A small sea at large: Mediterranean controls on global climate

In the late 1990s, R. G. Johnson noted that the Aswan Dam on the river Nile was causing the Mediterranean Sea to become more saline. He suggested far-reaching implications for global climate, including the formation of a new ice sheet in Canada – all because of the saltier water flowing from the Mediterranean into the Atlantic. In fact, he went so far as to propose a dam across the Strait of Gibraltar to stop this from happening.

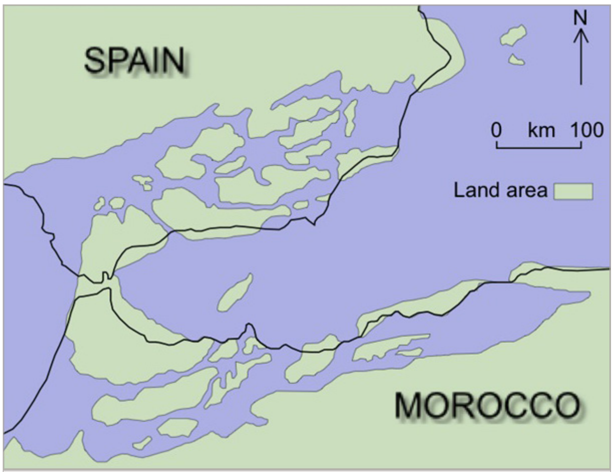
Oceans form an integral part of the global carbon cycle and also serve as a major heat sink – clearly, they play a pivotal role in the global climate system. But can a change in the salinity of a small sea such as the Mediterranean really bring about climatic change on a global scale?

Models of the present day suggest that this is indeed possible. Relatively warm, saline (and therefore dense) Mediterranean outflow water enters the Atlantic at depth and strengthens the deep-ocean part of the thermohaline circulation, the 'global conveyor belt' of currents that move water around the world. The long timescales (centuries) on which the thermohaline circulation changes, however, mean that past events may yield useful insights about potential consequences of fluctuations in Mediterranean outflow water.

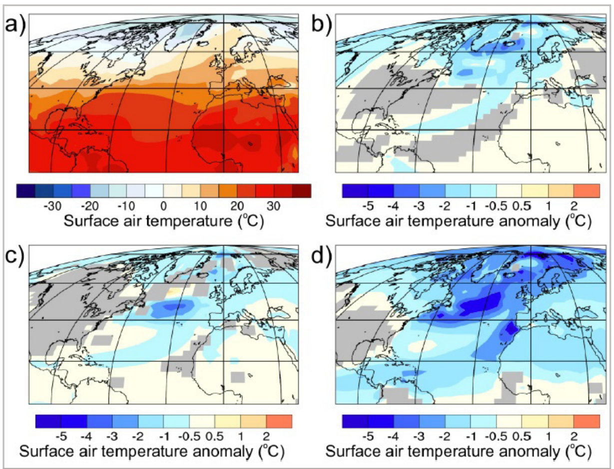
Ruza Ivanovic and her team have investigated a particularly pertinent case study of how changes in the Mediterranean have driven global climate in the past. During the so-called Messinian Salinity Crisis (MSC) between 5.96 and 5.33 million years ago, sediments show that the Mediterranean Sea underwent severe fluctuations in temperature and salinity. It may even have dried up completely at several points during this period! The team use a sophisticated general circulation model (GCM) to simulate changes in Mediterranean outflow water into the Atlantic and their global-scale climatic impact during the MSC. The results are published in Climate of the Past.

Ivanovic and her colleagues had to calibrate their GCM to simulate what Earth was like over 5 million years ago. Back then, our planet was warmer and wetter on average and the Himalayas and Rocky Mountains were lower, so the distribution of vegetation – an important carbon sink – was different. The Antarctic and Greenland ice sheets were smaller than they are today, so sea levels were 25 m higher. Finally, the Central American Seaway between North and South America was still open and the thermohaline circulation was weaker. All these changes mean that fluctuations in the Mediterranean had a greater impact on global climate back then than they would today.

The researchers first ran their 'Messinian' GCM for a period of 2,400 years to allow a steady state to emerge. From this steady state, they simulated several different extreme scenarios of Mediterranean hypersalinity, freshening (becoming less saline) and different outflow strengths, and compared their outcomes to a control scenario with no changes.



The Messinian Salinity Crisis is thought to have been caused by extreme restriction of the exchange between the Mediterranean and the Atlantic. The black lines show the present-day Strait of Gibraltar as delineated by the coasts of Spain and Morocco. During the salinity crisis, the green land areas limited flow. (Credit: Ivanovic)



Surface air temperatures during the initial steady state are shown here in panel a). Panels b) and c) show changes relative to this steady state in two different scenarios with elevated Mediterranean salinity levels, while panel d) shows what happens if the Mediterranean freshens. (Credit: Ivanovic et al., 2014)

Ivanovic and her team found that if the Mediterranean were to dry up so that no water enters the Atlantic, the Labrador Sea east of Newfoundland would become warmer, raising temperatures across Canada. In the Messinian, then, damming the Mediterranean as Johnson proposed would indeed have prevented the formation of a new Canadian ice sheet.

Increasing Mediterranean salinity (and therefore increasing density) produces marked cooling in the north Atlantic and over Canada, Greenland and Europe. Dense, deep water normally flowing south from the far northern Atlantic is essentially replaced by Mediterranean outflow water so that the northern latitudes remain cooler.

Conversely, a freshening Mediterranean becomes less dense than the Atlantic, meaning that water flows into the ocean at the surface rather than at depth. The entire Atlantic water column freshens, with extreme and widespread consequences. The thermohaline circulation breaks down completely in the Atlantic, so warm, tropical water no longer reaches higher latitudes. Cool, fresh water even spreads into the Pacific through the Central American Seaway. As a result, the entire northern hemisphere cools by as much as 8 °C. On the other hand, parts of the southern hemisphere experience some warming because cold, north Atlantic water is no longer transported south.

The Earth was a very different place during the MSC than it is now, so naturally the results Ivanovic and her colleagues obtained differ from studies looking at present-day climate. Then as now, however, it is clear that R. G. Johnson was not exaggerating when he claimed that the Mediterranean could wreak havoc with global climate. It remains to be hoped that potential far-reaching impacts are considered when planning future mega-projects like the Aswan Dam.

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References

Ivanovic, R. F. et al.: Sensitivity of modern climate to the presence, strength and salinity of Mediterranean-Atlantic exchange in a global general circulation model, Clim. Dyn., 42(3–4), 859–877, 2014

Ivanovic, R. F. et al.: Modelling global-scale climate impacts of the late Miocene Messinian Salinity Crisis, Clim. Past, 10, 607–622, 2014

Johnson, R. G: Climate control required a dam at the Strait of Gibraltar, Eos Trans. AGU, 78(27), 277–281, 1997

Nuccitelli, D. et al.: Comment on 'Ocean heat content and Earth's radiation imbalance. II. Relation to climate shifts', Phys. Lett. A, 376(45), 3466–3468, 2012

Local flaring, global impacts: modelling Arctic black carbon

Although most of the Earth's population isn't aware of it, the Arctic is burning. The flames are being fed by natural gas produced as a by-product of crude oil extraction, which is then flared away at the surface. Although practiced worldwide, high-latitude gas flaring has the greatest impact on the fragile Arctic environment. Since the black carbon emissions resulting from flaring know no national boundaries, only a global solution will bring about results to improve conditions in the Arctic.

The flaring of natural gas impacts the Arctic (Credit: Fabien Darrouzet, distributed via imaggeo.egu.eu)

Modelling black carbon

Black carbon (soot) and other combustion emissions from flared natural gas are released into the Earth's atmosphere where they move in patterns that atmospheric scientists try to model. However, standard models have trouble predicting the patterns of black carbon transport into the Arctic. This has been confirmed by Andreas Stohl of the Norwegian Institute for Air Research and his collaborators. According to their research, published in Atmospheric Chemistry and Physics, the atmospheric concentration of black carbon found in the Arctic is underestimated by all existing models.

What makes the Arctic atmosphere so difficult to model? It is a combination of factors, including the complex seasonal changes that occur in higher latitudes (above 40 degrees). The relative inefficiency of aerosol removal in late winter and spring, known as the Arctic Haze phenomenon, also complicates the modelling process.

"It is the removal of black carbon from the atmosphere that is so difficult to model. Black carbon is mainly scavenged by precipitation, which is relatively inefficient in the period between January and March, but the deposition is not very well modelled and the existing models do not show enough black carbon being transported into the Arctic in relation to ground measurements," said Stohl.

The politics of flaring

It is not always clear how much associated natural gas will be produced from an oil well, and it may change in amount, quality and chemical composition over the life of a field. Producers often find