Putting the brakes on the hurricane heat engine

Kerry Emanuel's elegant description of hurricanes as heat engines (PHYSICS TODAY, August 2006, page 74) leads to the question of whether it might be possible to weaken a hurricane by interfering with that engine. It is well known that covering the water with a surfactant can reduce water evaporation by an order of magnitude. If that could be done in advance of a hurricane, the amount of latent heat of condensation available to drive the storm would be reduced.

Dispensers of surfactant could be placed on the ocean floor in the path of a hurricane. They could be distributed by aircraft along the storm's path a few days before its predicted arrival, or earlier and more broadly on the continental shelf, and opened by acoustic signal when a storm is imminent. The quantity of surfactant required is modest: Covering a 100 km × 1000 km storm track with a monolayer requires only about 100 tons.

The important questions are how long the surfactant layer would last (it could be continuously replenished by suitable dispensers), how effective it would be in reducing evaporation in real near-hurricane ocean conditions, and how much effect it would have on the hurricane. These questions can only be answered empirically, but the cost of such an experiment would be much less than the damage—tens of billions of dollars—that a severe hurricane would do to a populated seacoast.

Jonathan Katz
(katz@wuphys.wustl.edu)
Washington University in St. Louis
St. Louis, Missouri

Emanuel replies: Jonathan Katz advances the intriguing idea that hurricanes could be mitigated by attacking the air–sea interface, through which enthalpy must flow to power the storms. The notion that the fluxes could be reduced by applying a surfactant was first proposed, to the best of my knowledge, by Robert Simpson and Joanne Simpson.[1] But the idea remained on the table for decades and has yet to be adequately tested. A few years ago, Moshe Alamaro and I did experiment with surfactants using a wind–wave flume, a laboratory apparatus in which air is moved at high speed over a water surface. We confirmed that at low wind speeds, surfactants dramatically reduced surface enthalpy flux. But at high speeds, the surfactant layer disintegrated and showed no measurable effect on the fluxes. We were only able to experiment with a limited number of candidate substances, but, given the stakes, this idea is surely worth deeper exploration.

Reference

1. R. Simpson, J. Simpson, *Trans. NY Acad. Sci.* **28**, 1045 (1966).

Kerry Emanuel
(emanuel@texmex.mit.edu)
Massachusetts Institute of Technology
Cambridge

Postscripts on geodynamo's beginnings

I agree with Henry Kolm that we need to "stand on the shoulders of giants" (PHYSICS TODAY, October 2006, page 14), but he needs to put his giants in the right place, and get his facts right.

Much of my 1949–52 PhD work at the University of Manchester in the UK was a laboratory-model simulation and extension of an early idea of Edward Bullard's that a single eddy in Earth's core could perturb the dipole field sufficiently to give a local focus of the nondipole field. Toward the end of that work, my fellow student Arvid Herzenberg became interested and produced a formal algebraic solution; in 1957 the two aspects were reported together.[1] Herzenberg then extended his work on a single eddy to two eddies, and showed that such a two-eddy situation could give a self-exciting dynamo.[2]

But Herzenberg's paper was highly mathematical; it also considered only a steady-state situation, while the geomagnetic dynamo was reversing intermittently. By then I was teaching at Newcastle, so I selected a promising graduating student, Ian Wilkinson, and we set about building a laboratory-scale, self-exciting dynamo based on Herzenberg's geometry. In 1963 we reported steady-state self-excitation.[3] Our dynamo was made of Perminvar, a magnetically soft steel alloy, and used 3.5-cm-diameter half-cylinders (not the "two meters" Kolm states). The cylinders rotated with their axes at right angles in a larger stationary block, with a thin layer of mercury (not just "equatorial") between the rotors and the block. By going to a larger system made of annealed mild steel, with 5-cm-diameter rotors and variable geometry, we eventually produced a reversing dynamo. Kolm says that the field "reversed its direction every 20 minutes," giving a period of 40 minutes. However, we reported that the reversals "mostly had a period of the order of 5 minutes, but that periods up to 20 minutes have been observed."

In a separate approach in 1955, Bullard published the results of numerical integration of a very simple lumped-constant dynamo model. In that model, based on a Faraday-disk dynamo, the output current flowed through a coil to give positive feedback to the initial imposed axial magnetic field.[4] Essentially it was a single-stage amplifier with positive feedback; depending on the conditions, it could give periodic oscillation but no reversals. In 1958 Tsuneji Rikitake (in Tokyo, and never Bullard's student) extended the lumped-constant model to two Faraday disks in series.[5] His model was equivalent to a two-stage amplifier with positive feedback; under certain conditions, it could give oscillations of increasing amplitude, which led to reversals. But the reversals were not periodic; that model is now recognized as an example of a chaotic system.

I have some other comments: The best-fit dipole is currently about 500 km from the geocenter—about 4%, not 10%, of Earth's diameter. Also, the geomagnetic field does not reverse periodically; it is because the reversal record is so erratic that it can be used for dating rocks.

References

1. A. Herzenberg, F. J. Lowes, *Philos. Trans. R. Soc. London Ser. A* **240**, 507 (1957).
2. A. Herzenberg, *Philos. Trans. R. Soc. London Ser. A* **250**, 543 (1958).
3. F. J. Lowes, I. Wilkinson, *Nature* **198**, 1158 (1963).
4. E. C. Bullard, *Proc. Cambridge Philos. Soc.* **51**, 744 (1955).
5. T. Rikitake, *Proc. Cambridge Philos. Soc.* **54**, 89 (1958).

Frank Lowes
(f.j.lowes@ncl.ac.uk)
Newcastle University
Newcastle upon Tyne, UK

Kolm replies: I think Frank Lowes's memory is as overpacked as mine. The essence of our disagreement is that he remembers a 1963 model with 5-centimeter-diameter rotors, reversing at a 5-minute period, while I remember seeing a model with 1- to 2-meter-diameter rotors reversing at 20-minute (not 40-minute) periods at a 1967 symposium at the University of Newcastle.[1]

A dynamo of that size is not easily forgotten. The model towered above the heads of the crowd. It was described in the symposium presentation as the "Bullard–Rikitake model," so I assumed that it was based on Bullard's collaboration with a thesis student.

I don't want to engage in a polemic, but I do want to record two facts. First, Earth's magnetic field in the southern Atlantic Ocean is about one-third as strong as it is in diametrically opposite northern Siberia. I measured it with a proton precession magnetometer aboard the research vessel *Pilsbury* in 1968, and I doubt that displacement of a dynamo by only 4% of Earth's diameter will account for so large a difference. Maps of Earth's magnetic field, published by the US Office of Naval Research, confirm the difference. I was searching for magnetic monopoles in deep-sea sediment at the time.

Second, my invitation to the symposium was prompted by Bullard's interest in my published supposition that reversals of Earth's magnetic field might be caused by the planet's encountering magnetic monopoles. Monopoles would have been attracted to Earth's opposite poles and trapped in deep-sea sediment or in surface outcrops of magnetite or hematite.[2] My supposition was later disproved when I found no monopoles in deep-sea sediments or surface outcrops.

References

1. S. K. Runcorn, ed., *The Application of Modern Physics to the Earth and Planetary Interiors*, Wiley Interscience, New York (1969).
2. H. Kolm, *Sci. J.* **4**, 60 (1968). See also H. Kolm, F. Villa, A. Odian, *Phys. Rev. D* **4**, 1285 (1971).

Henry H. Kolm
(henrykolm@concast.net)
Francis Bitter National Magnet Laboratory
Massachusetts Institute of Technology
Cambridge

Correction

May 2007, page 64—The Hoover Institution was mistakenly referred to as the Hoover Institute. ■