The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization
IAEA International Atomic Energy Agency

SMR/1837-9

2007 ICTP Oceanography Advanced School

30 April - 11 May, 2007

Thermohaline circulation of mediterranean sea sensitivity to wind stress, diffusion,strait dynamics, etc..

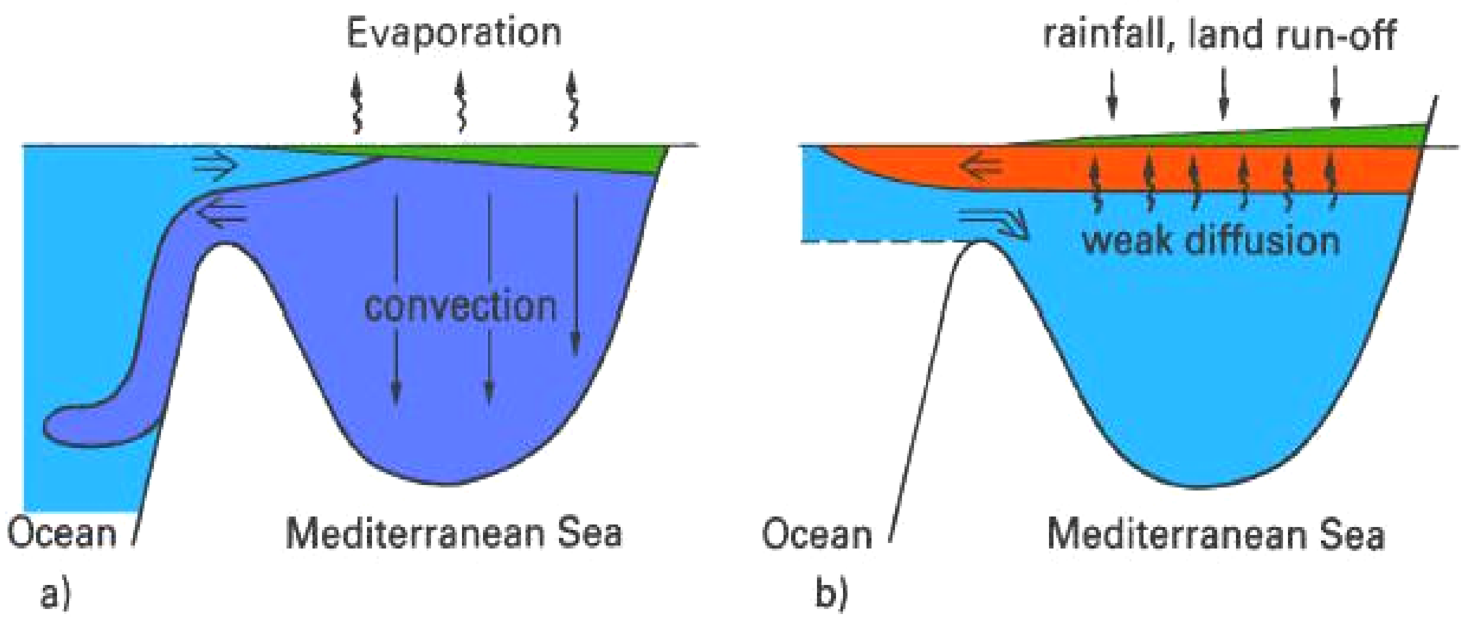
V. Artale
ENEA C.R. Casaccia, Rome Italy

Third Part

thermohaline circulation of mediterranean sea
sensitivity to wind stress, diffusion, strait dynamics, etc..

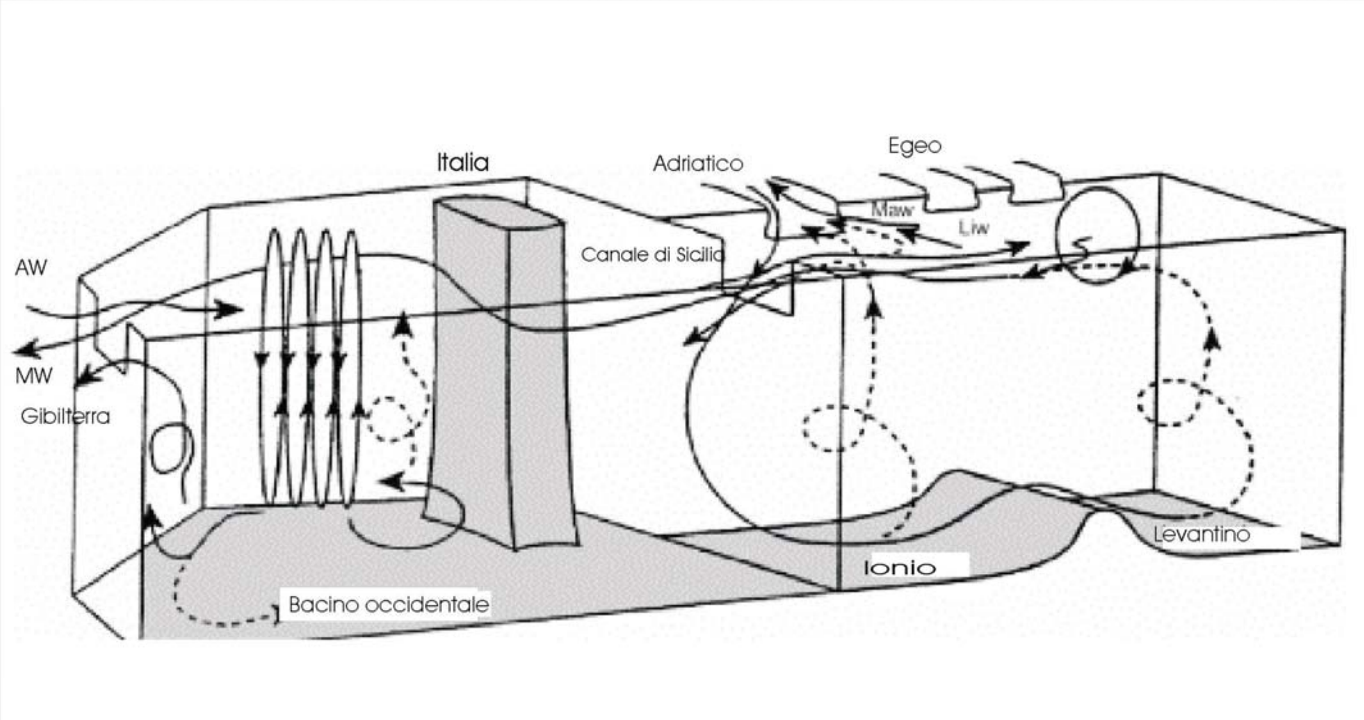
Mediterranean general circulation

- The Mediterranean is an evaporative marginal sea
- The basic circulation is antiestuarine
- The straits play an important role
- The renewal time is around 100 yrs



Schematic illustration of the circulation in mediterranean seas; (a) with negative precipitation - evaporation balance, (b) with positive precipitation - evaporation balance.

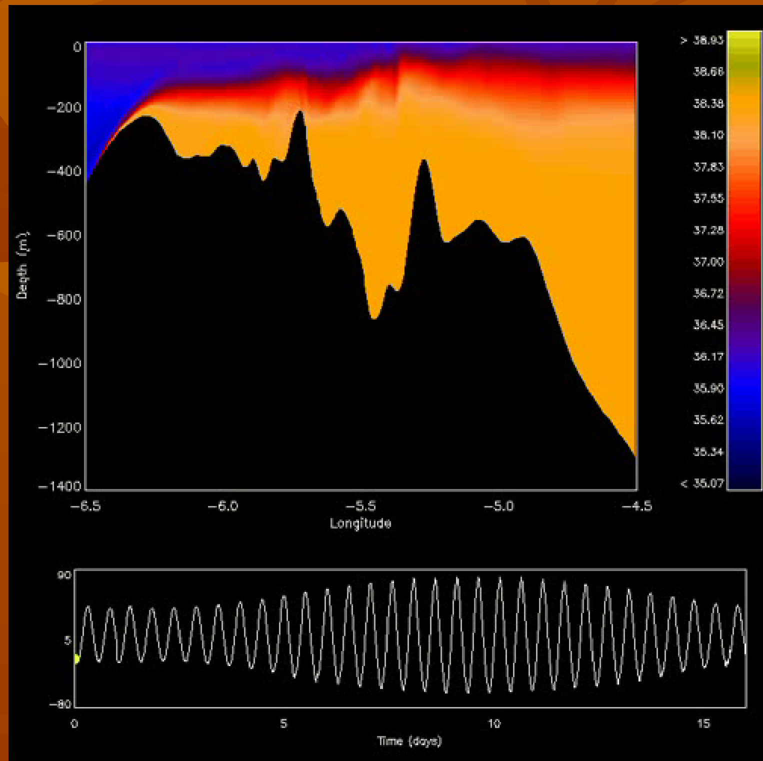
The functioning of the mediterranean sea



THESE ANOMALIES MAY PASS THROUGH GIBRALTAR STRAIT: GETAWAYS TO THE ATLANTIC

ROLE OF GIBRALTAR STRAIT:
LIMITING FACTOR OF GENERAL CIRCULATION:

TIDE AND HYDRAULIC CONTROL

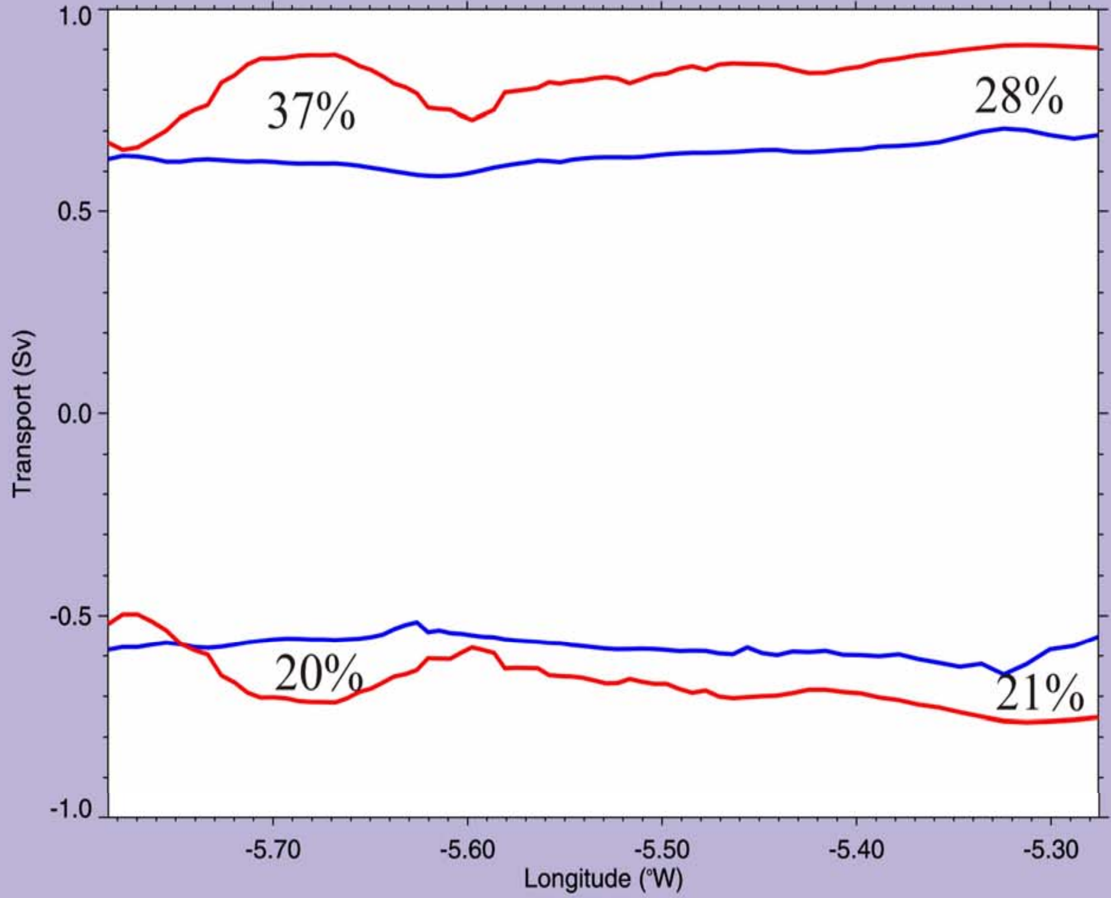


Velocity field up

Velocity field down

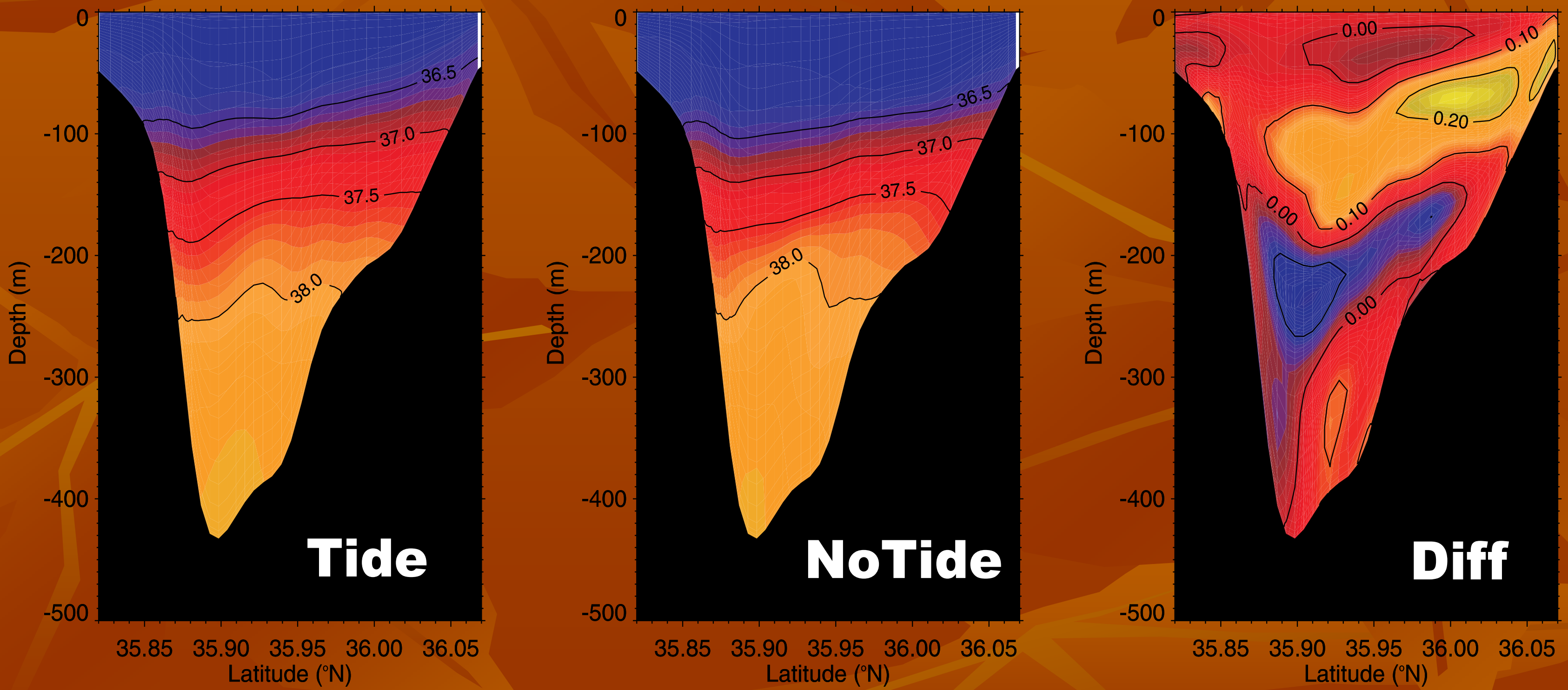
TIDAL TRANSPORT - T. DEPEN. VS T. INDEP.

Along-strait Upper Layer Transport and Lower Layer Transport: RED is for Time Dependenta BLUE for Time Independent

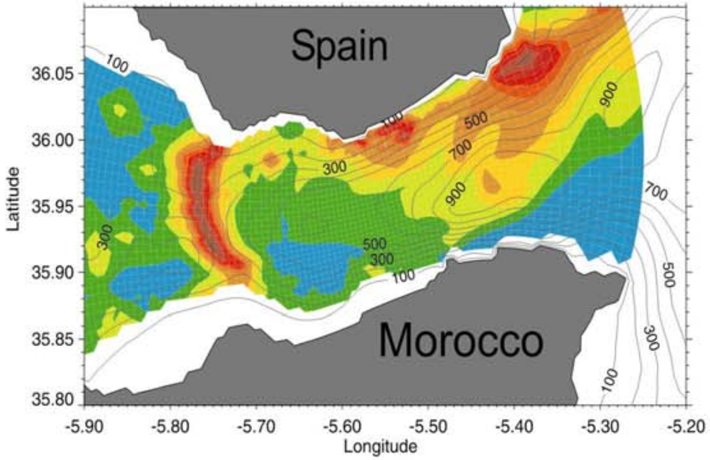


SALINITY DIFFERENCE BETWEEN THE EXPERIMENT WITH AND WITHOUT TIDE

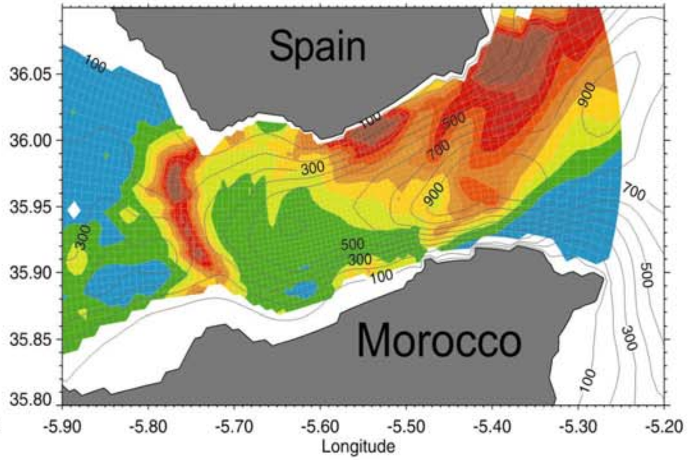
Western Entrance

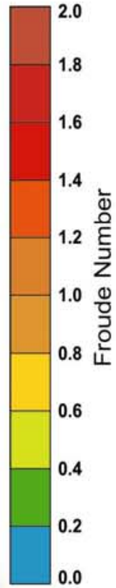


$\Delta S = 2.0$

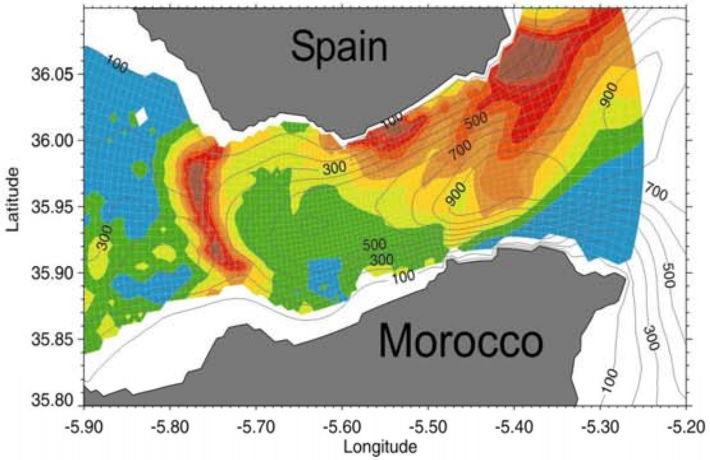


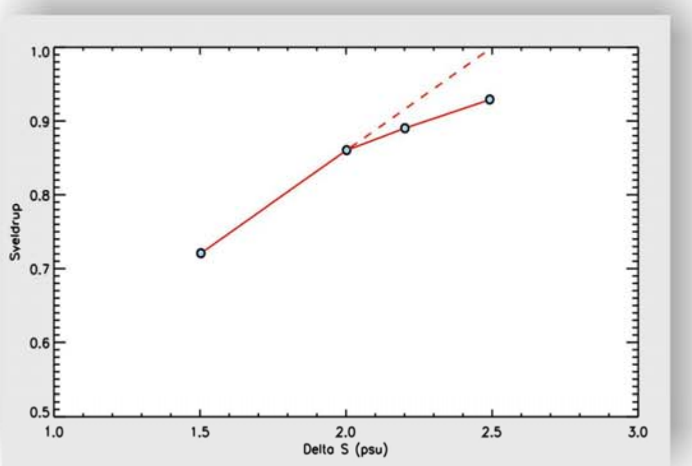
$\Delta S = 2.5$



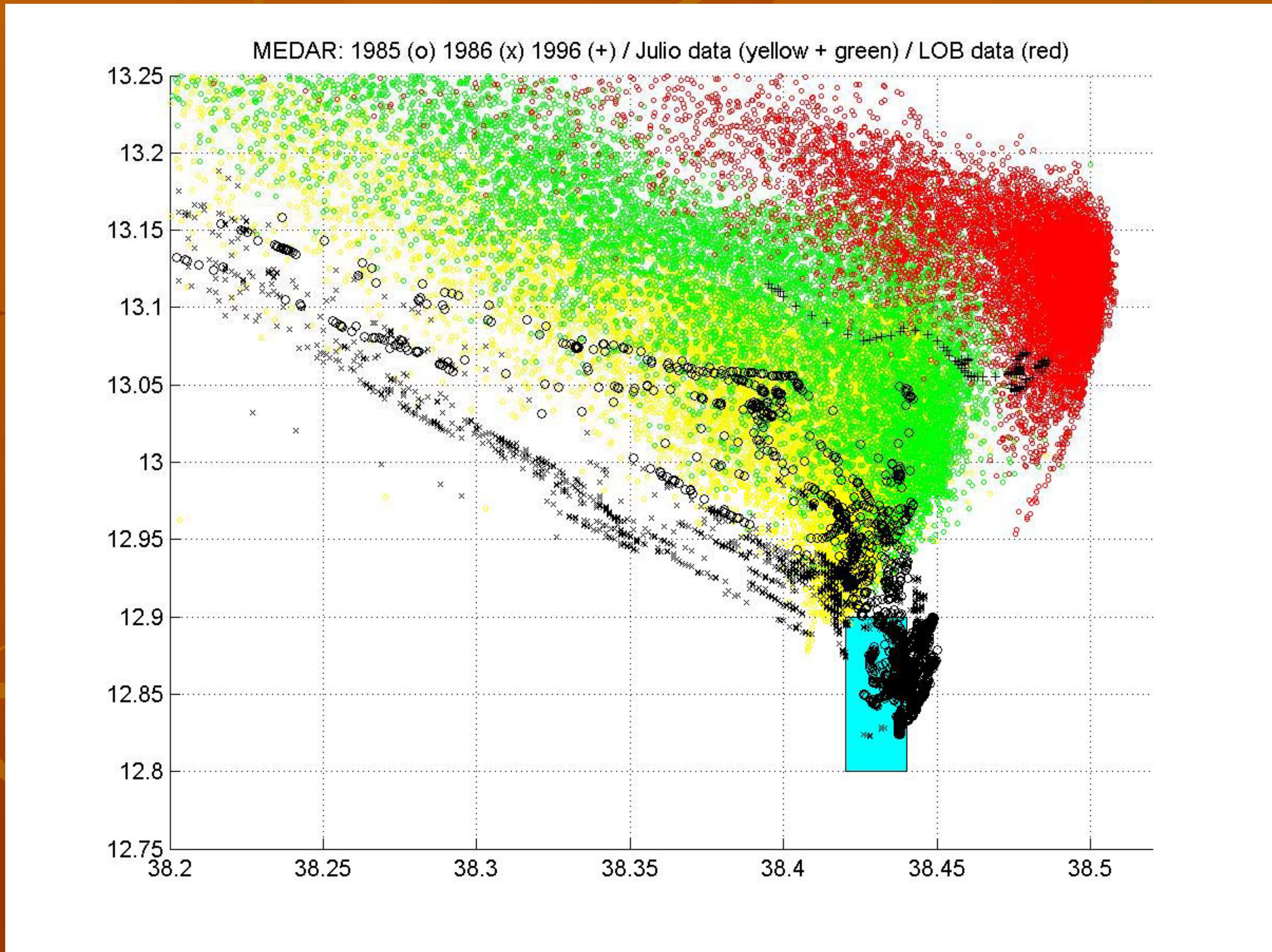


$\Delta S = 2.2$





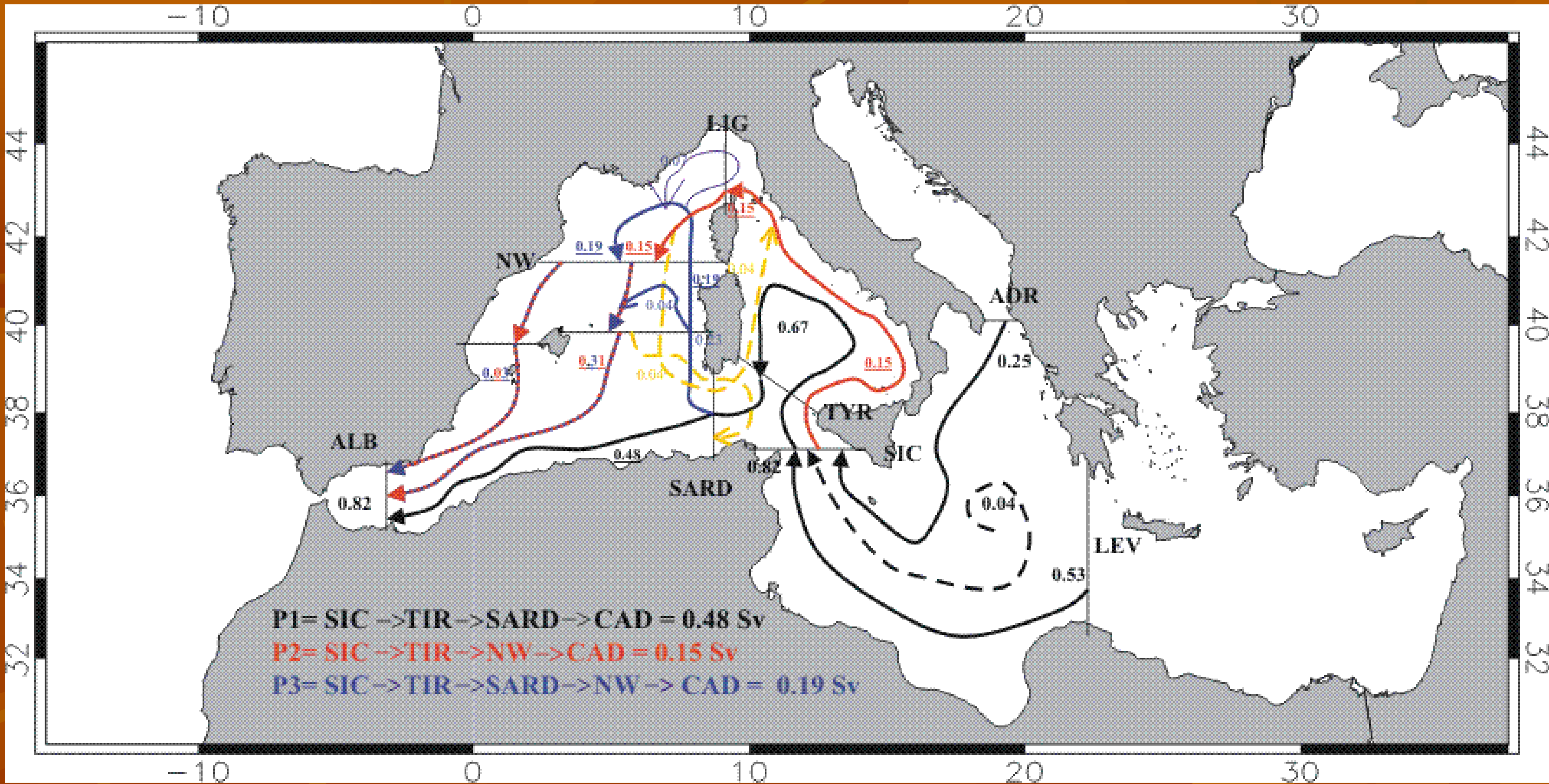
…..and today could be stronger ….



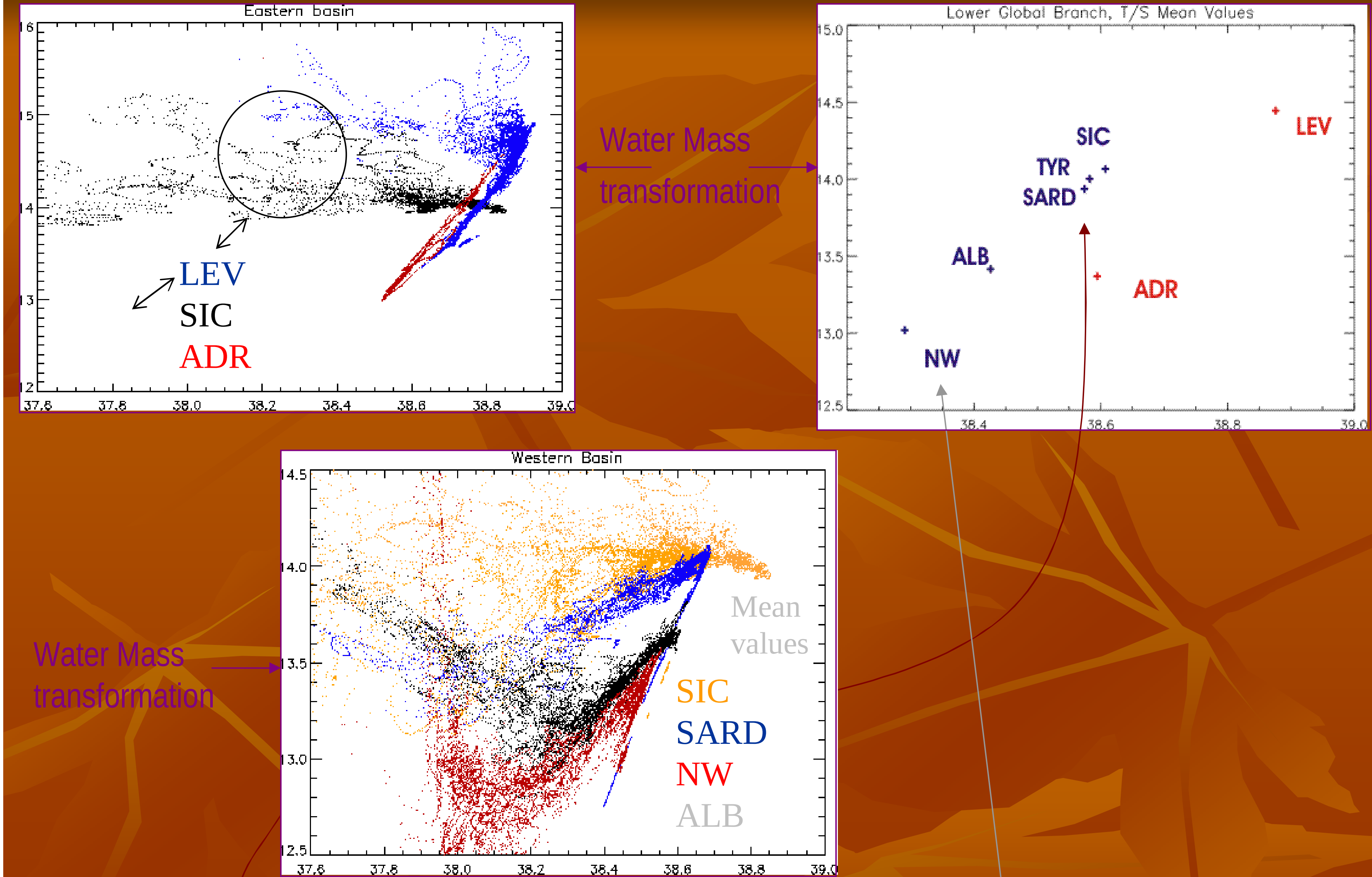
From Millot et al (2006)

yellow+green+red data : 2003-2004

Global Cell, Lower Branch



From Rupolo et al. JGR, 2003



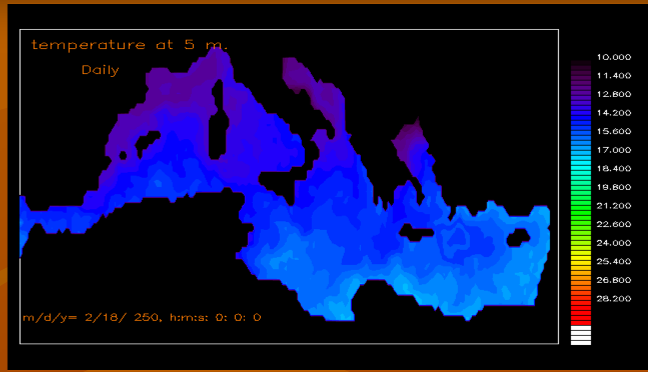
T and S of the outflowing water in the Alborean Sea strongly depend on mixing between water of eastern origin with fresher and cooler water in the North Western Mediterranean paths P2 and P3 (strongly depending on deep convection in the NWM)

Ocean numerical Model
ENEA-Roma

- **MOM and MIT for global circulation**
- **POM for regional studies**

V. Artale, A.Bargagli, A. Carillo, E. Napolitano, V. Rupolo, G. Sannino
……….

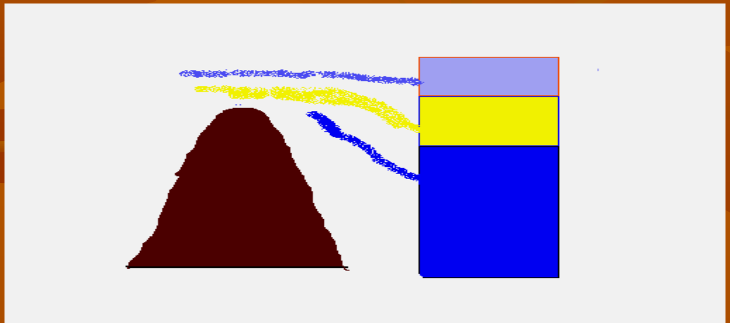
MEDMOM

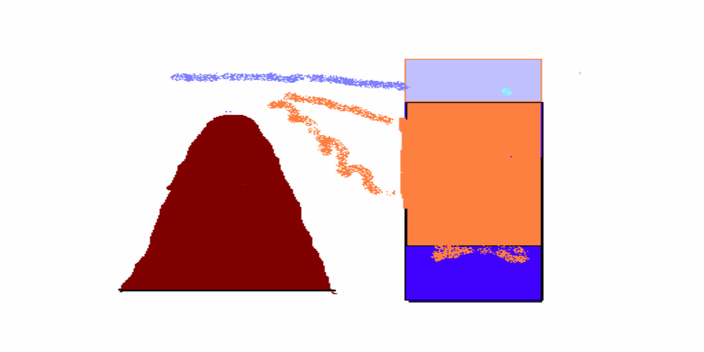


Surface temperature

- Primitive equation Cox – Bryan model for Climatic studies
- “Coarse resolution” 0.25° x 0.25° x 19 levels (deformation Rossby radius from 5 to 30 Km)
- Rigid lid, surface restoring conditions (SSST and MODB SSS)
- **Perpetual year forcing (different forcing, 1988)**
- **Horizontal** and vertical mixing scheme (different diffusivity parameterization)
- **Long integration experiments (equilibrium)**
- **Lagrangian trajectories and diagnostics**

Vertical stratification



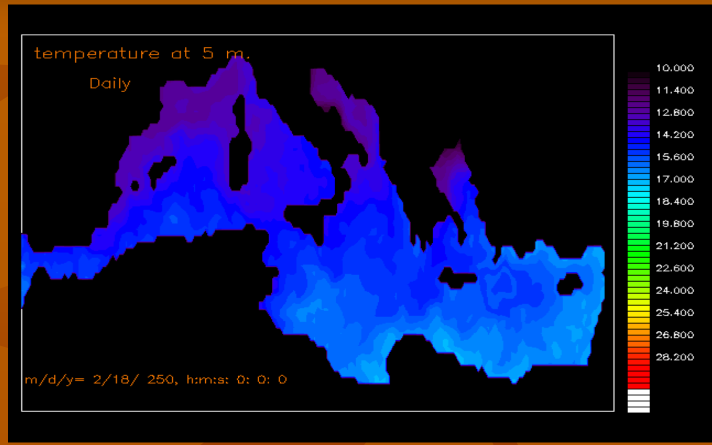


- Three main water masses (MAW, LIW and W-EDW)
- LIW depth ≈ sills depth
- DW formation maintains LIW at intermediate depth
- LIW at intermediate depth is a precondition for WDW formation

Before going on higer resolution work on

Surface forcings, tracer diffusivity

MEDMOM domain



SST

Model resolution
0.25° x 0.25° x 19

(In the shaded area tracers are restored to 3D climatological fileds)

Gibraltar:

3 points T and two points u

Model equilibrium

- Kinetic energy (≈ 10 years)
- Tracer drift (≈ 30 years)
- Equilibrium between surface boundary conditions and water masses dynamics (≈ 100 -150 years)

⇒ ⇒

LONG INTEGRATIONS

(at least 300 years)

Sensitivity studies

Long integrations (at least 300 years, model equilibrium)

Laplacian operator for diffusion
Monthly forcing restoring surface condition (perpetual year)

BBRS Parameterization for tracer diffusivity Biharmonic operator for diffusion (perpetual year for surface forcing)

BBRS: BBRS Parameterization

SM: Smagorinsky paramaterization

Khprof:vertical profile of diffusivity (constant in time and horizontally)

Keke: tracer diffusivity proportional to eddy kinetic energy

Daily: daily wind and surface temperature (SST), restoring

Monthly: Monthly surface forcing, restoring

Sflux1: Salinity surface fluxes from Monthly (E-P ≈ 80 cm/year)

Sflux2: as Sflux1 with E-P ≈ 20 cm/year

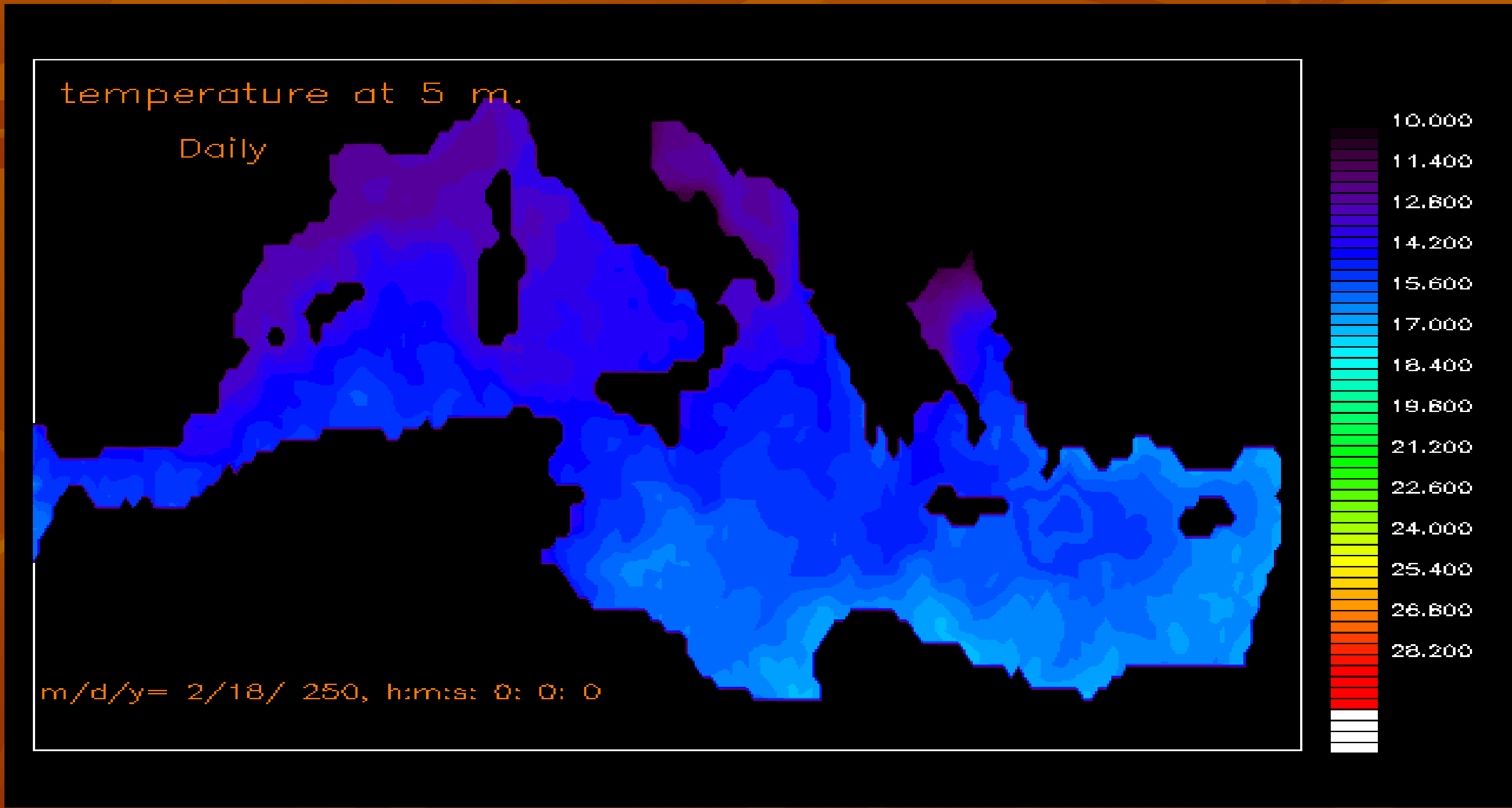
Surface forcing

(biharmonic operator)

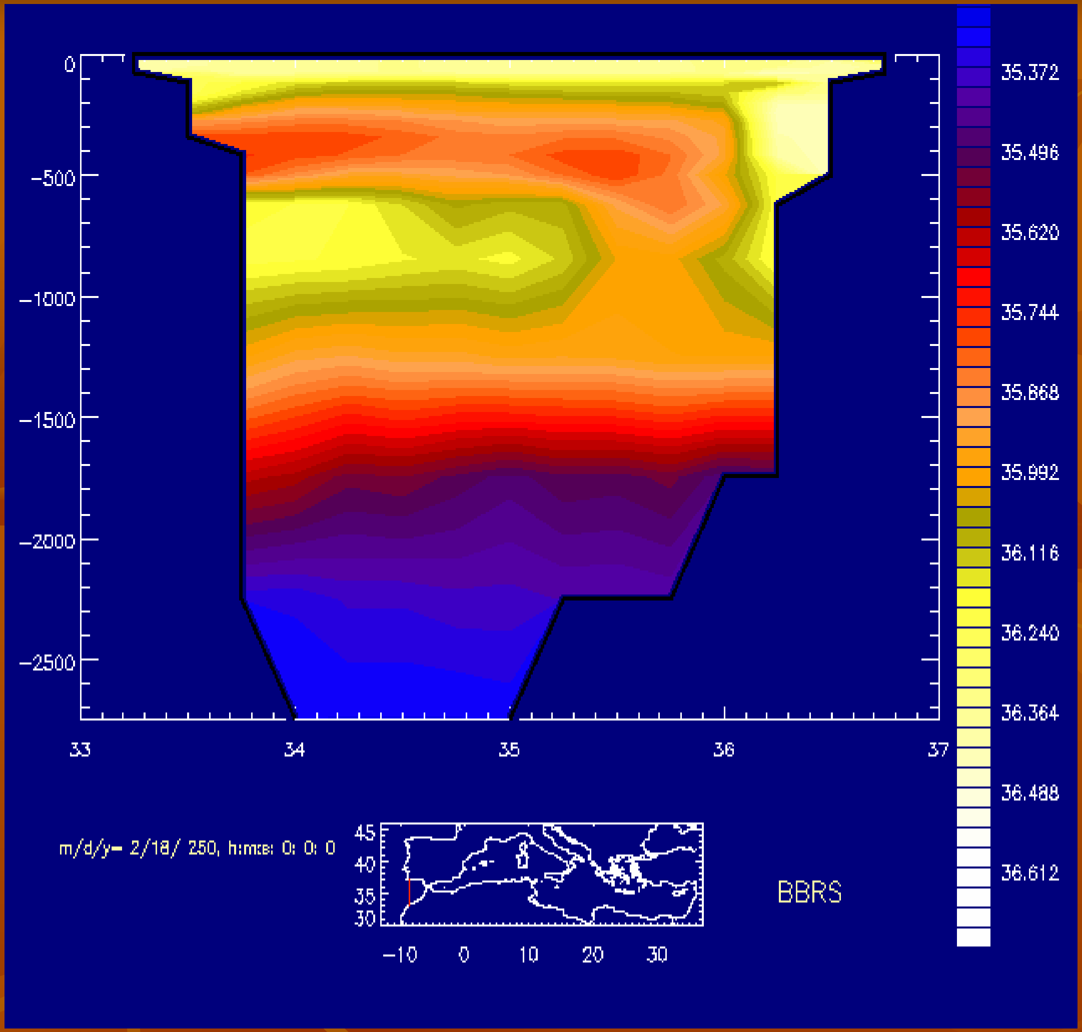
- **Monthly**: Monthly forcing, (SST, ECWM wind, MODB salinity)
- **Daily**: Daily forcing for wind (ECWM and SST), monthly forcing for salinity

- **Sflux1**: Monthly forcing for T and wind, E-P surface flux from ten year averages (150°-160° year of Monthly ≈80 *cm/year*)
- **Sflux2**: as Sflux1 with E-P=1/4 of Sflux1 (≈20 *cm/year*)

Temperatura superficiale nel Mediterraneo



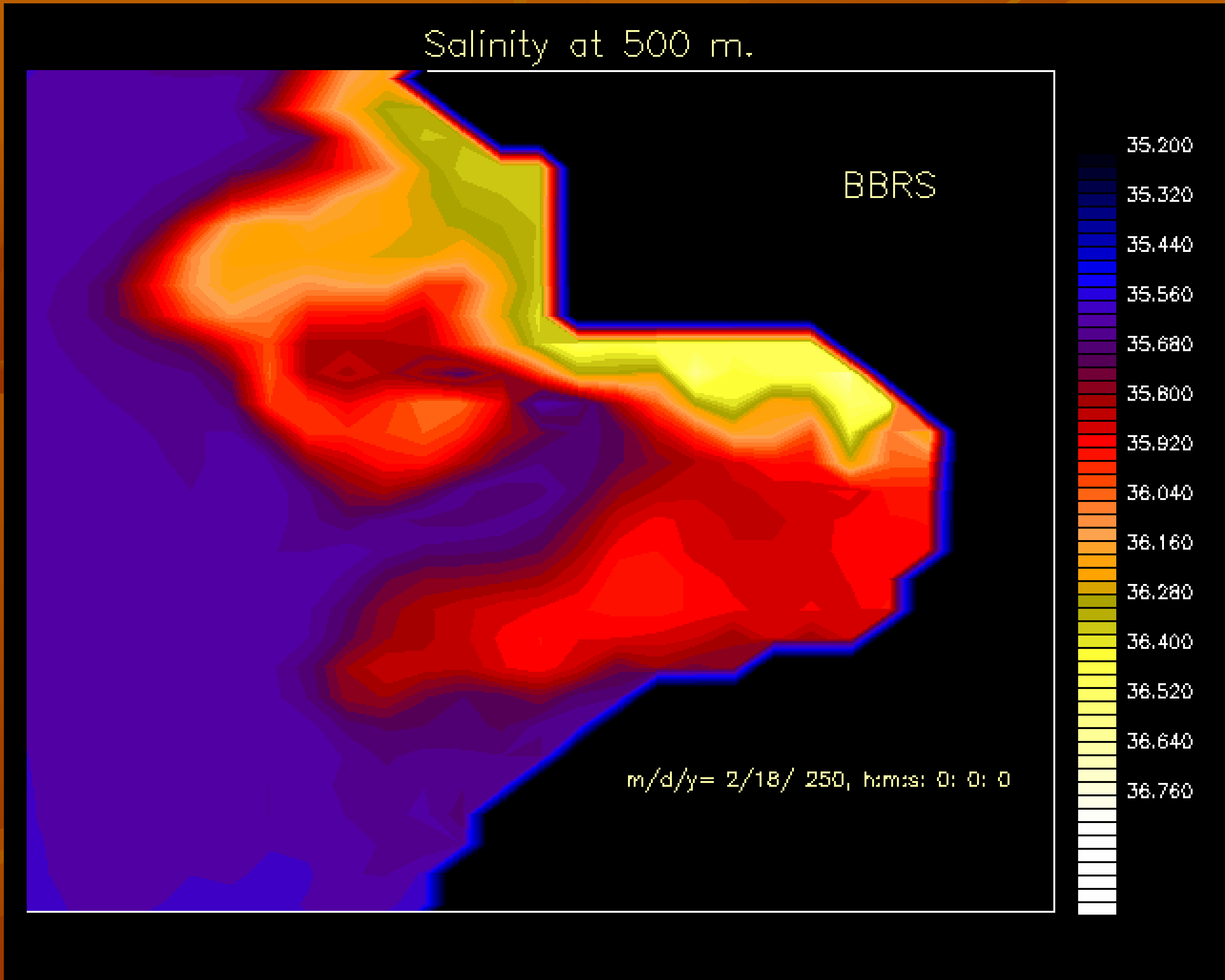
About 1500 particles are released at Alboran Sea



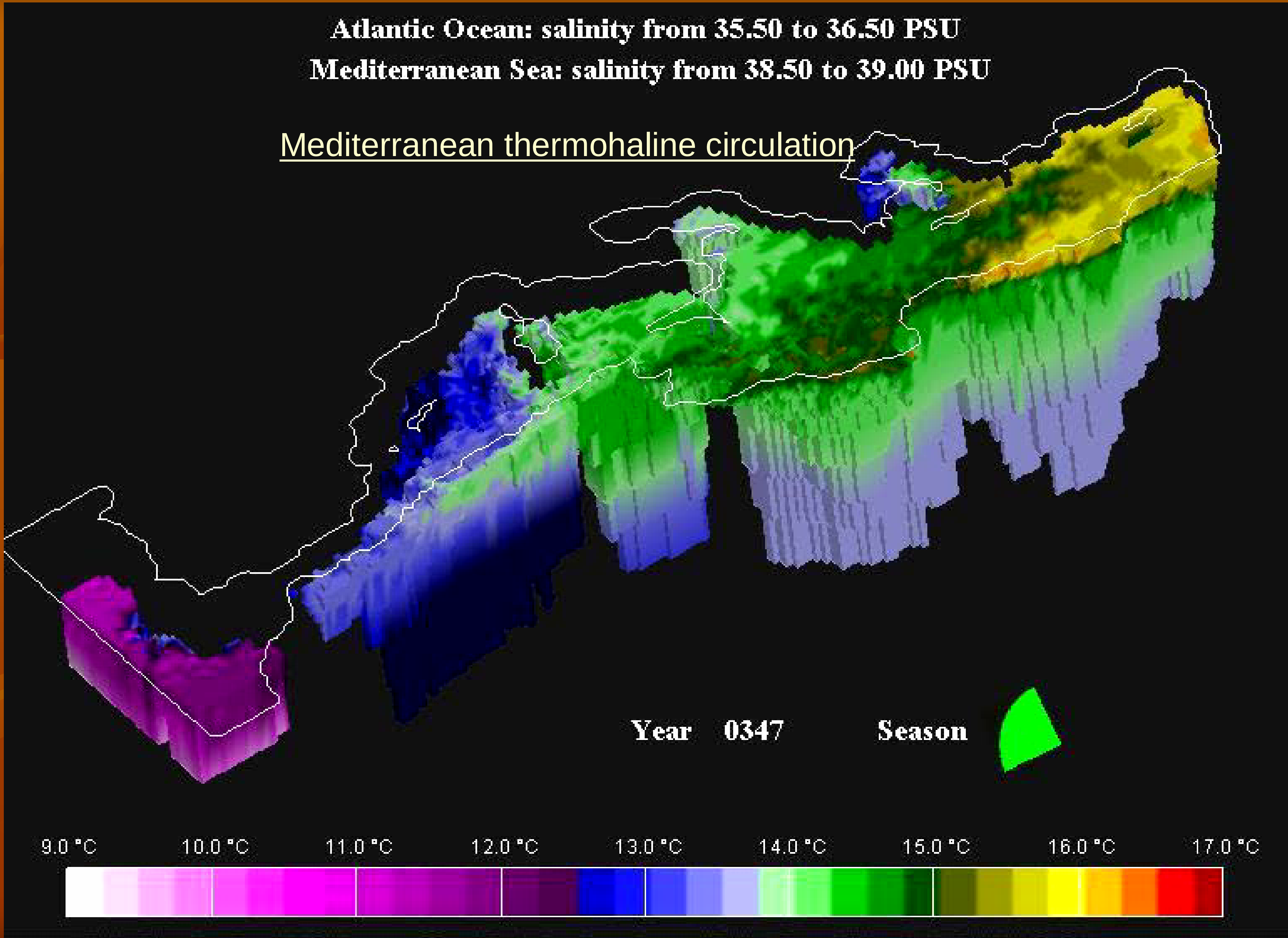
Sezione verticale di Salinità nel Golfo di Cadice.

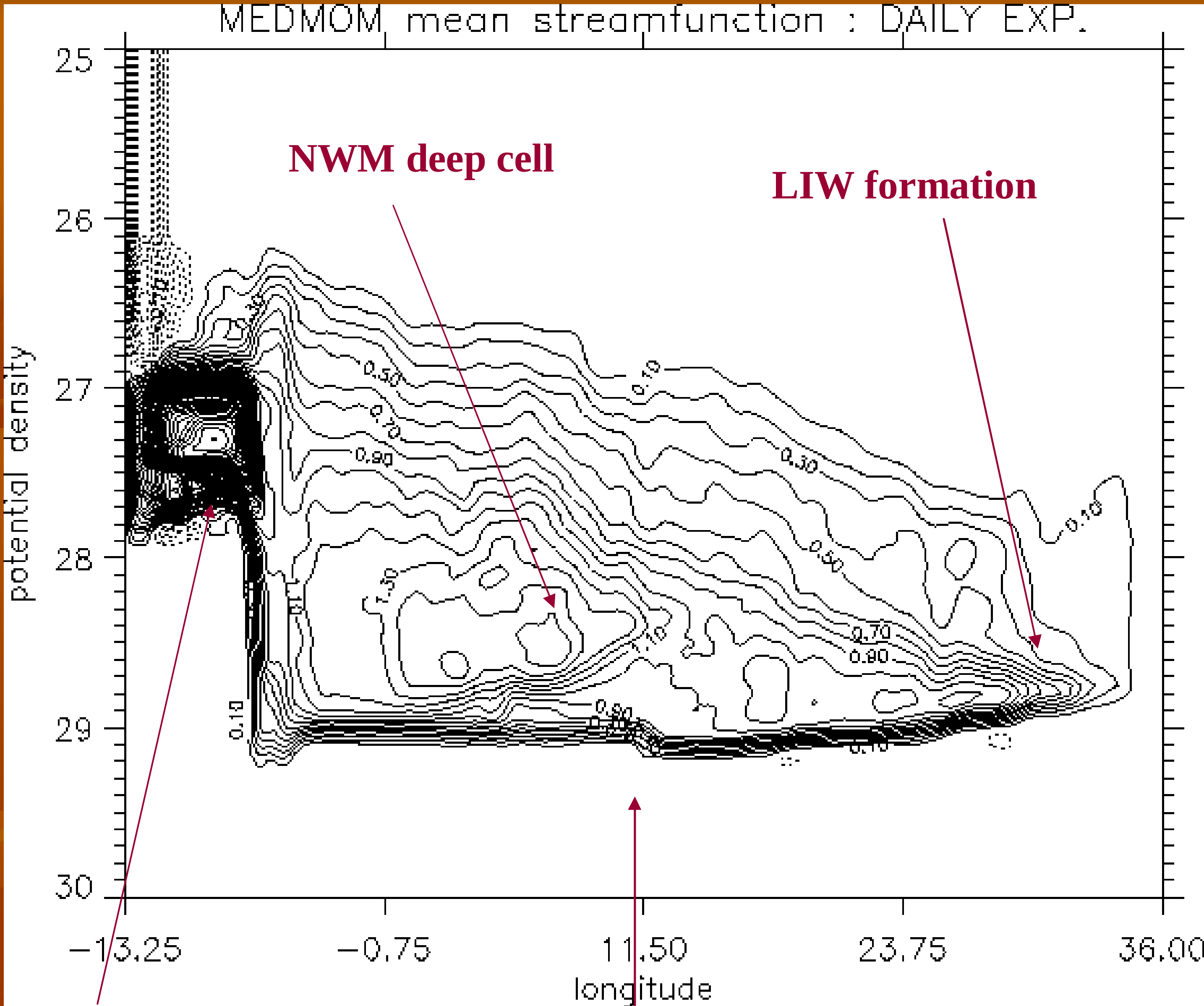
I colori rappresentano la salinità.

La vena di acqua salata (gialla) a 800-1000 Metri e’ acqua di origine Mediterranea.


Salinity at 500 m.
BBRS
35.200
35.320
35.440
35.560
35.680
35.800
35.920
36.040
36.160
36.280
36.400
36.520
36.640
36.760
m/d/y= 2/18/ 250, h:m:s: 0: 0: 0

Mediterranean thermohaline circulation





Gibraltar

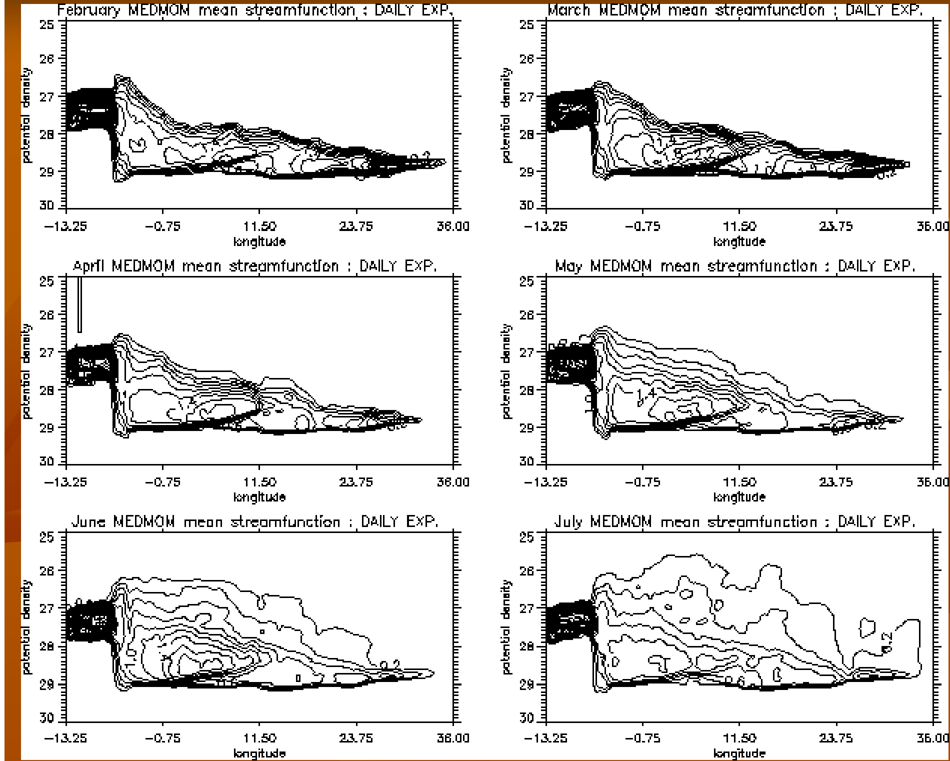
Sicily

No drifts

Lttle diapycnal mixing

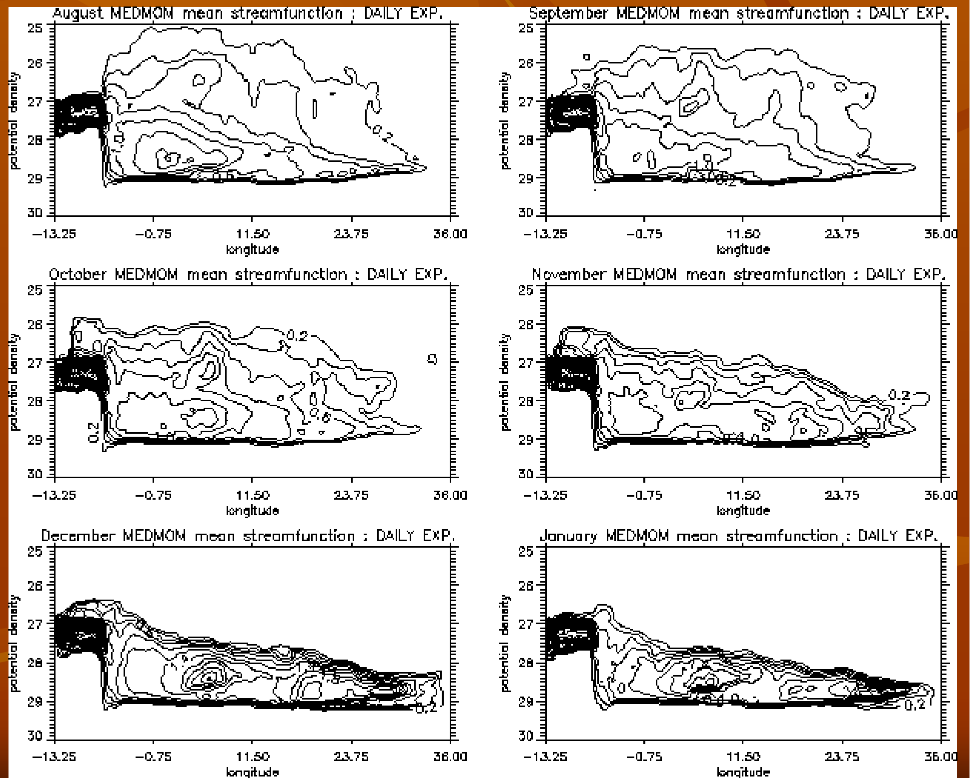
100th year of integration

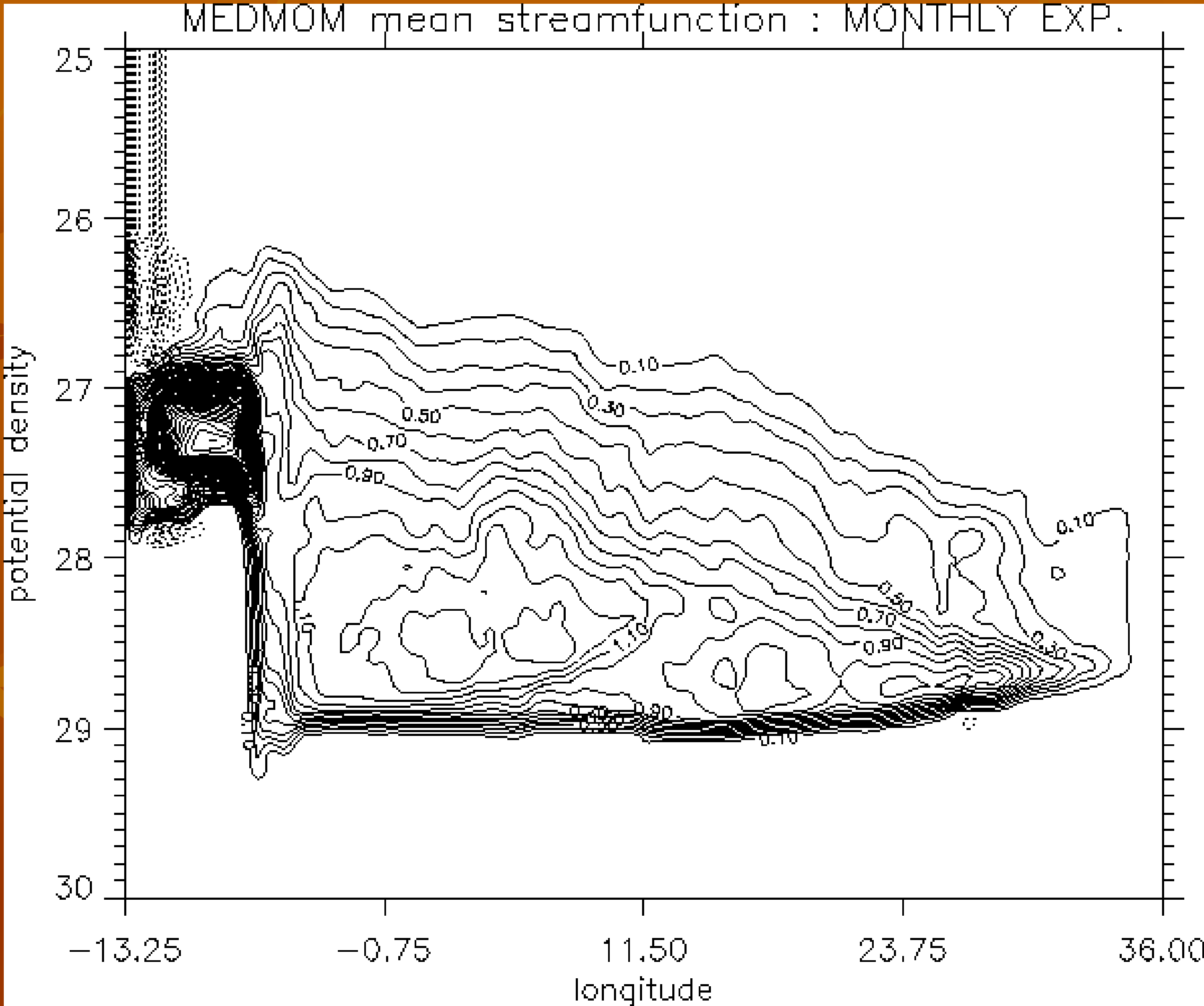
DAILY EXP: Monthly averaged stream function as a function of density



February to July

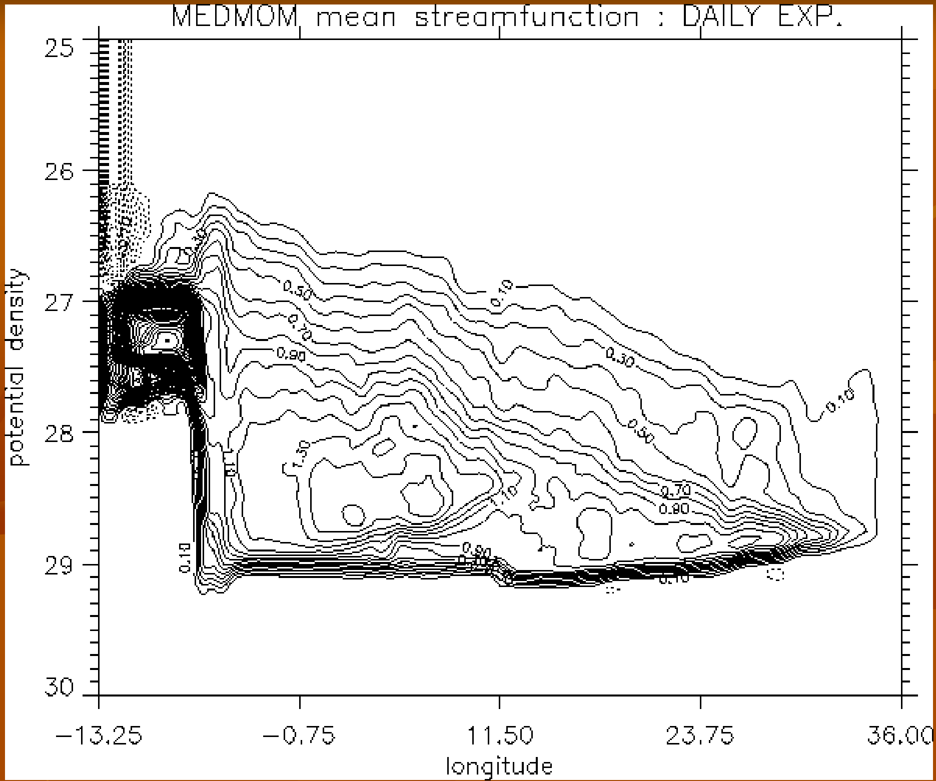
August to January

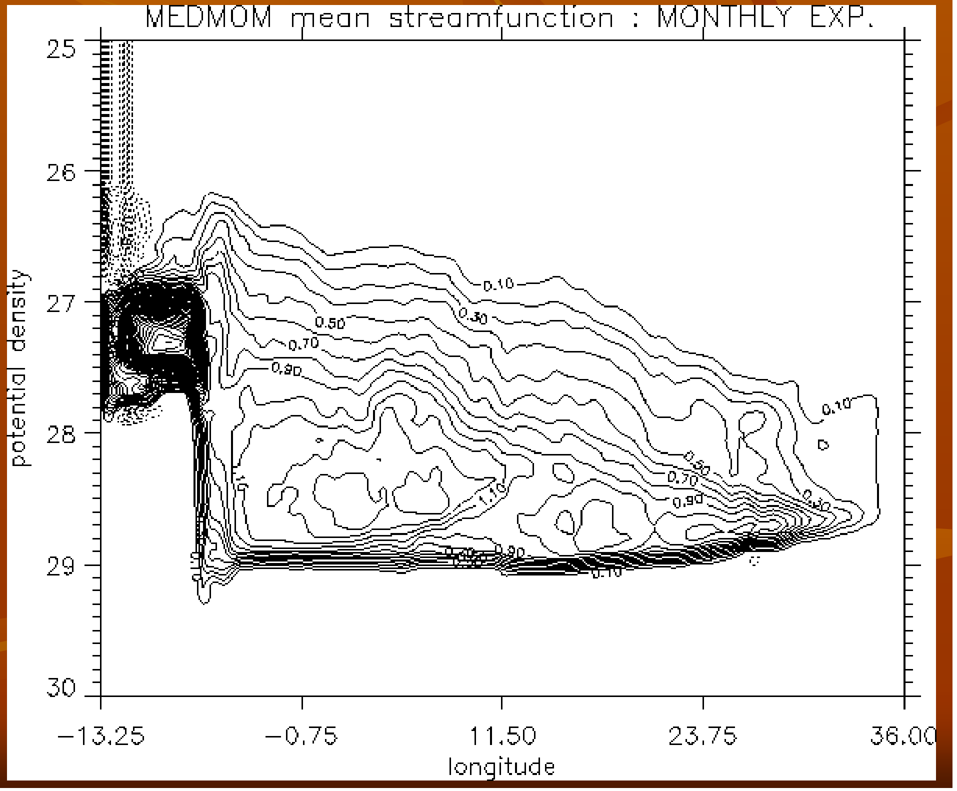




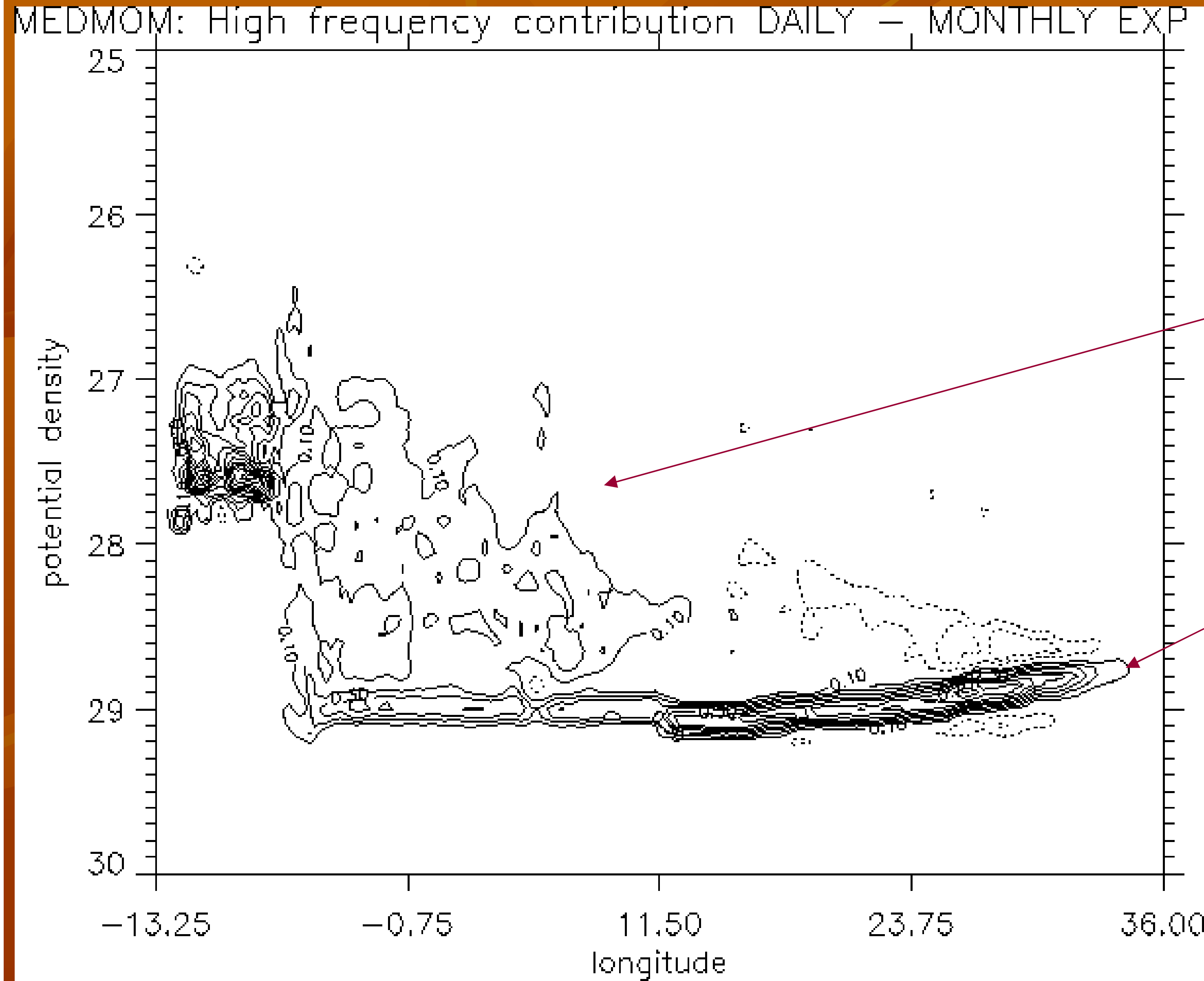
MEDMOM mean streamfunction : MONTHLY EXP.
potential density
25
26
27
28
29
30
longitude
−13.25
−0.75
11.50
23.75
36.00
0.10
0.30
0.50
0.70
0.90
1.10

MONTHLY





DAILY

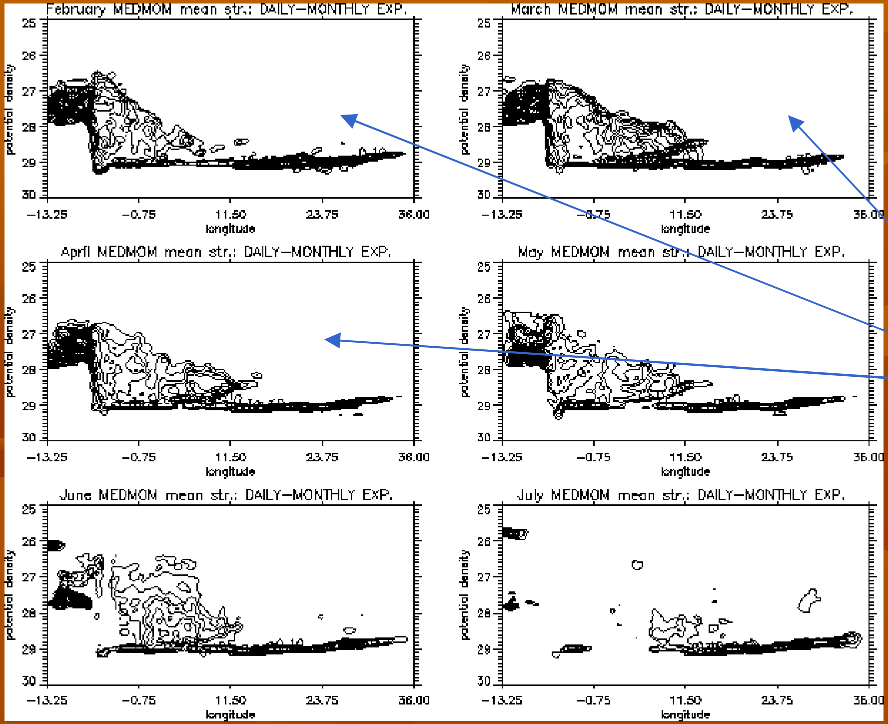


Effect of HF forcing:

Western cell more active

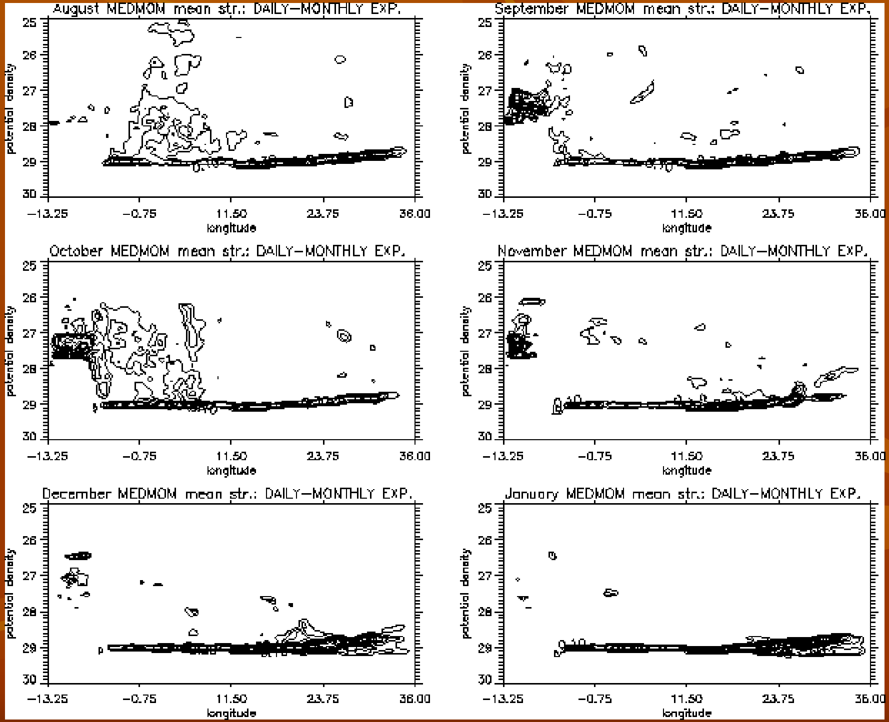
Lower branch of THC denser

DAILY – MONTHLY EXP monthly averaged stream function: contribution to the THC of high frequency forcing



With high frequency forcing western cell more active in ‘winter’

February to July



August to January

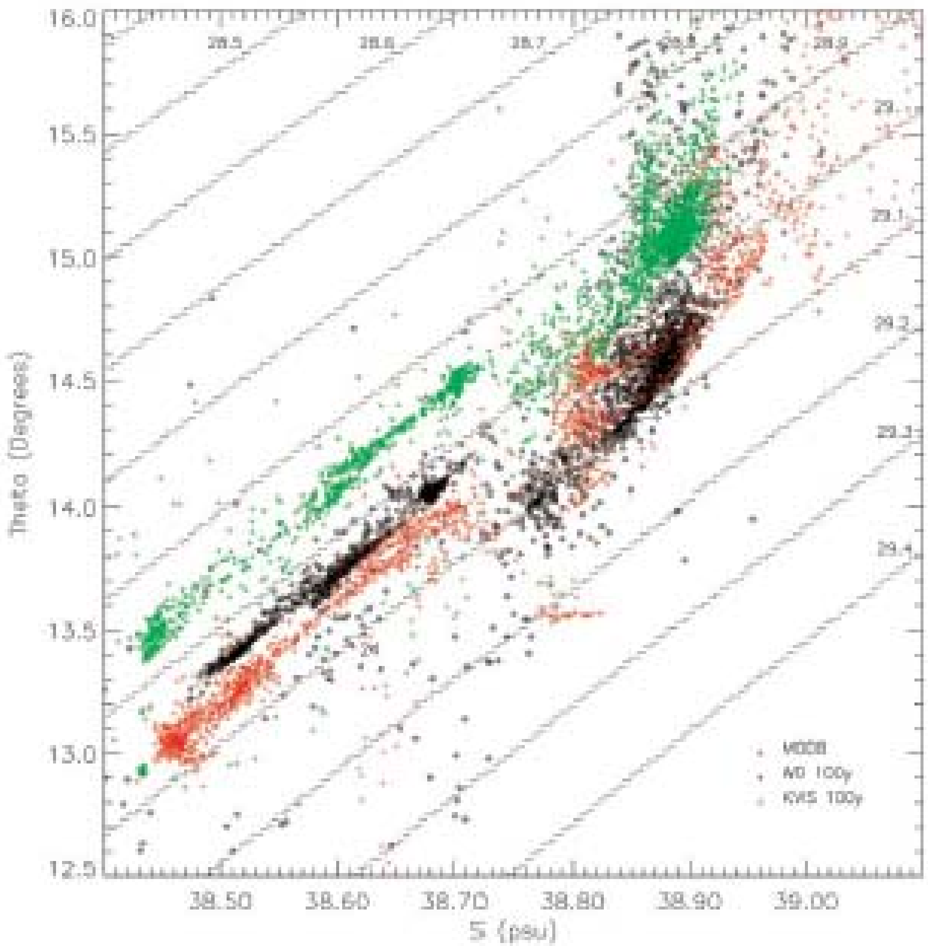


Figure 9. T/S scatter diagram showing the water mass properties of the basin relative to the maximum salinity.

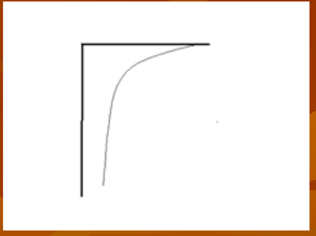
Tracer Diffusivity parameterization

- **BBRS**: $K \propto <\sigma'^2><Z^{-1/2}>$

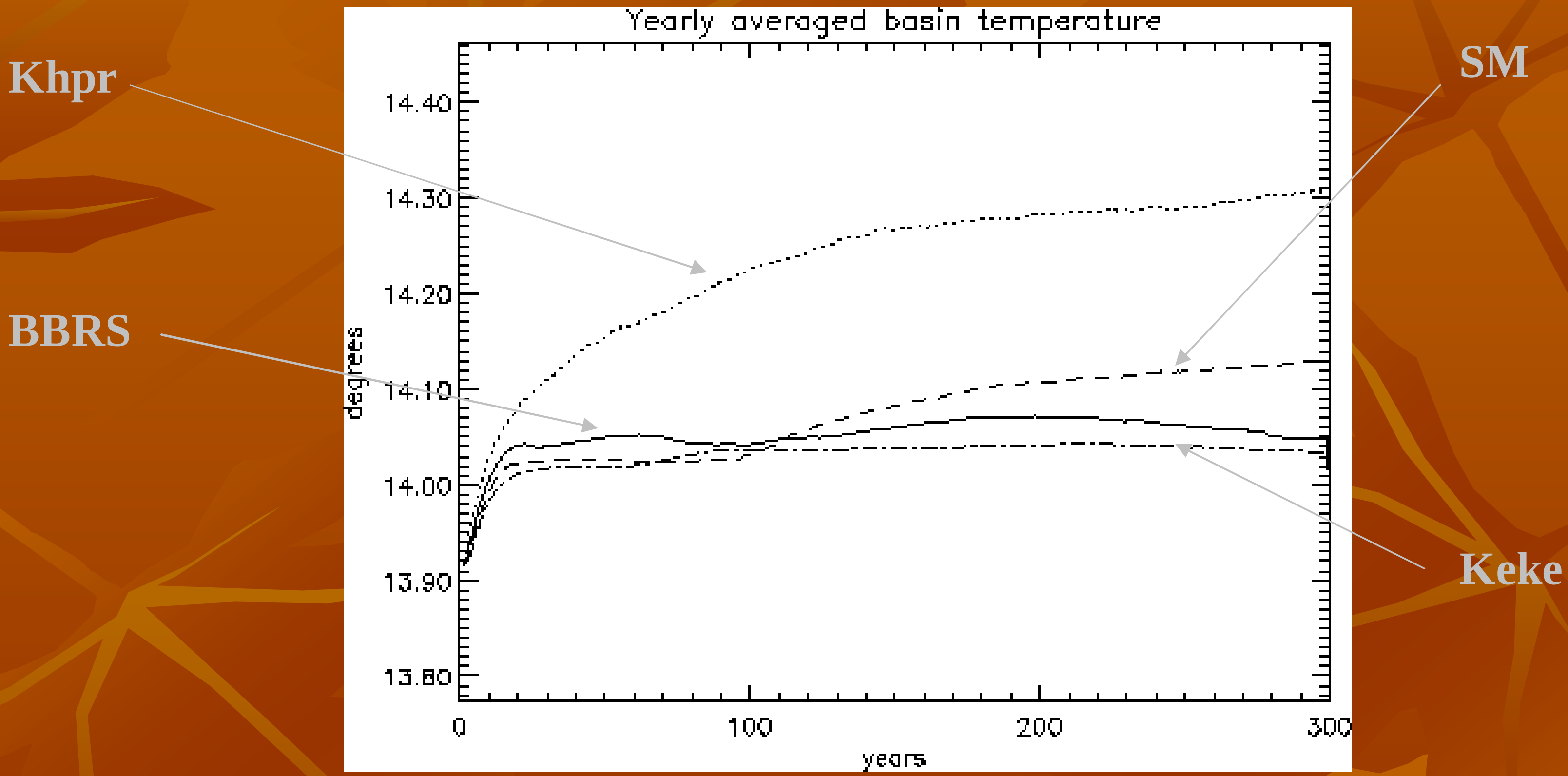
- **SM**: $K \propto h^2 (N^2+S^2)^{1/2}$

- **Keke**: $K \propto <\sigma'^2>T\_L$

- **Khprof**: $K=K(z)$



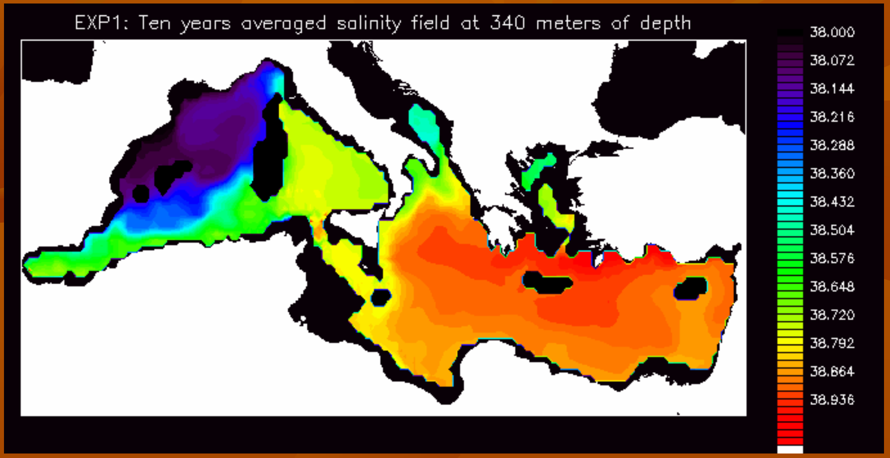
Temperature vs. time in the Tracer diffusivity experiments



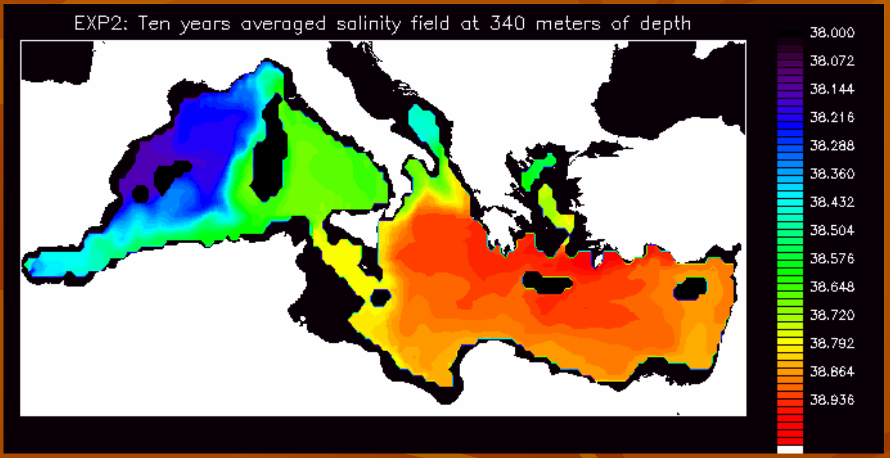
The three space and time dependent diffusivity parameterizations decrease tracer drift. Mean temperature are almost constant after 30 years of integration

Ten year averaged (150-160) salinity field

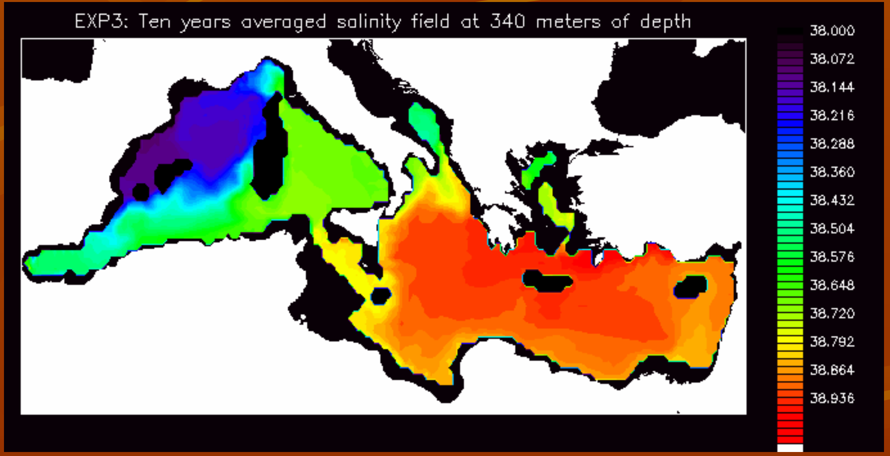
Khprof



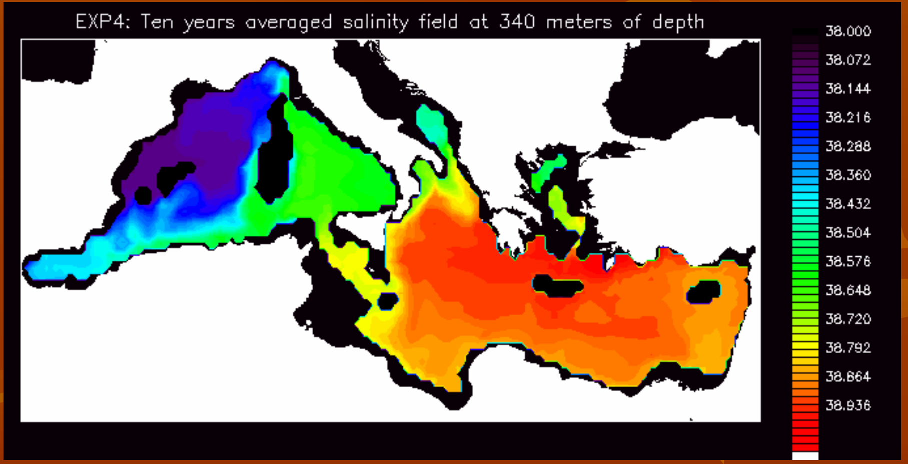
BBRS



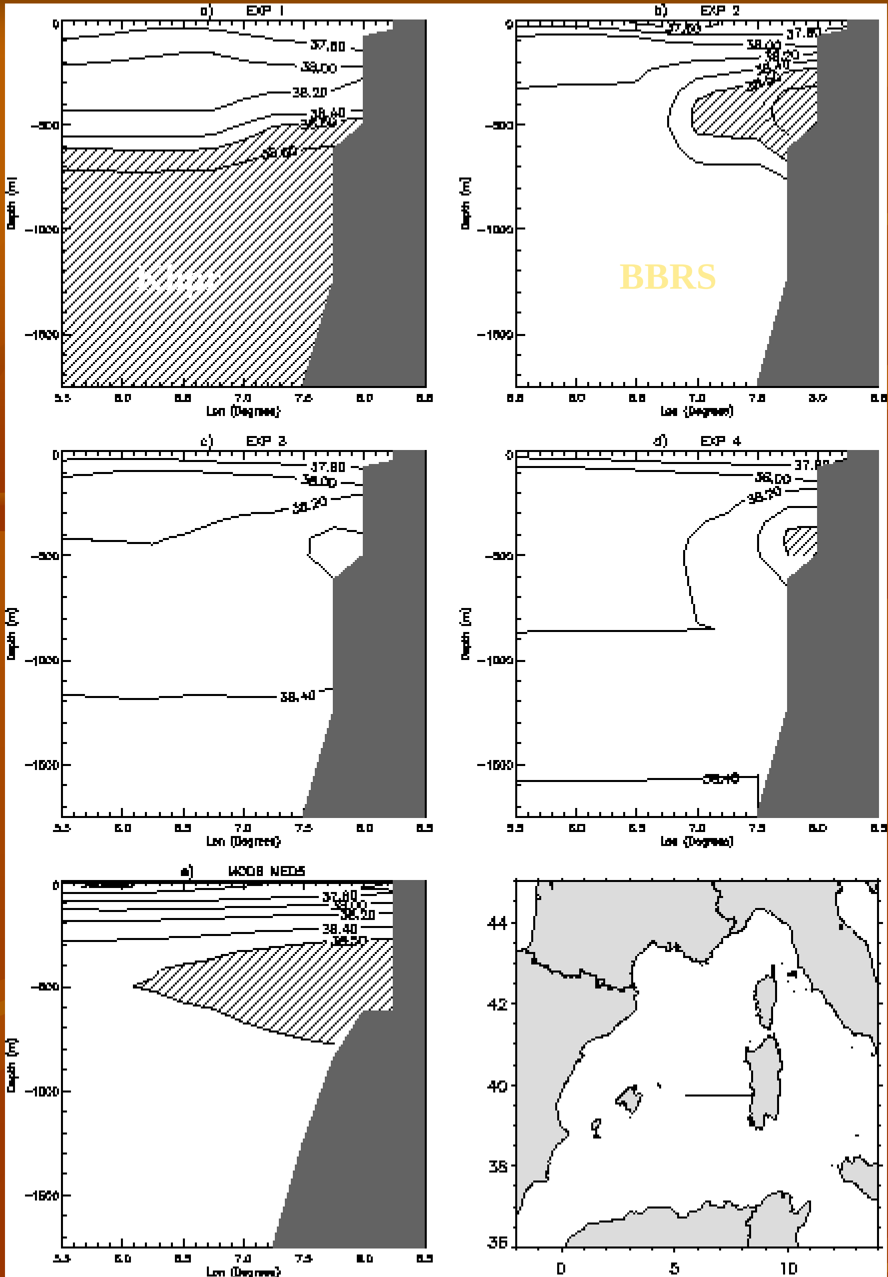
SM



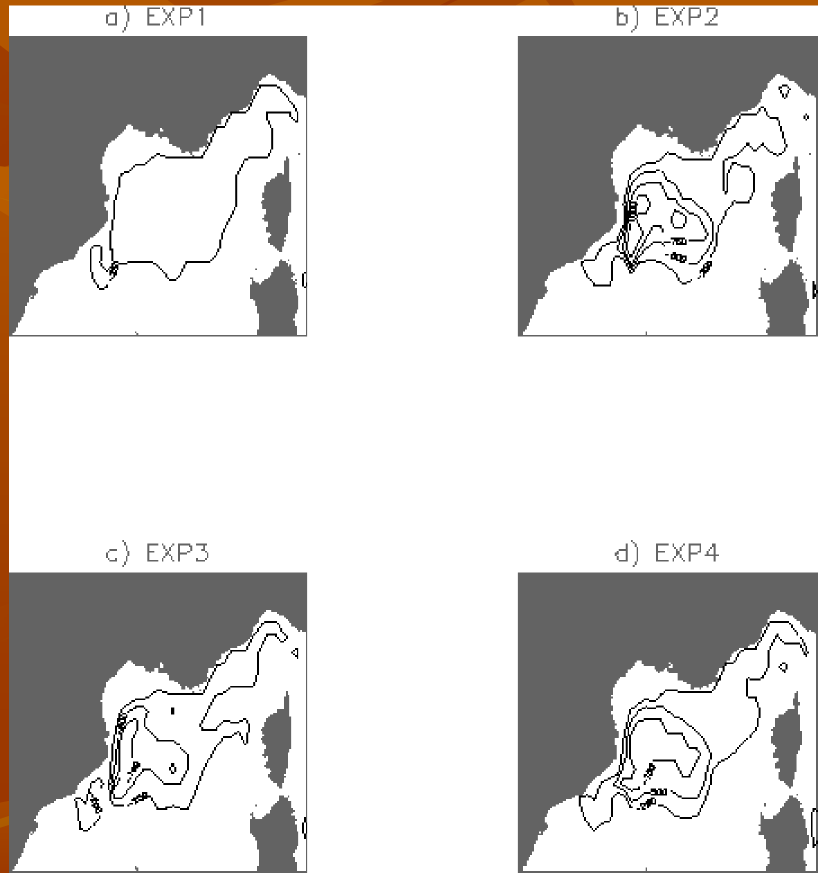
Keke



Existence of LIW very important for deep water formation



Salinity sections



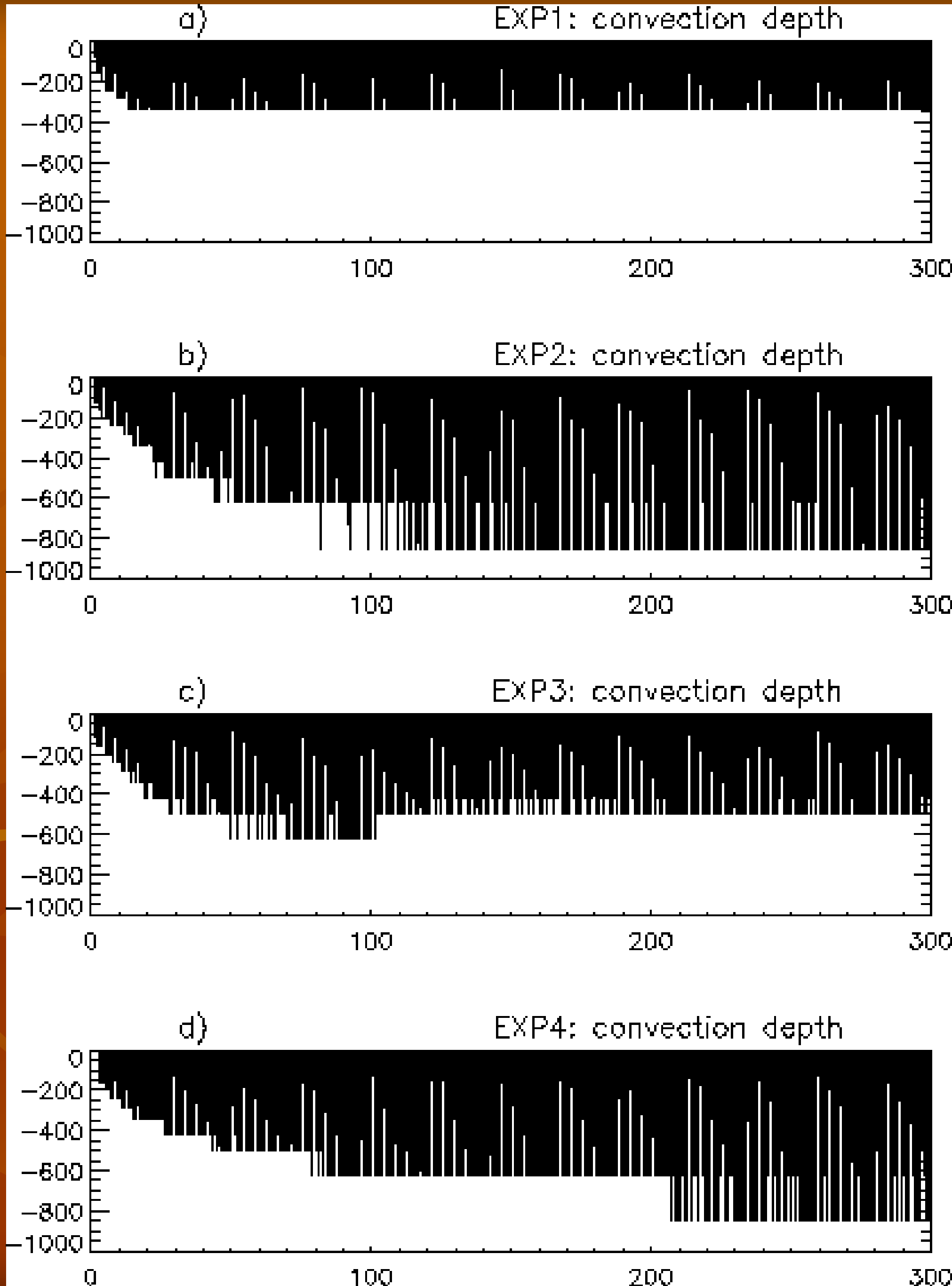
isolines of convection depth

Khprof

BBRS

SM

Keke



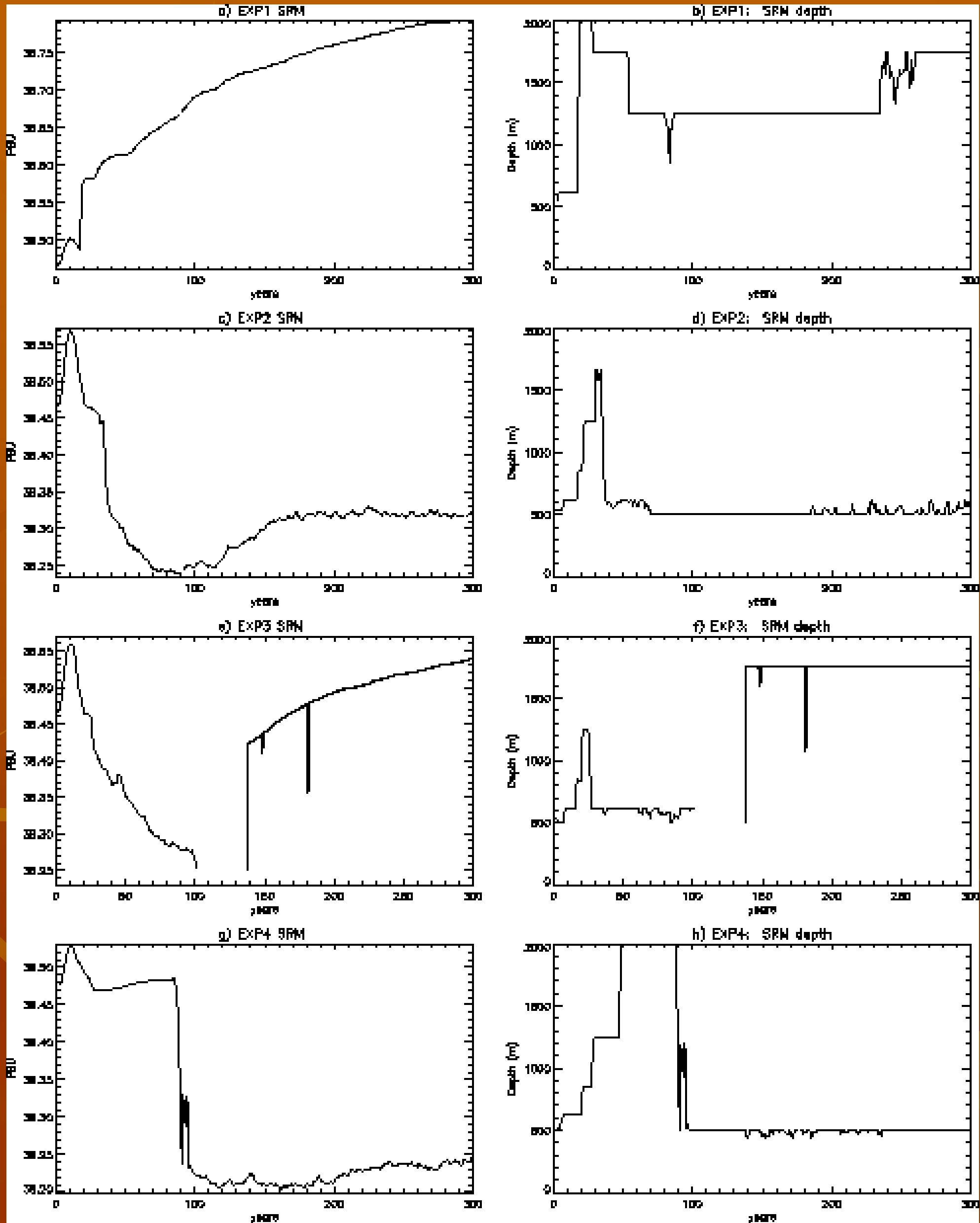
InBBRS the equilibrium between surface forcings and water mass structure and dynamics is reached only after 100-120 year of integration

Khprof

BBRS

SM

Keke



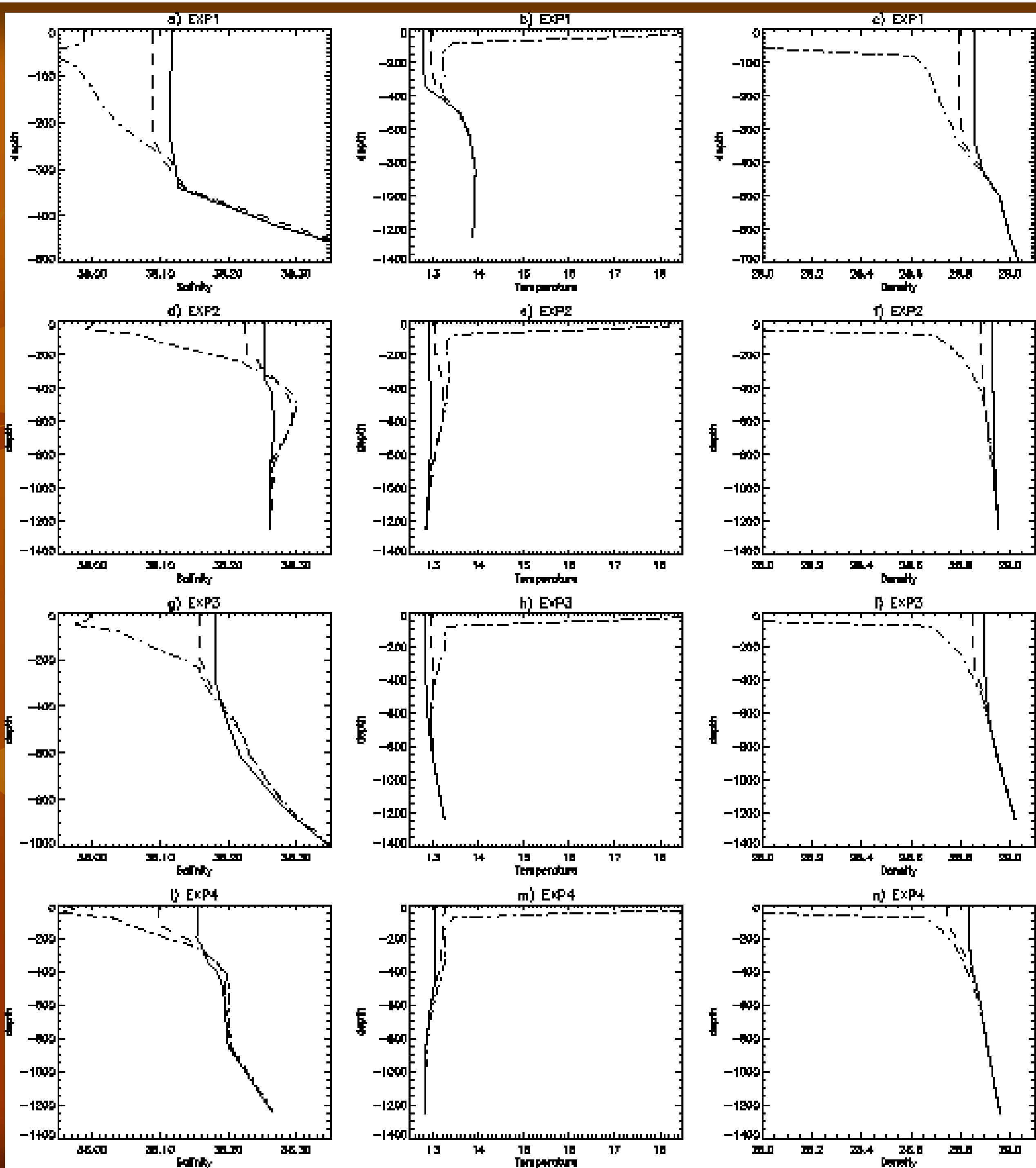
Salinity relative Maximum in the NWM (left) and its depth (right)

Khprof

BBRS

SM

Keke



Salinity (left) Temperature (center) and density profiles in the NWM before, during and after a conection event

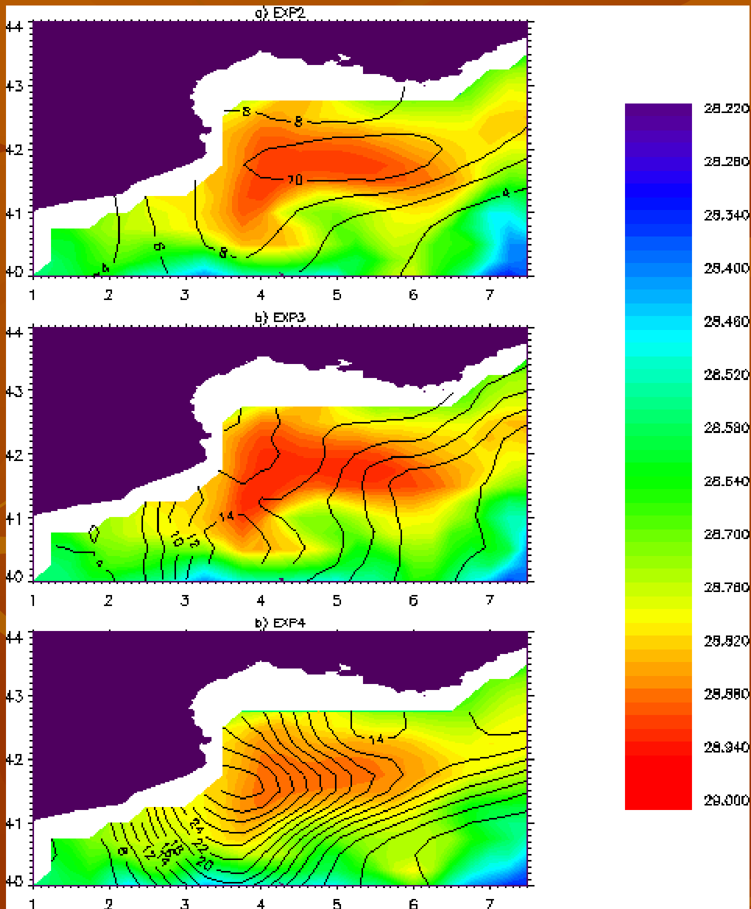
February diffusivity and density field in the Lyon Gulf

BBRS

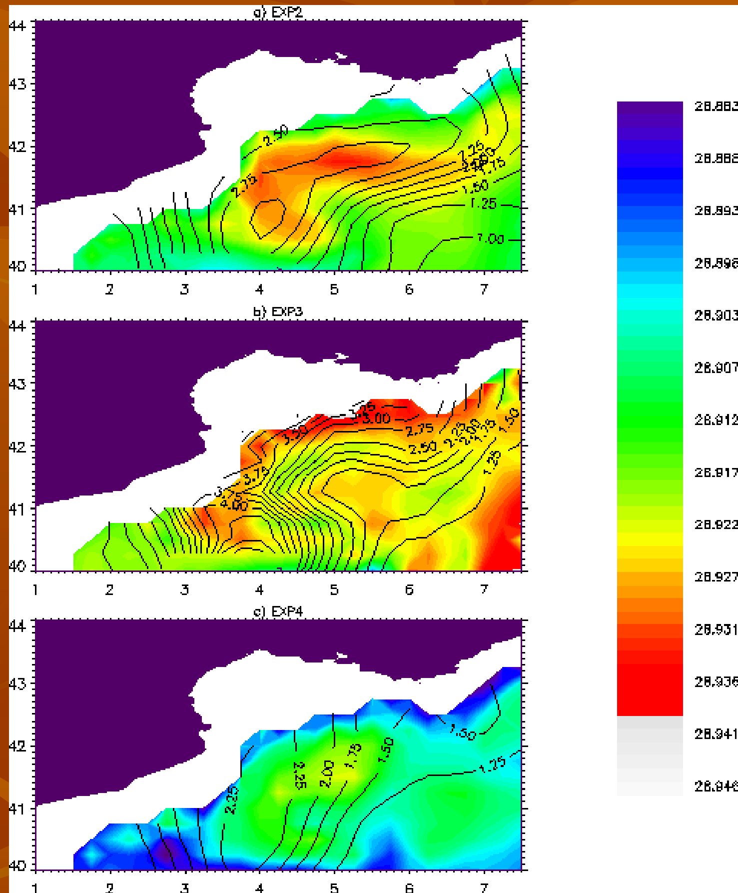
SM

Keke

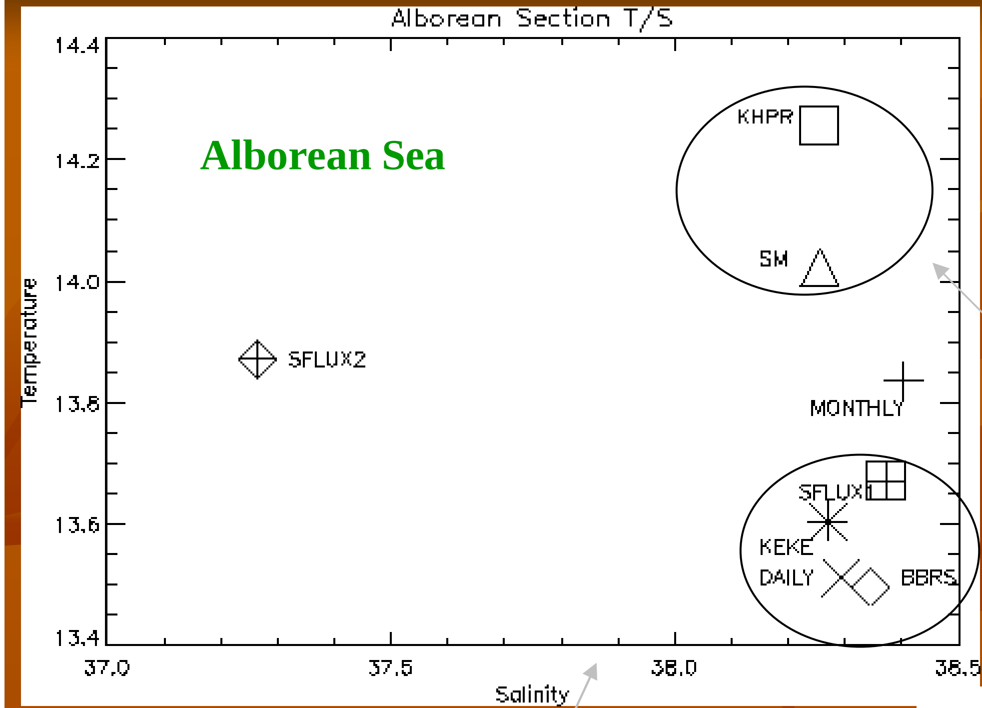
80 m.



850 m.



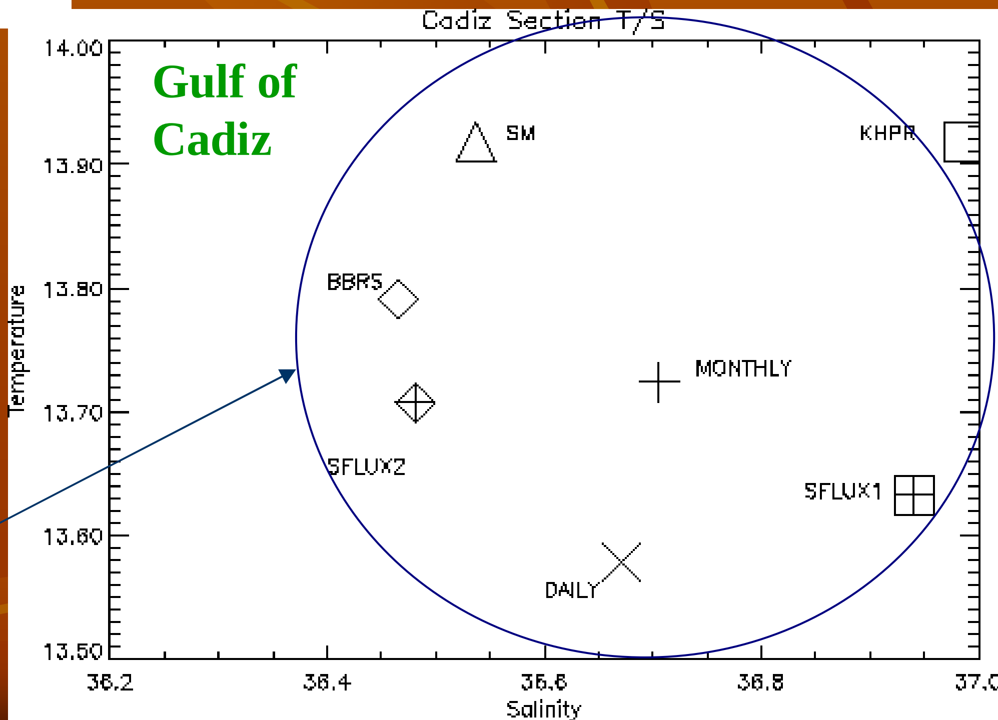
MEDMOM results



Shallow convection in the NWM

Deep convection in the NWM

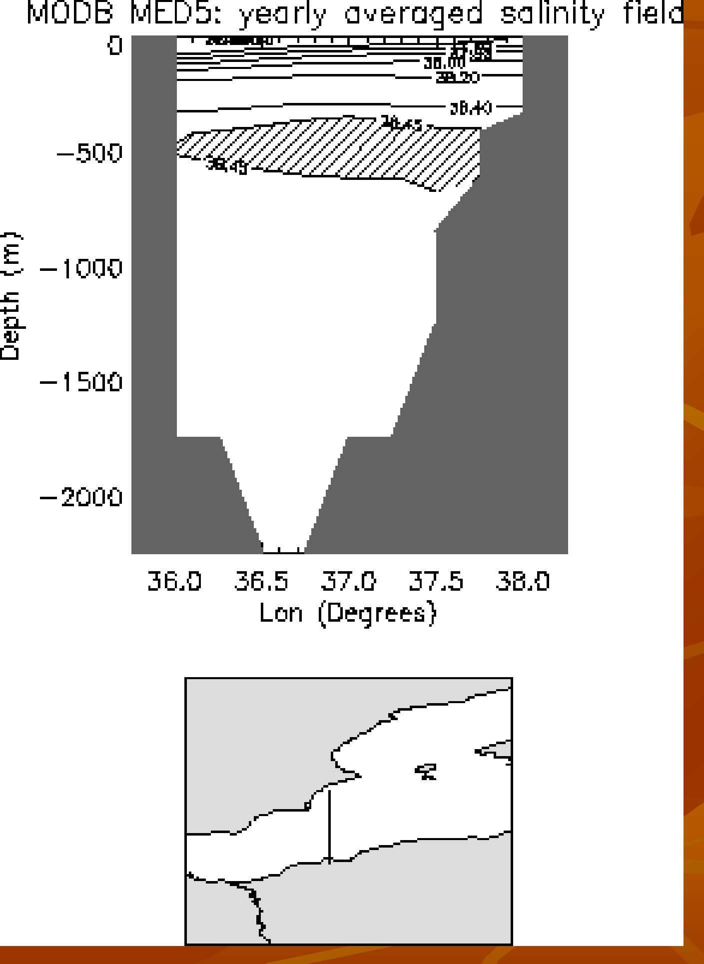
T/S diagrams of the outflowing Med water in the Alborean Sea and in the Gulf of Cadiz



No obvious relations, probably numerical noise determine hydrological properties

MODB MED5: yearly averaged salinity field

in the Alborean Sea



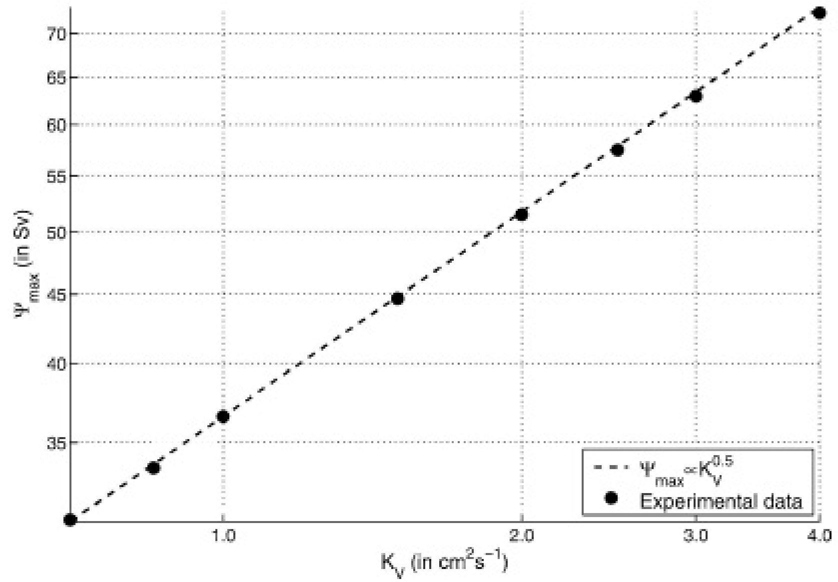


Fig. 9 Dependence of maximum value of the THC on the value of the vertical diffusivity for northern sinking pattern under symmetric boundary conditions. For this plot, we set the relaxation surface temperature by choosing $\bar{T}_o = 15°C$, $\Delta\bar{T} = 23.5°C$, and the freshwater flux by choosing $\Phi_N = \Phi_S = \Phi_{av}$