Unlocking the secrets of slow slip by drilling at the Hikurangi subduction margin, New Zealand

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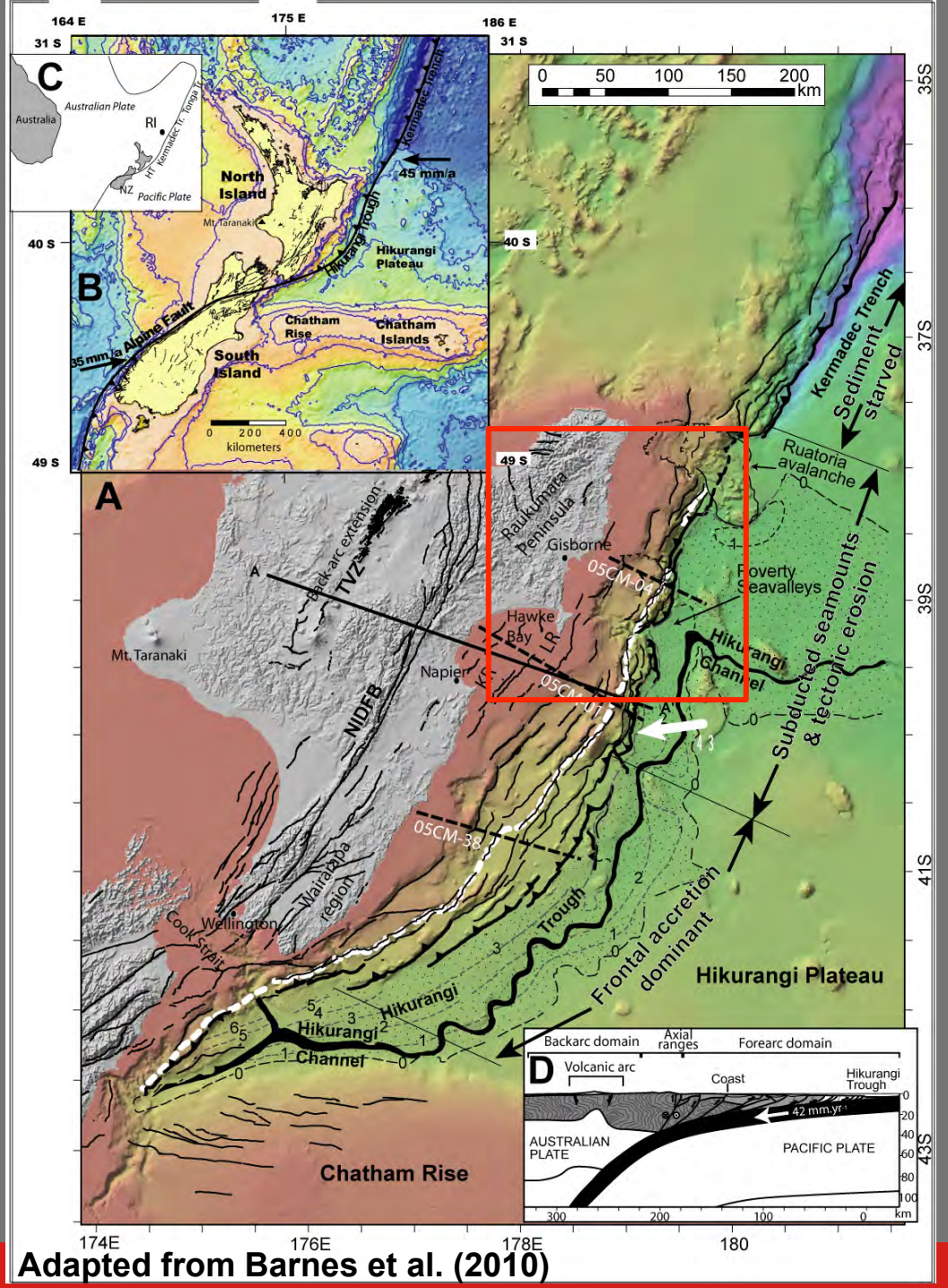
A large, international group of proponents submitted two full proposals to IODP in October 2011 to drill at the offshore Hikurangi subduction margin to investigate slow slip event phenomena

New Zealand: Philip Barnes, Stuart Henrys, Stephen Bannister, Daniel Barker, John Beavan, Susan Ellis, Joshu Mountjoy, Ingo Pecher, Rick Sibson, Rupert Sutherland, John Townend
Japan: Yoshihiro Ito, Shuichi Kodaira, Kimihiro Mochizuki, Kazushige Obara, Arito Sakaguchi
USA: Laura Wallace, Nathan Bangs, Rob Harris, Miriam Kastner, Kathleen Marsaglia, Greg Moore, Demian Saffer, Heather Savage, David Schmidt, Susan Schwartz, Eli Silver, Harold Tobin, Marta Torres, Mike Underwood
Canada: Kelin Wang
United Kingdom: Rebecca Bell, Lisa McNeill
Germany: Nina Kukowski
Italy: Francesca Remitti
South Africa: Ake Fagereng

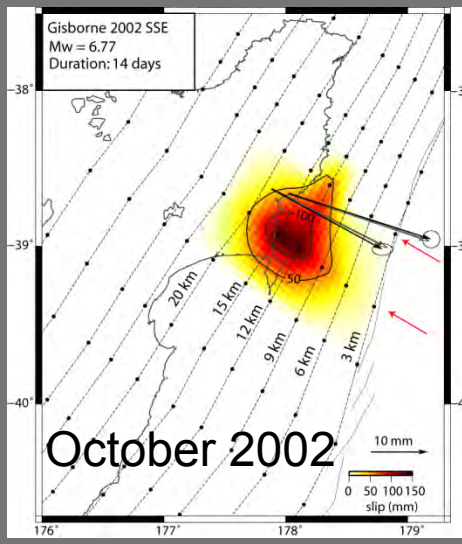
The Hikurangi subduction margin

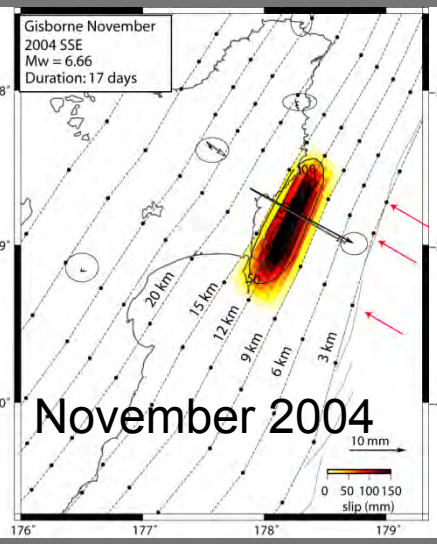
- The Cretaceous Hikurangi Plateau (an oceanic Plateau, part of the Pacific Plate) is being subducted beneath the eastern North Island, New Zealand at the Hikurangi Trough
- Convergence rates at the north Hikurangi Trough are 4-6 cm/yr, and decrease to 2-4 cm/yr at southern Hikurangi
- The northern portion of the Hikurangi margin is the focus of our drilling proposal. Offshore tectonics are dominated by subduction erosion and seamount subduction.
- The northern Hikurangi margin is relatively sediment-starved, with <1km of sediment blanketing the incoming Hikurangi plateau

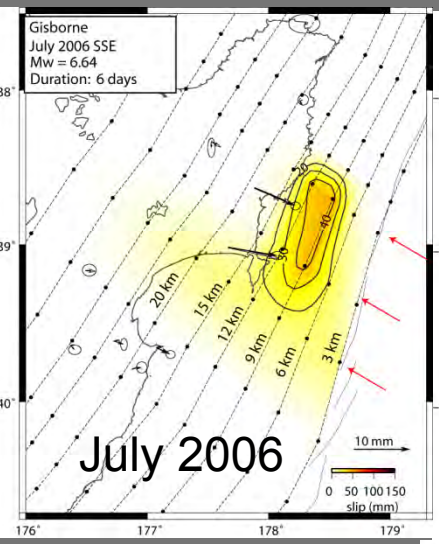


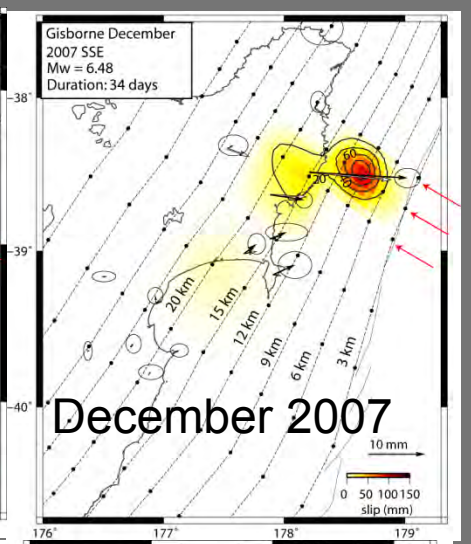
Adapted from Barnes et al. (2010)

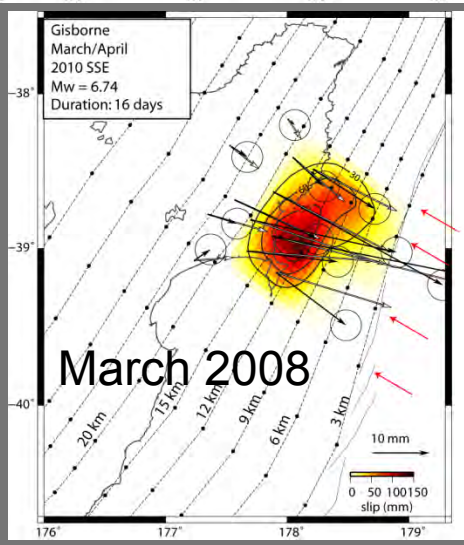
Shallow slow slip events (<5-15 km depth) on the subduction thrust at northern Hikurangi repeat every 1.5-2 years, and last for 1-2 weeks

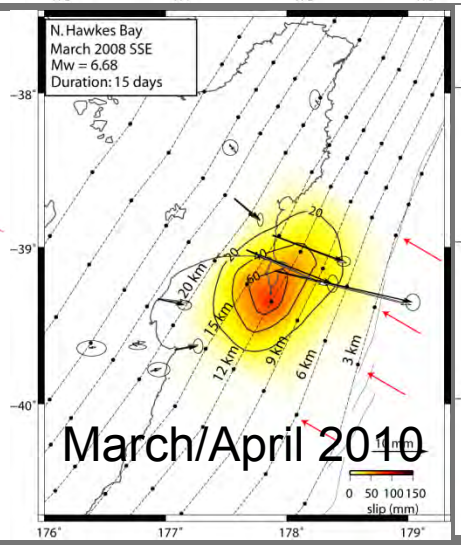


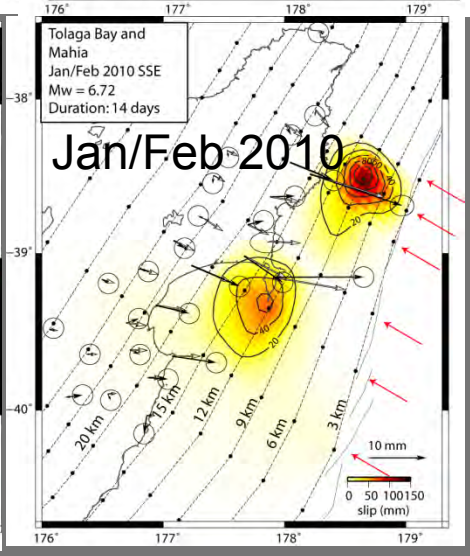








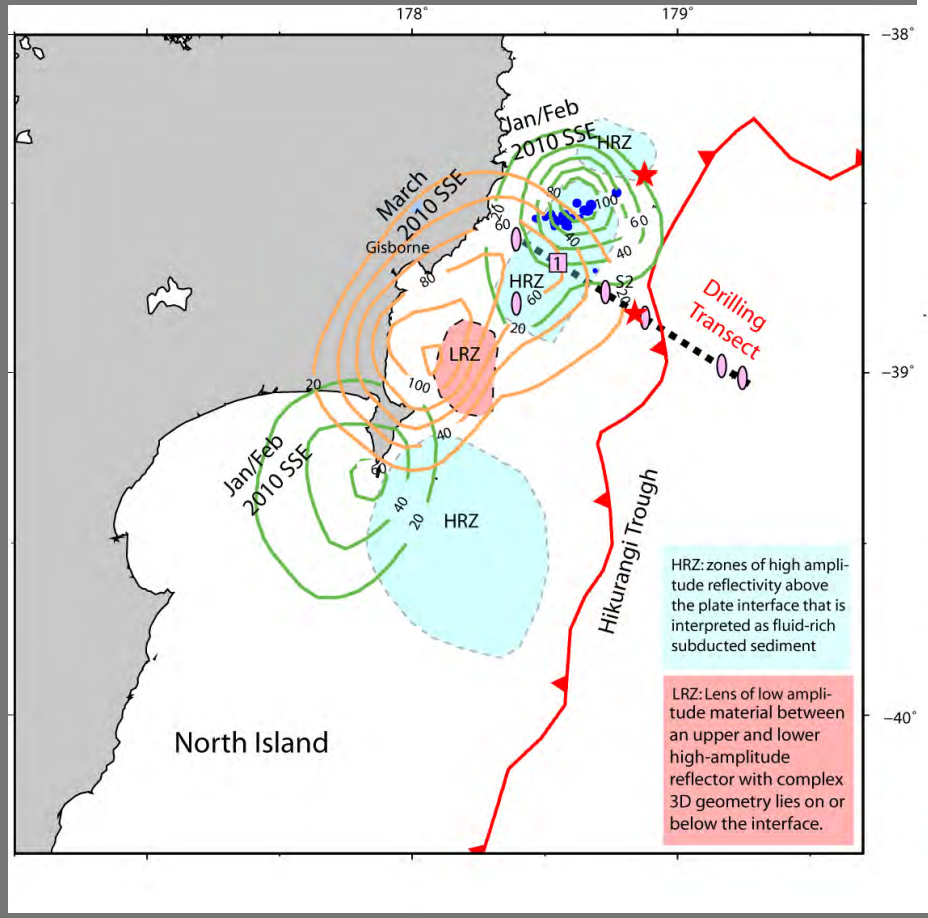


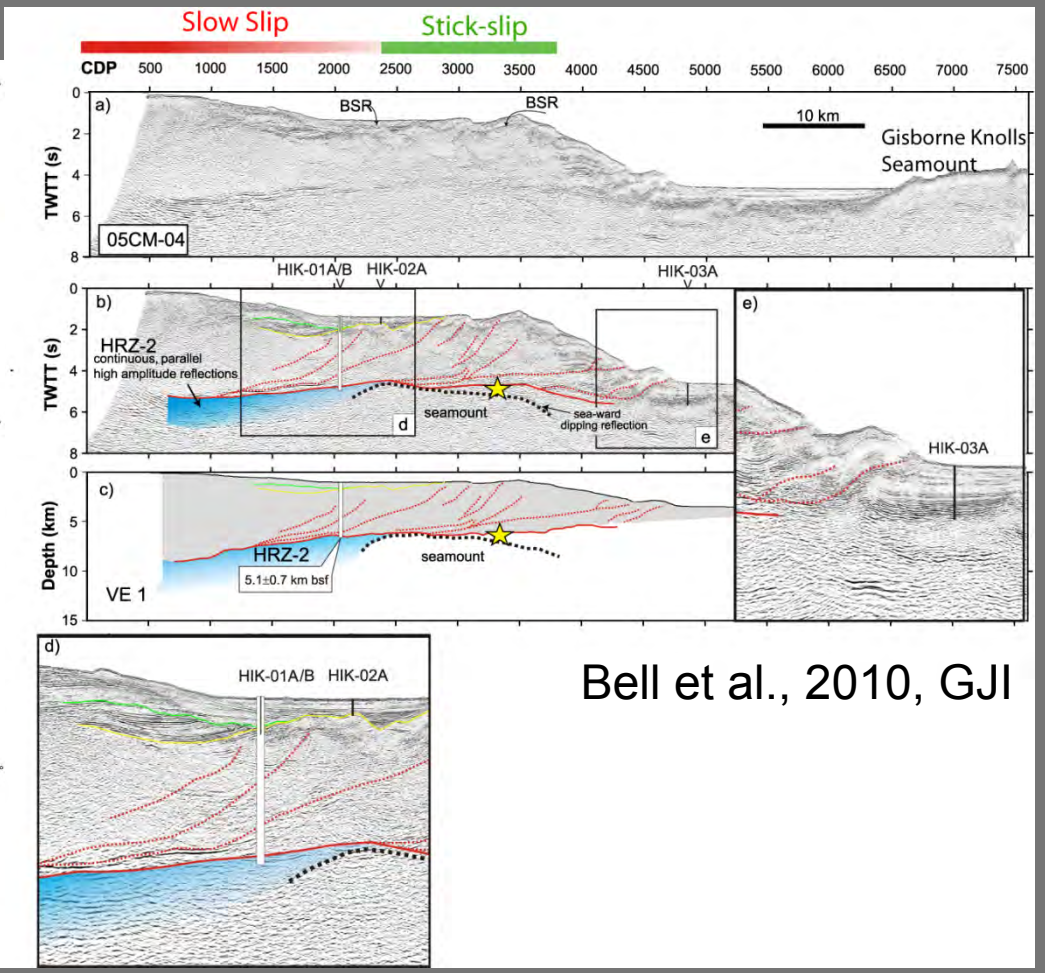


These are the shallowest, well-documented SSEs on Earth, and the SSE source area is within range of riser drilling capabilities. cGPS data show that the SSEs occur to at least 5 km below the seafloor (in ~1000 m water depth), and it is possible that they propagate all the way to the trench

Wallace and Beavan, 2010, JGR

North Hikurangi slow slip events are associated with a zone of high-amplitude reflectivity at the interface, which may indicate abundant fluids at the SSE source





Bell et al., 2010, GJI

The high amplitude zone and the SSE source is the drilling target (~5 km below the seafloor, in 1 km water depth). After submitting a preproposal on the project in 2010, SSEP requested that we develop the project into a Multi-phase drilling project. We submitted the MDP and one of the daughter proposals outlining the riserless/observatory phase in October 2011.

What KEY questions can we answer about slow slip events (SSEs) and megathrust behavior by drilling into and monitoring a SSE source area?

(1) Do SSEs occur under highly elevated fluid pressures?

(2) What role does fault strength and rock frictional properties play in slow slip?

(3) What are the rock types and fault zone structure associated with slow slip? What is the width of the zone where SSE slip occurs?

(4) Do short-term hydrological variations facilitate SSE occurrence?

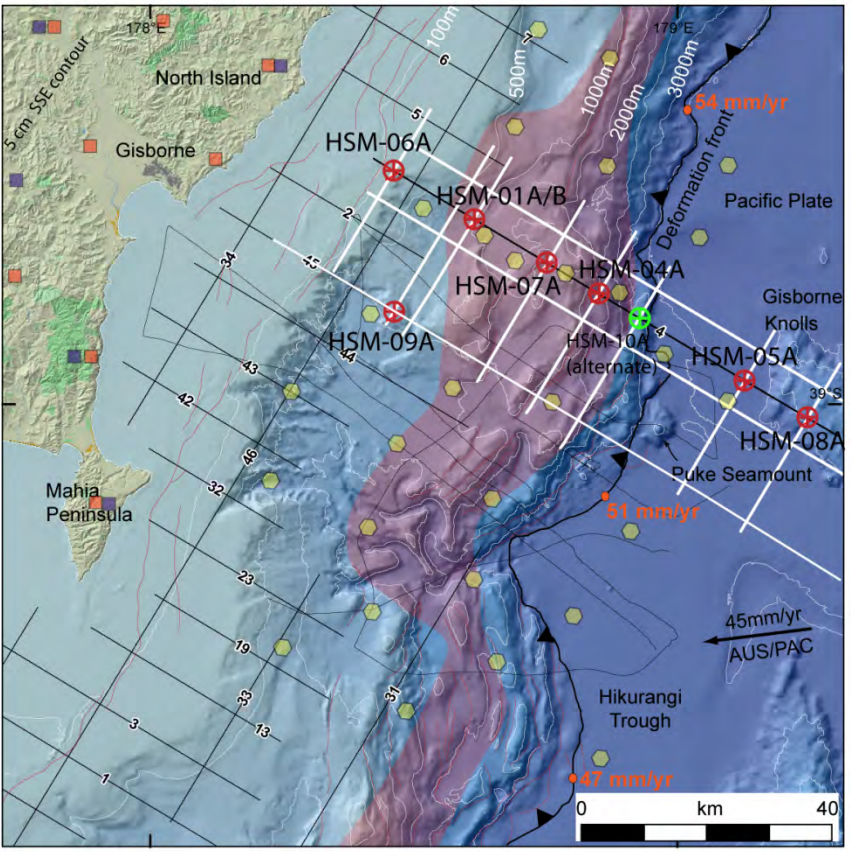
(5) How do fluid chemistry, pressure, temperature, and fluid flux (near the surface and at the SSE source) vary in response to SSEs?

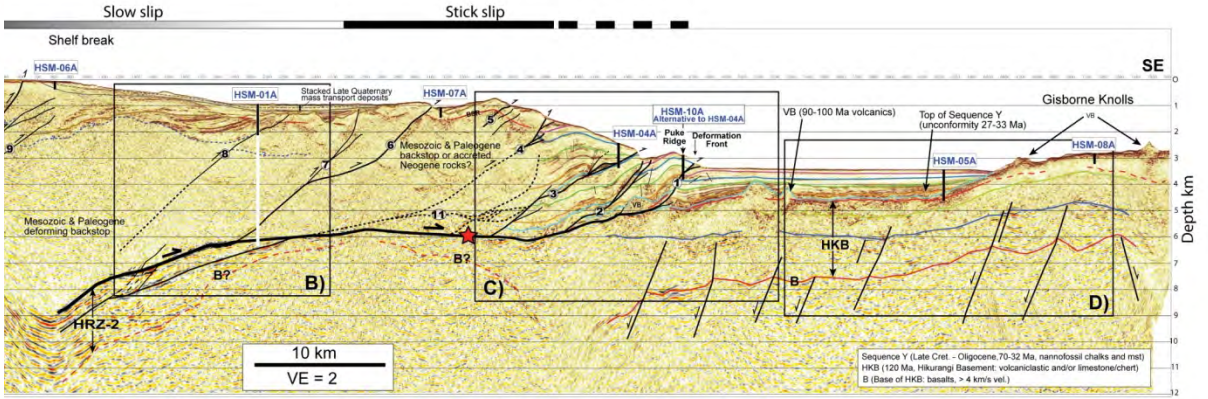
(6) Does temperature have an influence on the occurrence of SSEs?

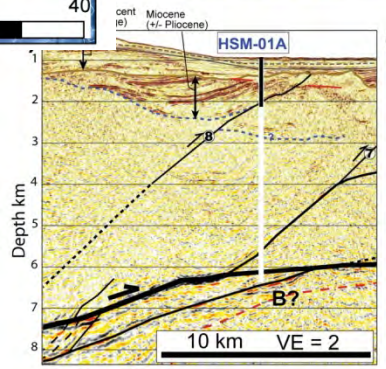
(7) Can SSEs propagate all the way to the trench?

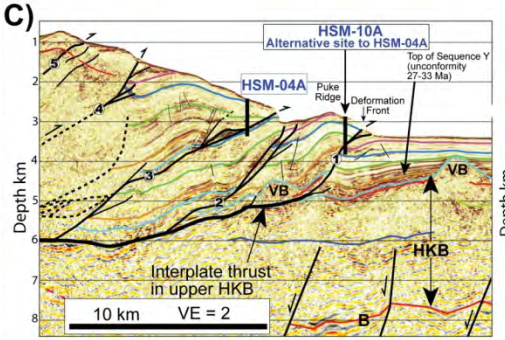
SAMPLING, LOGGING, AND MONITORING ABOVE AND WITHIN THE SSE SOURCE AREA USING IODP DRILLING IS THE ULTIMATE WAY TO SOLVE THE MYSTERY OF WHY SLOW SLIP EVENTS OCCUR

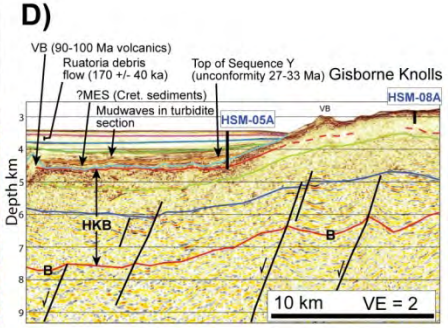
Our three-phase project to unlock the secrets of slow slip involves both shallow (<2 km) and deep (5-6 km) drilling



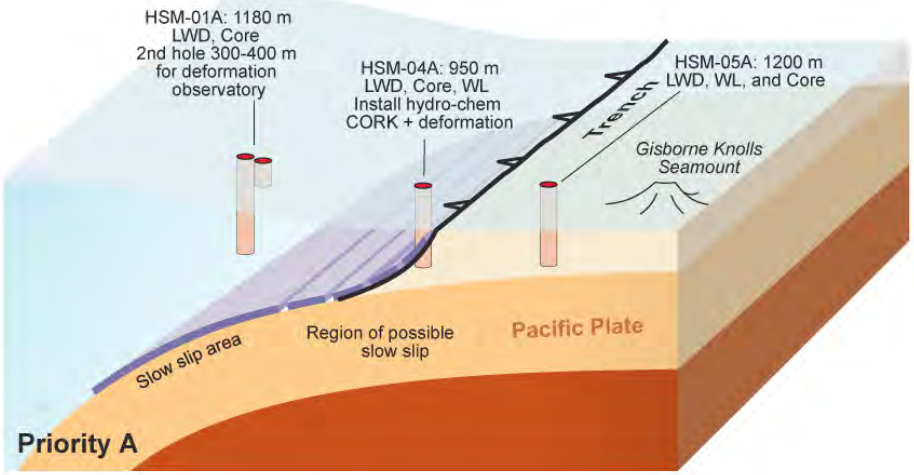


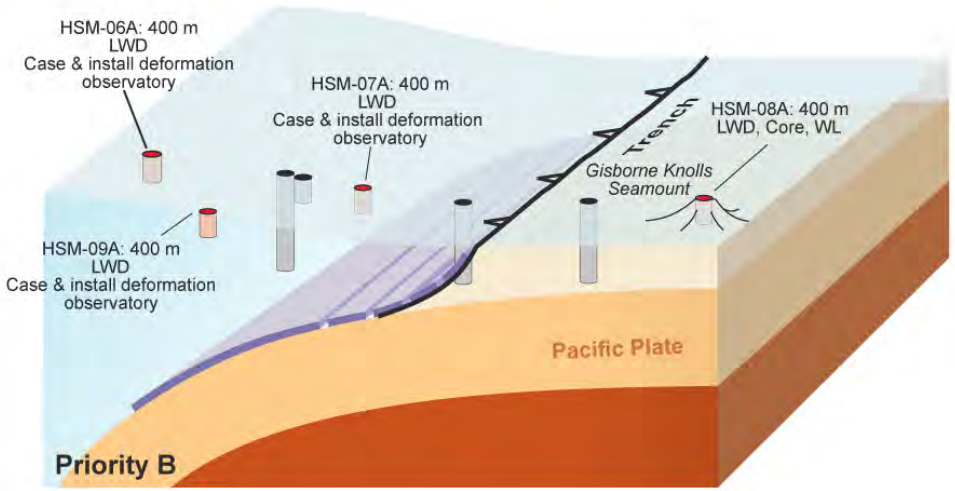






Phase 1: Riserless drilling and shallow observatory spanning the SSE source and incoming plate



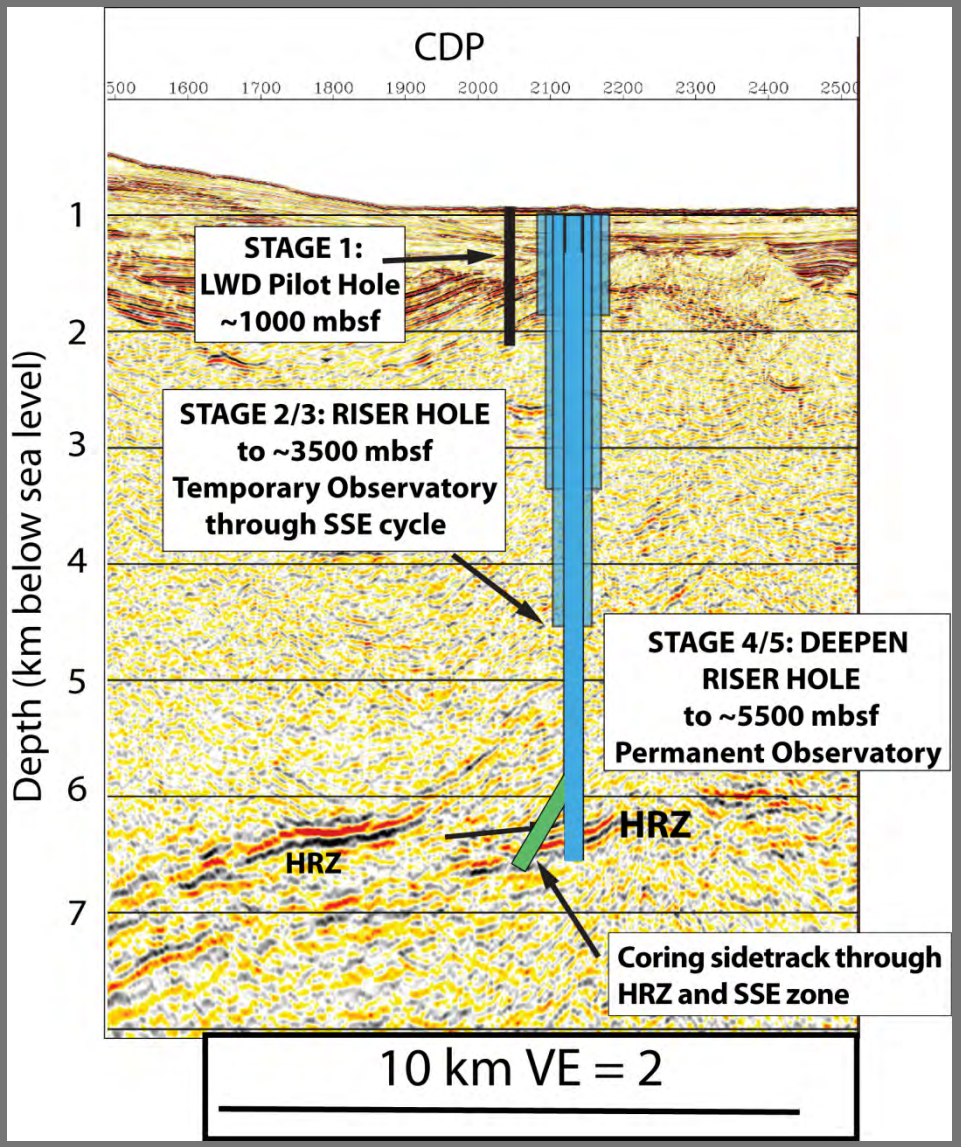


Phase 1: Seven shallow (~400-1200 m below the seafloor) riserless sites to collect samples and geophysical logs of the overriding and subducting plates, and install observatory equipment to monitor near-surface changes in deformation, seismicity and physical properties throughout a SSE cycle and characterize the distribution of SSE slip with very high fidelity.

Monitoring the transect spanning the SSE source area will also allow us to determine if SSEs propagate all the way to the trench. If so, the SSE source area might be accessible using riserless drilling.

A key role of the sites on the incoming plate is to sample and characterize the rocks that host SSE prior to their subduction.

Phases 2 and 3: Deep riser drilling and long-term monitoring at the SSE source area



Phase 2: A deep riser hole (~5-6 km below the sea floor) to penetrate the subduction interface and ***directly sample rocks from the SSE source region***, collect logs across the fault zone(s), and measure temperature, fluid pressure and chemistry, and stress.

Phase 3: Installation of a long-term borehole ***monitoring*** system to detect changes in deformation rate, and physical and chemical properties ***at the SSE source*** during a complete SSE cycle.

Main site survey needed for this: 3D seismic

Where to from here?

- After extremely favorable external reviews of 781-MDP and 781A-Full, PEP has forwarded proposal 781A-Full (riserless transect and observatory) with an "Excellent" rating on to the Operations Task Force for ranking and scheduling of the project.

- We intend to submit a proposal for the riser drilling and deep, long-term observatory phase for the April 2013 IODP proposal deadline, and just before the Chikyu+10 meeting.

- We have obtained sufficient site survey data for the riserless drilling component of the project (Phase 1); however, for Phases 2 & 3, additional data are needed (most notably, 3D seismic)

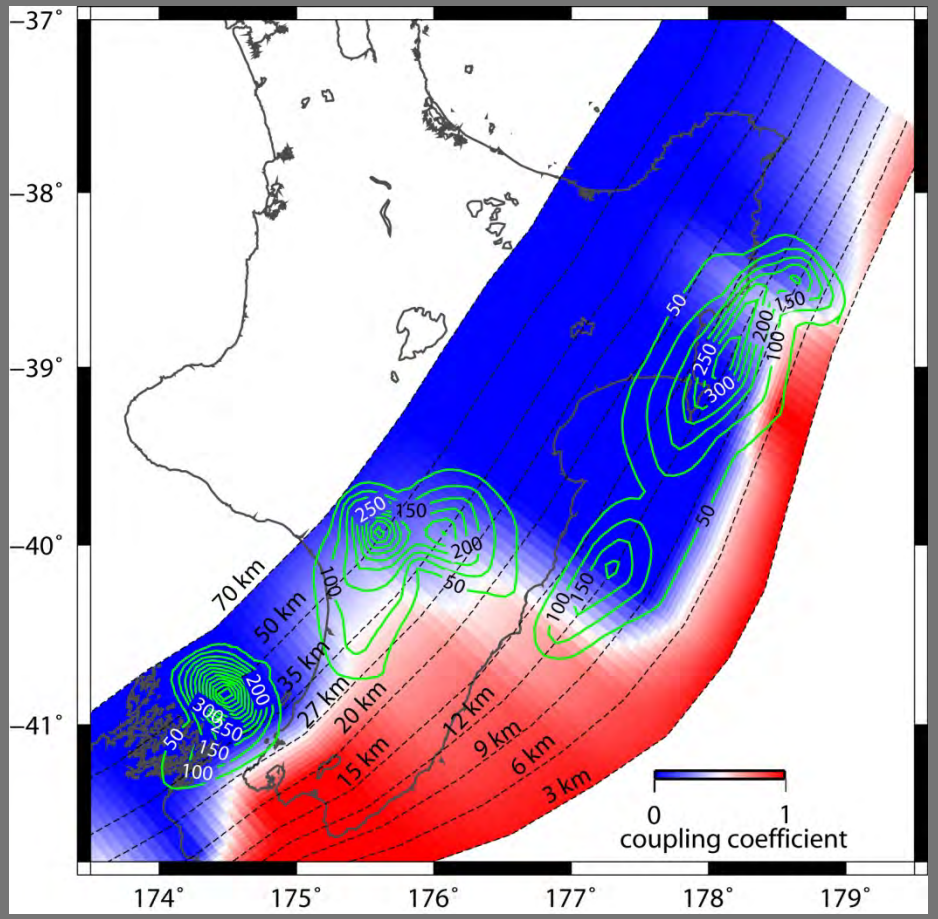
- Efforts are currently underway to develop proposals to undertake a number of auxiliary projects to better characterize the slow slip drilling target (OBS/OBP deployments, heatflow studies, 3D seismic, among others).

- An observatory plan is being developed and we are seeking funding for this.

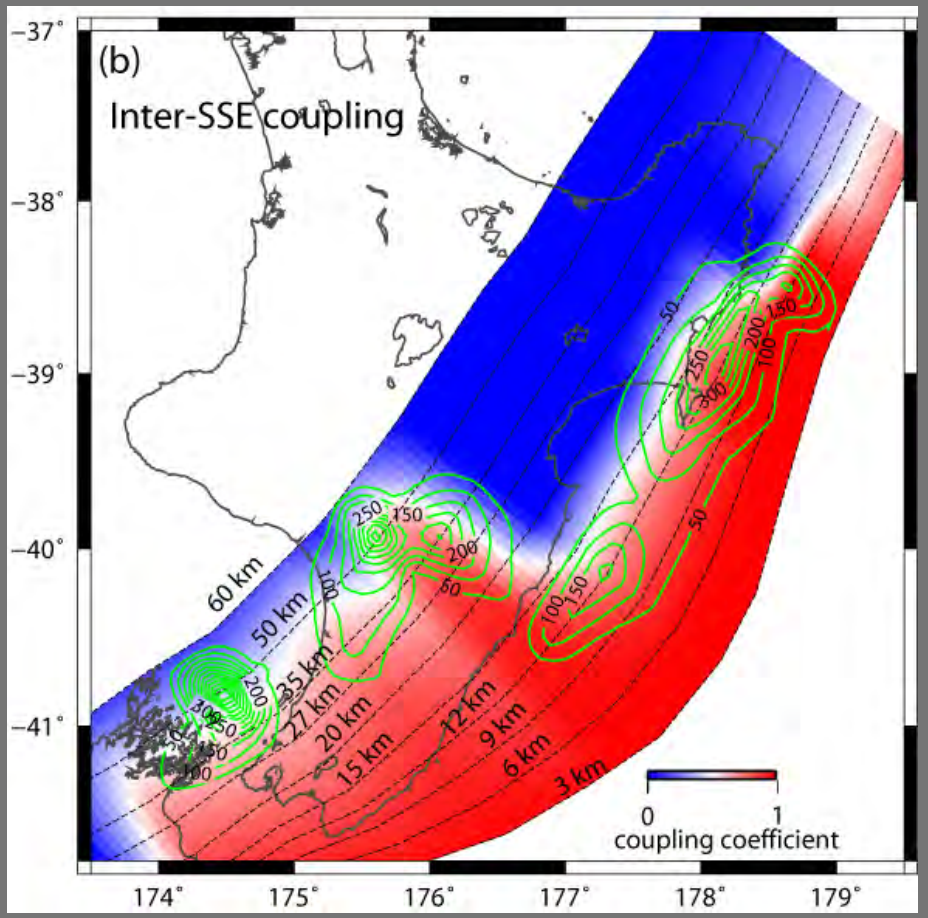
Slow slip events and their relationship to interseismic coupling at the Hikurangi margin

Green contours show total slip on the interface in SSEs since 2002

Interseismic coupling using campaign GPS velocities averaged over the last ~15 years

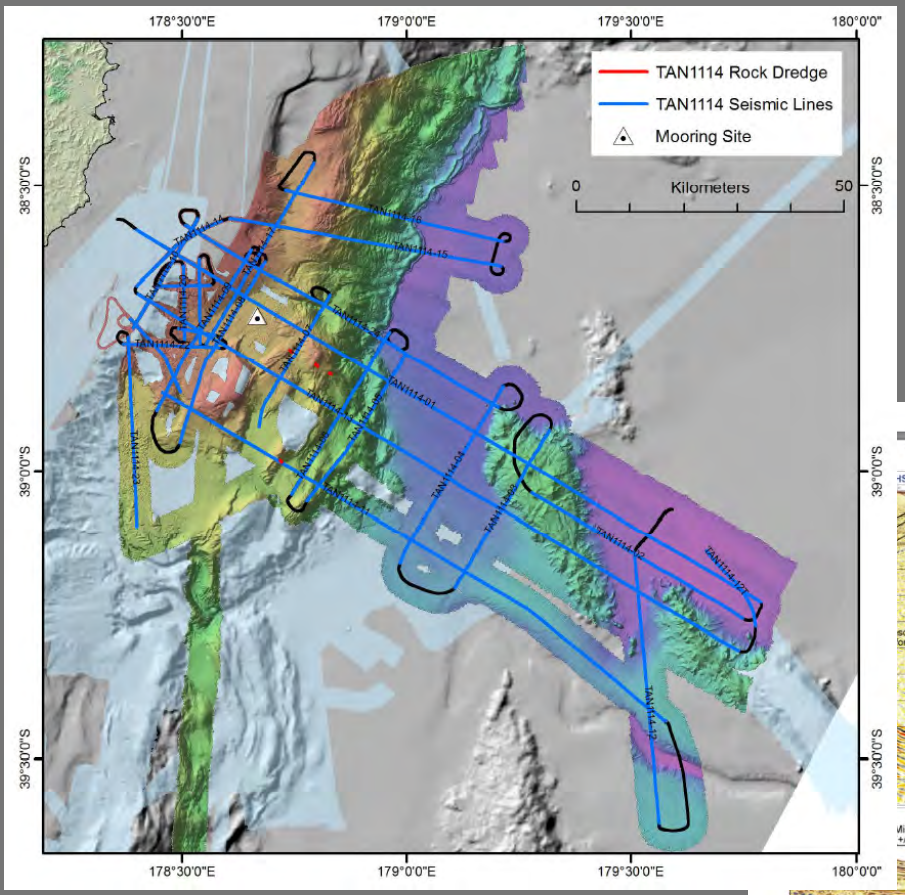


Wallace and Beavan, 2010, JGR



Interseismic coupling using “inter-SSE” velocities from the continuous GPS network

Site survey data required for the riserless drilling has already been acquired



The high-quality 2D MCS line across the drilling transect was acquired in 2005 (NZ MED funded), and crossing seismic lines were acquired on the RV Tangaroa by NIWA and GNS in October 2011