Utpal Kumar | Curriculum Vitae

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https://github.com/earthinversion • Website: earthinversion.github.io

- I have a strong inclination towards understanding the Earth processes with computers and data (see my GitHub page).
- For my PhD, I use seismic and GPS data to understand the crustal, mantle and core structure. Seismic data gives indirect capability to inspect the interior of our planet whereas GPS has incredible accuracy for understanding the crustal processes.
- I invest my significant time in learning and experimenting with new skills for use in data-intensive research.
- Please have a look at https://iescoders.com/ and my github repo for some of my open source packages.

EDUCATION

Ph.D., Computational Geophysics

2014 - Current
National Central University + **Academia Sinica** (*Taiwan International Graduate Program*)
Thesis: Geophysical Data Analysis for Seismological and GPS-based Applications
Thesis Advisor: *Prof. Benjamin Fong Chao*, Distinguished Research Fellow, Institute of Earth Sciences, Academia Sinica

Integrated B.S.-M.S, Earth Sciences

2009 - 2014
Indian Institute of Science Education and Research, Kolkata
Thesis: Surface Wave Group Velocity Dispersion study of the Eastern Himalayan Foreland Basin
Thesis Advisor: *Prof. Supriyo Mitra*, Professor, Department of Earth Sciences, IISER Kolkata

SKILLS SUMMARY

Computing

- **Open source** programmer, with an inclination in scientific computing, including visualization, automation, and machine learning.
- Proficient in **Python** and its libraries such as Numba, Cython, Dash, Flask, Numpy, Pandas, Scipy, Scikit-learn. Good knowledge of **C** and interfacing to legacy **Fortran** code.
- Comfortable with a variety of tools and programming languages, including **Bash**/csh, **R**, Perl, Fortran, **MATLAB**, LaTeX, HTML, CSS, Javascript, Git/GitHub [Visit my blog "IEScoders" for basic tutorials].
- Other Scientific Softwares: **Generic Mapping Tools (GMT)** for plotting high resolution maps, Seismic Analysis Code (SAC) for plotting seismic waveforms

Technical

- **Computer Operating Systems:** Mac (or Unix), Linux (Ubuntu, Fedora, Opensuse), Windows (7)

- **Database Development:** SQLite, PostgreSQL and Pandas DataFrame
- **Designing:** Proficient in Adobe Illustrator, Adobe Photoshop, iMovie, HTML/CSS and JS
- **Writing:** Microsoft Office Suite (Word, Excel, Powerpoint), Google Docs (collaborative writing), Wordpress (blogging), Mac Pages and Keynote, LaTeX, Markdown, **Jupyter Notebook** (for presentation of software packages)

PUBLICATIONS

- Kumar, U., B. F. Chao, Y. Hsieh, and E. T. Y. Chang (2017), A meteor shockwave event recorded at seismic and infrasound stations in northern Taiwan, Geoscience Letters, 4(1).
- Kumar, B., K. Krishna Reddy, J. Janapati, T. Rao, P.-L. Lin, C.-Y. Liu, and U. Kumar (2016), Precipitation and cloud microstructure variations between two southern Indian stations.
- Janapati, J., B. K. Seela, P.-L. Lin, P. K. Wang, and U. Kumar (2019), An assessment of tropical cyclones rainfall erosivity for taiwan, Scientific reports, 9(1), 1–14.

CONFERENCE PAPERS

- Utpal Kumar, Benjamin F. Chao, Emmy T. Y. Chang (2018) Spatio-Temporal EOF Analysis of Common-Mode Error on the Dense, Continuous GPS Data of Taiwan [SE28-D4-PM1-P-012 (SE28-A029)] presented at 2018 AOGS, Hawaii.
- Utpal Kumar, Benjamin F. Chao, Emmy T. Y. Chang (2018) Common-Mode Error in GPS Displacement Field of Taiwan in Relation to Atmospheric Mass Loading [G13B-0522] presented at 2018 Fall Meeting, AGU, Washington DC, 10-14 Dec.
- Utpal Kumar, Benjamin Fong Chao, Emmy Tsui-Yu Chang (2019) What Cause the Common-mode Error in Array GPS Displacement Fields: Case Study for Taiwan in Relation to Atmospheric Mass Loading [SE30-D4-PM1-P-260 (SE30-A015)].
- Utpal Kumar, Benjamin Fong Chao (2019), GPS crustal motions along Taiwan's east coast: EOF analysis, Abstract [G43B-0746] presented at 2019 Fall Meeting, AGU, San Francisco, CA, 9-13 Dec.
- Utpal Kumar, Benjamin Fong Chao (2019), Crustal fluid and afterslip drive transient postseismic deformation associated with the 2016 Meinong earthquake (M_w 6.4), Abstract [G43B-0743] presented at 2019 Fall Meeting, AGU, San Francisco, CA, 9-13 Dec.

FINISHED STUDIES

- **A Meteor Shockwave Event Recorded at Seismic and Infrasound Stations in Northern Taiwan [*Published*]**
  Utpal Kumar[1,2,3], *Benjamin F. Chao*[2], *Yikai Hsieh*[4], *Emmy T. Y. Chang*[5]

  Three mysterious explosion sounds were heard in the coastal towns of Tamsui, west of Taipei in northern Taiwan, in the early evening of December 5, 2013. The event left clear signals that are identified in the recordings of 12 regional seismometers and 3 infrasound sensors and processed by means of travel time analysis. The apparent velocity of ~ 330 m/s of the signals confirms that the energy transmission was through the atmosphere, and the characteristics of the waveforms suggest the meteor-generated

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[2]Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan
[3]College of Earth Sciences, National Central University, Jhongli, Taiwan
[4]Research Institute for Sustainable Humanosphere, Kyoto University, Kyoto, Japan
[5]Institute of Oceanography, National Taiwan University, Taipei, Taiwan

shockwaves. We use the graphical method as well as the Genetic Algorithm optimization approach to constrain the trajectory of the meteor and to locate its projected intercept with the ground (25.33 N, 121.26 E), approximately 20 km off the coast of Tamsui. The trajectory has azimuth (measured from north in a map view in the clockwise direction) of 303° and (near-vertical) elevation angle of 70°. From the observed period of 1.3 s at the maximum amplitude of the infrasound signal, we estimate by conventional scaling law that the meteor in question had impact energy on the order of 5×10^{10} J (equivalent to an earthquake of local magnitude 4) or roughly a size of ~ 0.5 m across.

- **Anisotropic Rayleigh Wave Phase Velocity Maps of Gujarat, India [*Manuscript in Preparation*]**
  Utpal Kumar[1,2,3], *Cédric Legendre*[2], *Ajay Pratap Singh*[6], *Santosh Kumar*[6], Li Zhao[2,7]

  We explore the Rayleigh wave phase velocity anomalies beneath the Gujarat, a westernmost province in India, in a broad period range of 20-200s. Rayleigh wave dispersion curves are measured using the two-station approach and incorporating the broadband waveforms at 30 seismic stations from 1462 global earthquakes. We obtained 287 inter-station dispersion curves that are inverted for high-resolution isotropic and azimuthally anisotropic phase velocity maps independently at each period. The shorter periods (20-40s) results coincide well with the known geological features - the thick sedimentary layers of Kachchh exhibits low-velocity anomaly while the reduced crustal thickness of Saurashtra Horst and Mainland Gujarat reflects relatively high-velocity anomalies. The three major rift zones of the region, consisting of thick sedimentary deposition, are revealed by the low-velocity anomalies at shorter periods (20-40s). The persistent low-velocity anomalies beneath the Kachchh zone at longer periods may be an indication of asthenospheric flow. Azimuthal anisotropy at longer periods (> 70s) shows fast polarization directions broadly similar to the northward drift of the Indian plate towards the Eurasian plate. At shorter periods, the fast polarization direction has mostly east-west trend which correlates well with the E-W oriented rift faults of seismically most active Kachchh region.

- **What Cause the Common-Mode Error in Array GPS Displacement Fields: Case Study for Taiwan in Relation to Atmospheric Mass Loading [Under Review]**
  Utpal Kumar[1,2,3], *Benjamin F. Chao*[2], *Emmy T. Y. Chang*[5]

  We analyze forty-seven best-quality, ten-year-long daily Global Positioning System (GPS) position time series of Taiwan, to understand the origin of the GPS's common-mode error (CME) whose seasonality in the standard deviation evidences a meteorological origin. We employ the efficient Empirical Orthogonal Function analysis to extract the CME as the leading island-wide mode for all three components (whereas the second mode relates to the El Nino-Southern Oscillation). We find that the CME correlates well with the acquired variations in the atmospheric mass loading (AML) displacement field for Taiwan courtesy of NASA Goddard Space Flight Center for the Vertical component with high coherence around 11-14 cycles per year. Further regression analysis shows that up to 90% of the non-seasonal AML displacements in Taiwan is evident in the CME variations.

- **STADIUM-Py - I: Automated receiver functions measurements applied to USArray [Manuscript in Preparation]**
  Utpal Kumar[1,2,3], *Cédric Legendre*[2], *B. S. Huang*[2]
  We propose an open source automated framework, namely STADIUM-Py, specifically designed for the computation of Receiver Function (RF) and Shear-wave splitting (SKS) measurements. The RF package includes automatic RF and SKS analysis module, related quality control modules, and H-κ stacking module for receiver function analysis. The package takes advantage of huge open source

[6]Institute of Seismological Research, Gujarat, India
[7]Peking University, Beijing, China

available modules of Obspy and rf library developed by T. Eulenfeld. Most of the available software for receiver function analysis perform measurements on single traces or single station. We developed the Python library that allows user to efficiently request and preprocess seismic data, execute the receiver function analysis, save and plot the results in a fully automated way. We present two case studies to show how STADIUM-Py can be used to perform such tasks. This code will be released at the following url: https://github.com/utpalrai/STADIUM-Py/.
In this manuscript, we will show the framework using USArray stations to measure Receiver Functions.

- **STADIUM-Py – II) Automated analysis of SKS splitting beneath Germany [Manuscript in Preparation]**
  Utpal Kumar[1,2,3], *Cédric Legendre*[2], *B. S. Huang*[2]
  We propose an open source automated framework, namely STADIUM-Py, specifically designed for the computation of Receiver Function and Shear-wave splitting (SKS) measurements. This part talks about the SKS measurements package of the framework. The SKS package includes module for data download required for SKS analyses, related quality controls, computation of SKS measurements and its visualization. Most of the available software allow to perform measurements on single traces or single station. The framework is primarily build upon the open source package, splitwavepy, developed by Jack Walpole and available at https;//github.com/JackWalpole/splitwavepy to compute SKS measurements and the phase picker implementation of Obspy to identify SKS arrivals. We present two case studies to show how STADIUM-Py can be adopted to perform such tasks efficiently.
  In this manuscript, we will show the application of the framework using broadband seismic stations beneath Germany to measure shear-wave splitting of SKS phase. We found good correlation of our results with the previous studies. The advantage of STADIUM-Py over other recent frameworks is its full automation, the consistency of results - essential for the comparison of results at different geographical locations, and building a reference SKS measurements database.

- **Crustal fluid and afterslip driven co and transient post-seismic deformation associated with the 2016 Meinong earthquake (Mw 6.4) [Manuscript in Preparation]**
  Changyi Xu[8], *Utpal Kumar*[1,2,3]

  The 2016 Meinong earthquake (Mw 6.4) occurred in the southern Taiwan, and caused heavy causalities and one building collapse in Tainan city. Here we employ the empirical orthogonal function (EOF) to capture the coherent spatio-temporal features of surface deformation associated with this event in the continuous GPS (cGPS) time series. The solved EOF modes feature the dominant coseismic offsets for three components which are constant with the forward modelling using the seismic dislocation theory, and a significant transient postseismic deformation, which mainly reflect in the E component. There is no clear pre-seismic deformation rate change in the cGPS time series through the Monte-Carlo simulation and statistical test based on the time series of mode 1. The effect of the poro-elastic rebound, viscoelastic relaxation of the upper mantle, and the after-slip is combined to explain the observed postseismic deformation. Results show that the viscoelastic relaxation plays a negligible role in the postseismic deformation. Such transient postseismic deformation is dominated by the poro-elastic rebound and possible after-slip, which only lasts few months.

ONGOING STUDIES

- **Fully-automated Focal Mechanism Determination System and it's Application on the Events Located in Northern Philippines**

[8]Institute of Earthquake Forecasting, China Earthquake Administration

Utpal Kumar[1,2,3], *Li Zhao* [2,7], *Po-Fei Chen*[3]

Principal constraints on the source retrieval from the regional seismograms is the non-linearity of the course of steps, time-involved in estimating the stable and reliable solution. We have developed a fully-automated set of programs that can invert for the highly stable source-mechanism of an event using the given set of seismograms. In this study, we adopted the stable and reliable "cut-and-paste" source estimation technique (Zhao and Helmberger, 1994). We have modified and some programs to the original set of programs written by Lupei Zhu, to make it user-friendly. Our set of programs also includes the adaptive data preparation category, in addition to the green function calculation and the inversion of the seismograms. The additional programs have been currently written in Bash and Perl. We aim to re-write it in Python and also create graphical user interface (GUI) which can be run easily in Windows and Mac environment. We apply our programs for obtaining the focal mechanism and stress inversion in the northern Philippines.

- **A Study Guide for Theoretical Global Seismology by Dahlen and Tromp (1998)**
  Li Zhao[2,7],*Utpal Kumar*[1,2,3]
  Theoretical Global Seismology by Dahlen and Tromp presents an advanced theoretical treatment of global seismology, describing the normal-mode, body-wave, and surface wave methods employed in the determination of the Earth's three-dimensional internal structure and the source-mechanisms of earthquakes. The book consists of thousands of equations in a very concise form and without a proper understanding of these equations, the readers will be short of grabbing its real purpose. We endeavor to prepare a comprehensive study guide consisting of all the details of the book and the stepwise derivation of all the equations. This will be approachable for the undergraduate students and other readers from different fields referring to this book.

- **Spatial Analysis of Anomalously Large Co-seismic Deformation in the 2016 $M_L 6.6$ Meinong, Taiwan, Earthquake using EOF method on dense continuous GPS data of Taiwan**
  Utpal Kumar[1,2,3], *Benjamin Fong Chao*[2]

  Taking advantage of the dense continuous GPS network data, we demonstrate the effective utility of the method of empirical orthogonal function (EOF) in obtaining the coseismic deformation (vector) field on the crustal surface caused by anomalously large displacement caused by the Meinong Earthquake. The EOF analysis is capable of extracting the coseismic deformation in the form of coherent spatial pattern and time evolution. The extracted coseismic spatial patterns provide evidences linking the regional tectonics with the orogenic process in Taiwan under the plate convergence. We compare the pre and post-seismic coherent spatial pattern using the Dynamic Time Warping algorithm.

- **Hierarchical Agglomerative Clustering based on Dynamic Time Warping to explore the Regional Tectonics in Taiwan using GPS data**
  Utpal Kumar[1,2,3], *Benjamin Fong Chao*[2]

  Hierarchical Agglomerative Clustering (HAC) analysis based on Dynamic Time Warping (DTW) offers an objective tool for delineating the adequate crustal block structure using the three component continuous GPS data. DTW can identify the subtle crustal motion patterns by comparing two GPS position daily fluctuations (non-tidal, non-seasonal and non-CME). We apply a nonparametric, hierarchical agglomerative clustering algorithm based on the DTW for 200 three-component, GPS daily fluctuations from 2007 to 2018 in Taiwan. The analysis is completely data-intensive undertaking and uses no prior geologic information other than the GPS daily fluctuations. Agglomerative Clustering algorithm can categorize the tectonics of Taiwan into optimal number of geographical clusters based on pairwise DTW distance metrics. Combining HAC with DTW can overcome several limitations of the recent

clustering studies and extract detailed information by employing the full waveform approach.

OTHER NOTABLE PROJECTS

- **Masters Thesis:** *Surface Wave Group Velocity Dispersion study of the Eastern Himalayan Foreland Basin*
  Utpal Kumar[1,2,3], *Supriyo Mitra*[9]

  Seismic surface waves, recorded at regional distances, sample the 1-Dimensional structure between the earthquake source and receiver. Dispersed surface waves are sensitive to the vertical average of shear wave velocities in a layered medium. Using both these properties, we model the crust and upper mantle shear wave velocity structure of the eastern Himalayan foreland basin by modeling multi-mode surface wave group velocity dispersion data. We use earthquakes originating in Sikkim-Bhutan Himalaya and the Bengal basin recorded at the permanent broadband seismological observatory at Bakreshwar (BAKR). Source-receiver raypaths sample the foreland basin adjacent to the Sikkim-Bhutan Himalaya and the Bengal Basin. We measure Rayleigh and Love waves dispersion for both fundamental and the first higher mode, in the frequency-time domain, using the multiple filter analysis (MFA) technique. Observed dispersion curves are clustered into 2 groups based on the raypath sampled. Rayleigh and Love wave dispersion data for Cluster 1 ranges from 6 to 30 s and 5 to 19 s, respectively, for the fundamental mode. Similarly, the fundamental mode Rayleigh wave dispersion data for Cluster 2 ranges from 9 to 36 s. Clustered multi-mode dispersion data has been jointly inverted to model the crust and upper mantle structure beneath the sampled regions. The Eastern foreland basin has 4 km thick sedimentary layer as compared to approximately 7 km thick sedimentary layer of Western and Central Foreland Basin. The crustal thickness of Bengal Basin, which is overlain by 18 km thick sediments / sedimentary rocks, is just 20 km. This shows that it is a continental margin crust which has been overlain by the sediments brought down by the rivers like Ganga and Brahmaputra from the orogeny.

- **Precipitation and cloud structure variations between two southern Indian states [Published]**
  Balaji Kumar Seela[1,2], *K. Krishna Reddy, J. Jayalakshmi, T. Narayana Rao, Pay-Liam Lin, Chian-Yi Liu, Utpal Kumar*[1,2,3]

  Raindrop size distribution (RSD) characteristic variations between two southern Indian stations [Gadanki (13.5° N, 79.2° E) Kadapa (14.47° N, 78.82° E)] using ground based parsivel disdrometer data are studied. Number concentration of mid and large drops is more over Gadanki when compared to Kadapa precipitation. The mean value of mass weighted mean diameter (Dm) is higher in Gadanki than Kadapa precipitation. Both monthly and diurnal variations of Dm show higher values of Dm over Gadanki than Kadapa. After classifying the precipitations systems into stratiform and convective, Gadanki has higher (lower) Dm than Kadapa in stratiform (convective).

- **Understanding of Taiwan typhoon rainfall erosivity using raindrop size distribution [Published]**
  Jayalakshmi Janapati[10], *Balaji Kumar Seela*[1,2], *Pay Liam*[9],*Pao Wang*[11,12], *Utpal Kumar* [1,2,3]

  Rainfall erosion has severe implication on agriculture, water, and land use management. Though there were rainfall erosion studies on regional/global scale, tropical cyclones' rainfall erosion is poorly assessed

[9]Indian Institute of Science Education and Research, Kolkata
[10]National Central University
[11]Academia Sinica
[12]University of Wisconsin-Madison

and have been not documented for some of the most cyclones affecting regions of the world like Taiwan. Here, using 15-years of raindrop size distributions and 60-years of hourly rain gauge data, we estimated cyclones' (also called typhoons) rainfall erosivity over Taiwan, and establish that typhoons' mean rainfall erosivity is higher than the global mean rainfall erosivity. Moreover, regional variability of typhoons rainfall erosivity showed an increasing pattern from north to south, with relatively higher values over the eastern and southern part of Taiwan.

RESEARCH AND TEACHING EXPERIENCE:

- **Ph.D student** in Taiwan International Graduate Program (TIGP), Earth System Science Program, Academia Sinica, Taiwan from September 2014 to till date.
- **Teaching Assistant** in Introductory Earth Sciences (Geophysics + Geology) course at Indian Institute of Science Education and Research, in 2013.
- **Summer Project Assistant** under Prof. S. S. Rai at NGRI Hyderabad in 2011.
- **Project Assistant** under Prof. Mrinal K. Sen at NGRI Hyderabad in 2012.

NOTABLE AWARDS, MEMBERSHIPS AND ACHIEVEMENTS:

- **Selected in the competitive and prestigious JEE-Advanced 2009**, an academic examination held annually in India. The qualification rate of the JEE-Advanced in 2017 was approximately 0.92% (about 11,000 out of 1,200,000 who applied for JEE Main).
- **All India Rank 32 in CSIR-UGC National Eligibility Test (NET)**, a test to determine eligibility for college and university level lecturership and for the award of Junior Research Fellowship (JRF) for Indian nationals.
- **Ranked 4th** in the state level competitive examination for the professional courses of Medical, Engineering and Agricultural streams in the Institutions of the state of Bihar [**Bihar Combined Entrance Competitive Examination (BCECE)**].
- Qualified in **Graduate Aptitude Test in Engineering (GATE)** in Earth Sciences in 2013. It is one of the most competitive examinations in India for admissions to various post-graduate education programs.
- **Winner of Indian Academy of Sciences summer research fellowship** (2013)
- **Best Poster** presentation in Department Day (Earth Sciences), IISER (2014)
- Member of AGU, AOGS (2018)
- **Best Poster** award in **Solid Earth Section, AOGS (2018)**. AOGS holds annual conventions providing a unique opportunity of exchanging scientific knowledge and discussion to address important geo-scientific issues among academia, research institution and public.
- **Won 3rd prize in NASA Hackathon Space Apps Challenge, Taipei and the complementary award from IBM Taiwan.** NASA and its partners put out challenges relating to current work for which space enthusiasts around the world of all backgrounds can develop innovative solutions (which can be more than just apps!), particularly focusing on use of NASA data and promoting education.
- **Annual member** of Asia Oceania Geosciences Society and American Geophysical Union for 2018, 2019

EXTRA-CURRICULAR ACTIVITIES

- I am the founder and administrator of '**iescoders.com**' website where several awesome students and researchers contribute towards making a rich repository of codes in Geophysics. This is very useful for undergraduate and graduate students who usually spend lots of time in learning the basic skills. I constantly get several emails from students and researchers appreciating the effort from all over the globe.

- I love analyzing the day to day data. One such example is using the easily available sensors (such as mobile phones) to record the 3D acceleration and analyze those to obtain meaningful results. One of the most exciting result was the XYZ component acceleration data from my home to the University and inverting that to obtain the exact route taken by the car.
- I am an amateur cyclist. Whenever I get time I hop on my bike and go for a ride.
- Voracious reader. My interests is mostly in scientific endeavor books and fantasy. Some of my favorites are Cosmos by Carl Sagan, A Short History of Nearly Everything, Lord of the Rings, Harry Potter Series, Jules Verne's Series such as Around the World in Eighty Days, Journey to the Center of the Earth.