Propagation of tsunami-induced acoustic-gravity waves in the atmosphere

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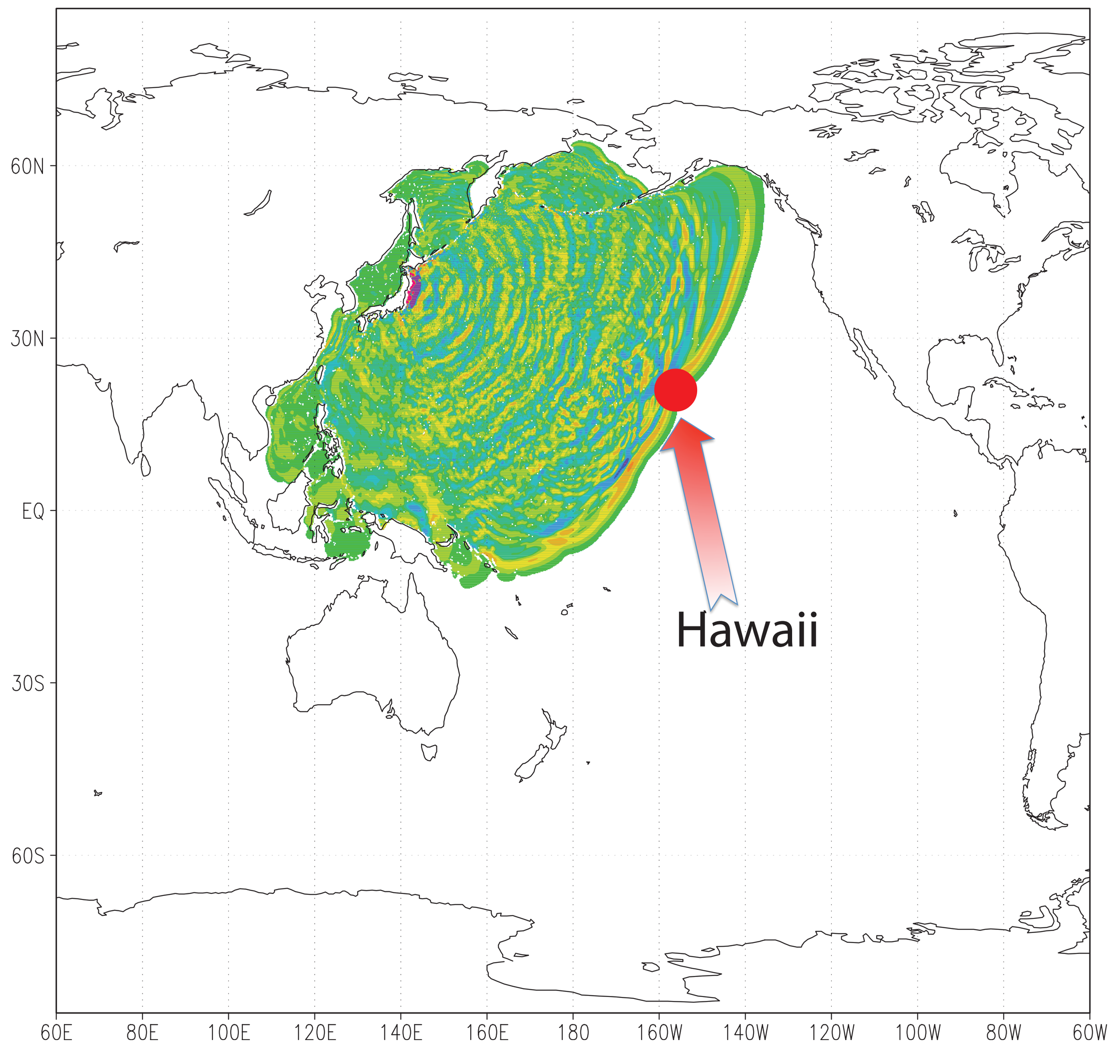
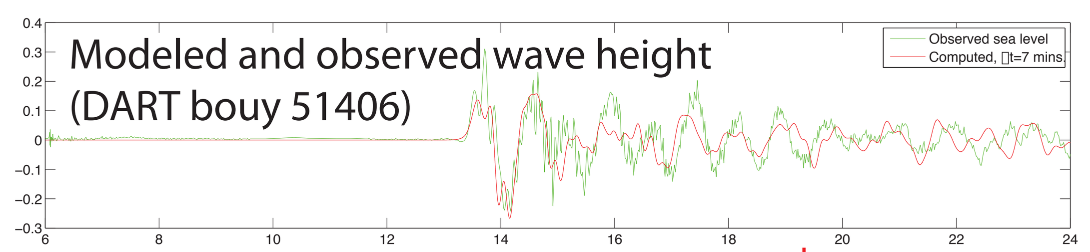
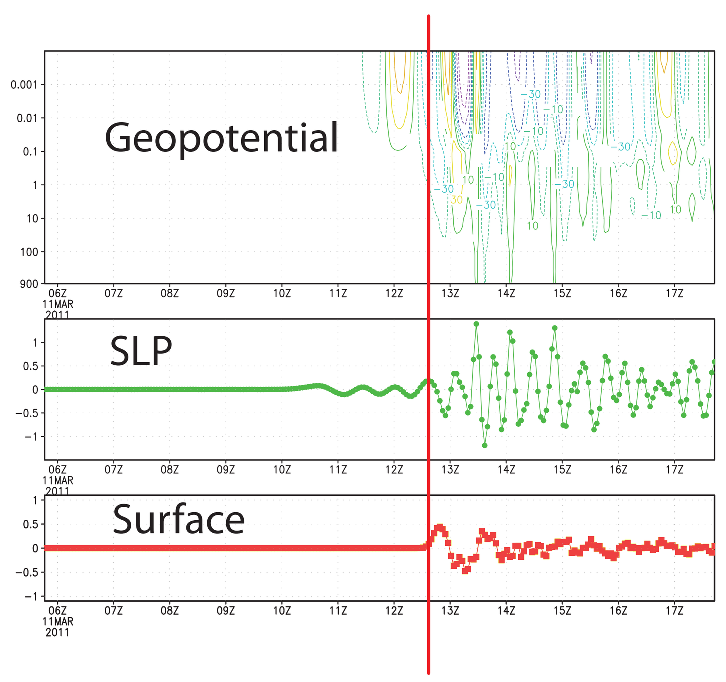
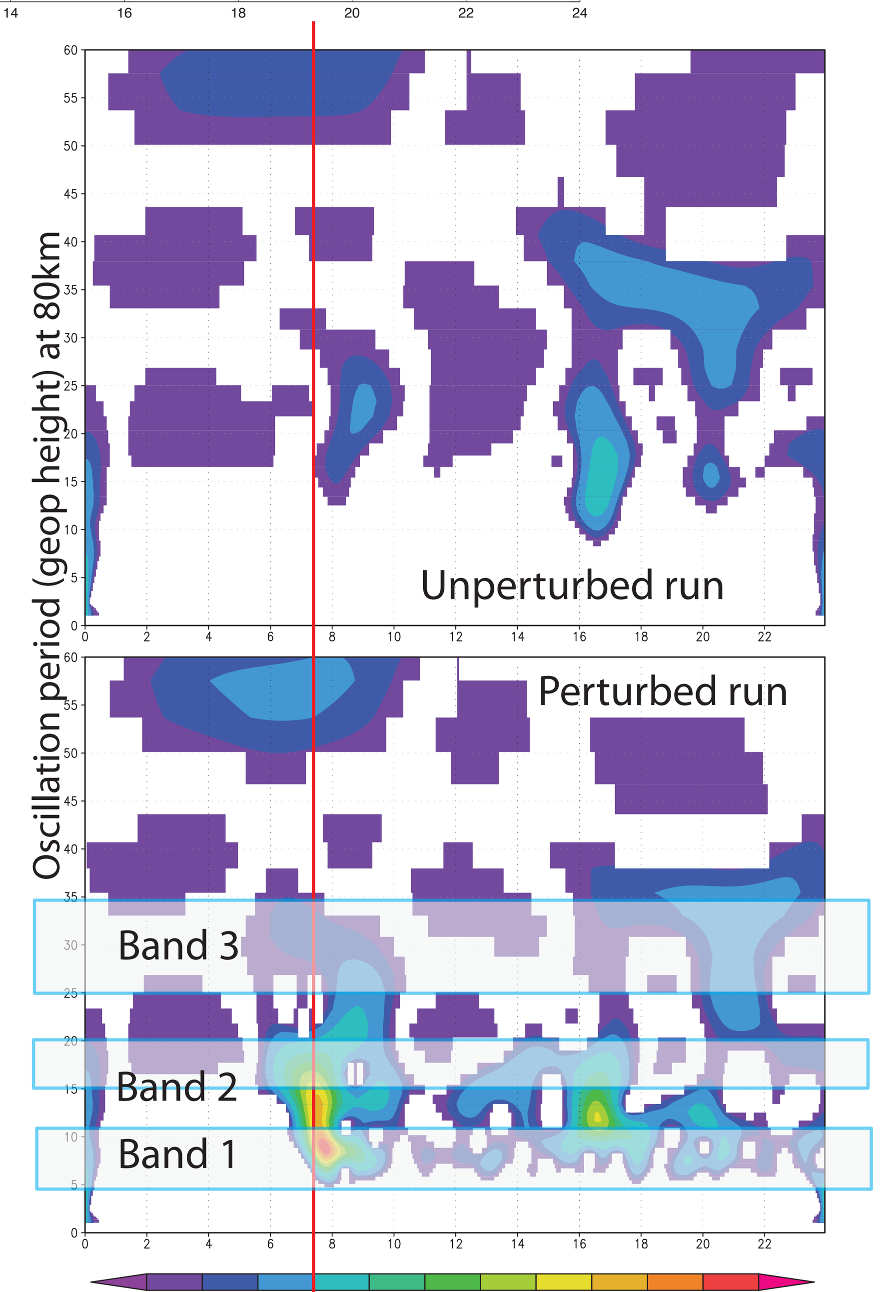
Abstract. A dynamical core of an atmospheric GCM is utilized for assessing the qualitative picture of propagation of atmospheric acoustic-gravity waves in response to perturbations generated by tsunami waves at the surface. Both resting isothermal atmosphere and model-generated atmosphere with realistic stratification and circulation features were considered. Shallow water tsunami model was run in two different configurations: ocean of equal depth of 4 km and ocean with realistic continents and bottom topography. Amplitude and timing of atmospheric response is analyzed as a function of vertical stratification and configuration of atmospheric jets. This approach has a potential for early tsunami detection by measuring changes in electric properties of the upper atmosphere in response to acoustic-gravity waves generated by tsunami.



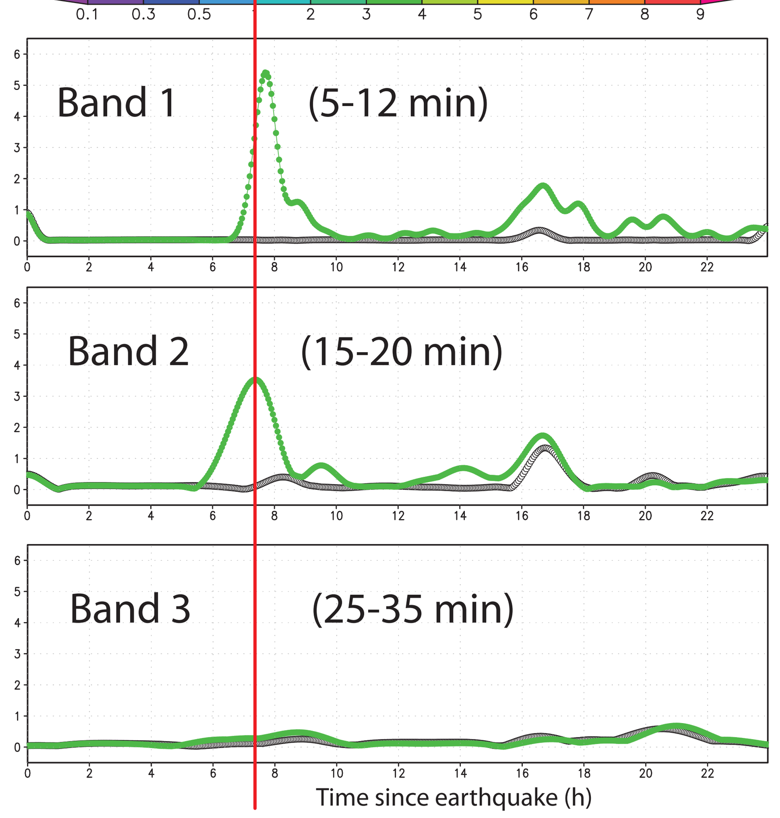


Signal in the atmosphere propagates faster than the tsunami wave, which is illustrated in figure below. Modeled output was analyzed using wavelets to determine the frequencies for early detection of the signal.

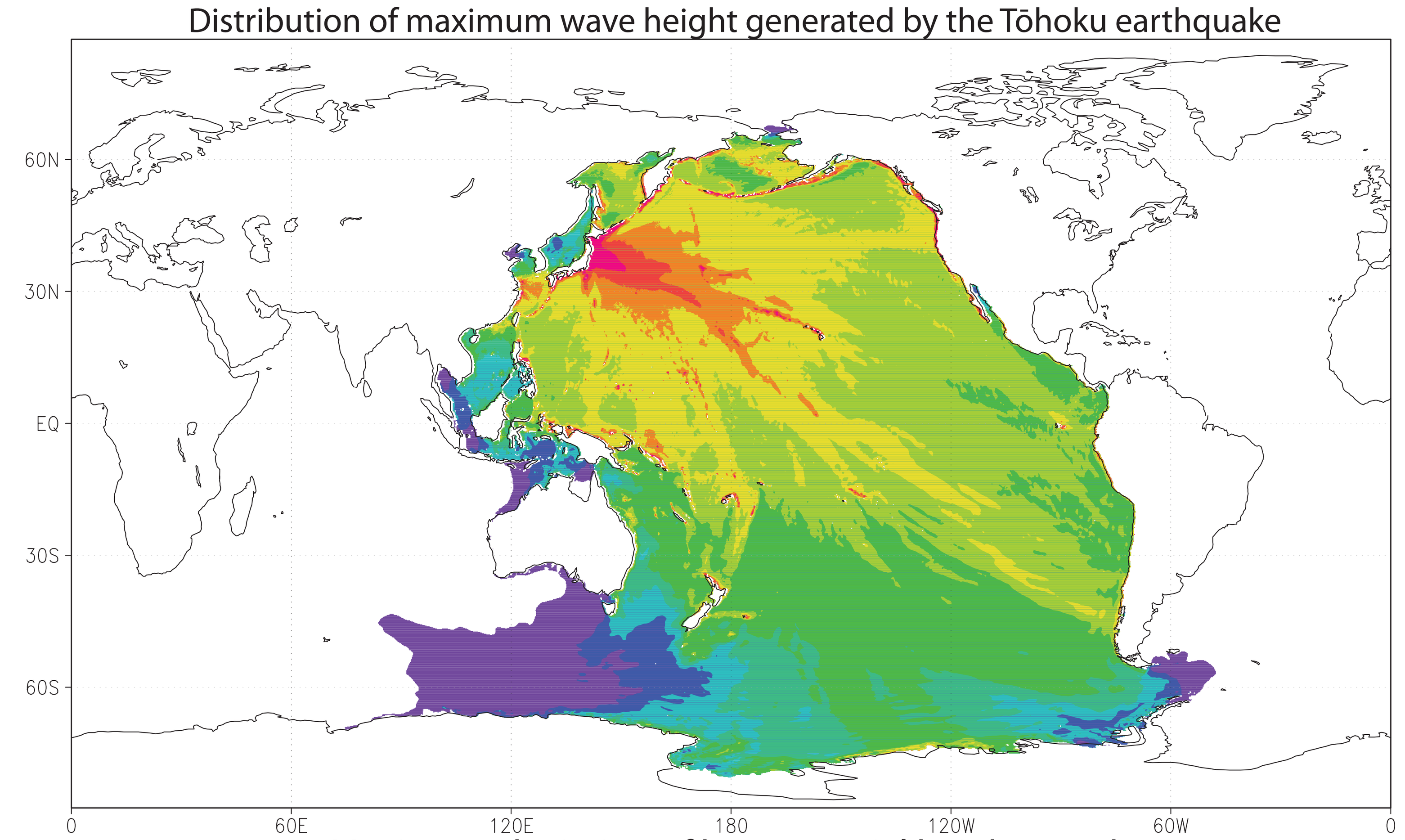




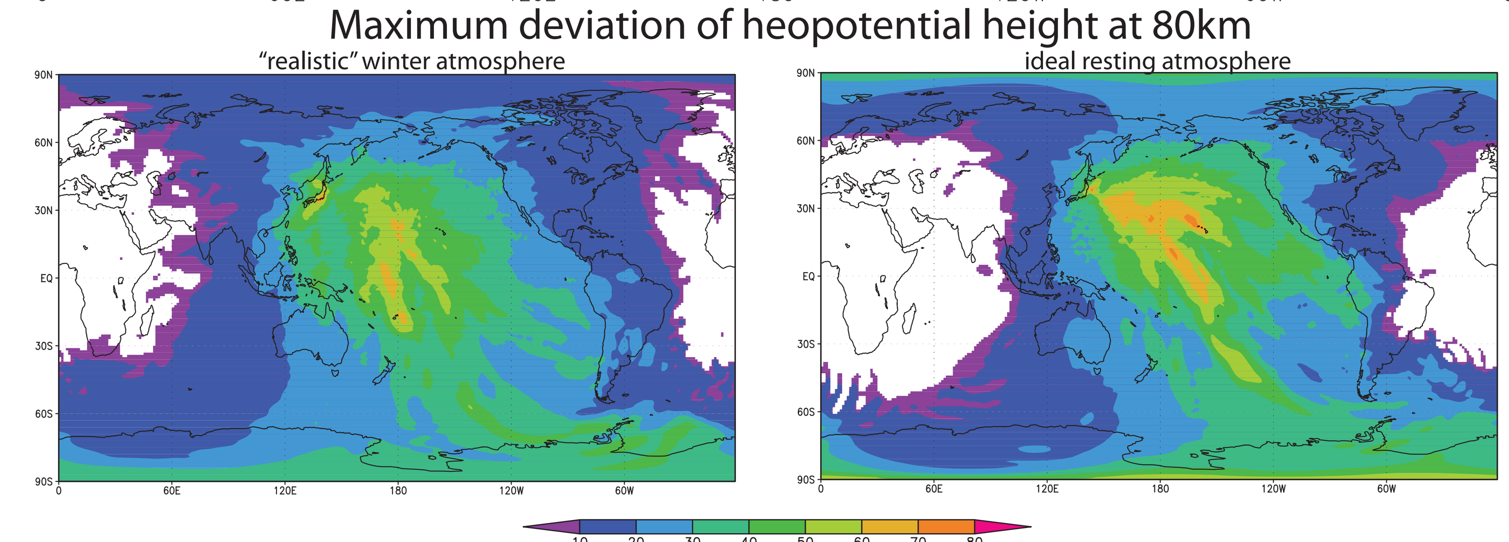
Both unperturbed and perturbed atmosphere were analyzed (set of figures on the right). There is a clear signal in the perturbed atmosphere on certain frequencies. Signal in band 1 arrives simultaneously with the tsunami wave. Bands 2 and 3 have the potential for early detection, but signal in band 3 is much weaker and probably is not practically useful. Timing of signal in band 2 could also make the detection problematic.

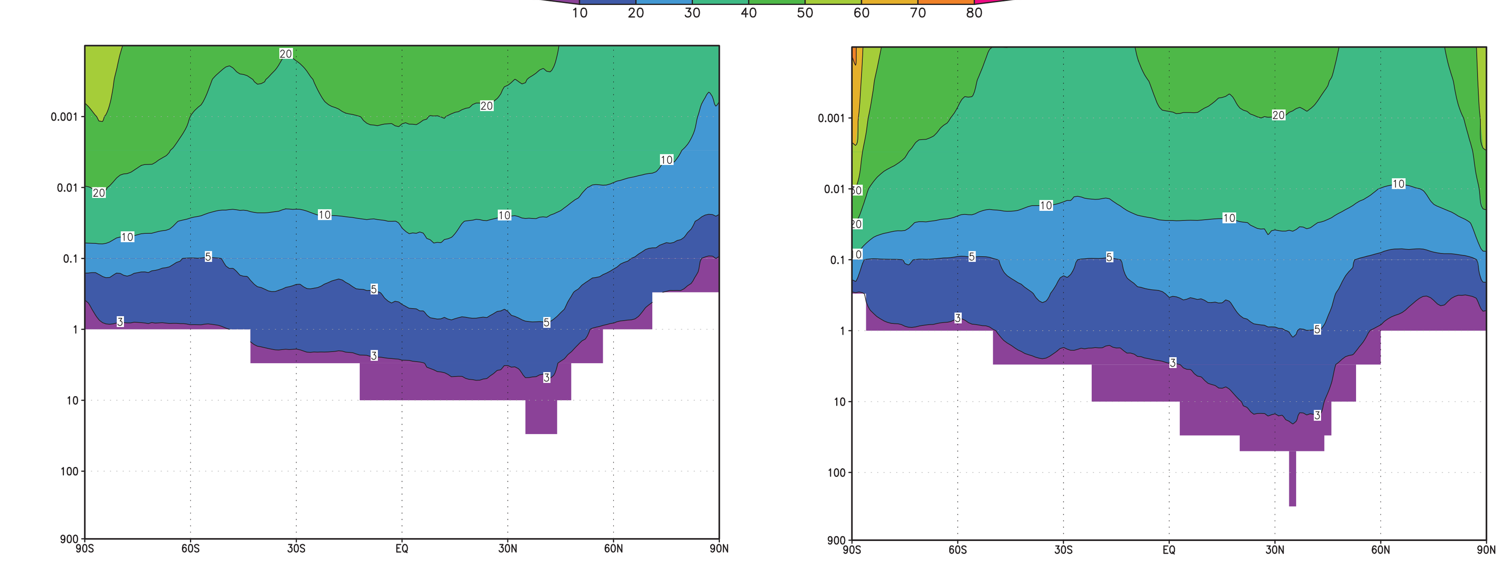


Distribution of maximum wave height generated by the Tōhoku earthquake



Maximum deviation of heopotential height at 80km





Perturbation in the atmosphere, at ca. 80km (upper panels) and zonally averaged (lower panels). The responses are quite similar, although the resting atmosphere allows the signal to propagate to Northern Hemipshere high latitudes. The "realistic" winter atmosphere does not, probably because of interaction of acoustic-gravity waves with zonal jets and stratification.

Conclusions.

1. Faster propagation of tsunami-generated acoustic-gravity waves makes early detection of tsunami possible by way of observing processes in the upper atmosphere, although the signal strength and detection success can vary.
2. Models need to be specifically designed to simulate all important processes (both "standard" atmospheric physics and electromagnetic) for successful reproduction of tsunami signal in the upper atmosphere.

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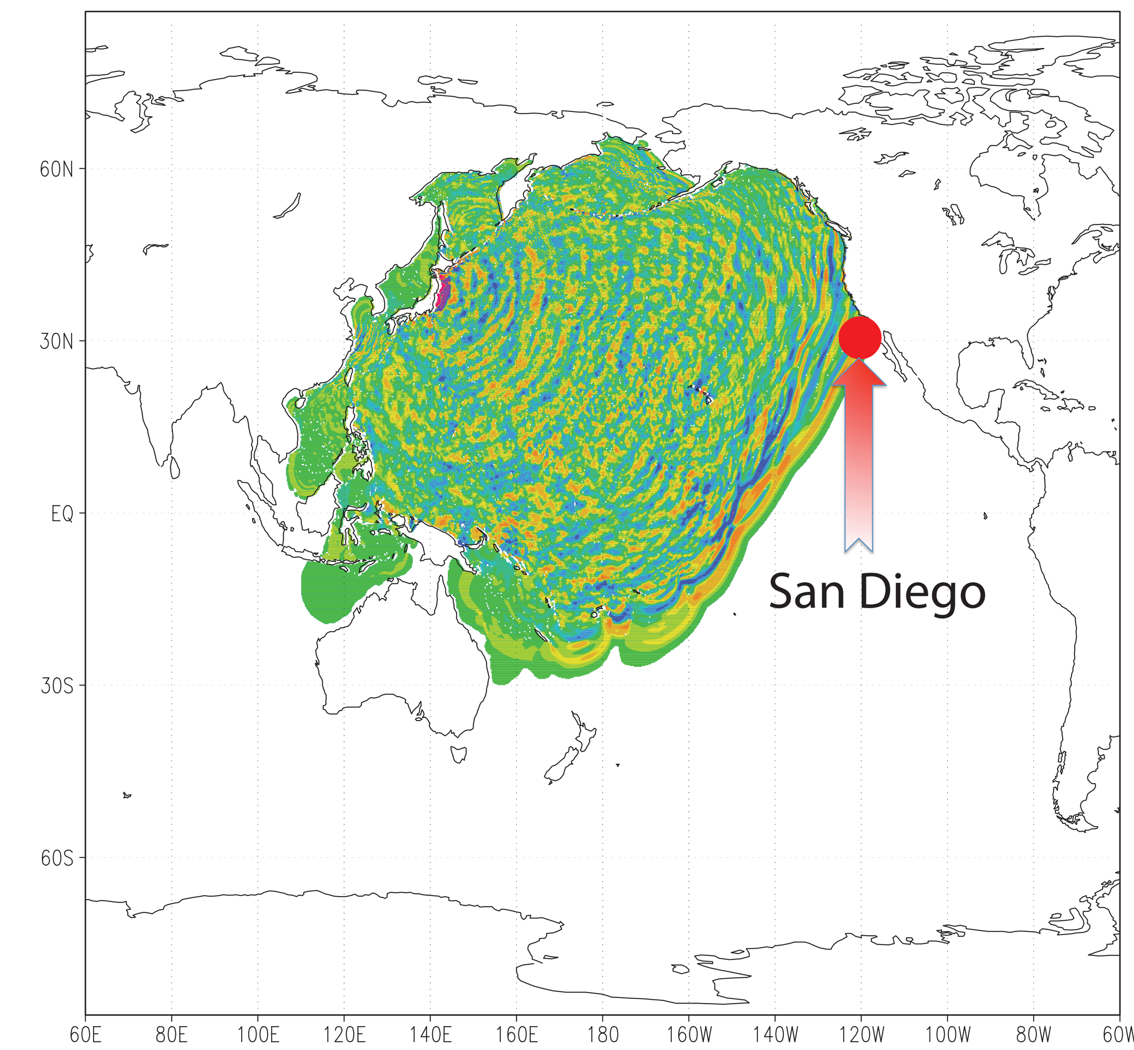
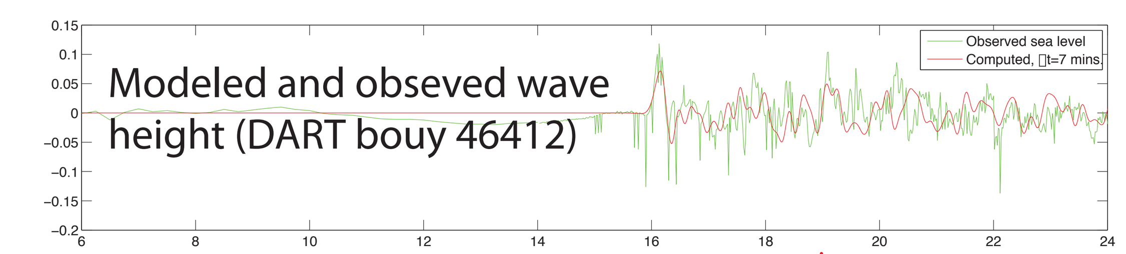
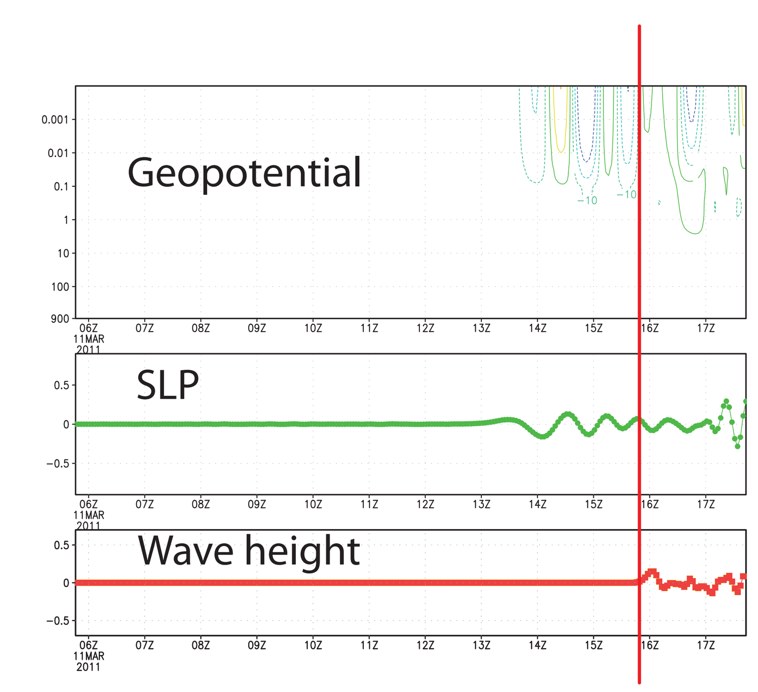
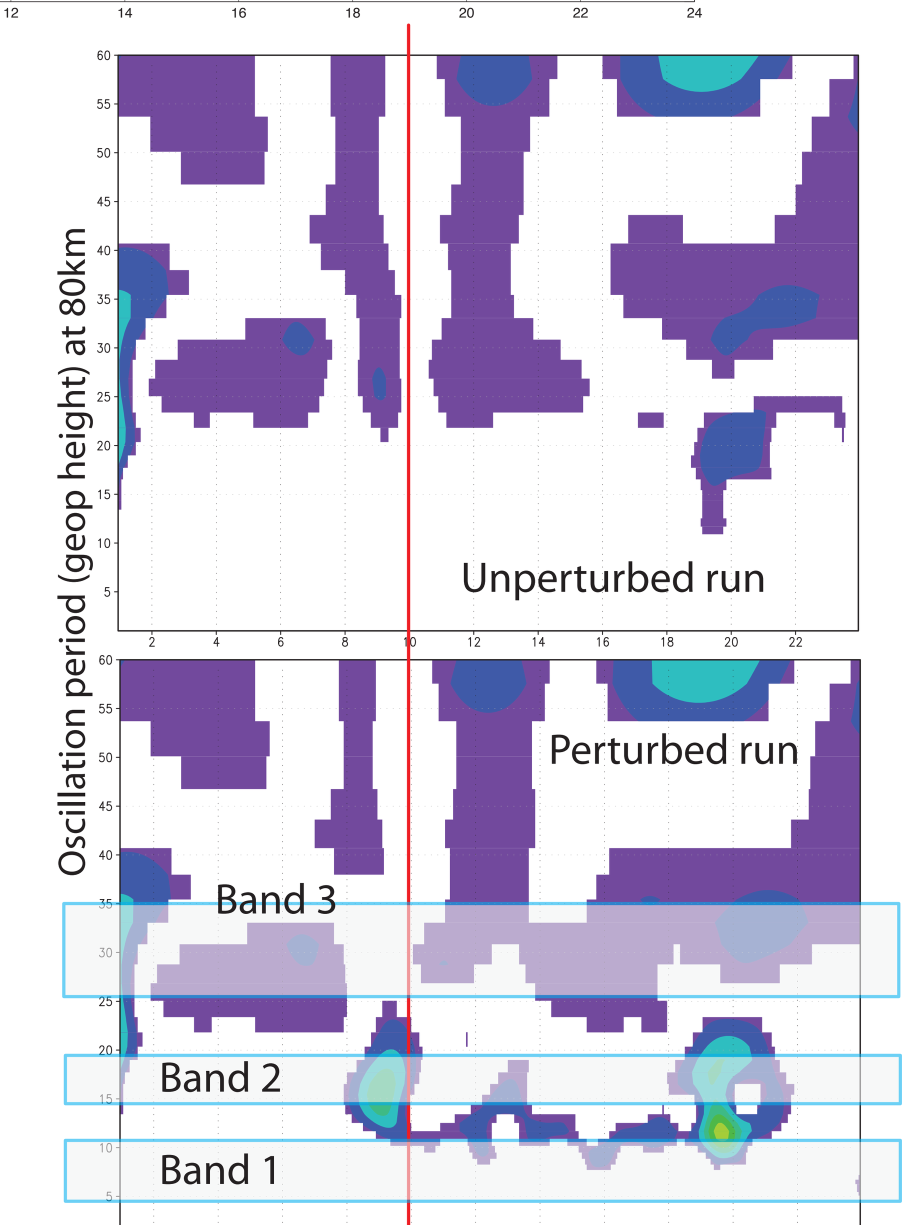




A similar analysis was conducted for San Diego area. Signal in the upper atmosphere arrives about two hours earlier than the tsunami wave (see figure below).





However, the signal in the San Diego area is generally weaker (see pictures of wave energy in the center), which makes the detection more difficult. Wavelet analysis still shows the signal from the tsunami above the noise level. Wave energy picture shows "preferred" pathways for energy propagation. San Diego is not on one of those pathways. Detection success will obviously depend on the strength of the signal in a particular location.