

Figure 9.8 Similar eight-year trends of increasing wind speed and deep-ocean particle flux in the Sargasso Sea. Wind speed is offset by 55 days and averaged over periods identical to the collection times of the sediment trap. The offset was determined by spectral analysis and represents the response time of the particle-producing biota to physical forcing plus the time required for particles to sink to a depth of 3200 m.

coverage to assess the pump on a global scale, let alone in a synoptic fashion. It is to be expected, however, that different proxies are needed for different oceanic regimes. What might work for the Sargasso Sea will not necessarily work for the subarctic Pacific or the Southern Ocean.

9.4 EPISODIC EVENTS

Finally, there are the episodic or "unusual" events. By definition, these are unpredictable. Yet, they could have the highest diagnostic value *if* they and their forcing conditions are properly recorded. Their statistics are quite odd (Weatherhead, 1986) and they have a vanishingly small chance of being recorded by means of periodic snapshot measurements. It is increasingly appreciated that they can

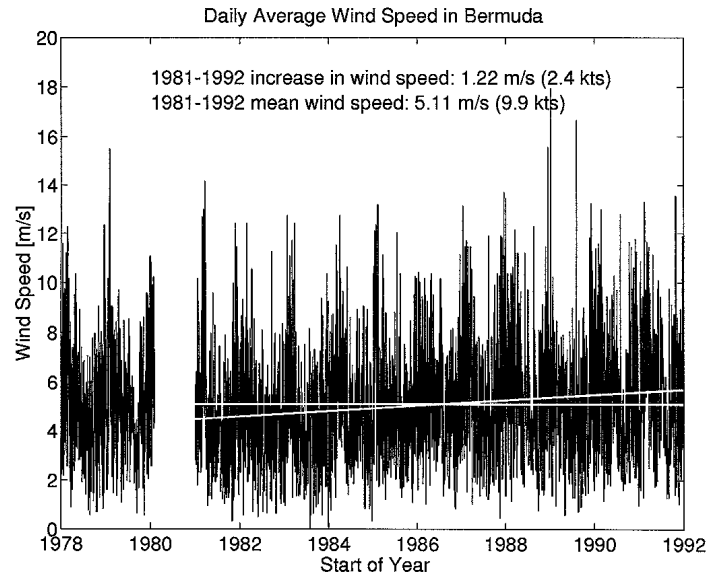


Figure 9.9 A steady change in daily average wind speed on the island of Bermuda. The best fit indicates a 24% increase over 11 years. The trend is significant well above the 99% confidence level.

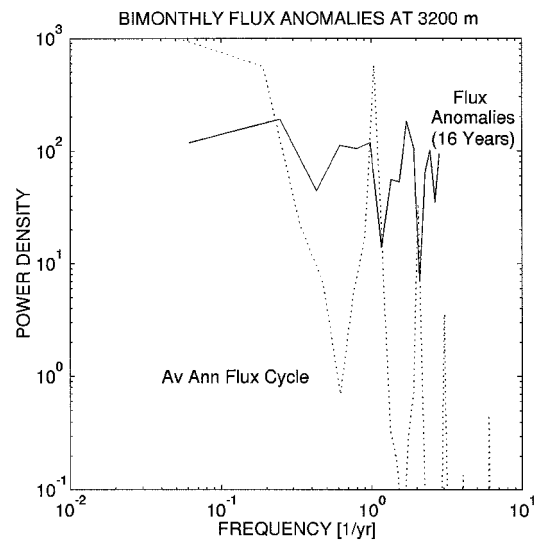


Figure 9.10 Power spectrum of 16 years of bimonthly flux anomalies (solid line), compared to that of the average annual cycle (dotted line).

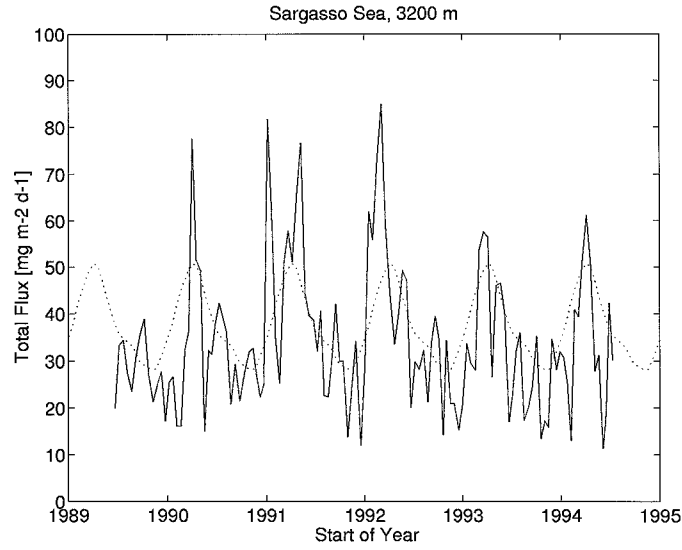


Figure 9.11 Variability of 5 years of biweekly particle-flux measurements in the deep Sargasso Sea. Each 2-week collection period is represented by its midpoint only. The dotted line repeats the average annual cycle shown in the right panel of Figure 9.2.

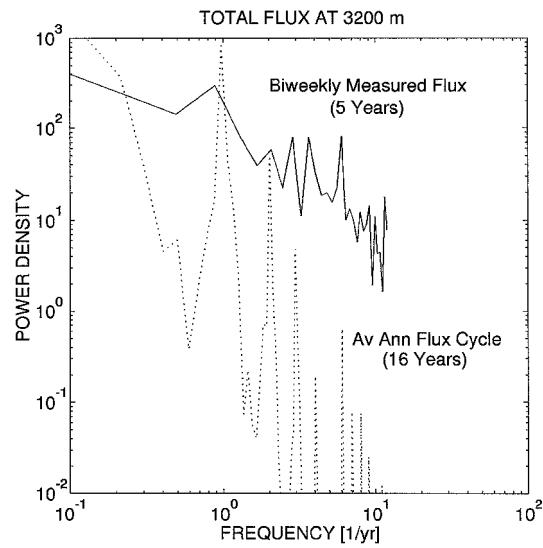


Figure 9.12 Power spectra of five years of biweekly flux variability (solid line) and of the 16-year average annual cycle (dotted line) as shown in Figure 9.11.

have major impact on ecosystems, far beyond their duration (e.g., Scranton et al., 1993). There are several examples of high-flux periods in our long-term record which cannot be attributed to unusual hydrographic conditions because the intermittent hydrographic measurements at Station "S" and, more recently, at the JGOFS BATS site, missed recording those conditions. Another good example was reported by Honjo (1982) who measured a carbonate flux (almost all consisting of coccoliths of *Umbellicosphaera sibogae*) of $1.6 \text{ g m}^{-2} \text{ d}^{-1}$, orders of magnitude higher than what is normally measured! And that was the average flux over two months. There can be little doubt that, in fact, the true flux was much higher for a much briefer period. Similarly high fluxes were recorded for the same time interval at three different depths. What were the conditions which triggered that event? What effect would such a massive (and geologically instantaneous!) sedimentation pulse have on the sedimentary record? How often do such events occur locally, or in the entire ocean? We cannot answer any of these questions.

9.5 WHAT IS NEEDED?

Time-series measurements in the ocean, while not widely appreciated just a few years ago, have proven their value. Their establishment and maintenance, however, are still entirely dependent on the rules and priorities of short-term funding schemes. This is not a healthy situation because the set of issues referred to as "Global Change" requires long measurement series. Their lack induces some people to make unreasonable claims based on short measurement series. It is quite impossible, for example, to attribute interannual differences in a two-year measurement series to the presence or absence of an El Niño event unless the interannual variability over a much longer period is known. Yet, this has been attempted. Sampling duration and frequency have to be planned with clear objectives in mind. For example, the lunar period cannot be assessed with monthly or biweekly sampling schemes.

Not even a large number of series of just one or a few years' duration can replace the value of a single series of a few decades' length. Similarly, once a series is stopped, a restart is unlikely and of questionable value (for example, the demise of the Ocean Weather Ships: while widely lamented, it is now irreversible). More series ought to be started and they ought to be maintained in a variety of oceanographic settings. And the measurements ought to be *continuous* in order that those rare but important unusual events can be recorded. Particle-flux measurements by sediment traps, in particular, are presently the best tools at our disposal for recording the link between climate-dependent events at the sea surface and their, by chemical and biological agents greatly "edited", record on the seafloor. While traps certainly do have their limitations and shortcomings,

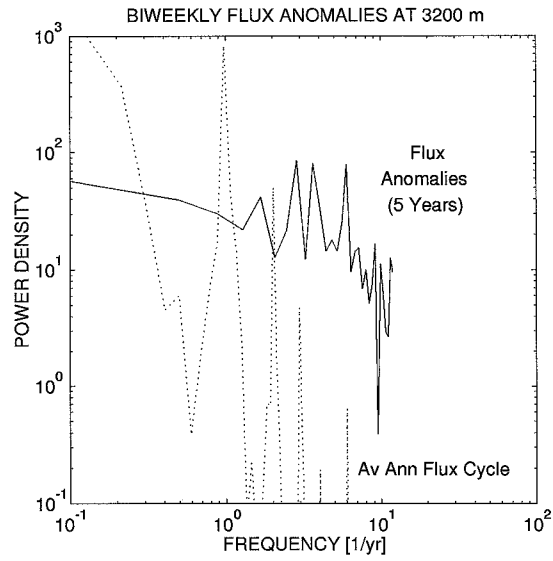


Figure 9.13 Power spectrum of the biweekly flux anomalies (five years of data), compared to that of the average annual cycle. Compare to Figure 9.12 and note the dominant peaks after removal of the annual cycle.

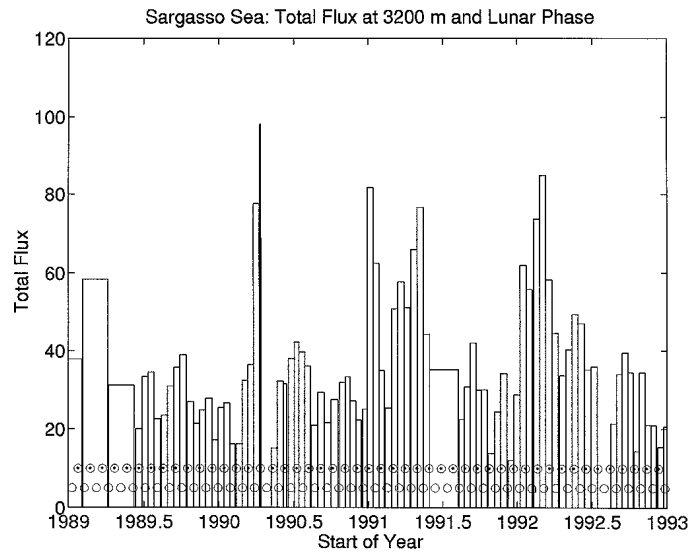


Figure 9.14 Superposition of total-flux measurements and lunar phase. The biweekly sampling scheme was too close to half the lunar period to allow a distinction between the two.

they do sample continuously and record the signatures of *all* upper ocean conditions and processes and not just those accessible to shipboard sampling at low and moderate sea states. They are also amenable to sampling on hourly to yearly schedules, depending on a study's objectives.

Clearly, simultaneous long-term sediment trapping in a variety of oceanic domains is not an easy order. Nobody appreciates that more than I do, as can be seen in Figure 9.15, which presents a juxtaposition of the rhythms of flux measurements and of my "oscillations" between Woods Hole and Bermuda for the purpose of regular recoveries of the mooring.

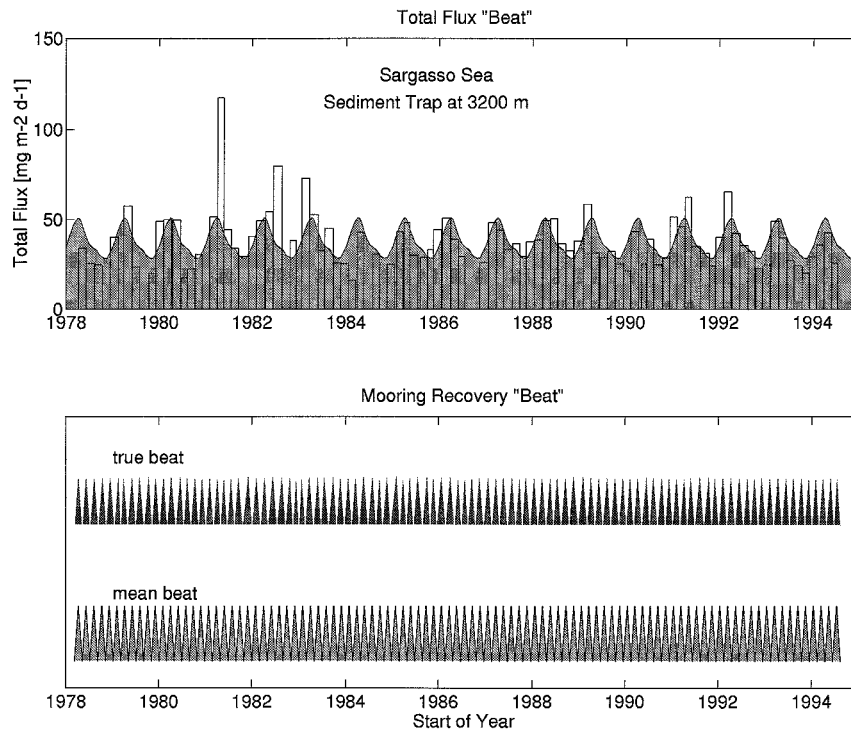


Figure 9.15 Juxtaposition of the rhythms of particle flux (upper panel) and mooring recoveries over the duration of the Sargasso Sea project (lower panel).

9.6 ACKNOWLEDGMENTS

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