The Mediterranean Sea: an indicator for climate changes?

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The Mediterranean Sea: a Miniature Ocean

- Being a semi-enclosed marginal basin of relatively small volume, the Mediterranean shows amplified and very fast response to climate changes.
- Mediterranean circulation is the result of a sensible and delicate equilibrium between several factors: evaporation, precipitation, river discharge and the water exchange at Gibraltar Strait.



The Past: the Mediterranean Crises

• Beginning of the History: Messinian 5 million years ago.

 Blockage of the Gibraltar Strait: the Med-Sea was dry, evaporated quite completely. A pure desert.

After the opening of the Gibraltar Strait, the basin was filled only by Atlantic water and not by the Red Sea. *Implication*: a **subtropical basin** with cold water marine species.

The last glacial episode: 18,000 years ago.

 Sea level was 1 meter less than the present level, Eastern Basin remained tropical, Central basin like present days, western basin cooler: subarctic fauna (like whales, penguins and seals) which explain why today there is a huge population of more than 3,000 blue whales.

Sapropels: 8,000 years ago.

This is a crucial period: mortality of of a huge quantity of marine organisms in a very short time due to the changing of hydrological conditions.

Sapropels: organic-rich sediments

- These were deposited during periods of of several thousands of years in a completely <u>anoxic</u> bottom-water conditions.
- This is a contrast with the modern condition of well oxygenated bottom waters.
- WHY?

Sapropels: organic-rich sediments (Continue)

• <u>The deluge</u> (the Holy Scripture): large precipitation and river (Nile) runoff in the Eastern Med formed a thin surface layer of freshwater; this layer "cut" the communication between the athmosphere and the sea water, and so under the freshwater layer, life died from lack of oxygen.





Nice, April, 29-30, 2004

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The First important human modification: the Suez Canal

• Lessepsian migration: the introduction into the Mediterranean Sea of tropical exotic species from the Red Sea through the Suez Canal.







The Present And, What about the Future?

- There are signals of climate change in the Mediterranean area.
- <u>CAVEAT</u>: Most of the scenarios related to the global change are obtained by models.

I - CONTROVERSY ABOUT GLOBAL CHANGE AND ITS IMPACTS

At a global scale, some facts are widely accepted now:

- The greenhouse effect is a scientific fact (Fourier, Arrhenius...).
- Climatic events are non-linear and most often irreversible.
- · Major uncertainties do remain and have to be handled in scenarios.
- The GHG concentration dramatically increased during the past century.
- The mean surface temperature increased by 0.6° since 1860.
- The sea level raised by 10 to 20 cm during the XX° Century.
- Rainfall increased by 0.5 to 1% per decade over most of the Northern medium/high latitude continents during the XX° Century.
- El Niño frequency and intensity increased since the mid-70s.

I - CONTROVERSY ABOUT GLOBAL CHANGE AND ITS IMPACTS

Evolution of the C0₂ atmospheric concentration (ppm) observed at the Mauna Loa Observatory, Hawaii (NASA, 1999)



I - CONTROVERSY ABOUT GLOBAL CHANGE AND ITS IMPACTS

Global air temperature anomalies record (1960-1990 baseline)



I - CONTROVERSY ABOUT GLOBAL CHANGE AND ITS IMPACTS

Projected Sea-level rise resulting from six emission scenarios (IPCC 2001)



REGIONAL ASPECTS OF CLIMATE CHANGE IN THE MEDITERRANEAN -

AN UNEP/MAP/BP & MEDIAS-France STUDY II - REGIONAL SCENARIOS - CONCLUSIONS, RECOMMENDATIONS Key results from recent studies: models intercomparison (CRU, 1996) - 2

- <u>Temperature</u>:
 - Yearly scale: temperature increase ranging from 0.7 to 1.6°. Small variations over sea, larger variations over land.
 - Seasonal scale:
 - Winter: wide extent of regions over which temperature grows more than average
 - Spring: opposite situation: large proportion of regions with warming under average
 - Summer: smaller proportion of regions with warming over average
 - Autumn: large area of strong sensitivity to climate change is evidenced.

II - REGIONAL SCENARIOS - CONCLUSIONS, RECOMMENDATIONS

Key results from recent studies: models intercomparison (CRU, 1996) - 3

- <u>Rainfall</u>:
 - Yearly scale: changes range from -12% to +13%.
 Rainfall increases in the North of basin and some parts between Italy and Tunisia.
 - Seasonal scale:
 - Winter: similar results than yearly ones, with larger variations (-2% to +26%)
 - · Spring: rainfall increase in the North and decrease in the South
 - · Summer: rainfall decrease almost everywhere
 - Autumn: rainfall decrease in the west and increase in the central and eastern parts.

What Are the present signatures in the Med-Sea?

- Temperature and salinity trends in deep water show a clear icrease starting from 1940.
- Temperature increase-> global warming?
- Salinity increase-> reduced fresh water inflow.
- <u>Models</u> show an increasing of the evaporation with respect to the precipitation/river run off.
- The eastern and western basins are more sensible to the climate changes.

What Are the present signatures in the Med-Sea? (Continue)

- <u>Dense water formation</u>: the Med-Sea is a site of formation of very dense waters: Gulf of Lion, the Adriatic Sea and the Aegean Sea. The Med transforms less saline surface Atlantic waters into deep saltier waters and send them, a century later, back to the Atlantic Ocean.
- From 1987 up to now : "East Mediterranean Transient", a phenomenon consisting in a strong production of dense water in the Aegean together with a decrease in the production in the Adriatic Sea.

Mediterranean Conveyor Belt



The Rise of Temperature and Salinity (Western Mediterranean deep waters)



East Mediterranean Transient (Cretan Sea, 1000 M depth)



East Mediterranean Transient Depth of the 29.05 Isopycnal



II - REGIONAL SCENARIOS - CONCLUSIONS, RECOMMENDATIONS

Specific impacts at regional level: agriculture

- In the North, potential yields are expected to increase for winter crops
- · In the South & Europe extreme south, the opposite is expected
- Wheat yield is expected to decrease
- Forests: substituting young plants to older ones could be beneficial
- Models accuracy (resolution, parameters) needs to be improved.

II - REGIONAL SCENARIOS - CONCLUSIONS, RECOMMENDATIONS

Specific impacts at regional level: ecosystems & biodiversity

- The Mediterranean is a hotspot ecological area.
- The present high rate of extinction is mainly induced by man.
- Climate change is likely to alter typical species composition.
- Some ecosystems could be reduced in size or cease to exist.
- Marine ecosystems are particularly threatened (climate and man)
- Arid regions ecosystems are rich but severely threatened.
- In the South, cultivated areas will increase in the detriment of forests, which raises water consumption concerns
- The opposite situation is expected in the North
- Summer heat waves can have severe implications for forest fires.

II - REGIONAL SCENARIOS - CONCLUSIONS, RECOMMENDATIONS

The state of art: an overall picture

- Downscaling from GCM results are method dependent.
- In particular, models results exhibit a tendency to excessive dryness.
- IPCC 2001 report refines/consolidates results at global scale; uncertain or ambiguous results appear when downscaling to the Mediterranean basin.
- Predictions are based upon scenarios that are always subject to uncertainties and unpredictability
- Overall temperature trends seem more reliable than rainfall pattern and extreme events trends
- Recent results tend to evidence a sea cooling contrasting with a warming over land. Nevertheless, oceanic models are still too coarse.

19