RACER: The tides at Palmer Station

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In a review of antarctic tidal measurements, Lutjeharms and Stavropoulos (1985) state that "Of all the regions in the world ocean, the Antarctic continent is particularly poorly served." Although more tidal data have been obtained in the decade since the data they reviewed were collected, a scan of papers in the annual review issue of the *Antarctic Journal of the U.S.*, volumes 1 through 26, reveals very few with the word "tide" in the title. At Palmer Station, sporadic efforts have been made over the years to measure tides, but there has been no permanent tide-station established. The utility of having a tide gauge at the station and ultimately a model for tide prediction is considerable. Operationally, there is a need to navigate and dock ships safely in the harbor. Any operation such as the possible salvage of the sunken *Bahia Paraiso* would require detailed knowledge of the tidal cycle. Scientifically, the results of the tidal measurements and predictions are many. For example, Peterson (1988) used one of the longest records of sea-level elevation (recorded at Faraday Station) to find coherence with a multiyear time-series of ocean-bottom pressures in the Drake Passage. The 18.6-year nodal period, governed by the cycle of the Moon's declination, has been shown to affect oceanic processes at high latitudes (Royer 1993). Such lengthy records are important too in providing data for the long-term ecological research (LTER) program. Continuous records of barometric pressure are now being acquired with an antarctic weather system installed at Bonaparte Point opposite Palmer Station. Work is in progress to make accurate sea-level measurements at an Argentine station on the Palmer Peninsula in a joint U.S. National Oceanic and Atmospheric Administration–Argentine project (anonymous 1993).

In January 1992, an ENDECO model 1029 water-level recorder was installed at the dock at Palmer Station. The goal of the project was to obtain tide data during the research on antarctic coastal ecosystem rates (RACER) and Antarctic Marine Living Resources (AMLR) projects (Amos, Jacobs, and Hu 1990; Amos and Lavender 1991). The pressure gauge is located at a mean depth of 3.275 meters (m) in a heavy-walled steel pipe welded to the dock bulkhead, and the recording module is mounted directly above it. The pipe acts as a stilling well. Differential pressure and sea temperature are recorded on a digital data cartridge at 10-minute intervals. At monthly intervals, the cartridges are removed and read on-station using the personal computer reader/interface. The raw data record is "zipped" (compressed), encoded, and transmitted via e-mail to the University of Texas Marine Science Institute.

The following discussion is based on a preliminary analysis of data acquired from January 1992 through May 1993. There have been some notable gaps, primarily due to battery failure. These problems seem now to have been resolved. The

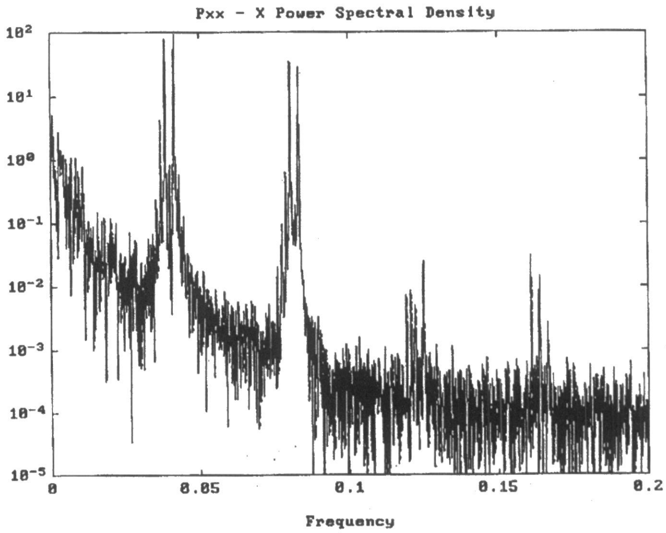

Figure 1. Power spectrum of water levels from a nearly complete year-long record of tides at Palmer Station. The frequency scale is in cycles per hour.

mean annual tidal range between a successive high and the subsequent low is 65 centimeters (cm) with a maximum of 1.65 m. The daily range would be closer to 1 m if the semidiurnal tide were ignored. The maximum excursion from the extreme high to the extreme low of the year was 2.19 m. A preliminary spectral analysis (figure 1) shows that the principal tide is the diurnal K_1 with the lunar constituent O_1 nearly as prominent. Of the semidiurnal tides, K_2 is the most prominent, closely followed by the principal lunar tide M_2. Thus, variations in the Moon's and Sun's declinations appear to be a major contributor to water-level fluctuations at Palmer Station. The combination of these with the lunar tides produces a mixed tide. There are intervals of several days when only diurnal tides occur and other times when the semidiurnal tides nearly predominate.

Figure 2 shows the February and June tides. Contrast the first week and last week in February 1993 (figure 2*A*). In June 1992 (figure 2*B*), the tides are diurnal throughout most of the month. In figure 2, sea temperature is also plotted. Note that in February there is evidence of a diurnal signal, probably due to solar warming. There is also evidence of tidal advection of cold water into Arthur Harbor around 19–21 February. There is little evidence of diurnal fluctuations in June with a mean temperature of −1.8°C. A preliminary spectral analysis of the year-long temperature field yields a peak at 23.98 hours.

Another aim of this program is to predict the tides at Palmer Station. Given at least a year-long record of uninterrupted measurements of water level, a tidal prediction model can be constructed. The process requires computation of the phase angles and amplitudes of the tidal harmonic con-

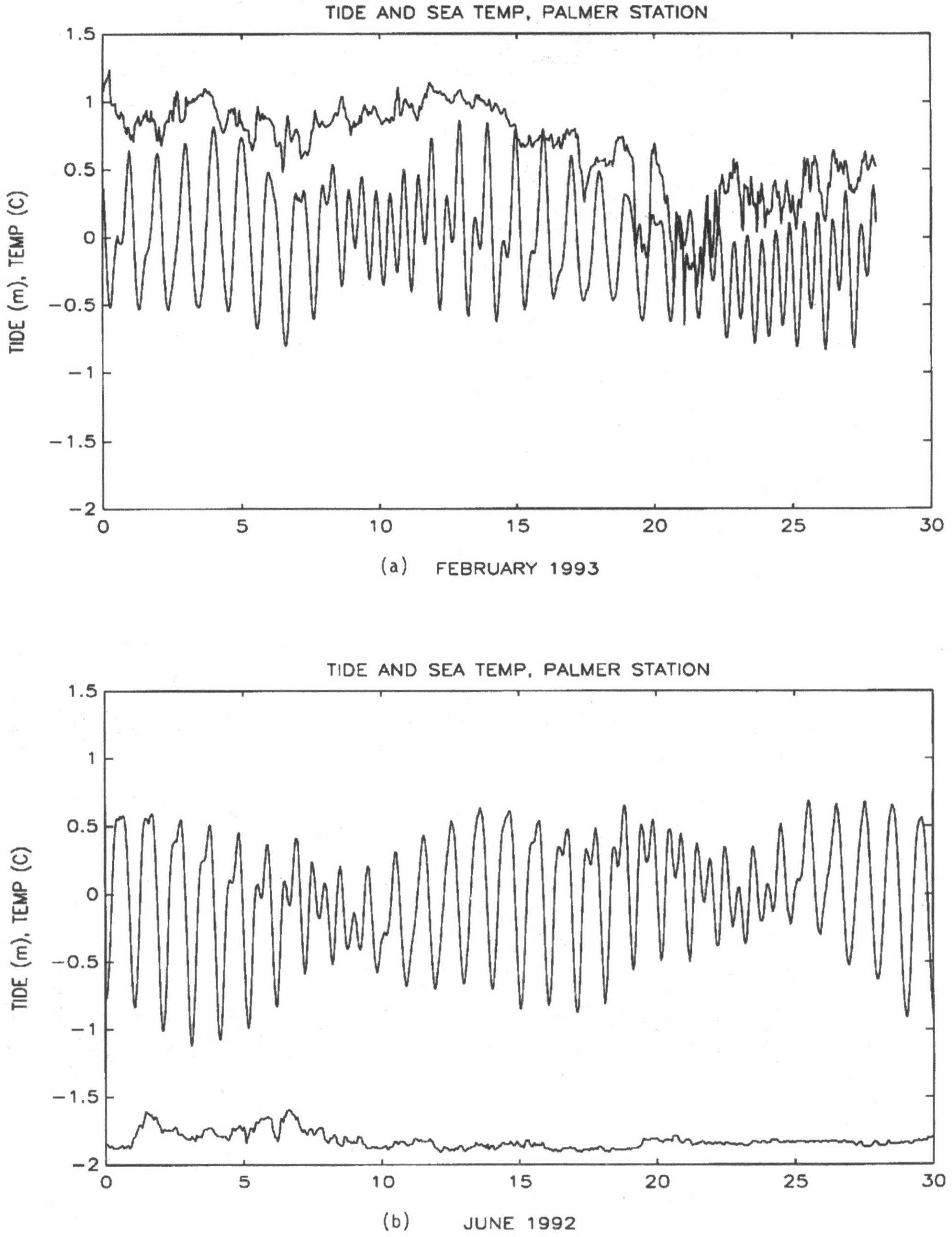

Figure 2. Water levels and sea temperatures measured at Palmer Station. *A*. February 1993. *B*. June 1992.

stituents. To include all 37 harmonic constituents that can be input to the program, more than a year of data is required. Nonetheless, the diurnal, semidiurnal, and higher frequency components can be predicted from a 365-day record. The incomplete record I've obtained so far shows a semiannual signal that may be related to astronomical, meteorological, or thermosaline cycles.

Once these computations have been made, the tides can be predicted for any future period with some degree of confidence. Monthly water-level predictions will be produced in calendar form, an example of which is given in figure 3 (the water levels shown in the figure are observed from the tide gauge data rather than predicted and are presented here as an example of the future product).

This was an unsupported "project of opportunity" done while I was visiting Palmer Station during the RACER cruises. I thank the University of Texas Marine Science Institute for the permission to use the tide gauge and data-acquisition equipment. I am most grateful to the Antarctic Support Associates personnel at Palmer who installed the gauge and who download the data regularly, in particular, Ritchie Skone, Al Oxton, Jim Meiss, and Jim Binford.

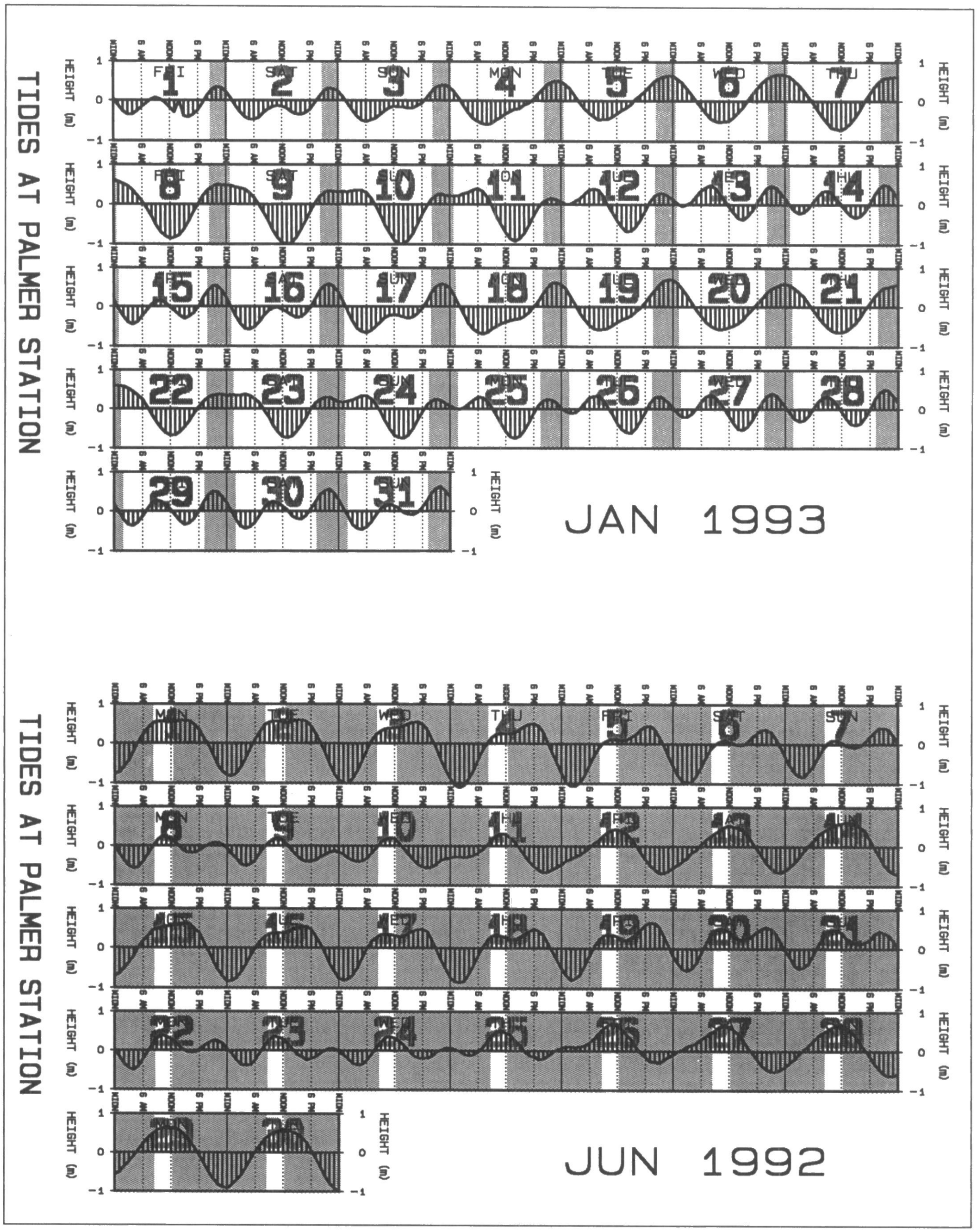

Figure 3. Water levels at Palmer Station illustrated in the form that the predictive diagrams will be presented (but using actual data). *A*. January 1993. *B*. June 1992. Shading shows the duration of darkness. The zero line is the mean sea level calculated from a nearly complete, year-long data set.

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