The Geometry and Seismic Properties of the Subducting Cocos Plate in Mexico

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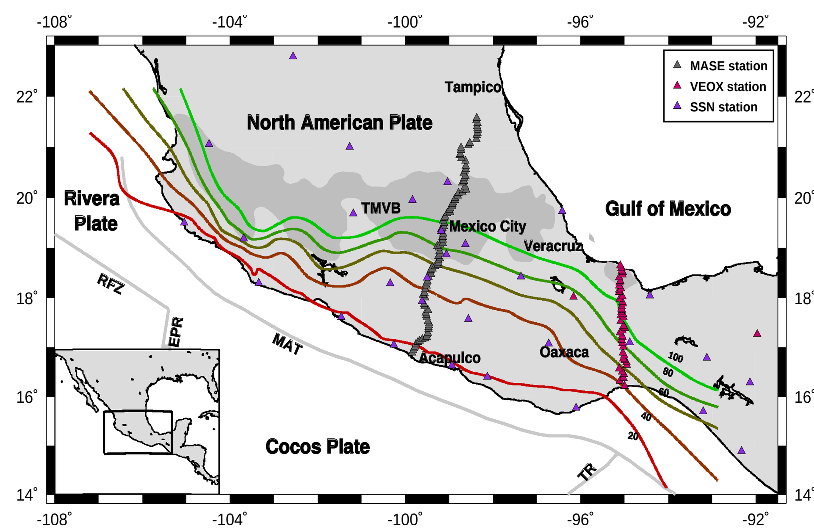
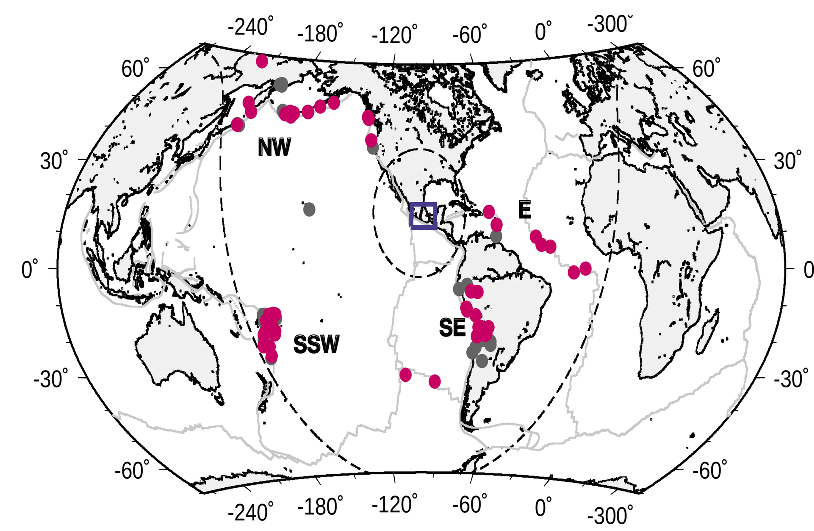
1 Abstract

The subducted Cocos plate beneath central Mexico as imaged with receiver functions (RFs) from the MASE (Meso-American Subduction Experiment) array tectonically underplates the continental crust for a distance of approximately 300 km from the trench. The receiver functions are modeled with a 2D finite-difference code, and the result shows the need for a low-velocity zone (lower than normal oceanic crustal velocities), corresponding to a thin serpentinized layer on the top of the subducting slab, to reproduce the impedance contrasts. This zone appears to absorb nearly all of the strain between the upper plate and the oceanic crust. By inverting RF amplitudes of the converted phases and their time separations, we produce detailed maps of the seismic properties of the upper and lower oceanic crust of the subducting Cocos plate and its thickness. High Poissons ratio and Vp/Vs ratio due to anomalously low S-wave velocity at the upper oceanic crust in the flat slab region may indicate the presence of water and hydrous minerals or high pore pressure. The evidence of high water content within the slab explains the flat subduction geometry without strong coupling of two plates. This may also explain the non-volcanic tremor activity and slow slip events occurring in the subducting plate and the overlying crust. Similar analyses will be performed utilizing the data from the VEOX (Veracruz-Oaxaca Seismic Line) array across the Isthmus of Tehuantepec in southern Mexico to compare the subduction process with the same slab, but where the dip angle is steeper.

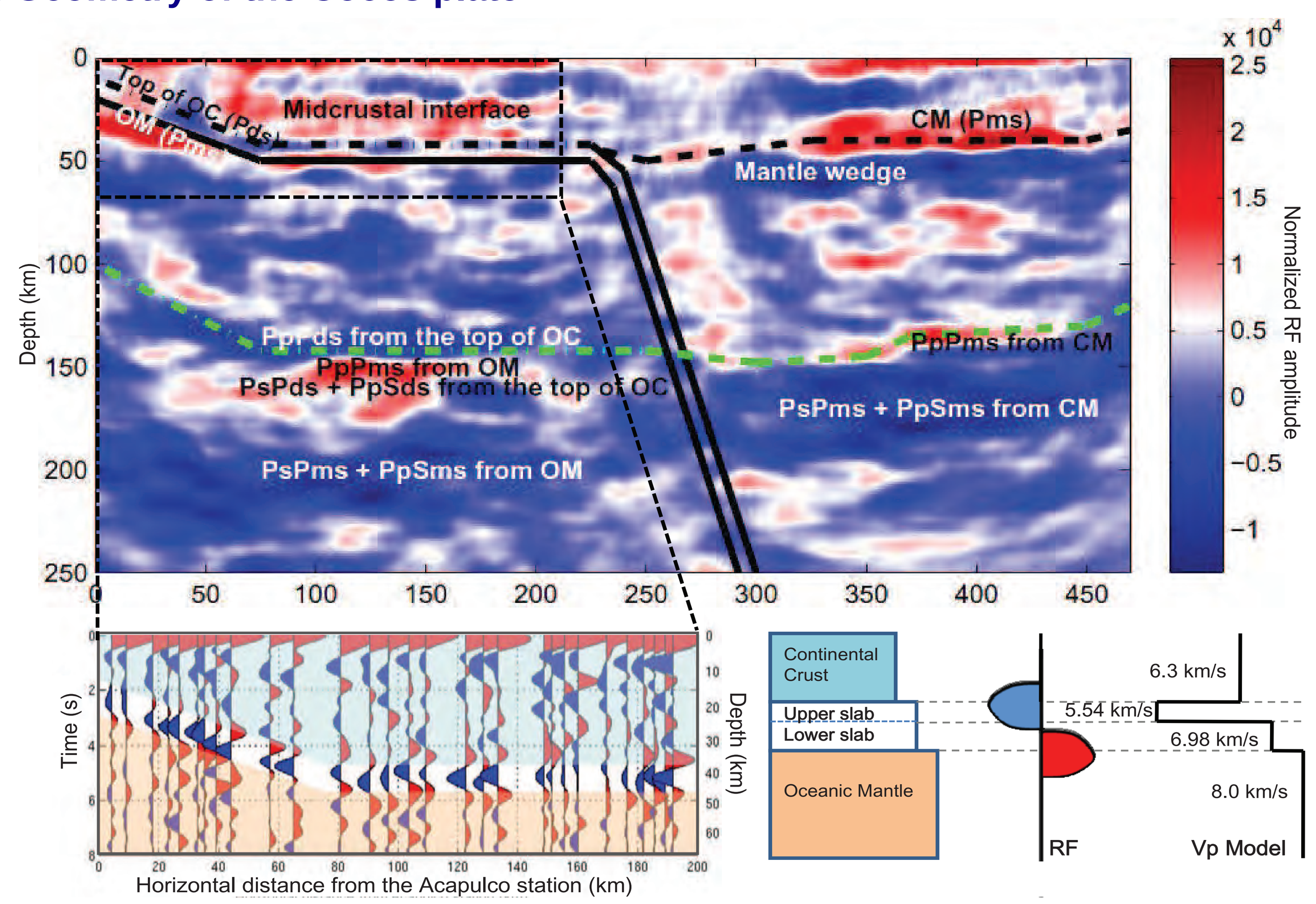
2 Data





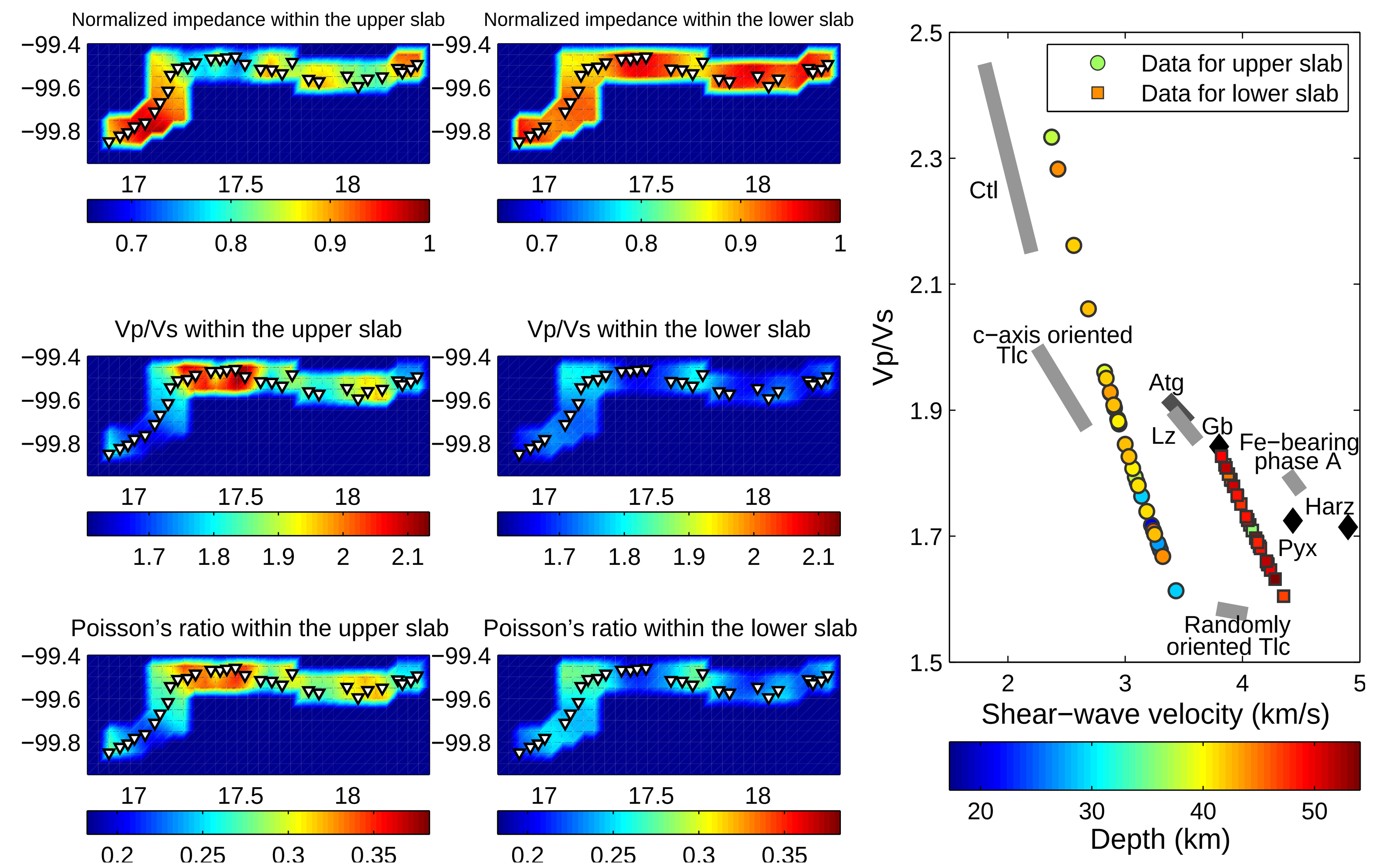
Map on the left shows the region of our study and two seismic arrays (gray triangles for MASE and red triangles for VEOX). Isodepth contours of the subducted Cocos plate beneath the North American plate (*Pardo and Suárez*, 1995) are shown in the map. Map on the right shows the distribution of teleseismic events used in the study (gray dots for MASE and red dots for VEOX). Dotted lines are distance of 30° and 90° away from the center of the study area.

3 MASE: Geometry of the Cocos plate



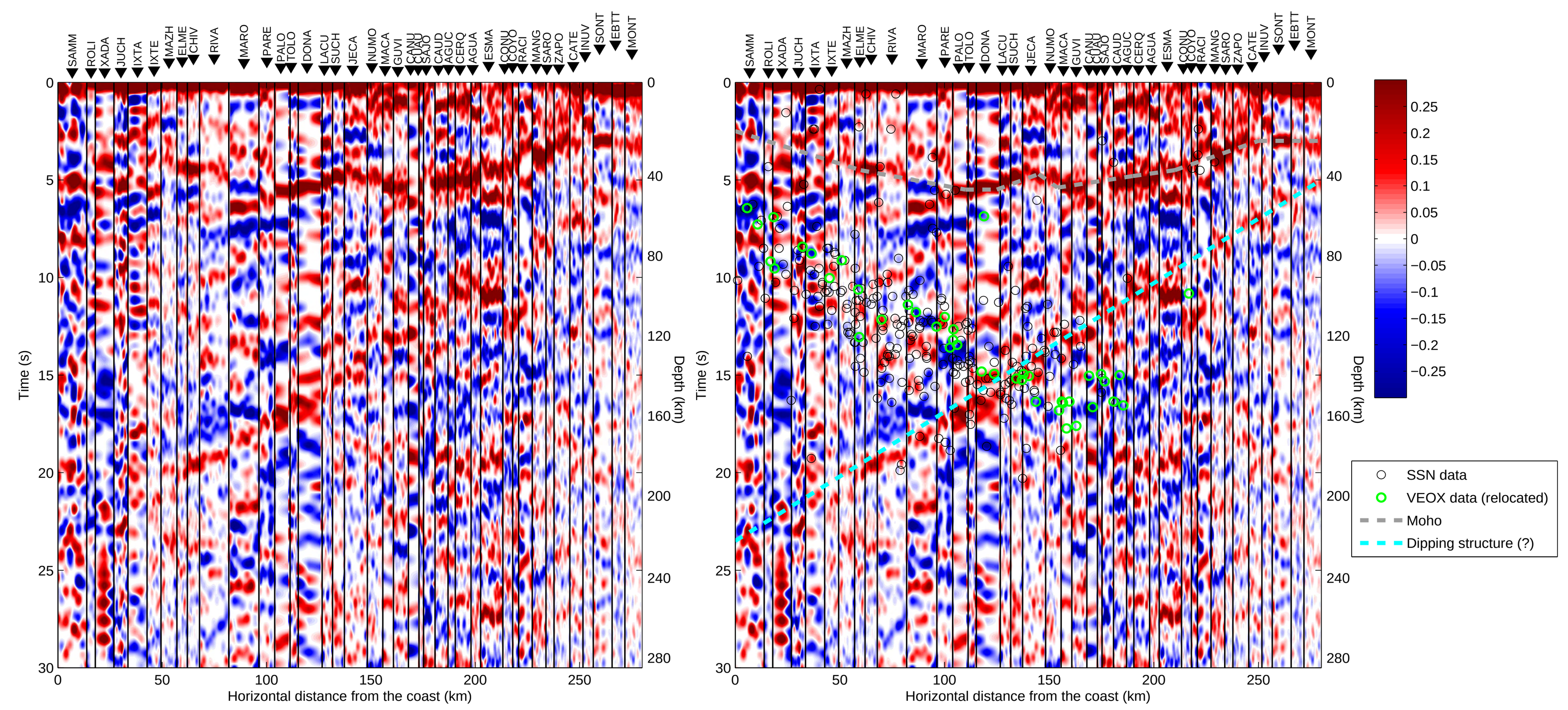
Migrated RF image showing the slab and Moho geometry in central Mexico. The top plot shows the migrated image using Pms and Pds phase. The thick dash-dot lines indicate the top of the subducting slab characterized by the very low velocity. The thick dashed line incidates the continental Moho, which extends from TMVB to the coast near Gulf of Mexico. The abbreviations shown in the image are OM = oceanic Moho; CM = continental Moho. Note that the green (dotted and dashed) lines are the multiples from the crustal interface (Pds and Pms), and the dipping slab can be located by changes in the depth of the seismic multiple changes. The bottom left plot shows RFs for one teleseismic event along the flat slab portion of the slab. The blue, white, and orange overlays denote the continental crust, slab, and oceanic lithosphere, respectively. The bottom middle plot illustrates the corresponding model. the bottom right plot shows the compressional-wave velocity model determined from the finite-difference modeling.

4 MASE: Seismological and mineralogical properties of the Cocos plate



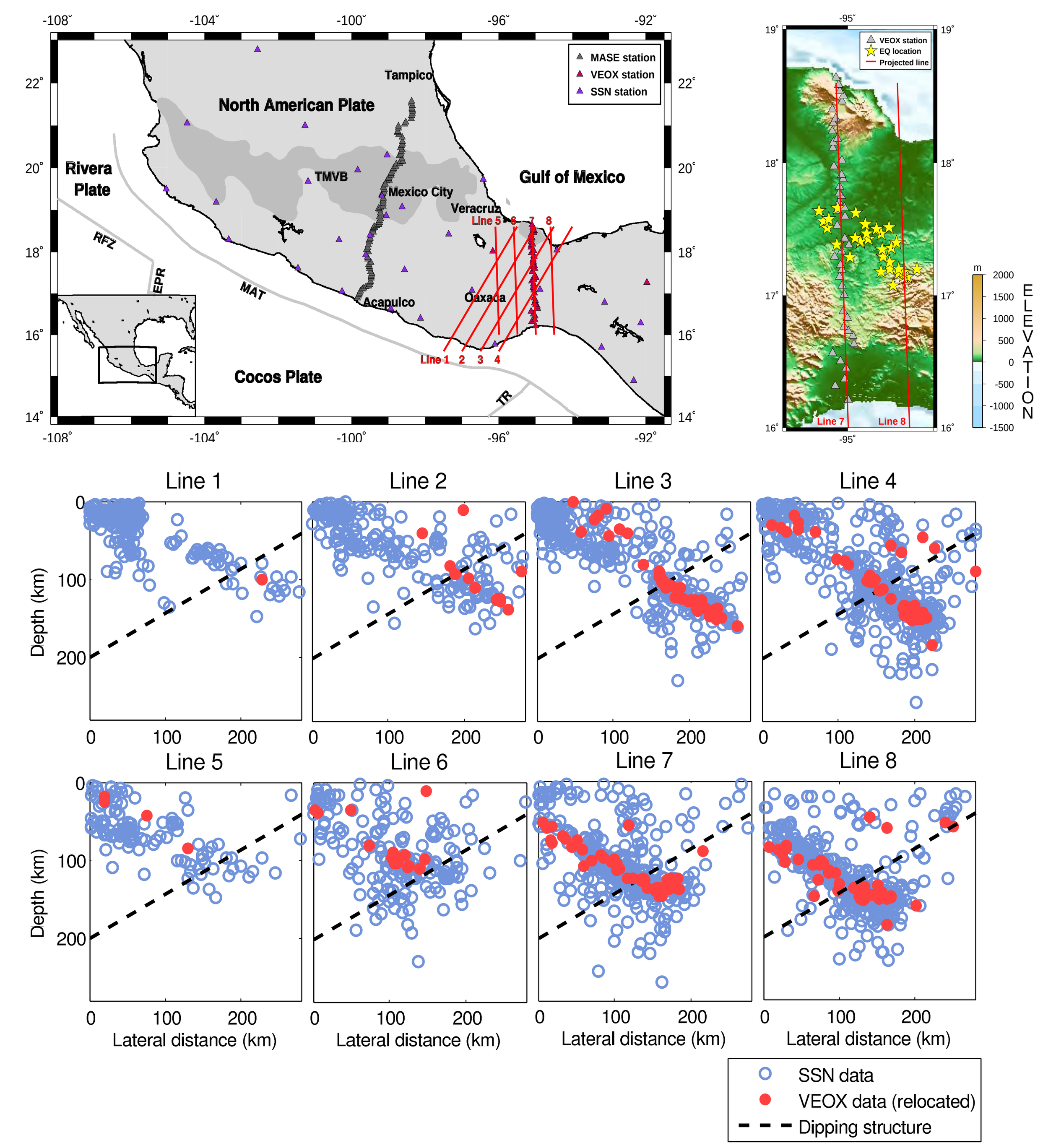
Seismic and minerological properties of the oceanic crust along the MASE array south of the TMVB. The plots on the 1st and 2nd columns show variations in the (normalized) impedance, Vp/Vs, and Poisson's ratios at upper and lower oceanic crust. The plot on the 3rd column show calculated Vp/Vs ratio versus S-wave velocity (Vs) at a depth of 35 km and a range of likely temperatures (500 - 800°C) at this depth for candidate hydrated phases (gray lines) and rock types (black diamonds). The points for randomly oriented talc and c-axis oriented talc are from *Mainprice et al.* (2008), and those for different rock types from *Christensen and Salisbury* (1975). The data points for the upper oceanic crust are highly varying in Vp/Vs and Vs domain (average Vp/Vs of 1.85) and lie close to talc phases, whereas those for the lower oceanic crust are tightly bounded (average of 1.72). The abbreviations are Ctl, Chrysotile; Tlc, Talc; Atg, Antigorite; Lz, Lizardite; Gb, Gabbro (fresh, unmetamorphosed); Pyx, Pyroxenite; Harz, Harzburgite.

5 VEOX: RF image showing controversial structure dipping from the Gulf of Mexico



Preliminary RF results for the VEOX array (uninterpreted display on the left and interpreted display on the right). The RFs obtained from the events located SE from the VEOX are used. Amplitudes are relative to incident P-wave. Red and blue colors correspond to velocity increase and decrease with depth, respectively. Strong azimuthal variations of Moho are observed especially in the mid- and end-section of the figure. Ths is partly due to the fact that the trench-normal plane of the subducting plate is tilting to the south-east. Note that structures near the Pacific coast are not clearly imaged due to poor station quality, and we observe a anomalously dipping feature indicated as a cyan dotted line.

6 VEOX: Projected seismicity along different sections



Earthquakes from SSN (National Seismic Network of Mexico) and VEOX are projected onto 8 different profiles (see map on the top left). Line 1 to 4 are roughly perpendicular to the Middle America Trench (MAT), line 5, 6 and 8 parallel to the VEOX array, oblique to the MAT, and line 7 are exactly on the VEOX array. Note that earthquakes recorded from the VEOX are relocated by the double-difference location method. Also, the dotted line indicates the dipping structure from the Gulf of Mexico that we have seen from the RF image (section 5). We observe that the seismicity along the line 5 to 8 is influenced by this anomalous structure. In particular, the structure truncates the seismicity along the line 5 at a depth of 120-130 km, and the seismicity at the line 6, 7, and 8 continues along the structure.

7 Future Work

- Kirchoff-like migration/inversion using teleseismic earthquakes will be used to obtain the image of the subduction structure down to 250 km. The noise in the RFs and/or azimuthal variations from the 3D structure can be suppressed by the stacking to produce a better image than the RF image.
- RF amplitude inversion technique proposed by *Kim et al.* (2009) will be used to investigate the variations in seismic and mineralogical properties within the slab for VEOX. Our preliminary result on the RFs shows that a thin low velocity layer (down to 100 km) is present on top of the slab, but not as strong as the one we have seen from *Kim et al.* (2009). Thus, we expect to observe considerable change in the impedance of the layer (due to the change in the water content and/or different mineral assemblages) or the thickness of the layer itself.
- By analyzing the data from the SSN, the slab geometry in 3D as well as variations in seismic and mineralogical properties in 2D along the Middle American Trench in Mexico will be obtained. Since the SSN station coverage is sparce between two dense seismic arrays (MASE and VEOX), we will need to incorporate other means such as seismicity and seismic refraction results to build the 3D model.

References

Christensen, N. I., and M. H. Salisbury (1975), Structure and constitution of the lower oceanic crust, *Rev. Geophys. Space Phys.*, *13*, 57-86.

Kim, Y., R. W. Clayton, and J. M. Jackson (2009), The geometry and seismic properties of the subducting Cocos plate in central Mexico, submitted to *J. Geophys. Res.*

Mainprice, D., Y. Le Page, J. Rodgers, and P. Jouanna (2008), Ab initio elastic properties of talk from 0 to 12 GPa: Interpretation of seismic velocities at mantle pressures and prediction of auxetic behaviour at low pressure, *Earth Planetary Sci. Lett.*, *274*, 327-338.

Pardo, M., and G. Suárez (1995), Shape of the subducted Rivera and Cocos plates in southern Mexico: Seismic and tectonic implications, *J. Geophys. Res.*, *100*(B7), 12357-12373.