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NEWS

Jason 1 Detects the 26 December 2004 Tsunami

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Satellite altimeters have detected mid-ocean tsunami waves only once in the past, with relatively small amplitude [*Okal et al.*, 1999], according to published reports. The 26 December 2004 tsunami changes this picture dramatically. This event was the strongest to have occurred since satellite altimetry started in the 1970s. Instruments now in orbit can measure sea surface height with sufficient resolution (a few centimeters for the average of a 5-km circle of ocean), but measure only along their tracks, and cannot provide a full picture of an event. Also, they are unlikely to be optimally placed for early detection near the source earthquake. By chance, however, Jason 1 was in the right place at the right time.

The earthquake occurred at 0100 UT on the morning of 26 December 2004. At 0255 UT, the Jason 1 altimetry satellite was over -10° latitude, 82° east longitude, about 1500 km south of Sri Lanka, heading northeast toward the Bay of Bengal above track 129 of its 254-track, 10-day pattern (Figure 1). This was the 109th time the satellite had followed this track. Figure 2 shows that the satellite passed over the front of the tsunami wave at about -5° latitude. At this point, the ocean surface started to rise above the height measured in previous cycles, to a maximum of about 70 cm above the previous average. The subsequent 30- to 40-cm drop below the average of previous cycles shows a total trough-to-crest wave height of about 1 m.

The measurements show an initial dominant wavelength of about 500 km, followed by significantly greater height variations in the Bay of Bengal compared with those observed in earlier cycles recorded 10, 20 etc. days before the event. Data from pass 110 on 5 January 2005 show a return to the undisturbed ocean.

The position of the wave at this time on 26 December is consistent with a shallow-water wave speed of about 200 m/s (750 km/h) in water about 4500 m deep. The wave would have traveled about 1500 km in the 2 hours since the earthquake off the coast of Sumatra. The altimeter measurements represent a profile through the wave at about 30° to its direction of travel, so that the true wavelength would be about 430 km. The period of the wave would then be about 35 min. The satellite traveled over this wavelength in about 100 s, so this time should be added to give a corrected period of about 37 min.

The Jason altimeter was launched in 2001 in a joint program between NASA and the French space agency Centre National d'Etudes Spatiale (CNES). This follows the TOPEX/ Poseidon mission that has provided data since 1992.

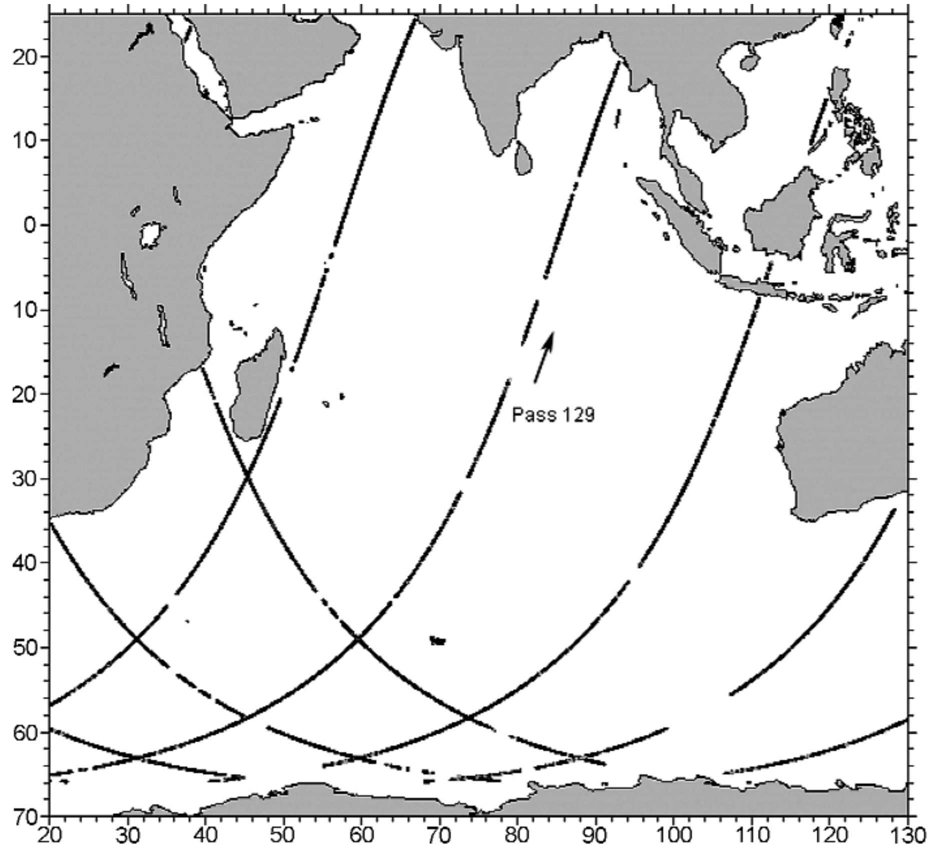

Fig. 1. Ground tracks of the Jason 1 altimeter on the early morning (UT) of 26 December 2004. Gaps in the tracks indicate where the RADS processing system edited data out as being unreliable. The track of pass 129 ascends from southwest to northeast across the center of this plot, into the Bay of Bengal, east of India, at 0300 hours, 2 hours after the earthquake. Sea surface height variations measured by the altimeter on repeated passes along this track are plotted in Figure 2.

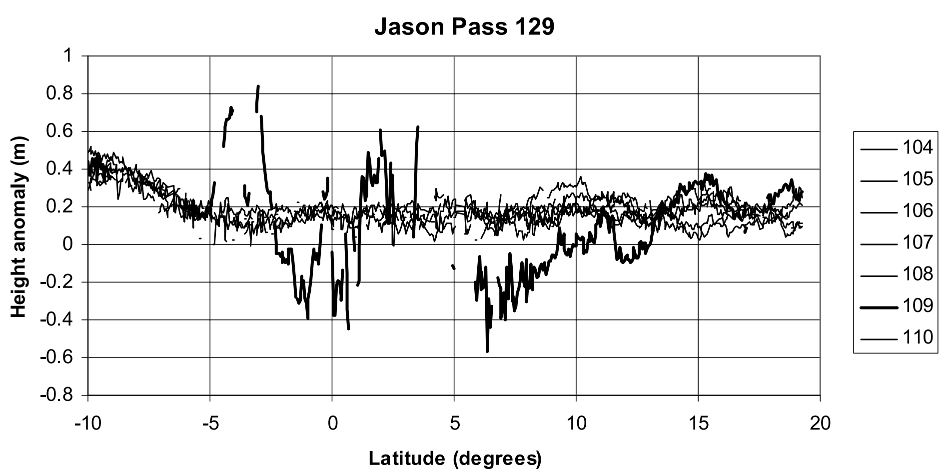

Fig. 2. Plots of sea surface height anomalies on pass 129 in cycles 104–110. The pass in cycle 109 (0300 UT, 26 December 2004, bold line) shows the profile of the tsunami wave, which had then reached -5° latitude, and the disturbed sea level behind it in the Bay of Bengal north of +5° latitude. Sea surface heights measured on the five cycles before, and the single available cycle after the event (thin lines), show close agreement in the open ocean, with more variation north of +8° latitude, due probably to tides in the Bay of Bengal. Data gaps occur in all passes. More specialized processing may fill in gaps and otherwise improve the 26 December data. Height anomalies apparently dropping to 0.25 m near latitude -3.5° after the first tsunami crest may indicate a more complex structure for the initial wave.

Data plotted here are those provided by the Radar Altimeter Database System of the Technical University of Delft, Holland. Data are processed for ocean circulation studies, and some tsunami data may have been rejected by quality control software.

Figure 2 shows that the signal in this case was easily detectable in data collected close to the start of the event. Subsequent passes should show movement of the tsunami over a much wider area. Data are also available from other altimeters, such as the Geosat Follow-On, TOPEX, and Envisat instruments. Satellite altimetry, perhaps from an expanded constellation of instruments, may well have a role in a future global warning system.

Reference

Okal, E. A., A. Piatanesi, and P. Heinrich (1999), Tsunami detection by satellite altimetry, *J. Geophys. Res., 104*, 599–615.

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MEETINGS

Science Opportunities for a Long-Range Antarctic Research Aircraft

PAGES 39–40

The polar regions play a critical role in the geodynamic and climate system of the Earth. Although located far from the main centers of human civilization, the polar atmosphere and oceans have strong global connections and therefore directly affect global weather, climate, and the world's population, living mostly in tropical and midlatitude environments. Antarctic geodynamic processes are the driving forces for ice sheet dynamics and global environmental change that affect current and long-term, large-magnitude sea level changes.

The importance of the polar regions for our natural environment has long been recognized. Many nations around the world are currently planning the International Polar Year 2007–2008 (IPY), an intense, coordinated effort of novel and comprehensive observations combined with multidisciplinary research, analysis, and educational activities (http://www. ipy.org).

Our present understanding of the polar environment is far more advanced for the Arctic than for the Antarctic. This imbalance results largely from ease of accessibility, in particular Arctic landing facilities for wheeled aircraft. Landing sites for wheeled aircraft in Antarctica are extremely limited, and the vast interior of the Antarctic continent currently can only be reached by ski-equipped aircraft because most existing wheeled aircraft do not satisfy the necessary safety and operational requirements for such an extreme environment.

We have a physically based, conceptual understanding of many of the significant interactions that affect climate and the Antarctic environment. Our observationally based knowledge, however, is inadequate in many cases to quantify these interactions or to predict their net impact.

To pursue key goals in Antarctic science and transform our conceptual understanding of the processes of interest into quantitative knowledge, it is necessary to acquire geographically diverse sets of fundamental observations at high spatial and often temporal resolution. We currently lack the data sets to build a comprehensive picture of the Antarctic environment because of a long-standing gap in our observational capabilities.

On the one hand, satellite-borne instruments provide continent-wide coverage, but often have limited spatial resolution and essentially no ability to penetrate beneath the surface. On the other hand, instruments deployed from remote field camps, seagoing vessels, and small aircraft can provide the necessary high spatial and temporal resolution, but lack the capability to operate over continent-wide scales.

The growing need for a long-range research aircraft in the solid Earth, glaciology, atmospheric science, and oceanography communities over the past several years resulted in a September 2004 workshop at Herndon, Virginia, that brought together Antarctic scientists in order to formulate a science justification for a long-range research aviation facility.

The overall goal of the workshop was (1) to identify the key scientific questions in Antarctic science that currently cannot be addressed because of a gap in our observational capabilities, and (2) to develop a strong science justification for the required new research tools. A primary objective of the workshop was to provide the U.S. National Science Foundation (NSF) with recommendations on the requirements for a long-range research aviation facility.

The key science questions are targeted at understanding the elements of the Antarctic environment: the bedrock, the cryosphere, the ocean, and the atmosphere. These questions also focus on the interactions among these key elements and how the Antarctic environment is connected to the global environment.

The large overlap between the key questions of each discipline shows that only an interdisciplinary approach can solve the outstanding questions.

Geology and Geophysics

- What is the role of subglacial sediments, volcanoes, and other geologic features on ice sheet dynamics?
- What are the interactions between tectonic and climate evolution of Antarctica?
- What is the geologic and tectonic setting of subglacial lakes?
- What was the role of East Antarctica in the Precambrian continental growth process?
- What is the magnitude and timing of Mesozoic to Cenozoic extension and its effect on the global plate motion circuit?

Glaciology

- What are the interrelationships between climate change and the ice sheet system?
- What are the controls and interactions governing ice sheet dynamics?
- What are the distribution, nature, and interconnection of subglacial lakes?
- What are the current dynamics of coastal areas?

Oceanography

- What is the interannual variation in sea ice thickness on a basin-wide scale?
- What is the role of water densification in polynyas and beneath ice shelves for the global ocean meridional overturning circulation?
- What is the temperature variability of the deep ocean waters over interannual scales?
- What is the large-scale drift of sea ice in the Antarctic Zone from its formation to melt?
- What is the role of marginal ice zones for physical and biological activity?

Atmospheric Sciences

- What is the role of the Antarctic atmospheric heat sink in global climate?
- What impacts do the mountainous topography of Antarctica have on the global atmospheric circulation?
- What is the role of the Antarctic ice sheets in global sea level variations?
- What is the nature of the air-sea interactions over the Southern Ocean?
- How is the atmospheric chemistry of the high southern latitudes tied to the atmospheric circulation?

New observational capabilities are needed to gather the necessary data sets. For the geology and geophysics community, a long-range research aircraft could map the subglacial topography, gravity, and magnetic anomalies that can be used to derive a structural tectonic framework in ice-covered regions. For the glaciology community, an instrumented long-range aircraft could provide a comprehensive survey of the surface and bedrock topography and the internal structure of the ice sheet, as well as monitor changes over the most dynamic parts of Antarctica.

The key oceanographic questions require measurements of sea ice thickness and transport, surface heat fluxes and ocean wave conditions, and the structure of the upper ocean from expendable conductivity-temperature-depth (XCTD) probes.

For atmospheric sciences, measurement of the atmospheric state variables (temperature, pressure, winds, and atmospheric moisture), turbulent fluxes, cloud microphysical parameters,