Water balance in the Black Sea

SIR—Murray *et al.*[1] suggest that the combined pycnocline/chemocline in the Black Sea has risen unexpectedly and at an alarming rate. Their argument rests on the comparison of the RV *Atlantis* II hydrographic station 1445 of March 1969, to the *RV Knorr* June 1988 station BS3-2, about 30 nm away in the western Black Sea basin. The two records showed a 0.1‰ increase in salinity between a depth of 50 and 100 m and a rise of the chemocline by 30 m. Murray *et al.* suggest that the water balance of the Black Sea has been upset by a decrease in discharge of Soviet rivers. To compensate, the input of Mediterranean water through the Bosphorus should have been higher. Indeed, a rough calculation of the water and salt balance based on this comparison does not exclude such an interpretation.

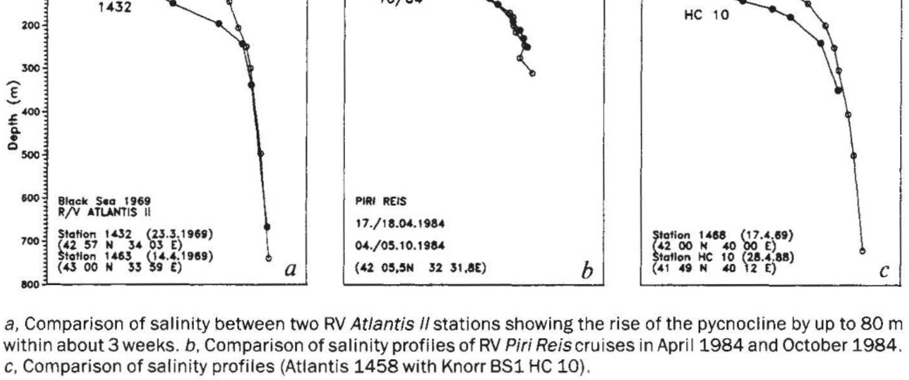
This interpretation, however, may be countered by field observations. For examples, stations Atlantis 1432 (23 March 1969) and 1463 (14 April 1969) were just a few miles apart but showed within three weeks a rise in the salinity profile of up to 80 m between 20 and 220 m depth, that is, a much larger rise than the one reported by Murray *et al.* (*a* in the figure). Second, our salinity measurements during the RV Piri Reis Black Sea cruises of 1984 show a rise of the pycnocline of 15 to 20 m between April and October (*b*). Third, during leg 1 of the *Knorr* Black Sea cruise (16 April–9 May 1988)[2], many conductivity–temperature–depth (CTD) stations were occupied (using the same Seabird CTD as Murray *et al.* and an independent instrument) throughout the entire southern Black Sea.

Nine of these stations can be compared with nearby former Atlantis stations. Seven of them show a higher interface in 1988 than in 1969, but two stations from the eastern Black Sea show a much deeper interface (*c*). Thus the interface seems to be intensively warped, possibly more pronounced in April 1988 than in March–April 1969. A net long-term rise cannot, however, be ascertained, at least not without mapping the interface throughout the entire basin simultaneously. Finally, we also occupied stations near the coast twice within a few hours and observed that the pycnocline moved up and down by several tens of metres between casts. These movements warp the chemocline along the coast and are associated with features of the coastal currents or with internal waves travelling along the pycnocline.

Variations in chemo- and pycnocline depths are strongly coupled. Our measurements of dissolved phosphate in May 1988 show upward movements similar to those observed by Murray *et al.* in the western Black Sea. In the eastern basin a depression of about 30 m was found relative to that at *Atlantis* station 1463. The structure of the manganese particle layer, which is found at the +100 mV level in the redoxcline (and associated with a density of 16.1–16.3σθ) may be indicative of the prevalent transport processes. The layer is deeper, more intense and thicker near the coast. It is often split into several sheets, each measuring a few metres in thickness only.

These sheets may represent layers of the water advecting laterally with different velocities. They could transport cold intermediate water towards the centre of the gyres causing a rise of the pycnocline offshore while at the same time warm and low-salinity surface water is displaced from the centre towards the margins of the Black Sea. Such a change could come about by more intensive coastal surface currents triggered by winter storms. This model would also fit the observations, suggesting laternal transport of resuspended shelf sediments within the upper 200 m of the water column and indicating radical changes in the annual vertical particle flux in the upper part of the water column[3,4,5].

We therefore believe that the observed differences between 1969 and 1988 are associated with interannual changes in the intensity of Black Sea surface currents and with internal waves rather than with anthropogenic changes of the Black Sea water balance.



a, Comparison of salinity between two RV *Atlantis II* stations showing the rise of the pycnocline by up to 80 m within about 3 weeks. *b*, Comparison of salinity profiles of RV *Piri Reis* cruises in April 1984 and October 1984. *c*, Comparison of salinity profiles (Atlantis 1458 with Knorr BS1 HC 10).

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Random thoughts

SIR—A minor slip in Hubert P. Yockey's most informative letter "When is random random?" (*Nature* **344**, 823; 1990) requires clarification. He writes: "Thus it is clear that pi and all other transcendental numbers have a finite amount of information, namely, that in the algorithm by which they are calculated." From this statement one would infer that every transcendental number may be calculated by some algorithm. But there are only countably many algorithms and uncountably many transcendental numbers. Hence one cannot conclude from Yockey's argument that each transcendental number contains only a finite amount of information. This issue is, of course, only incidental to the point of his letter.

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SIR—The discussion about the meaning of 'random' needs to take into account two separate uses of the word. Information-theoretic or algorithmic approaches to measuring the randomness in a sequence of digits may be appropriate after the sequence has been generated or defined, but there is also a sense in which a process may be agreed to be random before it has been used to generate any sequences whatever. A sequence produced by a random process is not necessarily random.

Yockey (*Nature* **344**, 823; 1990) blurs the distinction by using the name 'Bernoulli chains or strings' for the actual sequences of heads and tails (say) generated by what probabilists have long called 'Bernoulli trials'. It is not necessarily true that '[i]n the case of a sequence of heads and tails generated by

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