That's a lot of water

Watching the ocean's ebb and flow may be soothing, but the history of the sverdrup unit for ocean flow is more turbulent. Tor Eldevik and Peter Mosby Haugan recount an oceanographic journey reaching high tide with Harald Ulrik Sverdrup and his unit.

One million cubic metres of water per second is about five times what is carried by the world's largest river, the Amazon, or a melt rate that would leave Greenland ice-free in 90 years and cause a global sea level rise of 8 centimetres per year in the process. And it is one sverdrup, the unit used to measure ocean flow (Sv; not to be confused with the SI-unit sievert for radiation doses).

Incidentally — or actually not, as we will see below — 1 Sv is the influx of Pacific water to the Arctic through the Bering Strait. At the antipodal extreme, the Antarctic Circumpolar Current — the giant flow circulating Antarctica and interconnecting all the world oceans in the south — is estimated to exceed 100 Sv. The Atlantic Ocean's net flow of temperate water towards the Arctic, fed by the Gulf Stream, peaks at almost 20 Sv. With an approximate 20 °C cooling en route polewards, it gives up in excess of 1 PW of heat to the northern atmosphere — a climatic energy flux two orders of magnitude larger than the world's total energy consumption.

The sverdrup is named in honour of the Norwegian oceanographer, meteorologist and polar explorer Harald Ulrik Sverdrup (1888–1957; pictured). His volume *The Oceans*¹ (with Martin W. Johnson and Richard H. Fleming), published in 1942, concluded the realization of oceanography as a science based on first principles, guided by a revolution in observational procedures and analyses during the first half of the twentieth century.

Present-day earth scientists are probably most familiar with Sverdrup for explaining the gyre circulations spanning the world oceans. The vigour of the gyres, observable from space, follows directly from knowing the trade winds. Sverdrup thus unified the two defining features for the historical sailing routes connecting continents.

The questions of how fast, how deep or how voluminous are a human obsession. Scientific surveys to quantify the volumetric transport of ocean currents go back at least to the nineteenth century with the successful estimation of the Gulf Stream's vigour. However, the first modern-style oceanographic campaign has been attributed

Credit: UC San Diego Library

to Count Luigi Ferdinando Marsili. In 1680, he explained the exchange flow of the Bosphorus connecting the Mediterranean and the Black Sea based on the trinity of theoretical consideration, dedicated observations and accompanying experiment².

Marsili showed how the 'weight' of the saline (and thus heavier) Mediterranean water drives a northward flow at depth with a compensating southward flow of fresher Black Sea water in the surface. His observational design included a very early current meter — a wheel of paddles — and he furthermore proved his exchange-flow concept experimentally. Considering that Marsili's work preceded both Newton's *Principia* and Bernoulli's principle, his appreciation of pressure at work — and even in the ocean — is remarkable.

The young Sverdrup also advanced current measurements as the scientific leader of Roald Amundsen's *Maud* expedition (1918–1925). He detailed the Arctic tides using the prototype Sverdrup–Dahl electric current meter constructed while on board. Even though Amundsen's quest to reach the North Pole failed, the expedition was an unprecedented success in observing the unknown Arctic from its marine geology, via the tides to the Aurora Borealis.

The Arctic is also the origin of sverdrup, the unit. In the 1950s and early 1960s both Soviet and North American scientists contemplated the damming of the Bering Strait. The idea was that the Arctic Ocean would be dominated by temperate Atlantic water — thus making, for example, Siberia

and northern Canada more habitable — by blocking the relatively cold inflow of Pacific water.

The consequential accounting of the numerous branches of ocean circulation within and beyond the Arctic was critical to these considerations. While assessing the dam in the context of 'the living resources of northern Canada'³, the Canadian oceanographer Maxwell Dunbar found the repetitive reference to millions of and cubic meters per second "very cumbersome" and proposed in passing "that a new unit of water transport be adopted, [...] a 'Sverdrup' after Dr. H. U. Sverdrup. Let us take it, then, for purposes of argument, that the inflow through Bering Strait is one Sverdrup." After reiterating his proposition at an international gathering of oceanographers⁴ — in response to Håkon Mosby, the grandfather of the second author of this Measure for Measure — the sverdrup soon made its way into common use⁵.

The idea of a dam was discarded for all the uncertainties inevitably associated with continental-scale climate and ecosystem manipulations. It is less reassuring that the idea has recently resurfaced as a means to combat global warming. And this time around, the argument is the opposite: that a dam will help to preserve the Arctic cryosphere. If anything, this proves the point from some 60 years ago that the implications of geoengineering are uncertain. □

Tor Eldevik^{1,2} ✉ and
Peter Mosby Haugan^{1,3} ✉

¹Geophysical Institute, University of Bergen, Bergen, Norway. ²Bjerknes Centre for Climate Research, Bergen, Norway. ³Institute of Marine Research, Bergen, Norway.

✉e-mail: tor.eldevik@uib.no; peter.haugan@hi.no

Published online: 6 April 2020
<https://doi.org/10.1038/s41567-020-0866-0>

References

1. Sverdrup, H. U., Johnson, M. W. & Fleming, R. H. *The Oceans, Their Physics, Chemistry, and General Biology* (Prentice-Hall, 1942).
2. Pinardi, N. et al. *J. Phys. Oceanogr.* **48**, 845–860 (2018).
3. Dunbar, M. J. In: Bladen, V. W. (ed.) *Canadian Population and Northern Colonization* 125–135 (Univ. Toronto Press, 1962).
4. Vowinkel, E. In: *Proc. Arctic Basin Symposium October 1962* 84–85 (Tidewater, 1963).
5. Pickard, G. L. *Descriptive Physical Oceanography* (Pergamon, 1964).