Wave Observations in the Storm of 17-18 January, 1988

By Richard J. Seymour
Scripps Institution of Oceanography, UCSD
La Jolla, CA 92093

INTRODUCTION

SOUTHERN CALIFORNIA, BECAUSE of the complexity of its maritime borderlands, its relative susceptibility to wave attack from major storms anywhere in the Pacific Basin, the economic significance of its developed shoreline and offshore petroleum production facilities, and the wisdom and foresight of a few government sponsors, is blessed with perhaps the greatest concentration of wave measurement devices of any comparable area in the world. Therefore, although the Great Storm of January '88 was small in area, it was still possible to observe some of the structure in its wave fields as it developed and moved ashore. This paper will report on the observations and will consider some aspects of their characteristics.

WAVE MEASUREMENT STATIONS

In all, 21 stations between San Francisco and the border with Mexico reported the storm. Five of these were buoys operated by NOAA as part of their data gathering in support of weather forecasts and other services. The remaining 16 are operated by Scripps as part of the Coastal Data Information Program (CDIP) and sponsored jointly by the Coastal Engineering Research Center of the U.S. Army Engineers and by the California Department of Boating and Waterways[6]. Although the CDIP data gathering network was unaffected by the storm, the Pacific Telephone lines on which it depends went out close to the peak of the storm, resulting in a data gap of several hours. A utility power outage at Imperial Beach kept that station down throughout the storm. The locations of the 21 active measurement sites are shown in Figure 1.

Of the CDIP stations, eight of these (Mission Bay entrance, Scripps Pier, Del Mar, Oceanside, San Clemente, Sunset Beach, Marina and Santa Cruz) are nearshore stations (average depth about 30 ft) and are sheltered in various degrees by the offshore islands or headlands. The Mission Bay Buoy, although in deeper water, is similarly sheltered. This limits the usefulness of these stations for this study. The remaining 7 stations, either in deep water or on open coastlines, have been selected for their generality in characterizing the storm (although the Santa Cruz Canyon buoy, in deep water, is sheltered by the Channel islands). The deep water NOAA buoys (Catalina Ridge is partially sheltered), plus the 7 selected CDIP stations provide the most general data on the storm.

WAVE DATA

Figure 2 shows the growth and decay of the significant wave height measured at the three stations in the vicinity of the Channel Islands. The gap in the CDIP data caused by the loss of telephone service is clearly evident. The highest measurement at Begg Rock (33.4 ft) was the maximum measured by any of the stations during the storm and the energy at this point was peaked at a period of about 15 s. Because of the similarity in the rise and decay between the Begg Rock buoy (essentially open ocean exposure) and the nearby and partially shadowed NOAA Catalina Ridge site, the peaking of NOAA buoy an hour or so after the start of the data gap, and the rapid rise rate of the Begg Rock significant height all suggest that the actual peak weight may have been significantly higher than recorded here - perhaps as great as 36-38 ft, with the peak period near 17 s. If so, this would imply a one-in-one-thousand wave height of about 75 ft! This assumption is based upon a theoretical distribution of wave heights for a storm in which conditions change very slowly. It would not necessarily be the best model for this rapidly changing event.

Figure 3 shows the build up and decay of wave heights near Point Conception. The maximum significant height

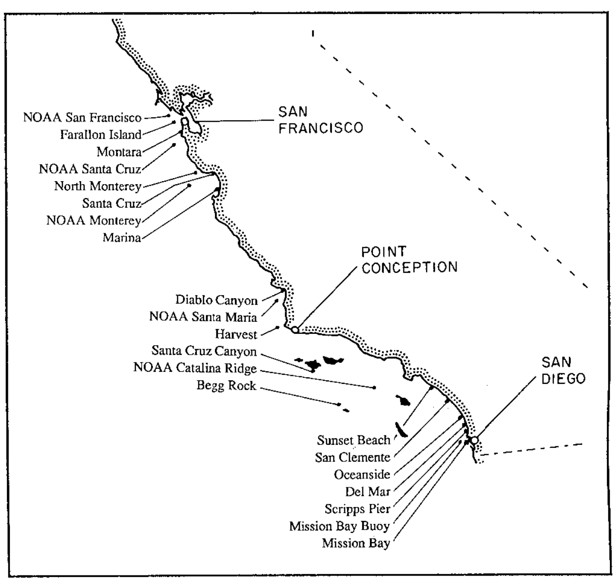

Figure 1. Wave measurement stations that reported during the storm of 17-18 January, 1988.

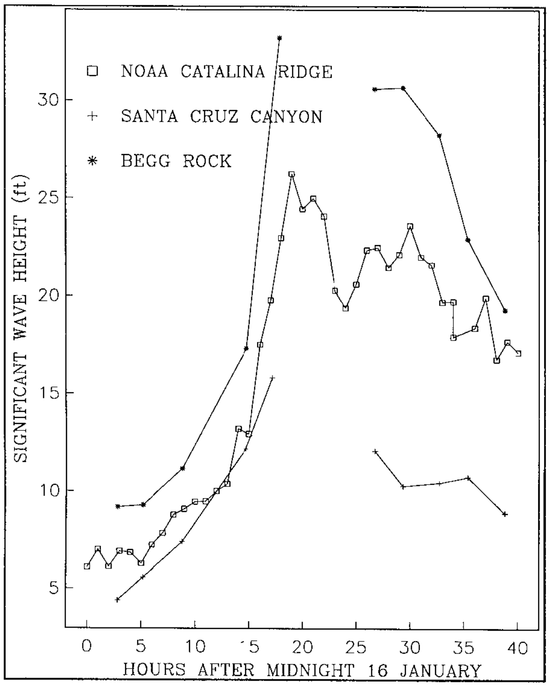

Figure 2. Wave heights near the Channel Islands during the storm.

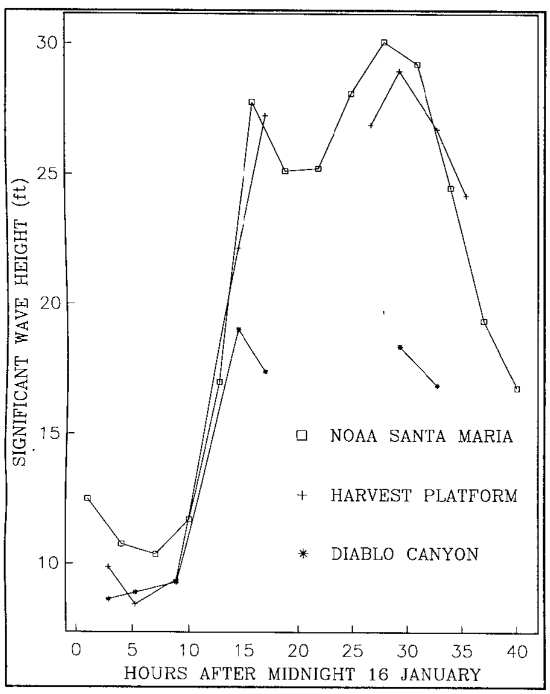

Figure 3. Wave heights in the vicinity of Point Conception during the storm.

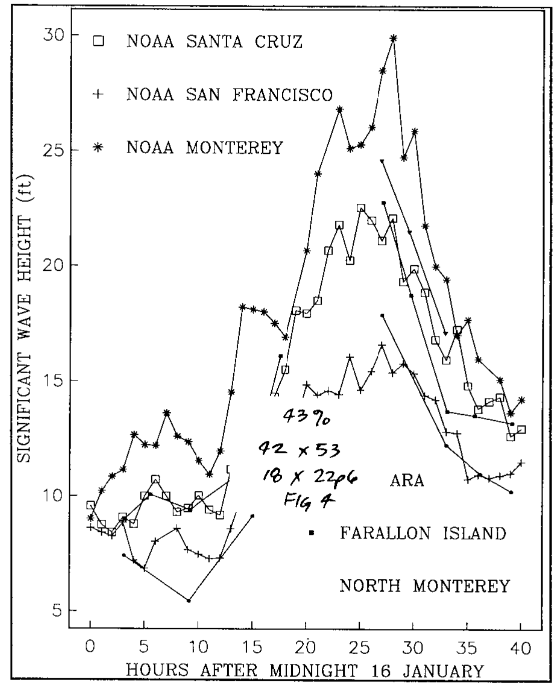

Figure 4. Wave heights in Central California, between Monterey Bay and San Francisco, during the storm.

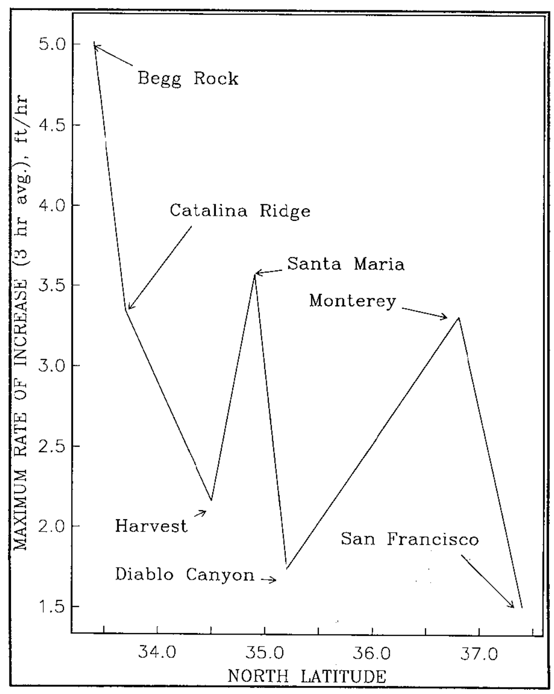

Figure 5. Maximum growth rates of significant wave height, averaged over 3 hour periods, from a number of open coast sites.

measured in this region was 30.4 ft at a peak period of about 17 s. In Figure 4, the heights from the 6 reporting stations in the Monterey/San Francisco area are shown. The maximum height here was the same — 30.4 ft — but was peaked at only 15 s.The intensity of the winds and, very probably, the existence before the storm of long period swell (about 17 s) of considerable height (about 10 ft), caused a very rapid increase in the significant wave height. Figure 5 shows the maximum rise rates (3 hour averages) for several open coast sites with Begg Rock measuring about 5 ft/hr. This compares with a maximum growth rate of about 1 ft/hr at this same site during the 27 January, 1983 storm when the significant height reached 24 ft[1]. It should be noted that the peak wave generation zone was far removed in space and time from the Begg Rock measurement site in 1983, but was probably very close in 1988. A better comparison can be made with rise rates for the 1 March storm, the largest in 1983. Earle *et al*[3] shows, in the generation area about 1500 miles offshore, an average rise rate of 4.6 ft/hr in the 3 hours prior to the peak significant height of 39 feet. The growth of the '88 storm as a function of latitude is shown schematically in Figure 6.

STORM RANK

It is of interest to try to rank this storm in the long term wave climate of southern California. The record of storm wave observations along this coast is less than 100 years in length, so that very little can be said about return periods. However, it is possible to make some conjectures based upon what is known. Seymour *et al*[5] reported on the major storms in the period 1900–1983 in this region. Figure 7 shows a distribution of extreme significant wave heights taken from that study, as reported in Walker *et al*[8]. Moffatt & Nichol[4] calculated another return period estimate for various wave heights applicable to the southern California area and this has been plotted in Figure 8. The January, 1988 storm has been shown on both distribution lines. The return period implied by each of these distributions is much greater than 200 years, perhaps as much as 400–500 years. Because projections beyond about 200 years would be totally unwarranted, based upon the length of the data record, a recurrence interval of not less than 100–200 years for a storm of this magnitude appears reasonable.

Two recent studies of the January '88 storm further illustrate the intensity of this event. Seymour *et al*[7] describes the extreme damage to the Point Loma kelp forests, much greater than the combined effects of the six major storms of 1983 (the largest previous recorded). Dayton *et al*[2] deals with damage to geological structures at great depths (up to 100 ft) offshore of San Diego that also greatly exceeded that in the 1983 season. Table 1, taken from the latter study, suggests the likely reason for this increased destructiveness. It shows that, at a nominal depth of about 60 feet near the entrance to Mission Bay, both the maximum velocity-squared (proportional to the drag force) and the maximum acceleration (proportional to the inertial force) were about twice as great in the '88 storm as the worst observed during the '82–'83 season.

Table 1

Winter Season	Maximum Velocity Squared (ft^2/s^2)	Maximum Acceleration (ft/s^2)
82-83	58.2	3.5
87-88	110.1	6.3

CONCLUSIONS

It is clear from these wave observations that this was an exceptional event, far exceeding any ocean storm in recorded history in this area. As pointed out by Strange *et al* in this issue, the presence of pre-existing swell resulted in wave periods of much greater length and much larger significant heights than can be predicted by any wave generation model that starts, as the present models all do, from an assumption of a flat ocean. This may be the most important single observation about the Storm of '88 if it leads to successful research on wave generation with pre-existing swell.

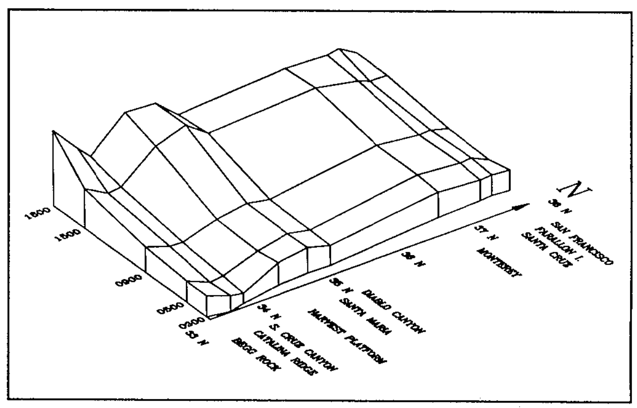

Figure 6. The growth of the storm along the coast. The vertical dimension is relative significant wave height, plotted against Pacific Standard Time on 17 January, 1988, and north latitude.

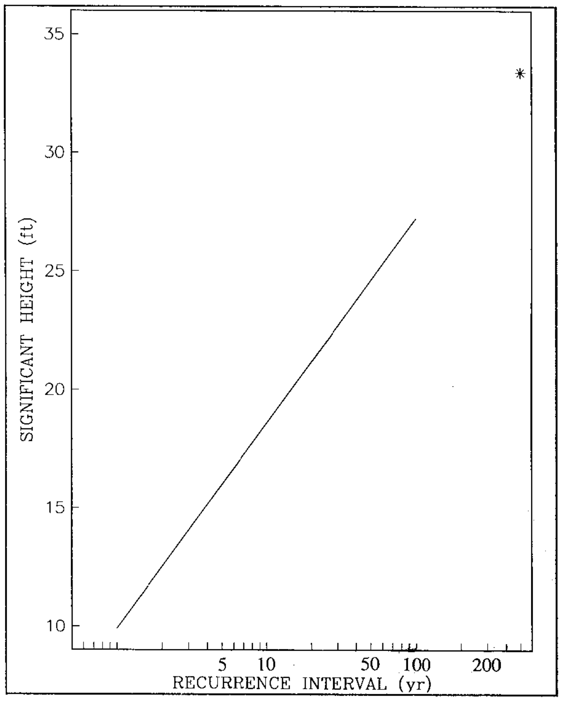

Figure 7. Return period estimation function for major storms of various significant wave heights from Walker *et al.*, 1984 The January 1988 storm is indicated with an asterisk.

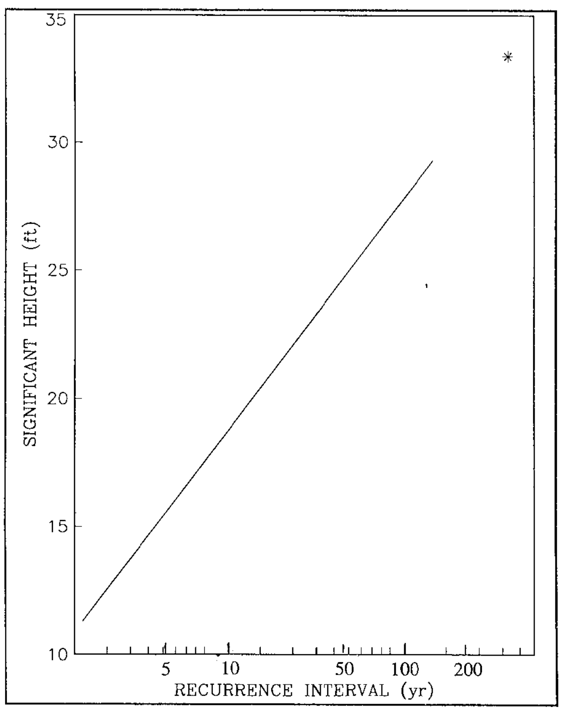

Figure 8. Return interval estimates, similar to Figure 7, from Moffatt & Nichol, 1988.

REFERENCES

1. Coastal Data Information Program (CDIP), 1983. *Monthly Report, January, 1983*. Scripps Institution of Oceanography, La Jolla, CA.
2. Dayton, P.K., R.J. Seymour, P.E. Parnell and M.J. Tegner, 1989. Unusual Marine Erosion in San Diego County from a Single Storm. *Estuarine, Coastal and Shelf Science*, Vol.28, (in press.)
3. Earle, M.D., K.A. Bush and G.D. Hamilton, 1984. "High-height Long-period Ocean Waves Generated by a Severe Storm in the Northeast Pacific Ocean during February 1983". *J. of Physical Oceanography*, Vol.14, No.8: pp 1286-1299.
4. Moffatt & Nichol, Engineers, 1988. *San Diego Region Historic Wave and Sea Level Data Report*. U.S. Army Engineers District, Los Angeles, CA.
5. Seymour, R.J., R.R. Strange, III, D.R. Cayan and R.A. Nathan, 1984. "Influence of El Ninos on California's Wave Climate". *Proc. 19th Intl. Conf. on Coastal Engrg*, Houston, TX, ASCE Vol. I: pp 577-592.
6. Seymour, R.J., M.H. Sessions and D. Castel, 1985. "Automated Remote Recording and Analysis of Coastal Data". *J. Waterway, Port, Coastal and Ocean Engrg*, Proc. ASCE, Vol. 111, No. 2: pp 388-400.
7. Seymour, R.J., M.J. Tegner, P.K. Dayton and P.E. Parnell, 1989. "Storm Wave Induced Mortality of Giant Kelp, Macrocyctis pyrifera, in Southern California". *Estuarine, Coastal and Shelf Science*, Vol. 28, No. 3: pp 277-292.
8. Walker, J.R., R.A. Nathan, R.J. Seymour and R.R. Strange, III, 1984. "Coastal Design Criteria in Southern California". *Proc. 19th Intl. Conf. on Coastal Engrg*, Houston, TX, ASCE Vol. III: pp 2827-2841.