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Serpent: Magnetic signatures of serpentinized mantle and mesoscale oceanic variability along the Alaska/Aleutian subduction zone

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NASA recently solicited suborbital missions as a part of its new Earth Venture program element. These missions are designed as complete PI-led investigations to conduct innovative, integrated, hypothesis or scientific question driven approaches to pressing questions in Earth System science. The missions should require sustained observations (<5 years) and significant resources (<30 million USD). The submitted mission proposals have been under evaluation since last November, and NASA is scheduled to make a decision in April. We, a team led by Raytheon's Photon Research Associates, propose to carry out a suborbital magnetic survey of the Aleutian subduction zone using NASA's Global Hawk to test the magnetic serpentinite hypothesis. This hypothesis states that dewatering of the descending slab within subduction zones produces an observable static magnetic signature through the formation of serpentinite in the overriding mantle. This signature may serve as a predictor of the location of large megathrust earthquakes and their associated tsunamis. Magnetic field measurements from 20 km (sub-orbital) altitude are essential to the testing of this hypothesis; analysis shows orbital and/or near-surface measurements are not likely to provide sufficient sensitivity and uniform calibration to confirm or reject the hypothesis, nor to consistently map its presence around the world. Static and dynamic magnetic signatures from the motion of seawater in the earth's magnetic field have the potential to confound an evaluation of the magnetic serpentinite hypothesis. Through a combination of modeling and exact repeat surveys over the subduction zone, spaced weeks to as much as six months apart, we can study the magnetic signature of the motion that characterizes the mesoscale oceanic circulation in order to develop the best possible corrections for lithospheric imaging, and elucidating the intrinsic and unique oceanic information content in the magnetic fields for the first time ever.

The role of water in subduction zones, and in the overlying ocean, can be traced by sustained suborbital observations of the magnetic field. At critical depths of 40 to 50 km, subducting ocean crust goes through important metamorphic changes that release large amounts of water into overriding mantle rocks. Introduction of water into the mantle produces serpentinite, a highly magnetic, low-density rock. Thermal models indicate that, in many of the world's subduction zones, this part of the mantle is cooler than the Curie temperature of magnetite, the most important magnetic mineral in serpentinite, and thus large volumes of mantle in subduction-margin settings should be magnetic. Indeed, analysis of magnetic data from some subduction zones indicates that magnetic mantle can be detected in long-wavelength magnetic anomalies. The presence of serpentinite in subduction margins has two important links to large within-slab and giant megathrust earthquakes, and associated tsunamis. First, release of water from the subducting slab is thought to embrittle the slab, thereby promoting within-slab earthquakes (M 7-8). Thus, we expect to see a spatial association between this type of earthquake and mantle magnetic anomalies. Second, in cool subduction margins, the down-dip limit of megathrust earthquakes (M 8.0-9.6) is controlled by the slab's first encounter with serpentinized mantle. Again, we expect to see a spatial association between these devastating earthquakes and magnetic anomalies. The magnetic serpentinite hypothesis can be tested by comparison to free-air gravity, geologic, topographic, and bathymetric data of comparable resolution.

Significant static and dynamic magnetic fields also originate as a consequence of oceanic flow in electrically conducting ocean water above the subduction zone. Although these signals are of much lower amplitude than the magnetic field associated with serpentinite, they can have significant power at short spatial scales, and thus have the potential to confound estimated magnetic source depths that rely on inferences from the horizontal magnetic gradient. Although a source of noise from the perspective of imaging the lithosphere, the motionally induced magnetic fields also present new opportunities for remote sensing in ocean and climate studies.