Discovering the Indonesian Throughflow

BY KLAUS WYRTKI

In the summer of 1954, I accepted a position as an oceanographer at the Marine Science Institute in Djakarta, Indonesia. When I arrived in November 1954, I found out that all the Dutch scientists had left—I was the only scientist and the director of the institute. I had a fine, almost new research vessel, the 200-ton *Samudera*. It had only six Nansen bottles, one bathythermograph, and two winches with about 1500 m of wire. I also inherited a well-established "ship-of-opportunity" program, which collected salinity samples over the entire Southeast Asian waters from Hong Kong to Singapore, to Jakarta, to Ambon. We issued monthly maps of surface salinity for the region. Surface salinity offered much insight into the advection of water in this area, which has such a pronounced annual reversal of the circulation.

Because the *Samudera* offered only limited possibilities for research, I soon decided to concentrate on analyzing existing data. My goal was to give a comprehensive description of the circulation and the water masses of the entire Southeast Asian waters. I realized that by combining information from sources such as surface currents, dynamic calculations, sea-level observations, property distributions, and water-mass analysis, one could obtain a better understanding of the circulation than would be possible from each component alone.

As a starting point, I constructed monthly maps of the surface circulation based on ship-drift observations. These charts led me to wonder where all the water goes that flows east in the Java Sea during the northwest monsoon, and where the water comes from during the opposite season. The source had to lay in the Eastern Archipelago, in particular,

Figure 1. Left: The Indonesian Research Vessel *Samudera* in 1957. Above: Klaus Wyrtki and a technician with Nansen bottles.

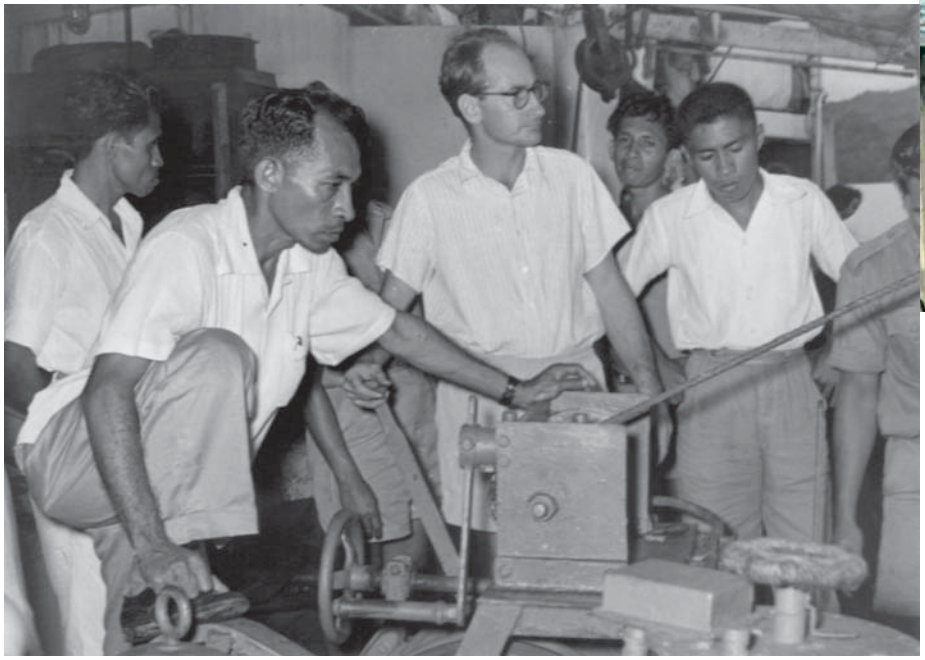

Figure 2. Left: Klaus Wyrtki and technicians on the winch. Above: A technician removing a Nansen bottle from the wire.

the Banda Sea. Studying the data from the *Snellius* expedition of 1929, I found that their observations were made during October near the end of the southeast monsoon season. So I decided to conduct an expedition into the Banda Sea to observe the conditions in March, at the end of the northwest monsoon. The difference between the two surveys was striking. From March to October the thermocline had risen dramatically, indicating the presence of strong upwelling.

As a next step, I tried to construct maps of the region's mass transport based on surface currents, dynamic calculations, and sea-level observations. These maps showed an inflow of water from the Pacific into the Eastern Archipelago during the northwest monsoon and an outflow to the Indian Ocean during the southeast monsoon. The maps also made it clear that the seasonal upwelling and sinking in the Banda Sea was intimately related to these changing flows. Furthermore, important evidence for the throughflow came from a flow of high-salinity water from the Pacific into the Eastern Archipelago at a depth of about 150 m within the thermocline. This flow reaches as far as the Timor Sea. Other evidence came from the spreading of low-salinity water from the Banda Sea into the Indian Ocean at a depth of about 1000 m.

The discovery of the throughflow was a by-product of my attempt to understand and document the circulation in the Southeast Asian waters. Like many new discoveries, this one was incomplete. I underestimated the magnitude of the throughflow, and I did not think that the bulk of it goes through the Makassar Strait even though I was aware of the current measurements by the *Snellius* that showed a southward flow in the Makassar Strait. On the other hand, the determination of the annual cycle and its relation to the monsoons was correct.

I presented this discovery of a throughflow from the Pacific to the Indian Ocean for the first time at the Pacific Science Congress in Bangkok in 1957, but the results were not published until 1961. It is very gratifying to know that this early study has stimulated a great deal of additional research on this important link in global ocean circulation. I am sure that the extended direct measurements of the throughflow that are now underway will eventually determine its correct magnitude and variations and will form the basis for a continuous monitoring of the circulation in this region.

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