Characterization of structure and properties of the northern Hikurangi margin using OBS seismology for studies of slow slip and along-strike variations in plate interface coupling

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The Hikurangi subduction system exhibits a range of slip conditions, from aseismic to strongly coupled, with strain release by coseismic, slow slip, and repeating microseismic events. Multi-disciplinary studies as summarized in Wallace et al. (2009) point to a number of factors which affect frictional properties and stress along the Hikurangi plate interface. These factors are identified as also important in other subduction systems and include the presence of fluids and accretionary sediments, serpentinization and other hydration processes in the slab and plate interface, shear localization and stress buildup, temperature, lower plate morphology (seamounts, plateaus), and aseismic slip processes. Slow slip earthquakes (SSE) are still not well understood, but studies consider conditionally stable frictional regimes, in the transition zone between velocity strengthening (e.g., aseismic slip) and velocity-weakening (e.g., stick-slip) behavior on the interface (e.g. Scholz 1998; Schwartz and Rokosky 2007). Many workers also suggest that fluids play a major role in the occurrence of slow slip events and associated non-volcanic tremor (e.g., Obara et al., 2002; Liu and Rice, 2007).

The New Zealand continuous GPS and seismic national networks have led to the identification of slow slip events at the Hikurangi subduction margin. The northern Hikurangi margin SSEs are shallow (<15 km depth), occur more frequently, have shorter durations (1 week up to 2 months) and smaller equivalent moment release (~6.5-6.8) and possibly associated with subducted fluid-rich sediment (Bell et al., 2010). In contrast, the Southern Segment SSE events (e.g., Fig. 1) are deep, (35-50 km depth), characterized by long durations (1-1.5 years) and larger equivalent moment release (> Mw 7.0). Relevant scientific questions include how do the physical properties of the interface change in the downward transition from strong coupling to slow slip? Do SSE occur in regions of locally elevated fluid pressures? If so, how does this fluid pressure evolve along the interface and within the overlying plate during an SSE cycle? Will substantial fluid migration occur, influencing SSE behavior and nearby seismicity? Integrated, multi-disciplinary studies are required and are direct targets for the proposed series of IODP boreholes (as summarized in IODP slow slip event workshop; Bell et al., 2012). These Hikurangi source areas are accessible for geophysical observations that will aid in the assessment of the physical controls on SSE behavior.

Three major regions of along-strike coupling conditions have been identified by Wallace et al (2009) and listed in Fig. 2. The areal extent of strong coupling is much broader in the south than for the Northern and Central Segments, suggesting conditions for a future large magnitude megathrust event. Seismic transects are now established in the Central and Southern Segments (NIGHT and SAHKE projects, respectively; Henrys et al., 2006; Henrys et al., submitted). The proposed IODP drillhole transect nicely forms a baseline for a broader seismic transect of the Northern Segment subduction margin. Such a transect would allow for direct comparison of these three major along-strike zones.

We propose OBS-based studies at different scales that target high resolution images of the proposed borehole region and also provide the broader regional context of the subduction system for the net drillhole transect. At a broader scale, a pair of refraction-wide angle reflection transects are proposed (Fig 3): (a) an OBS-portable land instrument onshore-offshore seismic profile through the drillhole sites extending landward in the slab downdip direction and (b) an OBS-only strikeline that will examine local lateral variations in the plate interface, overlying and subducting plates. Seismic airgun sources will be used. These transects will provide seismic velocities and possible direct waveform images of major structures such as overlying plate internal structure and downdip Moho, the plate interface, Hikurangi plate structure (sedimentary basins, plateau/oceanic crust) and sub-Moho lithospheric mantle. They also will contribute information to the inferences of elastic and other material properties. The regional transects to the south offer indications of seismic opportunities; the SAHKE transect observes subduction channel reflections tracking downdip well beneath the land portion of the overlying plate (Henrys et al., submitted). Because of the major community focus on the offshore SSE region, these wide-angle transects can be designed with locally densified instrumentation to provide even higher spatial resolution along the borehole transect within the broader regional context. The transects will complement the 3D MCS survey that is being proposed by others.

In addition to the transects, within our working group we propose smaller-scale targeted OBS studies that examine the plate interface near the boreholes. An example includes several-km long crossing linear arrays centered on a major borehole with dense (100m) spacing to obtain seismic proxies for physical properties. Other targets include detailed imaging of plate interface structures (roughness). Discussions among our international working group members will continue with a goal to develop an implementation plan that includes science teams, time frames, and strategies for instrumentation, vessels for sources and deployments, proposals, and alignment of international funding periods.

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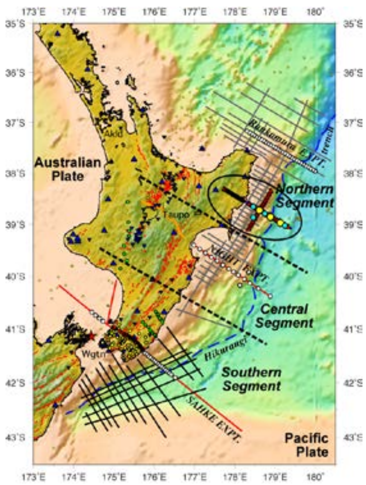


Figure 1 (left). Hikurangi subduction system, North Island, NZ. System varies along-strike (three segments). Seismic transects exist in southern two segments; we propose one in north. Proposed IODP wells (blue, yellow circles).

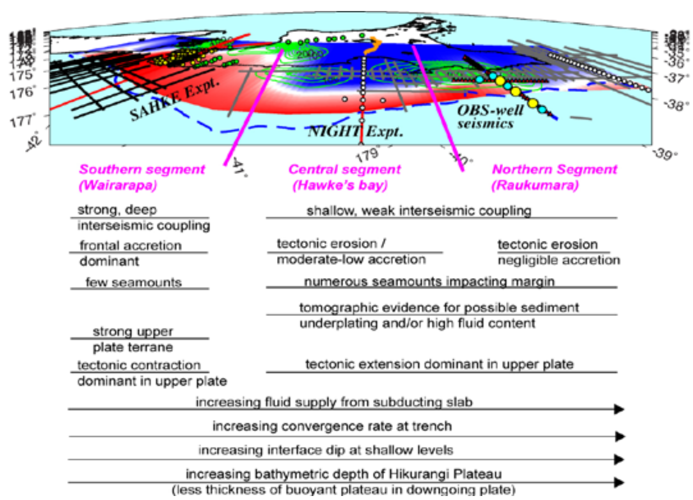


Figure 2. (right) North Island oblique view illustrating degree of coupling and list of properties/conditions that vary along-strike. Green contours denote SSE. Modified from Wallace et al (2010).

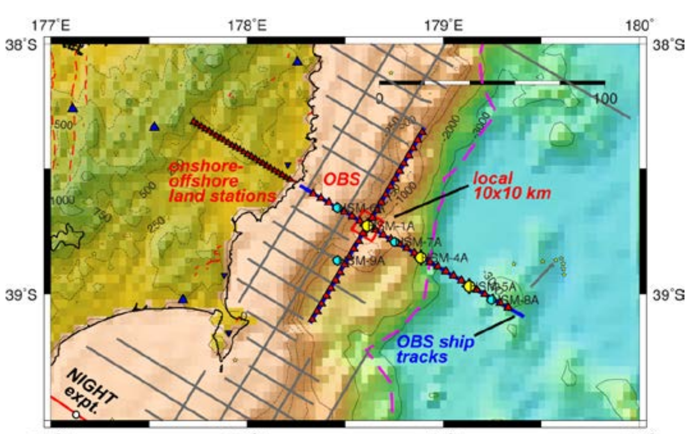
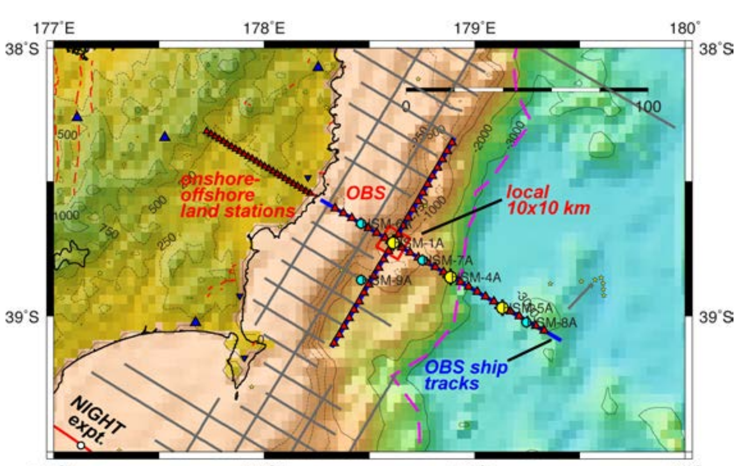


Figure 3. (left) OBS-based seismic transects coincident with proposed IODP borehole transect (blue-yellow circles). OBS (red triangles) will record airgun sources along ship tracks. OBS spacing will be finer based on instrument numbers. Densification will target main boreholes. Red box denotes possible site of focused higher resolution OBS seismic studies.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