# A Review of the Levantine Basin Circulation and Modeling of the Asia Minor Current

**On the occasion of the 25 years of POEM**


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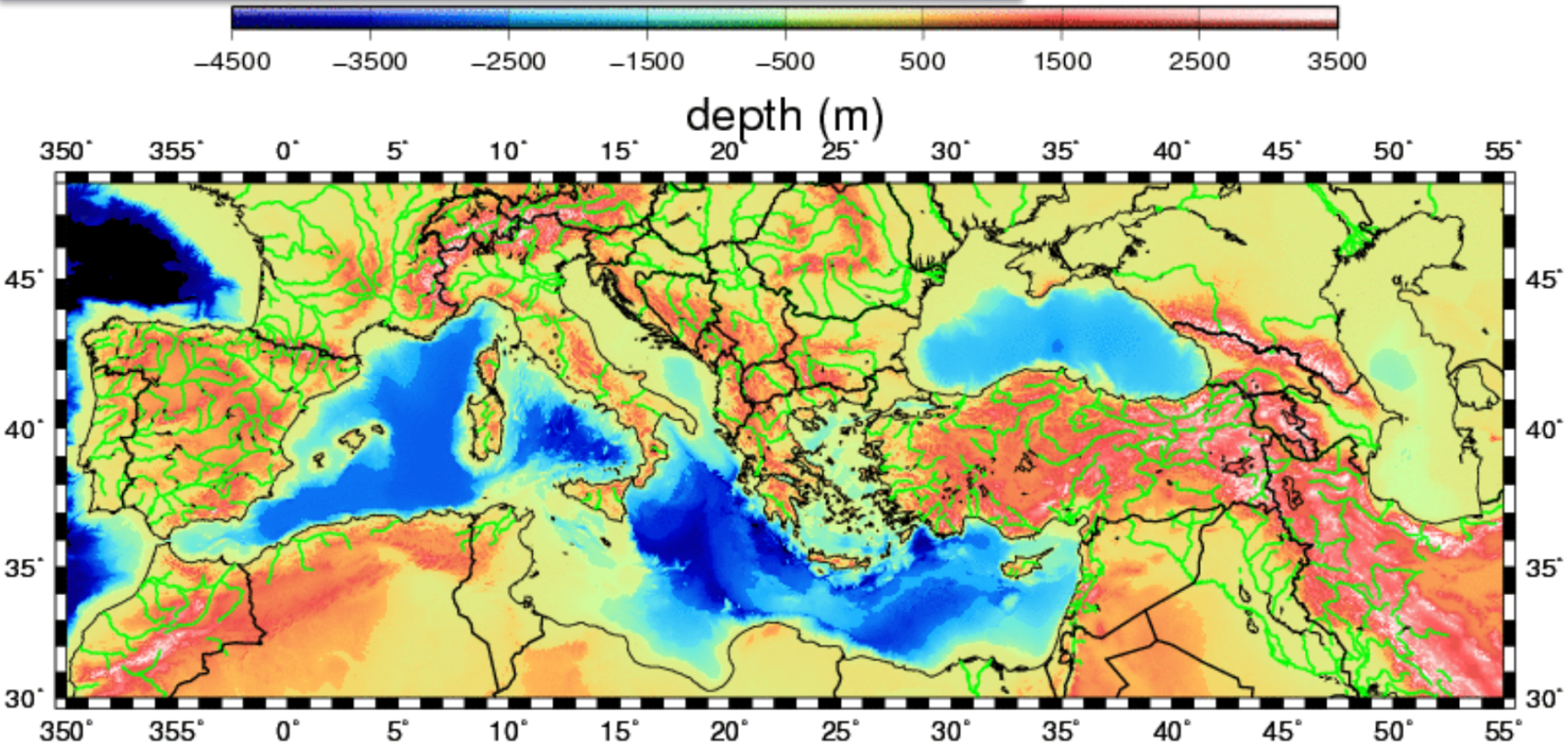
**Middle East Technical University,**
**Erdemli, Mersin**

# Seas of the Old World

Persistent observations needed in regions of high climate variability (Mediterranean, Black and Caspian Seas)



NATO Projects
Black Sea (3), Caspian Sea

European Projects
Ventilation of the Black Sea, Aral Kum,
MFS, MFSTEP, IASON, ECOOP, SESAME, PERSEUS,
MyOcean, MyOcean2, MyOcean Follow On,

Copernicus Marine Environment Monitoring Service (CMEMS)

+

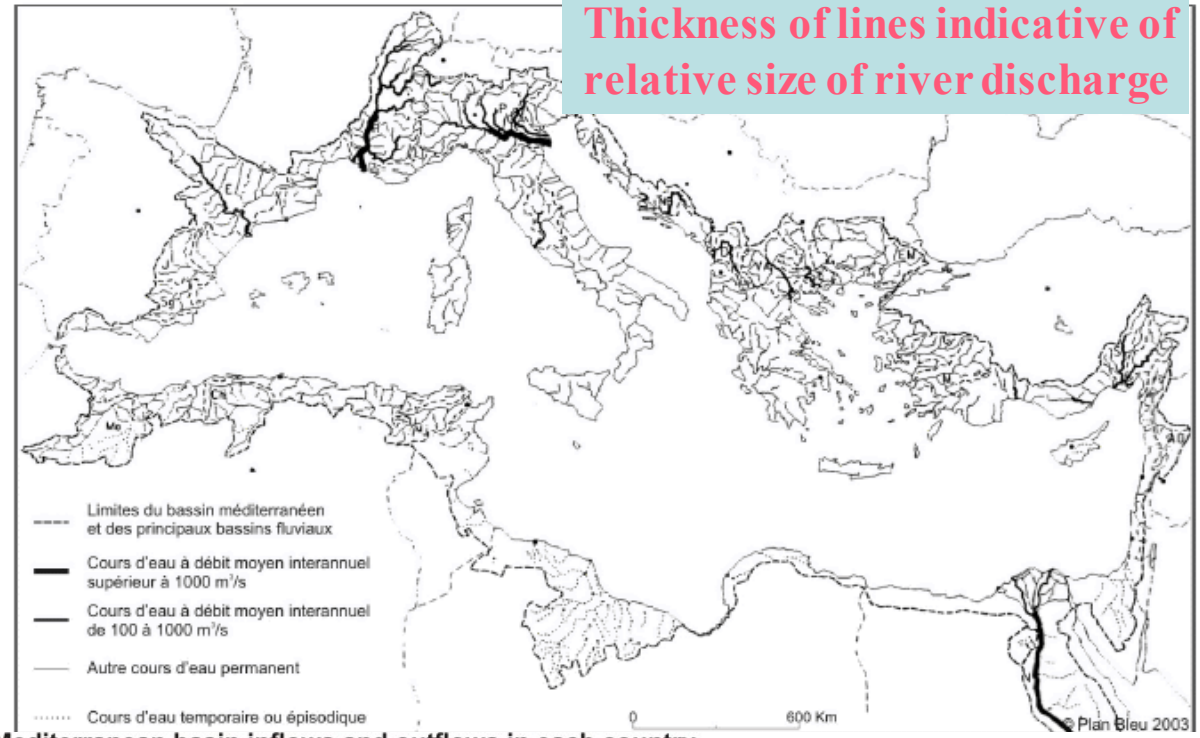
many TÜBİTAK projects
including MOMA (kamu)


BİLİM-2
MERSİN

# Coasts of Turkey to the Mediterranean Levantine Basin, Aegean Sea, Black Sea,Turkish Straits System:

Forcing - semi-enclosed seas - multi-scale (micro to climate):
- wind stress, wind setup, storm surge
- heat / salt / material fluxes / atmospheric transport
- water and buoyancy fluxes, water balance R+P-E
- sea level, hydrologic cycle
- barometric pressure

Time scales:
Bosphorus: Transit time < 1/2 day
Dardanelles: Transit time ~ few days
Black Sea: residence time 1yr for CIL, >2000yr for bottom
Marmara Sea: residence time 3mo for upper, 6yr for lower layer
Mediterranean: residence time ~100 yr

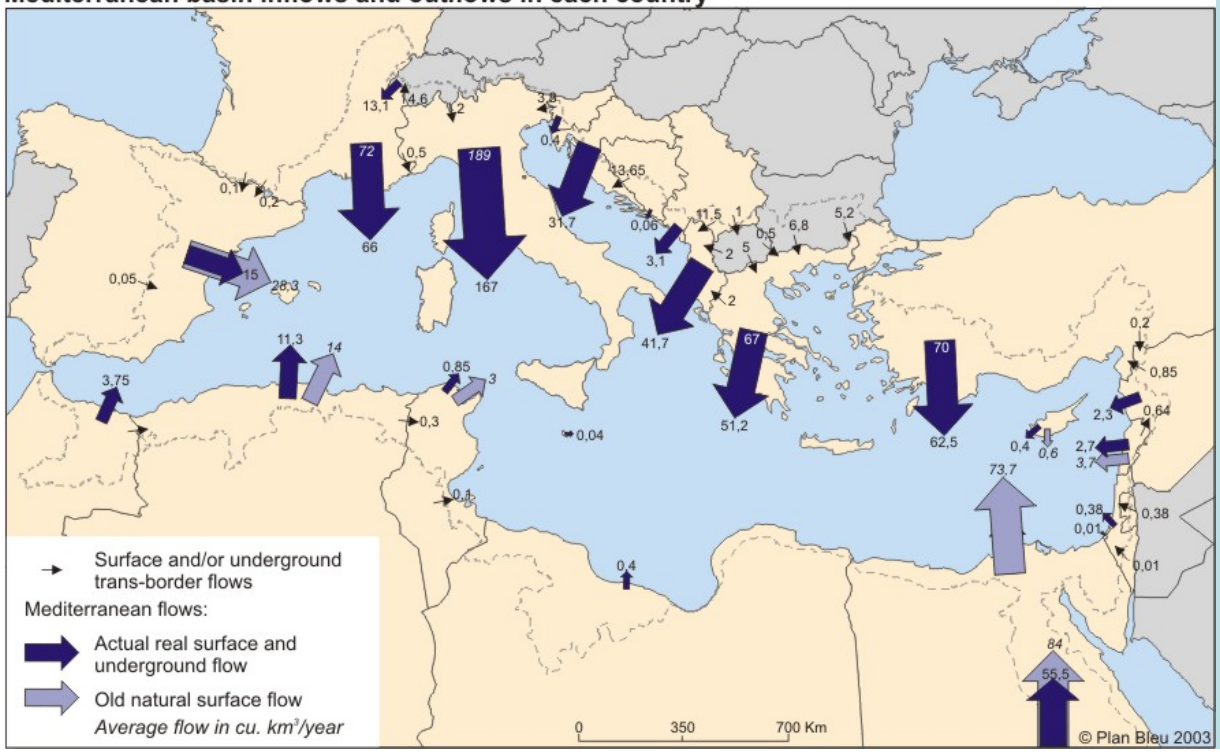



Mediterranean catchments:

north side: very narrow, but mountain sources abundant

south side: even narrower and dryer, with the exception of the Nile, intercepted by the Aswan high dam after 1960s

**Mediterranean basin inflows and outflows in each country**

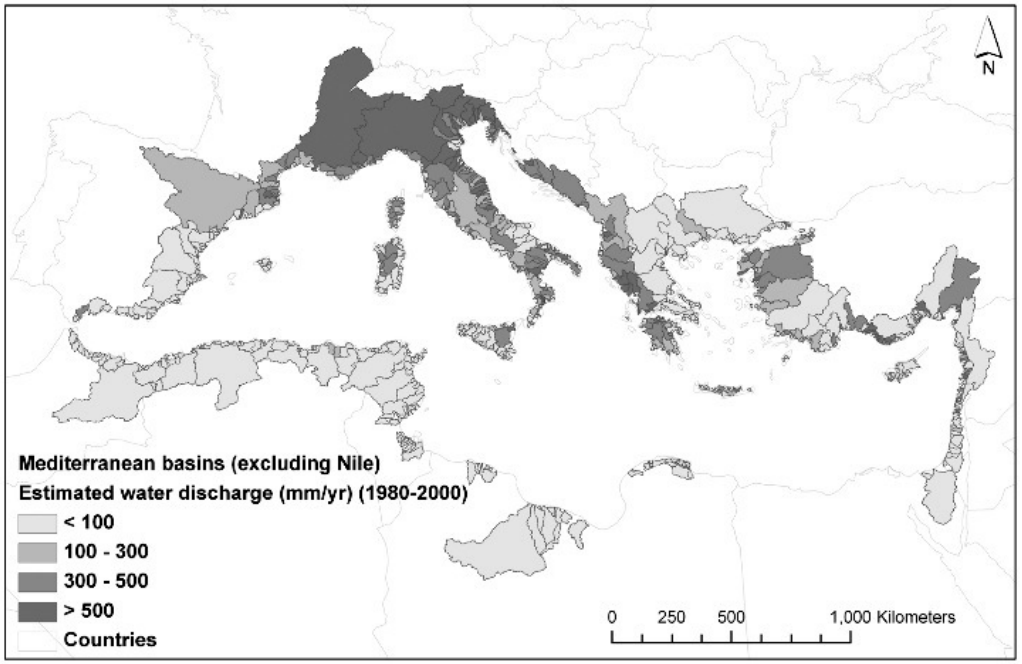



Fresh water inputs into the Mediterranean Sea from riparian countries in km3/yr (Plan Bleu)

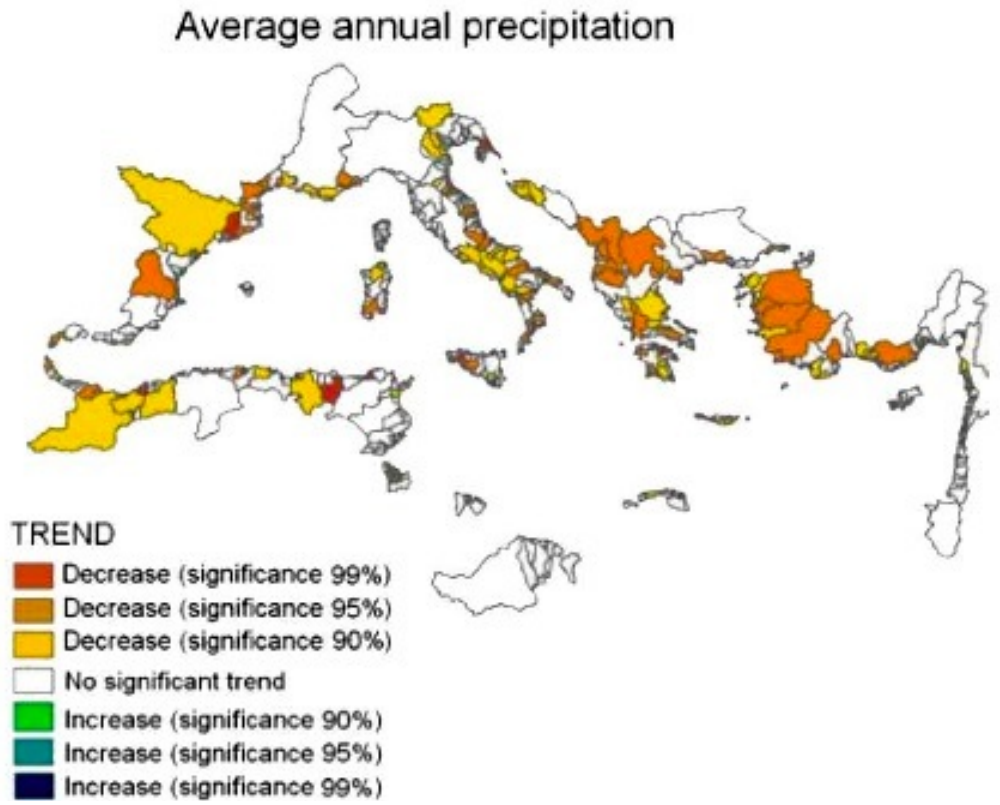
Dark blue arrows: existing surface and underground flows

Light blue arrows: surface flows that have ceased to exist

Bouraoui et al., 2009

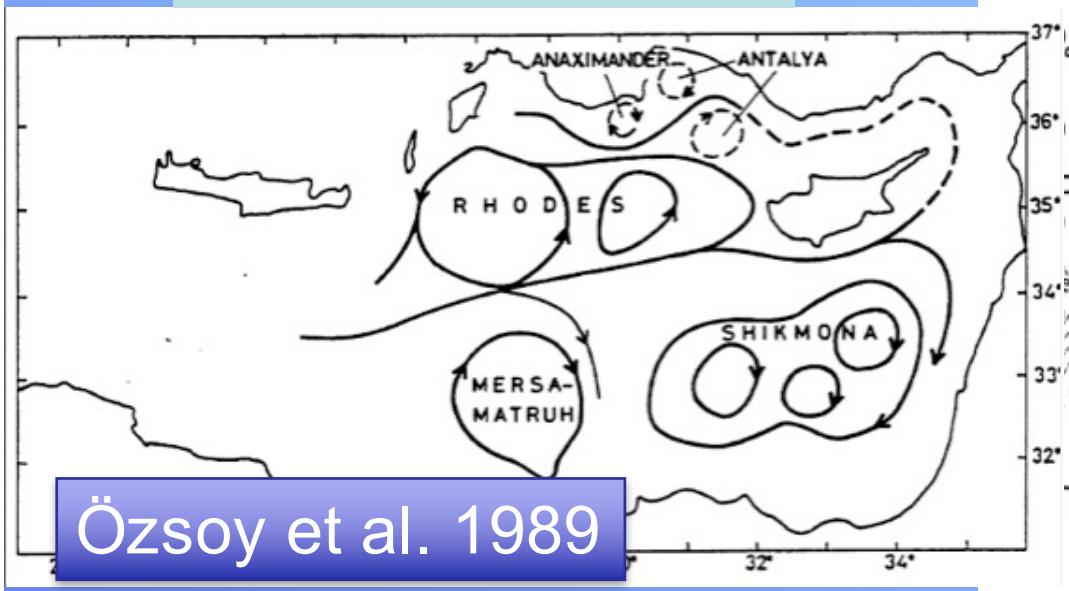



runoff to the Mediterranean excluding the Nile river

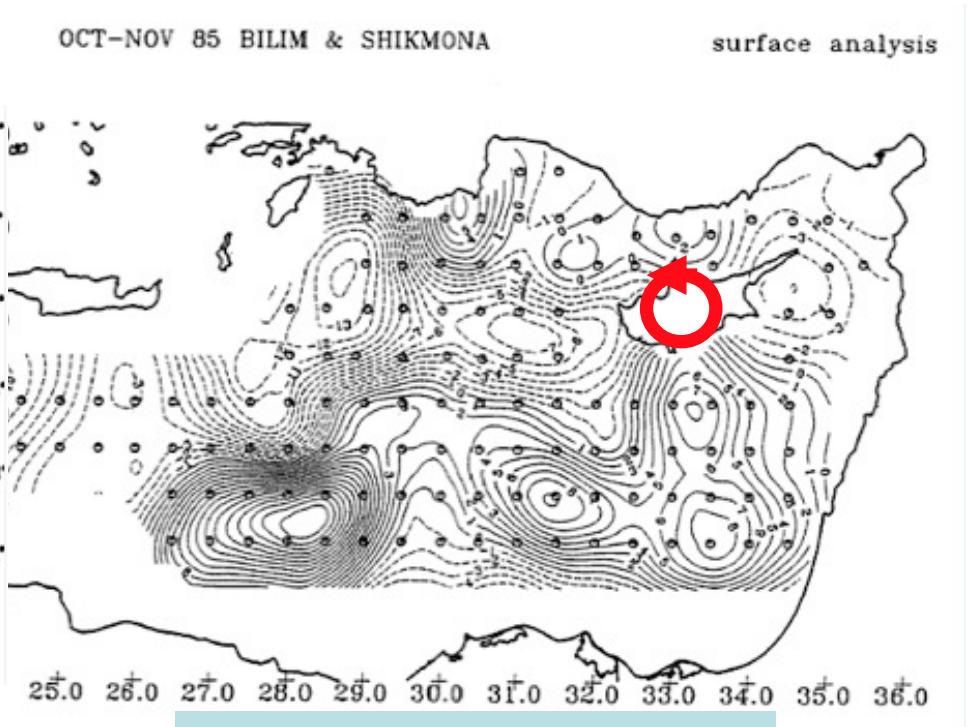



Changes in the runoff

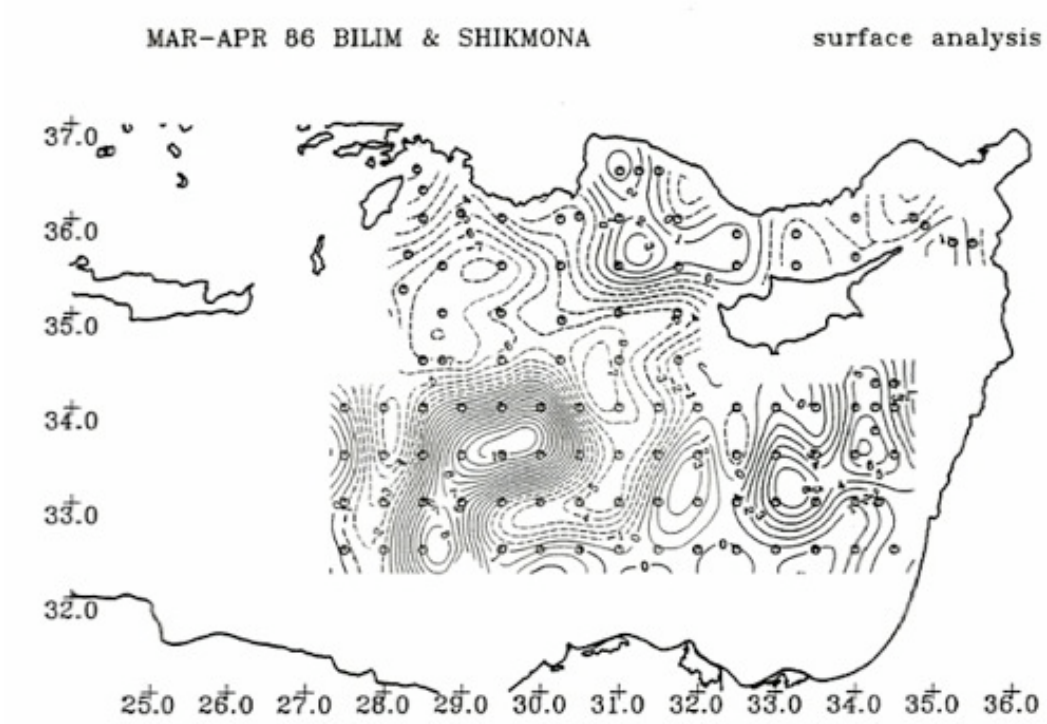
# POEM 1985-1991

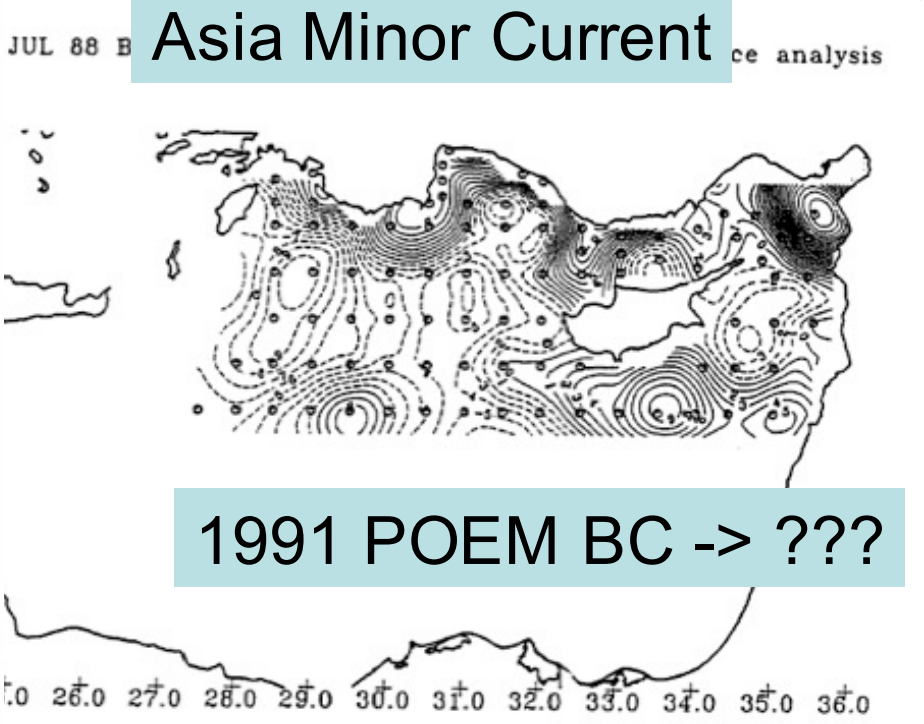



Özsoy et al. 1989

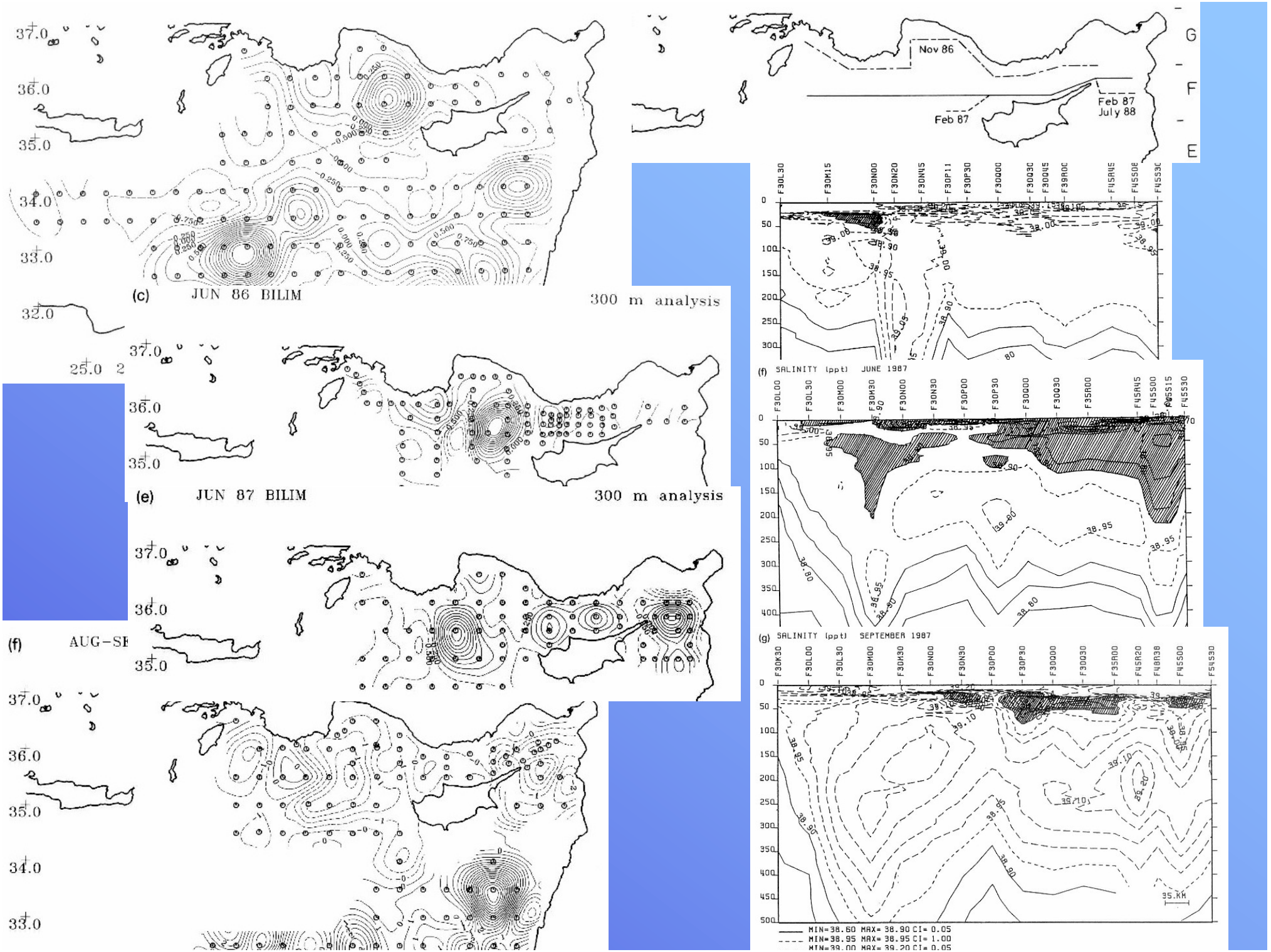


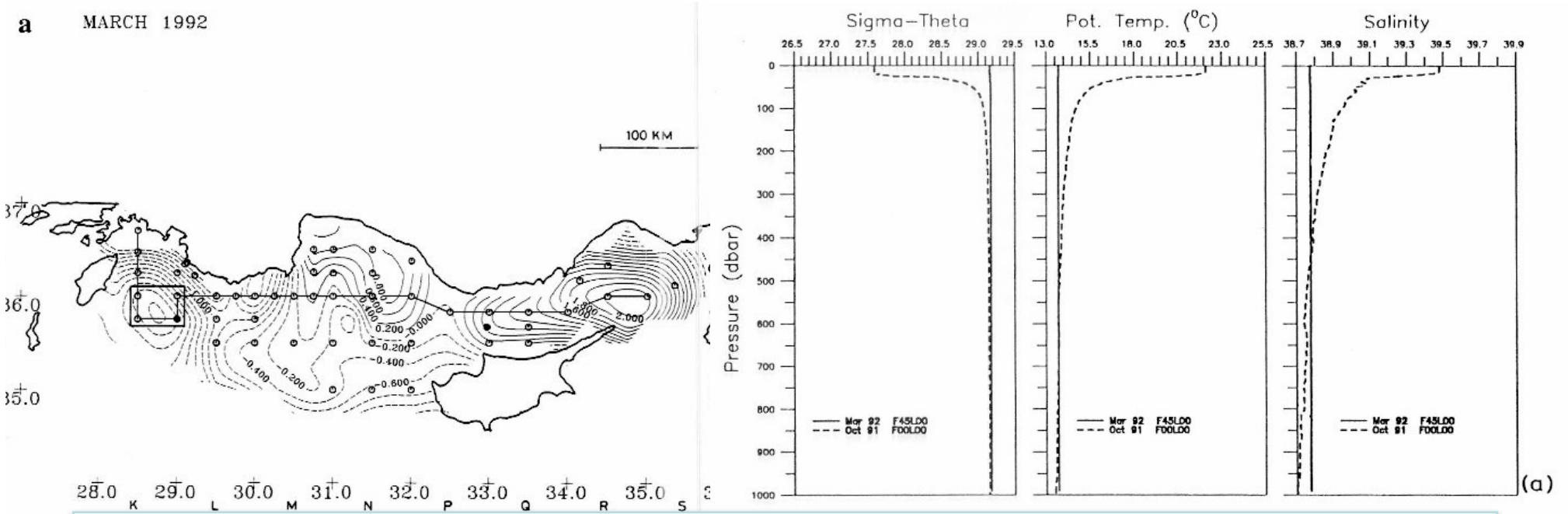

Asia Minor Current



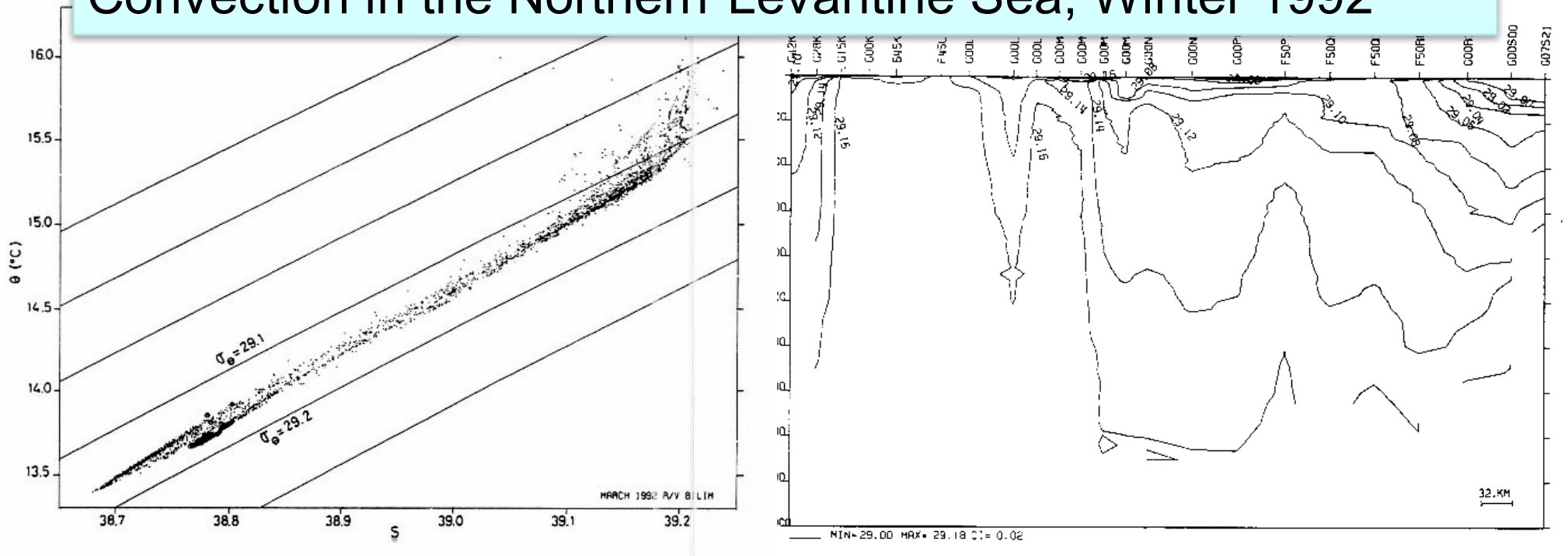



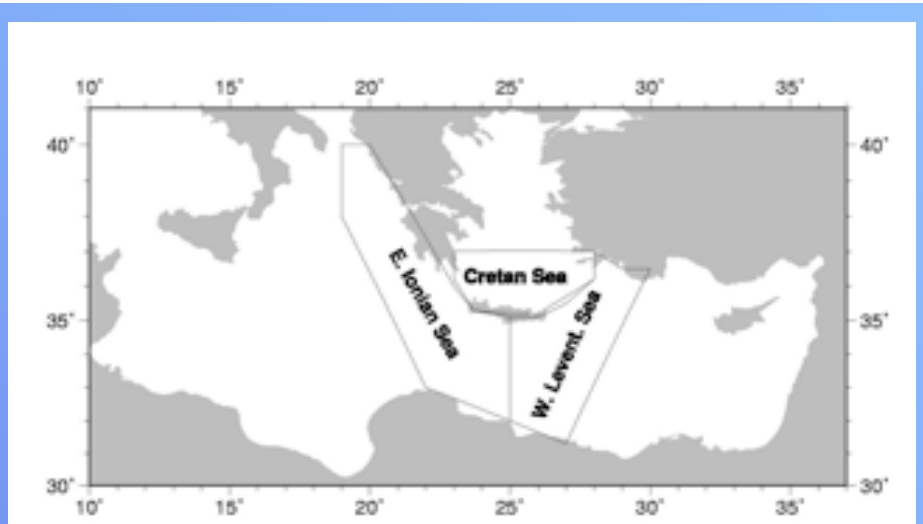

1991 POEM BC -> ???

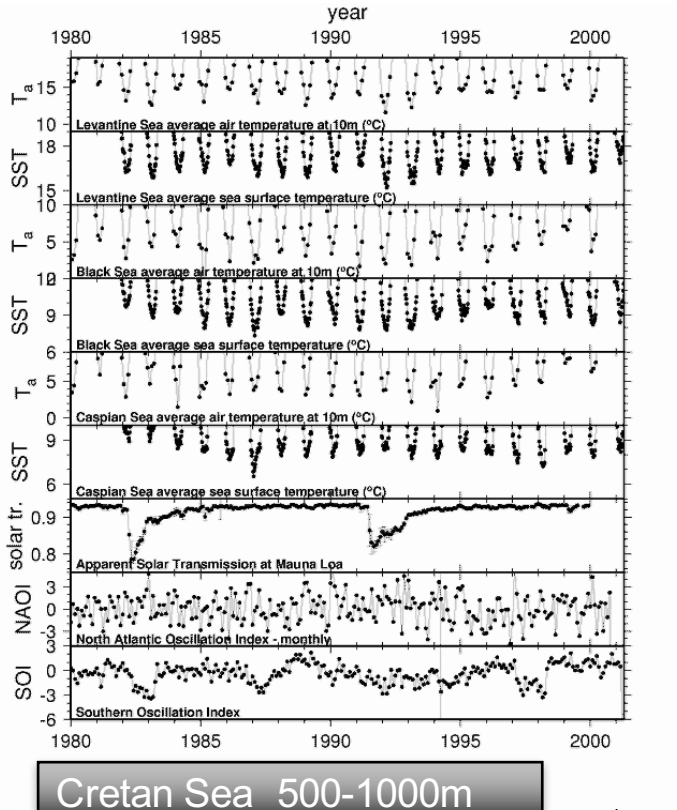

Nov 86
Feb 87
Feb 87
July 88
G
F
E
(c) JUN 86 BILIM 300 m analysis
(e) JUN 87 BILIM 300 m analysis
(f) AUG-SE
(f) SALINITY (ppt) JUNE 1987
(g) SALINITY (ppt) SEPTEMBER 1987
35.KM
MIN=38.60 MAX= 38.90 CI= 0.05
MIN=38.95 MAX= 38.95 CI= 1.00

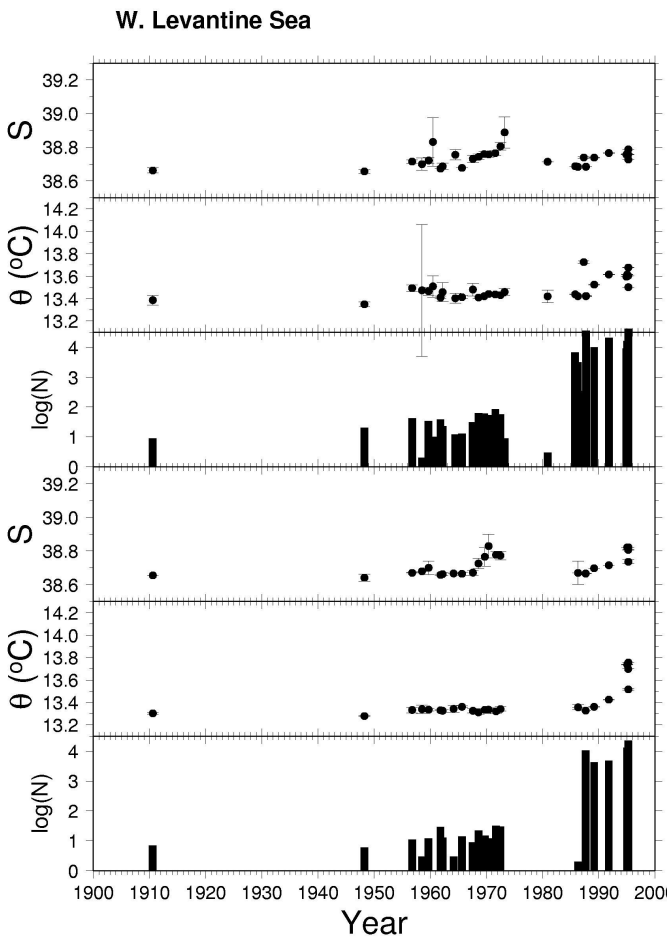


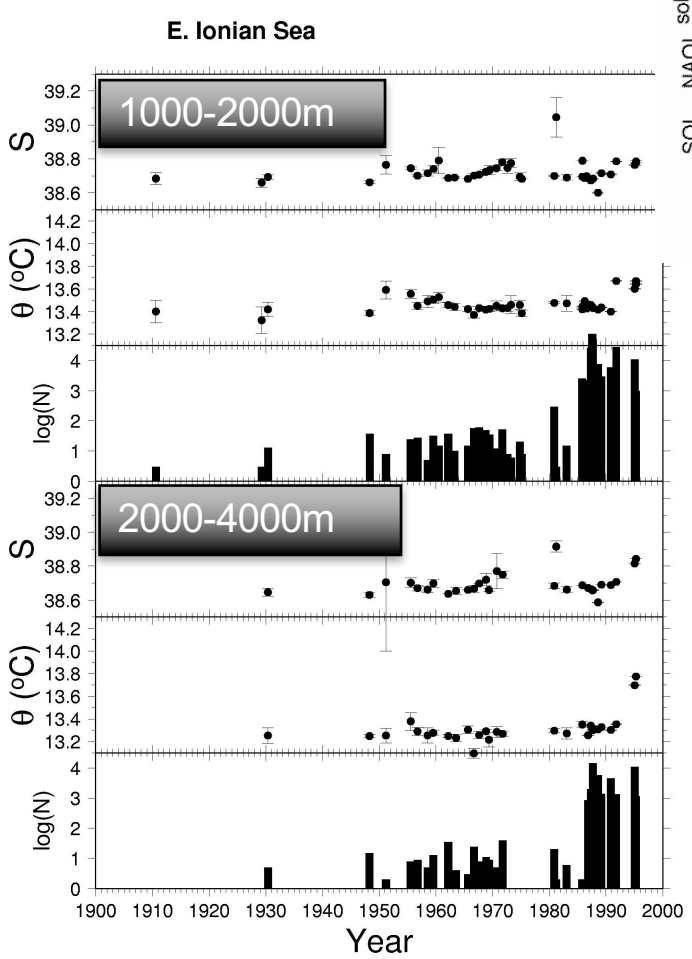

# Sur et al., 1992. Simultaneous deep and intermediate depth Convection in the Northern Levantine Sea, Winter 1992

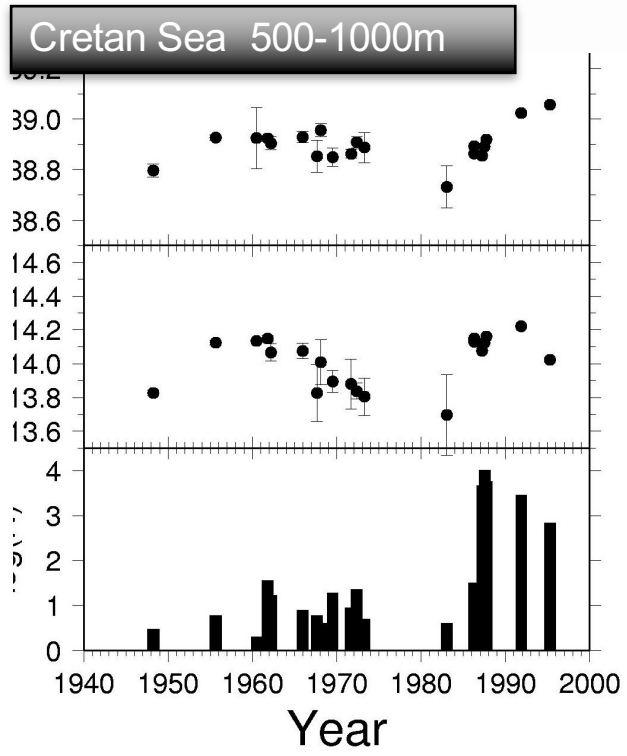



Cretan Sea
E. Ionian Sea
W. Levent. Sea

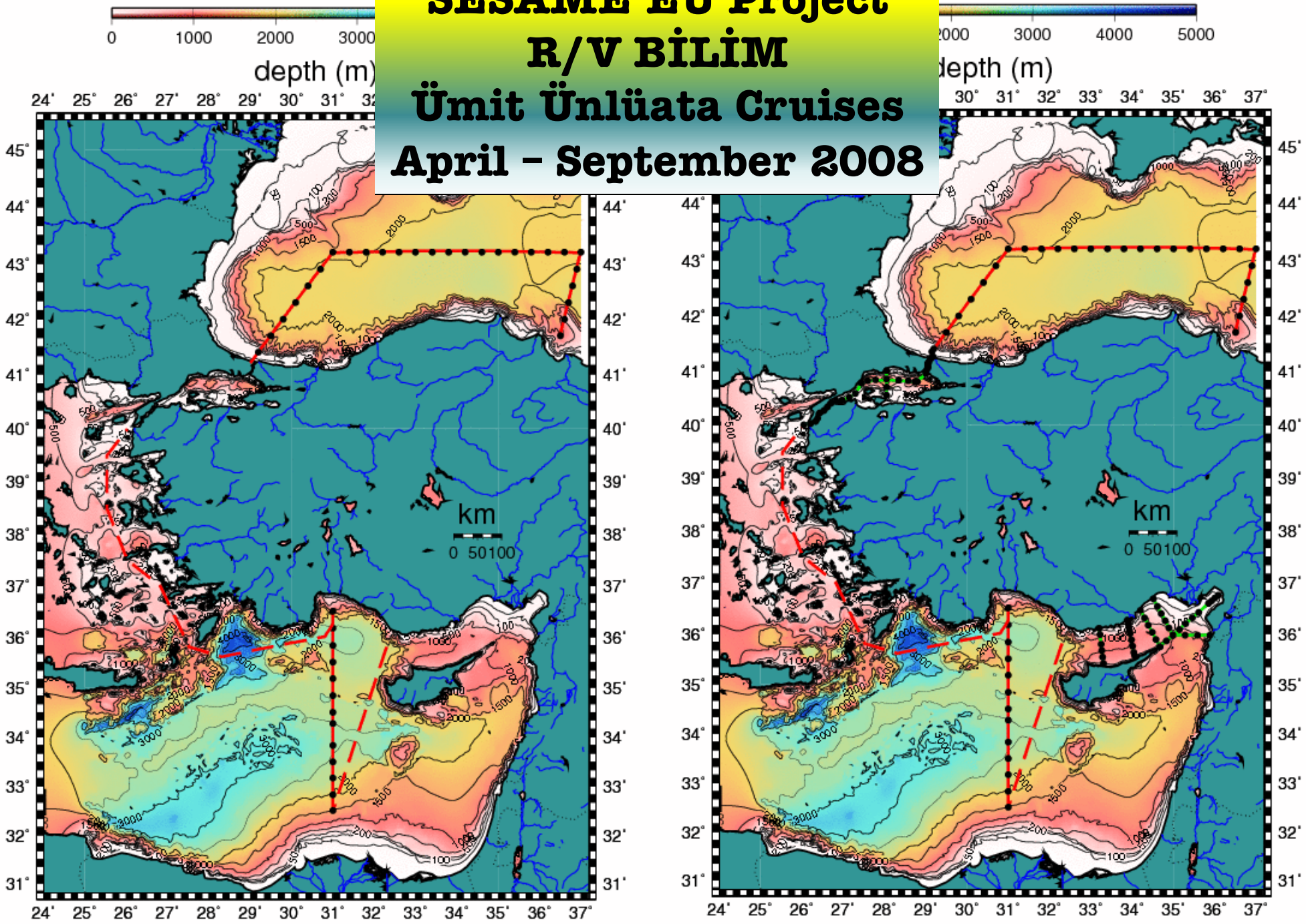

year
Levantine Sea average air temperature at 10m (°C)
Levantine Sea average sea surface temperature (°C)
Black Sea average air temperature at 10m (°C)
Black Sea average sea surface temperature (°C)
Caspian Sea average air temperature at 10m (°C)
Caspian Sea average sea surface temperature (°C)
Apparent Solar Transmission at Mauna Loa
North Atlantic Oscillation Index - monthly
Southern Oscillation Index


W. Levantine Sea
S
θ (°C)
log(N)
Year

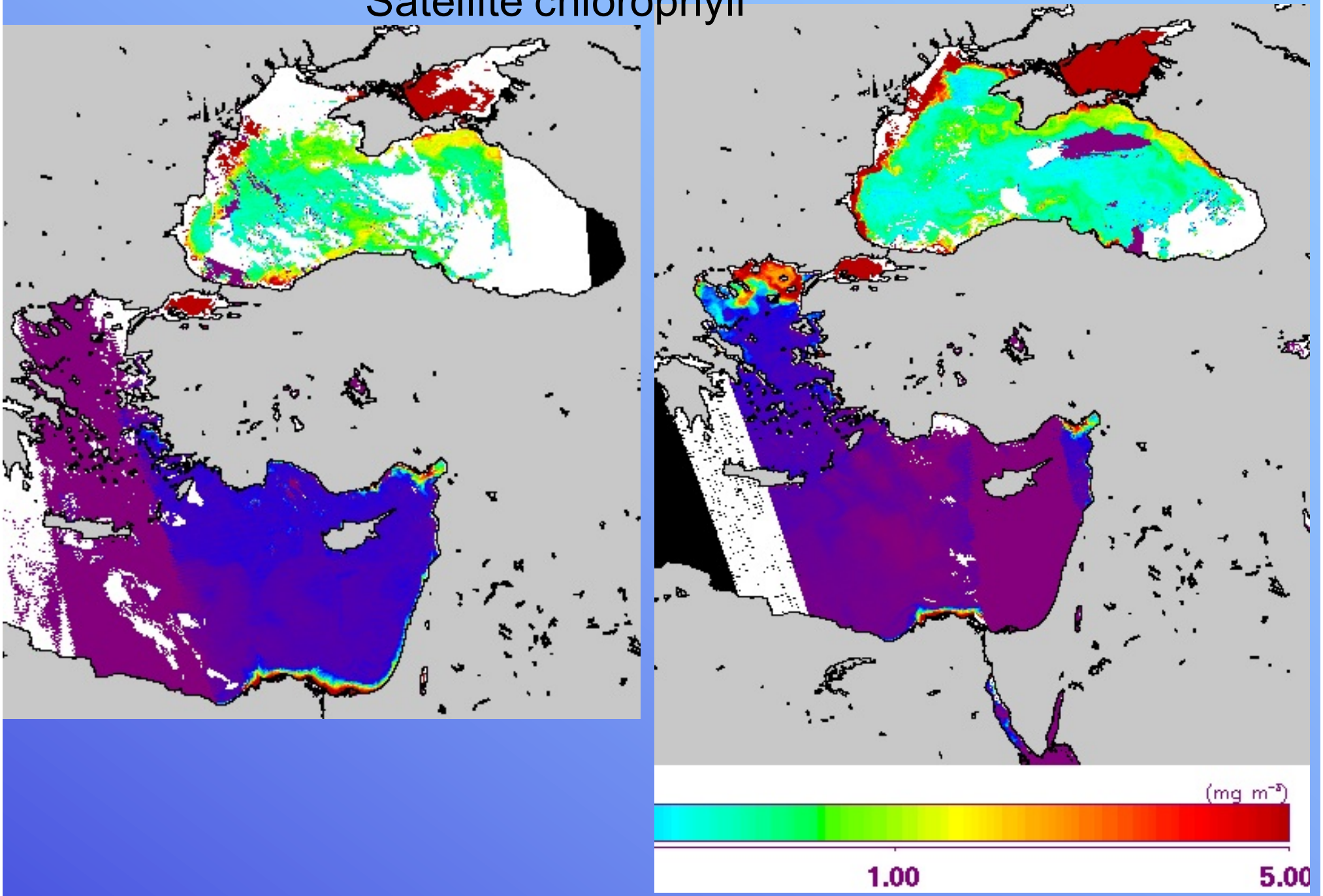

E. Ionian Sea
1000-2000m
2000-4000m
S
θ (°C)
log(N)
Year


Cretan Sea 500-1000m
Year

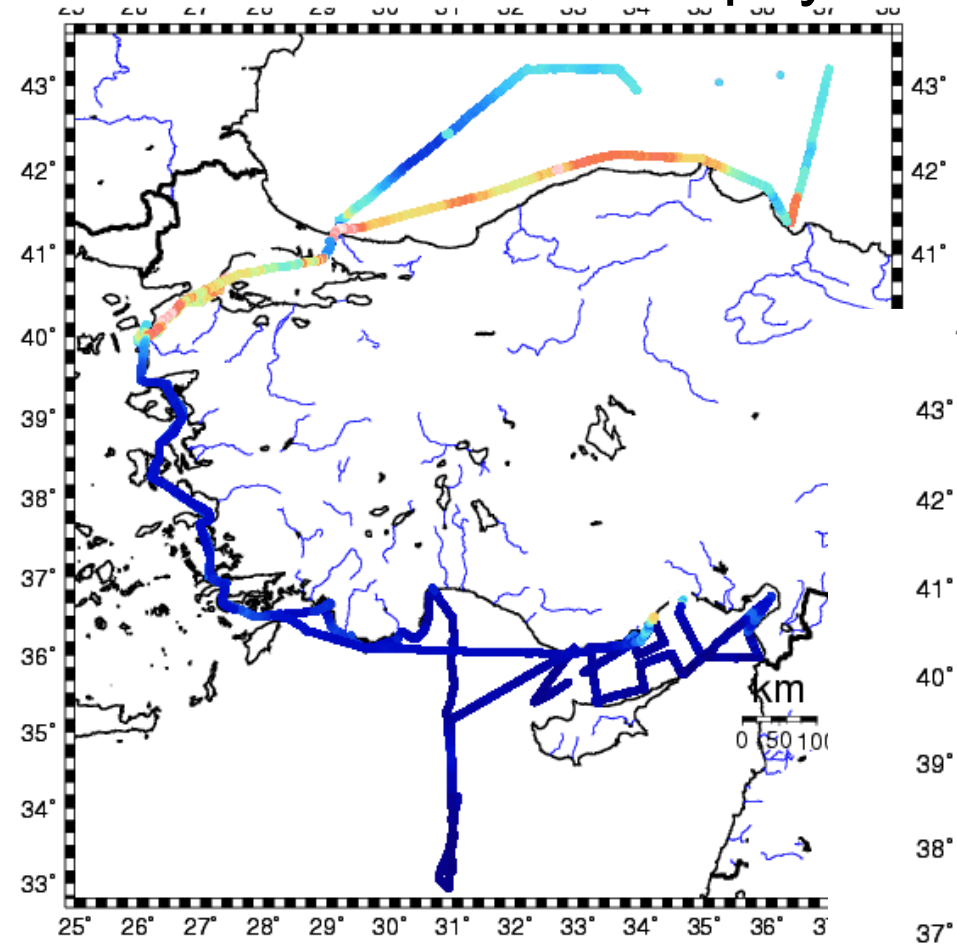
# SESAME EU Project
# R/V BİLİM
# Ümit Ünlüata Cruises
# April – September 2008

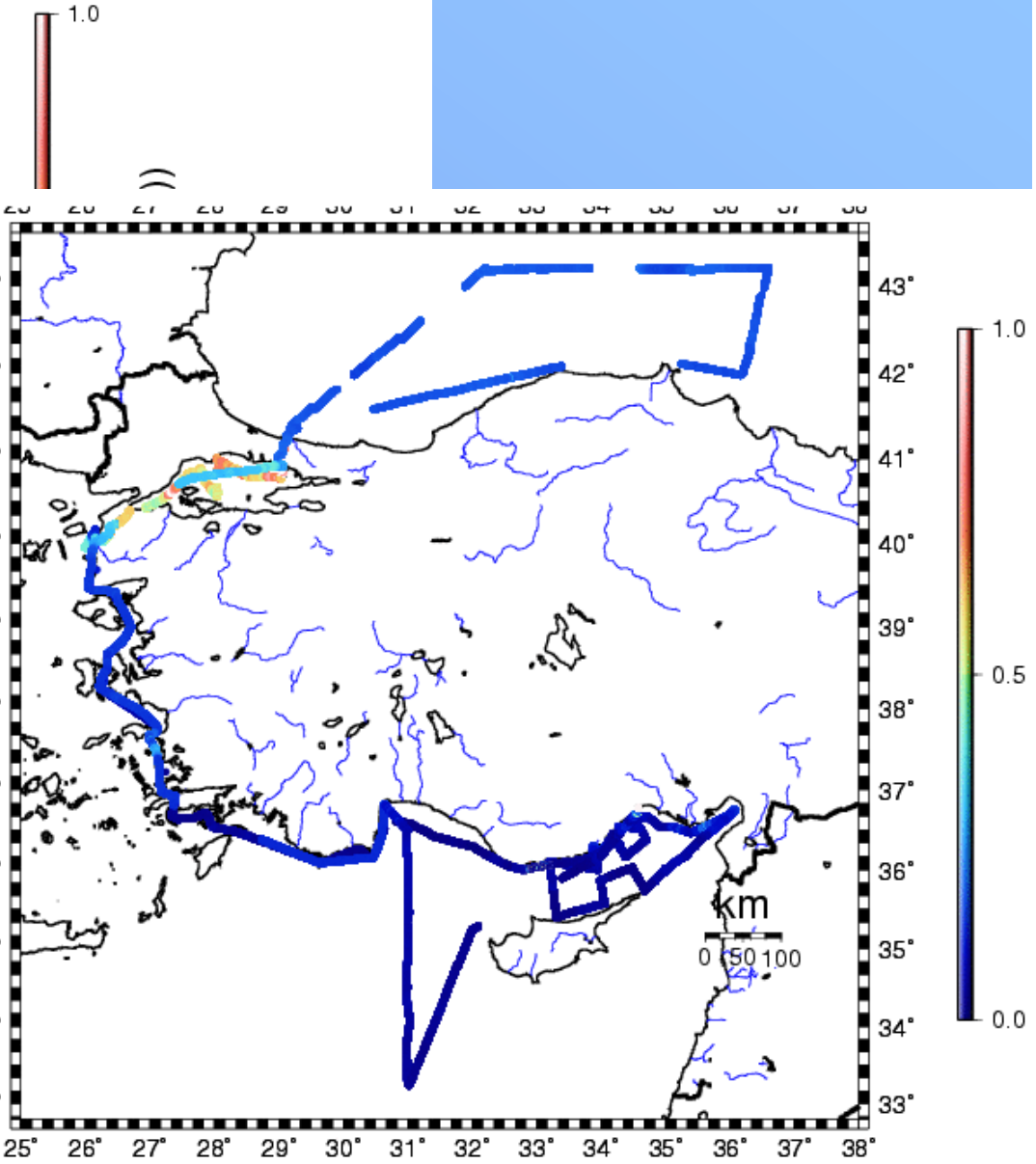


# Satellite chlorophyll



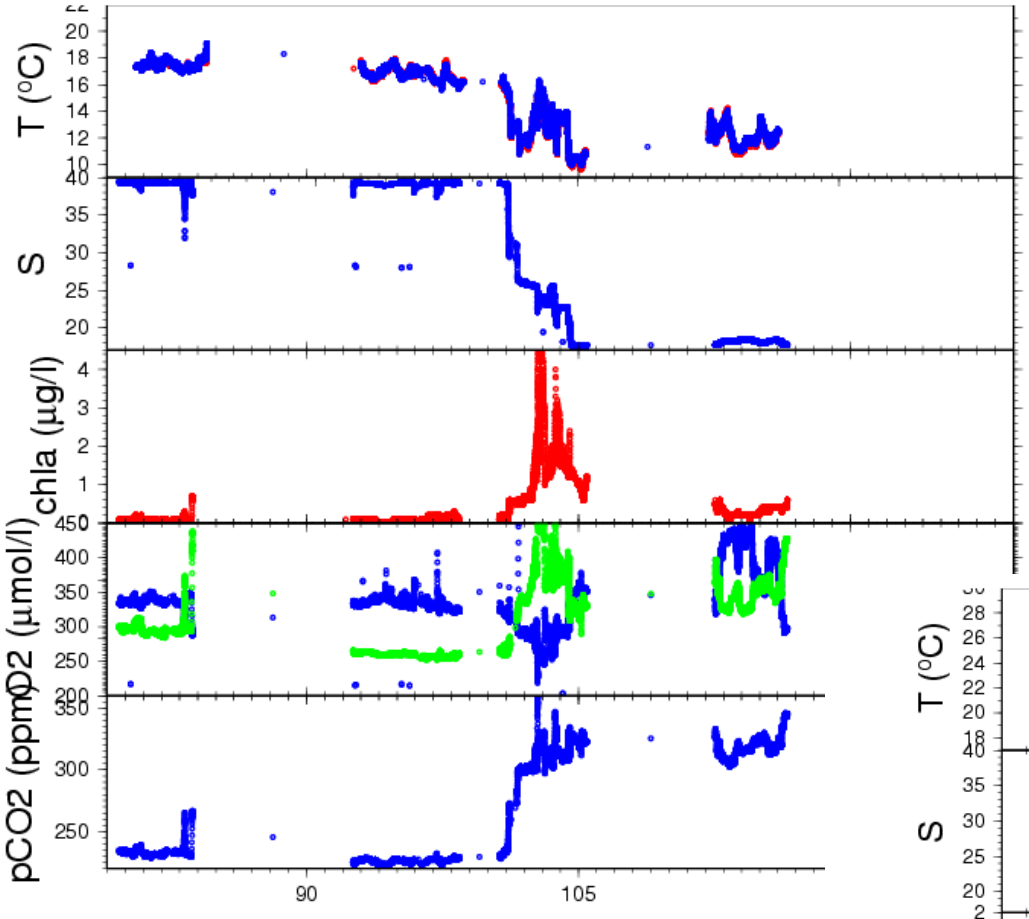
# Chlorophyll fluorescence - Sesame Ünlüata cruise



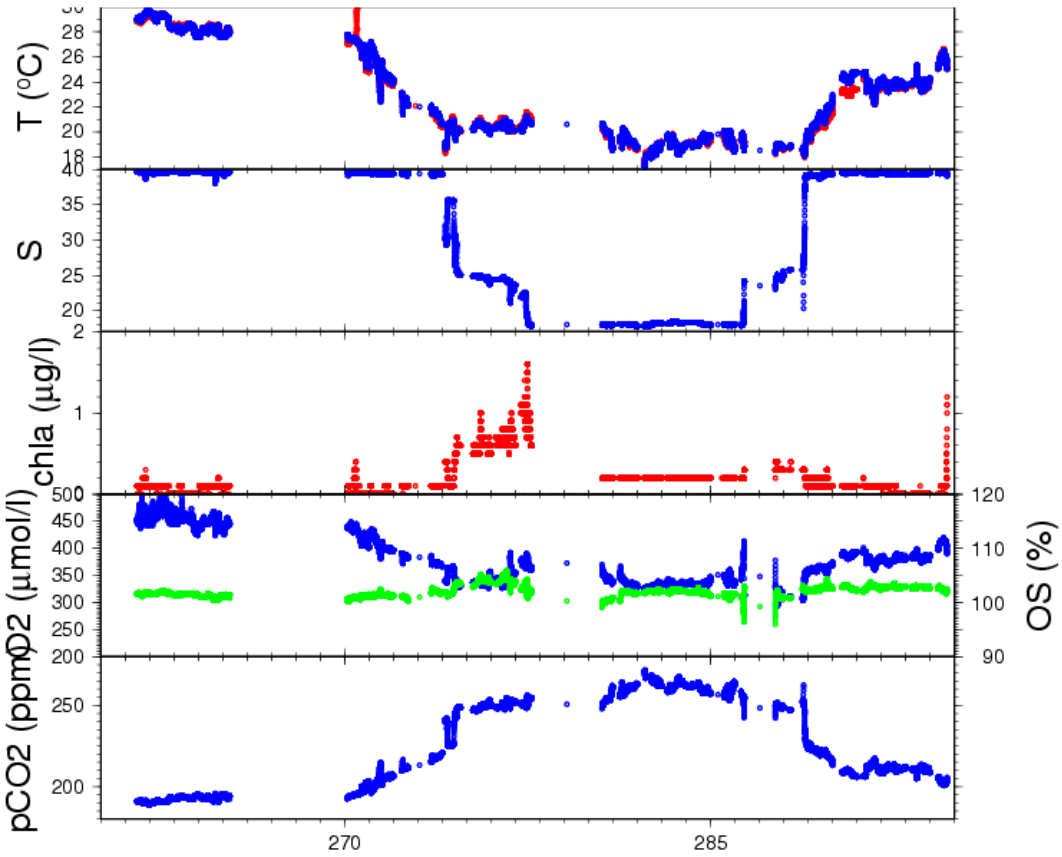



EU Project Sesame
Ümit Ünlüata cruises

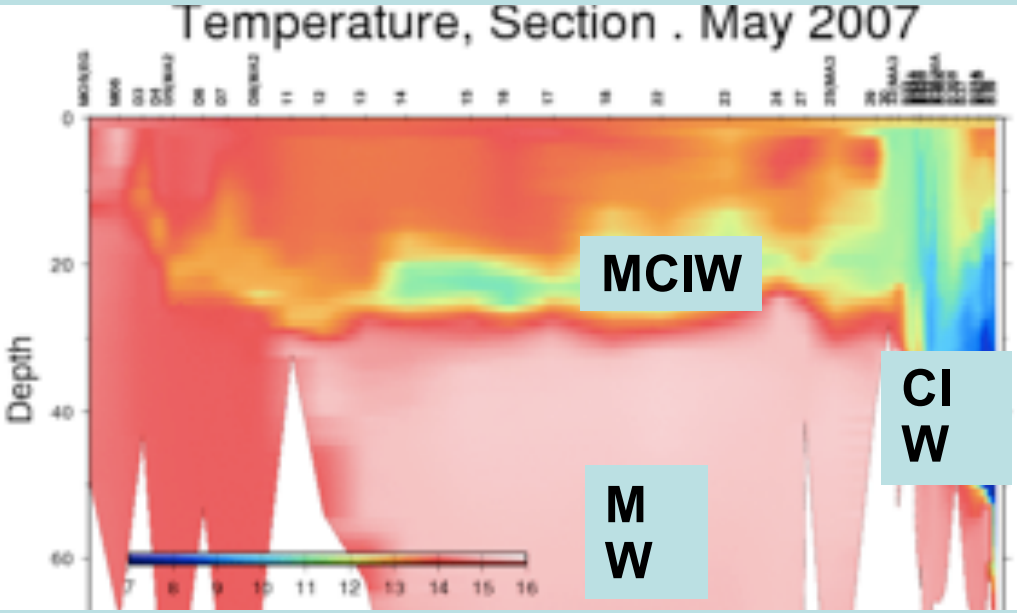
October 2008

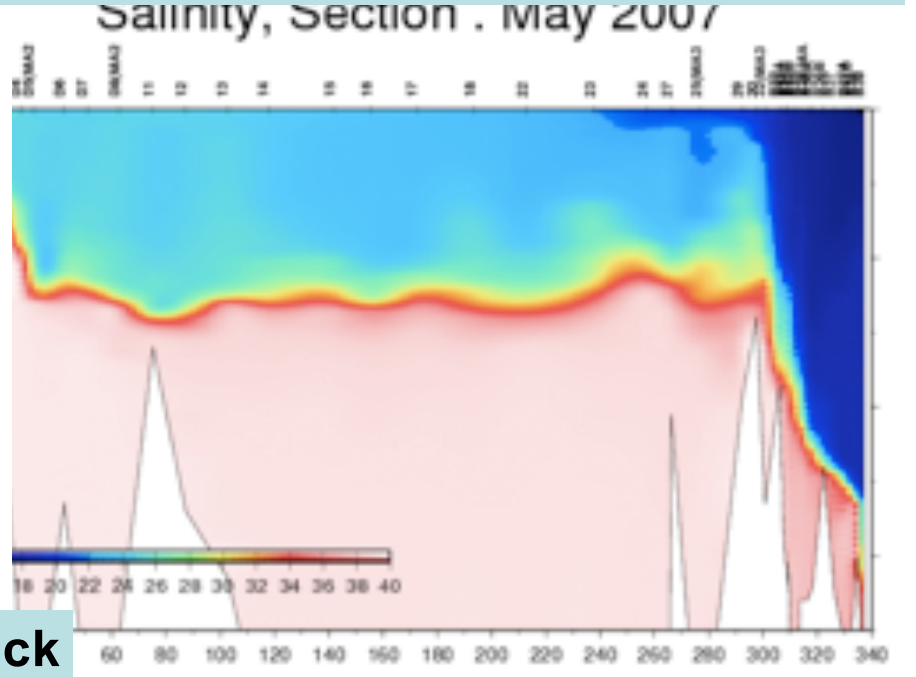



April 2008

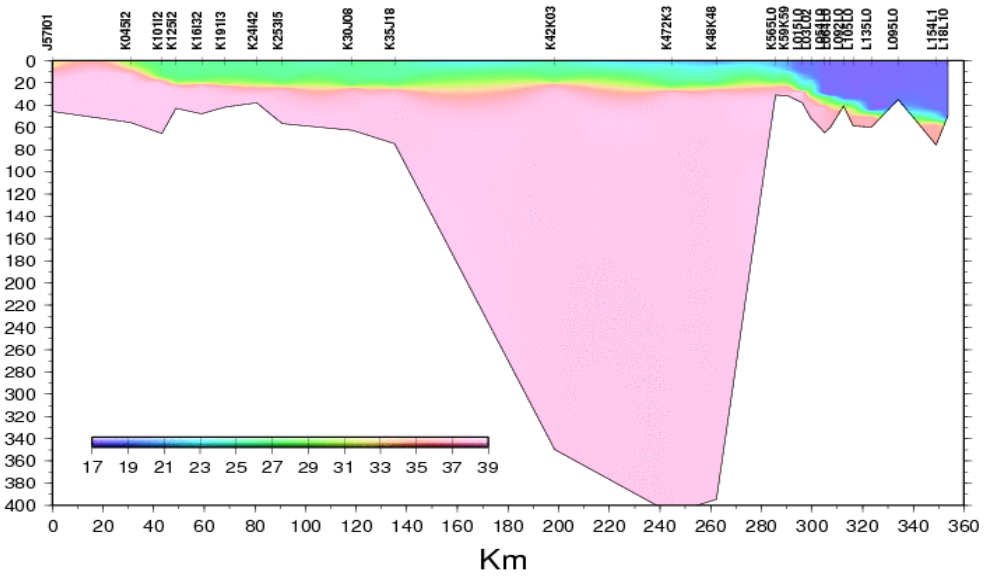


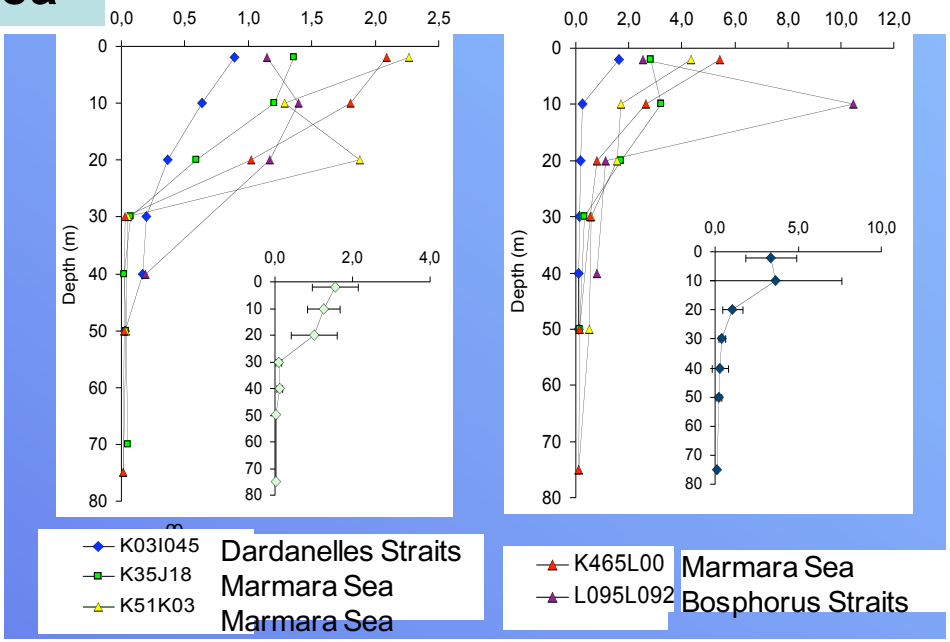
# Turkish Straits System / northern Aegean Sea exchange




**Aegean Sea** **Dardanelles Strait** **Marmara Sea** **Bosphorus Strait** **Black Sea**

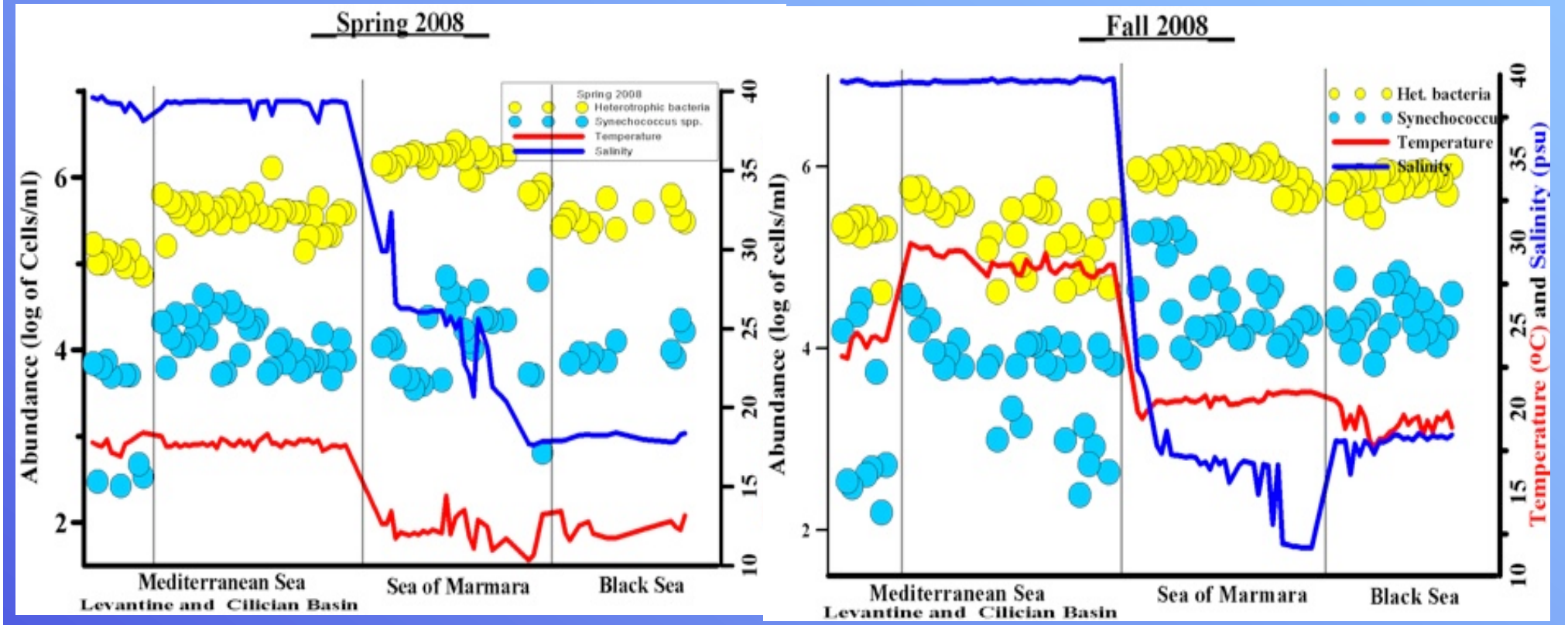


# Heterotrophic bacteria and Synechococcus

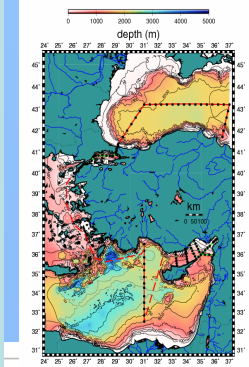
## Variation across basins

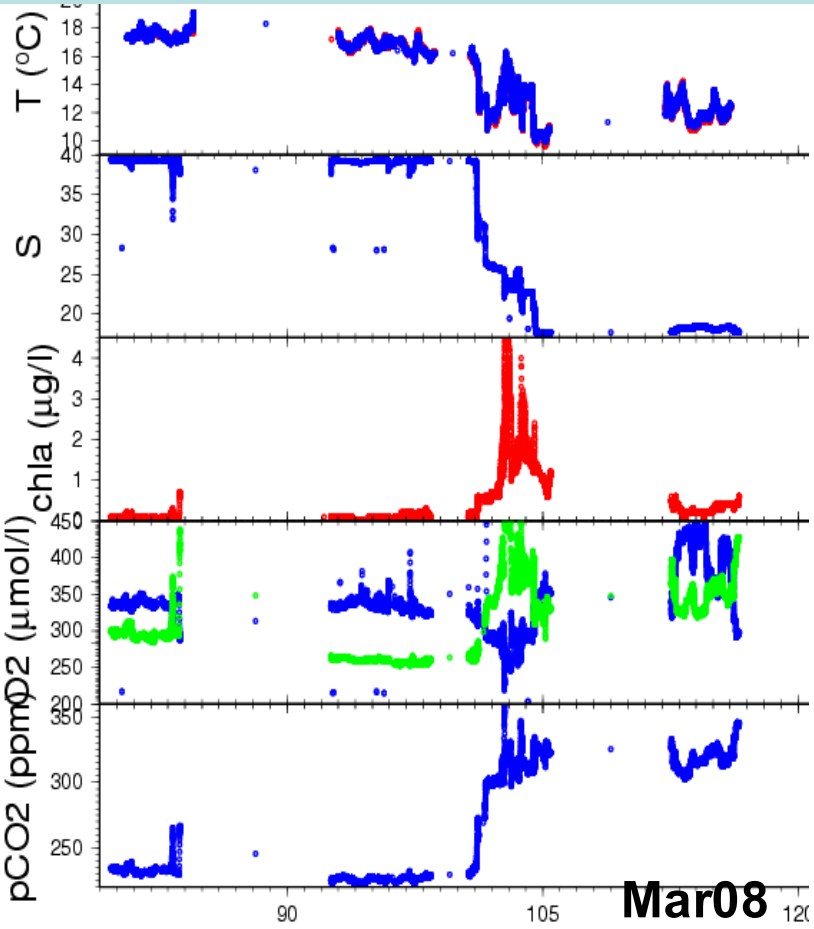
**Heterotrophic bacteria, Synechococcus (log scale !), temperature and salinity Changes from the Cilician - Levantine Basin to the Black Sea and through the Turkish Straits System**

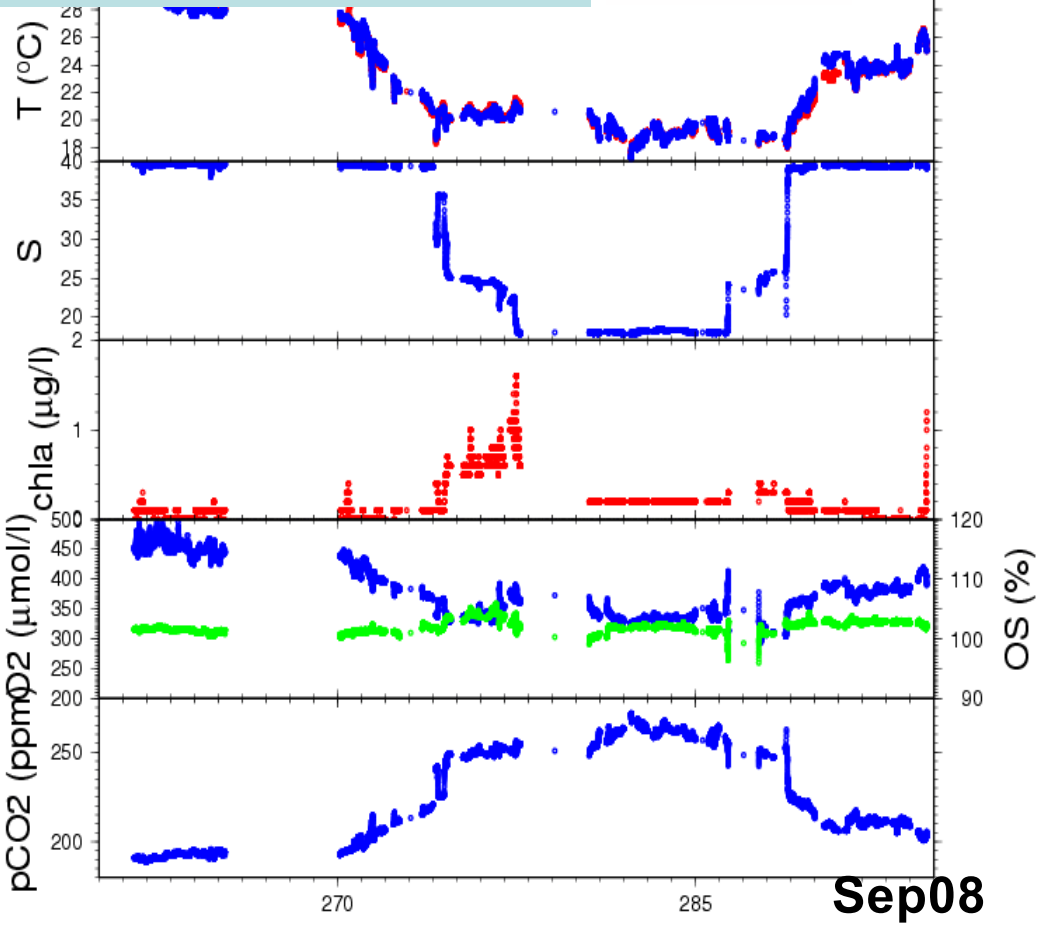


# Carbon sequestration and air-sea exchange

T, S, chla, $O_2$, $pCO_2$ From Levantine Sea to Black Sea and through theTurkish Straits System




**Cilician B Levant TSS Black Sea** **Cilician B Aeg TSS Black Sea Levant**

## Driver of Mediterranean coastal ecosystems: River inputs 274 km3/yr

| River | Mean annual runoff (m3/sec) | Reference |
|---|---|---|
| Ebro | 150 | Cruzado et al., 2002 |
| Rhone | 1690 | http://www.grdc.sr.unh.edu |
| Po | 1585 | Raicich (1994) |
| All other Adriatic rivers | 4091 | Raicich(1994) |
| Northern Aegean rivers | 515 | Kourafalou et al. (2003) |
| Nile | 110 | Hamza(2003) |
| All other Nile Delta runoff | 430 | Hamza(2003) |
| Total | 8571 | |

**Table 2** The major Mediterranean rivers and areas runoff values (major is considered to be a runoff greater than $100\frac{m^3}{s}$).

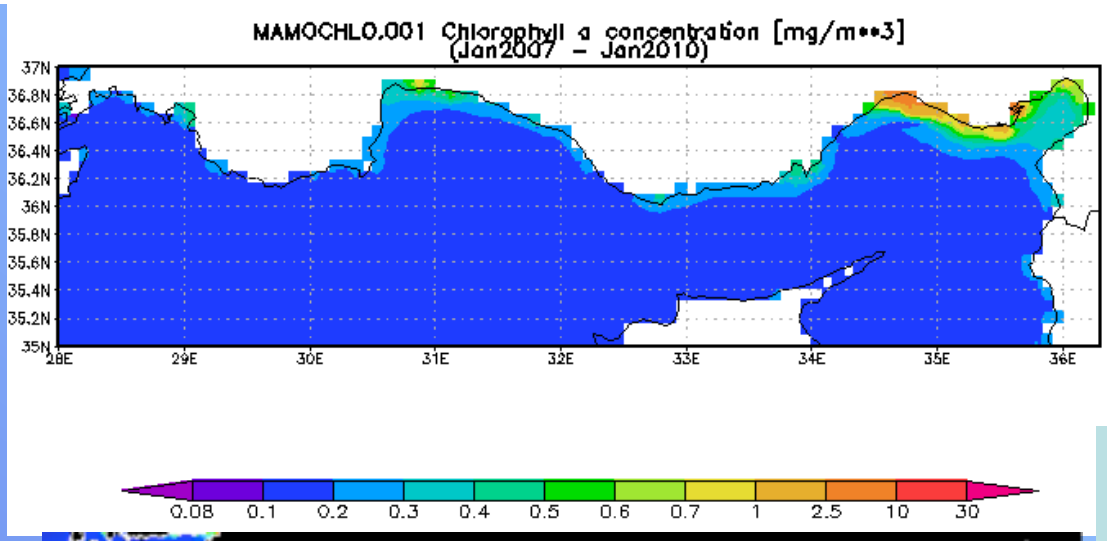
After Pinardi et al, The Sea, v.14

Levantine Basin: shortage of fresh water - shortage of nutrients

South: Nile discharge decrease after 1960's:
~ 6-15 km3/yr – Ludwig et al, 2009
(formerly ~ 83km3/yr at Aswan)

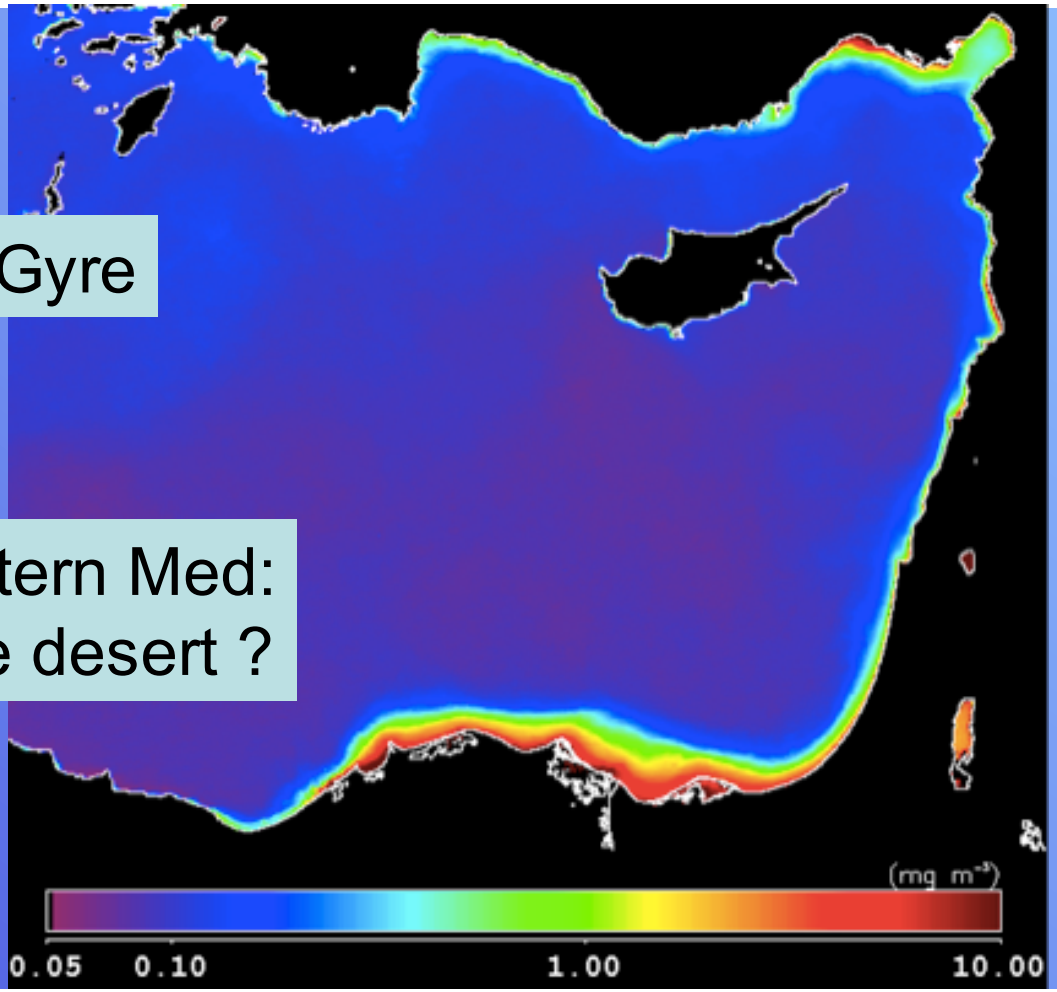
North: Göksu, Lamas, Tarsus, Seyhan, Ceyhan, Asi rivers contribute 28 km3/yr into the Cilician Basin.

satellite mean chlorophyll




Rhodes Gyre

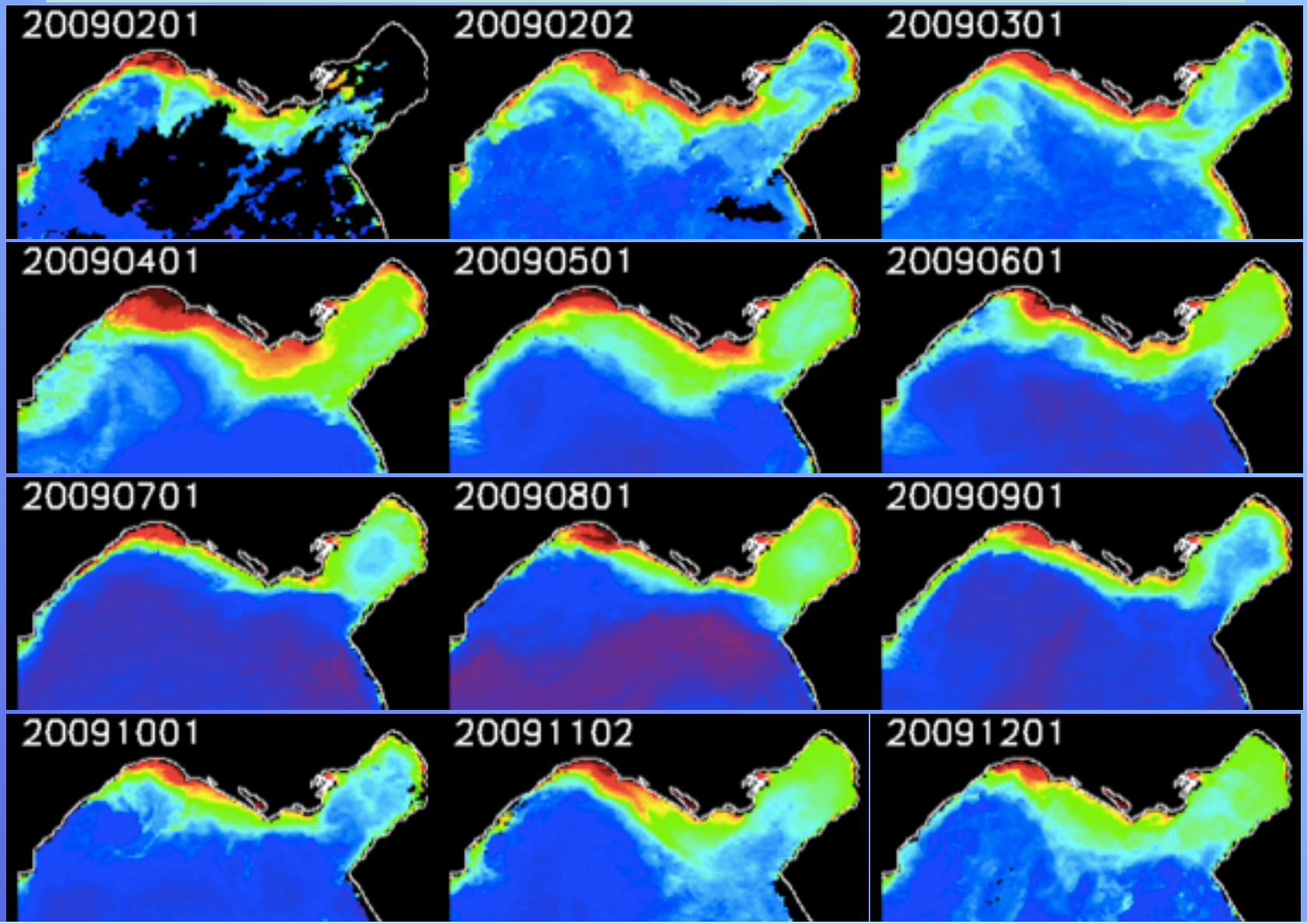
Eastern Med:
Blue desert ?



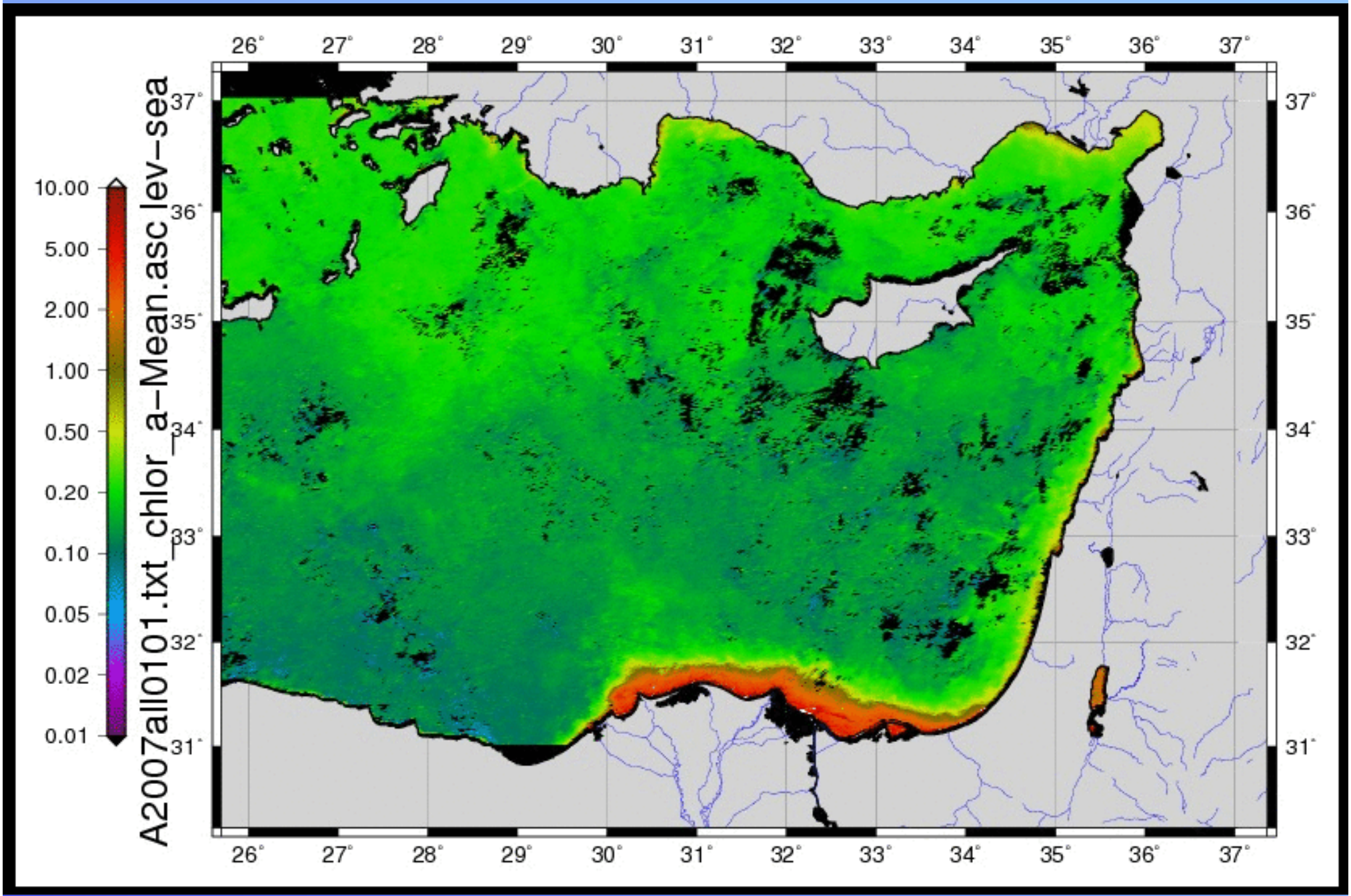

Rivers
Eşen,Manavgat,
Göksu, Seyhan,
Ceyhan, Asi
(north)

Nile
(south)

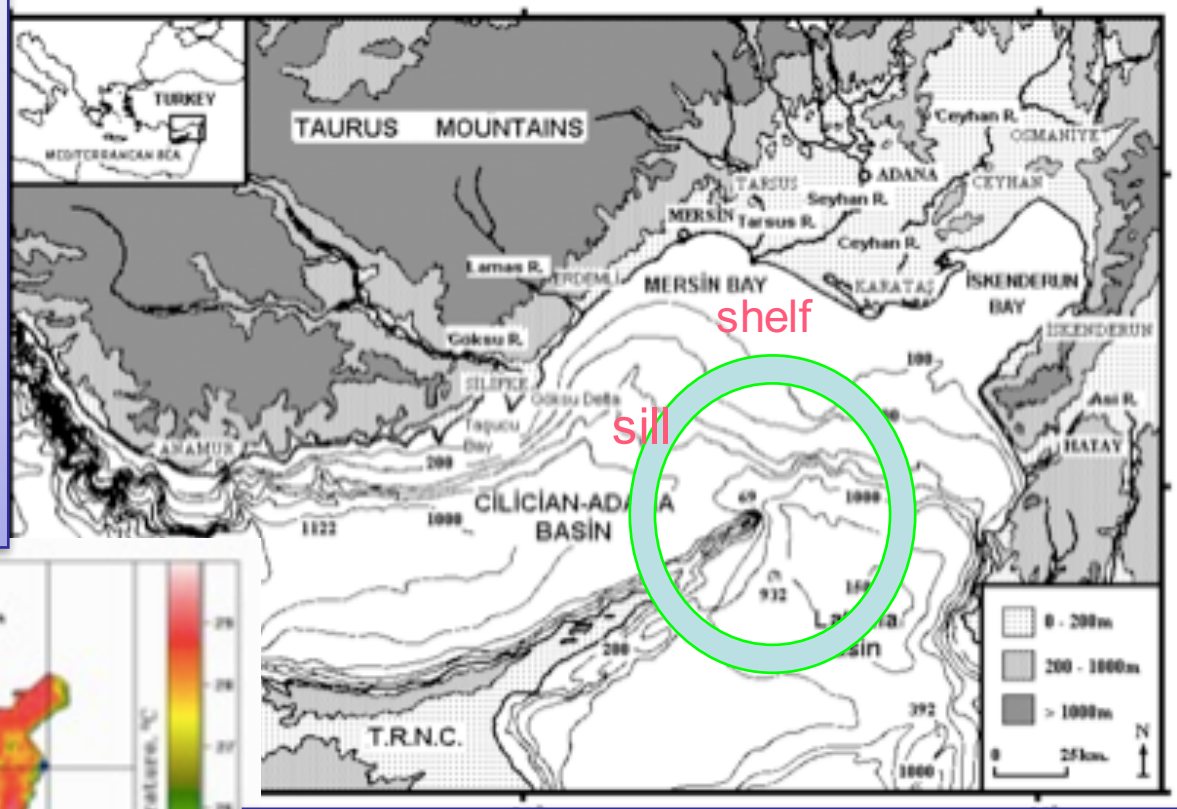
# Cilician Basin - Mersin Bay and Gulf of İskenderun

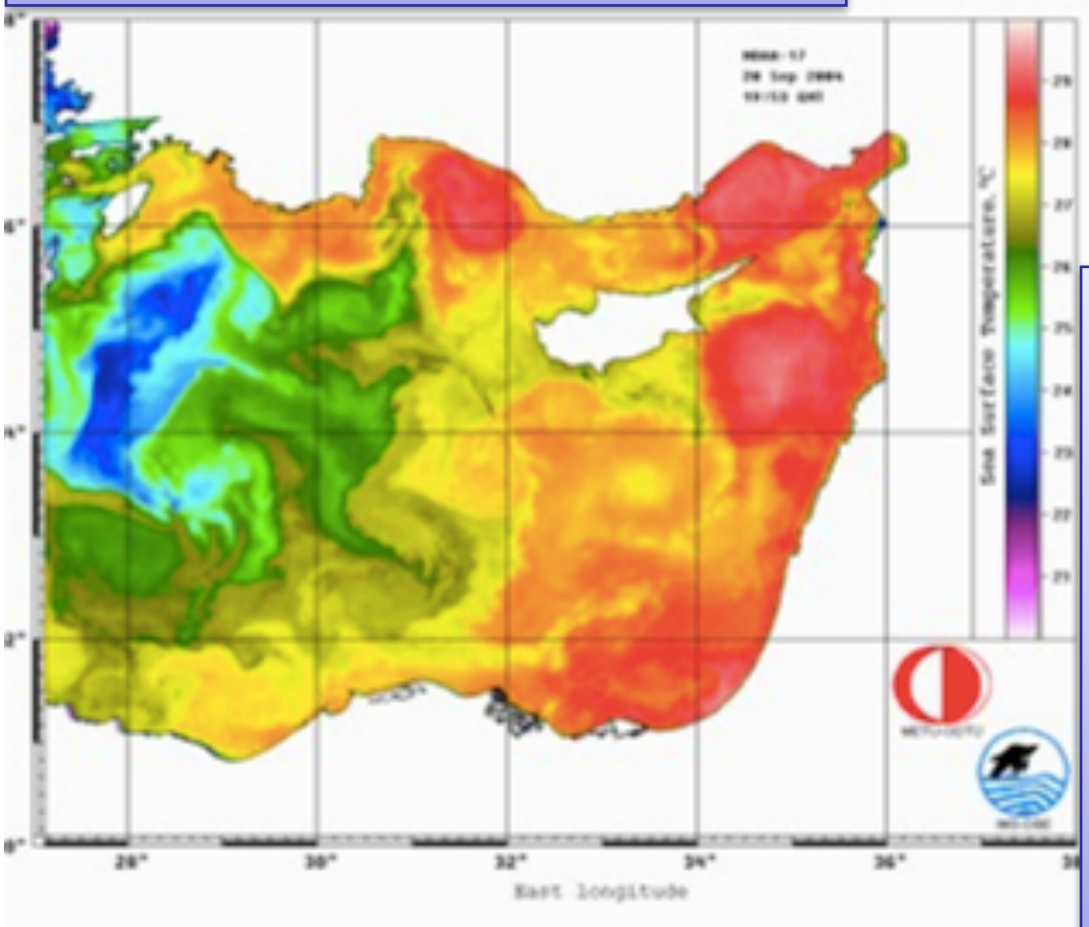



4 major rivers - Göksu, Seyhan, Ceyhan, Asi + streams supply fresh water, nutrient, wastewaters in an otherwise oligotrophic sea


A2007all0101.txt_chlor_a-Mean.asc lev-sea
10.00
5.00
2.00
1.00
0.50
0.20
0.10
0.05
0.02
0.01
26°
27°
28°
29°
30°
31°
32°
33°
34°
35°
36°
37°
37°
36°
35°
34°
33°
32°
31°

Levantine Basin Circulation Features:
"Rhodes" (permanent gyre)
"Mersa Matruh", "Shikmona", "Cyprus", "Antalya", "Ierapetra" (quasi-permanent eddies)
"mid-mediterranean jet"
"Asia Minor Current"

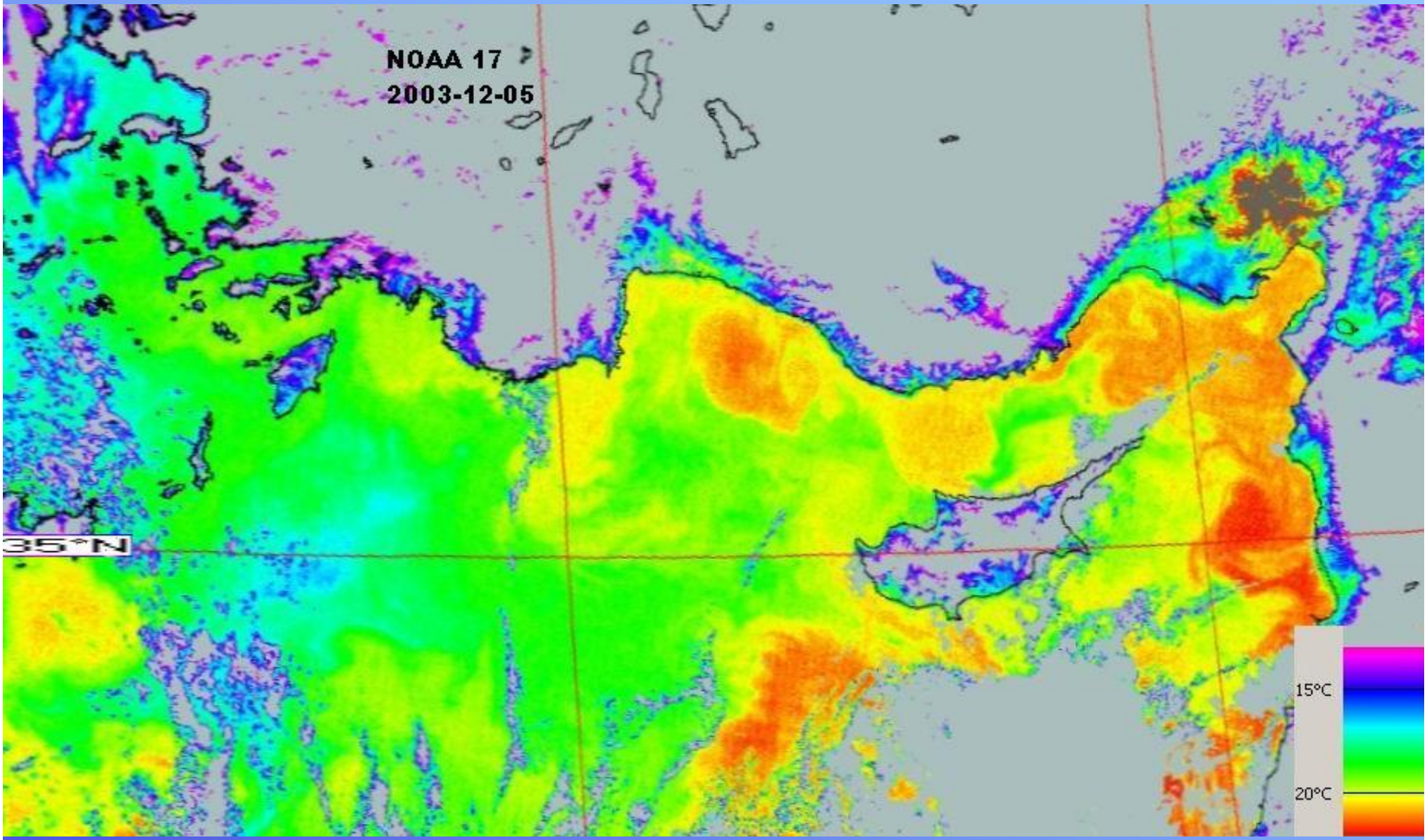


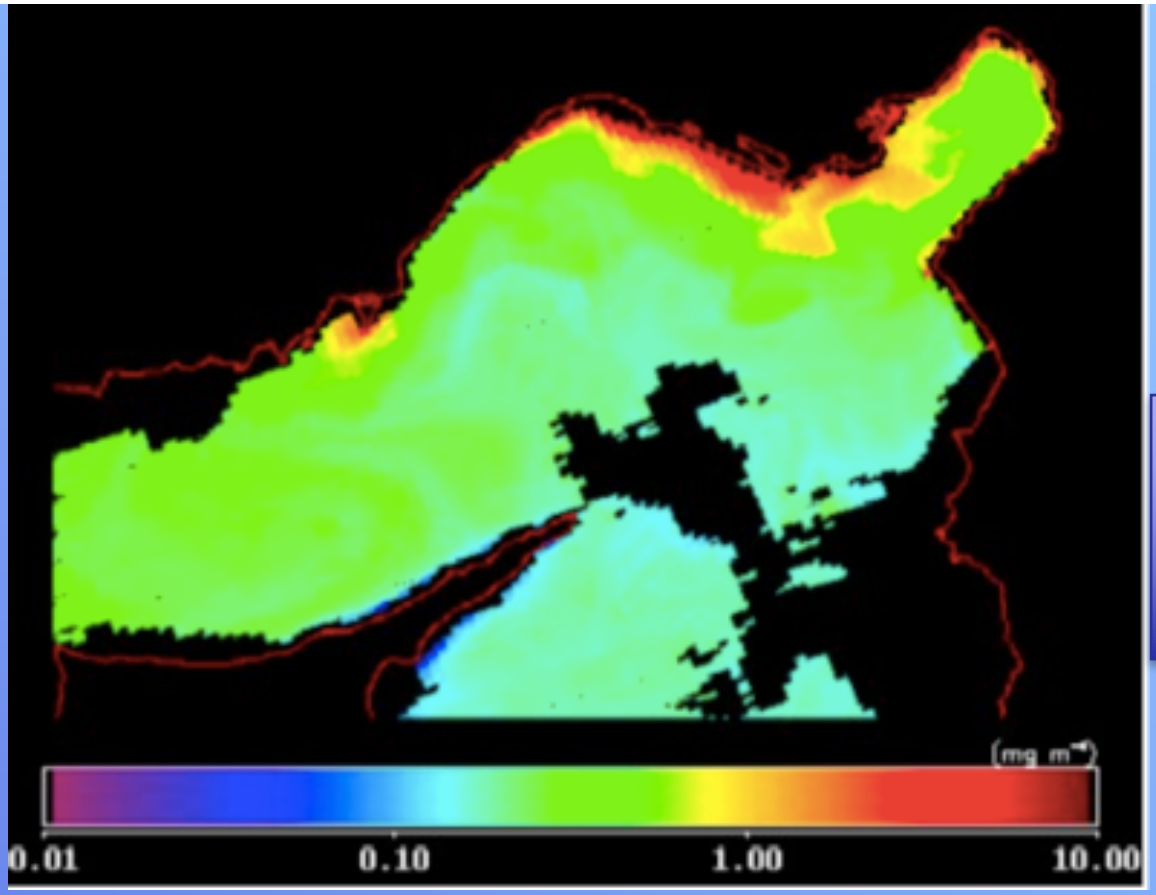




Cilician Basin - ROFI
"region of freshwater influence --- but --- in an oligotrophic sea of high contrast"

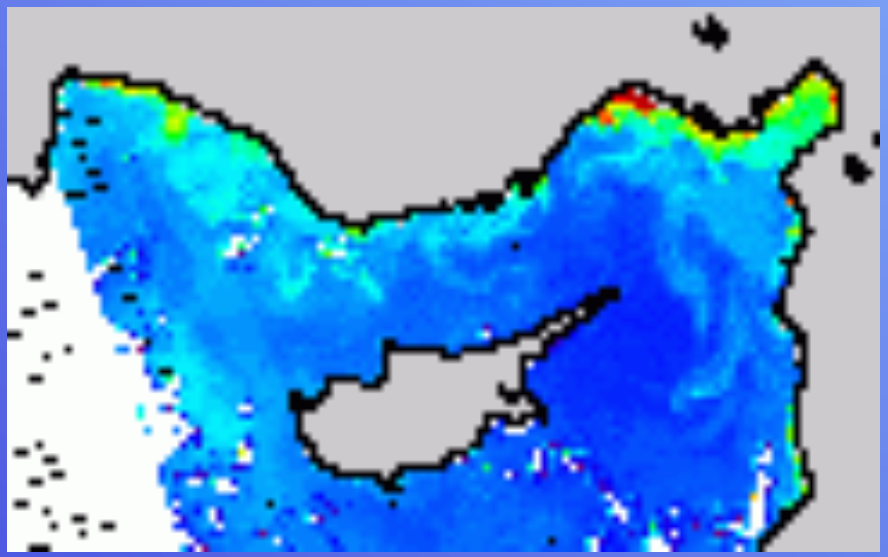
Cyprus – Gulf of İskenderun "Strait"

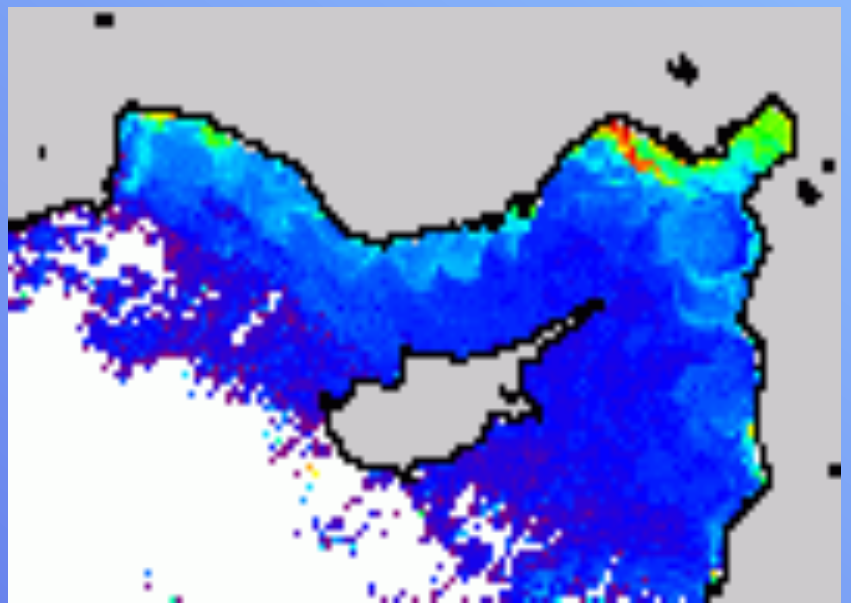
# Satellite observations



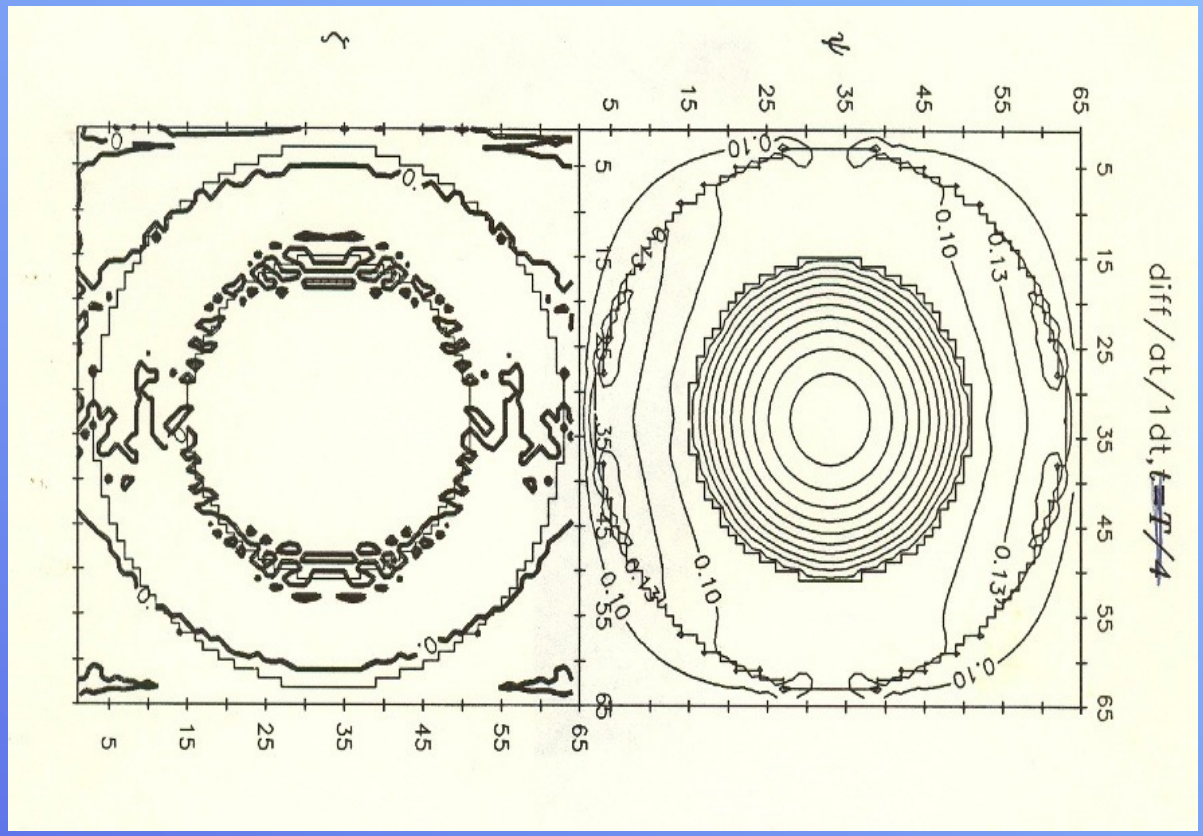



Region of
River Influence
Eddy dispersion



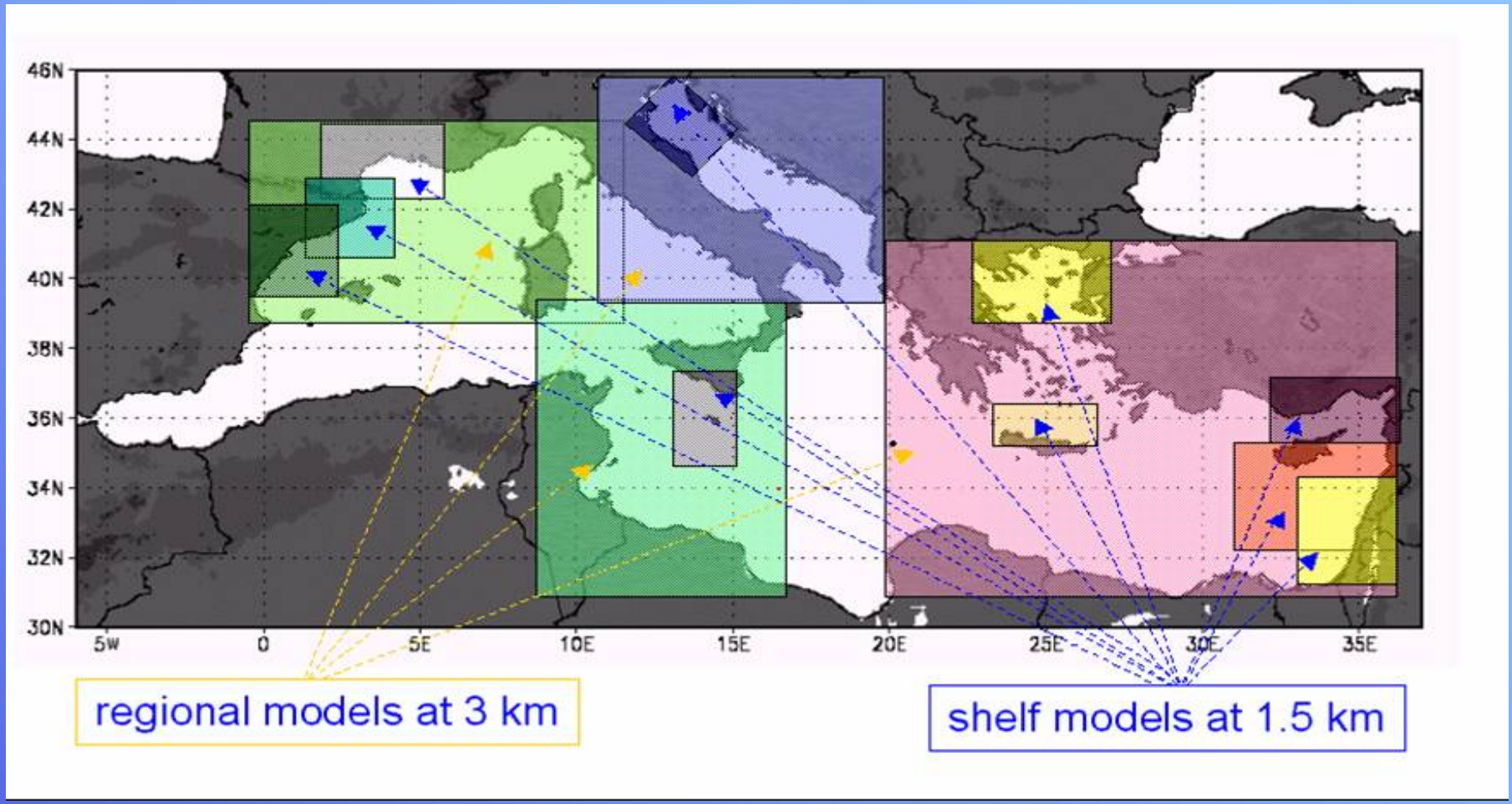


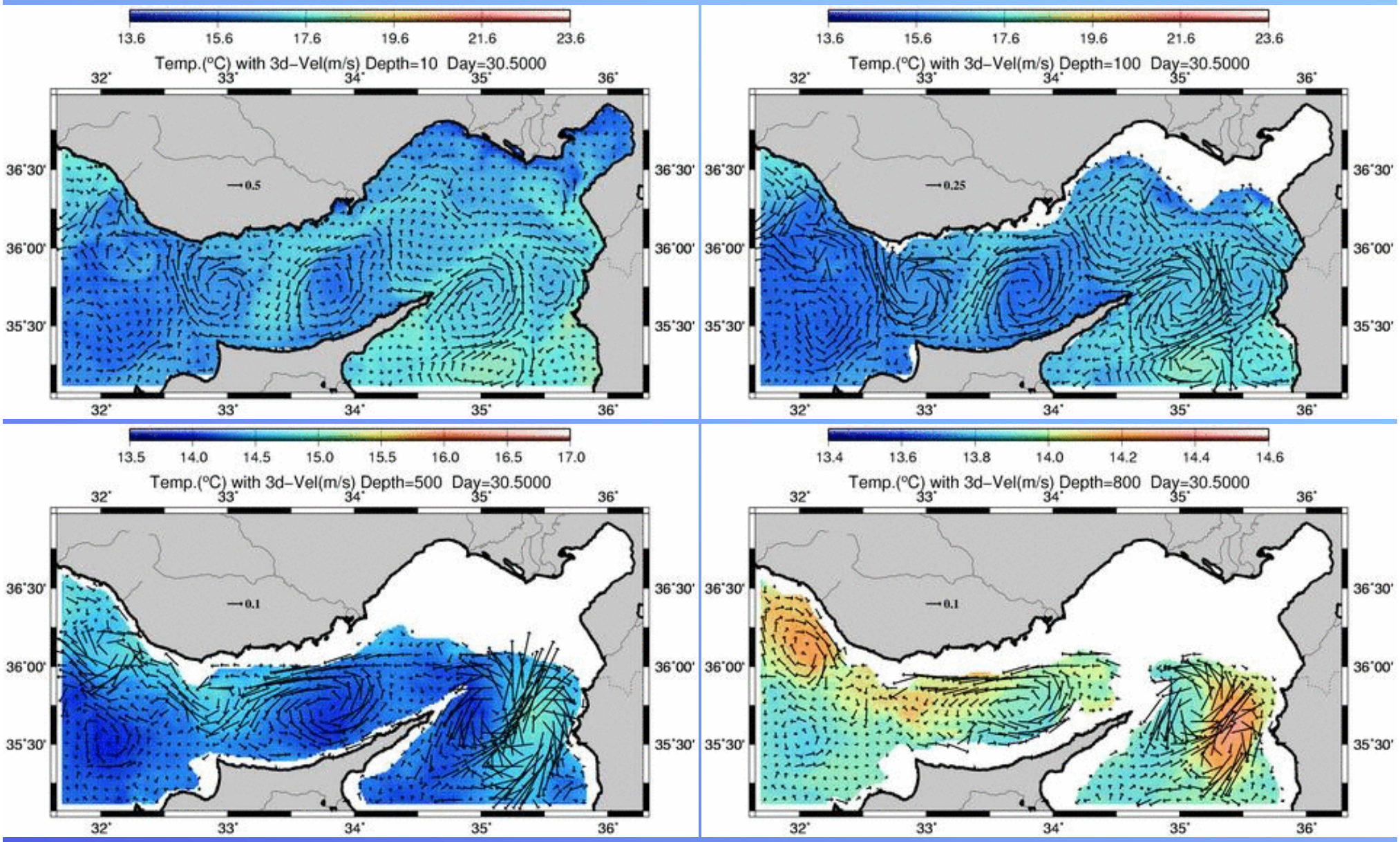
Özsoy, E., Lozano, C. and A. R. Robinson, (1992).
A Baroclinic Quasigeostrophic Model for Closed Basins or Semi-Enclosed Seas with Islands, Math. Comp. Simul., 34, 51-79.



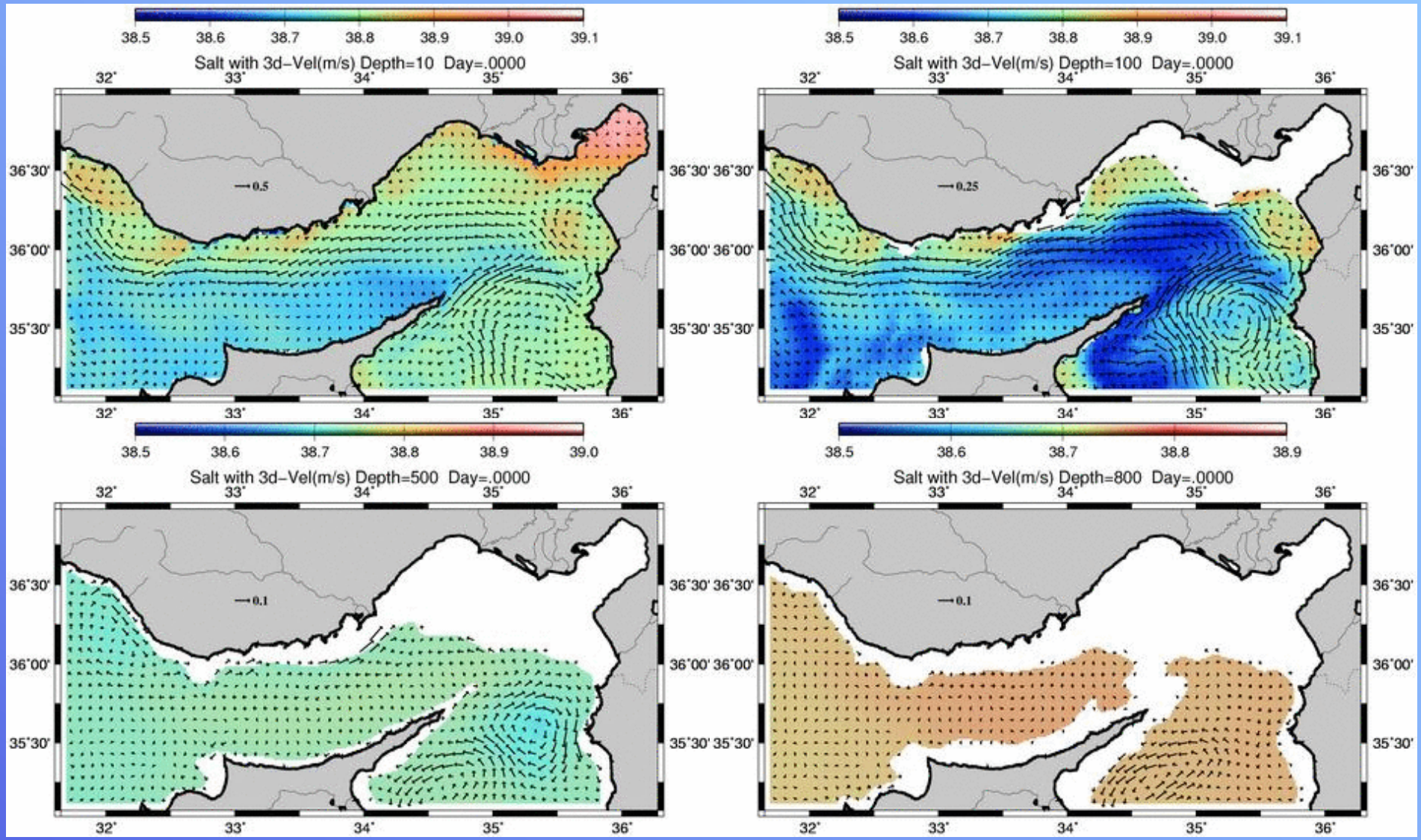

POEM - Physical Oceanography of the Eastern Mediterranean

# MFTEP MODELS HIERARCHY

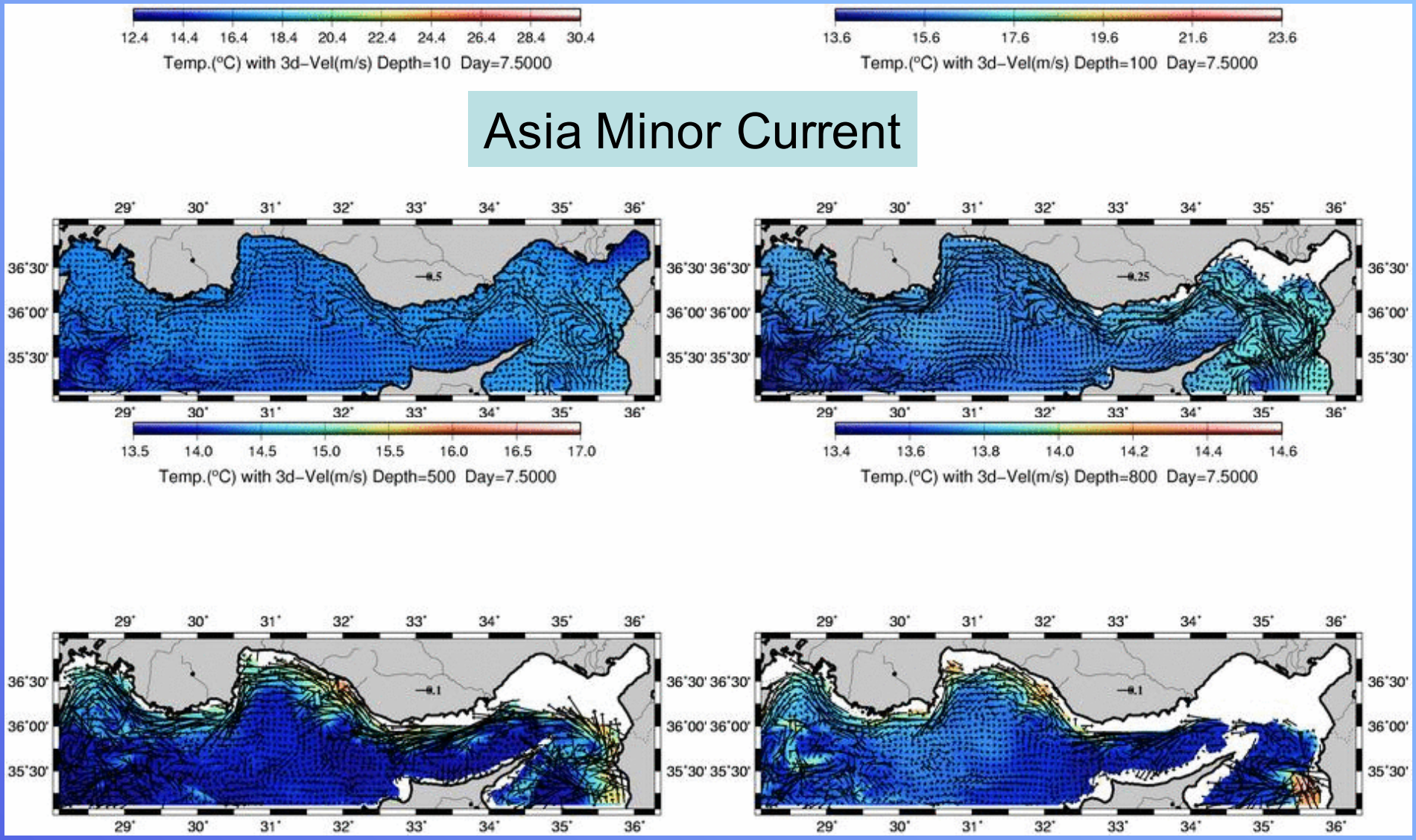





Cilician daily forecasts - MFSTEP Project
Resolution 1.35 km

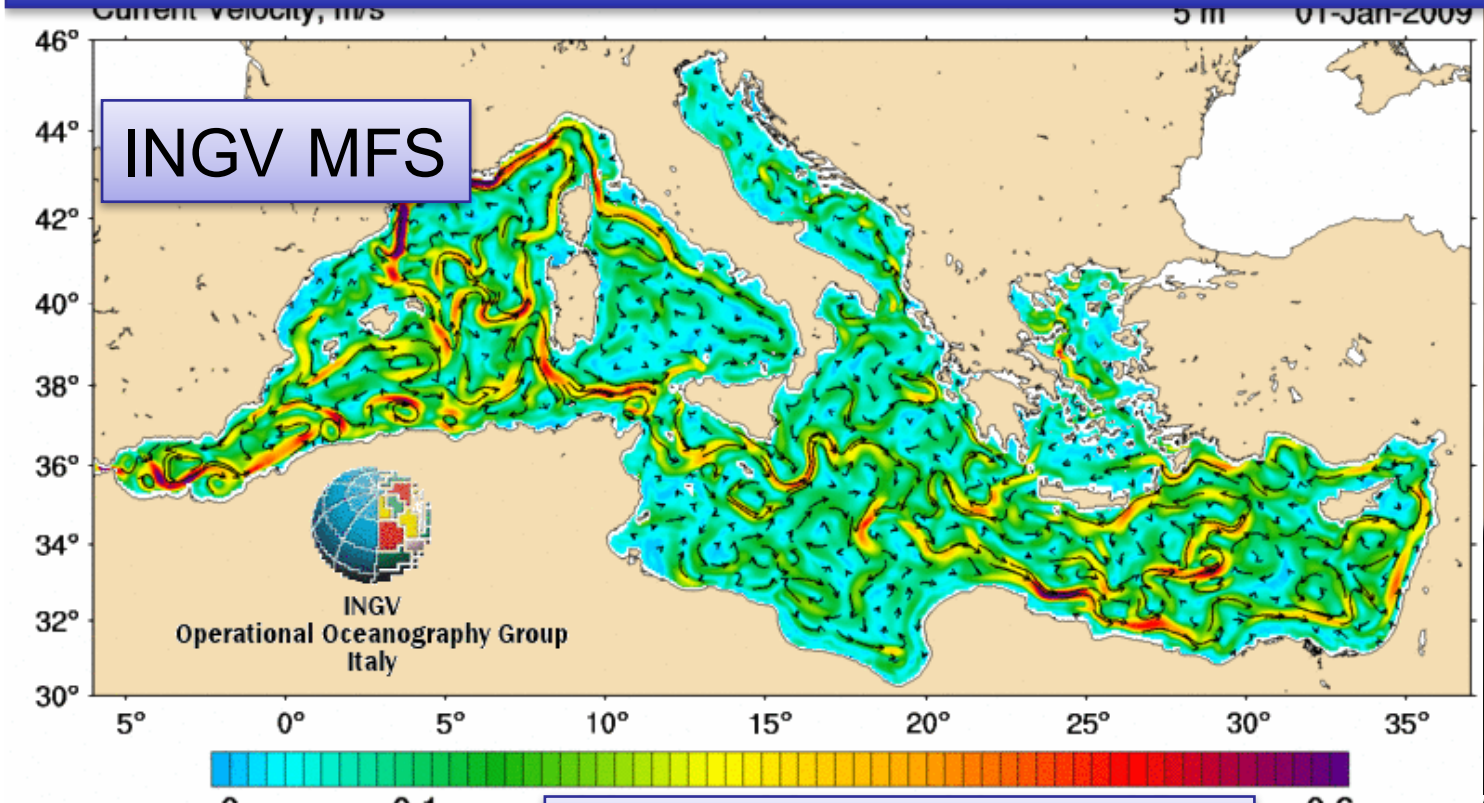


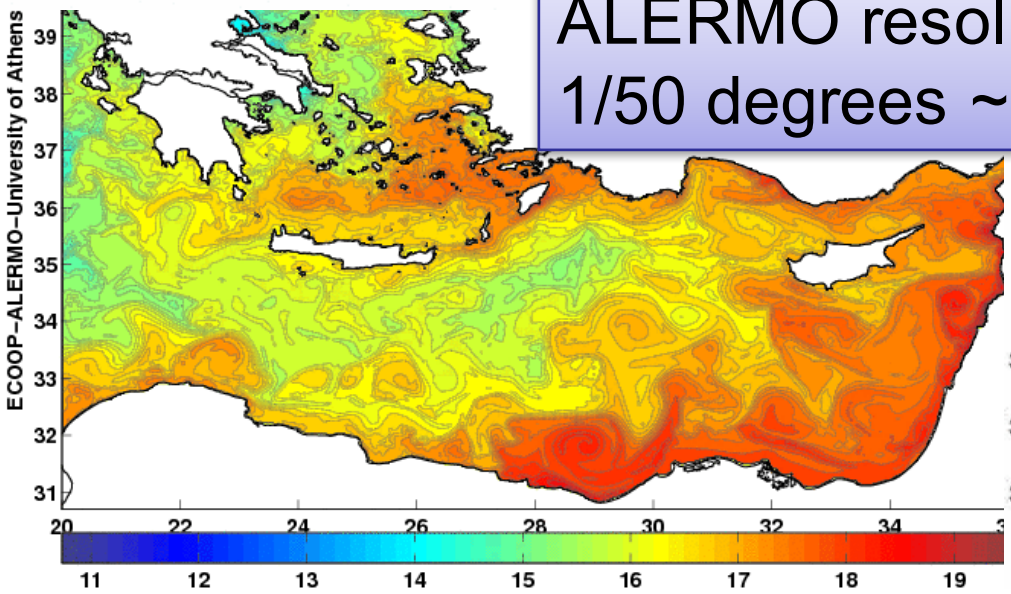

*Currents and salinity inJanuary 2003 SVP*
*At 10m, 100m, 500m and 800m depths*

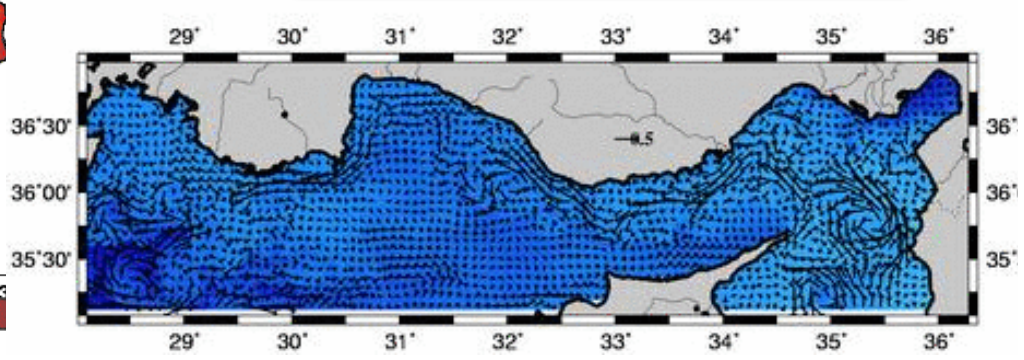



Northern Levantine Sea forecast system - res: 1.35 km (POM)

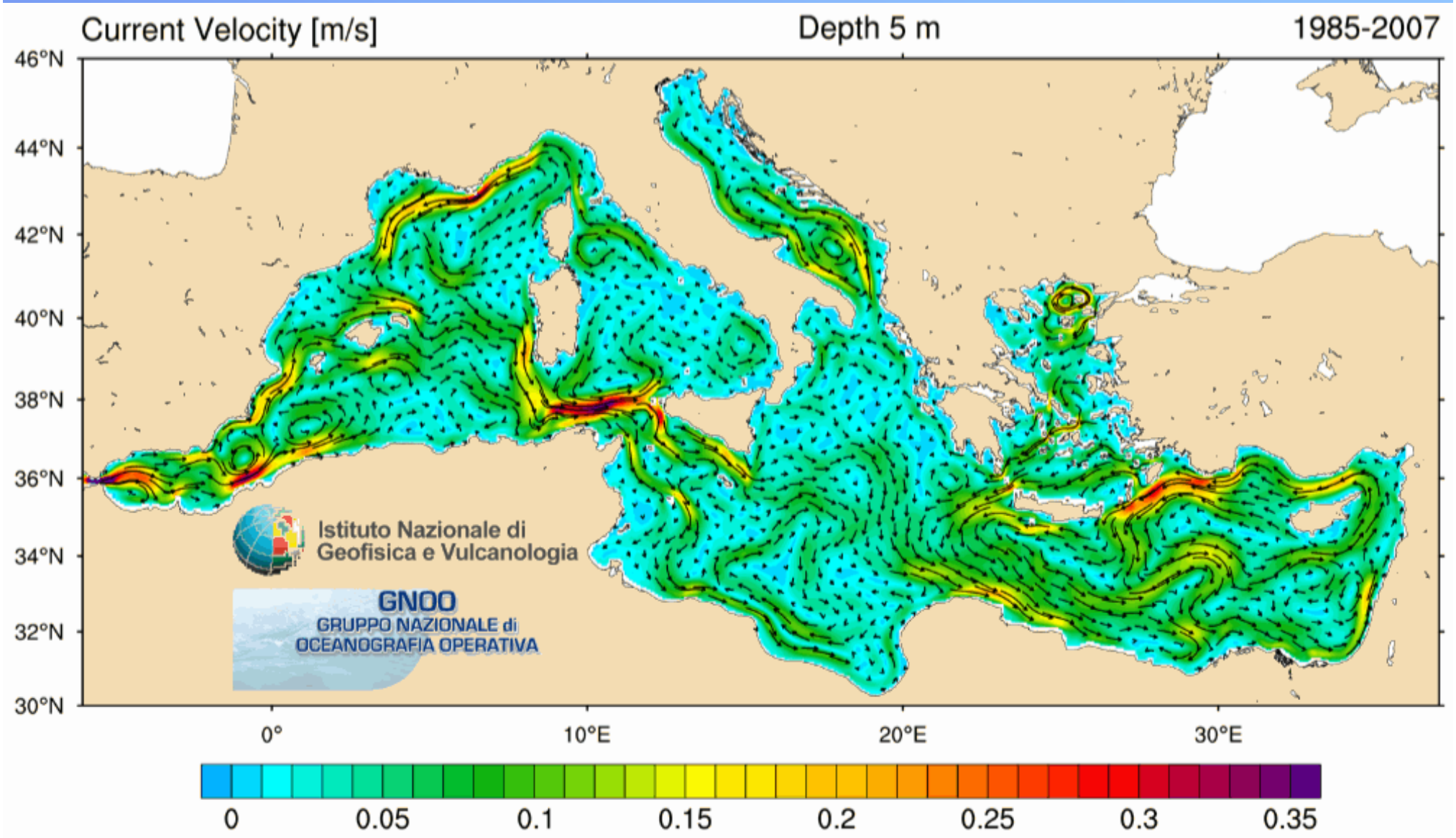
# European Operational Oceanography - along the footsteps of ARR



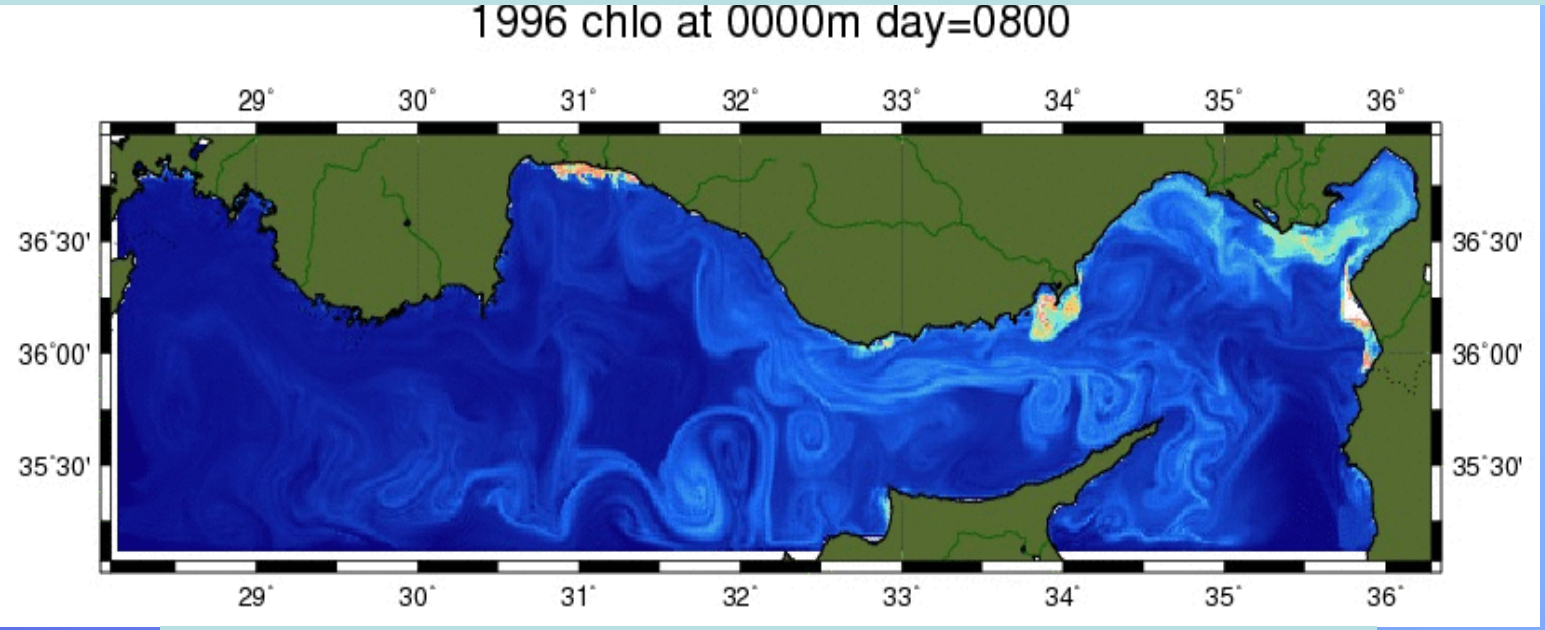



Pinardi et al. (2011). The Mediterranean Large Scale Low Frequency Ocean Variability from 1987 to 2007, A Retrospective Analysis



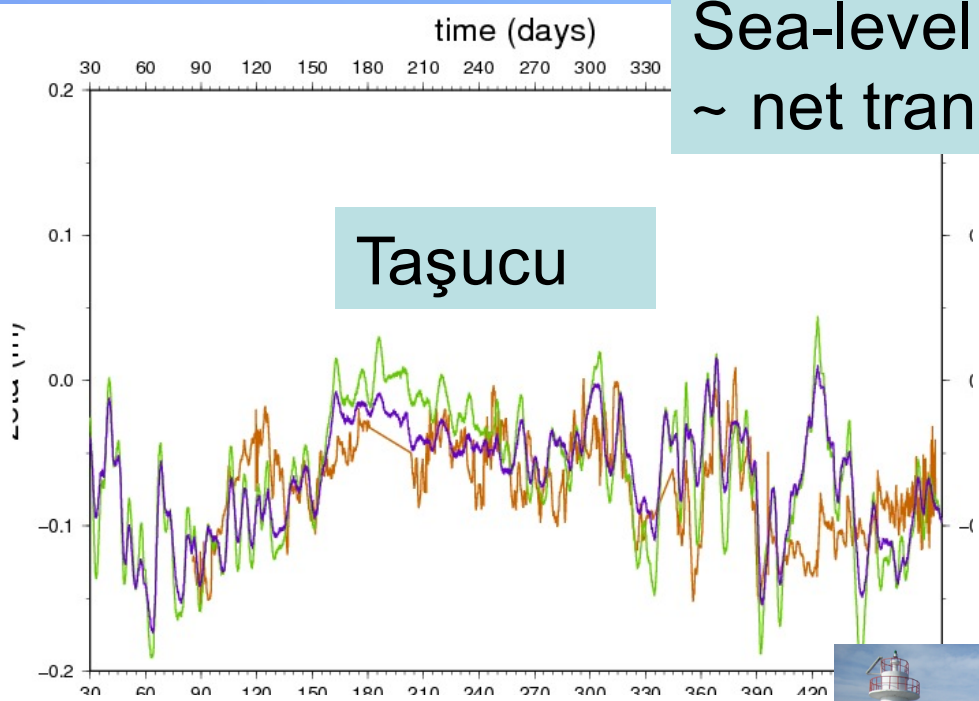
NLEV ROMS model: SESAME and MyOcean Projects
resolution 1.35 km in x and y, 30 s-levels in vertical
Large et al (1994) K-profile turbulence parameterization (LMD)
open boundary conditions 2drad,chapman+flather,T,S,u,v
surface atmospheric fluxes - INGV-SXG model scenario
lateral inputs: volume,T,S,NO3,NH4 at 14 rivers and streams
coupled ecosystem model - Bio_FennelNLEV

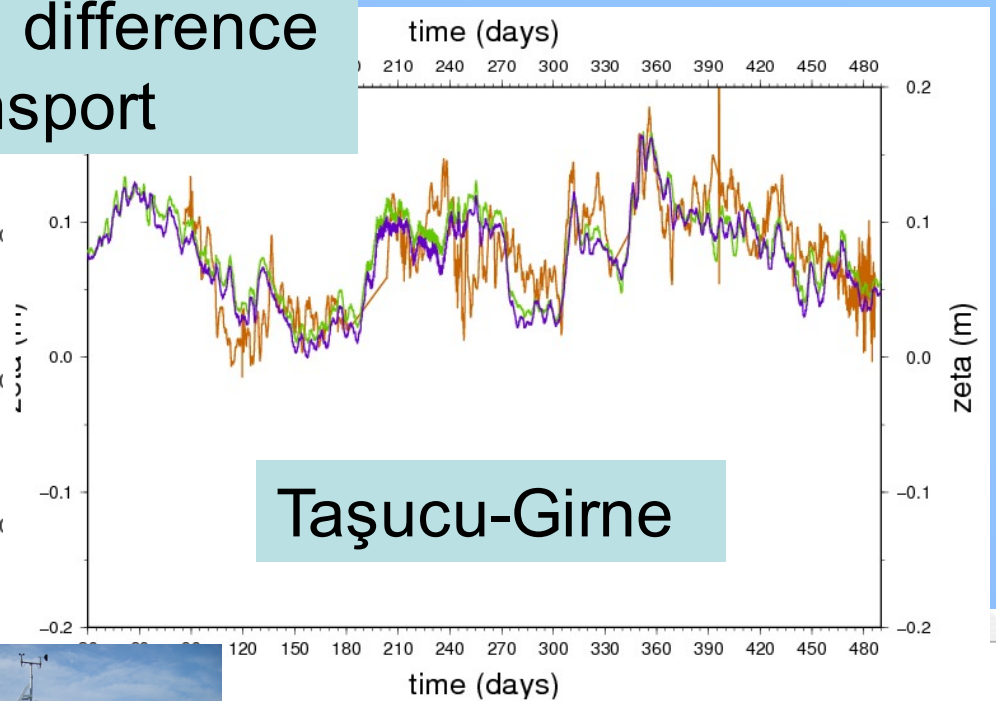


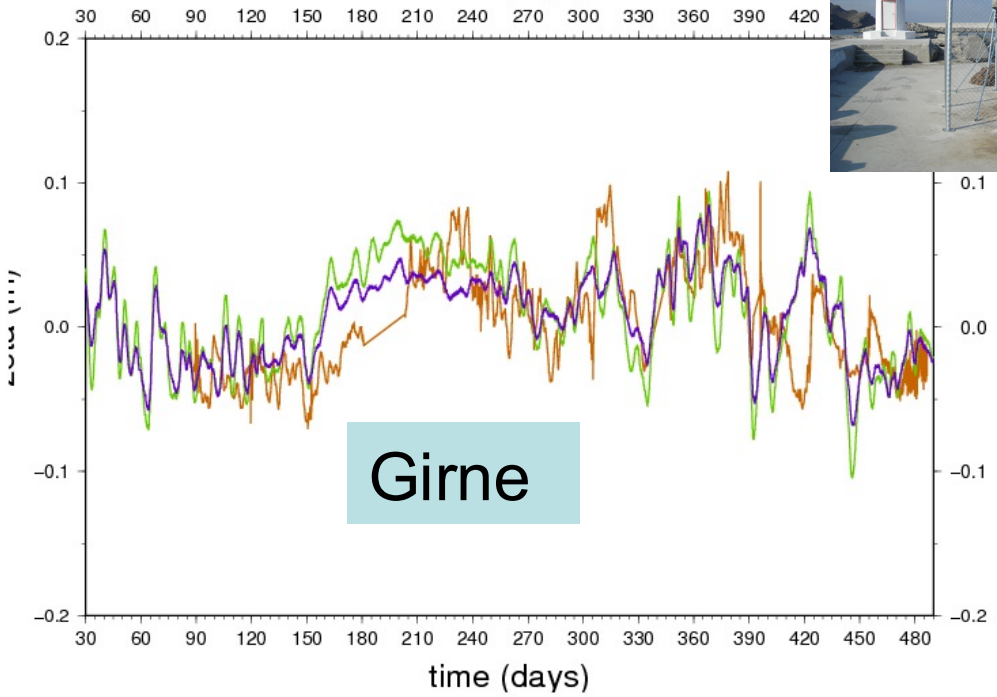

**Northern Levantine Basin**
**Multi-year coupled ecosystem model simulations (1996-2001) and (2030-2035 IPCC A1B)**

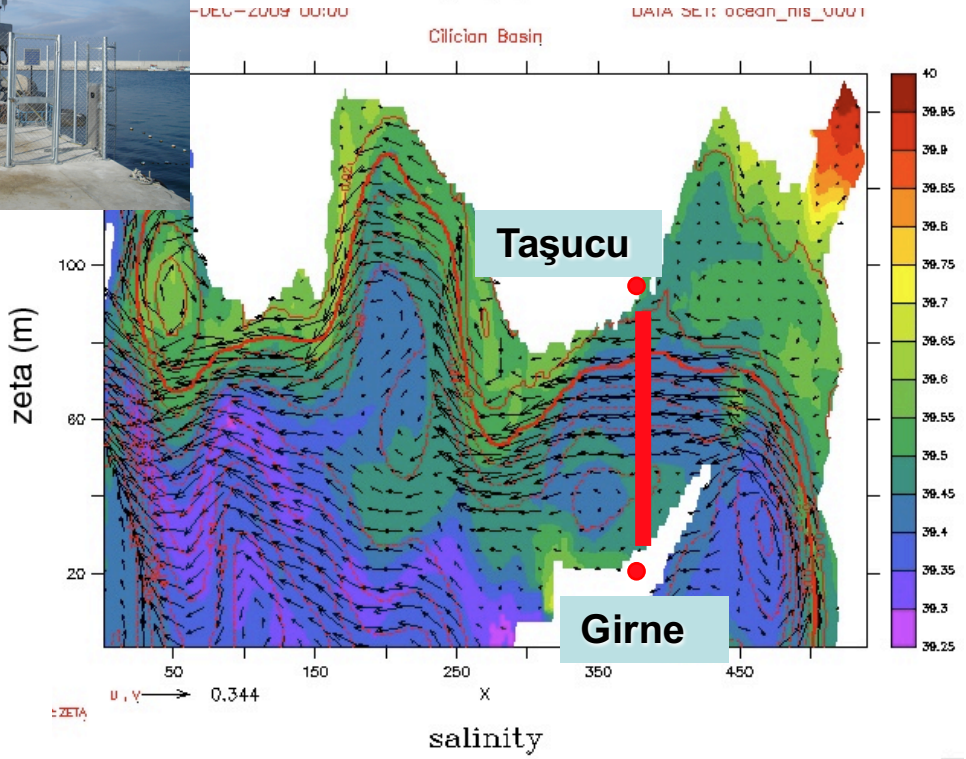
**Nested in OGS Mediterranean Sea model**

# Sea-level difference ~ net transport

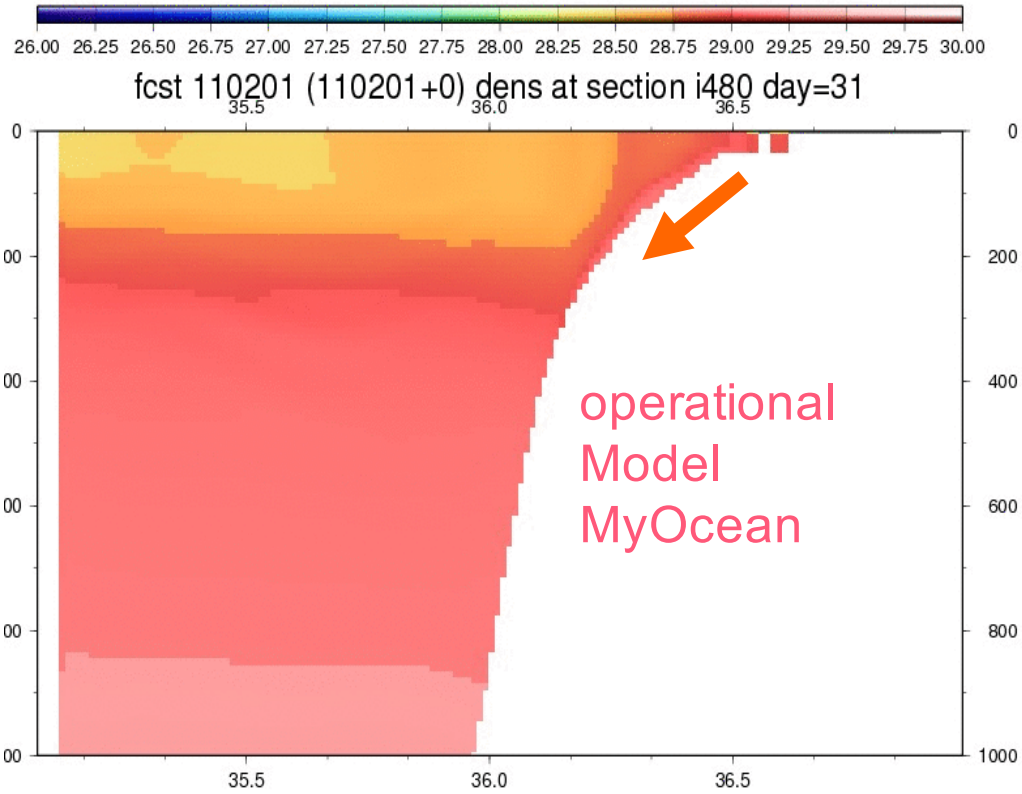


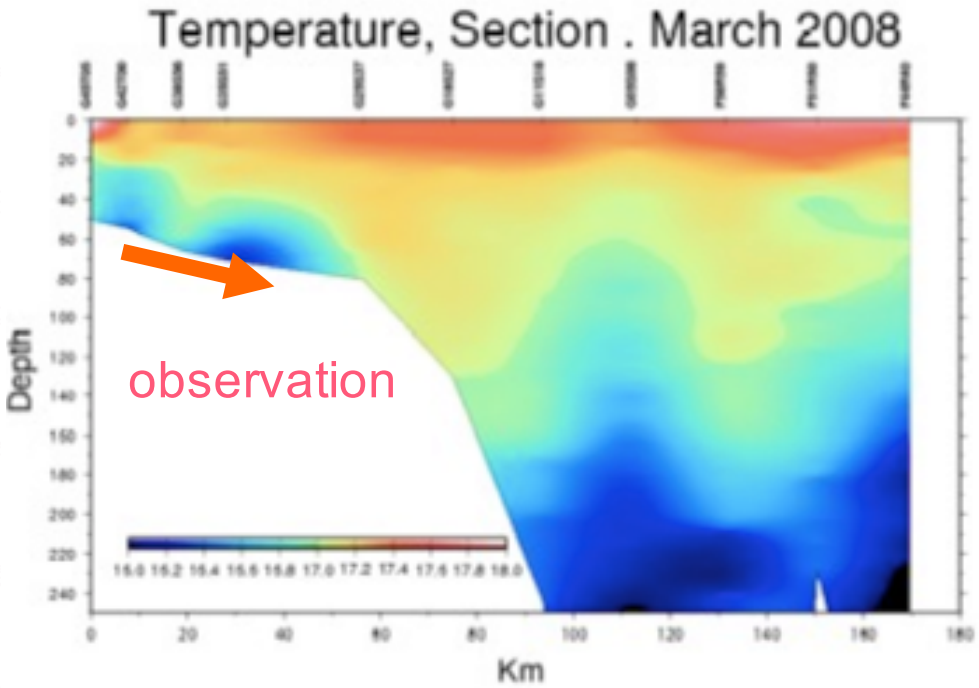



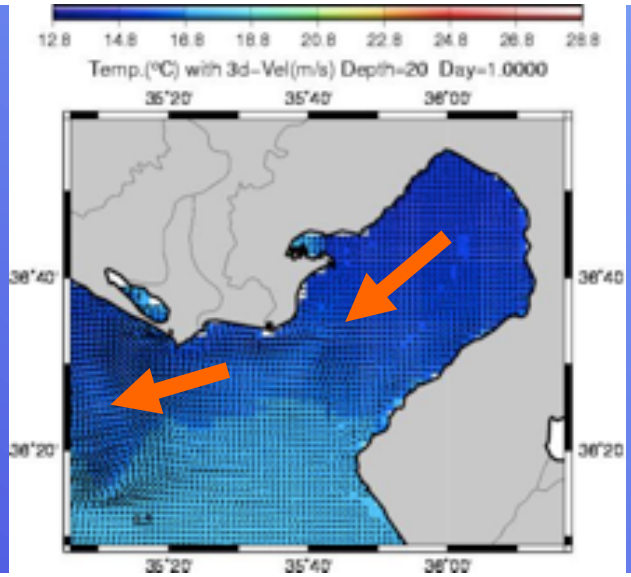



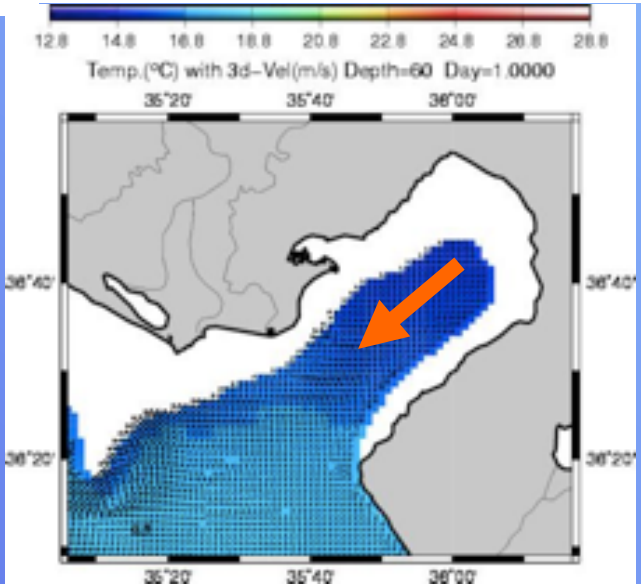



# Dense water (LIW) formation in the Gulf of İskenderun

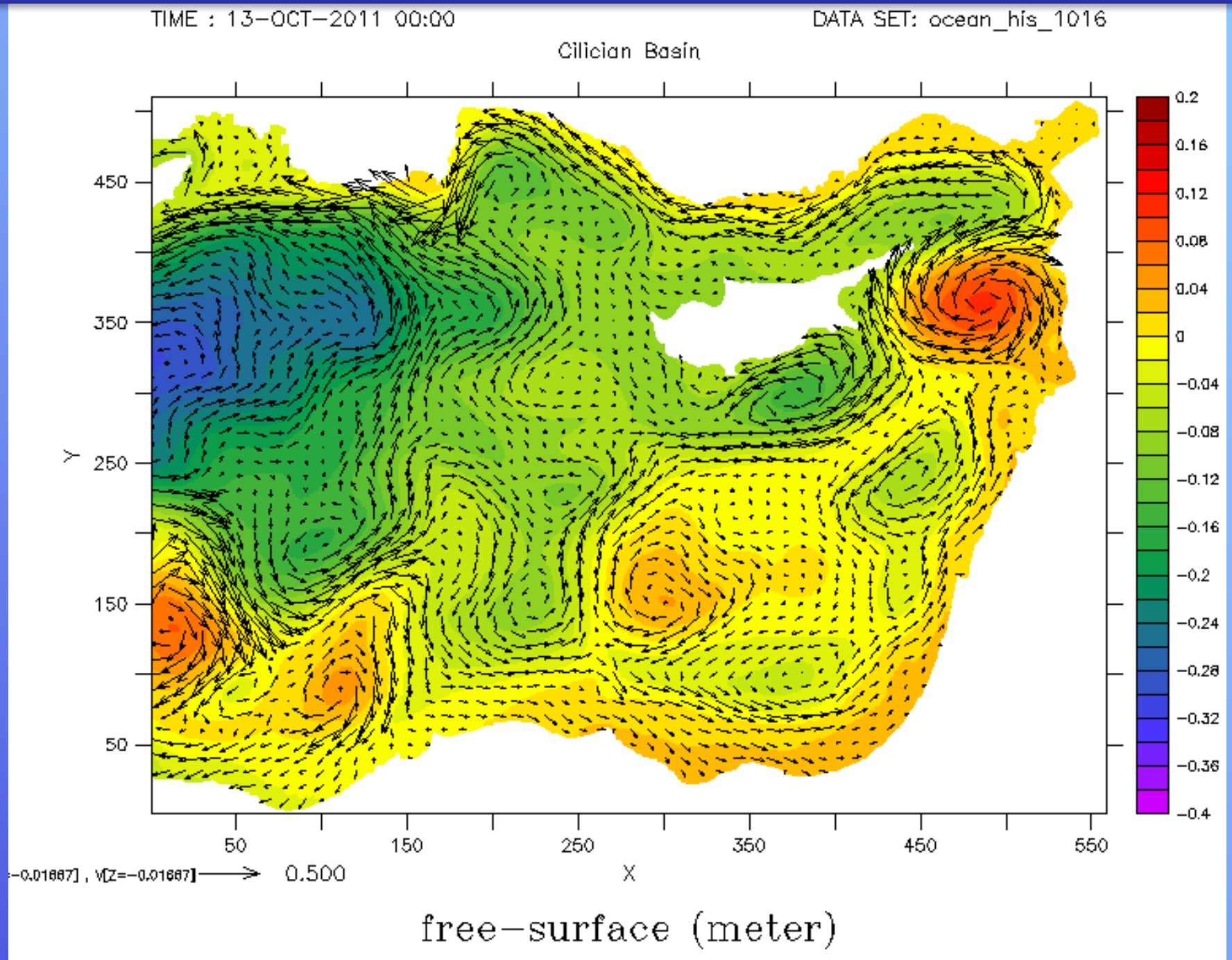


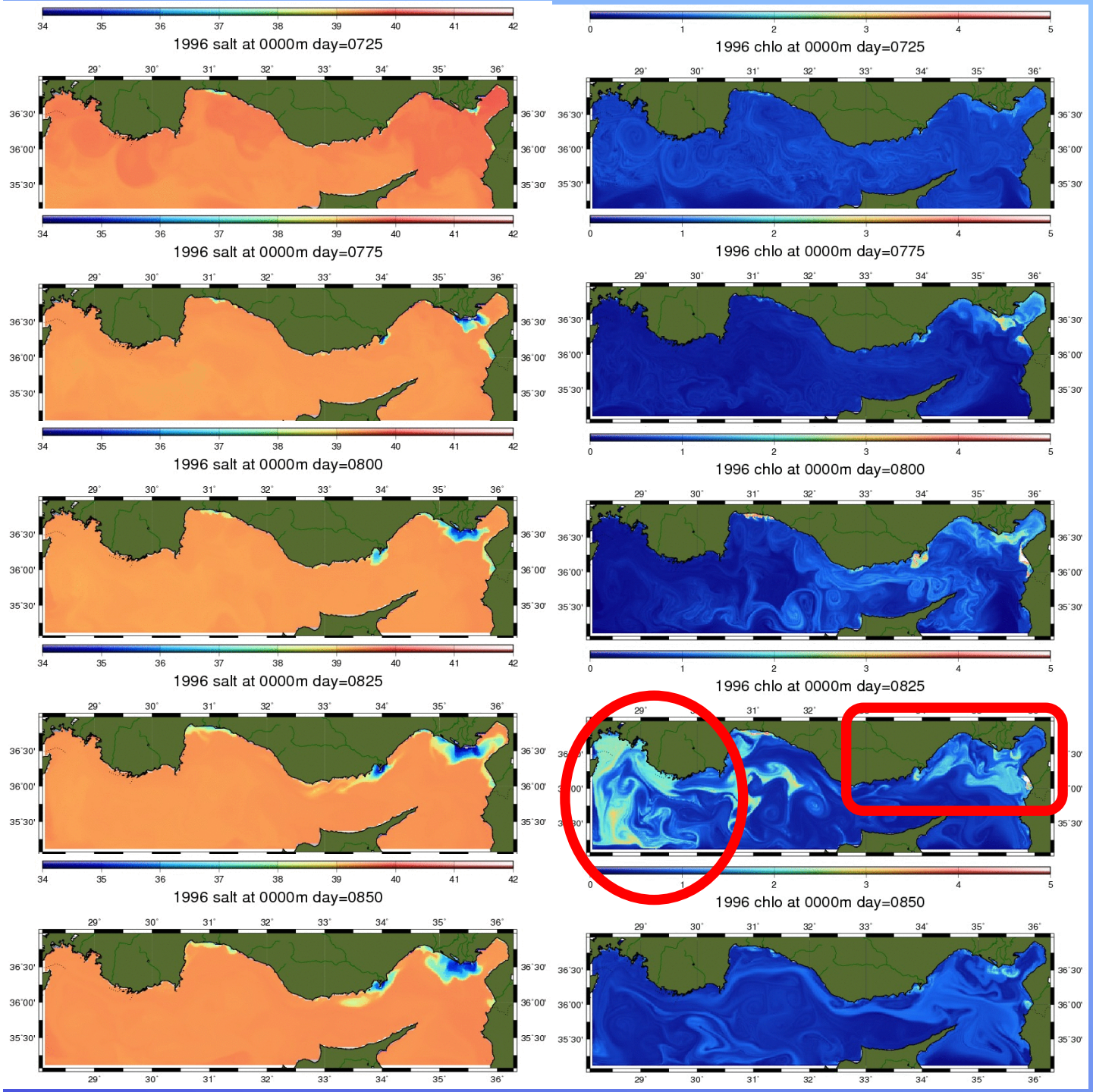



# LEV Levantine basin model – ROMS 1.35 km, operational soon






Dec 97

Winter mix.

Feb 98

Mar 98

Apr 98

Spring bloom

Rivers +

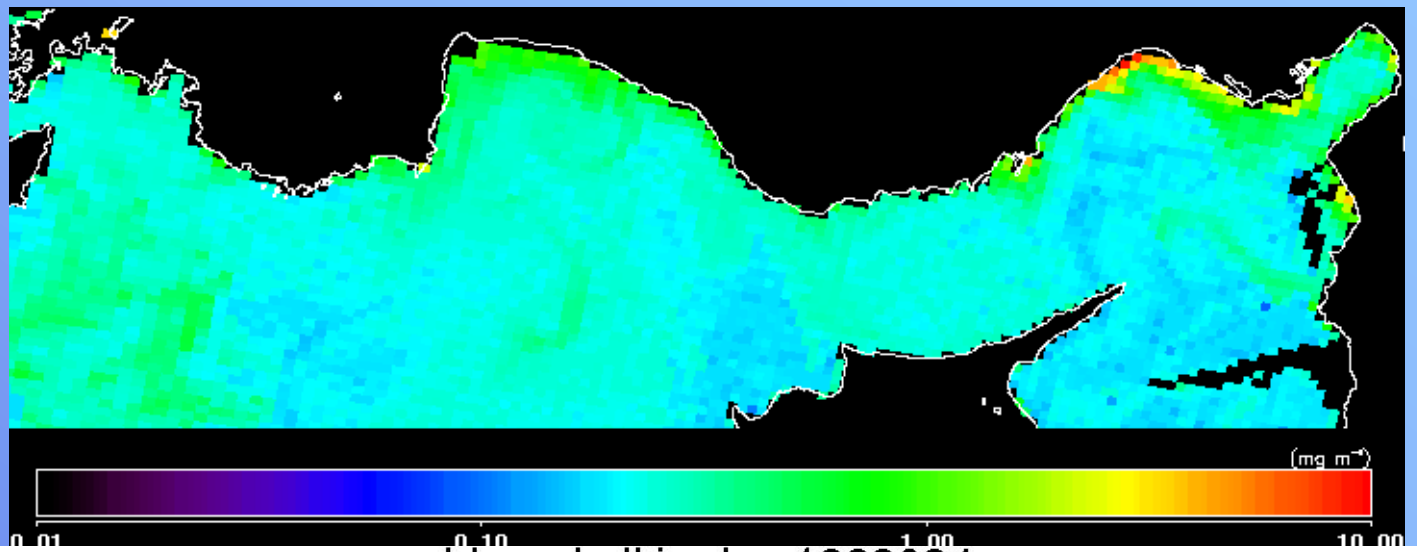
Rhodes Gyre

May 98

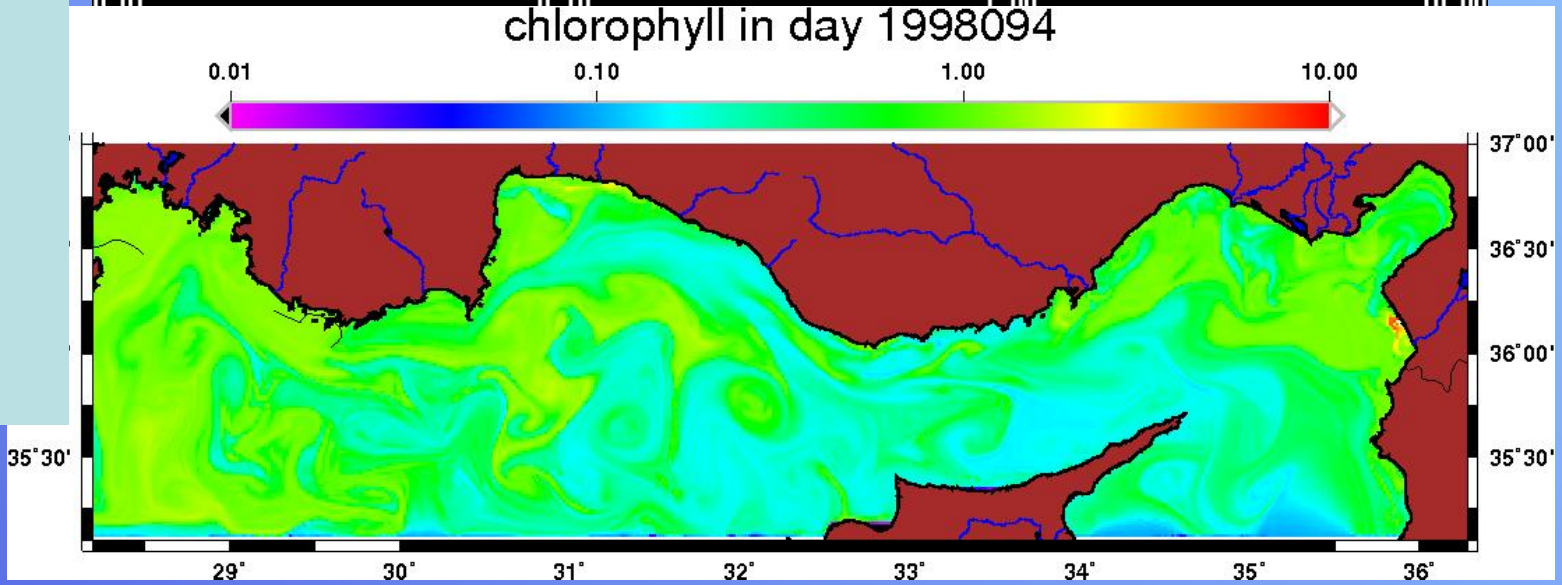
chlorophyll

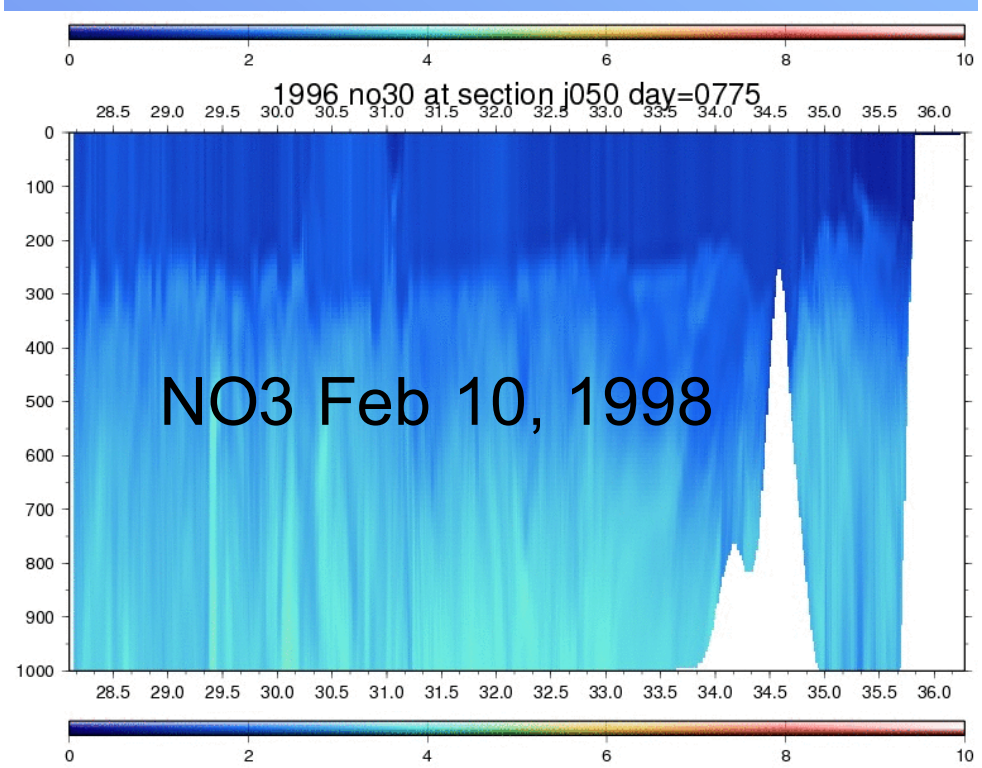
MODIS

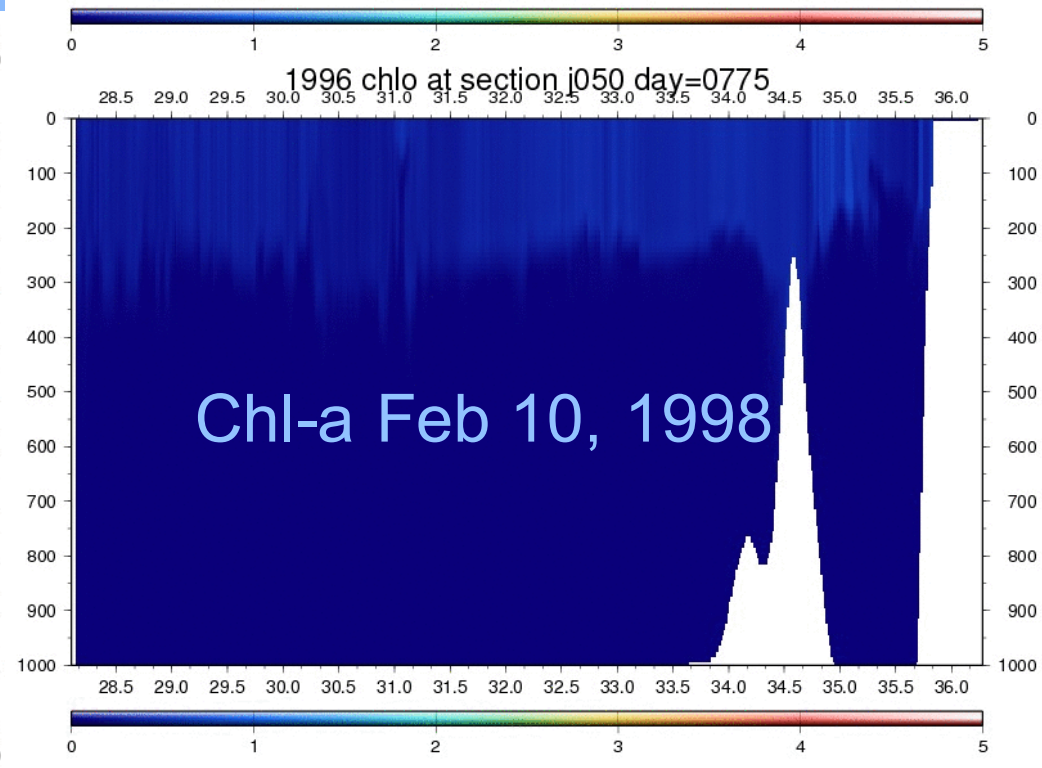
Mar 98

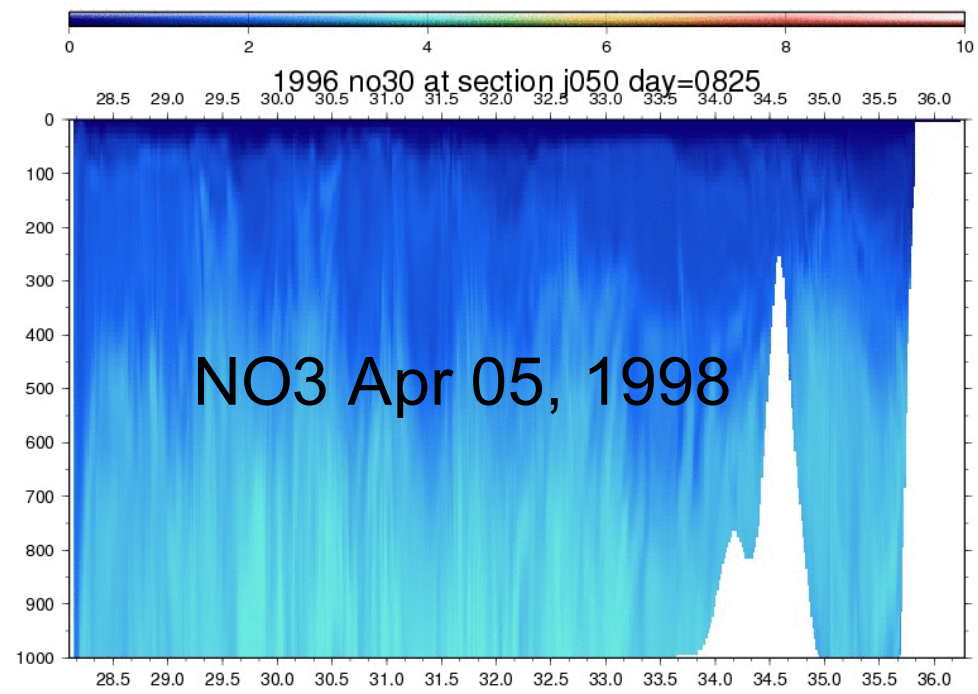


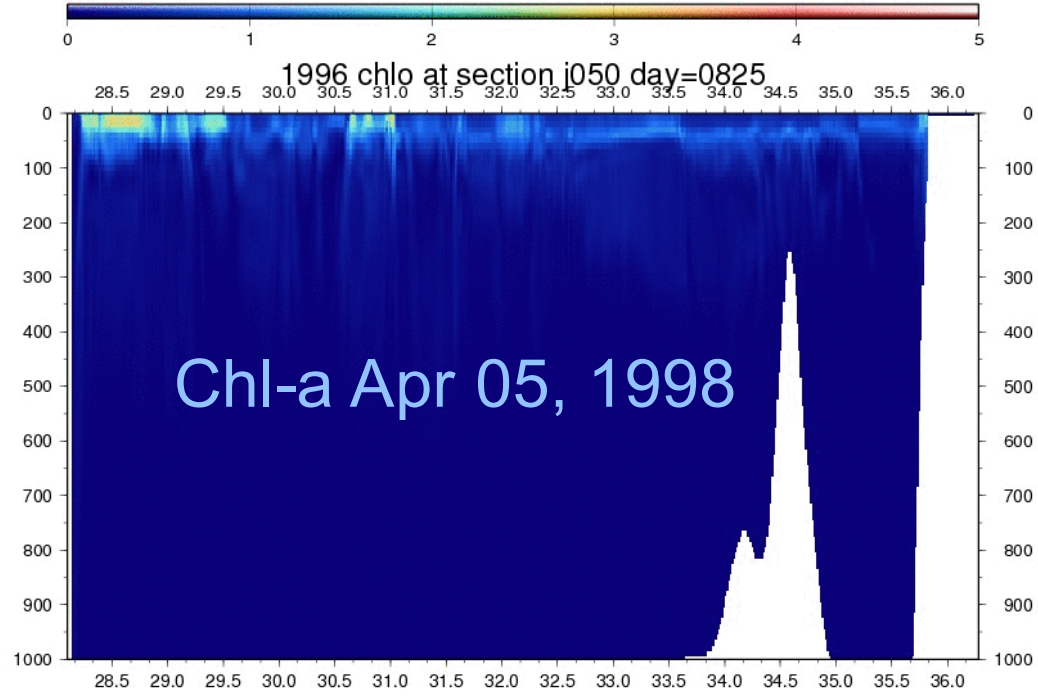

Model




1996 no30 at section j050 day=0775
NO3 Feb 10, 1998


1996 chlo at section j050 day=0775
Chl-a Feb 10, 1998

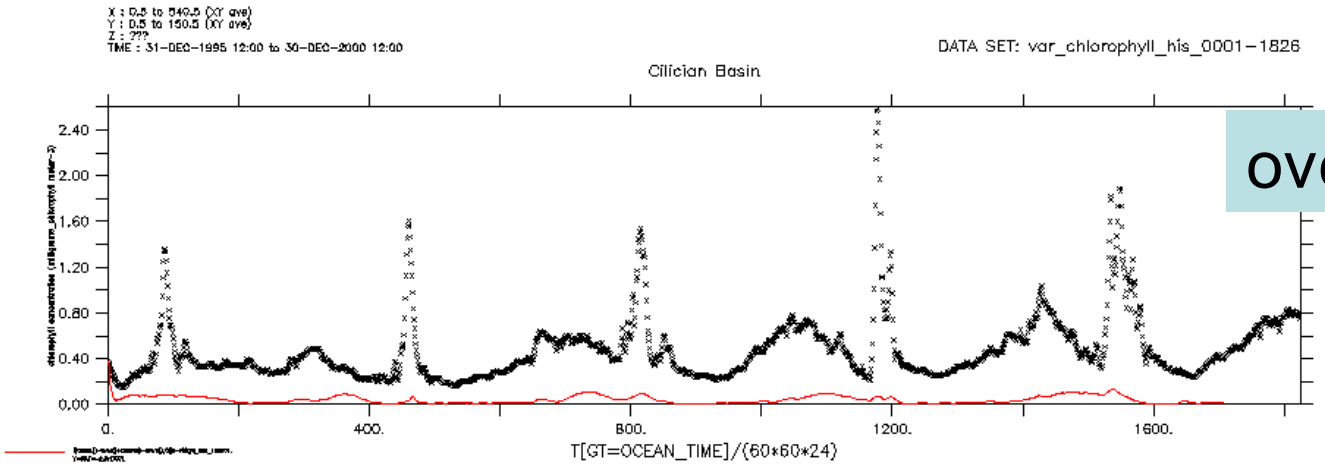

1996 no30 at section j050 day=0825
NO3 Apr 05, 1998


1996 chlo at section j050 day=0825
Chl-a Apr 05, 1998

1996-2001

chlorophyll
surface avg

red - bc
blk - model

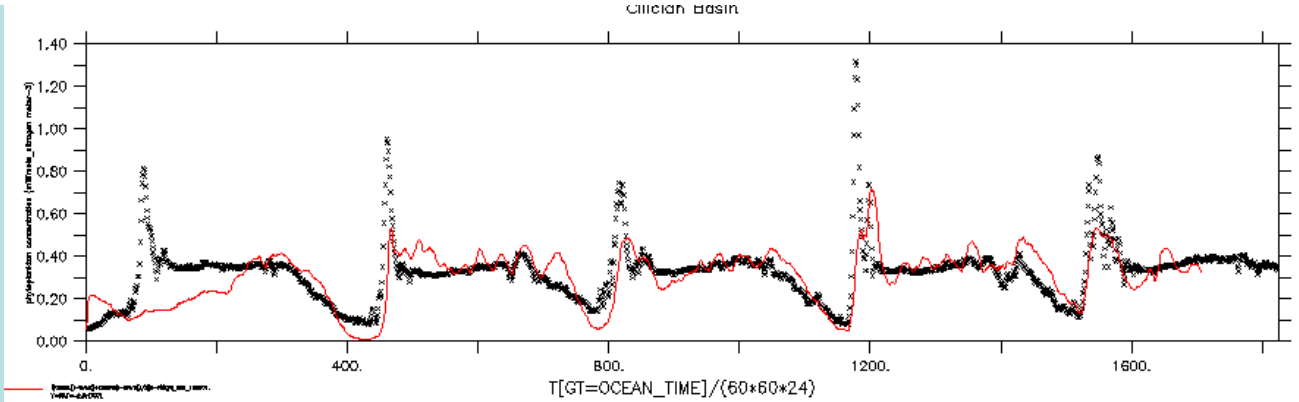



bnd srf vs model srf ave

overpredicted !

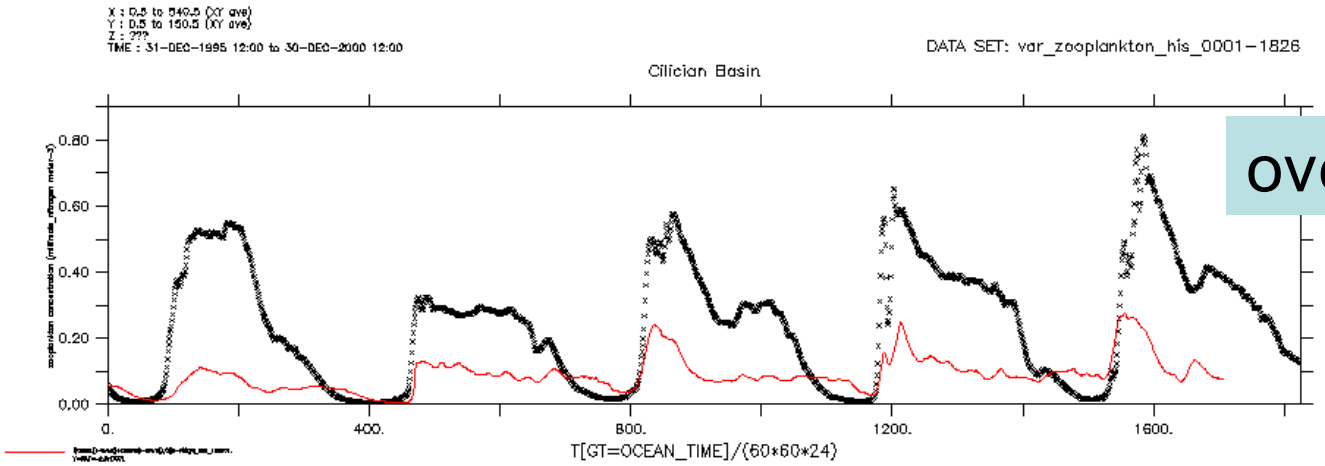
phytoplankton
surface avg

red - bc
blk - model




zooplankton
surface avg

red - bc
blk - model




bnd srf vs model srf ave

overpredicted !

## Discussion:

Observational and predictive model systems should go hand in hand in highly variable systems, especially in the age of climate change

Persistent long term observations combined with model predictions contributing to a better understanding of the complex Eastern Mediterranean system

Basic circulation features of the Levantine basin foreseen in POEM are confirmed by model-data syntheses: sub-basin scale gyres, jets, Intense currents, coherent eddies, multi-mode circulation cells, oscillations, Impulse response to strong events better monitored by better equipped / integrated ocean science community

rivers in the coastal areas, eddy dispersion and new production in the open sea (esp. Rhodes Gyre area), maintain productivity of the Ecosystem in the Levantine basin, which seem to be more effective to Distribute material distribution from the coastal areas to the open sea

possible shelf pump modes of material transport in shallow continental shelf areas created by dense water (LIW) formation

need extensive validation of properties, mixing, productivity

and, thanks!