The Harvest Experiment:

Monitoring Jason-1 from a California Offshore Oil Platform

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Platform Harvest

The *Arguello Inc.* Harvest Oil Platform is located about 10 km off the coast of central California near the Jason-1 launch site at Vandenberg Air Force Base (Figure 1). An impressive structure, the platform (Figure 2) is anchored to the sea floor and sits in about 200 m of water near the western entrance to the Santa Barbara Channel. Conditions at Harvest are typical of the open ocean and the seas can be quite heavy. Ocean swell and wind waves average about 2 m, though waves over 7 m can been experienced during powerful winter storms (Figure 3). Prevailing winds are from the northwest and average about 6 m/s (15 mph). The platform is served by helicopters from the Santa Maria, California, airport, and is regularly visited by supply boats. Operational since 1991, Harvest has produced over 44 million barrels of oil (as of July, 1997).

A Calibration Site for Jason-1

In addition to its primary mission to drill for oil, Harvest is a "calibration site" for the Jason-1 (December 2001 launch) and TOPEX/Poseidon (1992–) missions, and as such is an important international resource for the study of sea level from space. A consideration in designing the TOPEX/Poseidon (T/P) orbit was a requirement that the satellite pass directly over Harvest on a regular basis. Traveling in excess of 6 km/s at an altitude of 1330 km, T/P flies over the platform every 10 days en-route to tracing out its global pattern of sea-level measurements. Observations recorded with instruments attached to the platform are used to verify the sea-level readings from T/P taken at the instant of the overflight. After its own launch in December, 2001, Jason-1 will be placed in the same orbit, bringing it over Harvest in formation flight with T/P.

Why is Harvest such a good calibration site? For one, it is located sufficiently far offshore so that the area illuminated by the altimeter's radar pulse is covered entirely by ocean when the satellite is directly overhead. At the same time, the platform itself is small enough so that it cannot influence the reflected radar signal. The platform's location in the open ocean also implies that the altimeter missions are monitored in conditions under which their measurement systems are designed to best operate. Finally, the platform is located in proximity to important tracking stations in California and the western U.S, data from which contribute to measuring the positions of the satellite and platform through space-based surveying techniques.

How Does it Work?

How does this Harvest calibration system work? Attached to the platform are "tide gauges" that continuously measure variations in the sea level relative to the platform. These variations may be due to the effects of fluctuating ocean currents and atmospheric pressure in addition to astronomical tides. Any sinking or rising of the platform structure itself will also affect the tide-gauge measurements. As oil is pumped from the underlying deposit, for example, the sea floor supporting the platform structure subsides by almost 1 cm each year (Figure 4). This is measured using data from a global positioning system (GPS) receiver on the platform. Also computed with the GPS data is the absolute height of the platform relative to the Earth's center.

Combining the tide gauge and GPS results gives the local sea-surface height (SSH) relative to the Earth's center, the same quantity measured by the radar altimeter when it flies over the platform. By looking at the mismatch of the two SSH readings (Jason-1 vs. Harvest) at the overflight times, the errors in the respective measurement systems will be exposed. Errors in the platform measurements are minimized by using redundant systems, and through careful monitoring and routine maintenance of the Harvest instruments. Drawing on our experience with T/P, we expect the agreement between the instantaneous sea-level readings (Jason-1 vs. Harvest) for a typical overflight to be 3 cm or better. A multi-year time series of these overflight comparisons beginning with the launch of Jason-1 will serve as a vital performance record for the mission.

Why Calibrate?

The value of the Harvest experiment was amply demonstrated with results from the T/P mission. Shortly after the satellite launched in 1992, results from Harvest and other calibration sites showed that the TOPEX sea-level measurements were too high by almost 15 cm [Christensen *et al*., 1994]. The bias is now recognized as a consequence of an error in the software used to produce the TOPEX data for the mission scientists [Nerem *et al*., 1997]. As T/P continues its successful run, attention has turned to improving estimates of measurement-system stability in order to verify the emerging record of global sea-level change [see also Mitchum, 1998]. Figure 5 shows the current Harvest calibration time series for the Topex altimeter. The smoothed curves can be interpreted as an estimate of the errors in the TOPEX sea-level readings from 1992–2000. An erroneous, albeit subtle, increase in the sea level, commensurate with the slow aging of the original TOPEX altimeter (Side A) can be seen starting in 1996. A redundant system (Side B) was activated early in 1999, data from which show good consistency with the early Side-A data.

The experience spurred by switching the TOPEX altimeters proved to be excellent preparation for Jason-1. We expect even greater success for Jason-1, owing to improvements in both the platform and satellite systems. In addition, during the first few months of its mission, Jason-1 will pass over Harvest in formation flight with T/P. Because the ocean scene at Harvest cannot change appreciably in the few seconds separating the T/P and Jason-1 overflights, many sources of measurement uncertainty will cancel. This cancellation will significantly benefit cross-calibration of data from the two satellites. Jason-1 will also benefit from the ongoing minimization of systematic errors in the platform measurement system. Particular emphasis is being placed on monitoring the platform vertical position and velocity with GPS at the 1 cm and 1 mm/yr levels respectively. Throughout the Jason-1 mission, we will work closely with other Jason-1 investigators overseeing additional regional calibration sites, as well those performing drift calibrations using global tide gauges, to reach a consensus on the application of calibration corrections to the global mean sea level record.

- Christensen E. J., *et al*., Calibration of TOPEX/Poseidon at Platform Harvest, J. Geophys. Res., 99, C12, 24,465-24,485, l994.
- Mitchum, G., Monitoring the stability of satellite altimeters with tide gauges, J. Atmos and Oceanic Tech, 15(3), 721–740, 1998.
- Nerem, R. S., *et al*., Improved determination of global mean sea level variations using TOPEX/Poseidon altimeter data, Geophys. Res. Ltr., 24(11), 1331–1334, 1997.

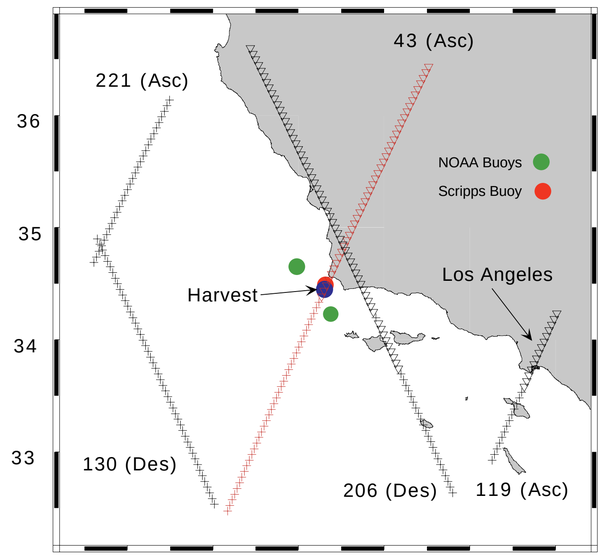

Figure 1: Map of Central California coast showing location of Platform Harvest. The red line shows the path Jason-1 will trace over the ocean (from the southwest) as it passes overhead every 10 days.

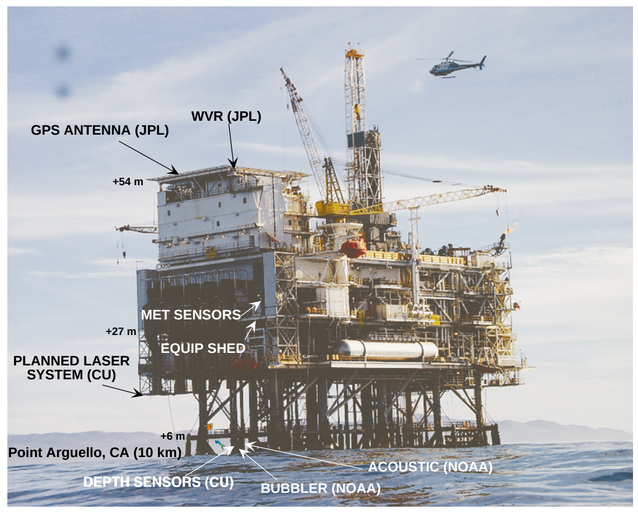

Figure 2: Arguello Inc. Platform Harvest, with locations of instruments that will be used to monitor the measurements taken by Jason-1.

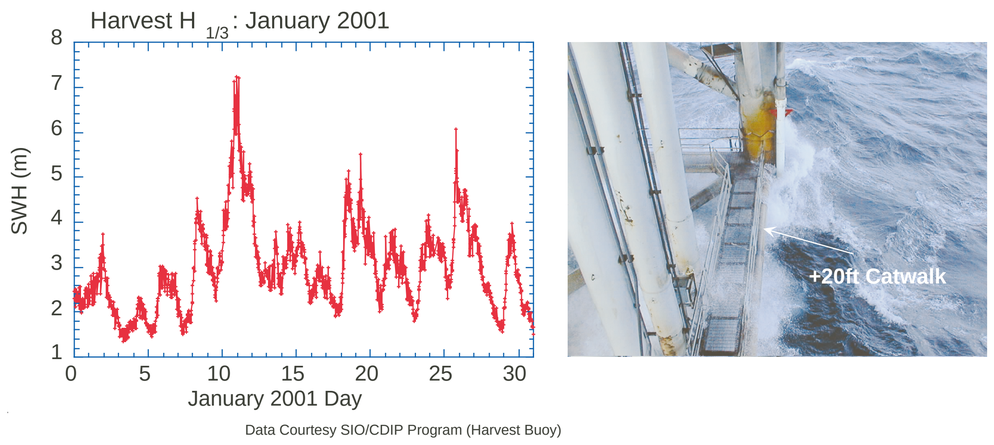

Figure 3: Wave heights at Harvest during the month of January 2001 (left). During the winter, waves commonly wash over the catwalk at the 20 foot level.

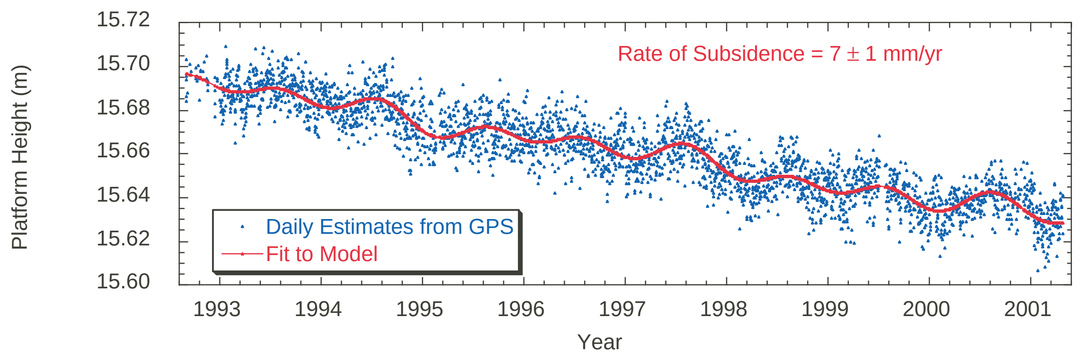

Figure 4: The height of the Platform Harvest helicopter pad with respect the Earth reference ellipsoid from continuous GPS measurements. The platform is subsiding by nearly 1 cm/yr due to the extraction of oil and other fluids from the Arguello Deposit.

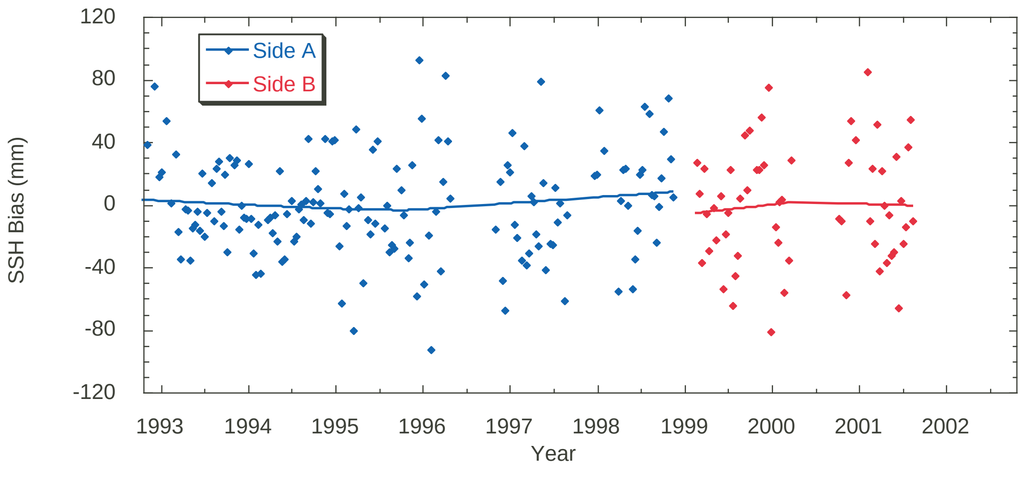

Figure 5: Sea-surface heights (SSH) measured independently by theTopex altimeter and the platform instruments are in good agreement dating back to 1992. (SSH Bias estimates are clustered about zero.)