A High Temporal Resolution Optical Flow Meter for Measuring Aqueous Flow in Active Plate Boundary Systems

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Plate boundaries are systems with dynamic fluid flow response to tectonic and overburden pressures, gas hydrate processes, heat flow and temperature anomalies, and chemical and biochemical reactions. Studies to date at accretionary margins indicate highly heterogeneous temporal variation in flow rate at the sediment-water interface. In 1998 and 1999 Chemical and Aqueous Transport (CAT) meters capable of detecting daily variation were deployed on Hydrate Ridge, Cascadia accretionary prism. Flow rates were found to vary at sub-daily tidal frequencies suggesting the need for a higher resolution record to understand fluid flow in relation to tidal variation and transient flow events such as those resulting from the instability of hydrates. Results from a 1999-2000 deployment of CAT meters on the Costa Rica Pacific margin, compared with simultaneous OBS measurements, emphasize the coupled nature of earthquakes and pulses of fluid movement through the seabed. In this instance flow meters placed on the toe of the accretionary wedge recorded transient flow events correlated with an increase in OBS noise, suggesting the capability of flow meter instruments to detect minute volumetric changes associated with aseismic slip in the upper few kilometers. CAT meters measuring flow rates from 0.001 to 15m/yr have a temporal resolution of 6-24 hours. Due to the rapid transient nature of gas hydrate, fault and slip related fluid events, a new Optical Flow Meter (OFM) is being developed to detect a large range of flow rates, 0.01 to 50+ m/yr, at a higher temporal resolution of 10-30 minutes. Depending on the site, a combination of both types of instruments will be used. Understanding the response of plate margins at all temporal scales to aseismic and seismic strain, the release of hydrates, and overburden is essential to understanding the response of these dynamic systems as a whole.

Like the CAT meter, the Optical Flow Meter measures aqueous flux at the seafloor by covering an area of the sediment surface and channeling the flow from this sealed off area through and outlet tube. They differ, however, in the method of flow measurement. The OFM, using the Persistor CF2 computer, injects pulses of fluorescent tracer at 10-30 minute intervals into the outlet tube. The Persistor records photodiode measurements of transmittance and fluorescence up and downstream of pulse injections as an LED shines through the outlet tube. Data will then be downloaded from the OFM upon recovery or transmitted via satellite buoy or cable network. Flow rates can be determined at the higher flow regimes from the delay time between pulse injection and detection of the pulse. As the tracer becomes more mixed at lower flow regimes, flow rates will be calculated from the amplitude of fluorescence and transmittance signals, which relates to the tracer concentration.

We plan to deploy prototypes of the OFM in conjunction with CAT meters in Monterey Bay, the Pacific Northwest (Nootka Fault zone), and the Costa Rica and Nankai margins. All the above areas are associated with either active convergent and/or strike slip plate boundary fault zones. Early in the program, I will be involved in the deployment of a collection of instrument types in Monterey Bay to characterize hydrologic flow, and check the calibration of the several methods for determining flow rate from the OFM's raw data in the lead up to the following main experiments. At the Costa Rica margin we wish to gain an understanding of the fluid variability at as it relates to convergent earthquake and silent-slip events. In contrast, the Nootka Fault is a highly seismically active transform plate boundary developing through the northern Juan de Fuca plate, and intersects the Cascadia subduction zone forearc at a Triple Junction. We seek to relate fluid flow and transient or volumetric strain events with other measurements of seismicity, pore pressure, temperature, and chemistry to fully understand the dynamics of active tectonic processes. In all of these environments, high-resolution measurements from OFMs that are sensitive to seismic and aseismic slip as well as gas transport events, are necessary to comprehend these dynamic hydrologic environments. We ultimately plan to hook the OFM to sub-sea cable and buoy based satellite networks for real-time analysis.

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