Resolving Equatorial Circulation in Time and Space

The evolution of our knowledge of Pacific equatorial circulation: Klaus Wyrtki's leadership.

- Large-scale description and monitoring
- The NORPAX Tahiti Shuttle
- Subsequent developments
Geostrophic transports of the Pacific equatorial countercurrent are calculated for 79 sections. A thermoclinic method, using only bathythermograph sections to estimate transports, is introduced and compared with the results of the geostrophic calculations. Thermoclinic transports are then estimated for 50 bathythermograph sections. It is shown that the average transports of the countercurrent decrease from about 40 million m³/sec in the western part of the Pacific Ocean to termination off the coast of Central America. The transports are highly variable but indicate a weakening of the current in the period March to June.
An Equatorial Jet in the Indian Ocean

Abstract. At the surface of the Indian Ocean along the equator a narrow, jet-like current flows eastward at high speed during both transition periods between the two monsoons. The formation of the jet is accompanied by thermocline uplifting at the western origin of the jet and by sinking at its eastern terminus. This demonstrates that a time-variable current can have profound effects in changing the mass structure in the ocean.

The Wyrtki Jet
From ship drift observations

Fig. 1. The equatorial jet in the Indian Ocean in May and October shown by surface current vectors for all 1-degree squares where the speed exceeds 20 miles per day (43 cm/sec), according to data in (1).
Island sea level for monitoring currents


Higher frequency (34-day period) signals in sea level:

Fig. 1. Meridional profile of dynamic height relative to 500 db averaged zonally between 140W and 170E together with positions of sea level stations, topographic features, and currents.
NORPAX Tahiti Shuttle

Use multiple cruises, flights, and instruments to resolve meridional and temporal variability for more than one year. 15 cruises, 43 sections, Feb. 1979 to June 1980.

- 1000-m CTD, 1-degree spacing increasing to 0.5 degree near equator.
- Profiling current meter (Düing profiler), upper 500 m
- Early Doppler profiler, 117-m range (see Luther and Johnson, 1990, JPO)
Fig. 1. Location of the Shuttle Experiment showing the ship track, aircraft sections, and sea level stations.

Figure from:

How I came to work with Klaus

Two circumstances:

1. Work in the Indian Ocean as a student, 1975 and 1976, using the PCM in INDEX.

2. Tragic loss of the Holo Holo on Dec. 11, 1978, with Bob Harvey and Mike Allen among those aboard.
INDEX: Pilot studies on La Curieuse

- 68-foot wooden schooner, based in Mahe, Seychelles
- 8 cruises in each of 1975, 1976, February-June
- Currents relative to about 300 m via PCM
- 0.5° sampling, 3°S to 2°N, on 55.5°E
- Purpose: define the time-evolution of the EUC, from NE to SW monsoon.
- No Wyrtki jet was seen during transition; maybe we were too far to the west.
The Wyrtki Jet
From ship drift observations

Fig. 1. The equatorial jet in the Indian Ocean in May and October shown by surface current vectors for all 1-degree squares where the speed exceeds 20 miles per day (43 cm/sec), according to data in (1).
Tahiti Shuttle results

- Mean hydrographic structure, and currents, and the annual cycle for a “typical” year.
- 8° span of longitude is too small to measure a zonal gradient with this sampling.
- Hint of deeper eastward flows in the geostrophic currents relative to 1000 m.
Example PCM zonal current relative to 300-500-m avg.
Wyrtki et al., 1981, Science

Fig. 4. Profiling current meter measurements at 153°W during January 1980. (A) Zonal component of the current (in centimeters per second) relative to the average current between 300 and 500 m and (B) temperature. Eastward transport is positive.
Transports from PCM sections; unresolved high-frequency variability and a well-defined annual cycle.

Wyrtki et al., 1981, Science

Fig. 5. Transport of undercurrent and the overlying South Equatorial Current relative to the 300- to 500-m layer at (●) 150°W, (■) 153°W, and (▲) 158°W. Eastward transport is positive.

1-year mean geostrophic flow relative to 1000 dbar.
PEQUOD Line Islands Profiling Project

- Equatorial Deep Jets: spatial structure and temporal evolution—do they propagate vertically?
- Use Pegasus, an acoustically-tracked dropsonde, to make full-depth absolute velocity profiles at 0.5° intervals from 3°S to 3°N on 159°W.
- Chartered auxiliary-powered staysail schooner (Machias).
- Based in Fanning Island (Marty Vitousek's research station).
- 21 cruises, March 1982 to June 1983
Figure 3. Average (a) and standard deviation (b) of the zonal current component during the 16 months of observations. Contours are on integral multiples of 10 cm/s, and there are additional contours at ±2.5 and ±5 cm/s. Westward flow is shaded.
1982-83 El Niño

Surprise! No big western buildup, odd timing, STRONG El Niño—not what we were looking for, but...

Fig. 1. Zonal velocity component on the equator at 159°W. Contour intervals are 20 cm/sec, with westward flow indicated by dashed lines. Tick marks at top show observation times. The EUC (shaded) was virtually absent from September through December 1982.
Subsequent developments

- Shipboard ADCP, pioneered by Lloyd Regier, Bob Knox, and Dave Cutchin on the Tahiti Shuttle, became a routine high-resolution, high-accuracy absolute profiling method.

- The importance of monitoring has become accepted, with an ever-expanding array of sensors and systems. E.g., TAO/TRITON, altimetry, ARGO, gliders.

- Island sea level measurements and dynamic height from hydrography remain important.
SADCP, 170°E to 140°W, 2004-2012
Conclusion

Despite the passage of time and improvements in technology, the job of resolving and understanding persistent zonal flows remains incomplete.