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International Atomic Energy Agency

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International MedCLIVAR-ICTP-ENEA Summer School on the Mediterranean Climate System and Regional Climate Change

13 - 22 September 2010

AO GCM Modeling the Mediterranean Sea general circulation and the interaction with the Atlantic

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Modeling the Mediterranean Sea and its interaction with the North Atlantic

by

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Trieste 13-22 September 2010, International MedCLIVAR-ICTP-ENEA Summer School on the Mediterranean Climate System and Regional Climate Change

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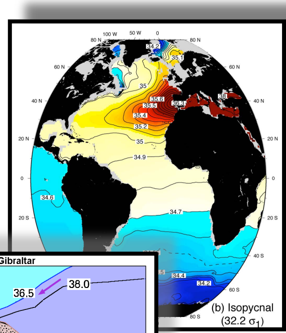
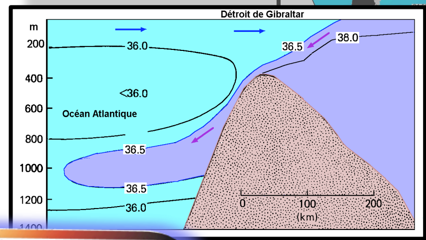
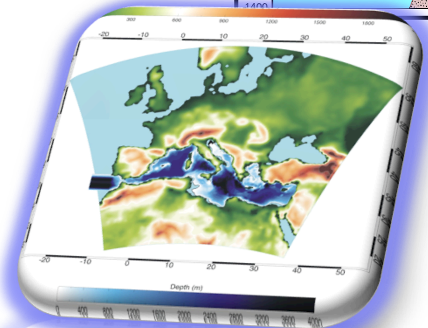
- ✓Climate role of the straits
- ✓Spreading of MOW
- ✓Crucial Numerical Experiments
- ✓Protheus System and
  some future scenarios





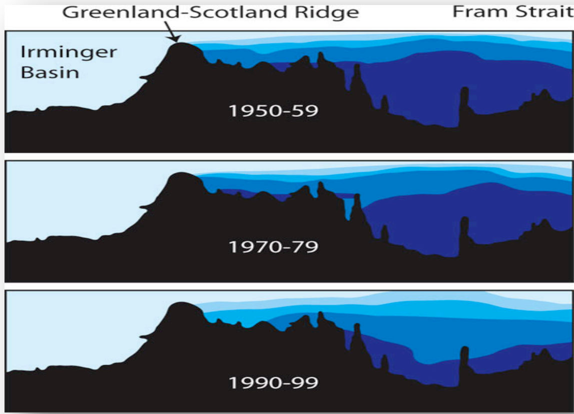


The climate role of the straits

Many of the basins of the world's oceans are separated by land and submarine ridges, and the exchange between basins is forced to occur in flow through gaps or over sills.

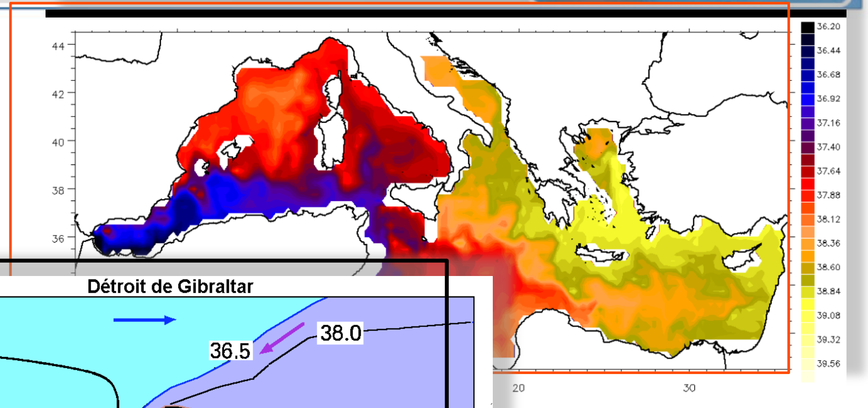
These topographic features have a remarkable impact upon the large scale thermohaline circulation of the ocean and hence upon climate

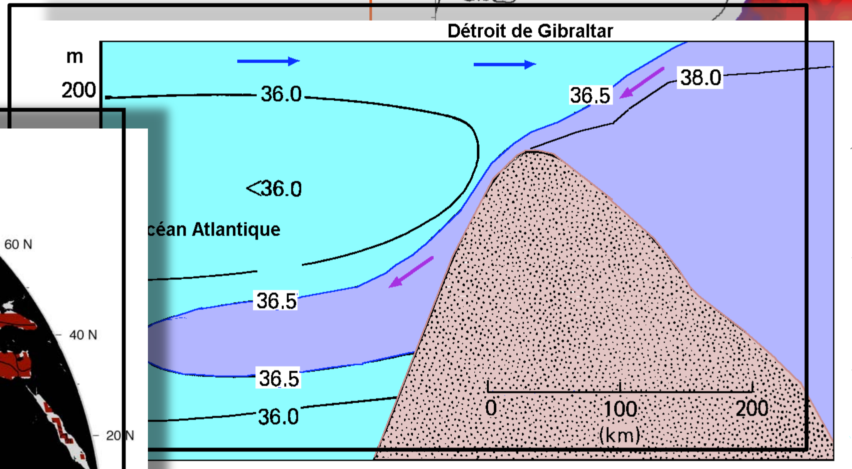
SENSITIVE SEAS (1): Arctic Ocean circulation limited by Bering, Fram, Denmark Straits

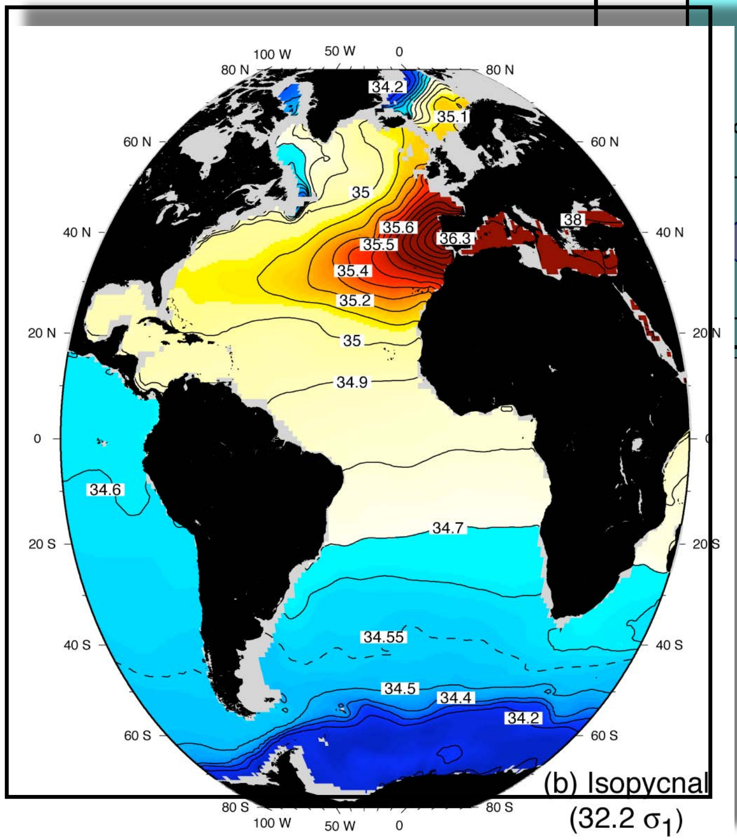


Cold, dense waters that propel the ocean conveyor form and accumulate primarily in certain locations in the Arctic and North Atlantic in the Greenland, Iceland, and Norwegian Seas and in the Labrador, Irminger, and Iceland Basins

SENSITIVE SEAS (2): THE STRAIT OF GIBRALTAR AS A CHOCK POINT OF THE ATLANTIC-MEDITERRANEAN SYSTEM







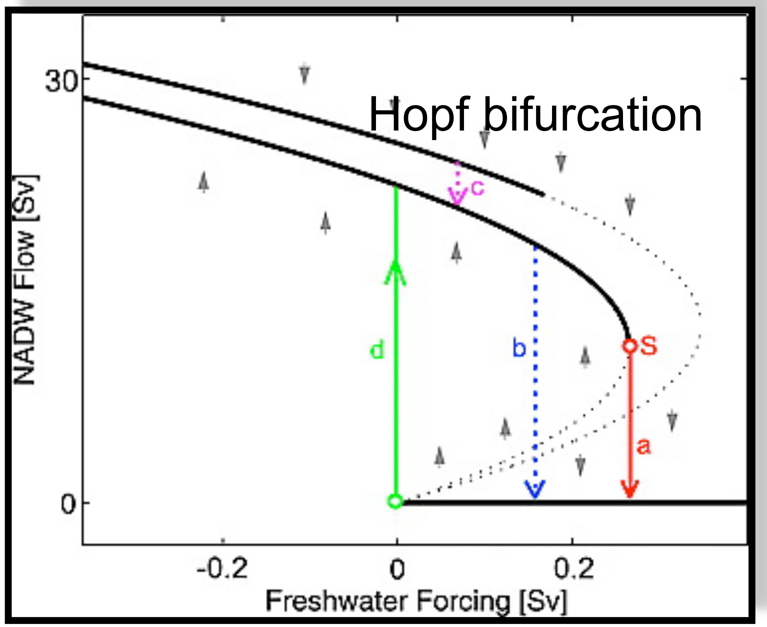
The Mediterranean thermohaline circulation produce an anomalously warm and salty tongue at intermediate depths (MOW)

The Mediterranean Outflow can be considered as a major contributor to the freshwater budget of the North Atlantic.

In particular, presently the Mediterranean Outflow corresponds to about 10–20% of the net annual evaporation over the North Atlantic

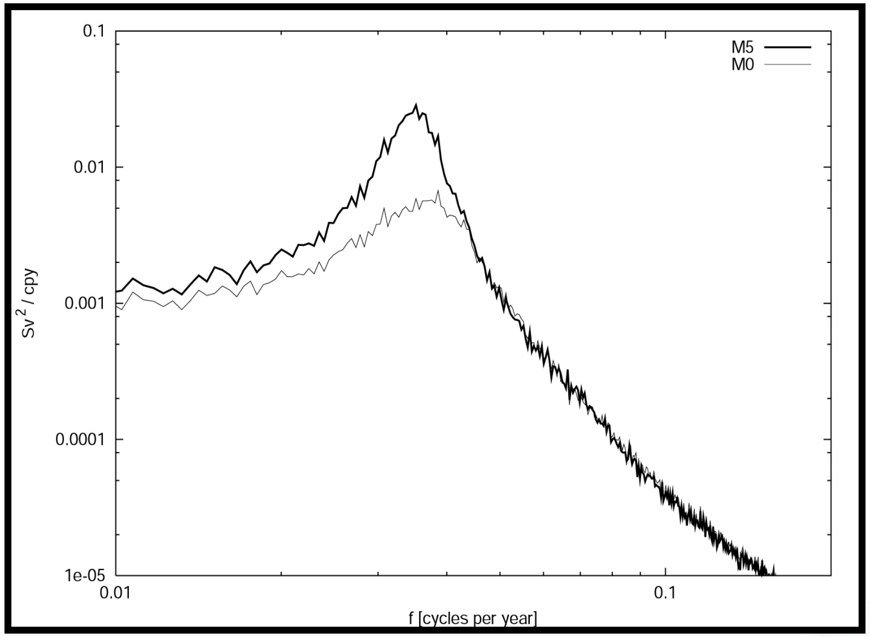
(Gerdes et al., 1999; Curry et al., 2003).

the freshwater **decrease** the THC stability



Rahmstorf, 1995, 1998

the salt **increase** the THC stability



Artale, Calmanti and Sutera, Tellus 2002, 2004

In the coupled solution, the impact of the improved overflow physics on the global climate is minimal, with North Atlantic sea surface temperatures and heat fluxes changing generally by less than 1 °C and 15W m^2, respectively. However, there is interesting spatial variability in the coupling strength, which ranges between ±20W m^2 °C^{-1} in the coupled case. (Wu et al, Ocean modelling, 2007)

Impact of MOW on THC and ventilation

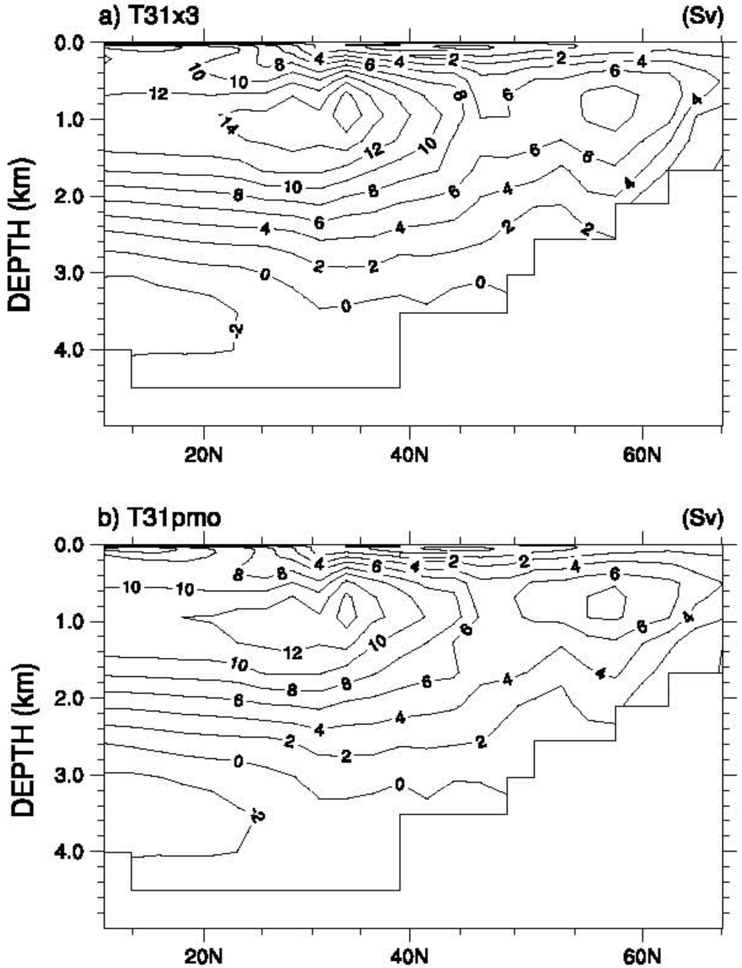


Fig. 9. Time-mean THC in the North Atlantic from (a) T31×3 and (b) T31pmo. The units are in Sv. The positive and negative contours denote clockwise and counter-clockwise circulations, respectively.

Impact of MOW on THC

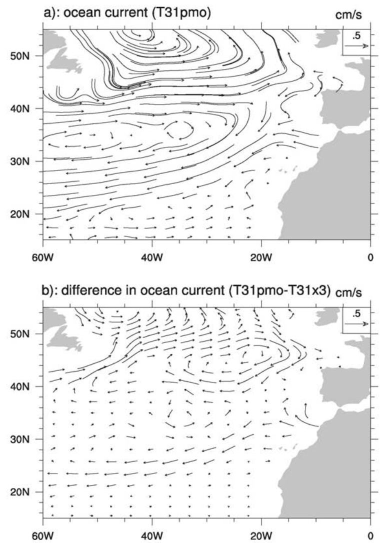


Fig. 7. Time-mean currents in the North Atlantic at a depth of 1100 m (a) from T31pmo and (b) its difference from T31×3.

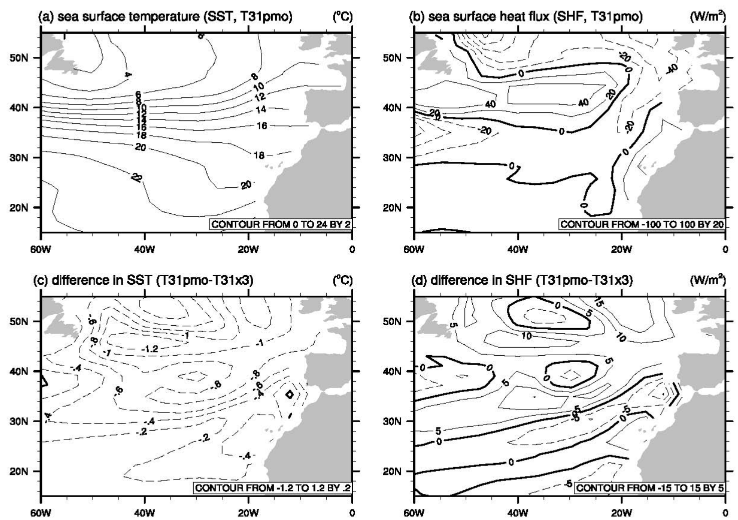
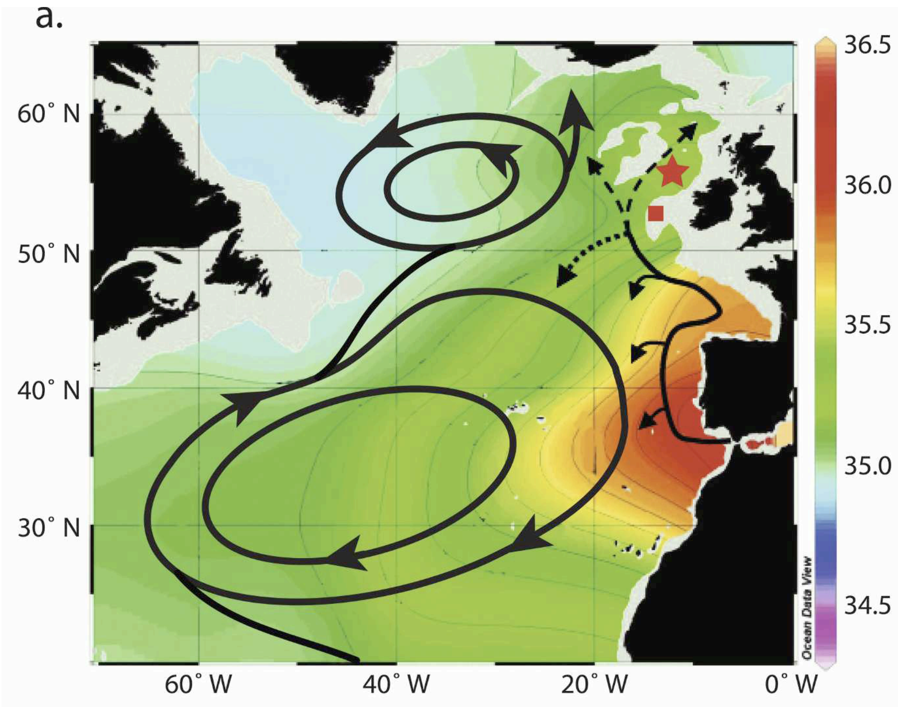
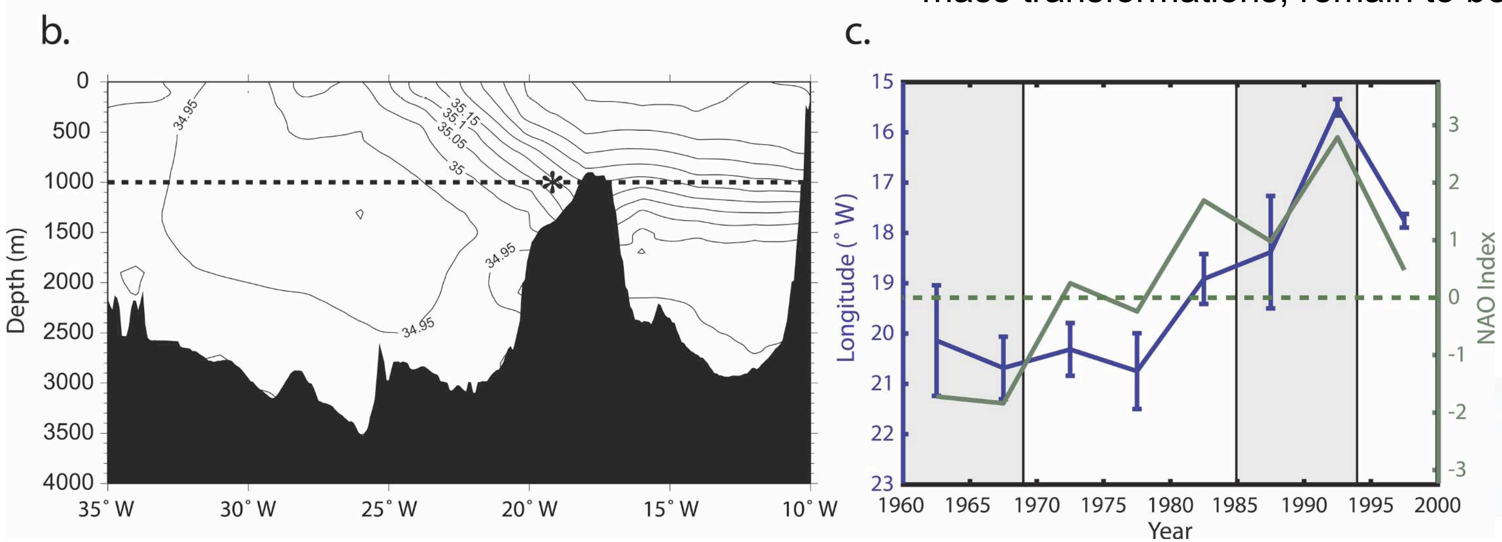


Fig. 11. Time-mean (a) sea surface temperature and (b) surface heat flux distributions from T31pmo. Their respective differences from T31×3 are given in (c) and (d). In (b d), the thin solid and dashed lines indicate positive and negative contour levels, respectively.

New research on MOW
(Lozier and Stewart, JPO 2008)



Historical hydrographic data in the eastern North Atlantic are used to suggest a connection between the northward penetration of Mediterranean Overflow Water (MOW) and the location of the subpolar front,the latter of which is shown to vary with the North Atlantic Oscillation (NAO). During persistent high-NAO periods, when the subpolar front moves eastward, waters in the subpolar gyre essentially block the northward-flowing MOW, preventing its entry into the subpolar gyre. Conversely, during low NAO periods,the subpolar front moves westward, allowing MOW to penetrate past Porcupine Bank into the subpolar gyre. The impacts of an intermittent penetration of MOW into the subpolar gyre, including the possibleeffect on water mass transformations, remain to be investigated.

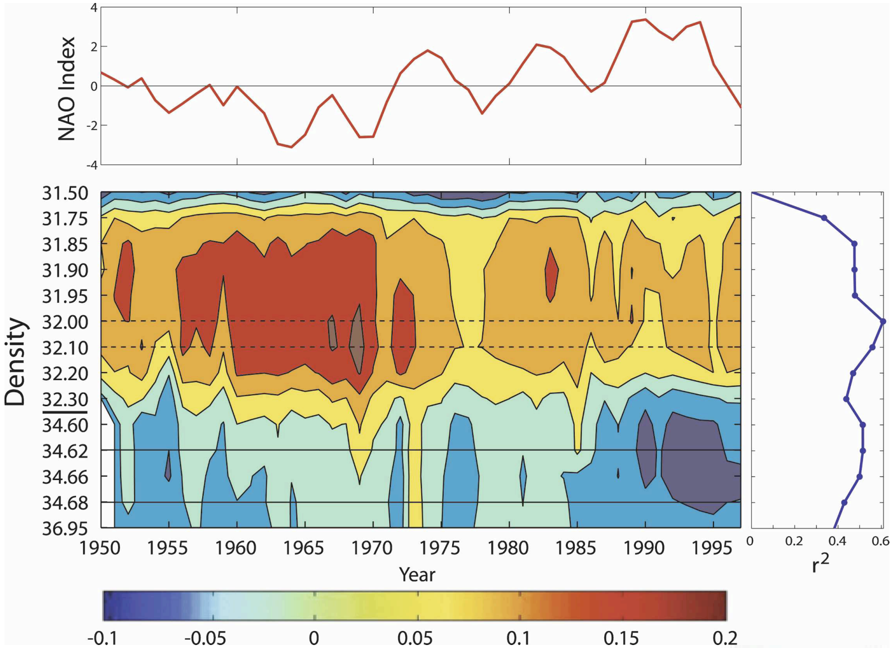


Solid black lines represent the circulation pathways for the subpolar gyre, subtropical gyre, and MOW.

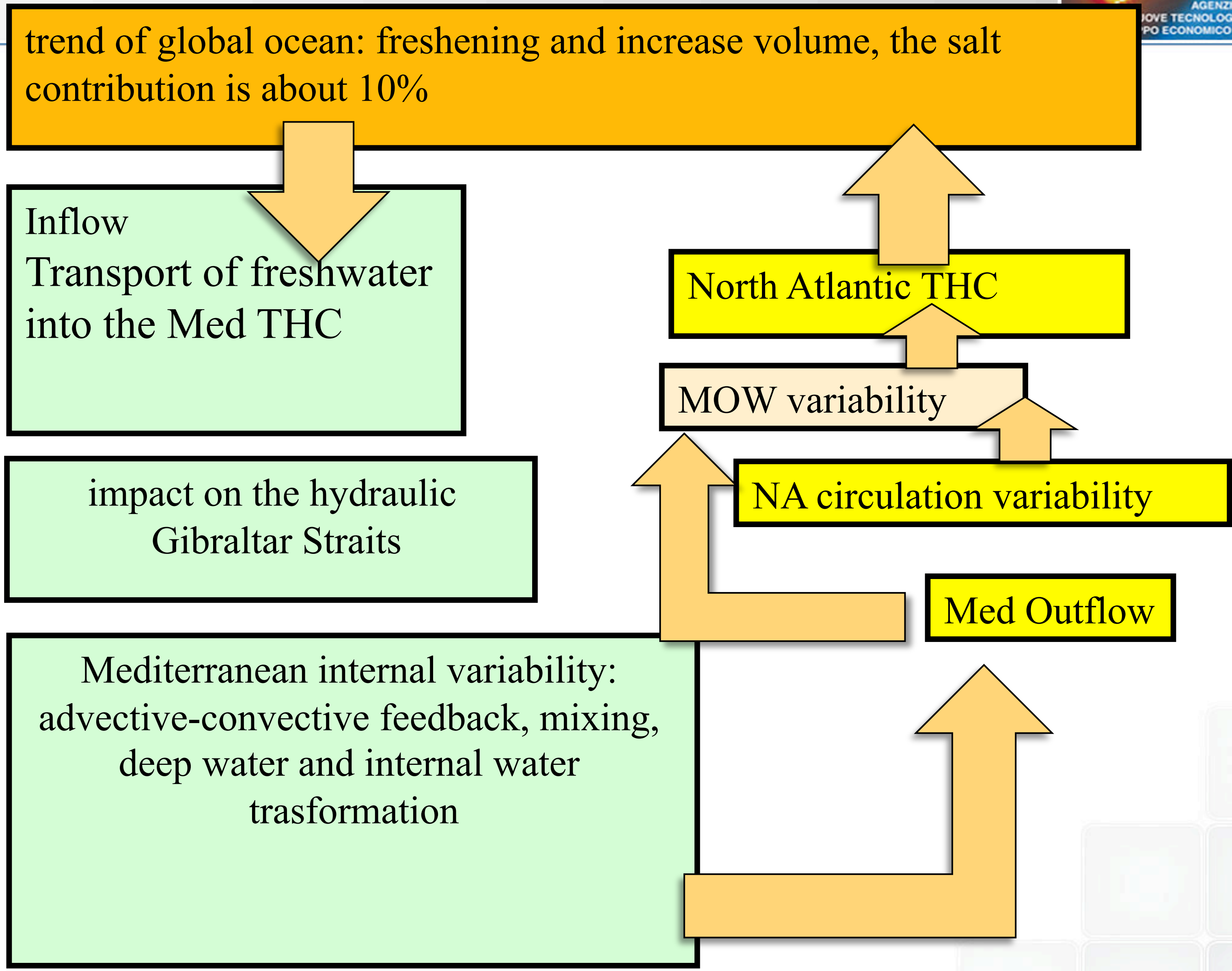
The dashed lines represent a conjectured northward penetration of MOW, while the dotted line represents the conjectured recirculation of the MOW within the subtropical gyre. The star (square) designates the location of Rockall Trough (Porcupine Bank). (b) Climatological salinity cross section at 55°N. The outcropping isohalines near 22°W indicate the location of the surface subpolar front. In this study, the subsurface subpolar front is defined as the longitude where the 35.10 isohaline intersects 1000 m (dashed line), as marked with an asterisk.

(c) Time series of the location of the subpolar front and the NAO index. The blue line is the longitudinal location of the front, and the green line is Hurrell's winter NAO index, averaged over the same pentad as the front. The 0 position of the NAO index is marked by the green dashed line. The coefficient of determination between these two time series (*r2) is 0.66 (p 0.01). Gray* shading denotes a predominantly NAO (NAO) time period: 1960–69 (1985–94). For the eight pentads beginning with 1960–64 and ending with 1995–99, 10, 31, 119, 69, 37, 121, 111, and 56 hydrographic stations, respectively, were used for the estimation of the subsurface subpolar front.

The role of the intermittent influence of this water mass on convective processes at high latitudes, whether it finds its way to the Nordic Seas or is instead recirculated within the subpolar gyre, remains to be investigated. Likewise of interest is the effect of the intermittent loss of salt on the subtropical basin. Ongoing data and modeling studies are focused on these investigations.

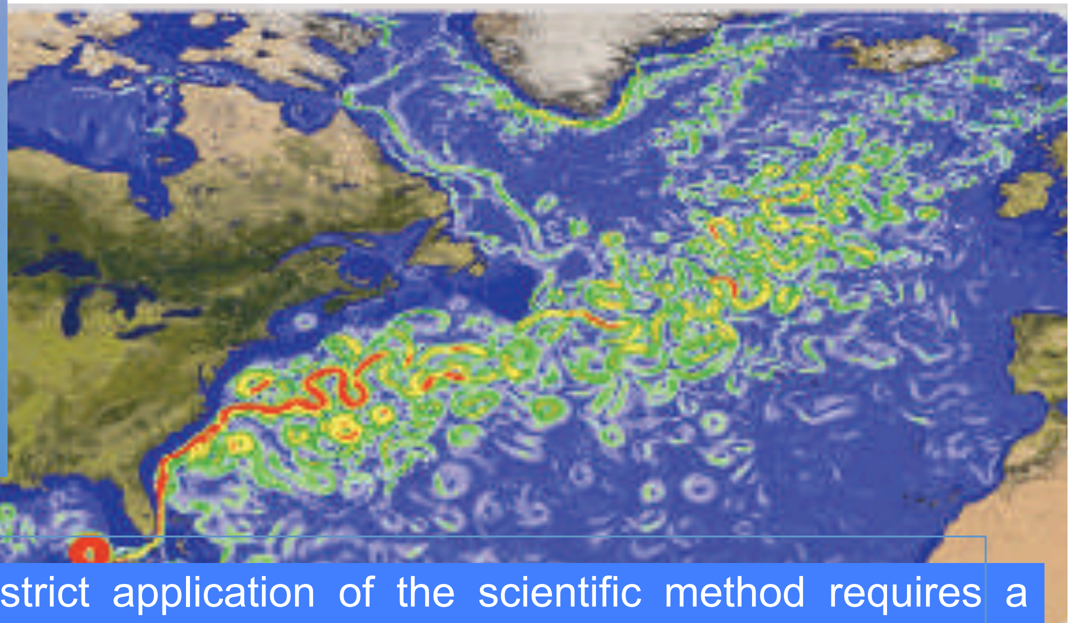


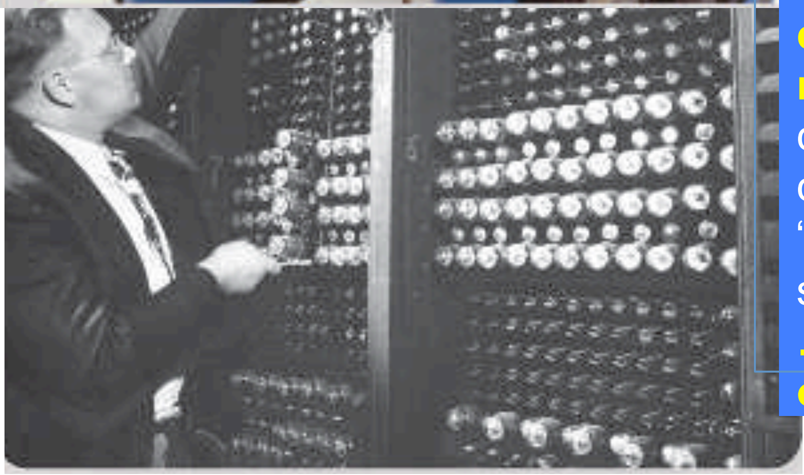
(bottom) Salinity anomalies (psu) in the Rockall Trough as a function of density; densities above the black bar along the left-hand axis are referenced to 1000 m, those below to 1500 m. The two dashed lines bracket the location of the MOW core in the Rockall Trough (Stewart 2005), while the two solid black lines bracket the LSW core. (top) The NAO index over the same time period as the salinity anomalies. The correlation coefficients between NAO and each density surface are shown to the right; the *r2 is calculated* using a 3-yr running mean for each time series with a 3-yr lag applied to the NAO time series. All *r2 values have a significant p value* (*p 0.01), except for the lightest density surface (1 31.50). Salinity anomalies are contoured every 0.05.*


trend of global ocean: freshening and increase volume, the salt contribution is about 10%
Inflow
Transport of freshwater into the Med THC
impact on the hydraulic Gibraltar Straits
Mediterranean internal variability: advective-convective feedback, mixing, deep water and internal water trasformation
North Atlantic THC
MOW variability
NA circulation variability
Med Outflow

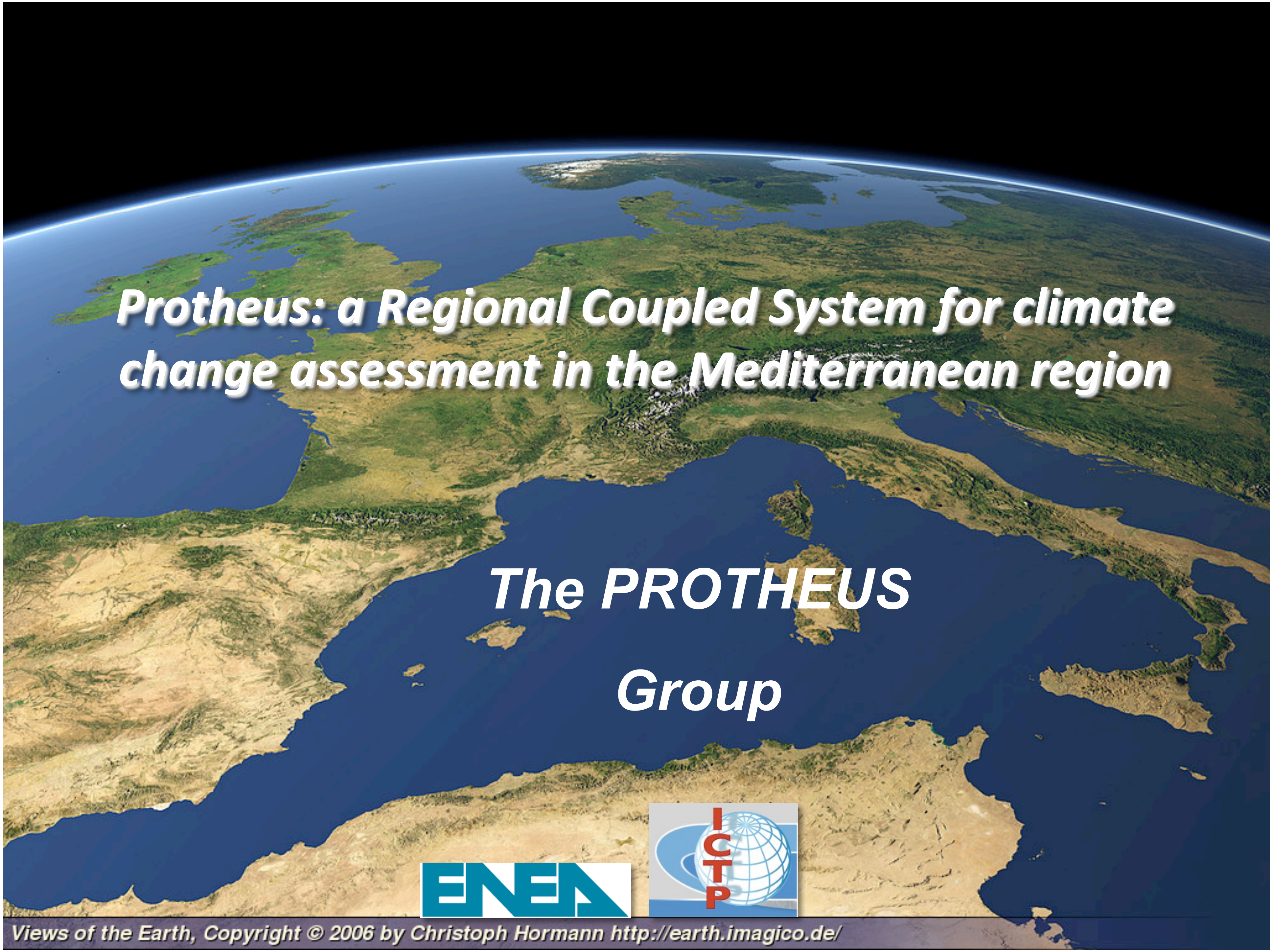
“CRUCIAL EXPERIMENTS”

ENEA AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE





A strict application of the scientific method requires a process of isolation of constituent subsystems and experimental verification of a hypothesis. **For the climate system, this is only possible by using numerical models.** Such models have become the central pillar of the quantitative scientific approach to climate science because they allow us to perform “crucial” experiments under the controlled conditions that science demands. **Sometimes crucial experiments are …like the quest for the Higgs boson currently going on at CERN.**

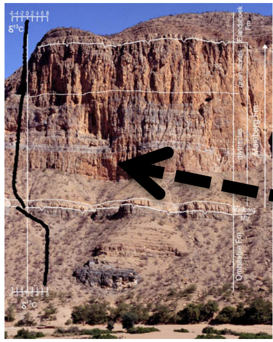


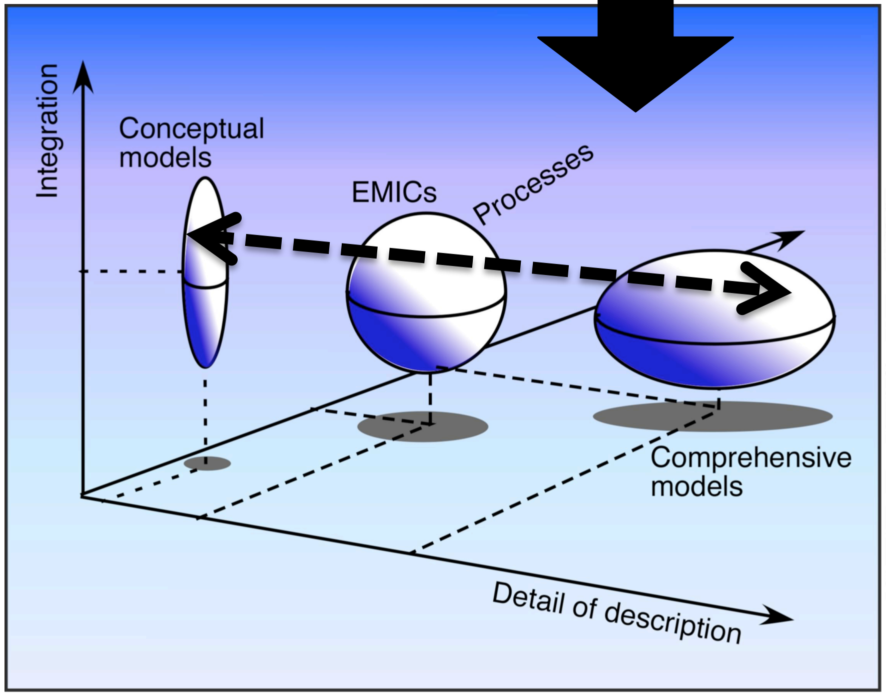
Protheus: a Regional Coupled System for climate change assessment in the Mediterranean region

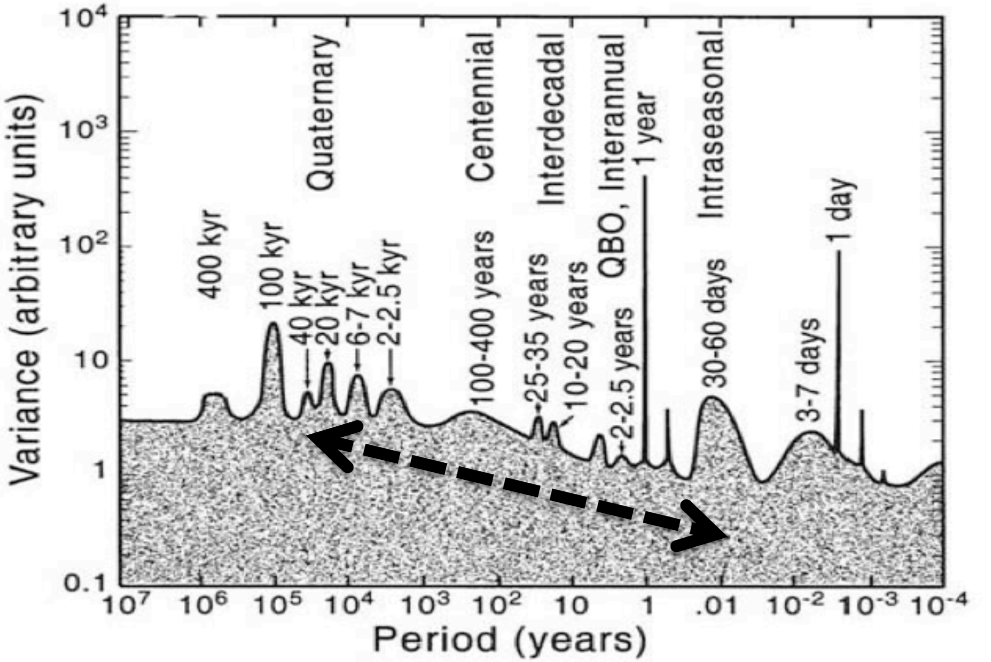
The PROTHEUS Group

ENEA ICTP

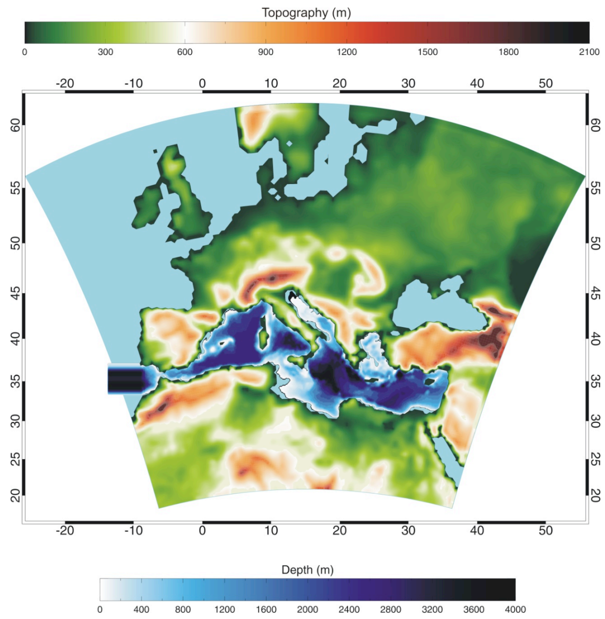
TEMPORAL SCALE INVOLVED IN CLIMATE SYSTEM AND MODELLLING SIMULATIONS: THE MEDITERRANEAN CASE

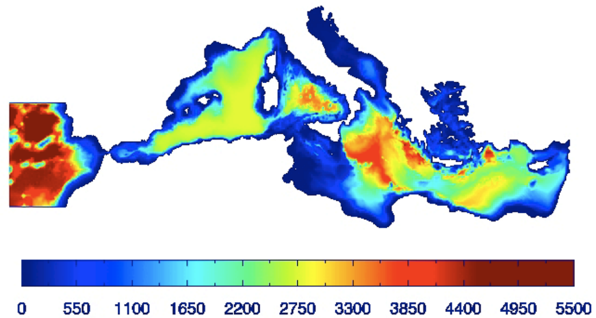






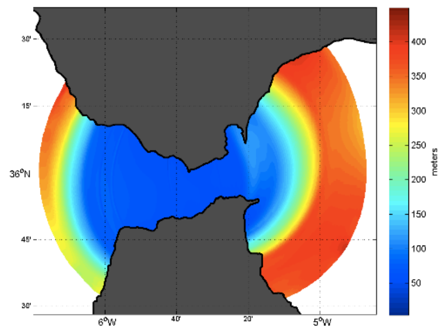
Modelli a scala regionale, di bacino e locali





Modello Mar Mediterraneo

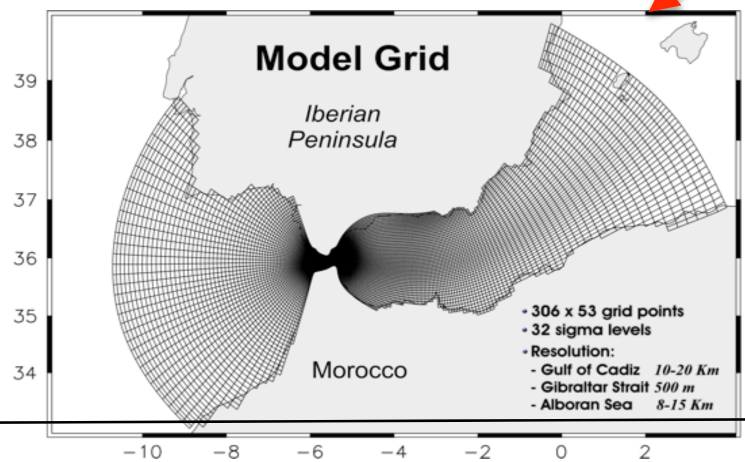
Modello locale

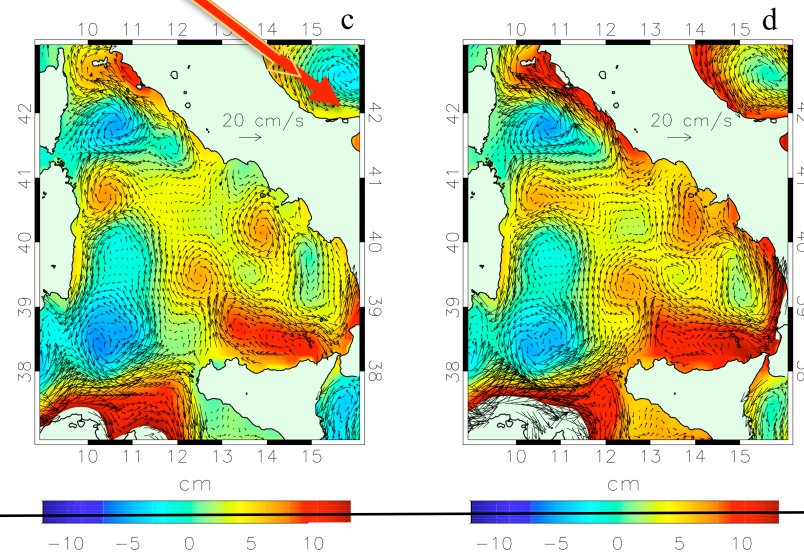


Modelli regionali

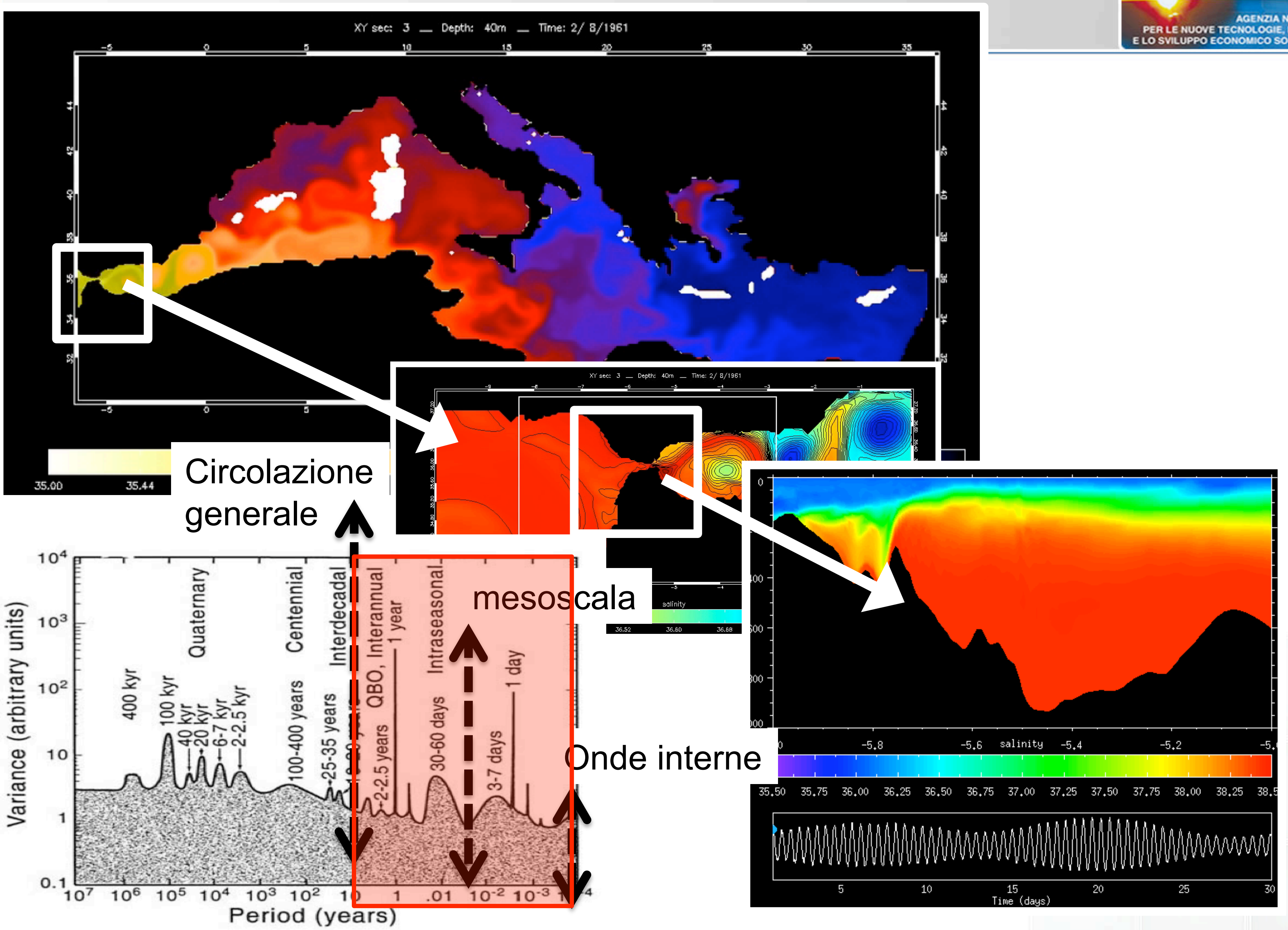
Modelli di sottobacino

Modello regionale climatico

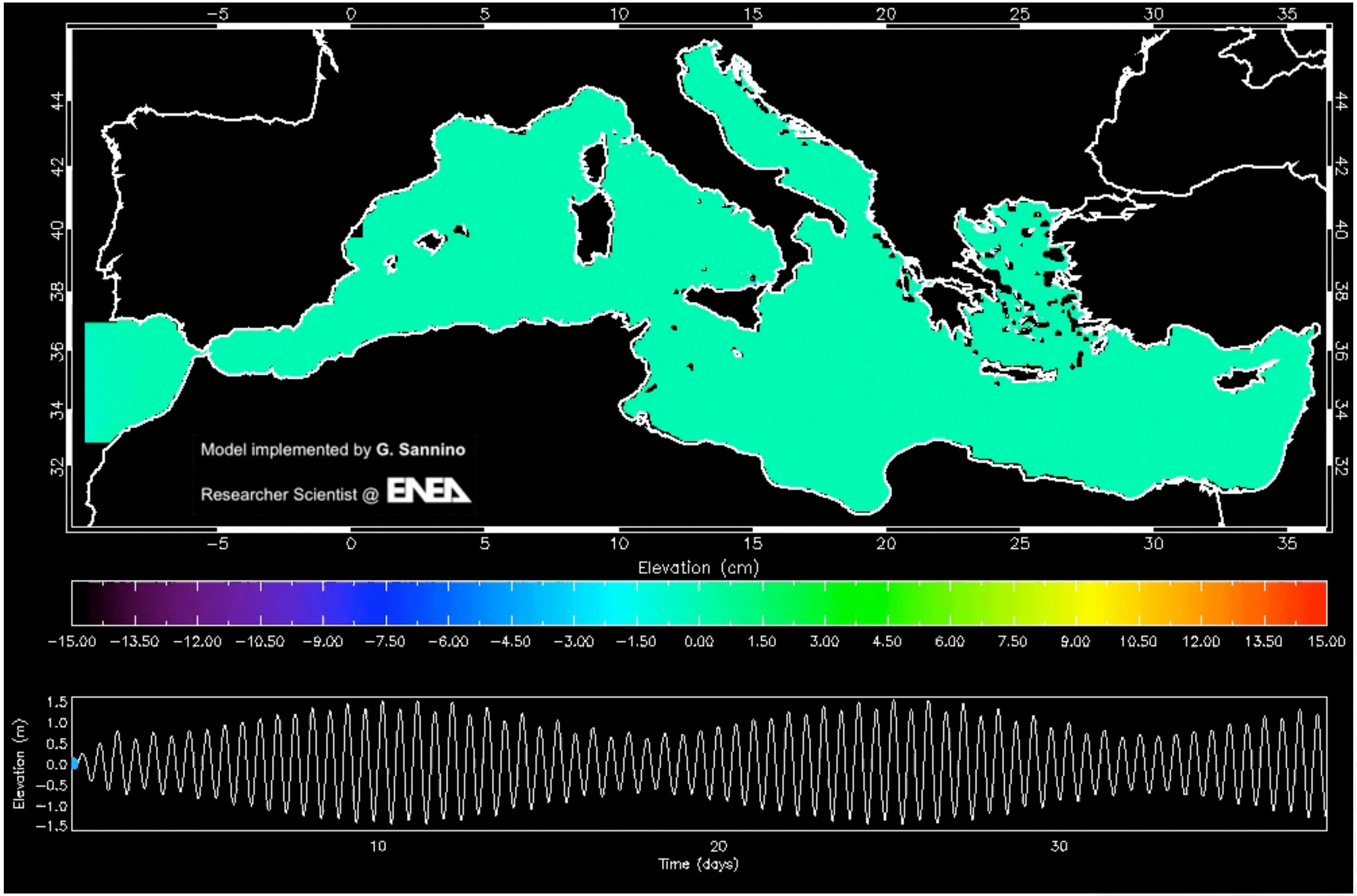




UTMEA - CLIM Lab.


XY sec: 3 — Depth: 40m — Time: 2/ 8/1961
Circolazione generale
mesoscala
Onde interne
Variance (arbitrary units)
Period (years)
400 kyr
100 kyr
40 kyr
20 kyr
6-7 kyr
2-2.5 kyr
Quaternary
Centennial
100-400 years
25-35 years
Interdecadal
QBO, Interannual
2-2.5 years
1 year
Intraseasonal
30-60 days
3-7 days
1 day
salinity
Time (days)

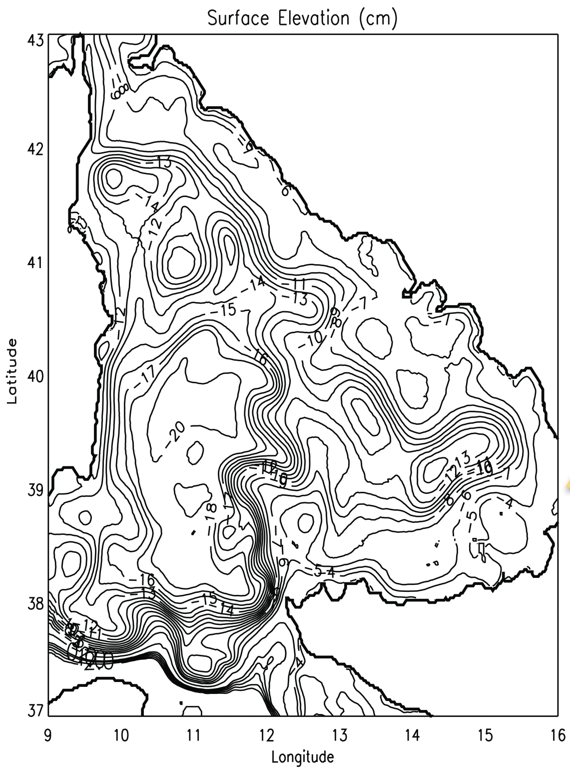
Total



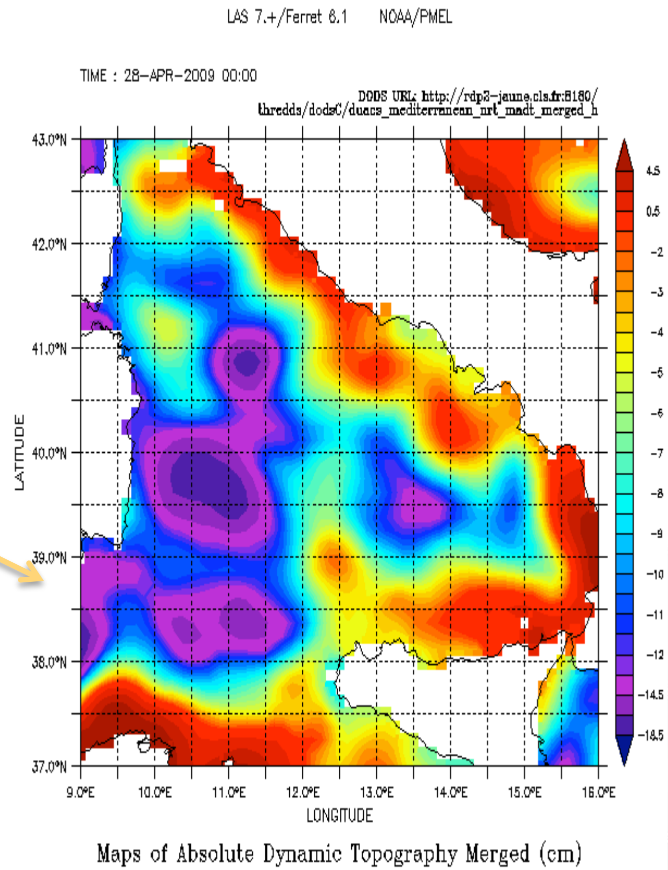
Model implemented by G. Sannino
Researcher Scientist @ ENEA
Elevation (cm)
−15.00 −13.50 −12.00 −10.50 −9.00 −7.50 −6.00 −4.50 −3.00 −1.50 0.00 1.50 3.00 4.50 6.00 7.50 9.00 10.50 12.00 13.50 15.00
Elevation (m)
Time (days)

Modello operativo Mar Tirreno - ENEA

POM4840: 1/48° x 1/48° x 40 livelli, operativo da Marzo 2009, fornisce “forecast “ di 7 giorni ogni giorno. Le condizioni al contorno sono date dal modello globale OPA1671 dell’INGV.



28 Aprile 2009:
confronto (elevazione)
tra “forecast”   dati
altimetrici



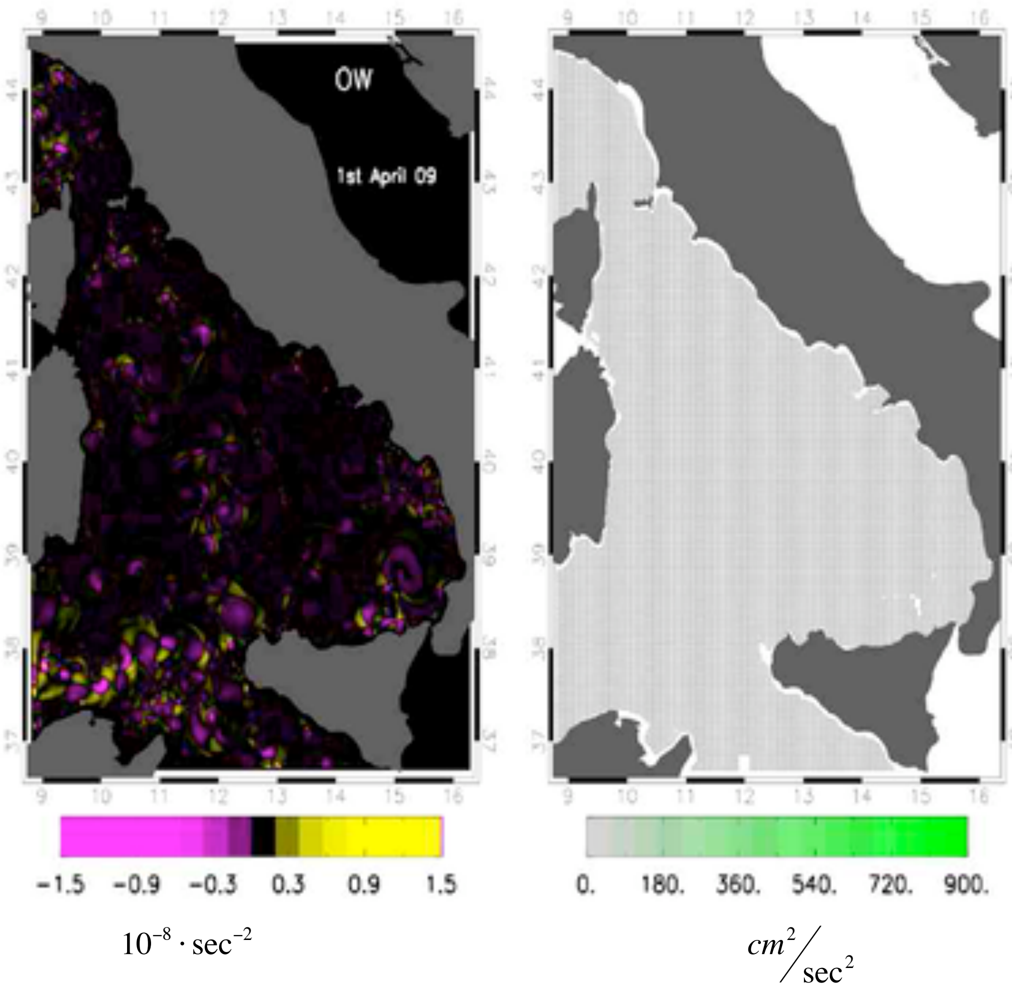
The quantity OW = $(\text{strain})^2 - (\text{vorticity})^2$

In order to be successful in this approach to the dynamics of the ocean a robust vortex detection algorithm is necessary. A possible choice of such a criterion is one based on the sign of the Okubo-Weiss parameter (Okubo 1970, Weiss 1991), which measures the relative contribution of deformation and vorticity.

Then, a coherent vortex can be defined as the simply connected region with negative values of the Okubo-Weiss parameter. Besides this definition only captures vortex cores, it has been shown that this method is adequate to detect marine eddies in model output. When a vortex, or its core, has been identified it is possible to estimate the individual properties of the vortex such as size, mean kinetic energy and amplitude and then analyze its statistical distribution.

Furthermore, it has been shown that these very coherent vortices are the principal responsible for the non-Gaussian behavior of the Velocity Probability Density Functions having a great impact on the dispersion and mixing processes (Isern-Fontanet et al. 2005b).

67931 particelle numeriche nel Mar Tirreno



67931 sono rilasciate in superficie (1/48° x 1/48°) ed integrate usando i campi di velocità dal 1° al 28 Aprile 2009

$$OW = s_n^2 + s_s^2 - \omega^2$$

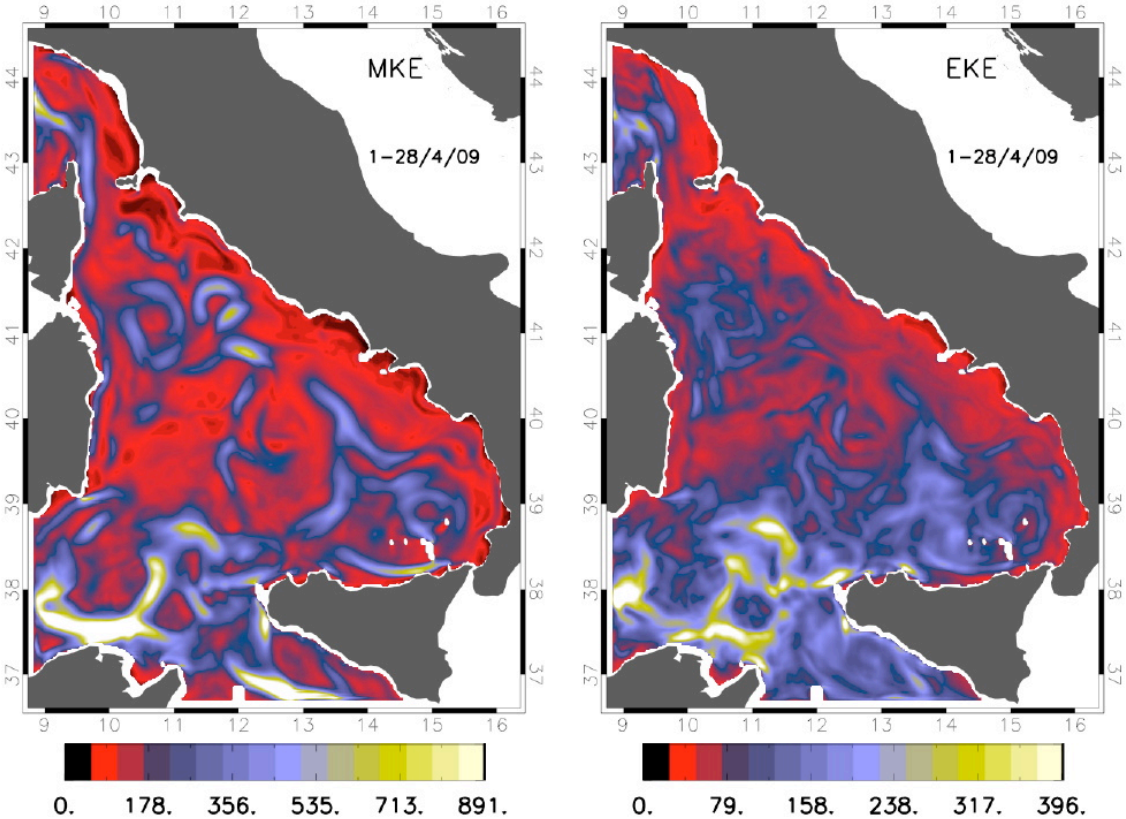
$$\omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

$$s_n = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

$$s_s = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}$$

parametro di Okub-Weiss

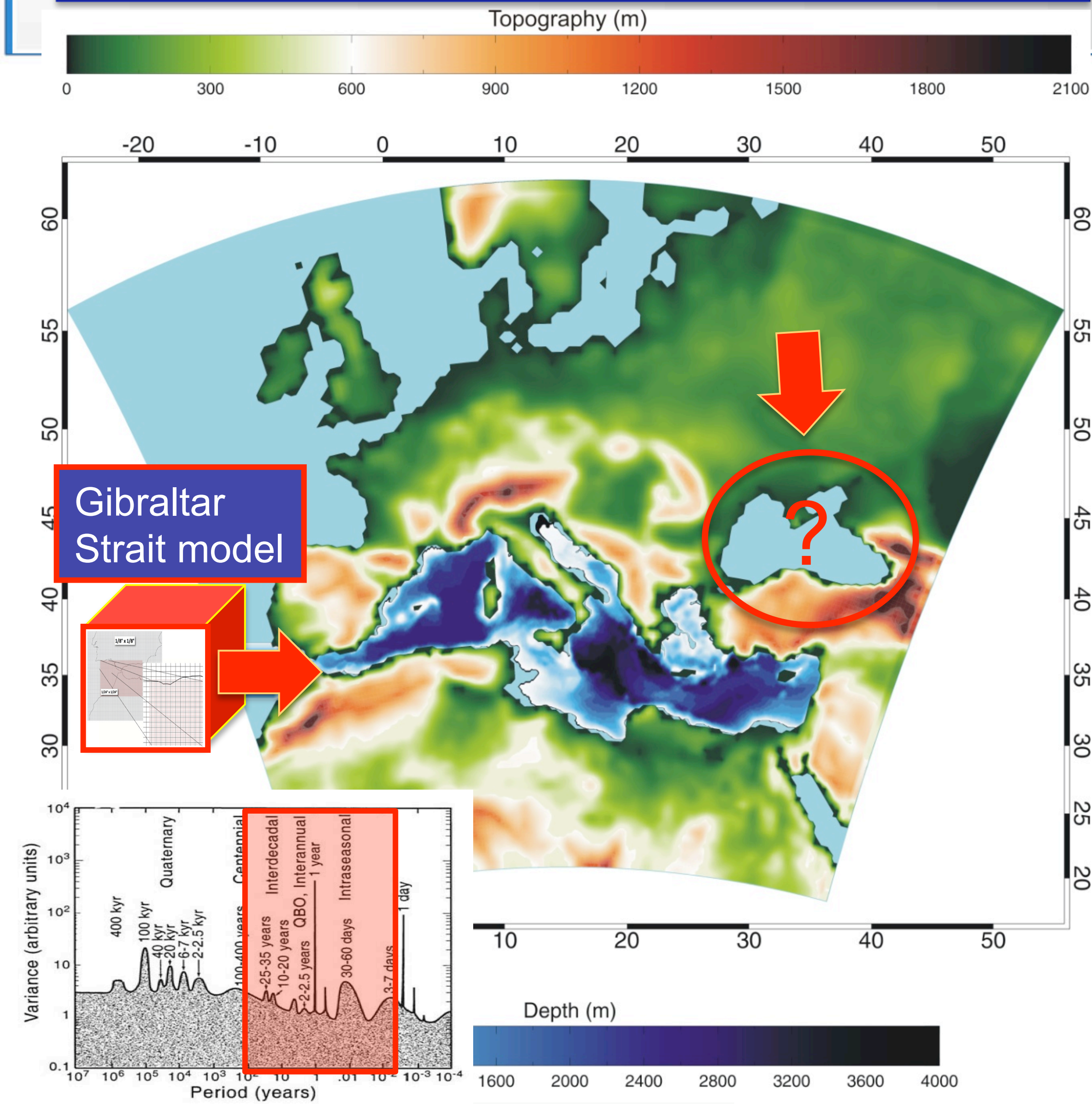
Energia media e "Eddy Kinetic Energy" Euleriane



cm^2/sec^2 cm^2/sec^2

28 giorni

PROTHEUS Model



Model domain

Model components

RegCM3

18 sigma vertical levels

30 Km horizontal resolution

BATS + IRIS

BATS: Biosph.-Atmosph. Transfer Scheme

IRIS: interactive RIvers Scheme

SST

OASIS 3

Freq. 6h

HF-WF-Wind

MedMIT

42 zeta vertical levels (partial cell)

1/8° x 1/8° horizontal resolution

Modellistica dei fiumi

Modello regionale
bilancio verticale dei flussi di acqua nel suolo in funzione delle proprietà del terreno

→ **Medie giornaliere di runoff** → **River routing model (CCNY-CUNY)** → **Campo bidimensionale della portata su tutto il bacino**

In collaborazione con il City College of New York, il Jet Propulsion Laboratory della NASA ed il World Wildlife Fund

↓

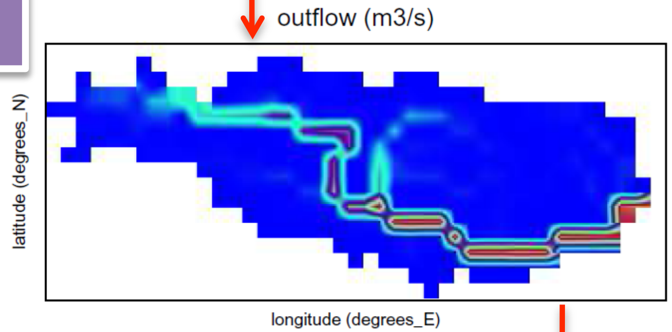
Medie mensili di runoff

↓

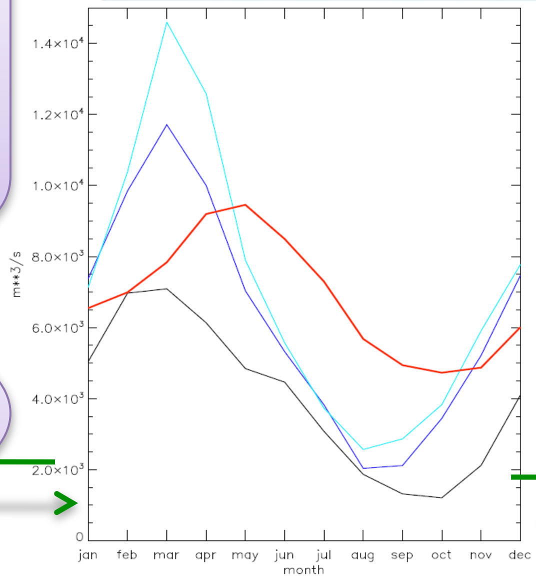
Interpolazione (IDI) sulla griglia regolare che ricostruisce i bacini idrografici
(Oki and Sud,1998 *Earth Interactions,* 2)

↓

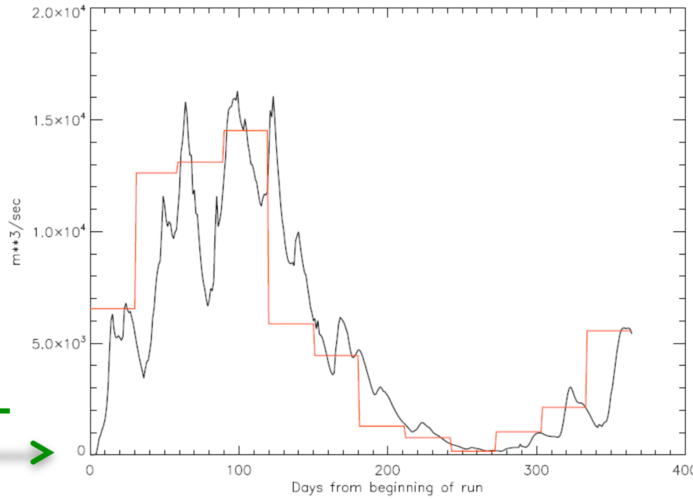
Portata media mensile del fiume alla foce



Range of outflow: -33.3959 to 10456.6 m3/s
Range of longitude: 9.25 to 29.25 degrees_E
Range of latitude: 42.25 to 50.25 degrees_N



DANUBIO



G.Pisacane, M.V.Struglia in preparation

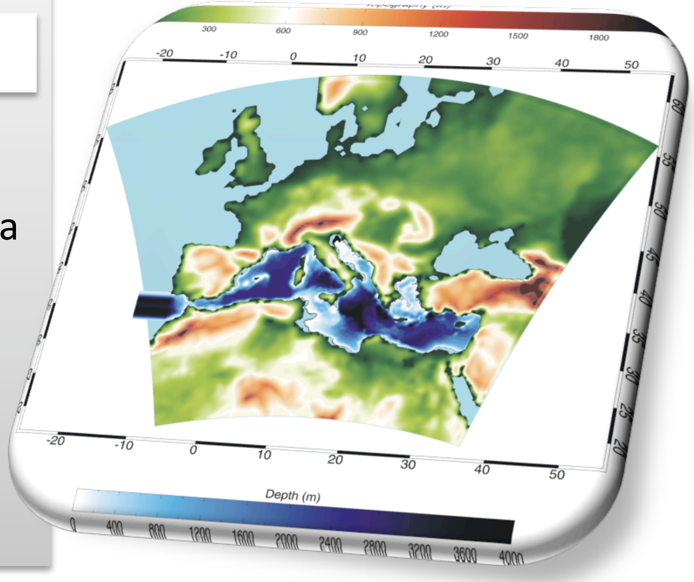
PROTHEUS Validation: Present climate simulation

Simulation details

Lateral BC
○ERA40 reanalysis 1958-2000

SST (Atlantic Box)
○GISST - Global Sea Ice Coverage and Sea Surface Temperature data -Met Office

Ocean initialization
○The oceanic component is initialized with MEDATLAS II data (MEDAR Group, 2002), then a 40 year spin-up is performed using a 3D relaxation of T and S to the climatological values.



Comparison with:

•**Stand-alone** configuration of the atmospheric model RegCM3 (forced by GISST data)

•**ERA40** Reanalysis

•**Observational datasets**

OISST (daily 1/16°x1/16° SST for the period 1985-2000, Marullo et al. 2007)

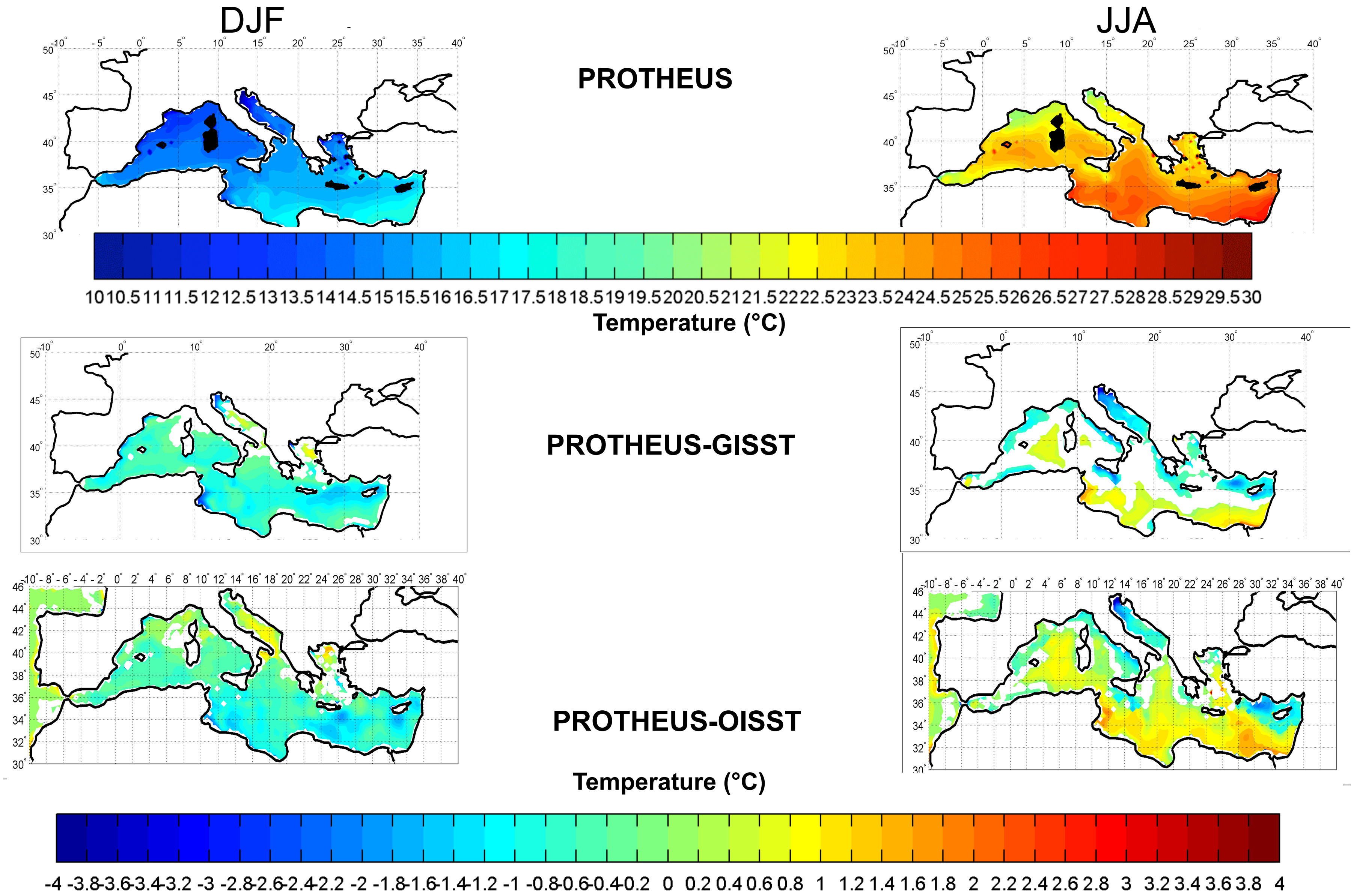
HOAPS (Hamburg Ocean Atmosphere Parameters and fluxes from Satellite data)

CRU (Climatic Research Unit, UK)

GPCP (Global Precipitation Climatology Project)

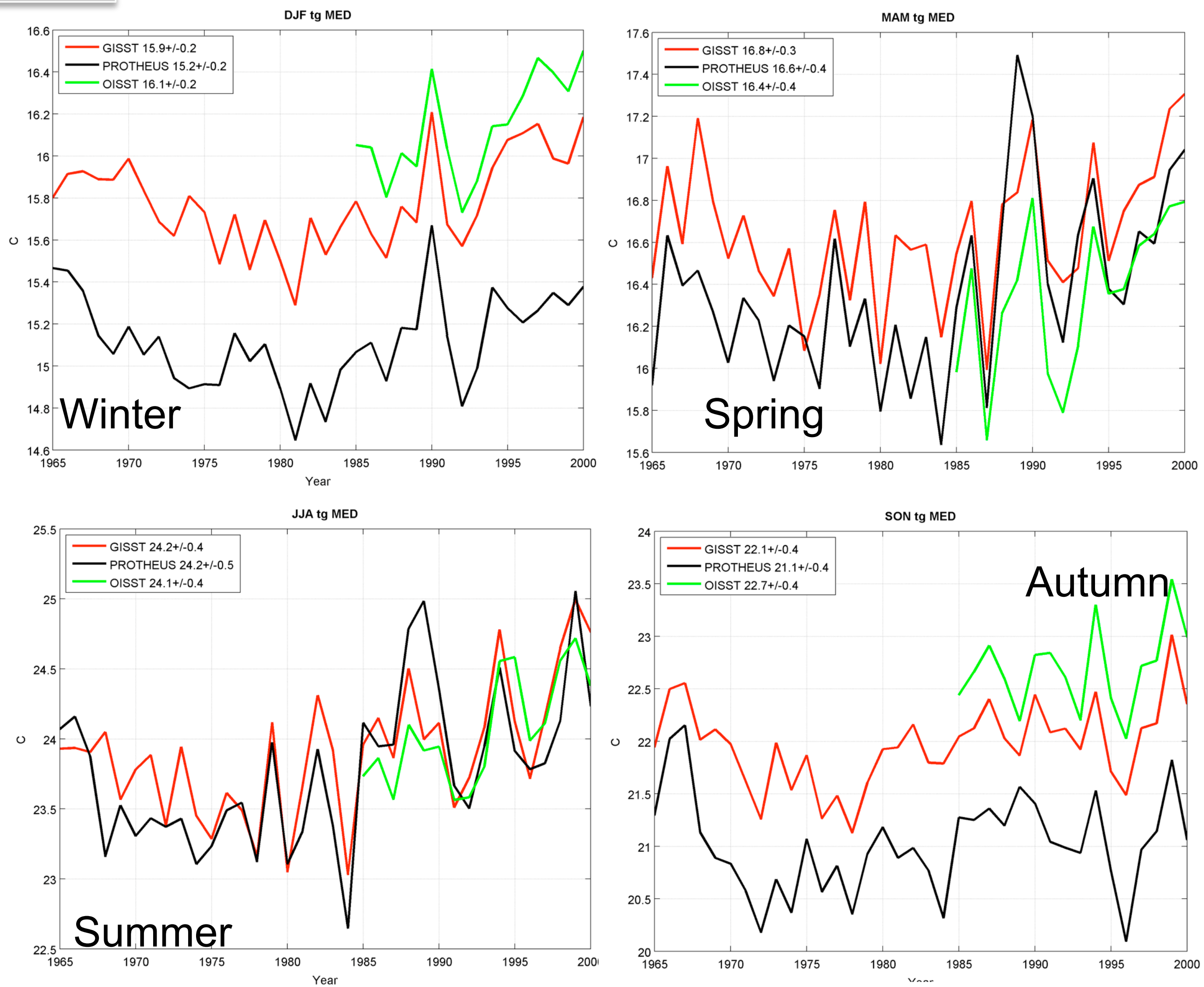
PROTHEUS Validation: Present climate simulation

PROTHEUS SST Climatology vs. Observations



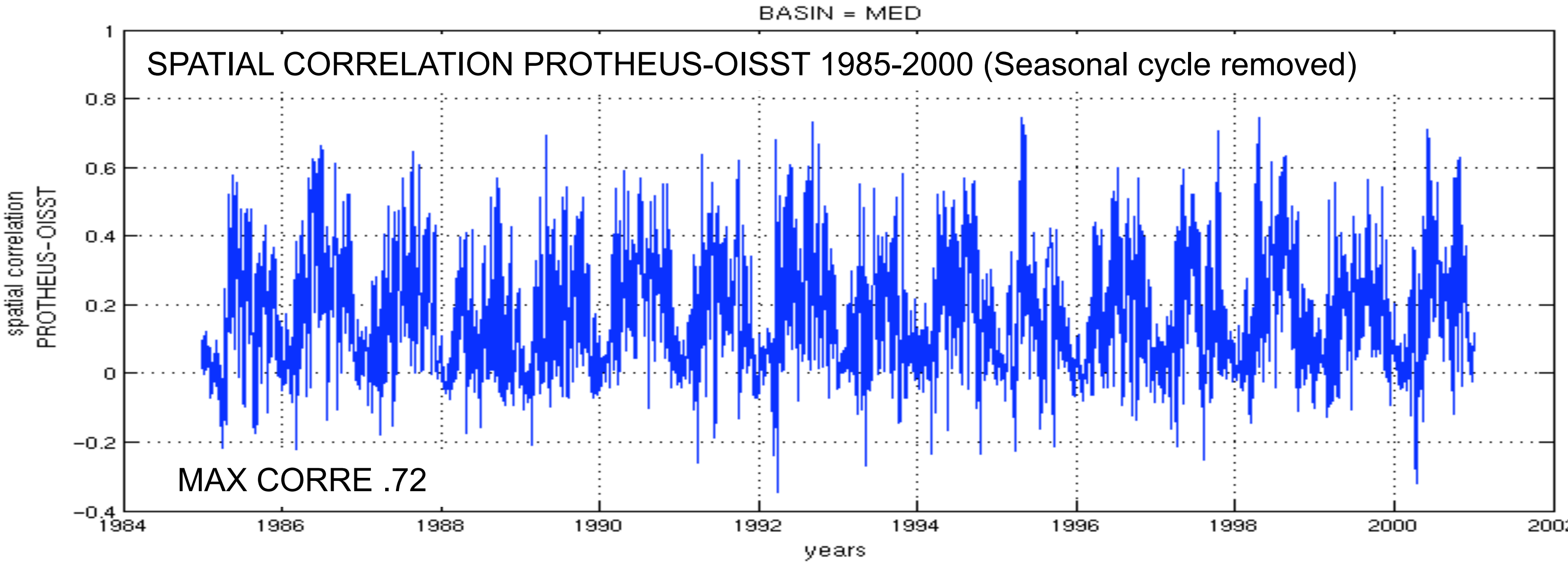
PROTHEUS Validation: Present climate simulation

PROTHEUS SST Climatology vs. Observations



PROTHEUS Validation: Present climate simulation

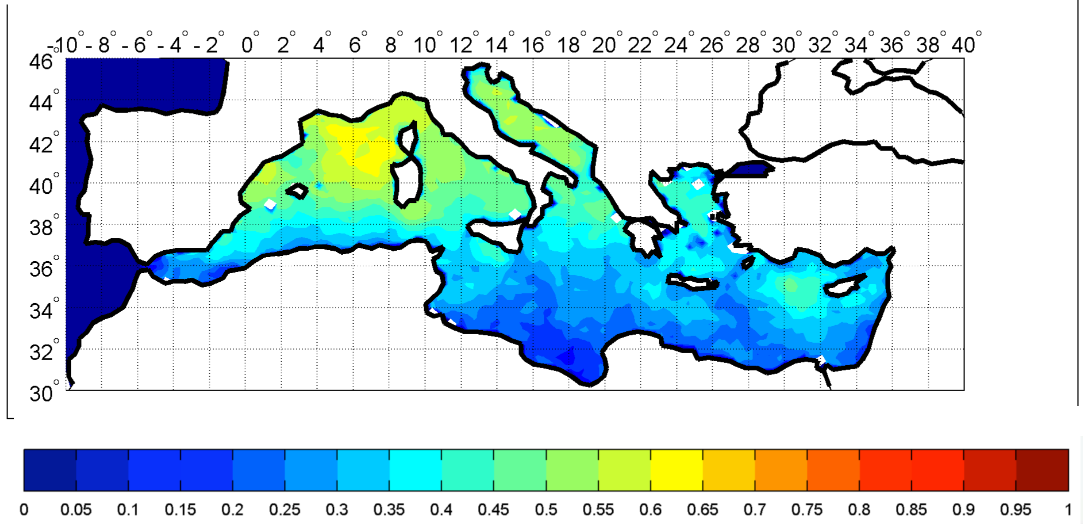
PROTHEUS SST Climatology vs. Observations



TEMPORAL CORRELATION

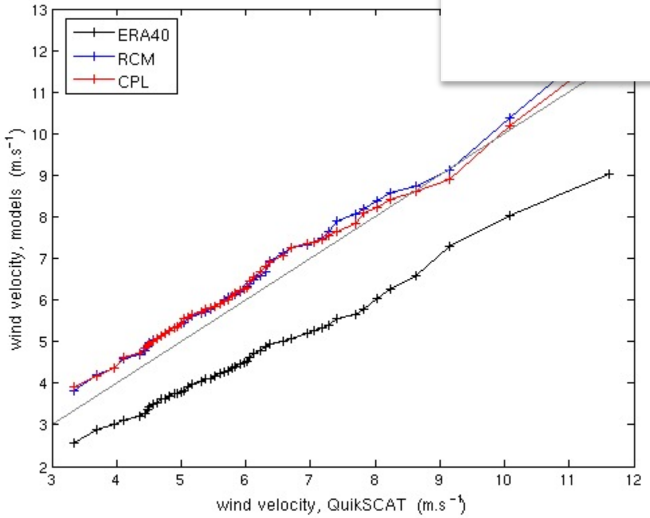
(Seasonal cycle removed)

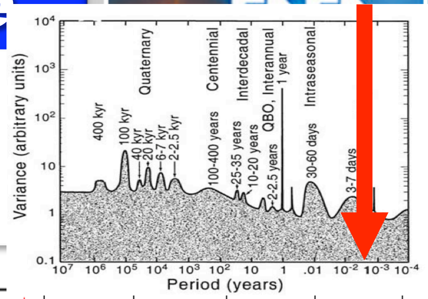
PROTHEUS-OISST 1985-2000

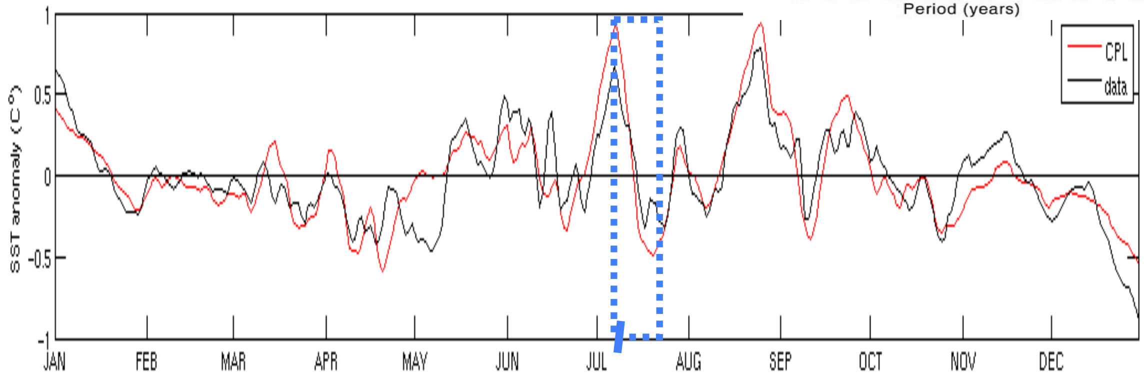


PROTHEUS Validation: Present climate simulation

PROTHEUS SST Climatology vs. Observations
A single year case study: **The 2000**

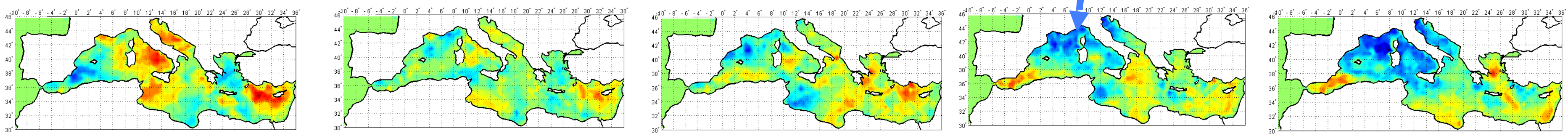




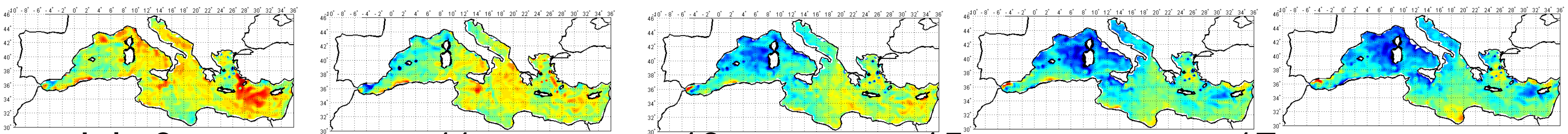


Time series of 2000 **SST anomalies** for the CPL simulation (red line) and satellite observations (black line). Values are averaged over the whole basin.

OISST



PROTHEUS



July 9 11 13 15 17

PROTHEUS Validation: Present climate simulation

Precipitation over land CLIMATOLOGY

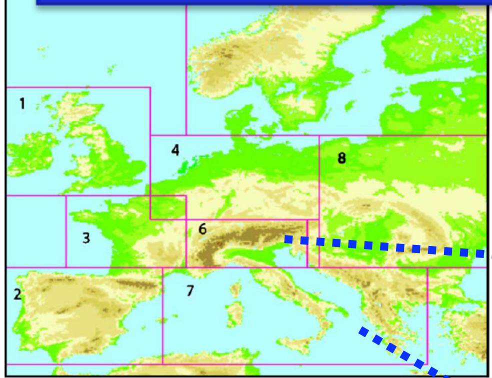
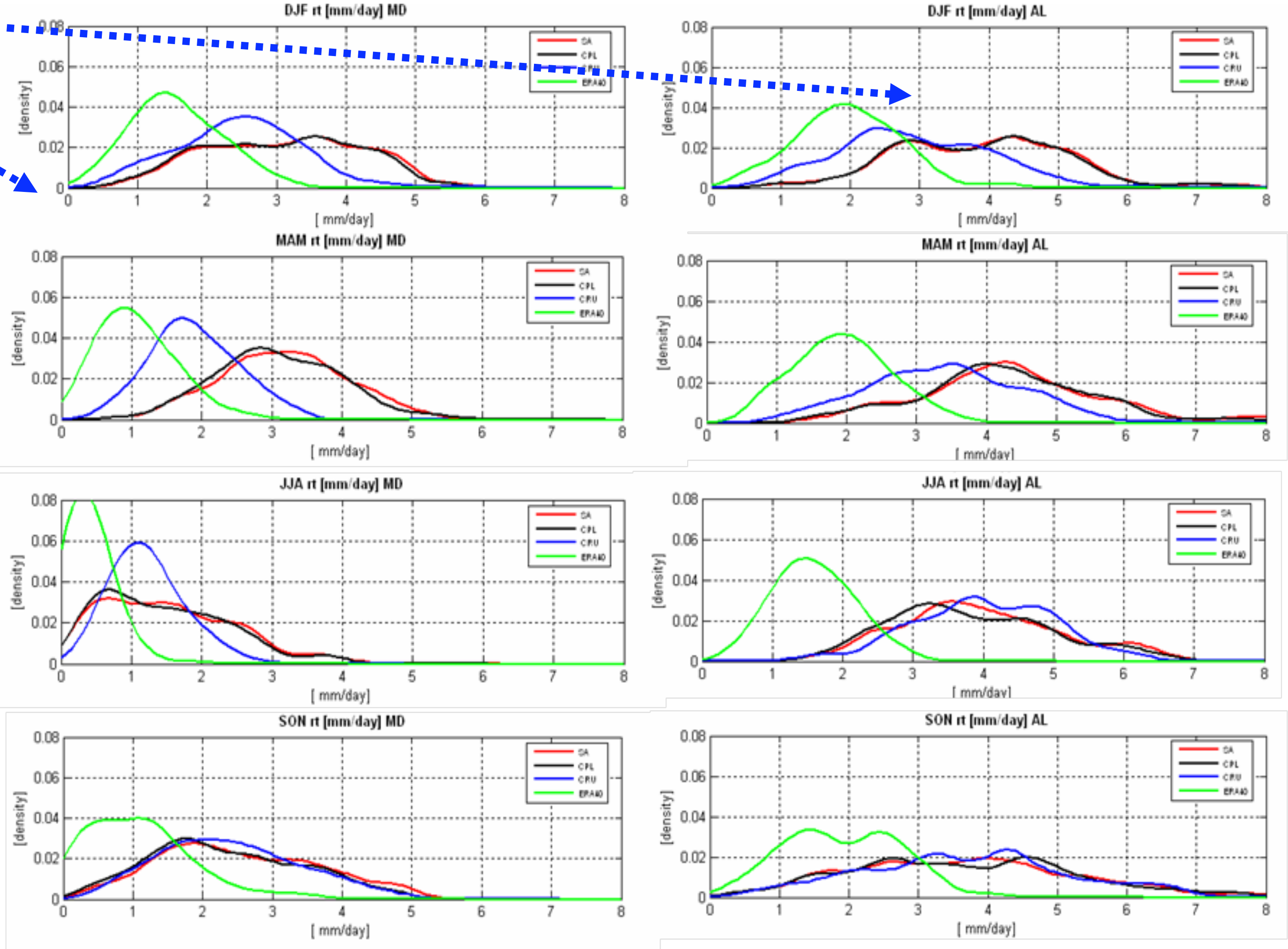


Fig. 4 European sub-areas

Area	West	East	South	North
1 (BI) British Isles	-10	2	50	59
2 (IP) Iberian Peninsula	-10	3	36	44
3 (FR) France	-5	5	44	50
4 (ME) Mid-Europe	2	16	48	55
5 (SC) Scandinavia	5	30	55	70
6 (AL) Alps	5	15	44	48
7 (MD) Mediterranean	3	25	36	44
8 (EA) Eastern Europe	16	30	44	55

MD AL



ERA40

CRU

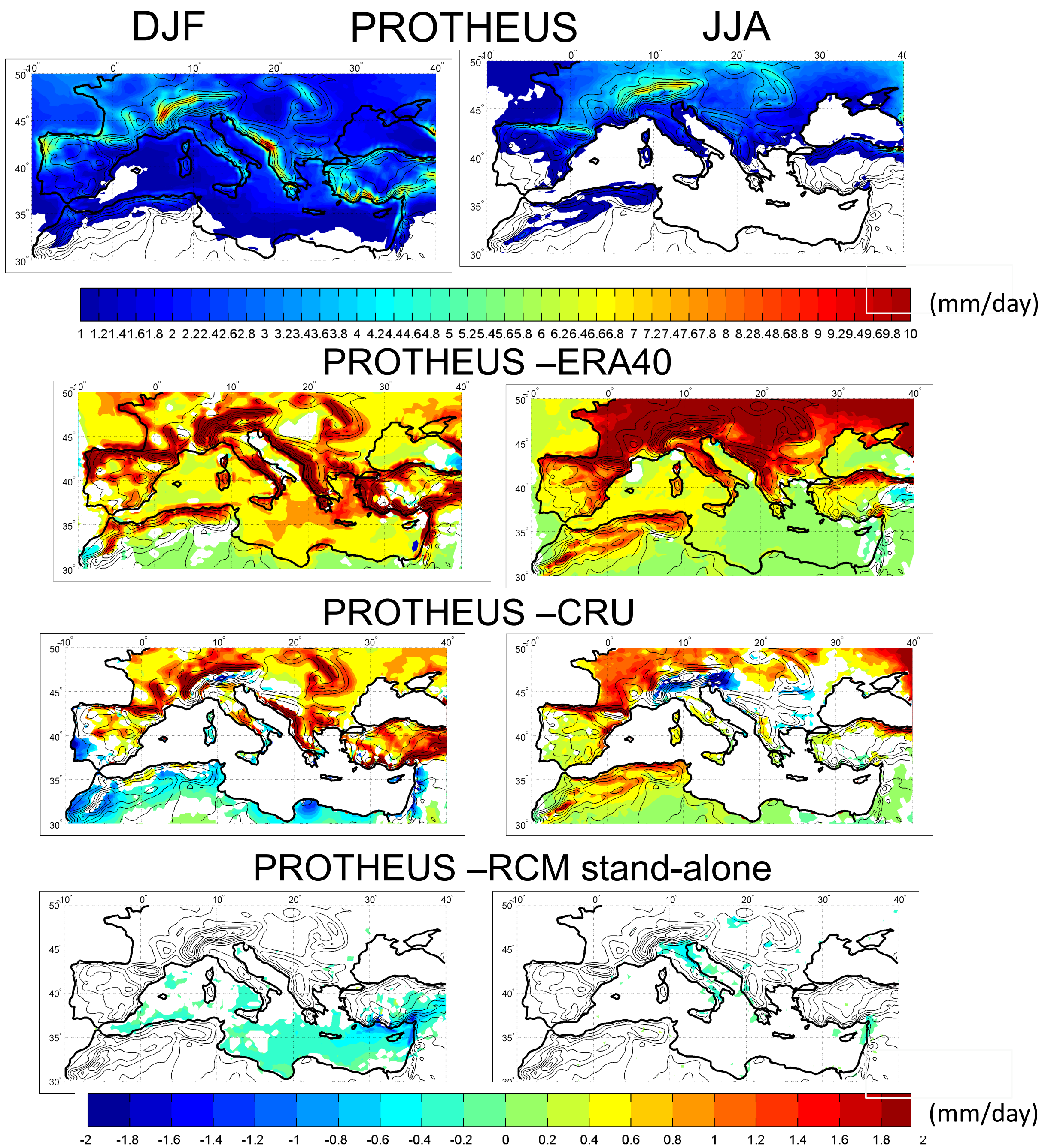
PROTHEUS

RegCM-SA

PROTHEUS Validation: Present climate simulation

Precipitation

CLIMATOLOGY



Precipitation

CLIMATOLOGY

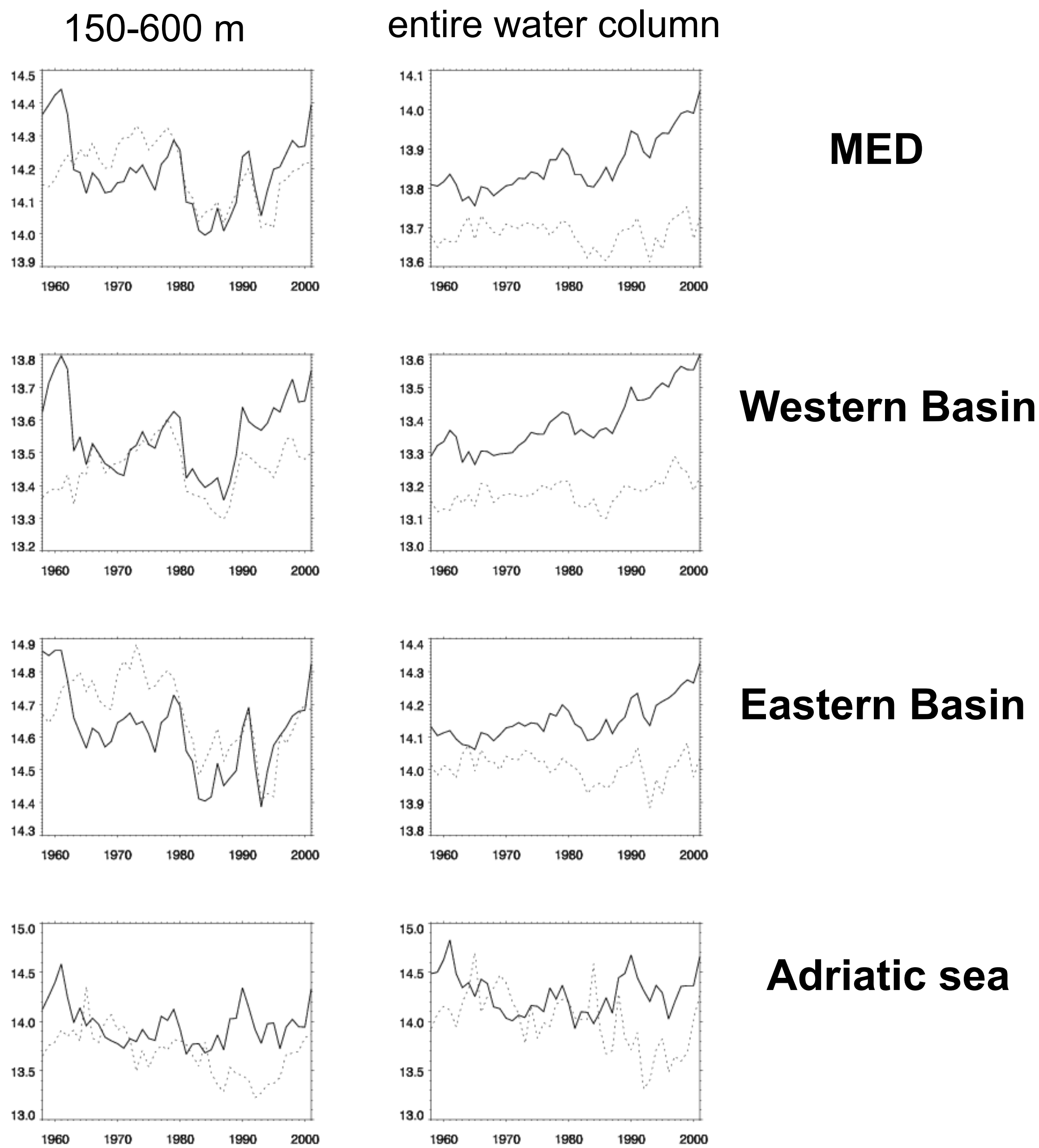
differences

PROTHEUS Validation: Present climate simulation

Ocean Temperature

CLIMATOLOGY

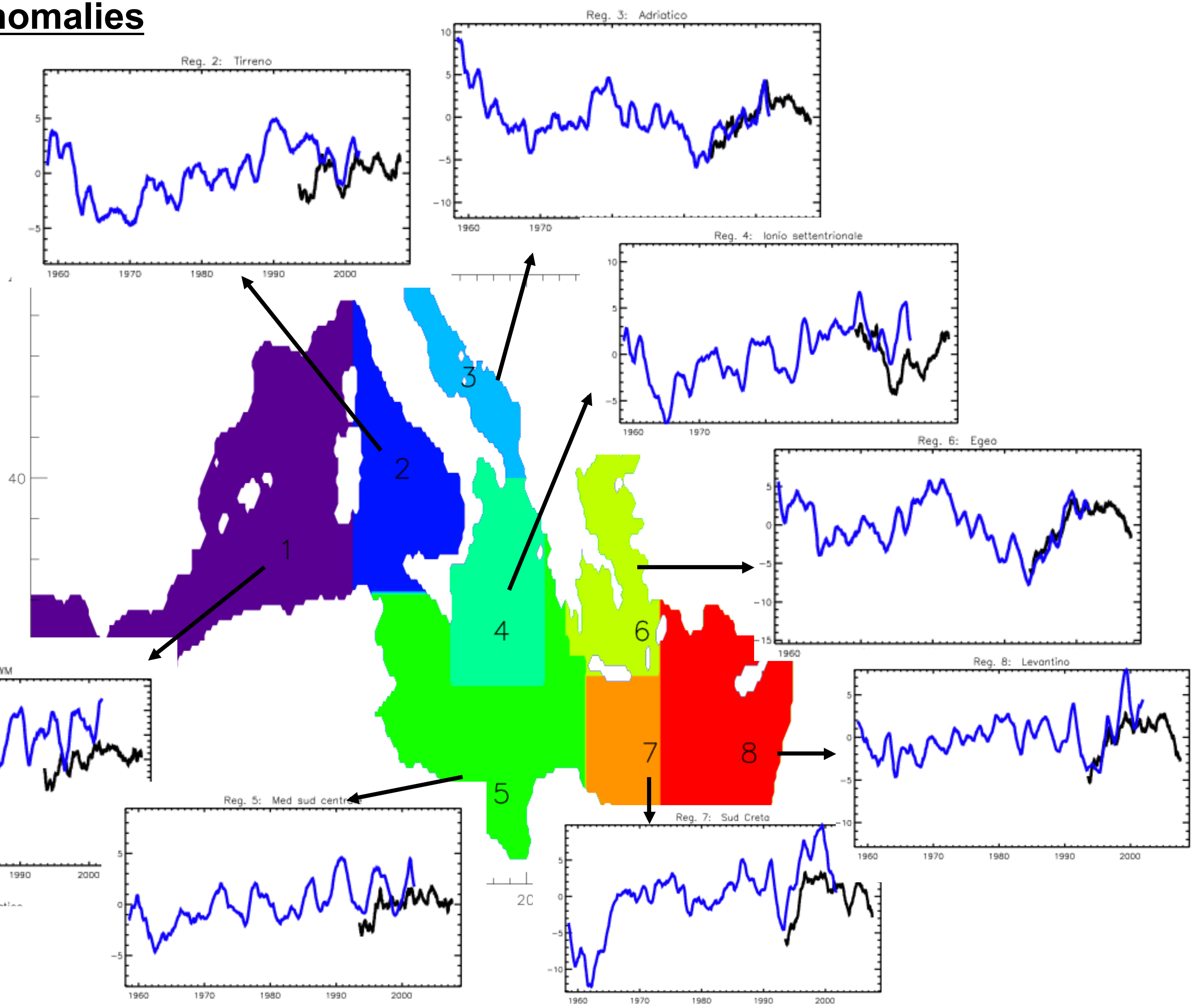
Time series of **temperature anomalies** averaged over the entire Mediterranean basin, the Western basin, Eastern Basin and Adriatic sea. **Model (solid line) data & MEDATLAS II database (dotted line).**

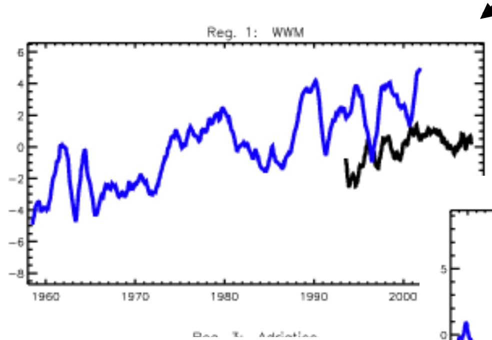


PROTHEUS Validation: Present climate simulation

Sea Level Anomalies

Total sea level anomalies for the Mediterranean sub-basins. Values computed from PROTHEUS ERA40 run (blu line) & altimeter data (black line).

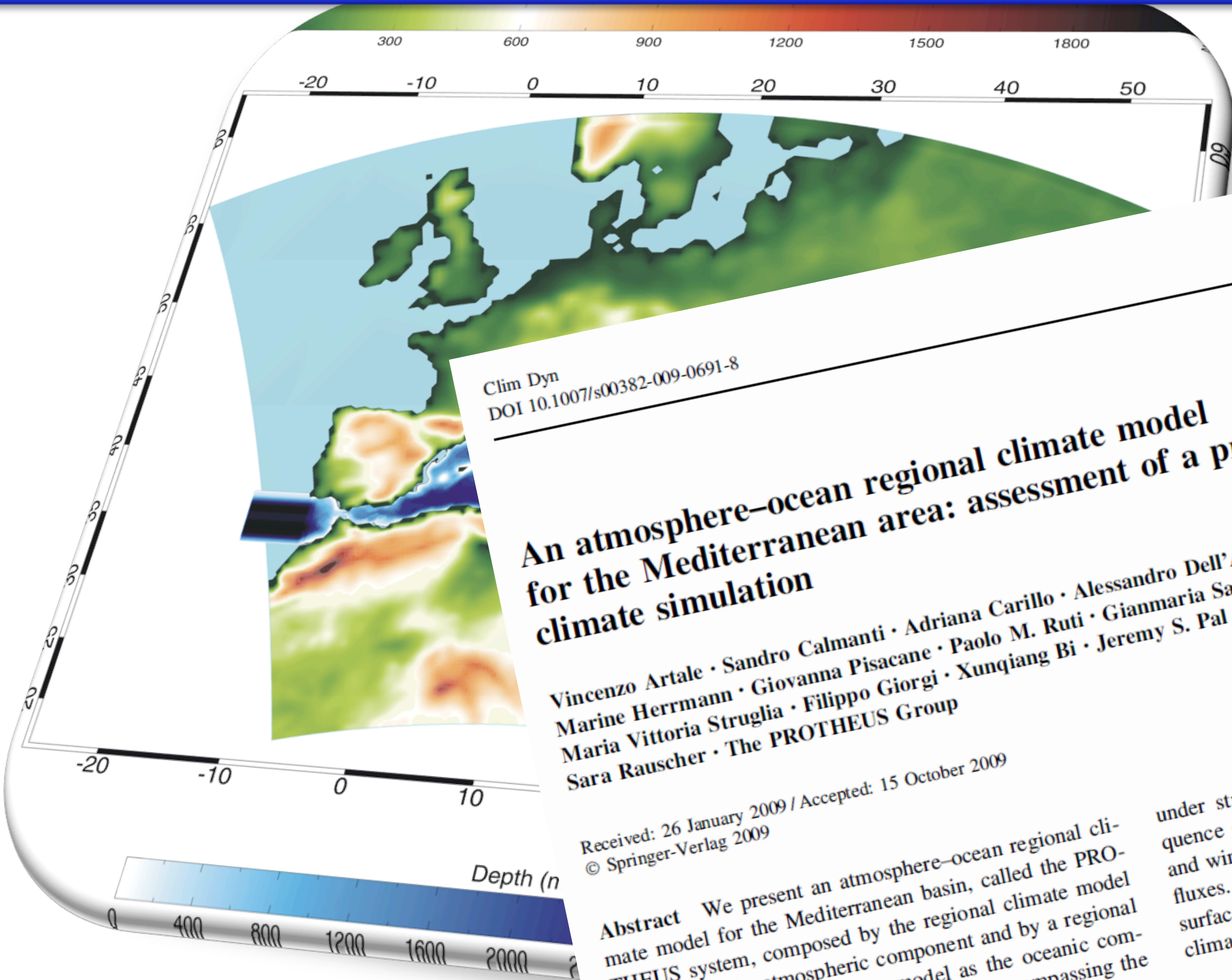




Present Climate Simulation : Major results

- 40-year simulation driven by ERA40 reanalysis at BC
- Realistic features reproduced (atmospheric circulations, land surface climate, ocean SST, ocean surface circulations and air-sea fluxes)
- The coupling does not affect the bulk characteristics of the atmospheric model
- The coupled model is capable of significantly improve the description of air-sea interactions in terms of sensible and latent heat, especially at small scales and for intense events
- Sea level anomalies correctly reproduced

PROTHEUS Validation: Present climate simulation



Clim Dyn
DOI 10.1007/s00382-009-0691-8

An atmosphere–ocean regional climate model for the Mediterranean area: assessment of a present climate simulation

Vincenzo Artale · Sandro Calmanti · Adriana Carillo · Alessandro Dell'Aquila · Marine Herrmann · Giovanna Pisacane · Paolo M. Ruti · Gianmaria Sannino · Maria Vittoria Struglia · Filippo Giorgi · Xunqiang Bi · Jeremy S. Pal · Sara Rauscher · The PROTHEUS Group

Received: 26 January 2009 / Accepted: 15 October 2009

Abstract We present an atmosphere–ocean regional climate model for the Mediterranean basin, called the PROTHEUS system, composed by the regional climate model RegCM3 as the atmospheric component and by a regional configuration of the MITgcm model as the oceanic component. The model is applied to an area encompassing the Mediterranean Sea and compared to a stand-alone version of its atmospheric component. An assessment of the model performances is done by using available observational datasets. Despite a persistent bias, the PROTHEUS system under strong air–sea interaction conditions. As a consequence of the model's skill in reproducing observed SST and wind fields, we expect a reliable estimation of air–sea fluxes. The model skill in reproducing climatological land surface fields is in line with that of state of the art regional climate models.

Keywords Regional climate model · Mediterranean · Air–sea interaction

PROTHEUS SCENARIO Simulation

Simulation characteristics:

Boundary condition from ECHAM5-MPIOM run performed in ENSEMBLES project:

20C3M: 1951-2000 climate of the 20th Century experiment

SRES A1B: 2001-2051 720 ppm stabilization experiment

Impose SRES A1B conditions and initialize with conditions from the end of the 20C3M simulation.

ECHAM5-MPIOM model characteristics:

Atmosphere (ECHAM5; Roeckner et al., 2003) resolution: T63 L32

Ocean (Marsland et al., 2003) resolution: 1. deg, conformal mapping grid with grid poles over Greenland and Antarctica, 41 vertical levels

BC for MITgcm

Temperature and salinity are relaxed in the Atlantic box to climatological monthly Levitus data in the present climate simulation and to monthly mean anomalies obtained from the oceanic component of the coupled global run in the scenario simulation.

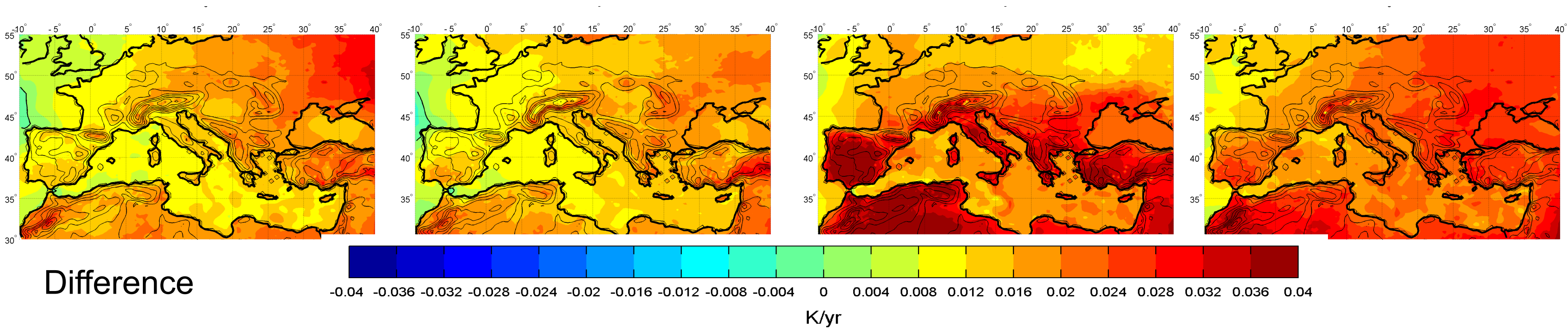
PROTHEUS SCENARIO Simulation

•Several Scenario Simulation planned (METEO-FRANCE, ECHAM5-MPIOM,…)

•**Simulation already performed:** 1951-2050 ECHAM5-MPIOM at BC (20c3m for 1951-2000 and SRESA1B for 2001-2050), at the moment we are preprocessing the ARPEGE simulation

PROTHEUS trend

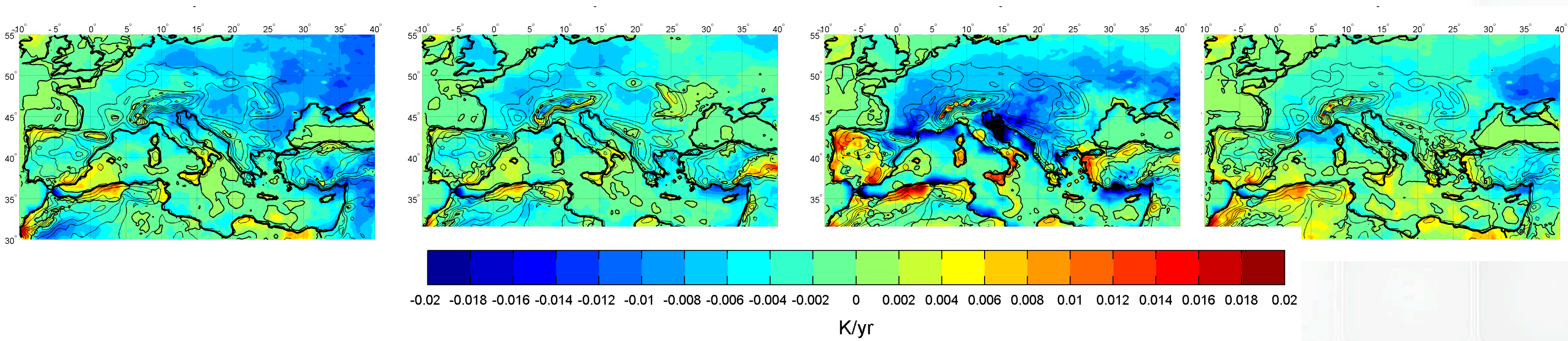
Trend Analysis :Surface Temperature



Difference

PROTHEUS-ECHAM5

DJF MAM JJA SON

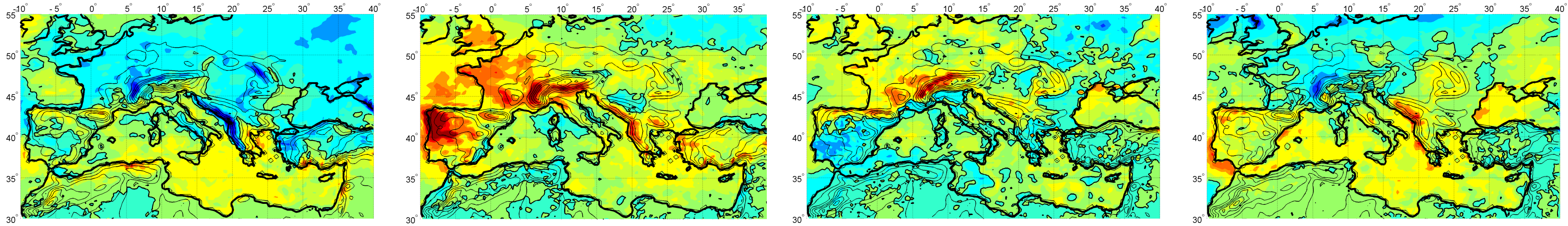


PROTHEUS SCENARIO Simulation: preliminary analysis

E-P FLUX TREND

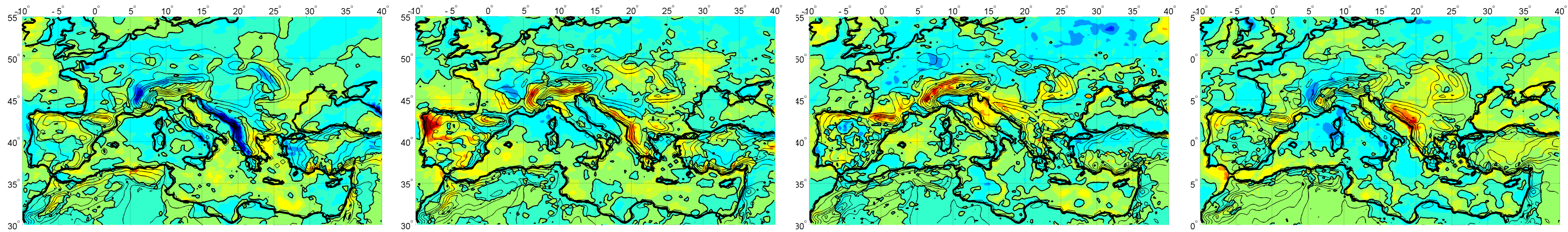
PROTHEUS trend

DJF MAM JJA SON

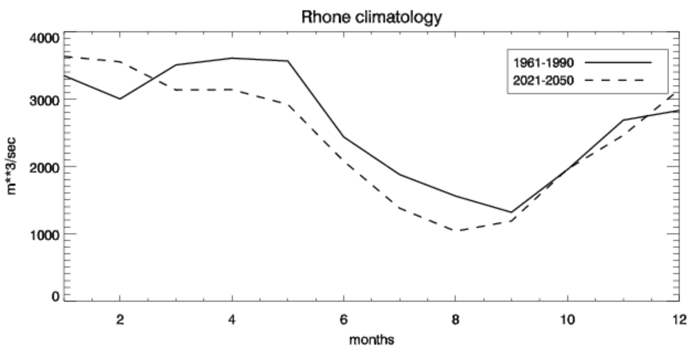


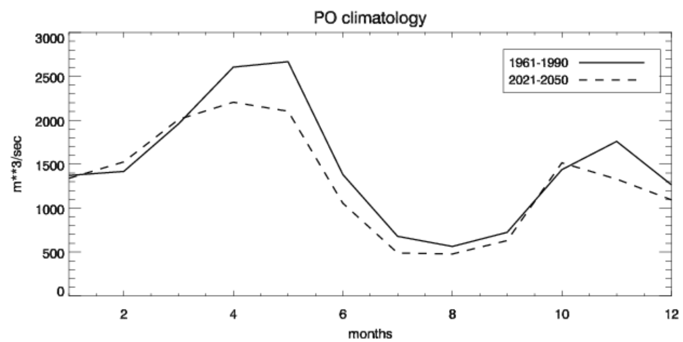
Difference

PROTHEUS-ECHAM5

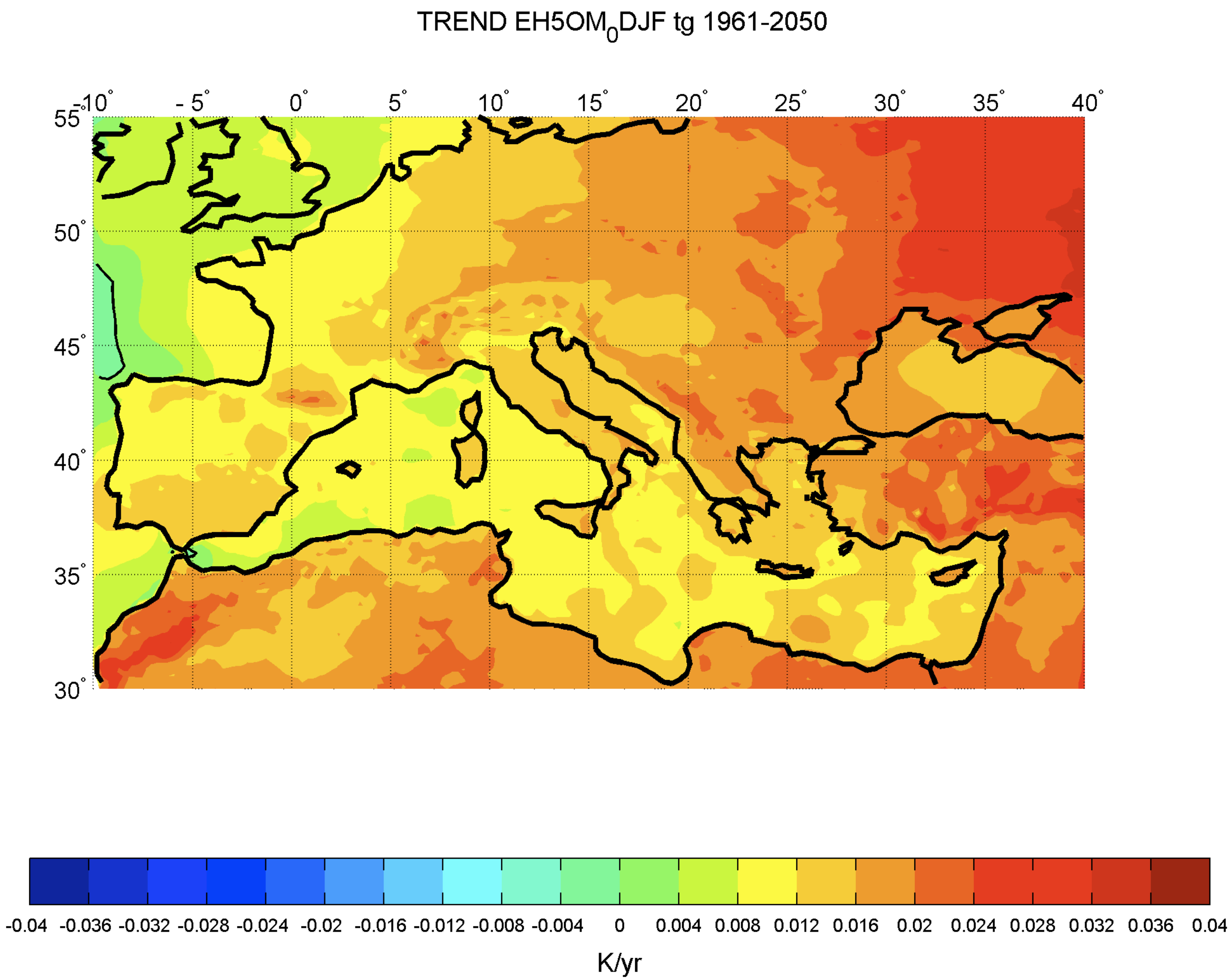


River Discharge

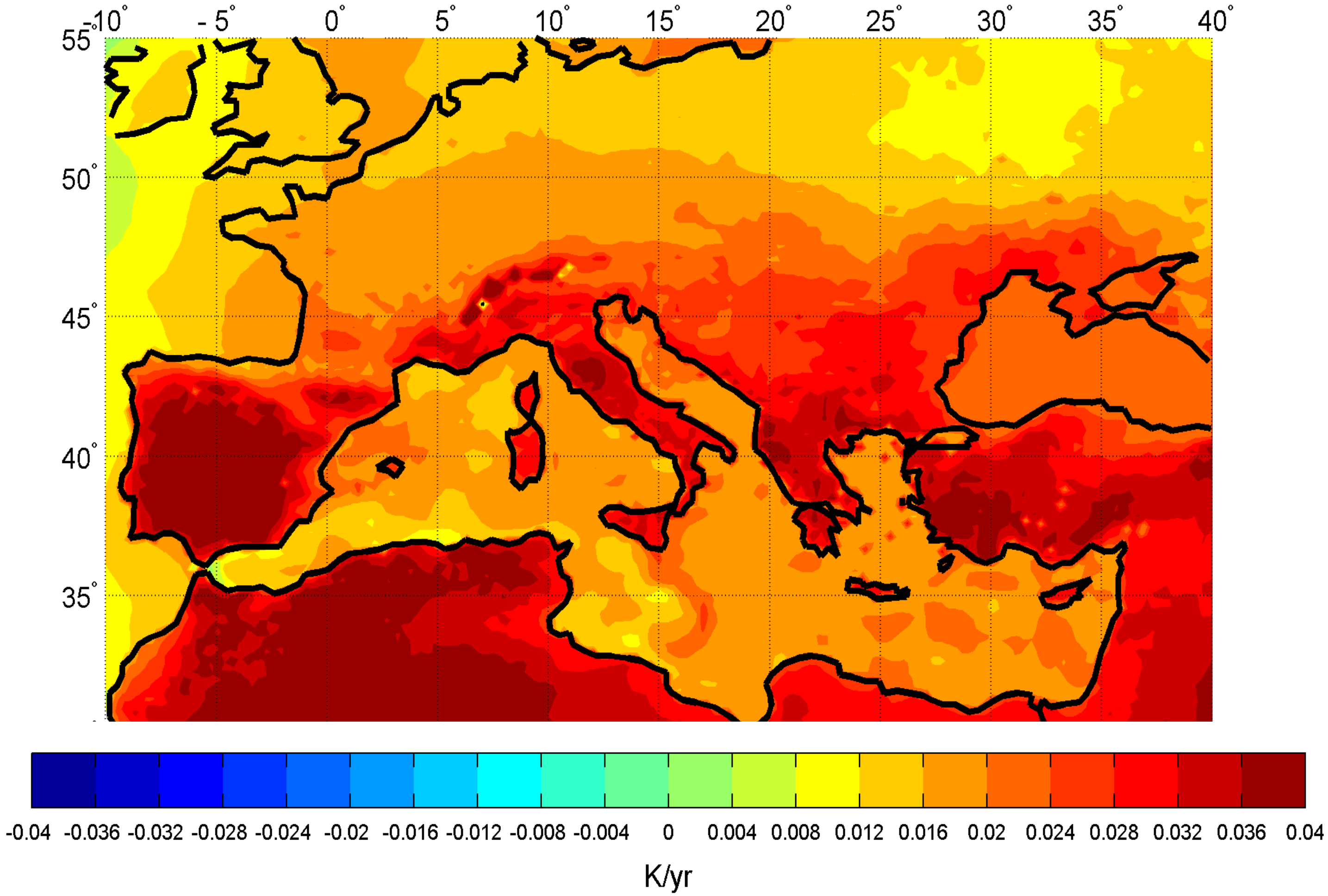




Winter SST trend 1951-2050 in A1B scenario

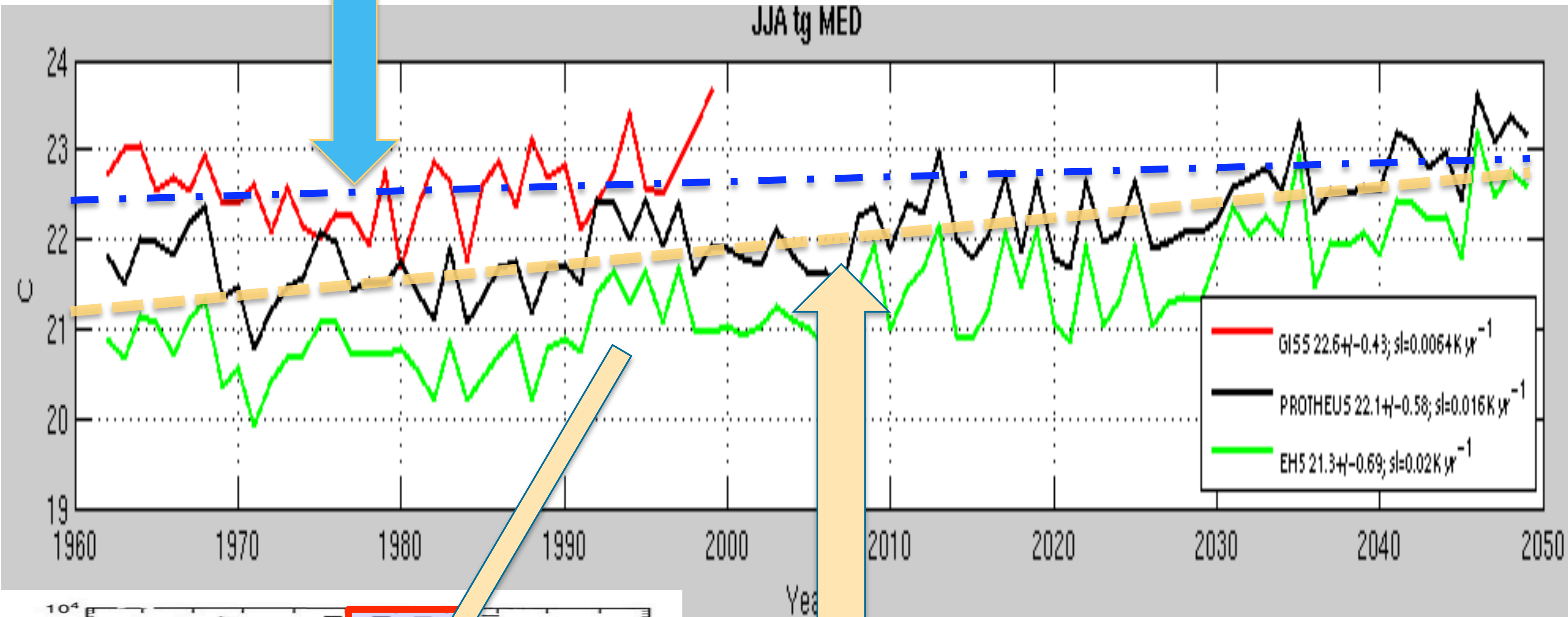


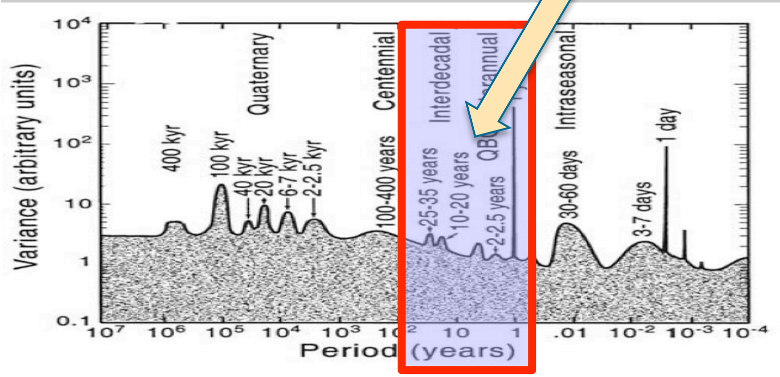
Summer SST trend 1951-2050 in A1B scenario



SST averaged over the whole basin in Summer

0.02-0.03/decade from the past observation or 0.06/decade for the last 50 yrs

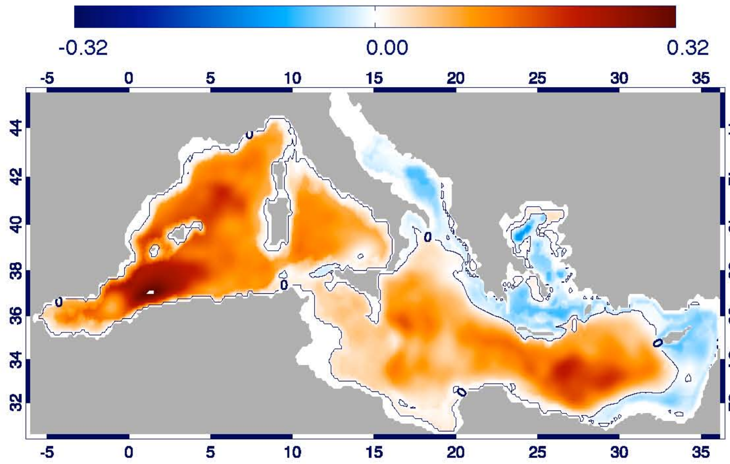




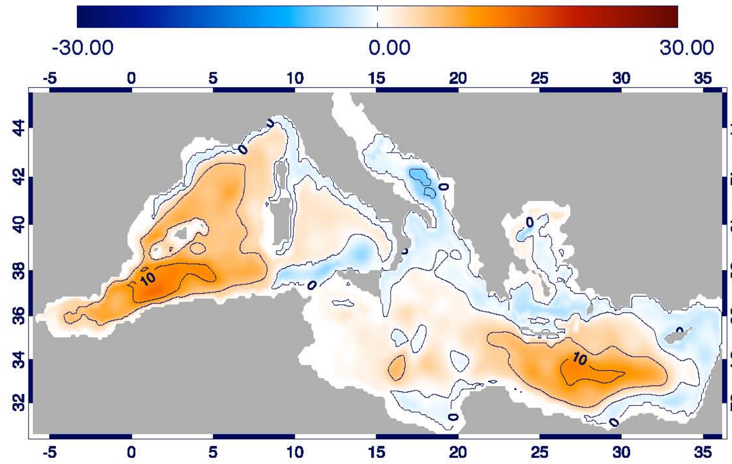
0.16/decade from our scenario

Sea level trend

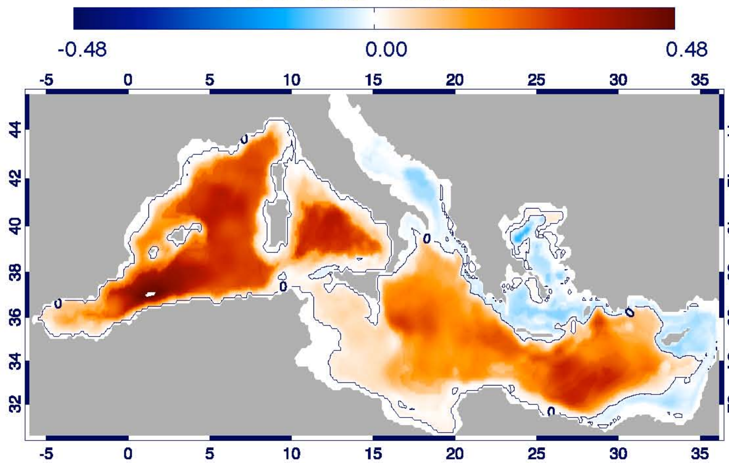
T-S C4 0-1000 m 1958-2001



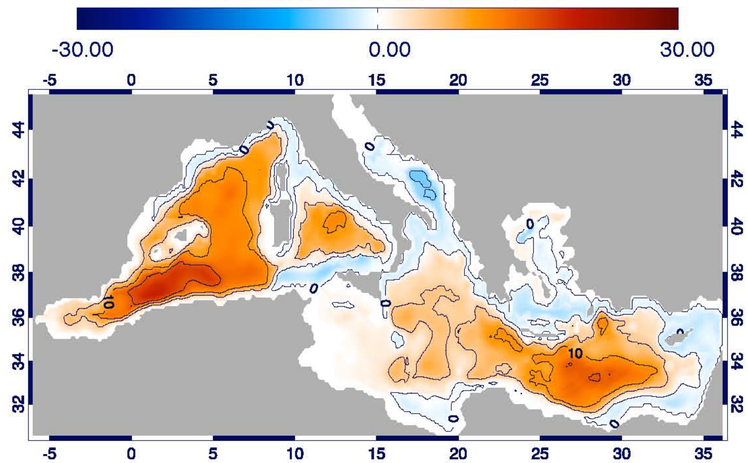
T-S 1000 m diff 2001-1997 1958-1963



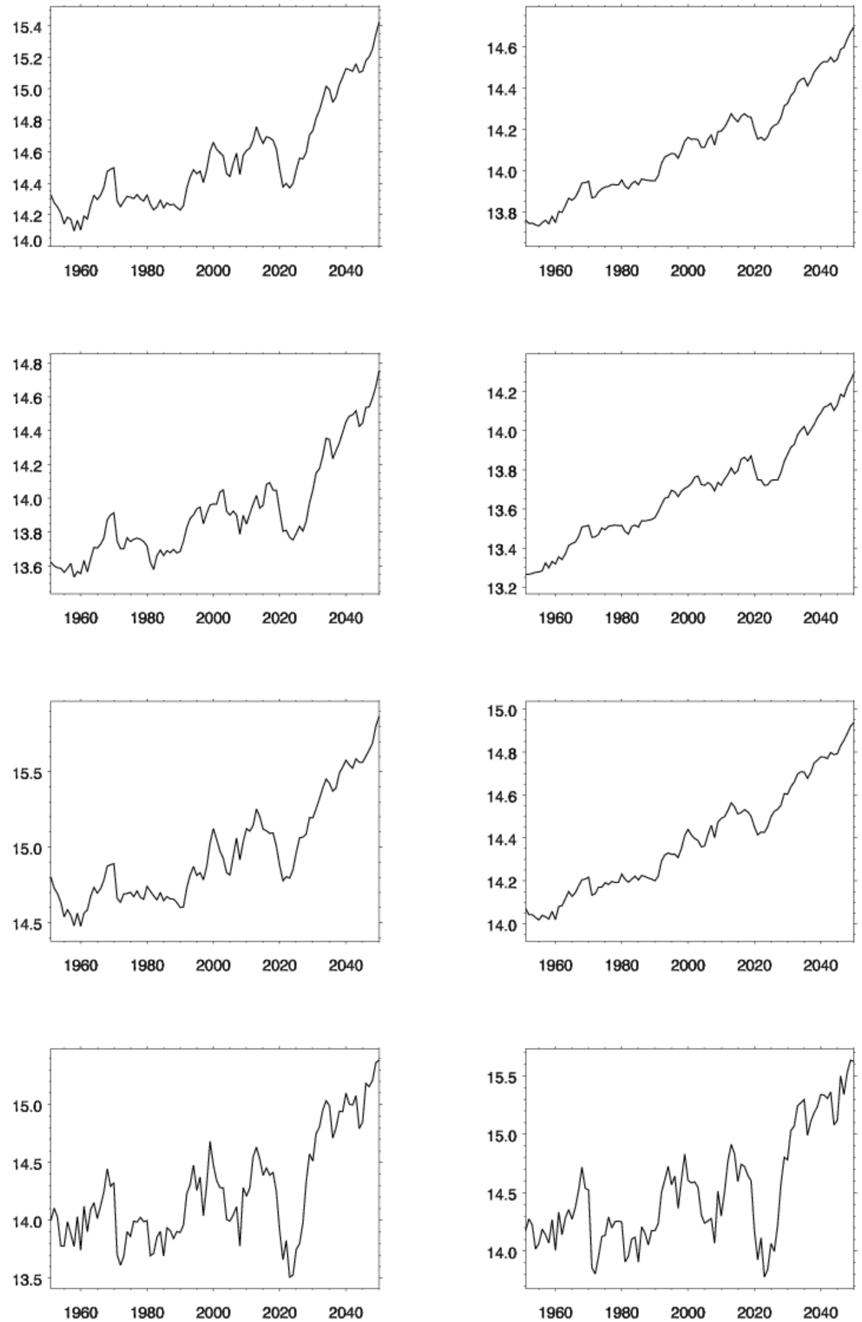
T-S C4 total 1958-2001



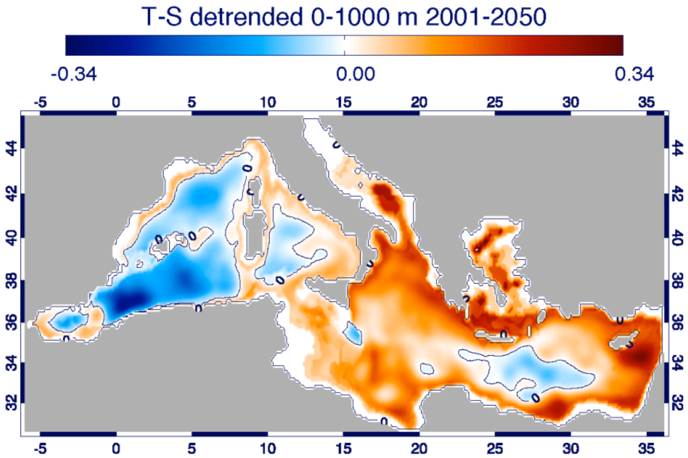
T-S total 2001-1997 1958-1963

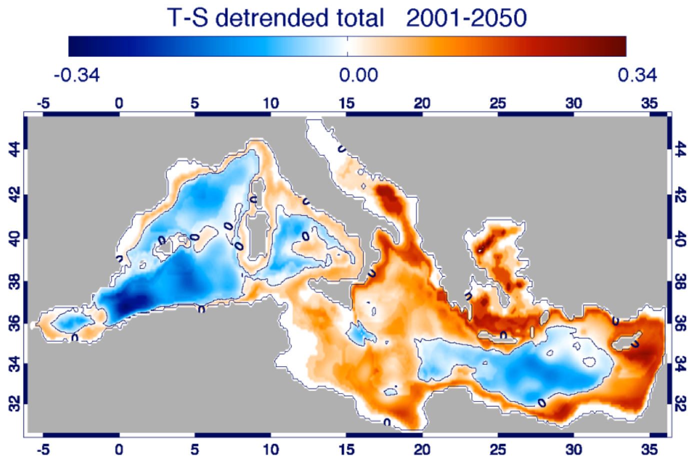


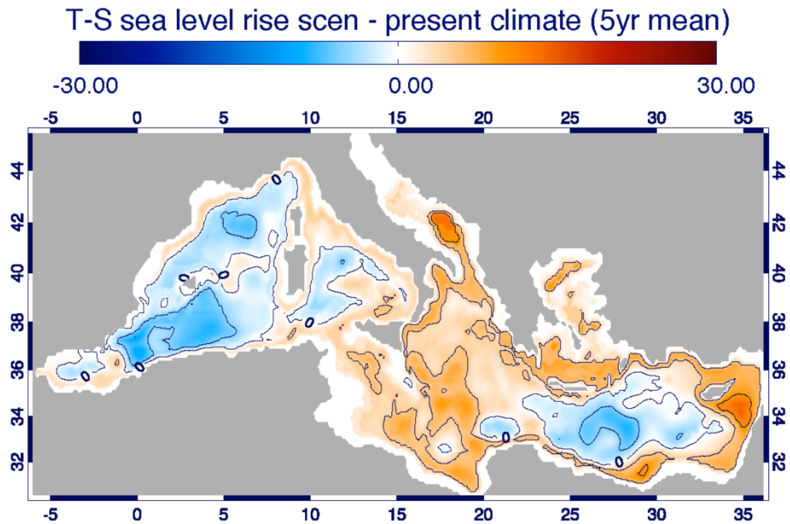
T trend 1951-2050 simulation



Sea level trend for the scenario period







Caveat for intepreting the western basin due to uncertainties related to the Atlantic water inflow

The Ionian and Adriatic Sea will experience the strongest sea level rise after 2040

BC for MITgcm

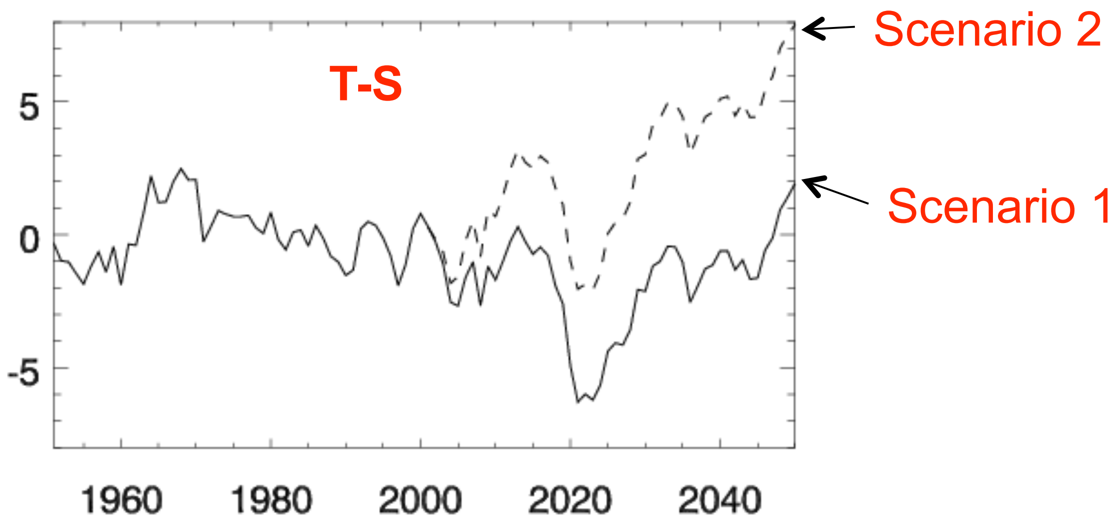
Scenario 1

Temperature and salinity are relaxed in the Atlantic box to monthly mean values. These values are obtained adding to the climatological data the tracers anomalies derived from the global coupled model and computed respect to the present climate simulation.

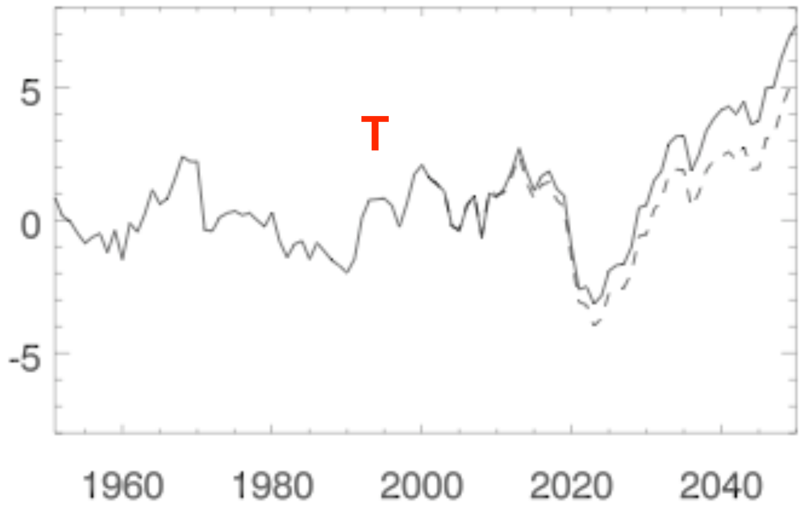
Scenario 2

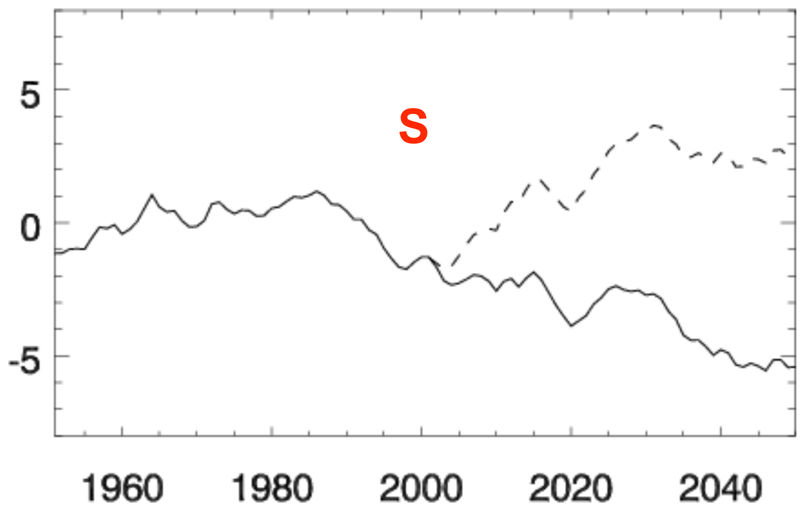
Temperature and salinity are relaxed in the Atlantic box to monthly mean values obtained from the coupled global run.

Steric sea level trend



Linear trend computed over the present climate run (1950-2000) has been subtracted



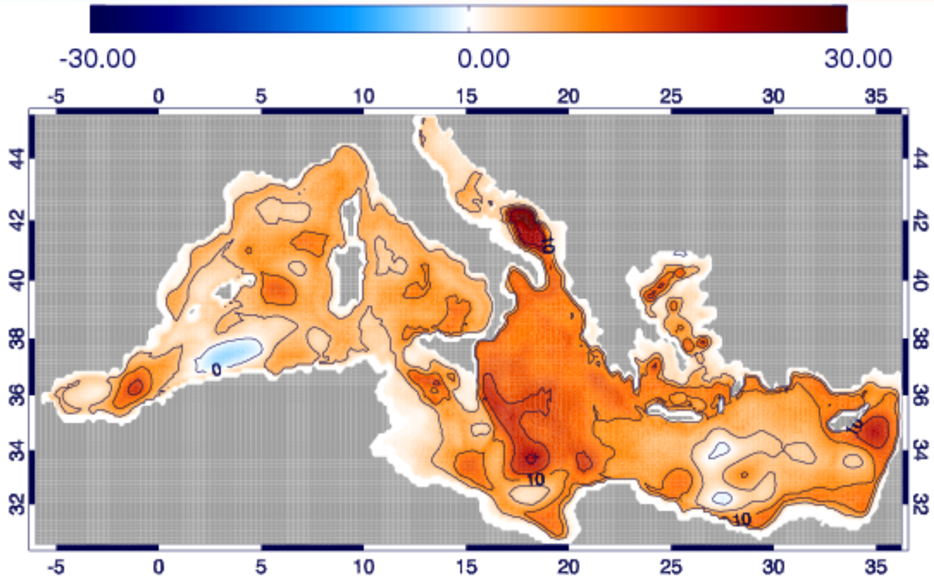


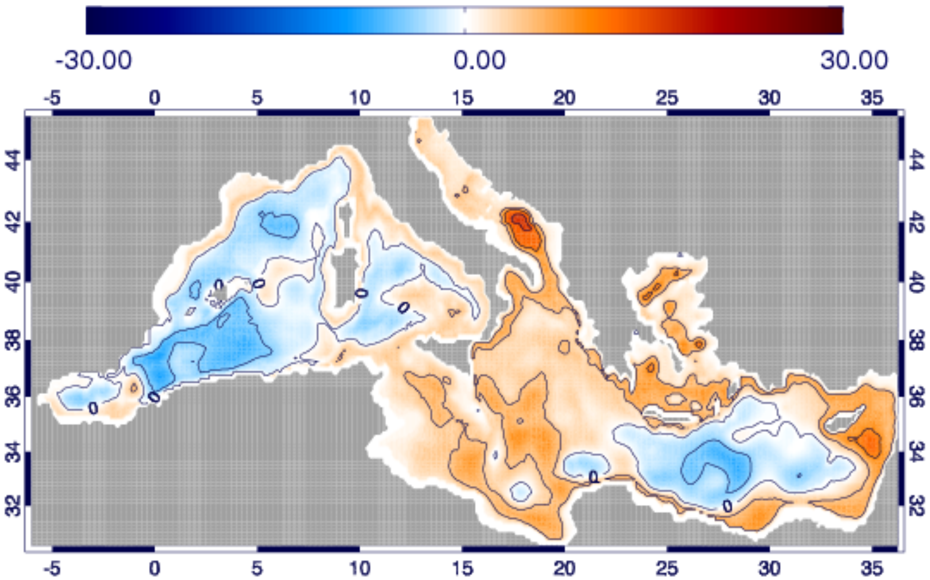
PROTHEUS scenario simulations

ENEA
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Steric sea level difference between the last and the first 5 years of the scenario simulation

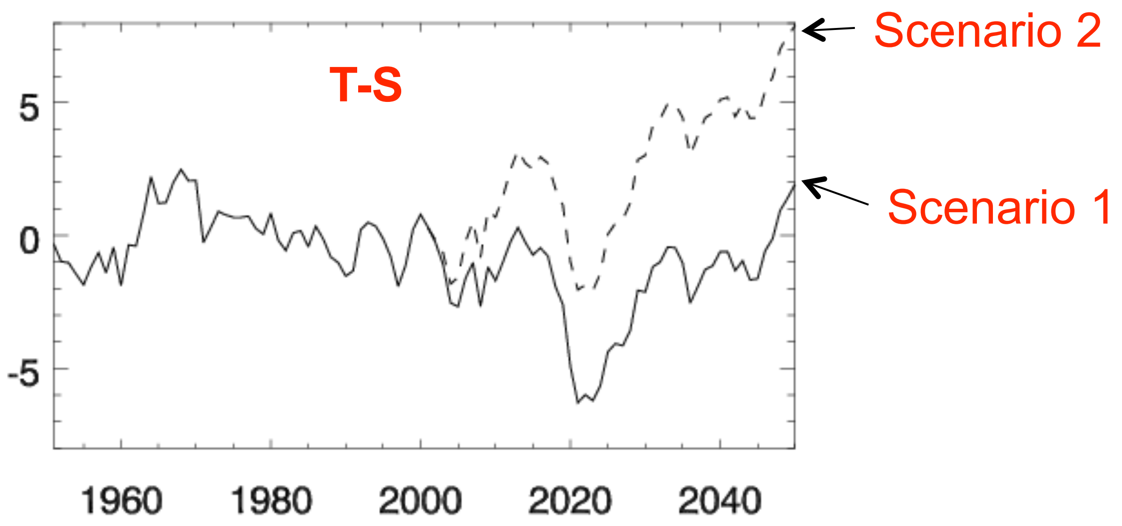
Scenario 2



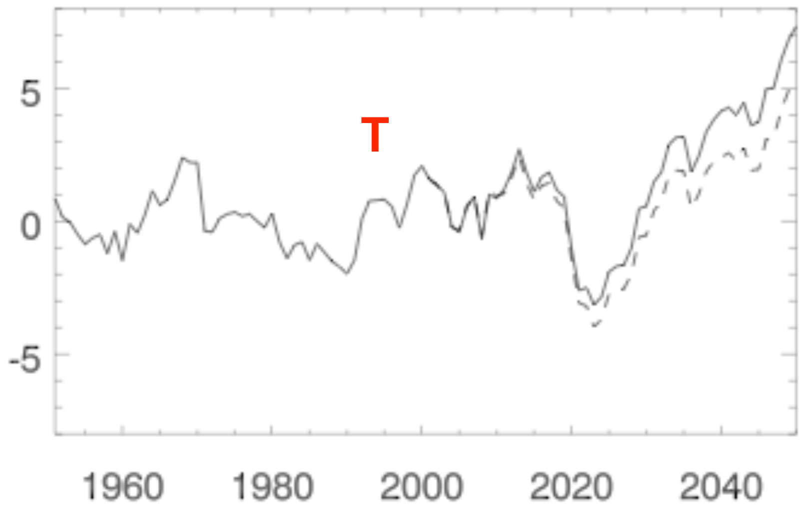


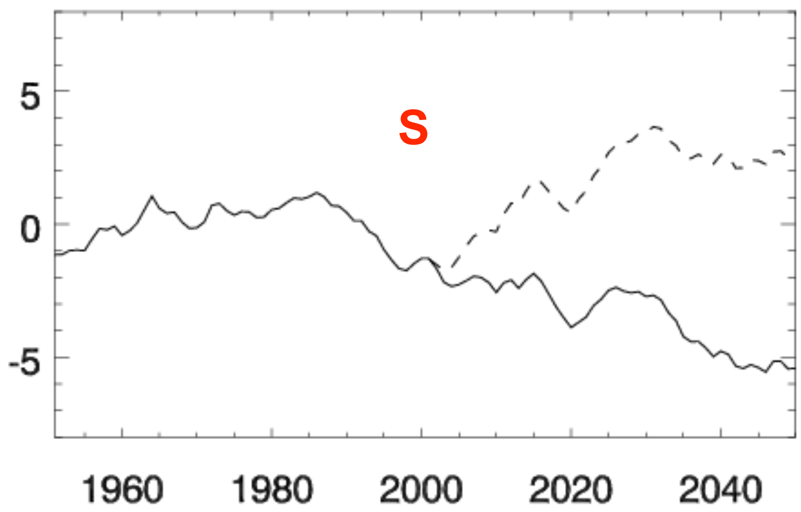
Scenario 1

Steric sea level trend



Linear trend computed over the present climate run (1950-2000) has been subtracted

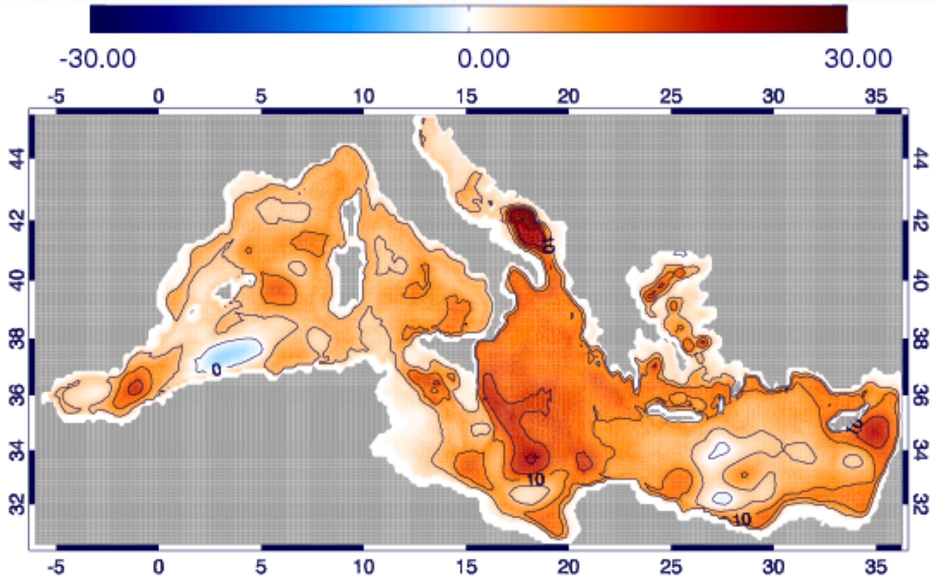


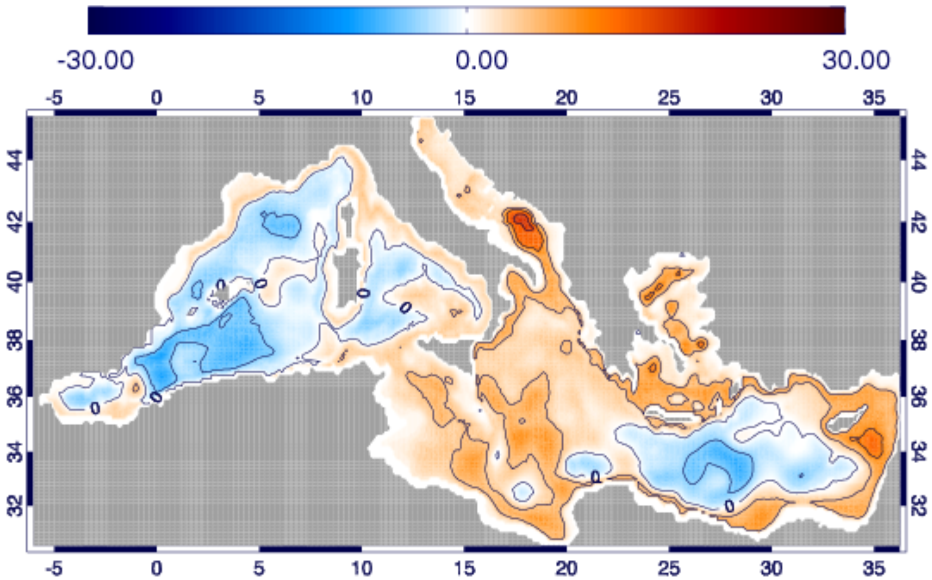


PROTHEUS scenario simulations

Steric sea level difference between the last and the first 5 years of the scenario simulation

Scenario 2





Scenario 1

Impact for future scenario of the Mediterranean sea

many of the key factors may depend from a good representation of the strait dynamics, for example:

sea level rise at global scale is slightly (10%) depending by salinity, **and in the Mediterranean sea (see Tsimplis papers…)**?

stratification, mixing, deep convection

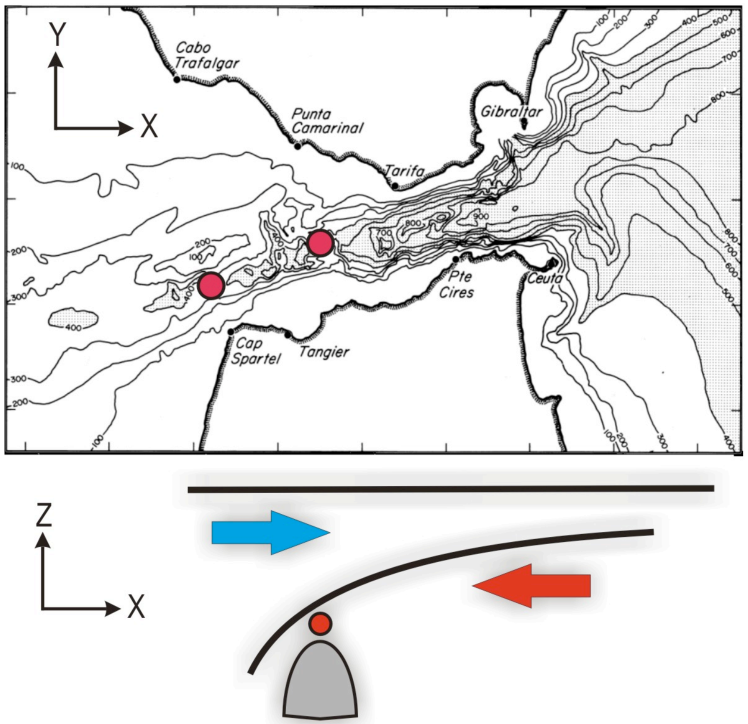
While in case of maximal regime the strait will respond relatively slow to an internal change of the thermohaline circulation of the Mediterranean Sea due to evaporation, a more rapid adaptation of the transports in the strait will be exhibited in case of submaximal regime.

► **The circulation within the strait is described as a two-layer system hydraulically controlled at Camarinal Sill.** (*Brayden and Stommel, Ocean. Acta, 1984*).

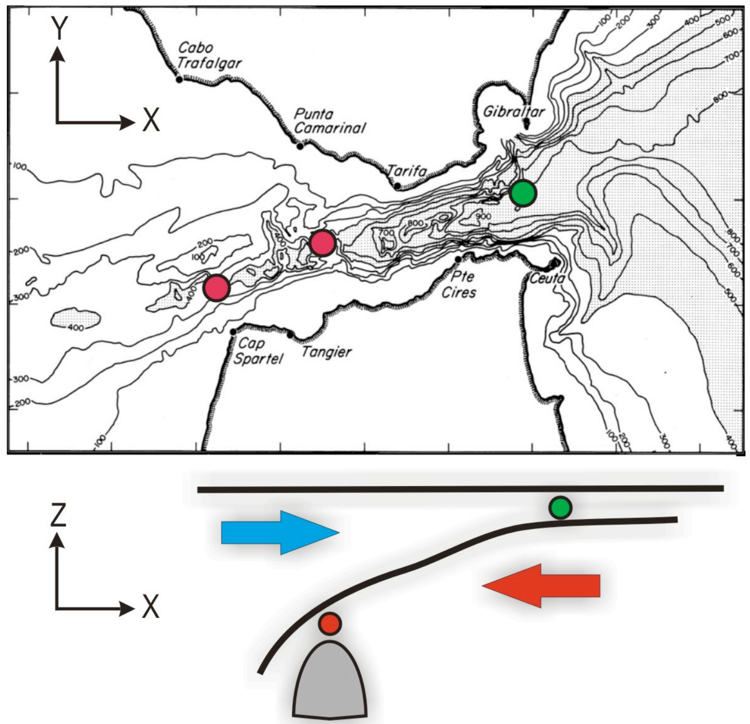
$$G^2 = F_1^2 + F_2^2 = 1$$

$$F_i^2 = \frac{u_i^2}{gh_i^2}$$

Submaximal Exchange



Maximal Exchange



An estimate of the transport can be made from Knudsen's relations (from Bryden and Stommel, 1984),

$Q_1 + Q_2 = Q_f\,(E)$,

$Q_1 S_1 + Q_2 S_2 = 0$,

↓

$Q_1 = S_2/(S_1 - S_2)\,Q_f$

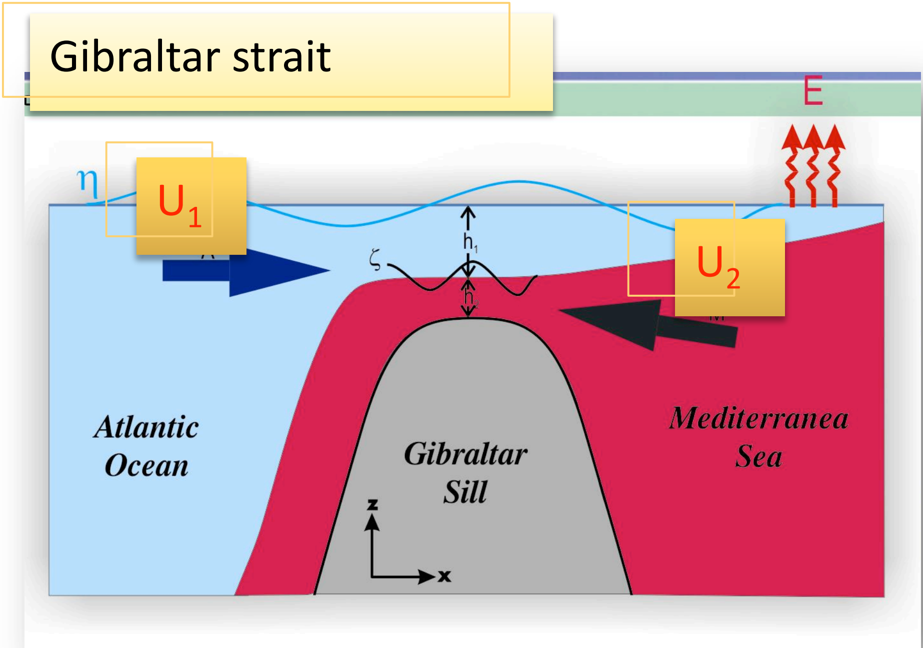
$Q_2 = S_1/(S_1 - S_2)\,Q_f$

↓

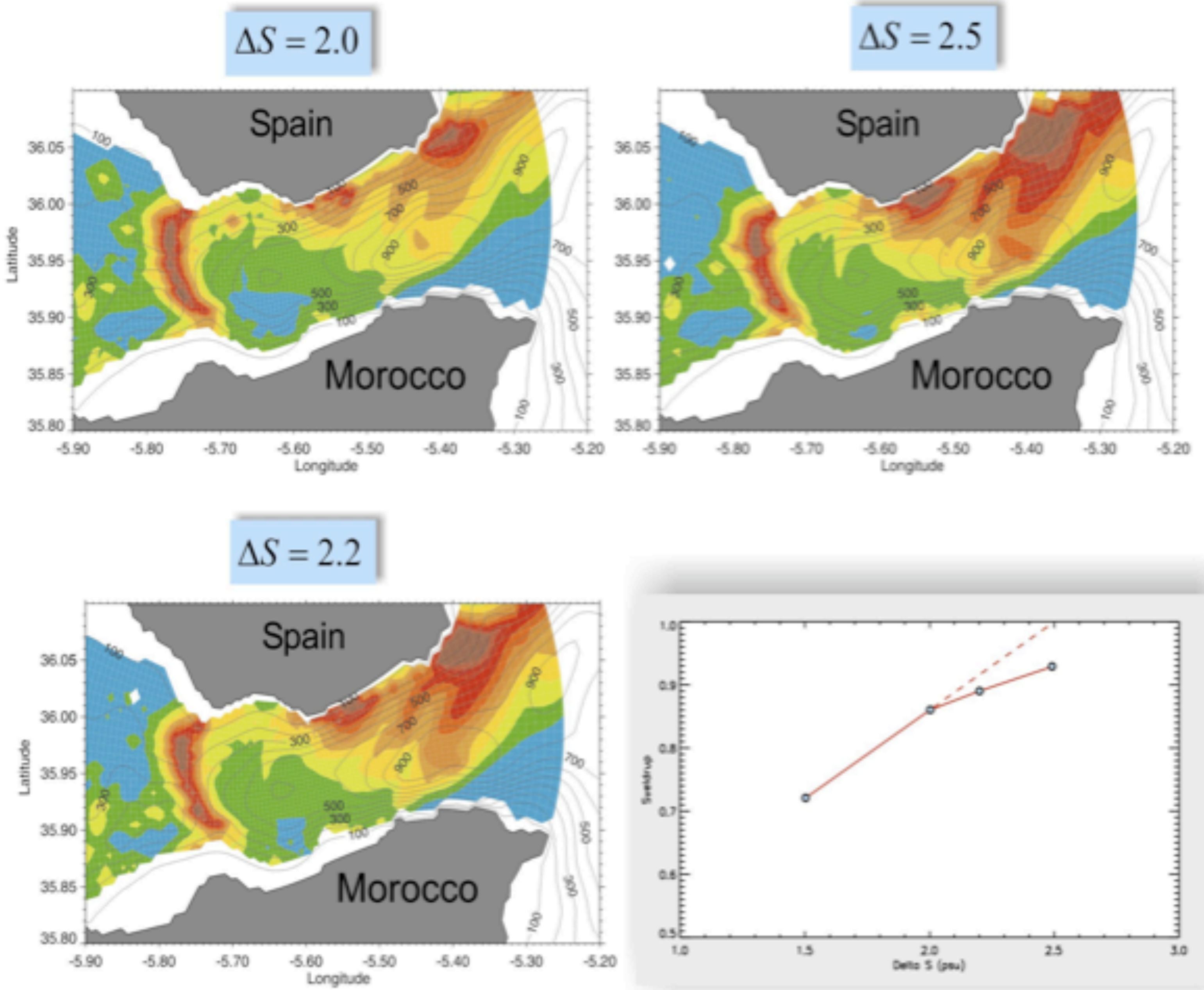
$U_1 = S_2 Q_f/(S_1 - S_2) H_1 W$

$U_2 = S_1 Q_f/(S_1 - S_2)\,H_2 W$

↓



minimum $(S_1 - S_2) \approx 1.10 \div 2.17$ psu → maximum transport



$\Delta S = 2.0$
$\Delta S = 2.5$
$\Delta S = 2.2$
Spain
Morocco
Latitude
Longitude
Froude Number
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Sverdrup
Delta S (psu)

Some Conclusion

From a review of all available data set for the Mediterranean Sea we found an warming trend of 0.022 °C/decade in SST over the last 150 yrs, moreover in the Gulf of Cadiz the MOW displays a trend of 0.16 °C/decade and 0.05/decade in salinity over the last 50 yrs;

The Mediterranean isn't a isolated basin, but is a relevant component of the North Atlantic climate system, e.g. the northern part of Atlantic and Mediterranean show an high correlated multi decadal variability typically of 70-yrs;

The coupled model (Protheus System) predicts significant interannual variability including EMT and acceleration of warming in particular after the 2020 with an average value of 0.16 °C/decade (not shown);

The steric sea level trend ranges in the basin from -0.32 cm/yr to 0.34 cm/yr , with a mean over the Mediterranean of 0.028 cm/yr . An important aspect is the large spatial variability of the trend with negative values over most of the Western basin and part of the Eastern and positive values principally in the Southern Adriatic and the Ionian Sea.

A strong increase in the sea level trend due to the thermal component is observed in the second part of the 50 year simulation.


Thanks for your attention !!

Algoritmo di integrazione e metodologia

Le traiettorie sono state calcolate usando l'algoritmo Runge-Kutta del II° ordine integrando l'equazione di avvezione senza nessun termine di diffusione.

Le particelle sono considerate traccianti ideali che non influiscono sul campo di velocità e non sono soggette a nessun tipo di trasformazione.

Le particelle sono sistematicamente rilasciate in superficie e vengono integrate considerando il campo di velocità 2D bidimensionale (componente verticale W=0, simulazione di oggetti galleggianti) del modelli operativi del Mar Tirreno POM4840).

Come campo Euleriano viene utilizzato quello di Aprile 2009. Le analisi di decorrelazione vengono effettuate prima su serie di 28 giorni (1-28 Aprile) e poi di 10 giorni (massima estensione dei "forecast")

Grandezze considerate per caratterizzare il bacino : frequenza inerziale, OW, EKE_L, T_v, T_a, $y=T_a/T_v$, K, FSLE