Signatures of large earthquakes in the atmosphere and ionosphere

Gopi K. Seemala[1], C.D. Reddy[1] and Pierdavide Coïsson[2]

1 Indian Institute of Geomagnetism (IIG), Mumbai, INDIA
email: gopi.seemala@gmail.com

2 Institut de Physique du Globe de Paris, Paris, FRANCE

IBSS 2016, 27 June – 01 July 2016, ICTP, Trieste

Introduction:

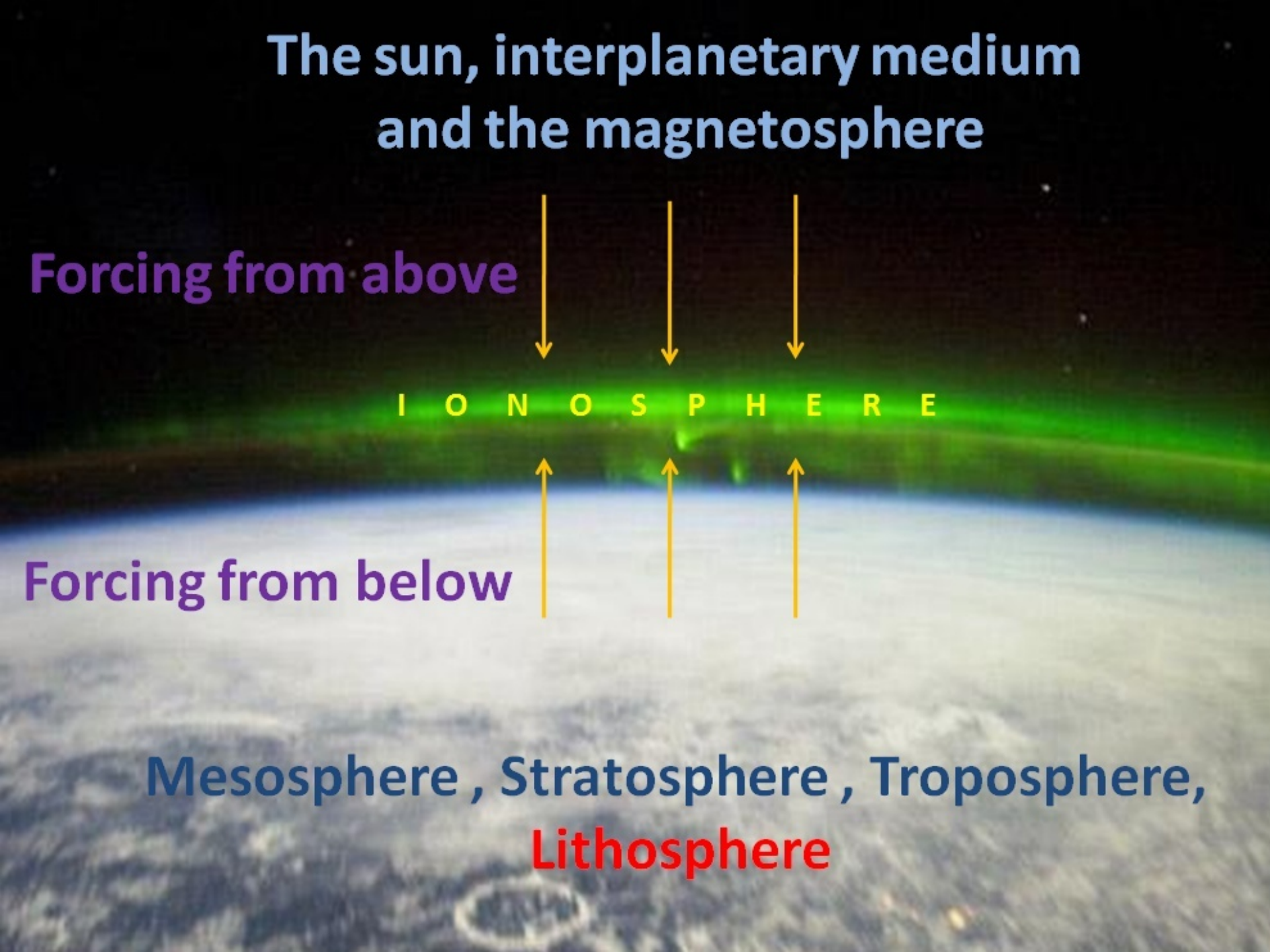
- The earth is surrounded by atmosphere. The troposphere, stratosphere, mesosphere, **ionosphere** and exosphere are the layers of the atmosphere

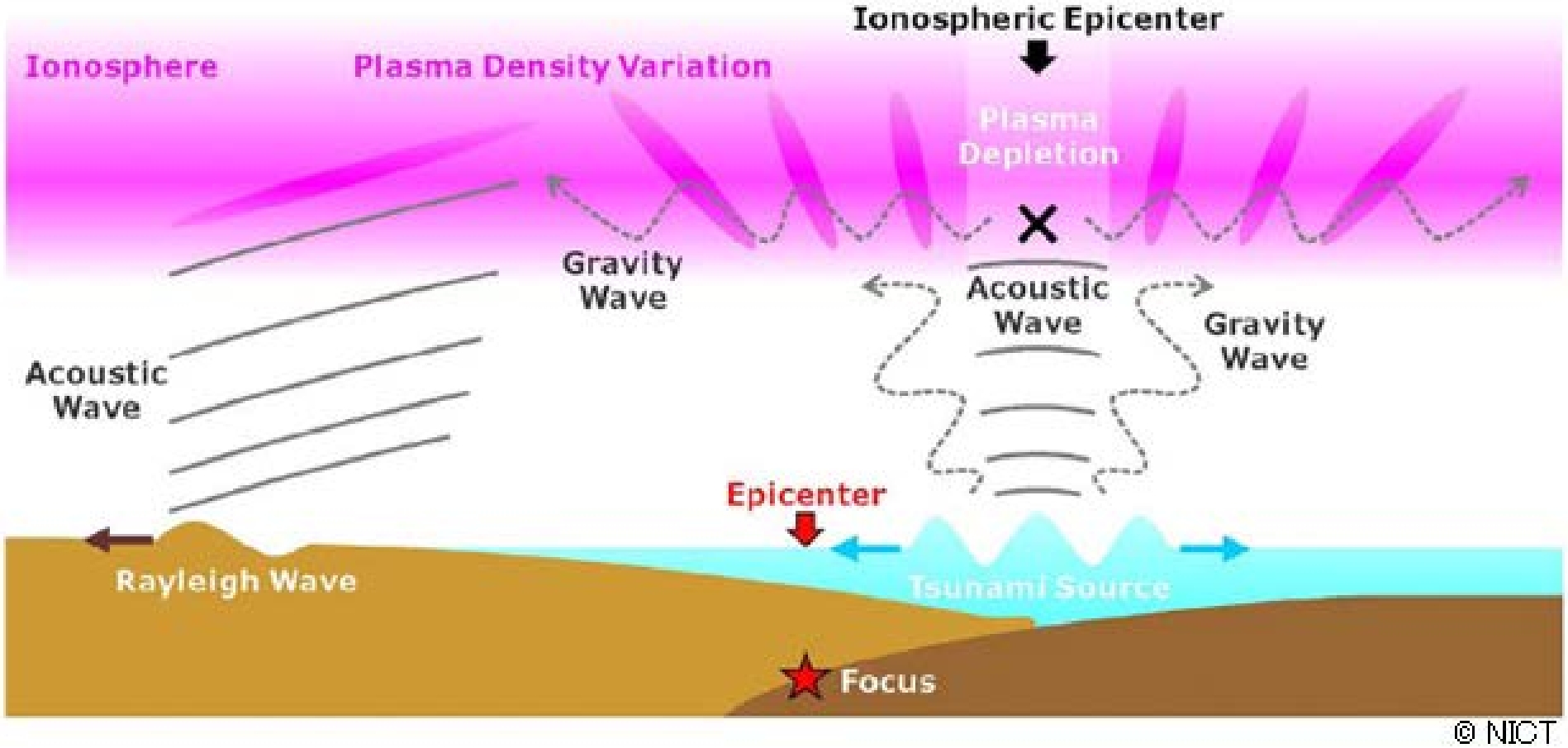
- The ionosphere is the part of the Earth's atmosphere located around 100 - 800 km altitude that contains ionized gas, called plasma, and affects radio propagation

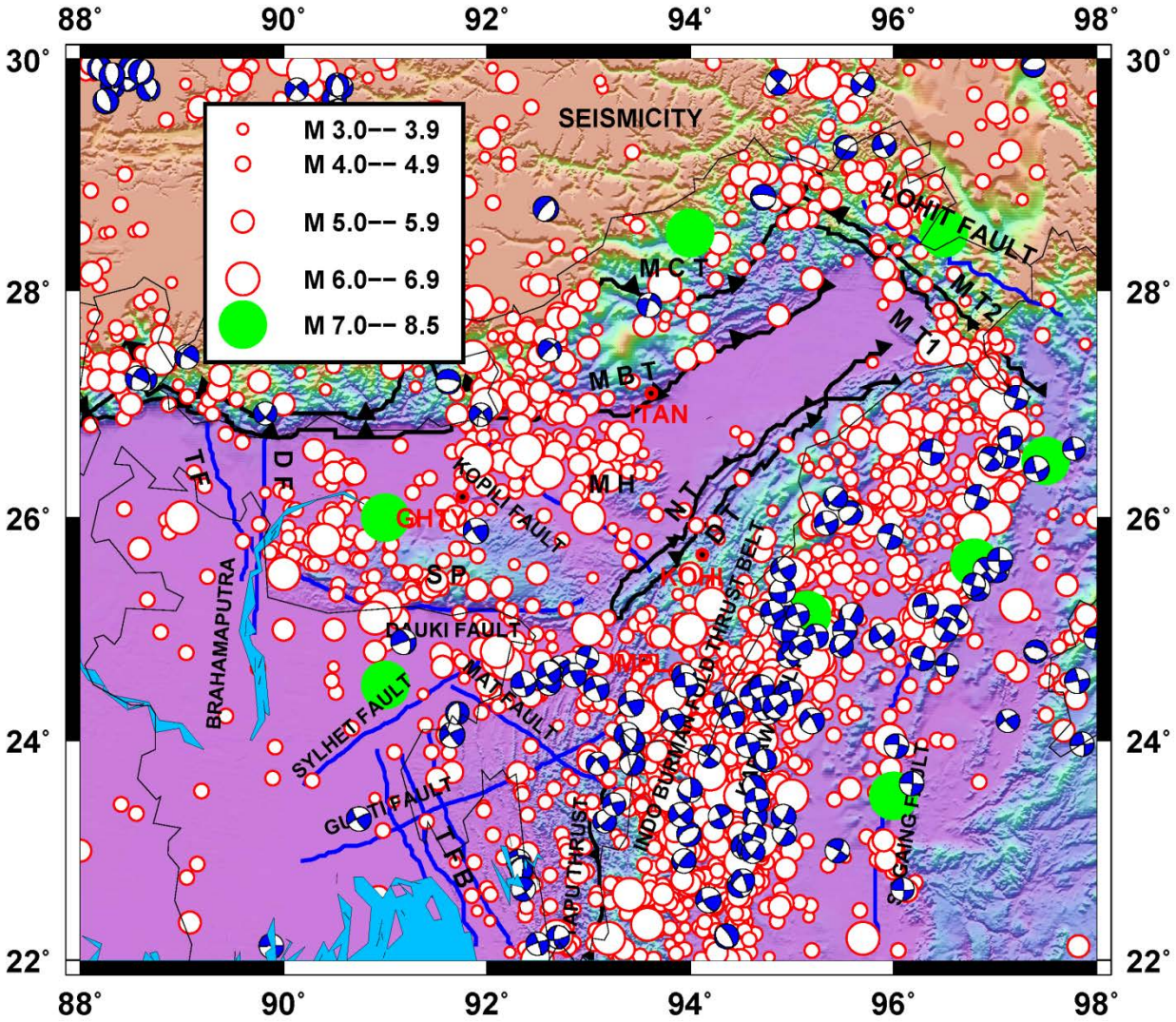
- Ionospheric disturbances are caused from the sources above e.g. the sun, interplanetary medium, magnetosphere, and below e.g. mesosphere, stratosphere, troposphere and lithosphere

- Lithospheric disturbances are mainly due to earthquakes, volcanic eruptions

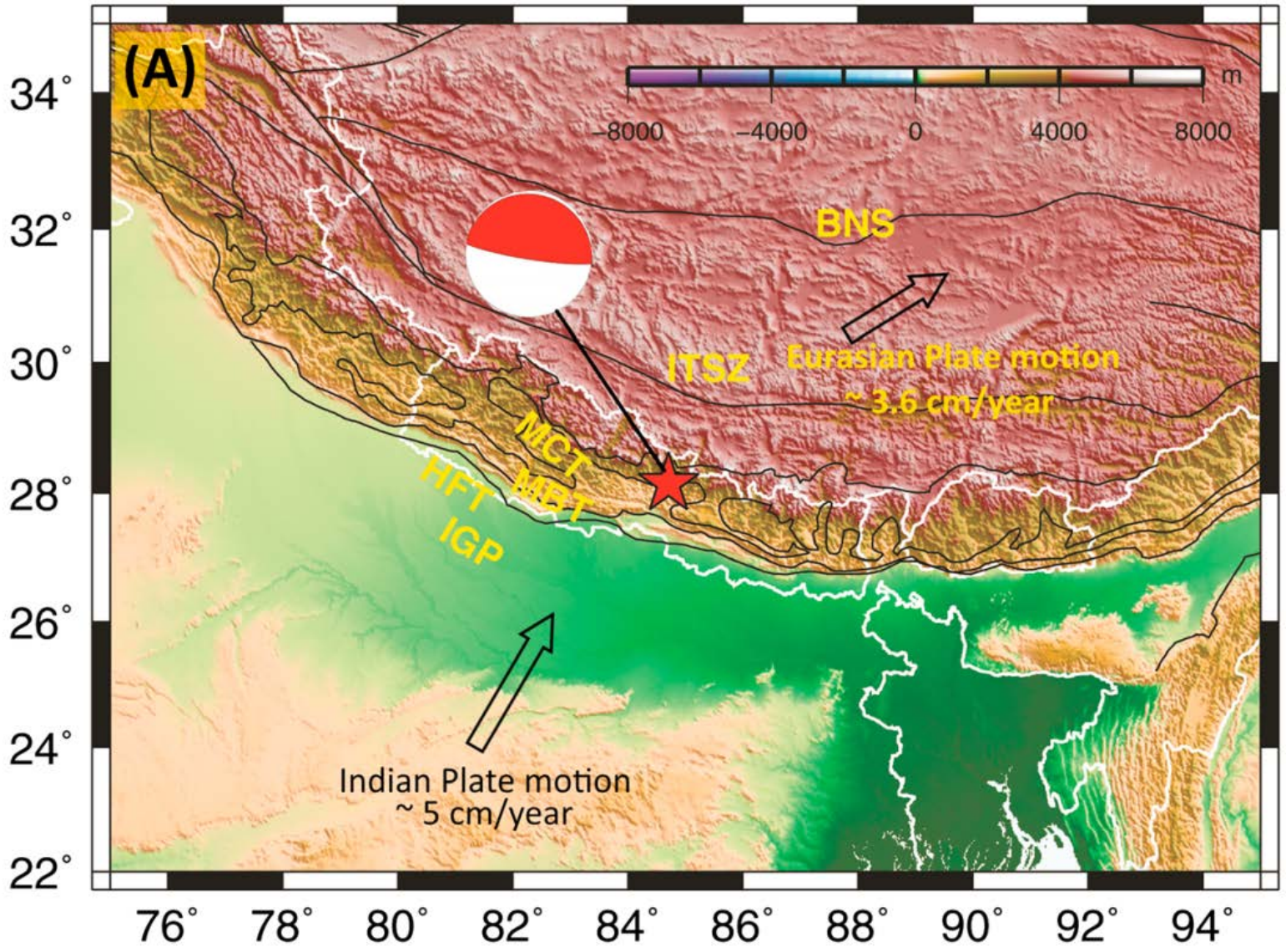
- Following an earthquake, the ionosphere is disturbed by shock acoustic waves, Rayleigh wave induced acoustic waves and tsunami induced gravity waves


The sun, interplanetary medium
and the magnetosphere
Forcing from above
I O N O S P H E R E
Forcing from below
Mesosphere , Stratosphere , Troposphere,
Lithosphere

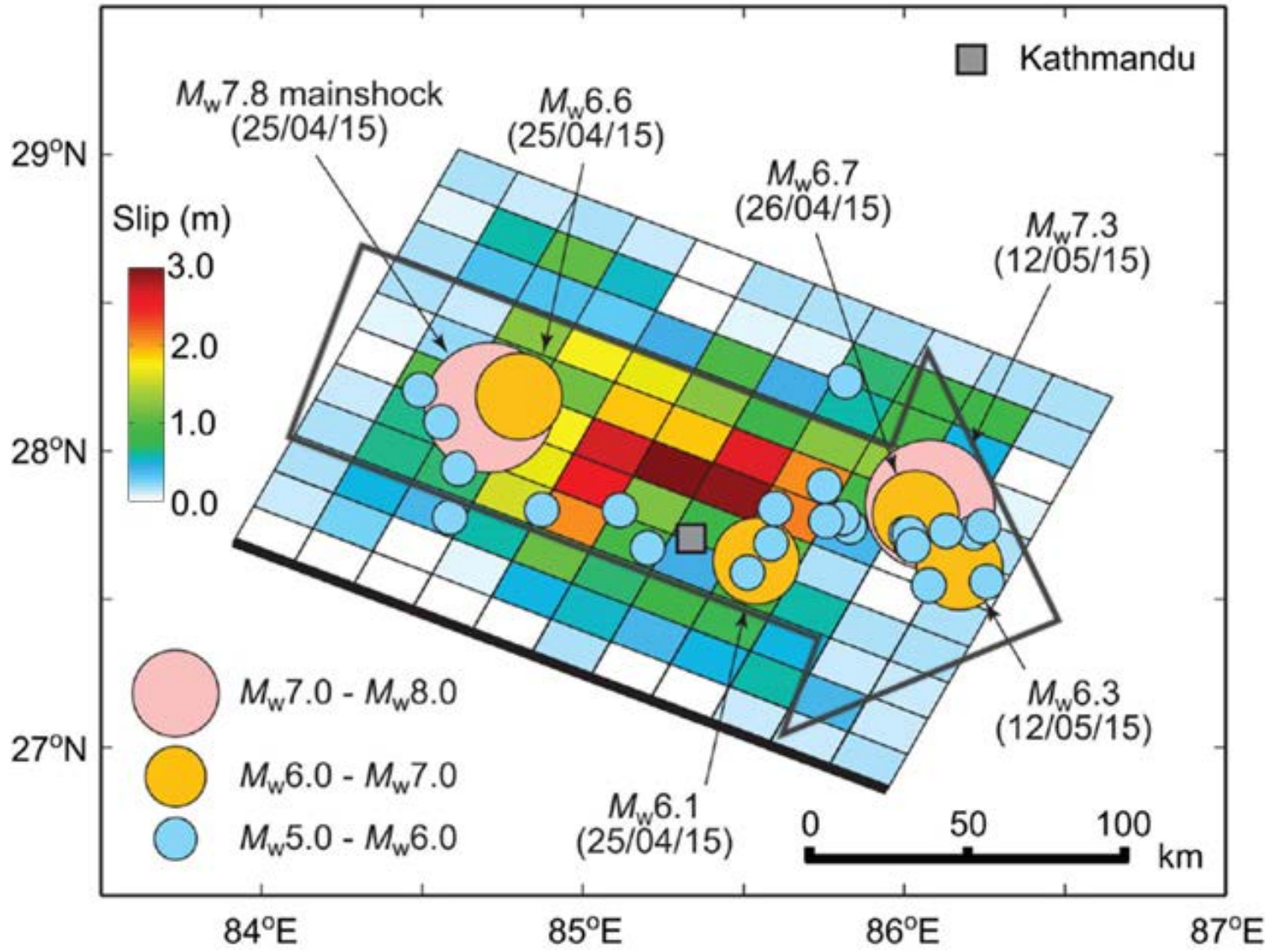

Ionospheric Epicenter
Ionosphere
Plasma Density Variation
Plasma Depletion
Gravity Wave
Acoustic Wave
Acoustic Wave
Gravity Wave
Epicenter
Rayleigh Wave
Tsunami Source
Focus
© NICT



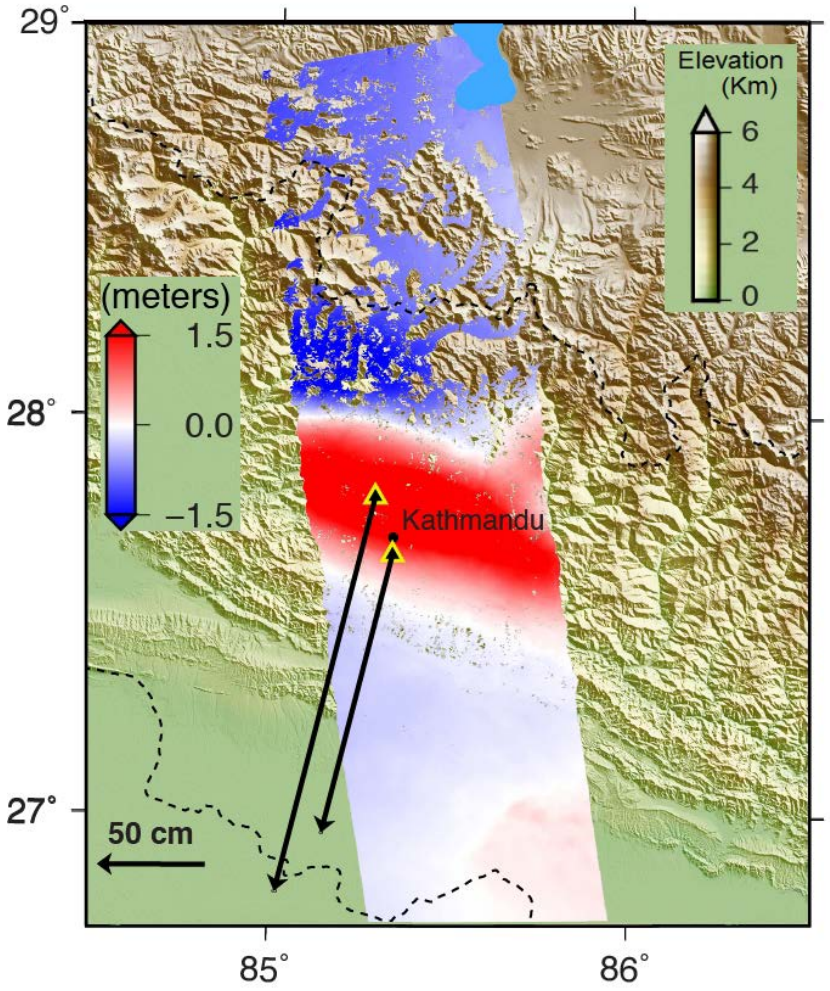
N-E Indian region has experienced a number of strong earthquakes (18 large earthquakes (M > 7)) during the last hundred years including the great earthquakes of Shillong (1897, M=8.7), Assam-Tibet border (1950, M=8.7) (Richter, 1958) and several hundred small and micro earthquakes.



The location of the M_w 7.8 Nepal earthquake on 25-04-2015 is shown by red star. The focal mechanism indicates that the earthquake is purely thrust in nature



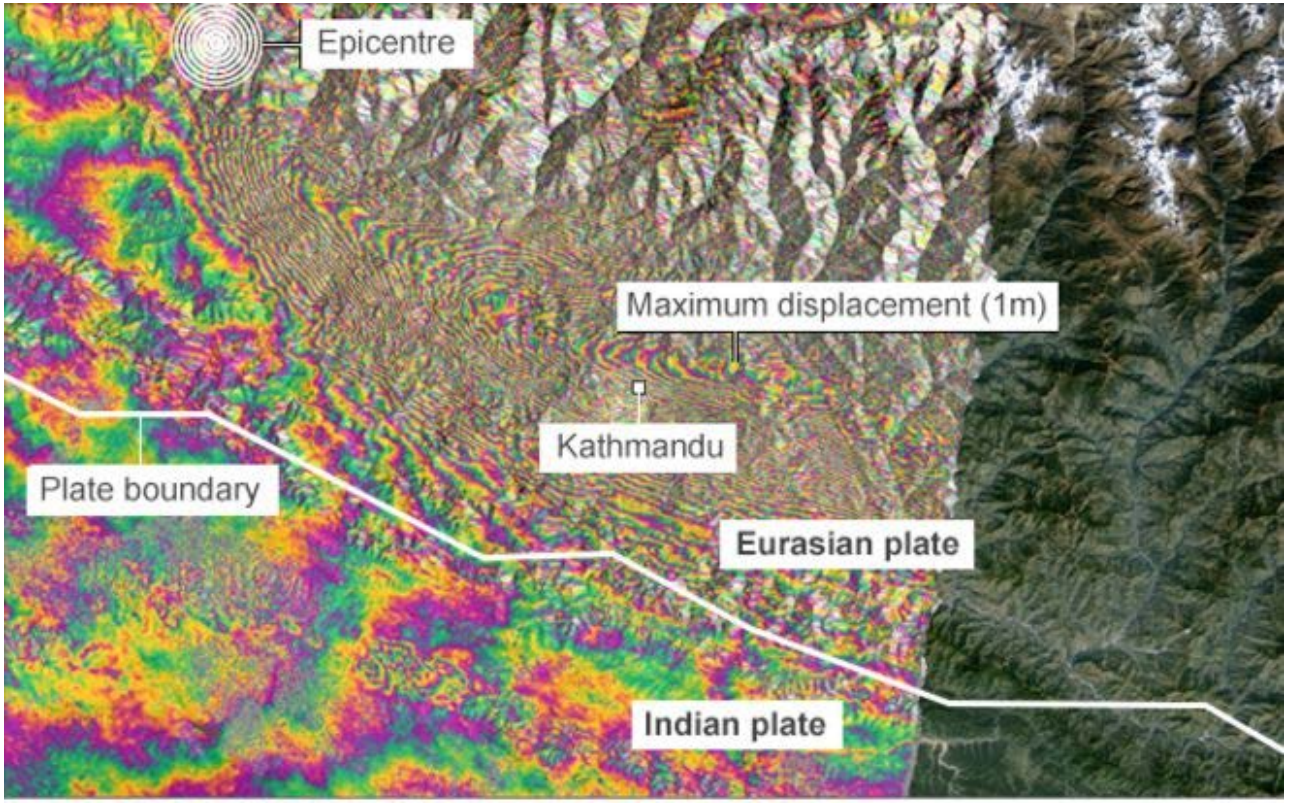
Surface slip distribution (an earthquake source model by the USGS) is shown along with aftershock locations, sized by magnitude, wherein ~ 3 m slip is seen in epicentral area. The open arrow roughly indicates the rupture direction (South-East).



- The surface deformation as seen by ALOS-2 satellite images between February 21 and May 2, 2015 (credit: NASA/JPL-Caltech/ JAXA).

- The red shaded areas indicates the land around Kathmandu has moved 1.4 m along line of sight (~ 1.6 m in vertical direction)

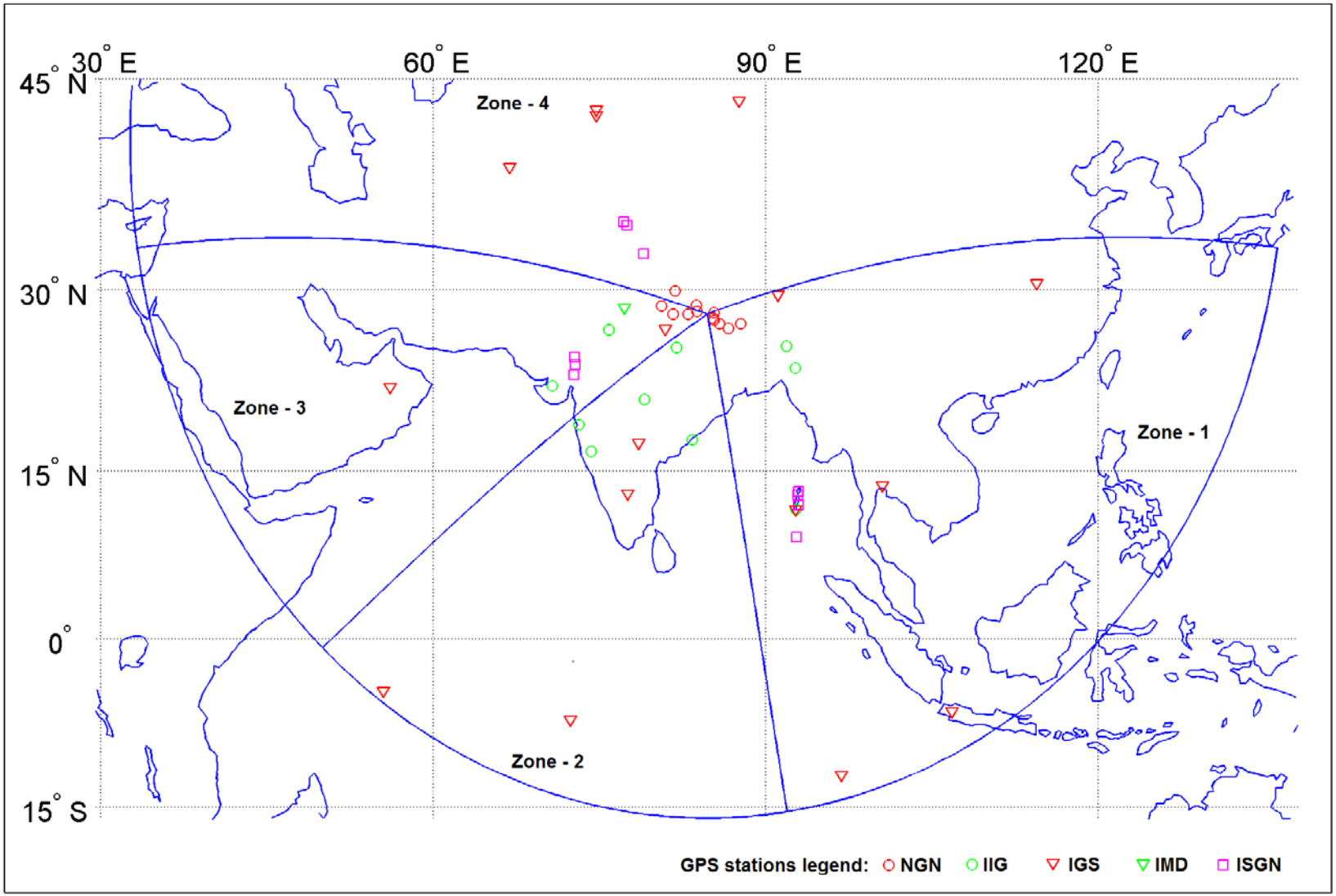
- The black arrows indicate horizontal surface displace-ment as estimated by GPS



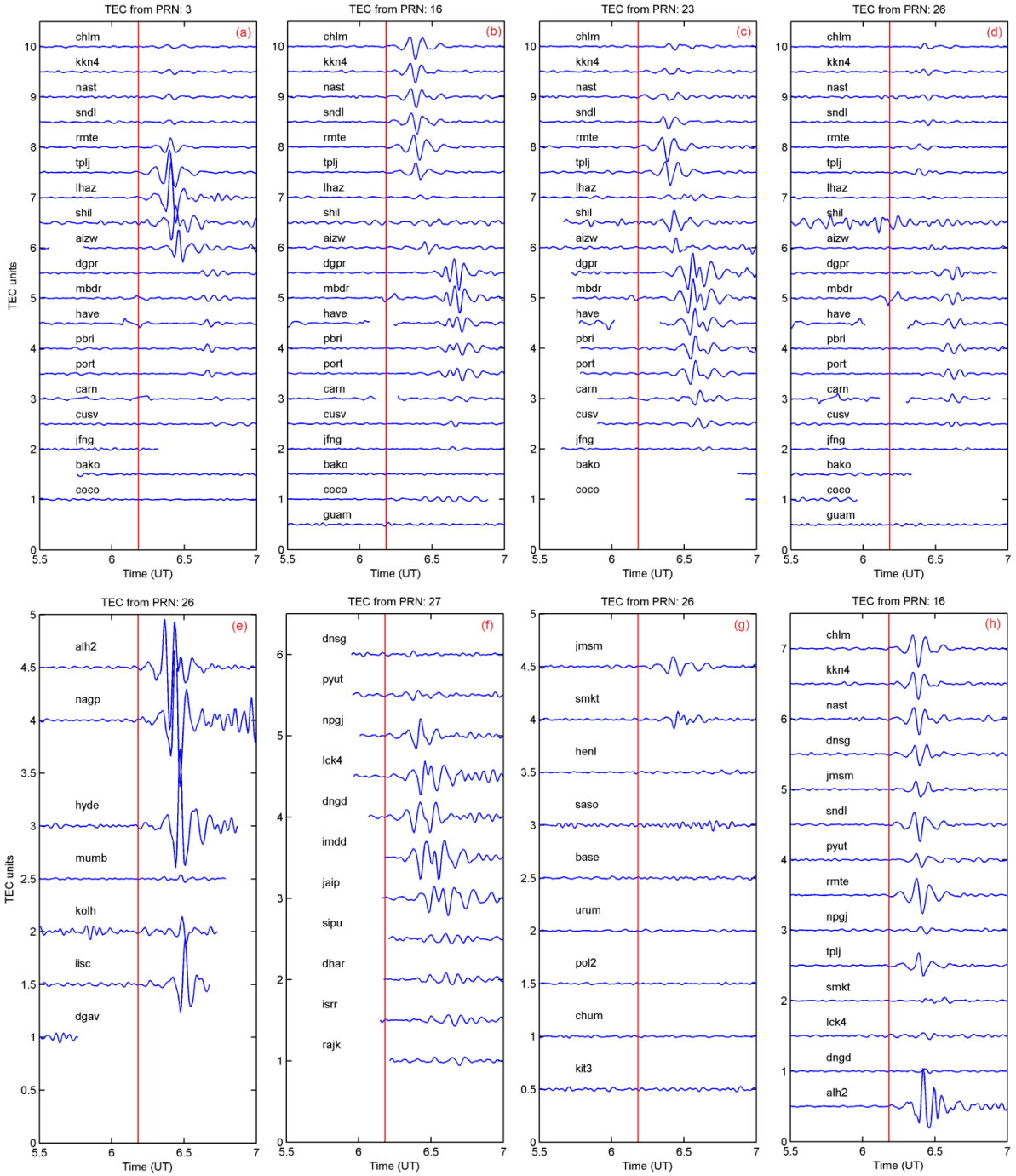
Interferogram produced by Synthetic Aperture Radar Interferometry (InSAR).

The differences in "before" and "after" radar pictures taken from space permits to detect even quite subtle ground movements. Amount of deformation is depicted in coloured contours, or "fringes"

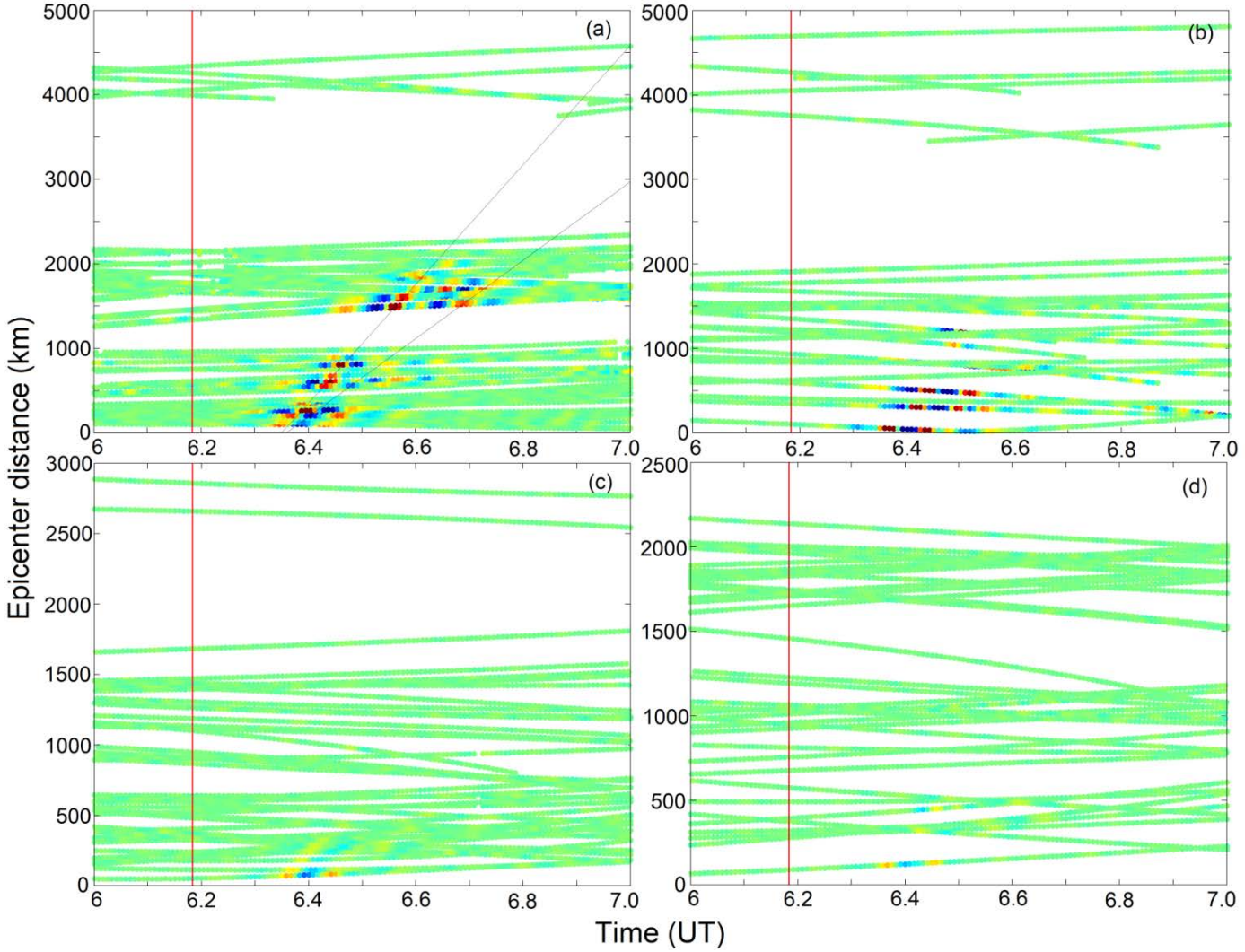
Each contour shows 2.8cm of ground movement with respect to Sentinel-1a, 34 fringes in this image equates to a peak ground deformation of about 1m Quake ruptured east from the epicentre; fault did not break the surface.



GPS sites from various networks indicated by the symbols Red circles (NGN), Green circles (IIG), Red triangles (IGS), Green triangles (IMD) and Magenta squares (ISGN). The intersection of four blue lines indicates location of the M_w7.8 Nepal earthquake on April 25, 2015

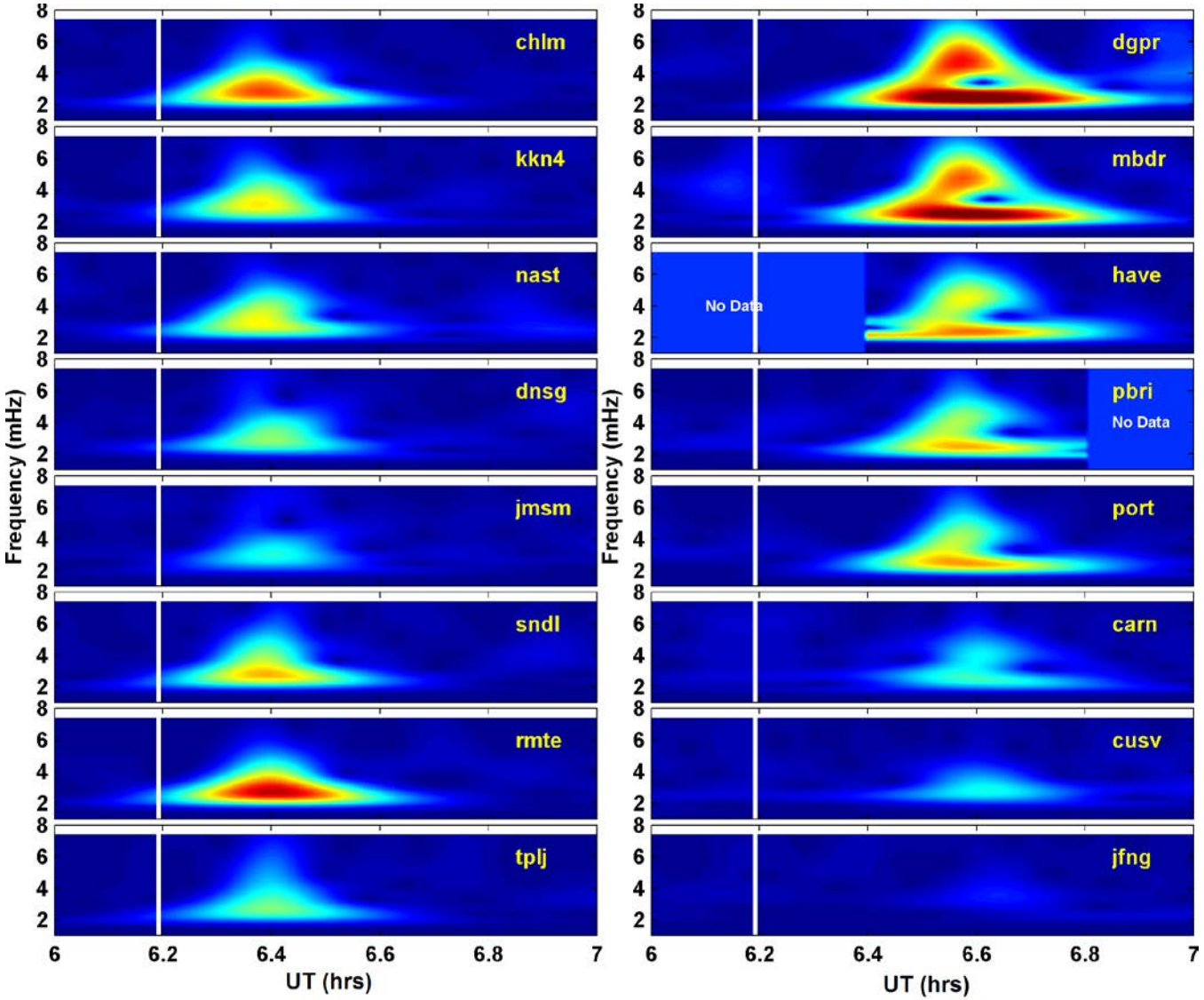


- Stacked ionospheric TEC response at various GPS sites estimated following 2015 Nepal earthquake
- Panels a,b,c, and d for the PRN3, PRN 16, PRN 23 and PRN 26 respectively for the GPS sites in zone 1.
- And panels e,f, g and h are for PRN 26, PRN 27, PRN 26 and PRN 16 for zone 2, zone 3, zone 4 and Caltech Nepal Network respectively.
- The vertical red line indicates the time of April 25, 2015 Nepal earthquake

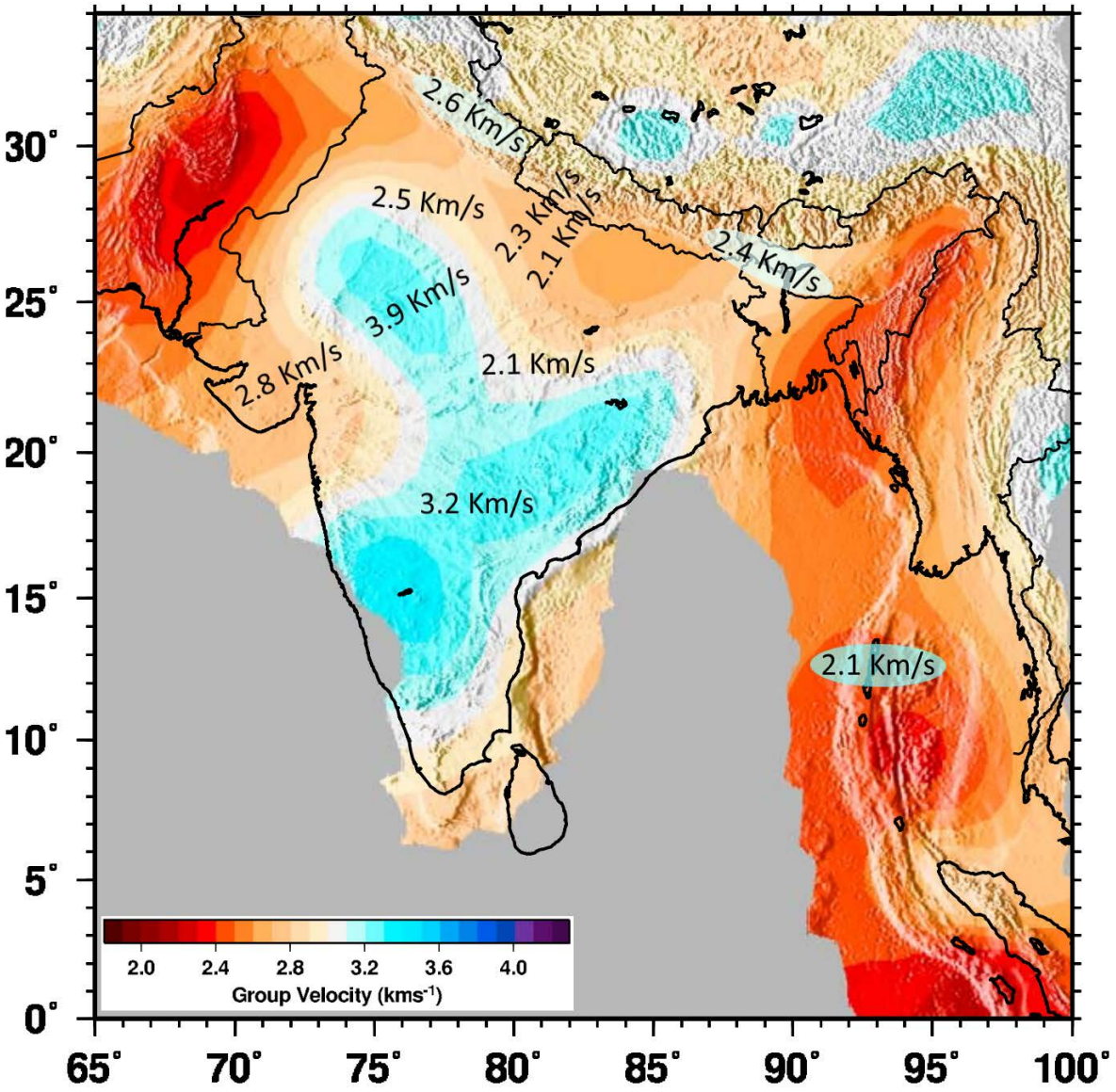


Hodochron plot (travel time diagram) showing variation in vertical TEC at various GPS sites as a function of time and epicentral distance, obtained from PRN 3, 16, 23 and 26

- Linear relationship between travel time and epicentral distance is seen for both shock acoustic waves and Rayleigh wave induced acoustic waves (shown as dashed blue lines) Slope of the slant lines1180 m/s and 2400 m/s give the average velocity SAW and the RWI respectively. (b) (c) and (d) are Hodochron plots for zone 2, zone 3 and zone 4 for PRN 3,16 and 27 respectively



Wavelet spectograms of vertical TEC time series for GPS sites in CNN network (left) and for the selected sites in Andaman Arc region (in zone 1)



The Rayleigh velocities calculated from the ionospheric response following Nepal EQ (marked in digits km/s) on the corresponding region for comparison with Rayleigh wave fundamental group velocity for 10 s obtained (contour color map) by Acton et al., [2010]

Thank you

Any Questions