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SOLID EARTH MODELLING PROGRAMME

Data from broadband seismic stations have been used to estimate Rayleigh wave dispersion maps for periods 8-60 sec for NW Himalaya and adjacent regions. The dispersion maps were inverted for 1-D Vs structure beneath each grid point, which were collected to form a 3-D Vs model for the region. A 3-D shear wave velocity model is presented for NW Himalaya for depths up to 100 km. The uncertainty analysis performed at both surface wave map generation and shear wave inversion to have higher confidence in the resulted model. First high resolution map (0.5 x 0.5 degrees) in the northwestern Himalaya around the syntaxial bend, providing improved estimates of the S wave structure corroborated by a) correlations with higher velocity gneissic domes and crystallines (Vs 3.8-4.0 km/s), b) by receiver function inversions and c) by convergence with velocities determined by other authors in the region surrounding the NW Himalaya.

Research article on Indian angular plate velocity published in Scientific Reports, Nature is recognized in the Top 100 earth science papers. GPS signals passing through atmosphere give valuable information on atmospheric water vapor and the Total Electron Content (TEC) in ionosphere. For the first time, TEC estimated using two decades of GPS data gave significant insights in to the ionosphere variability at low and mid latitudes of India and its relation to solar cycle 23 and 24. Research article published on ionosphere variability specific to Indian subcontinent has the distinction of 200 downloads within 6 months of publication. Observation network of cGNSS (continuous Global Navigation Satellite System) stations in Kashmir valley, Ladakh Himalaya and Peninsular India gave valuable insights on the accuracy of GNSS position estimates and uncertainties.

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5.1 Shear wave velocity structure beneath North-Western Himalaya

Shear wave velocity structure, together with Moho depths have been estimated beneath a regular grid of 0.5°× 0.5° in northwestern Himalaya, Hindu Kush and the Pamirs and at 1°×1° in the surrounding area, by inverting fundamental mode Rayleigh wave group velocities calculated from regional earthquake ($\Delta \leq 2500$ km) data, and also from their joint inversions with teleseismic receiver functions at 38 of the 59 broadband stations in the region that provided the data. Dispersion maps clearly mark the low velocity enclaves of western Tarim, Tadjik and the Himalayan foreland basins, showing strong correlation (-0.76 to -0.99) with the sediment thickness map. Shallower dispersion maps (10-20 sec) also delineate the high velocity southeastern margin of the Hindu Kush (V_{Rg} ~3.3 km/s) extending to the slightly lower velocity northwestern Himalaya (~3.1 -3.2 km/s). Tibet and northeastern regions are marked with low (~2.7-3.0 km/s) velocities in dispersion maps of higher than 30 sec, apparently representing the thicker crust underneath. The inverted shear wave velocity maps clearly demarcate the shallower structures, which have strong geomorphic signatures (as shown in Figure 5.1).

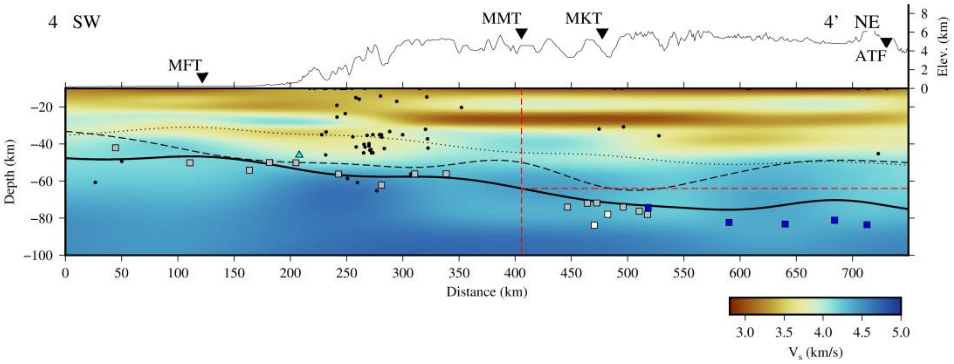

Figure 5.1 Posterior Vs cross-section and Moho depths marked by dotted, dashed and solid black lines, respectively estimated from 3 different initial a-priori models identifying the Moho surface with velocities of 4.0, 4.2 and 4.4 km/s. This NE-SW profile is same as of Rai et al. (2006). Gray squares represent the Moho estimates from Rai et al. (2006), blue from Wittlinger et al. (2004), and white from two stations further east of the profile, all constrained by joint inversions of receiver functions and surface wave dispersion data. This profile crosses the Himalayan foreland basin, Zanskar, and Ladakh Himalaya. The Moho depth beneath the MMT, marked by red dashed line, is ~64 km. Note the pervasive low velocity layer (~3.0 km/s) at depth of ~30 km beneath the Himalaya and a shallow high velocity (~4.0 km/s) at depth of 20 km beneath the Ladakh which correspond to the surface location of the Greater Himalayan Crystalline complexes.

For example, at 10 km, high shear velocities (~3.4 km/s) mark out the Hindu Kush subduction zone, the Pamirs and the northwestern Himalaya, while low velocities mark the sedimentary basins of Tadjik, western Tarim, and Himalayan foreland basin (~3.1 km/s). The high velocities correspond to surface location of high grade crystallines in the Nanga Parbat, gneiss domes in the Pamirs, the obducted Tethys ocean crust in the Hindu Kush, and subduction of the Neo-Tethyan oceanic crust beneath the Eurasian plate in Ladakh. The entire northwestern Himalaya and Hindu Kush is characterized by low velocities (~3.2 km/s) at 30 km depth except for the Pamir (~3.7 km/s). Another notable result is the distinctly shallower Moho beneath the Himalayan arc apparently segmented by arc-normal shear zones that cross the rupture zones of the 1905 Kangra and the 2005 Kashmir earthquakes, in turn, marked by the current epoch seismicity.

5.2 GNSS and its impact on position estimates

Global Navigation Satellite System (GNSS) is a space based radio positioning system with one or more satellite constellations which provide three dimensional position, velocity and time information to users on or near the surface of the earth. At present GNSS consists of global (GPS, Glonass, Galileo, BeiDou) and regional Quasi Zenith Satellite System (QZSS), Indian Regional Navigation Satellite System (IRNSS)/Navigation with Indian Constellation (NavIC) navigation systems. Even though satellite systems are similar at fundamental levels, differences exist in the reference frames, timing standards and signal structures. Multi-GNSS can improve start-up time, performance, satellite visibility, accuracy, spatial geometry and reliability compared to standalone GPS but on the flip side multi-GNSS can increase the noise, signal interference, hardware complexity of the receiver, inter-system interference and computation complexity which may degrade the performance.

Currently GPS and Glonass are only fully operational with global coverage and comparable precision to estimate the positions. Glonass satellite constellation, signal structure, epoch time and reference frame are different compared to GPS. For crustal deformation studies using static post processing, combined solution may degrade the accuracy, if these differences are not handled carefully. Combined GPS-Glonass solution may significantly improve the accuracy in navigation applications with increased satellite signal observations and spatial distribution of visible satellites. Currently only GPS observations are mostly used for crustal deformation studies. Computation of daily precise position estimates using static post processing with only GPS, Glonass as well as combined GPS-Glonass is being carried out.