# Late 1980s regime shifts: intriguing parallelisms in European (and other) seas

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# Summary

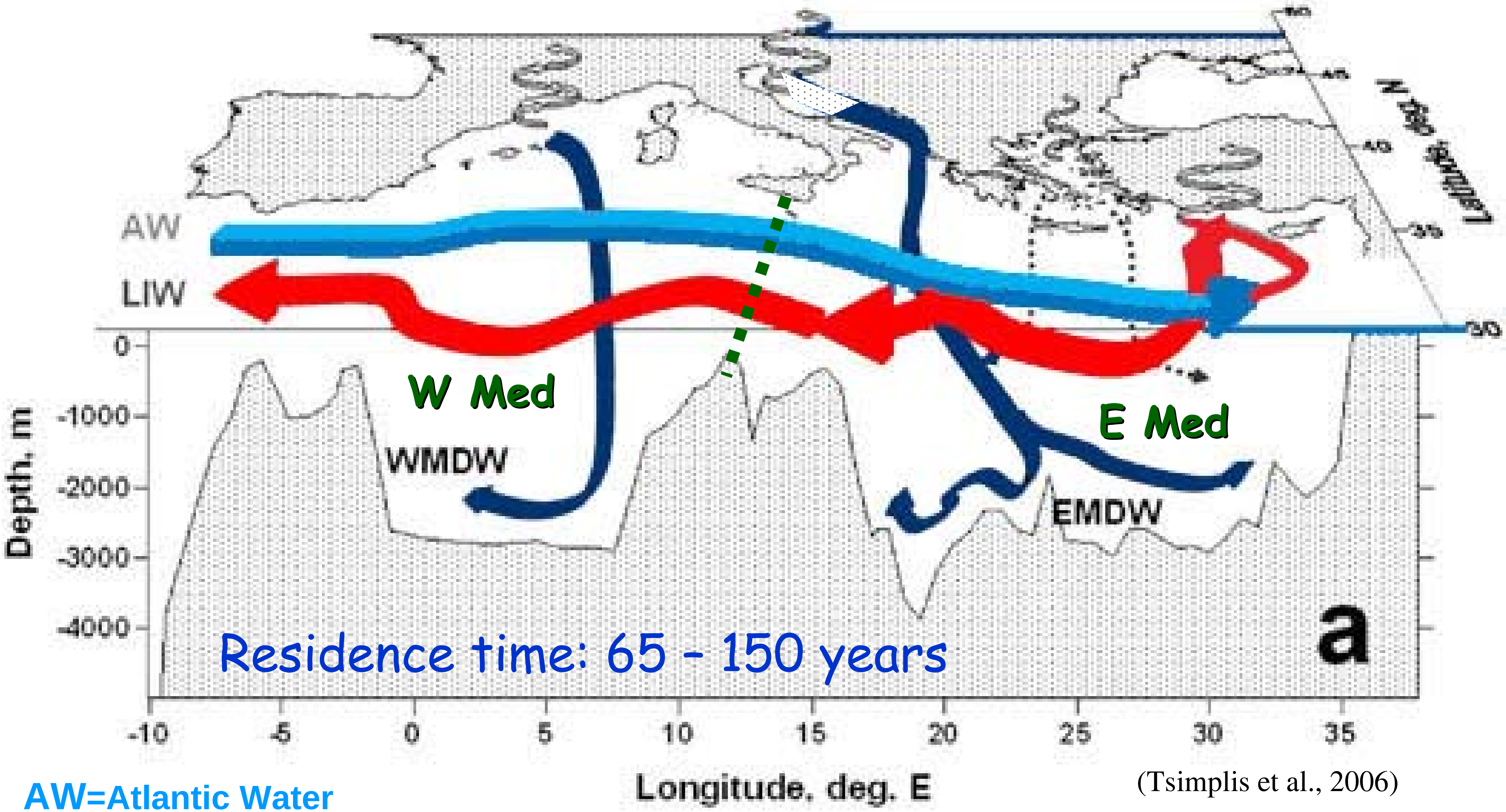
- A: Changes in the **Western** and **Eastern** **Mediterranean** ecosystems, at the end of the 1980s
- B: Intriguing parallelisms of shifts in all **European** marine ecosystems, during the same period
- C: Examples of similar shifts in **other world-ocean basins**
- D: Significance of **synchronous** regime shifts
- E: Next steps

## What are regime shifts?

- abrupt changes (within a few years)
- encompass a multitude of physical properties and ecosystem variables
- often resulting in a new system state
- non linear phenomena

They hold particular relevance in the marine realm, because they can involve all trophic levels of marine food webs and the associated biogeochemical cycles.

# Mediterranean Thermohaline Circulation



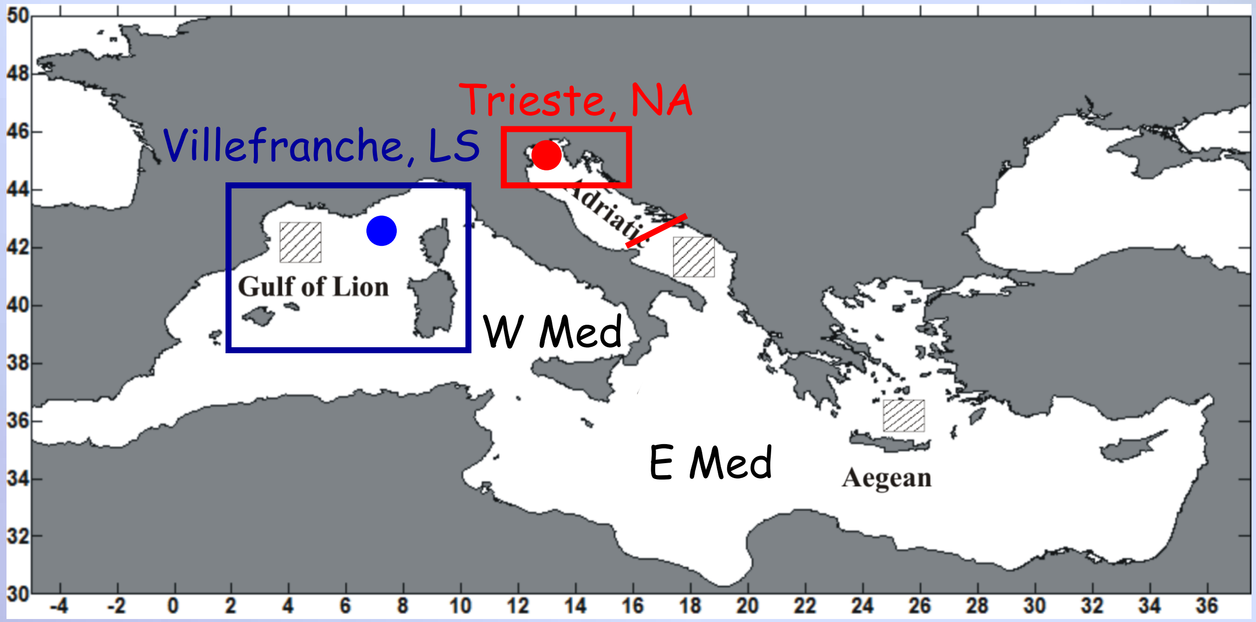

(Tsimplis et al., 2006)

**AW=Atlantic Water**
**LIW=Levantine Intermediate Water**
**WMDW=Western Mediterranean Deep Water**
**EMDW=Eastern Mediterranean Deep Water**

The Mediterranean is considered a miniature ocean

# A) The Mediterranean Sea late 1980s regime shift: hypotheses, and supporting evidence

# The data

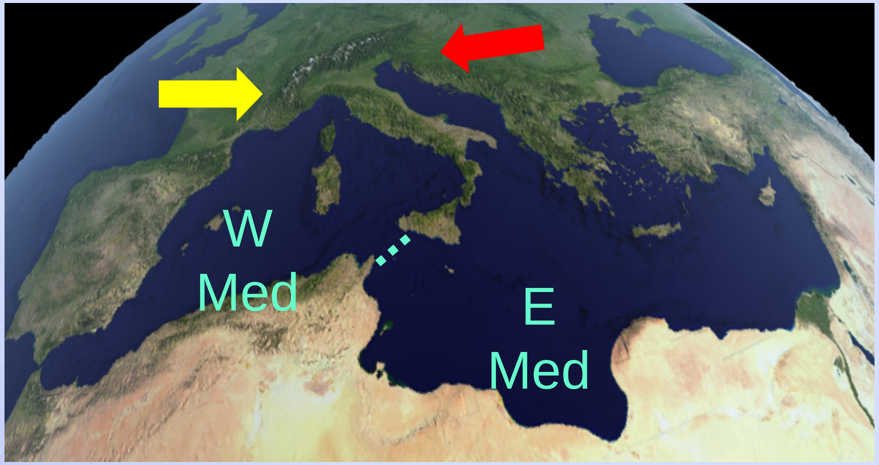



1970 -2005

- total **copepod** abundance (ind. $m^{-3}$), Gulf of Trieste, North Adriatic (NA), Eastern Mediterannean (monthly)
- the northern/central Adriatic **mucilage** events time series (episodes)
- the northern Adriatic **red tides** time series (episodes)
- the Adratic Sea **anchovy** stock biomass (yearly; 1976-2001)
- **zooplankton** abundance (ind. $m^{-3}$), Ligurian Sea (LS), Western Mediterranean (weekly, 1966 - 1993)
- **SST** (°C), and **SLP** (hPa) [CNR] Gulf of Trieste, Adriatic (winter) => **LOCAL**
- **SST** (°C) [iCOADS], and **SLP** (hPa) [NCEP] NW Med Sea (winter) => **REGION**
- **SST** (°C), [iCOADS] and **SLP** (hPa) [NCEP] Mediterranean (winter) => **BASIN**
- North Hemisphere Temperature (**NHT**) index (°C) (winter)=> **HEMISPHERE**
- North Atlantic Oscillation (**NAO**) index (winter) => **HEMISPHERE**

# Hypothesis 1

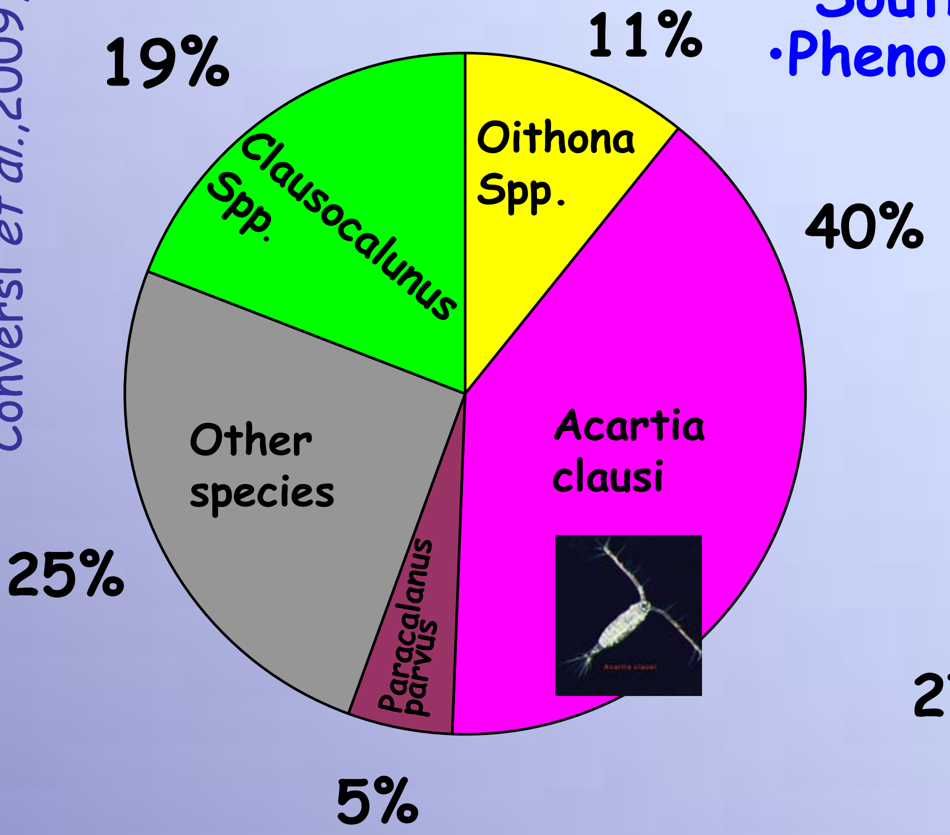
A step change is found in several components of the food web, and in both basins around the same period



# Changes in copepod community in the Gulf of Trieste

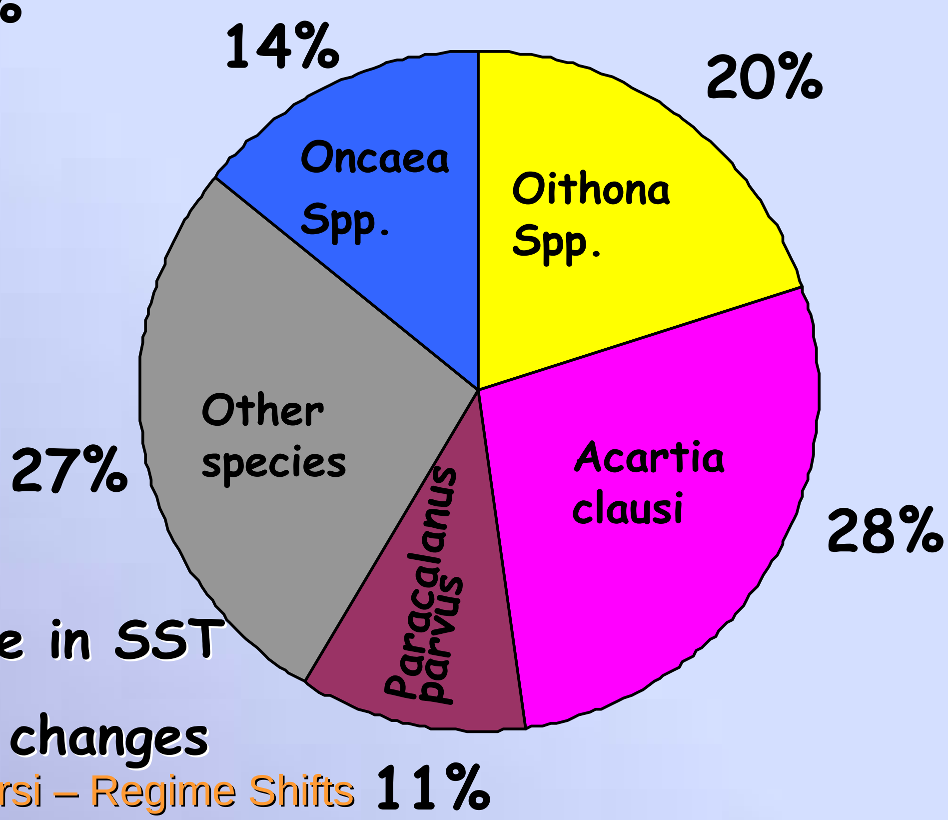
Conversi *et al.*,2009, JGR

- Cop abundance quasi doubled
- Increase of smaller species
- Cold species decrease
- Southern species spread northward
- Phenological changes in most species




1970-1987

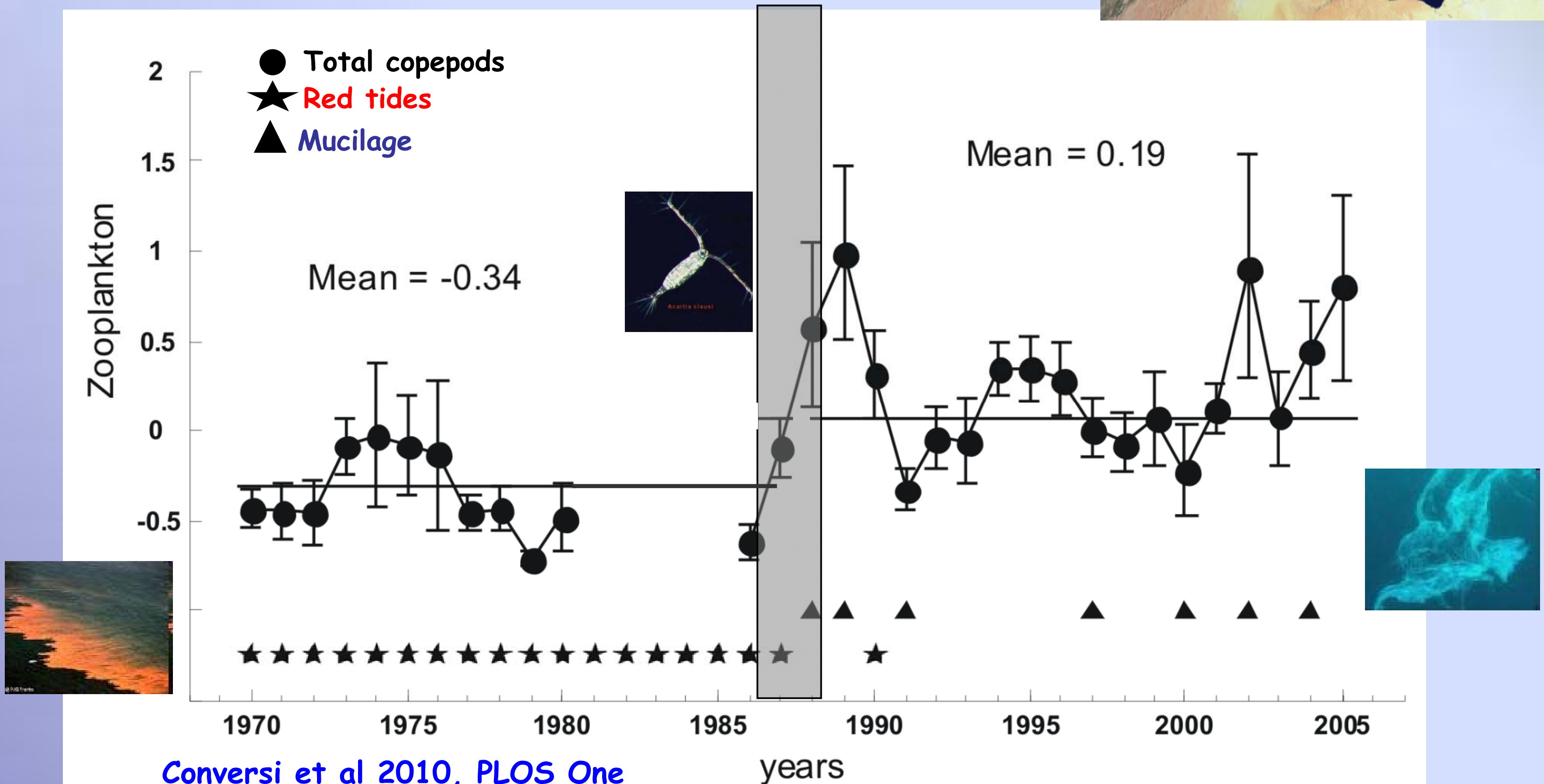
1988-2005




1 C increase in SST

Circulation changes

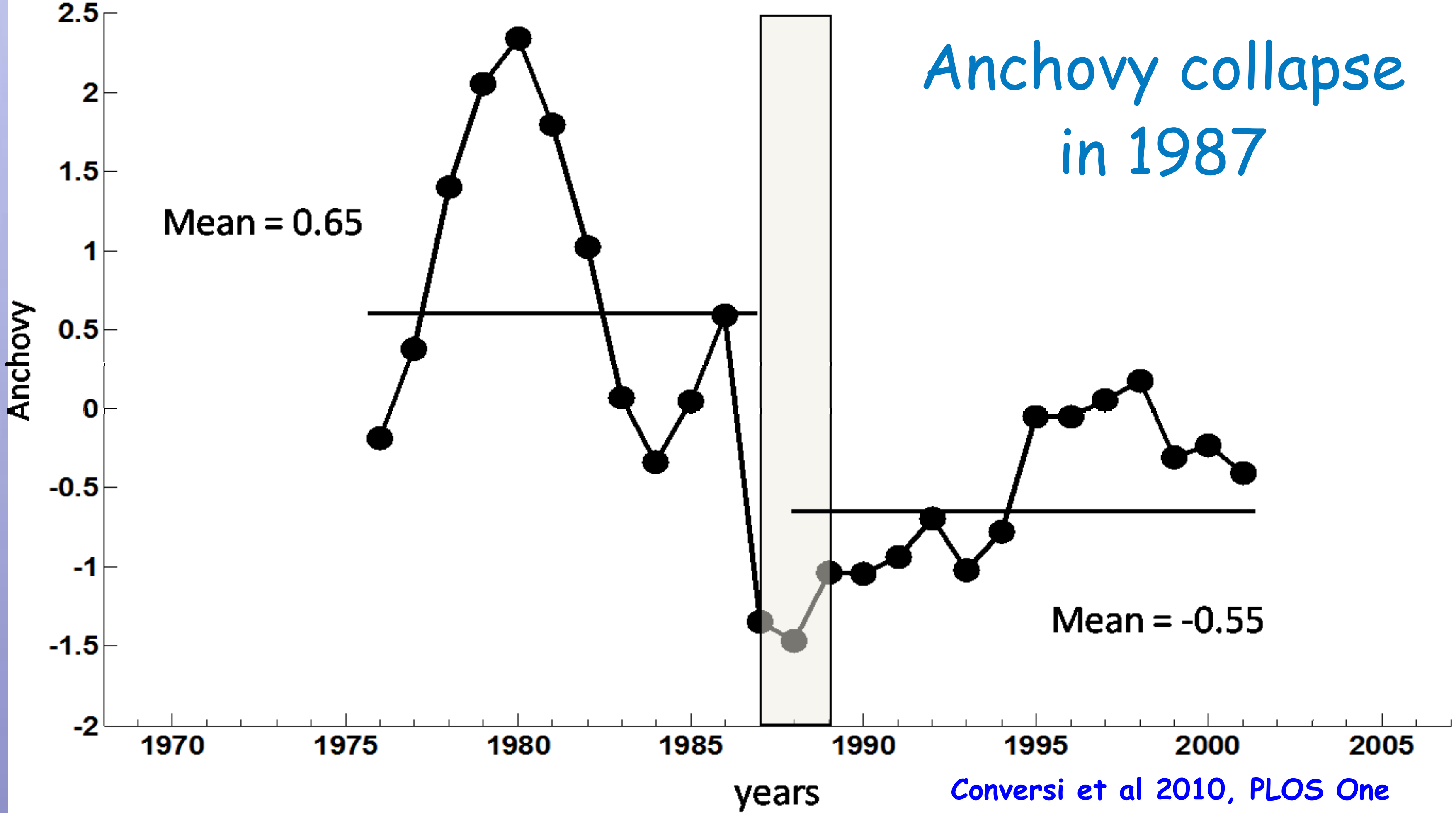
# Summary of changes in the Adriatic




Conversi et al 2010, PLOS One

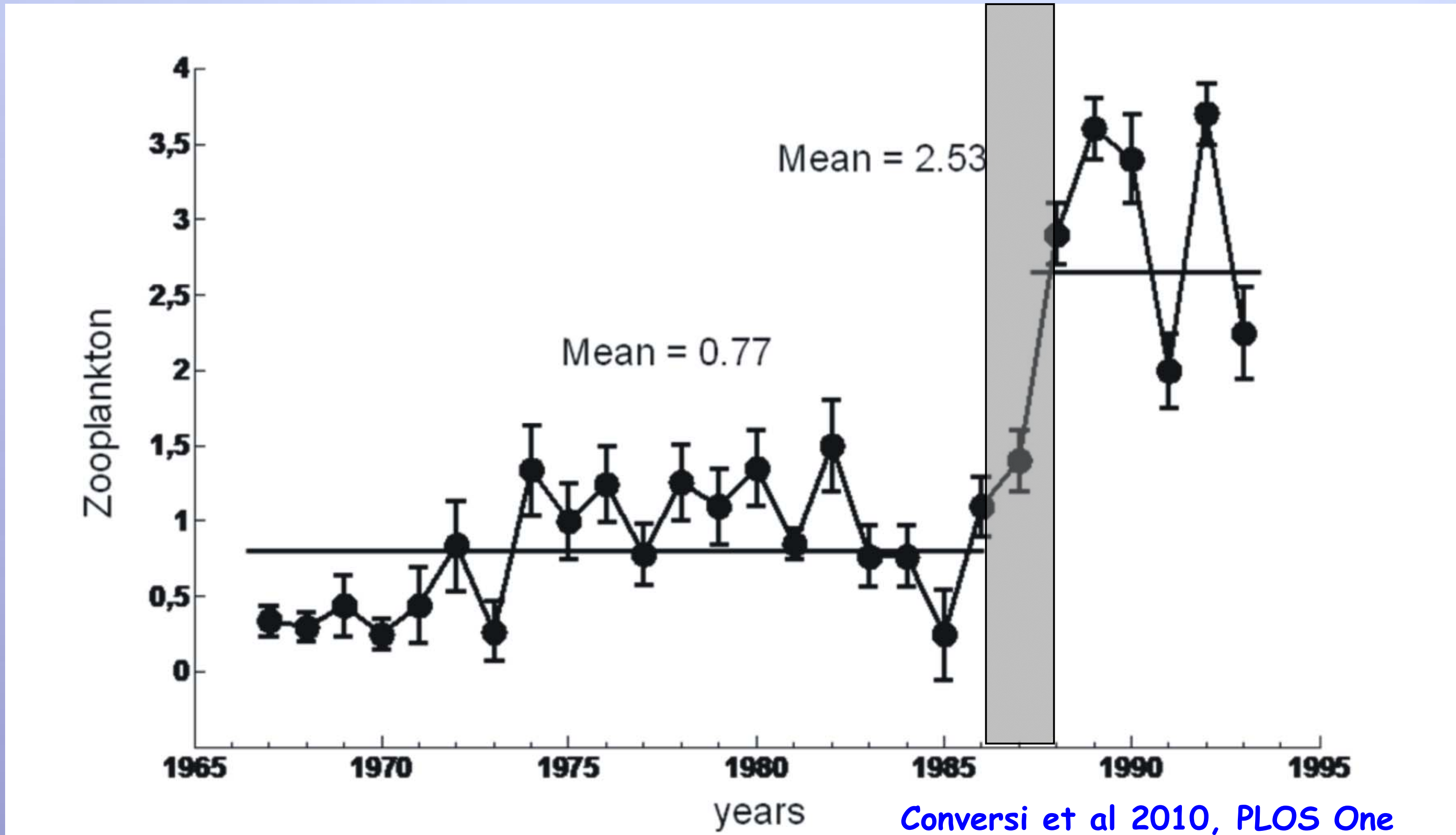
Also the chain of red tides - mucilage events in the northern Adriatic Sea is centered around 1987.

# Summary of changes in the Adriatic




Conversi et al 2010, PLOS One

# Summary of changes in the Ligurian Sea




Conversi et al 2010, PLOS One

Mean increase in zooplankton abundance is 228%, mainly gelatinous

# Results - 1

## The available biological time series point to a period of change in the late 1980s, in both Mediterranean sub-basins

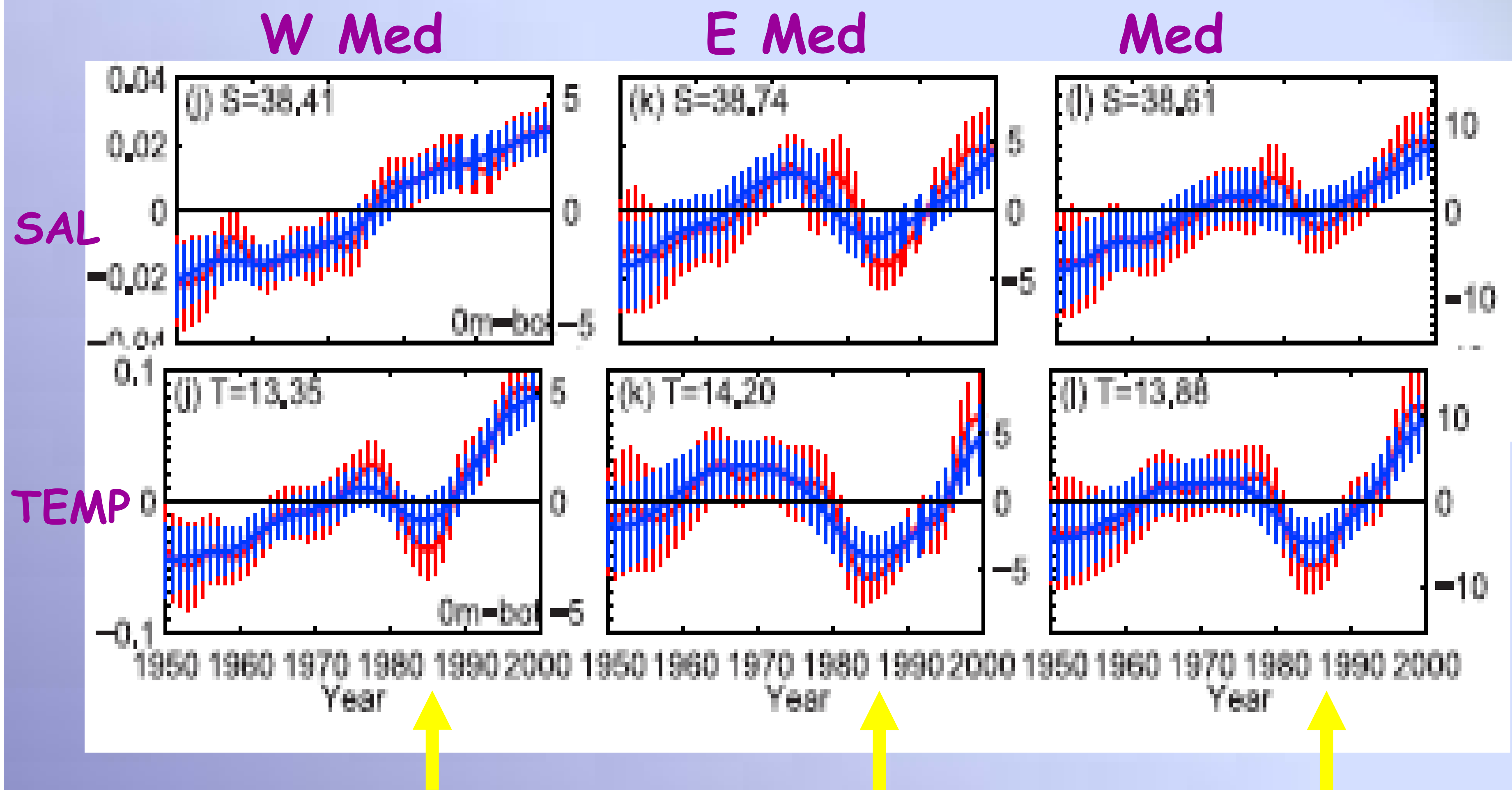
All t-tests indicate significant differences in T1 vs T2

# Hypothesis 2

The changes seen in the biological system are associated to changes in the Mediterranean physical system

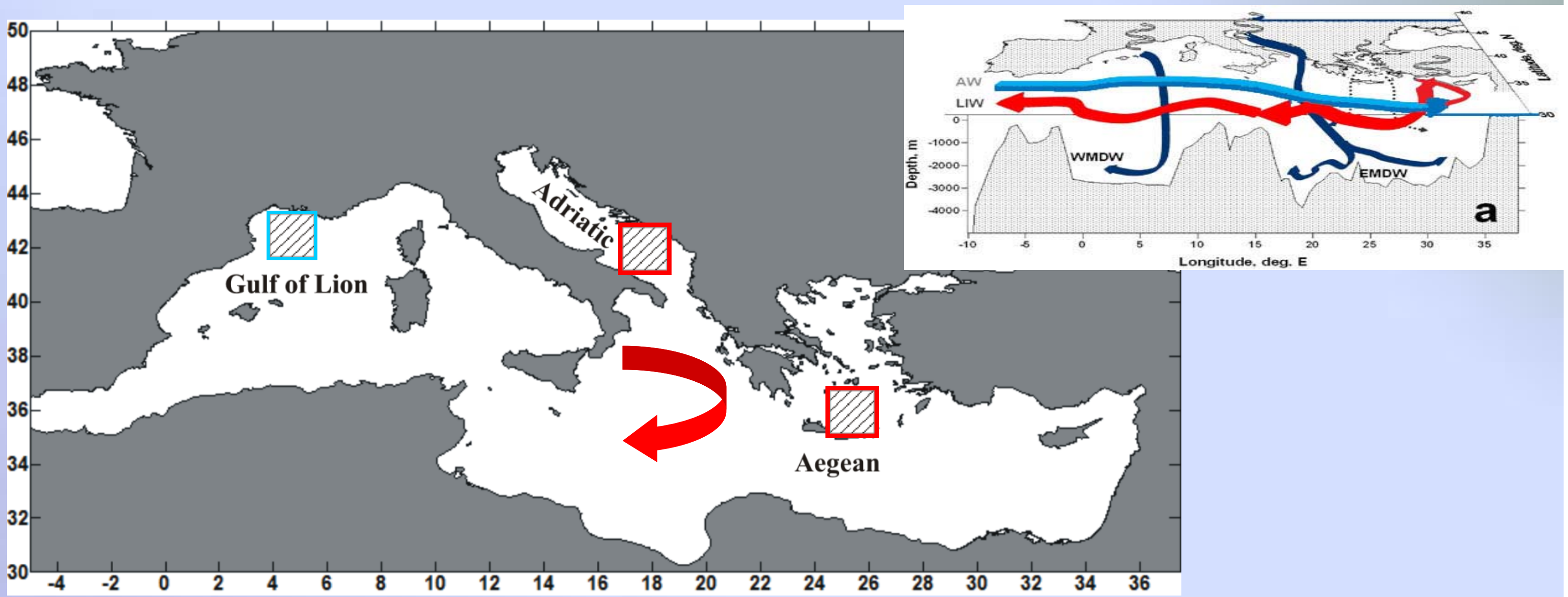
# Changes in the physical system - Observed data

## Mediterranean salinity (top) and temperature (bottom), surface-bottom, 1950-2000




Rixen et al, 2005 JRL

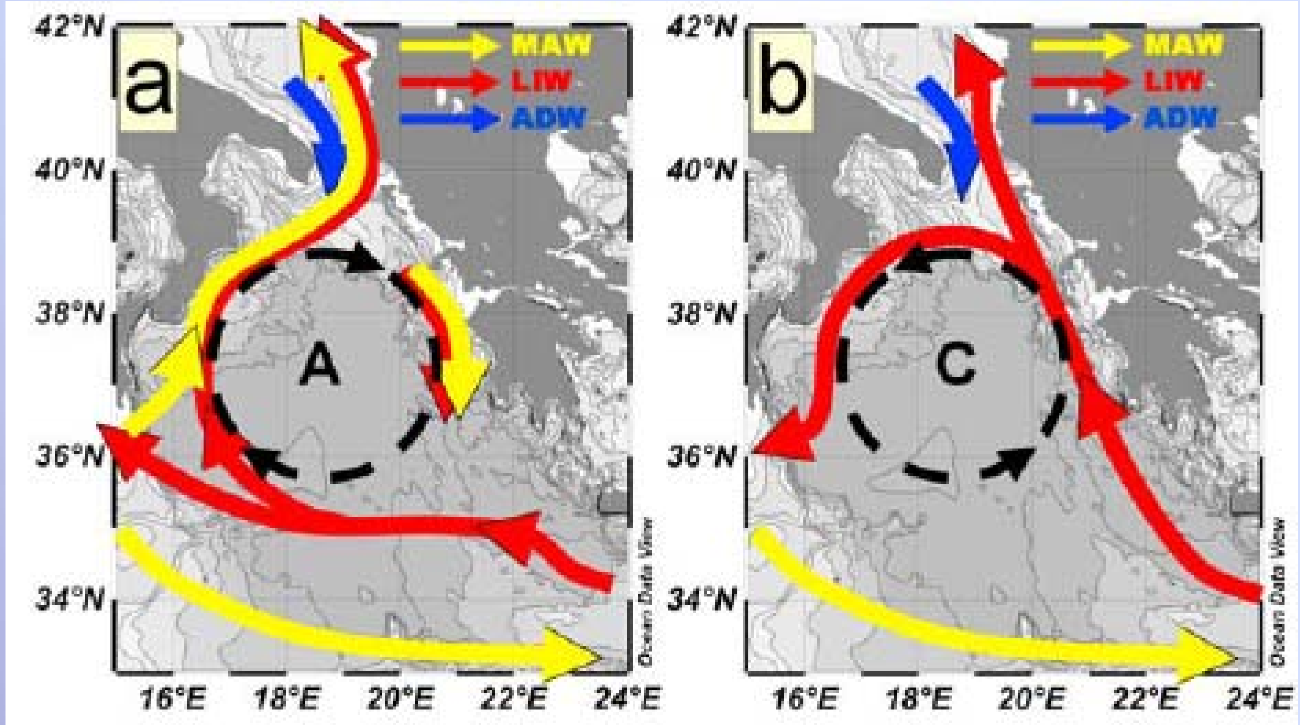
# Changes in the physical system, late '80s




- Surface circulation changes around 87, also different wind and precipitation regimes (MODEL: Demirov and Pinardi, 2002);
- Ionian gyre reversed in the summer of 1987 from its "usual" cyclonic state to an anticyclonic pattern (MODEL: Pinardi et al. ,1997; Korres et al., 2000), returned to normality in 1997 (OBSERVATIONS: Poujol and Larnicol, 2005)
- The largest modification in the Mediterranean is the Eastern Mediterranean Transient, the shift in deep water formation in the Eastern basin from its usual source in the southern Adriatic to a new source in the Aegean Sea, which also started at the end of the 1980s (Roether et al., 1996; Malanotte-Rizzoli et al., 1999; Lascaratos et al., 1999; Josey, 2003; Roether et al., 2007. Gacic et al 2010).

anticyclonic — cyclonic

start 87 until 96




Pre 87 and post 96

- Gacic et al 2010 and Civitarese et al 2010 propose a feedback mechanism (named the Adriatic-Ionian Bimodal Oscillating System – BiOS) between variations in the thermohaline properties of waters formed in the Southern Adriatic and the Ionian circulation, and propose it modulates the Adr ecosystem

**If this hypothesis is correct, we should find ecosystem changes in the late 90s – early 2000s**

# Results - 2

A literature review, including results from observations and models, indicates a change in surface and deep Mediterranean circulation in the late 1980s

# Hypothesis 3

- A regime shift is occurring at the end of the 1980s in the Mediterranean Sea

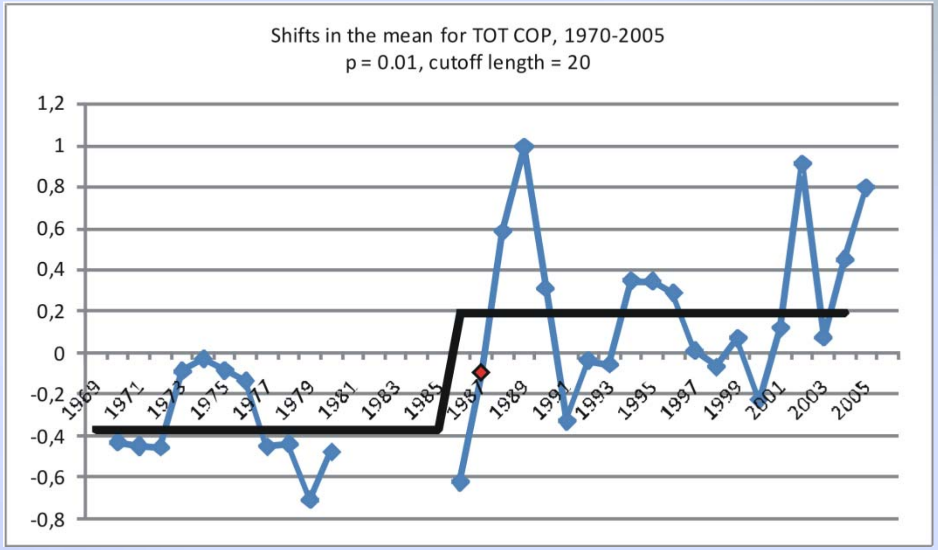
# Tests for Regime Shift

Conversi et al, Plos One 2010

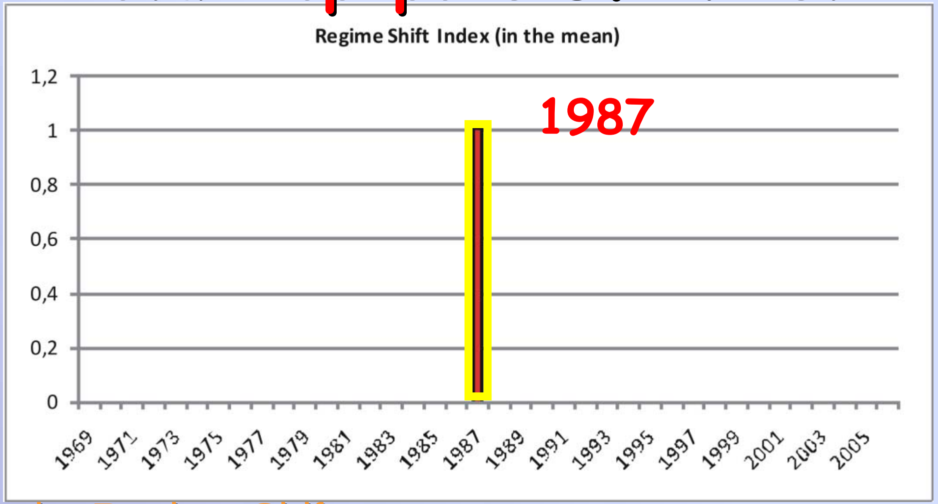
To test the regime shift hypothesis as a step change in mean level, we have used a parametric method based on sequential t-test analysis of regime shifts (STARS), modification by Rodionov and Overland (2005).

Cut-off lenght = 20
Probability level = 0.01

Same results on Ligurian zooplankton




Total Copepods G. Trieste



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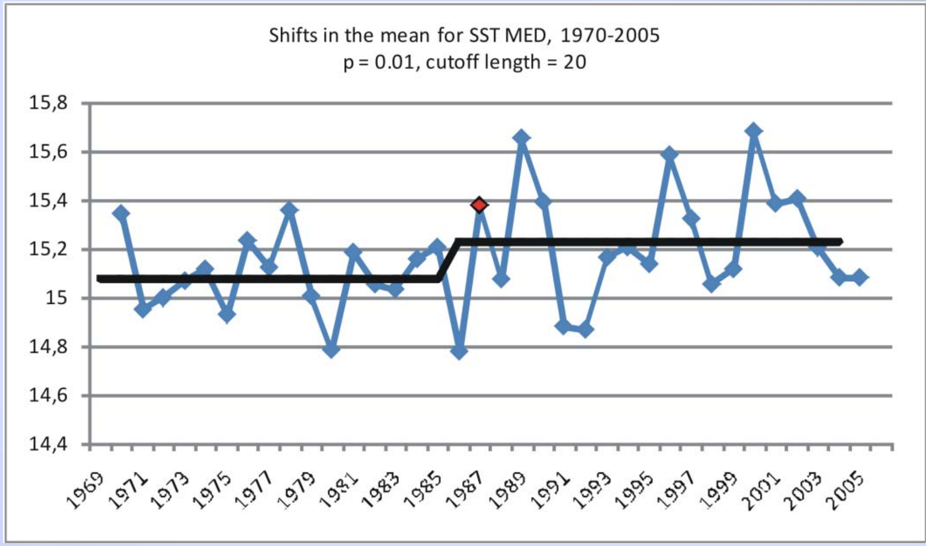
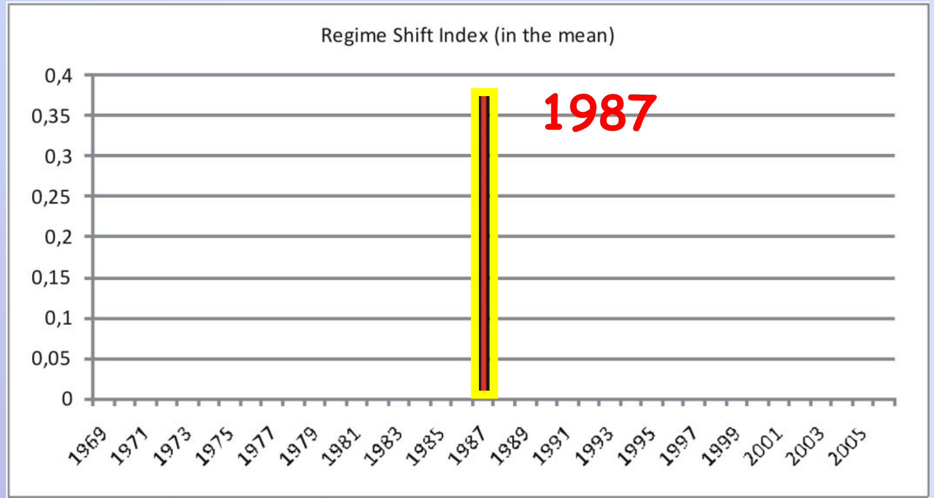
Winter SST, averaged over the entire basin [iCOADS]




SST Med



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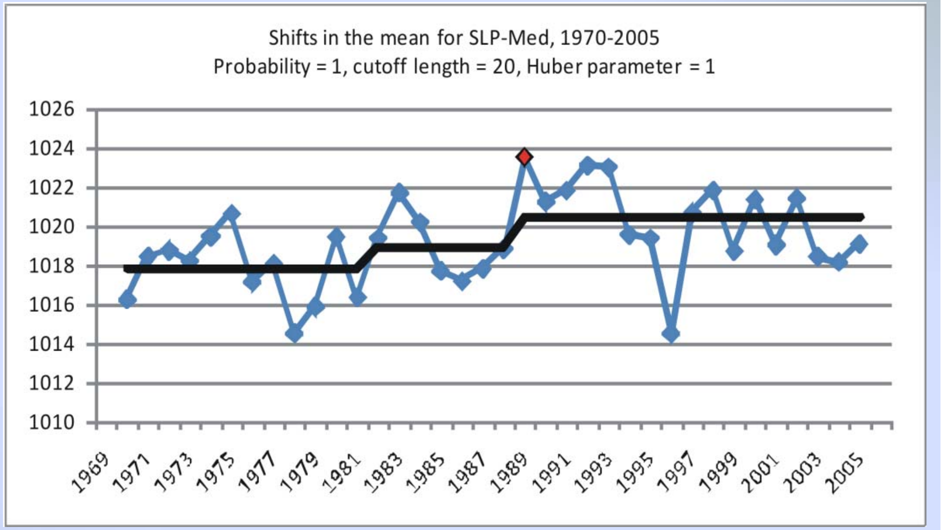
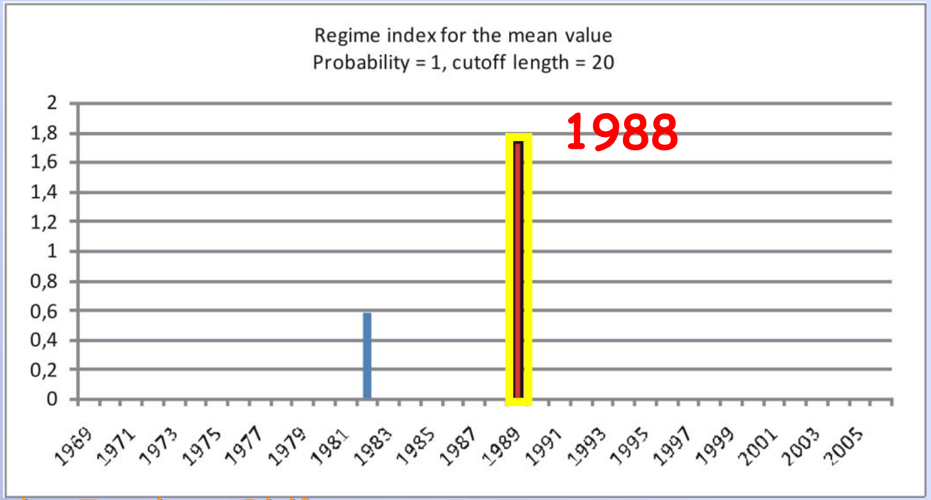



**SLP Med**



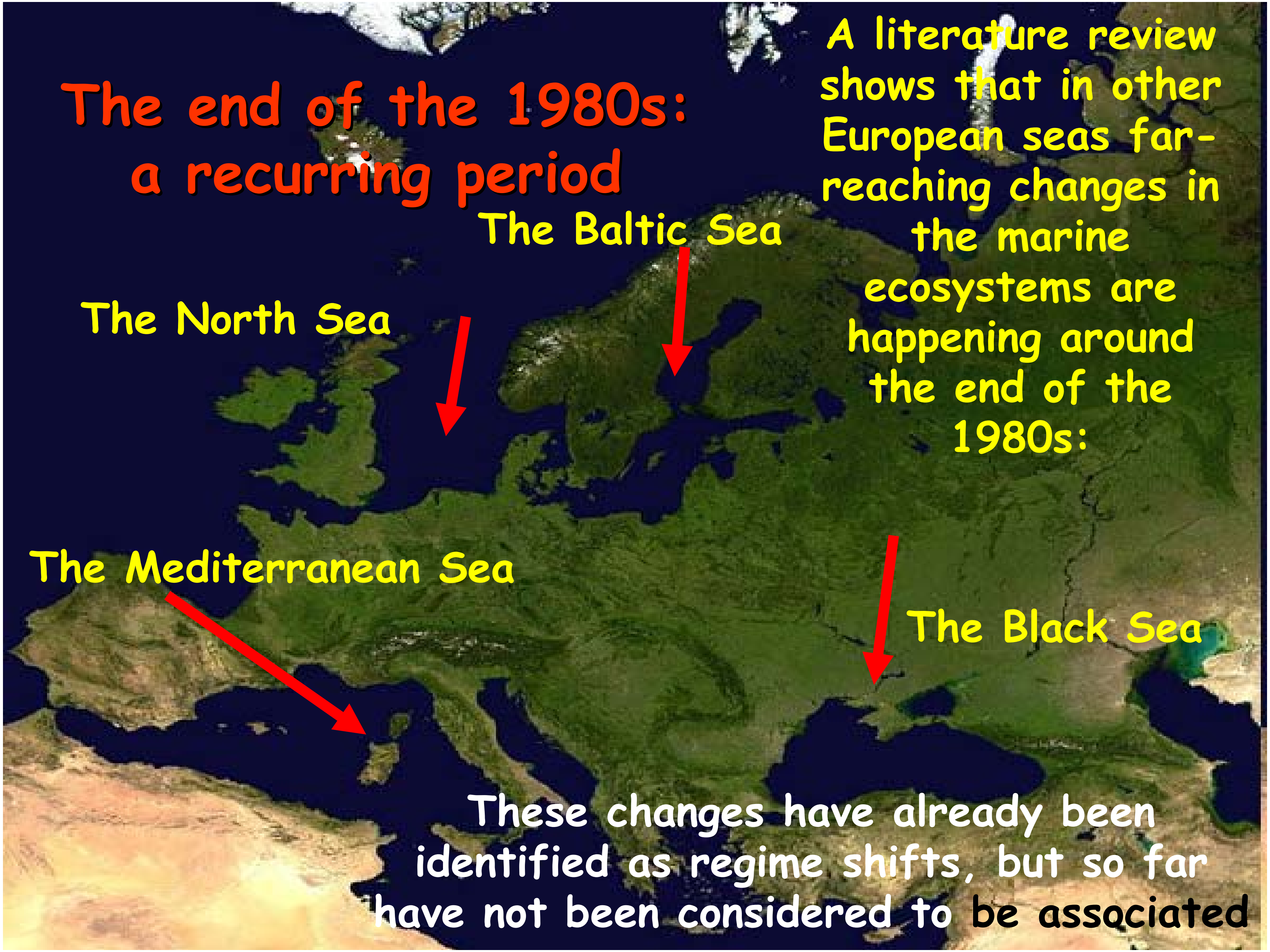

Cut-off lenght = 20
Probability level = 0.01

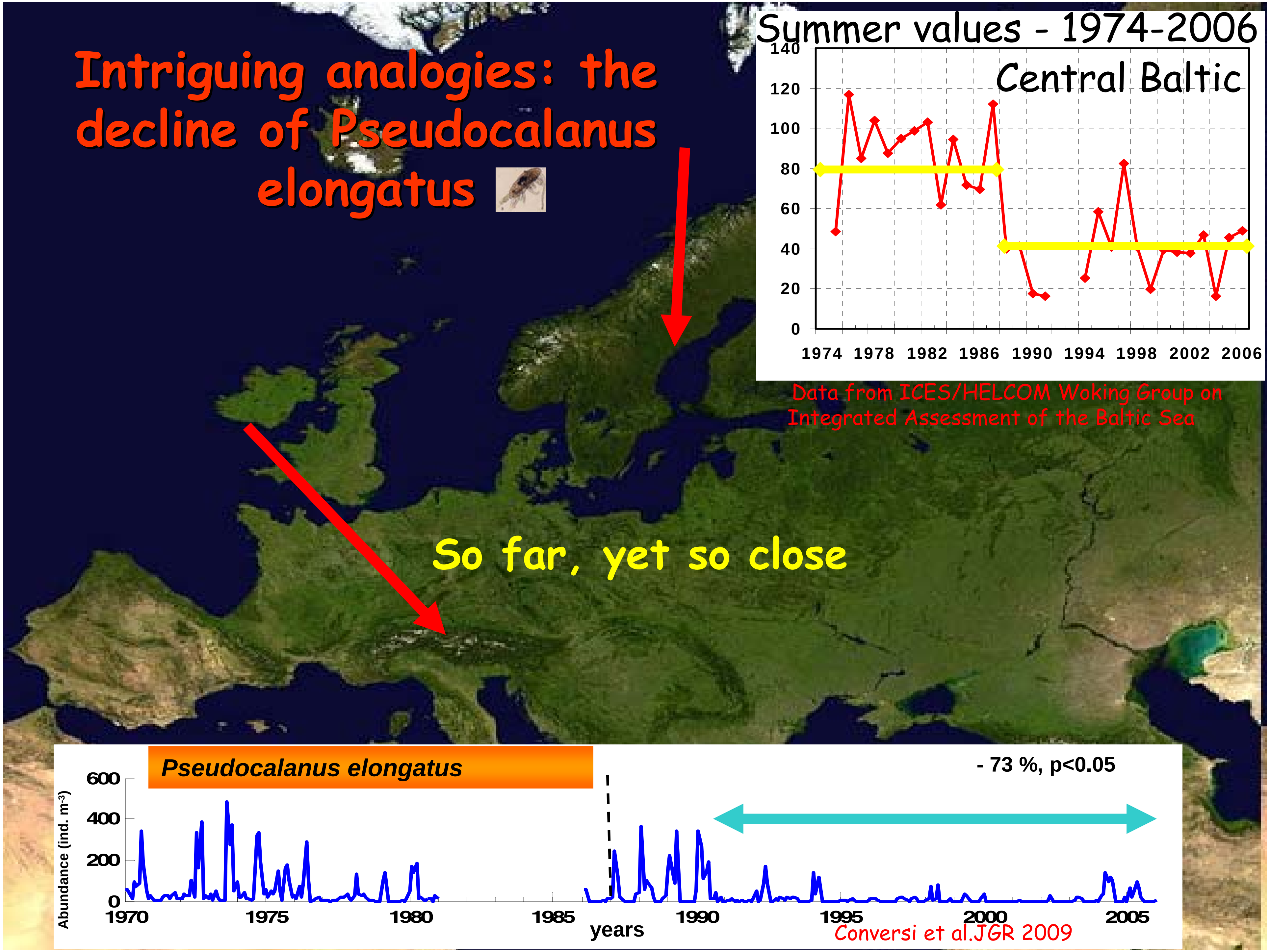
Winter SLP, averaged over the entire basin [NCEP]

# Results - 3

Regime shifts analyses support the hypothesis of an abrupt change in Mediterranean biotic and abiotic variables around 1987-88

But this period of time is peculiar


The end of the 1980s:
a recurring period
A literature review shows that in other European seas far-reaching changes in the marine ecosystems are happening around the end of the 1980s:
The Baltic Sea
The North Sea
The Mediterranean Sea
The Black Sea
These changes have already been identified as regime shifts, but so far have not been considered to be associated


Intriguing analogies: the decline of Pseudocalanus elongatus
Summer values - 1974-2006
Central Baltic
140
120
100
80
60
40
20
0
1974 1978 1982 1986 1990 1994 1998 2002 2006
Data from ICES/HELCOM Woking Group on Integrated Assessment of the Baltic Sea
So far, yet so close
Pseudocalanus elongatus
- 73 %, p<0.05
Abundance (ind. m-3)
600
400
200
0
1970 1975 1980 1985 1990 1995 2000 2005
years
Conversi et al.JGR 2009

# Hypothesis 4:

## These quasi-synchronous regime shifts are associated, part of a larger (hemispheric) scale change

Verifying this will require substantial international collaborations

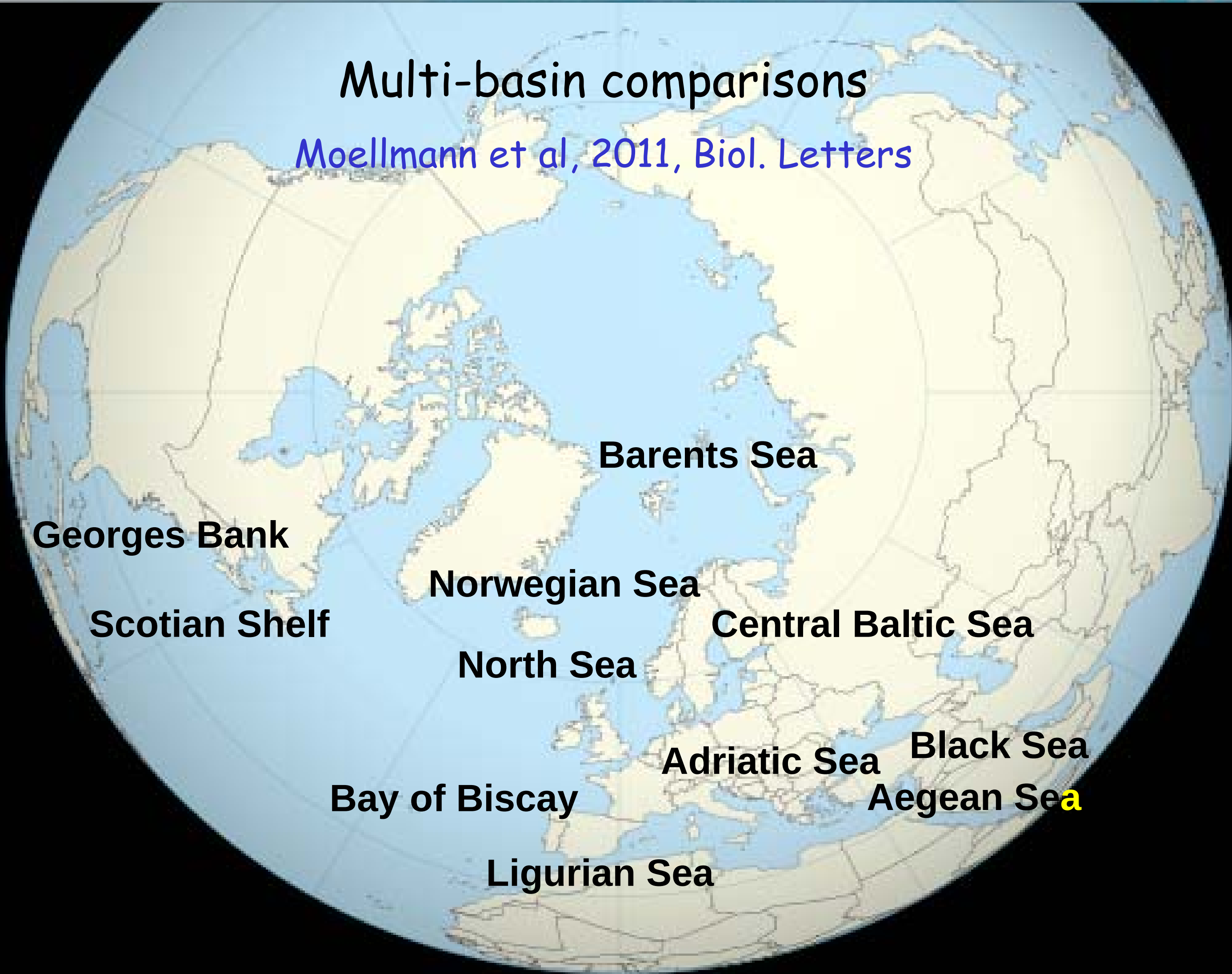
# Are they synchronous?

# Next steps:

## Multiple Basins Comparisons

# Multi-basin comparisons

Moellmann et al, 2011, Biol. Letters



# Conclusions: Significance of synchronous regime shifts

- Regime shifts have been identified for decades, in separated basins – what is <u>new</u> is the fact that, in some cases, they seem to co-occur
- In most cases, initially regime shifts have been linked to eutrophication, pollution, overfishing
- Co-occurring regime shift can provide key elements for distinguishing the above drivers (basin-related) from climate forcing (global scale)
- Their study can provide a new vision on the extent of climate forcing on shaping ecosystem variability

## Acknowledgments

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The EUROCEANS Foresight Workshop

Tiziana Peluso, Serena Fonda-Umani, Simone. Marini, Juan Carlos Molinero, Martin Edwards, Alberto Barausse, Christian Moellmann

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de Young et al, 2008, TREE

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Moellmann et al, 2011, Biol. Letters