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Topographically and hydrothermally controlled dynamic processes at Endeavour Ridge

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Endeavour Ridge, the northernmost segment of the 525 km Juan de Fuca Ridge system, has five known vigorous high temperature vent fields that are estimated to produce 1500 MW of power that is dissipated in turbulent mixing and buoyancy flux. The fields reside within a rift valley which provides an approximately 10 km long by 1 km wide and 100 m deep topographic constraint on the circulation. This valley is at the crest of the relatively gently sloping but much larger 90 km long ridge, which rises approximately 500 m from a basin depth of 2600 m.

The combination of topographic interaction with the ambient currents and energy input from the hydrothermal venting is an intense modifier of the local flow structure. Due to the generation of internal tide, semidiurnal tidal flow becomes more rotary and enhanced as it nears the larger ridge structure but is then rectified and aligned with the axis of the valley as it penetrates below 100 mab (metres above bottom). Topographic trapping, analogous to shelf waves, also causes diurnal tidal flow to develop strong rotary characteristics at the ridge crest but is strongly diminished within the valley. Storm-driven inertial waves propagate from the surface after winter storms and are episodically the strongest currents above the ridge crest (as much as 70 cm/s) but cannot enter the valley due to the low propagating angle ($\sim$1 degree from horizontal) of these waves. The enhanced generation of internal waves within the tidal band coupled with the occurrence of intense episodic inertial waves produce nonlinear higher constituents, most notable in the $f\mathrm{M}_2$ frequency band (at the sum of the inertial and M_2tidal frequencies) but also at other harmonics of the semidiurnal and inertial bands. Lower frequency energy is enhanced in the 4-day weather band with some evidence showing that it is due to waves propagating the entire length of the Juan de Fuca Ridge. Against the ambient southward 5 cm/s mean flow that is part of the deep circulation of

the Northeast Pacific, the hydrothermal venting drives a 5 cm/s mean flow northward up the rift valley in analogy to the sea breeze effect seen in the atmosphere prevalent to many coastal inlet valleys.

Near continuous current observations since 1984 are complemented with an array of three long-range 75kHz ADCPs (penetrating 500 mab) and 5 conventional moorings (current meters at 15, 30 and 75 mab). This array is situated within the valley in order to elucidate the spatial structure of the currents and verify the sea breeze hypothesis. The moorings are located in two cross axis lines, one between the southernmost vent field (Mothra) and the Main Endeavour vent field (MEF), the other north of MEF and south of the next field, Hi-Rise. Preliminary analysis of the data recovered in 2004 after a year long deployment shows variability in all but the very lowest frequency bands on spatial scales often smaller than the spacing of current meter moorings. The horizontal scale of the turbulence generated below the neutrally buoyant plume height (between 50 and 350 mab) and within the valley is such that the spatial homogeneity needed by the ADCPs to estimate velocity is not always satisfied and only the single point current meters can make reliable current measurements. All the moorings are located at least 1.25 km away from known active venting sites so the turbulence is not thought to be caused directly by the rising plume but from the exchange flow and the density instability introduced by the entrainment and thermal input of the venting.

The enhanced turbulence, the constrained tidal flow, the diminished low frequency flows and the inflow due to the sea breeze effect combine and contribute to make the water column in the rift valley an order of magnitude more productive than the nearby ocean which is dominated by larger scale motions that are not as conducive for biological productivity.