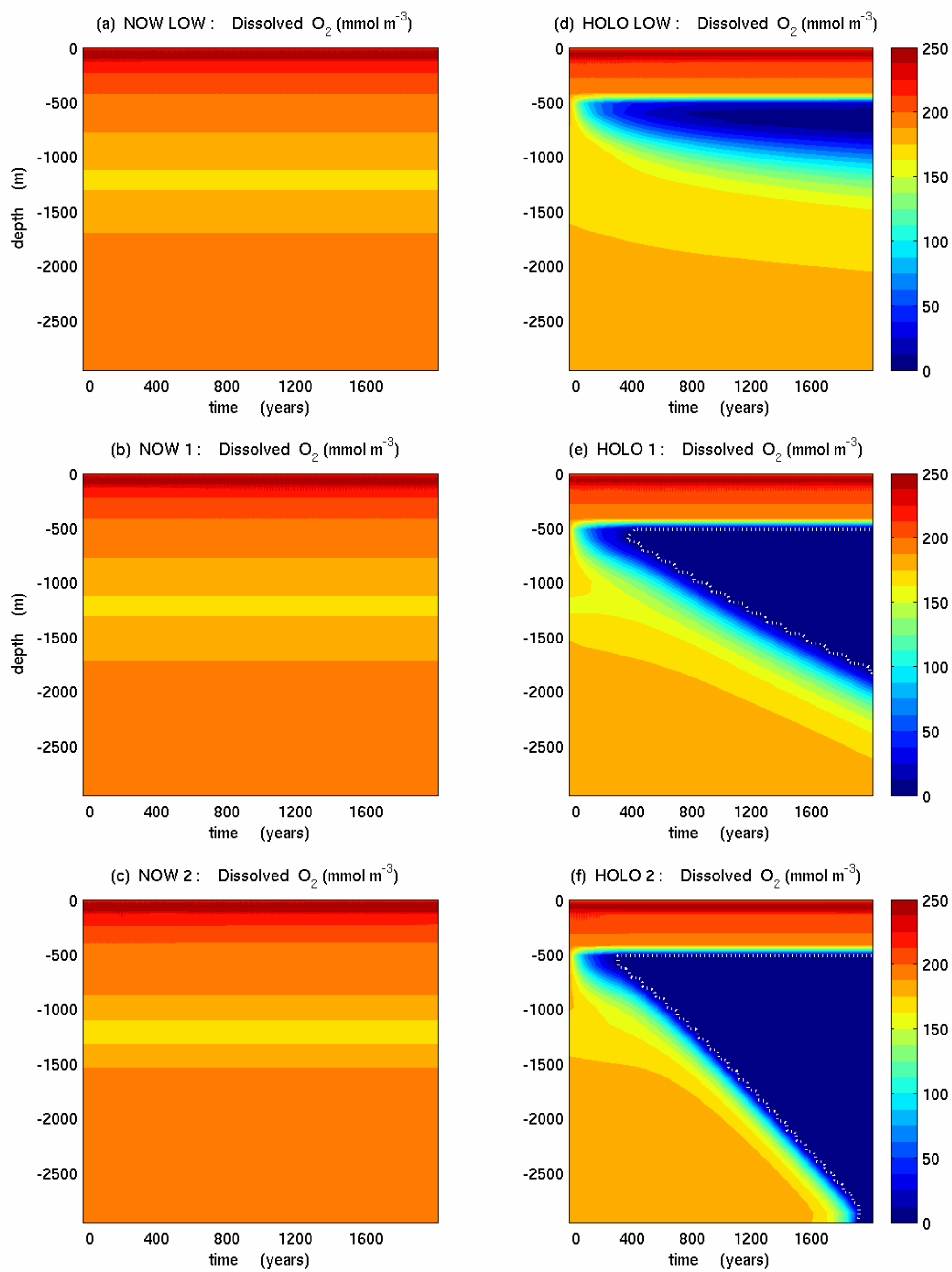
Spring DCM at 140m

Annual DCM at 70m…as suggested by several authors for the sapropel deposition time

Rapid formation of an oxygen minimum when reventilation is shut off (Holocene).

Holo 1 and *Holo 2* show a ‘top-to-bottom progressing oxygen depletion’.

Holo 2 : anoxic conditions reach the bottom, allowing the depositional flux of organic detritus (15 *mgC m-2d-1*) and its preservation in the sediment. The timescale of the process is in the order of 2000 years.



SENSITIVITY TO PARTICULATE SEDIMENTATION VELOCITY

Four additional experiments, under the Holocene physical conditions, to test the sensitivity to an increased sedimentation velocity (VSED) for particulate organic matter from 1.5 to 5.0 and 10.0 *md-1*.

H1-V1: Reconstruction 1; VSED=5.0 *md-1*
H1-V2 : Reconstruction 1; VSED=10.0 *md-1*
H2-V1 : Reconstruction 2; VSED=5.0 *md-1*
H2-V2 : Reconstruction 2; VSED=10.0 *md-1*

Net primary productivities fall in the range 150-500 *mgC m-2d-1* (**Fig. 5**), in agreement with estimates for S1 times.

Organic carbon fluxes, in the range of 10-30 *mgC m-2d-1*, are comparable to observations.

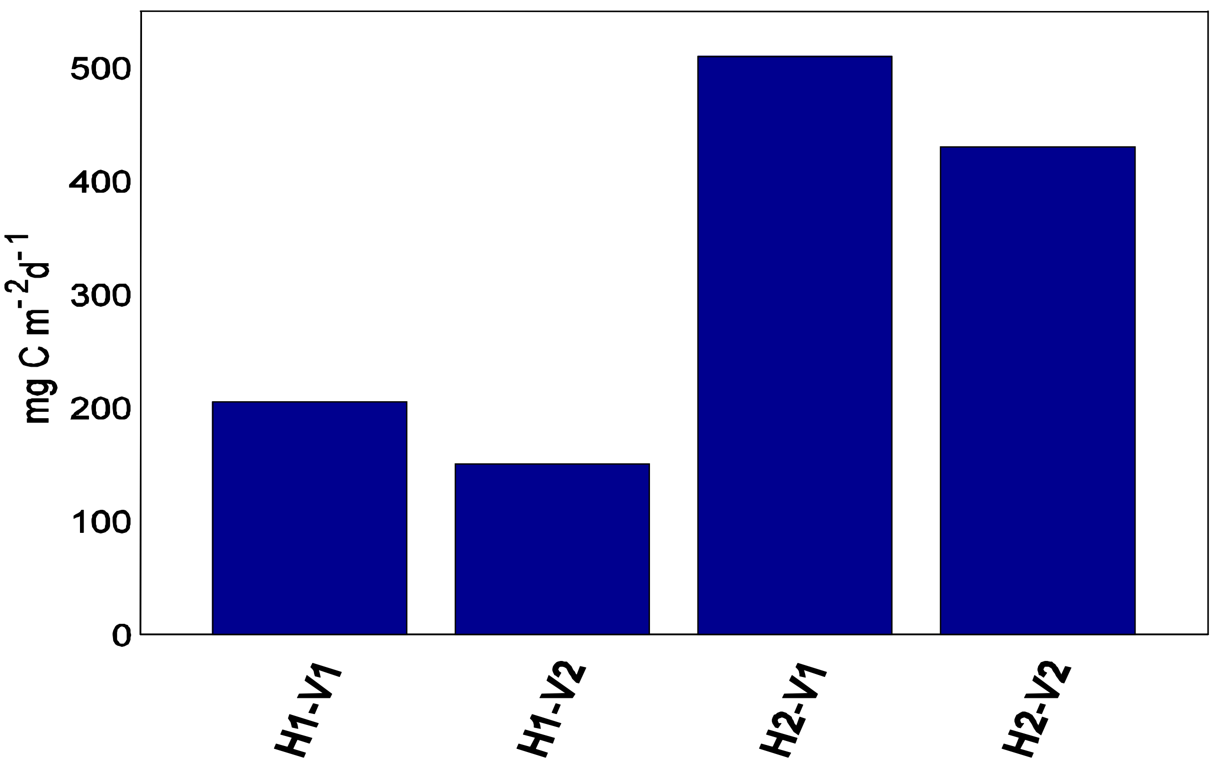
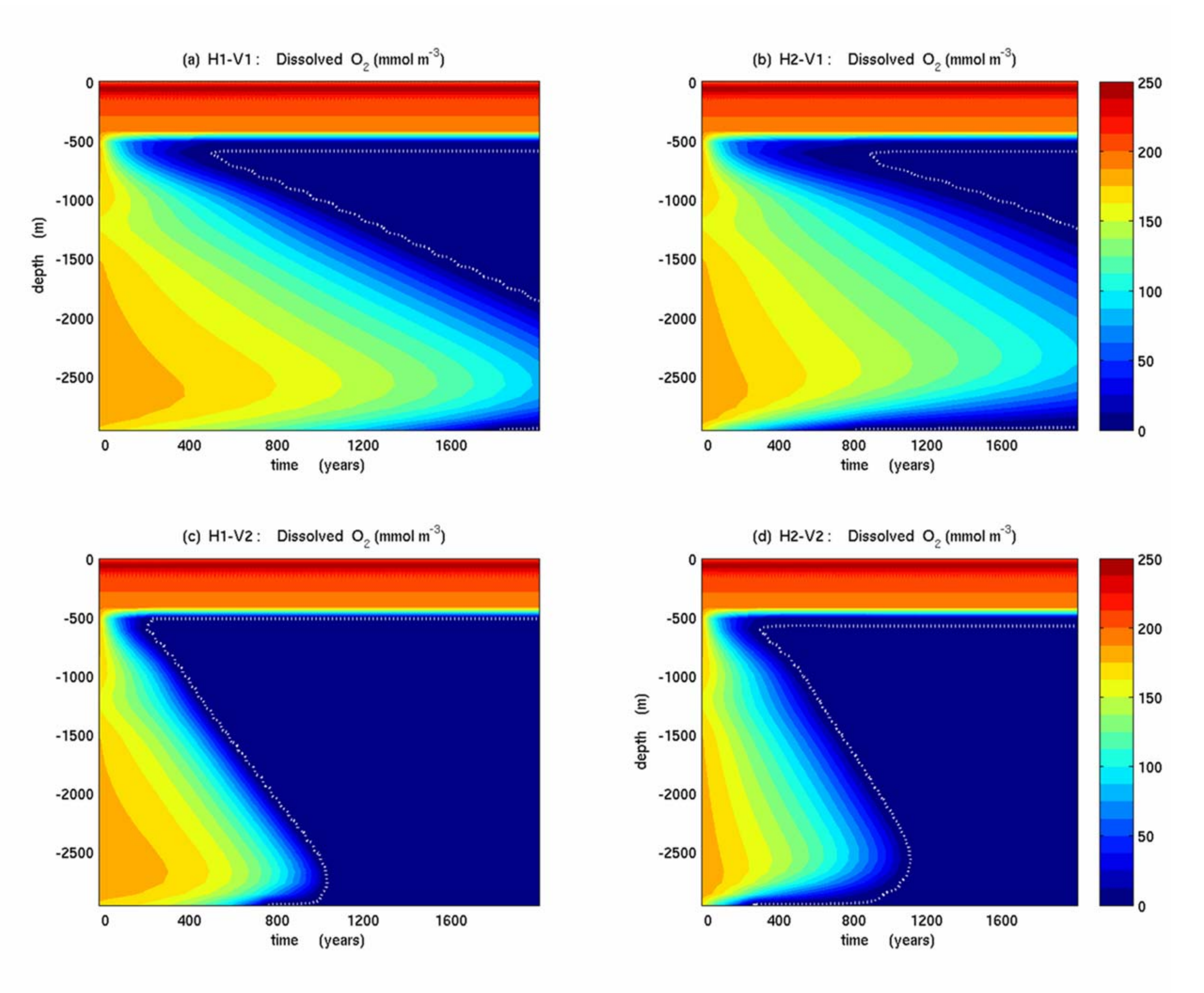


Fig 5 – Annual primary productivities (*mgC* m^{-2} d^{-1}); sensitivity experiments

Anoxic conditions develop at mid depth and at the sea floor, where an ‘anoxic blanket’ is formed.

The timescale for the onset of anoxia and sapropel deposition can be as short as 250 years, in agreement with the finding of the 200-years S1 interruption (Rohling et al., 1997).



CONCLUSIONS

•The enhanced nutrient supply and the interruption of deep reventilation are both necessary to allow organic matter deposition and preservation at the sea-floor

•A low sedimentation velocity for particulate organic matter determines a downward expansion of anoxia from middle-depth. The timescale is in the order of 2000 years

•An increased sedimentation velocity for particulate determines the formation of anoxic conditions both at mid-depth and in a thin layer at the sea-floor. The timescale of the process in the order of 200 years. This result is consistent with the short-timescale interruption found within S1.