# 4. Multi-scale Modelling Programme

This is a data intensive paradigm which addresses multiscale problems ranging from weather and climate, century-scale climate projections, space-based geodesy, computational geodynamics, surface processes and climate aspects from surface to ionosphere. The group continued development of system models and carried out the simulations of climate change, seasonal monsoon and climate under different aerosol scenarios, formulation of algorithms for analysis of simulations and deriving inferences in the field of climate sciences, lithosphere-hydrosphere-atmosphere-ionosphere interactions and computational geodynamics.

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## 4.1 On the build-up of dust aerosols and possible indirect eAect during Indian summer monsoon break spells using recent satellite observations of aerosols and cloud properties

Association of higher (lower) rainfall with lower (higher) Aerosol Optical Depth (AOD) is consistent with the understanding that increased washout (build-up) and shorter (longer) lifetime of aerosols occur in wetter (drier) conditions. Given the life-time of aerosols, it is imperative to examine how aerosols impact active/break (wetter/drier than normal) spells, prominent intraseasonal variability (ISV) of Indian summer monsoon (ISM), through their composite analysis using recent satellite observations of aerosols and cloud properties, circulation and rainfall. Dust aerosols can act as CCN and participate efficiently in cloud processes during active phase. During breaks, build-up of desert dust transported by prevalent circulation, is associated with lower cloud effective radius implying aerosols' indirect effect where they can inhibit cloud growth in the presence of reduced moisture and decrease precipitation efficiency/rainfall. Correspondingly, correlation albeit small, between intraseasonal anomalies of AOD and rainfall is negative, when AOD leads rainfall by 3–5 days implying that indirect aerosols impact is effective during breaks, though it is not the dominant responsible factor. During breaks, lower shortwave flux at top of atmosphere hints at dust-induced semi-direct effect. As breaks are permanent features of ISM, incorporation of dust-induced feedbacks in models, is essential for improved ISV simulation and ISM prediction.

## 4.2 Future changes in rice yield over Kerala using climate change scenario from high resolution global climate model projection

The impact of climate change on agricultural yield is one amongst the major concerns the world is witnessing. Our study focusses on rice yield prediction for an agricultural research station in Kerala with the help of climate change scenario input from the Meteorological Research Institute (MRI) Global Climate Model (GCM) projection under Representative Concentration Pathway 8.5 (RCP8.5). We have used Cropping System Model (CSM) Crop Estimation through Resource and Environment Synthesis (CERES) Rice within Decision Support System for Agrotechnology Transfer (DSSAT) package for predicting the yield. Our study has the novelty of using very high-resolution climate data from a model which is highly skilful in capturing the present-day climate features and climatic trends over India (in particular, over the Western Ghats), as input for simulating the future crop yield. From this study, we find that the rice yield decreases due to rise in temperature and reduction in rainfall, thereby reducing the crops maturity time in the future. Based on our results, the adaptation measures suggested to achieve better yield under future warming conditions are: (i) to opt for alternative rice varieties which have tolerance to high temperatures and consume less water, and (ii) shifting of planting date to the most appropriate window.

## 4.3 High-resolution climate change projection of northeast monsoon rainfall over peninsular India

In this study, projected changes in mean northeast monsoon (NEM) rainfall and associated extreme rainfall and temperature events, over peninsular India (PI) and its six subdivisions, are quantified. High-resolution dynamically downscaled simulations of the Weather Research and Forecasting (WRF) regional climate model driven by the boundary conditions from the Community Climate System Model version 4 (CCSM4) model (WRF-CCSM4) are compared with statistically downscaled simulations of NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP). Over PI, these downscaled simulations show low bias in mean NEM rainfall ($\leq$ 0.44 mm/day) and high pattern correlation coefficient (0.75), giving confidence in their future projections. Under future warming over PI, both downscaled simulations project future significant enhancement in

NEM rainfall with WRF-CCSM4 projecting 1.98mm·day1 (83.78% change with respect to the present-day mean) whereas the multimodel ensemble (MME) of eight NEX-GDDP models project $0.67 \pm 0.58$mm·day1 (19.78%) by the midddle of the century and 1.42±0.97mm·day1 (42.76%) by the end of the century. Analysis of extreme rainfall events shows that WRF-CCSM4 projects future enhancement (reduction) in extreme rainfall (R95p) days over 91.4% (8.6%) of grid-points over PI. In future, coastal areas of Karnataka and Andhra Pradesh will likely experience increased extreme rainfall occurrence by more than 25 days and 15–20 days respectively. Projected future enhancement in the mean and extreme NEM rainfall is attributed to the increased precipitable water under a warming climate. Future projection of extreme temperature indices shows an increase in minimum and maximum temperatures over PI during the NEM season. Over PI, future winter nights and days are found to be warmer than those in the present day and the temperature change in future winter nights is found to be larger than that in winter days. This climate change information would help decision-makers in evaluating existing policies and devising revised policies to reduce risk due to climate change.

## 4.4 Hydrology induced horizontal displacements of Nepal Himalayas and North-East India detected using GRACE gravity observations and GPS

The area of North-East India and Nepal Himalaya undergoes seasonal deformations due to the variation of the surface mass loads induced mainly by annual monsoon precipitation. The present study focuses on comparing seasonal horizontal deformations of the Earth's surface obtained over the area of North-East India and Nepal Himalaya using Global Positioning System (GPS) and the corresponding ones obtained from Gravity Recovery and Climate Experiment (GRACE) satellite mission data. Seasonal deformations of the Earth's surface in horizontal components were determined using daily observations from 36 GPS stations located in North-East India and Nepal Himalaya and GRACE-based Global Geopotential Models (GGMs). The consistency between these seasonal horizontal deformations was investigated using three statistical criteria, namely: the correlation, Weighted Root Mean Square (WRMS) reduction and Nash-Sutcliffe model Efficiency (NSE). The results indicate that nearly 89% of the seasonal deformations obtained using GPS and GRACE correlates well. However, the percentage of WRMS reductions (Figure 4.1) and median value of NSE shows poor agreement. The results reveal that seasonal horizontal deformations are influenced by local tectonics and emphasize the need of a realistic Earth model for better constraining the surface deformations over the area investigated.

## 4.5 Aliasing and Artifact free detection of ionospheric perturbations induced by Tsunami – A possible tool for tsunami early warning

Earthquakes and tsunamis killed more people than all other types of natural disasters, claiming nearly 884,000 lives, globally, between 1980 – 2014. Among these two natural disasters, tsunamis were the most deadly with an average of 79 deaths for every 1,000 people affected, compared to four deaths per 1,000 in the case of earthquakes, which make tsunamis almost twenty times more deadly than earthquakes. As there is no mechanism exists at present to forecast or predict the earthquakes and tsunamis, timely detection and early warning are the only alternative to reduce the loss of lives caused by these disasters. Monitoring ionospheric perturbation induced tsunamis using ground based GPS receivers can be a promising tool for the timely detection and early warning, provided the aliasing and artifacts free detection of ionospheric perturbations are ensured. Theoretical simulations and observational validation of the algorithm developed by Shimna and Vijayan at MSMP, CSIR-4PI reveals that the algorithm SPLA (Spatio-Periodic Levelling Algorithm) successfully removes the aliases and artifacts from ionospheric perturbations. Furthermore, the results show that SPLA is efficient to extract tsunami induced ionospheric perturbations from low

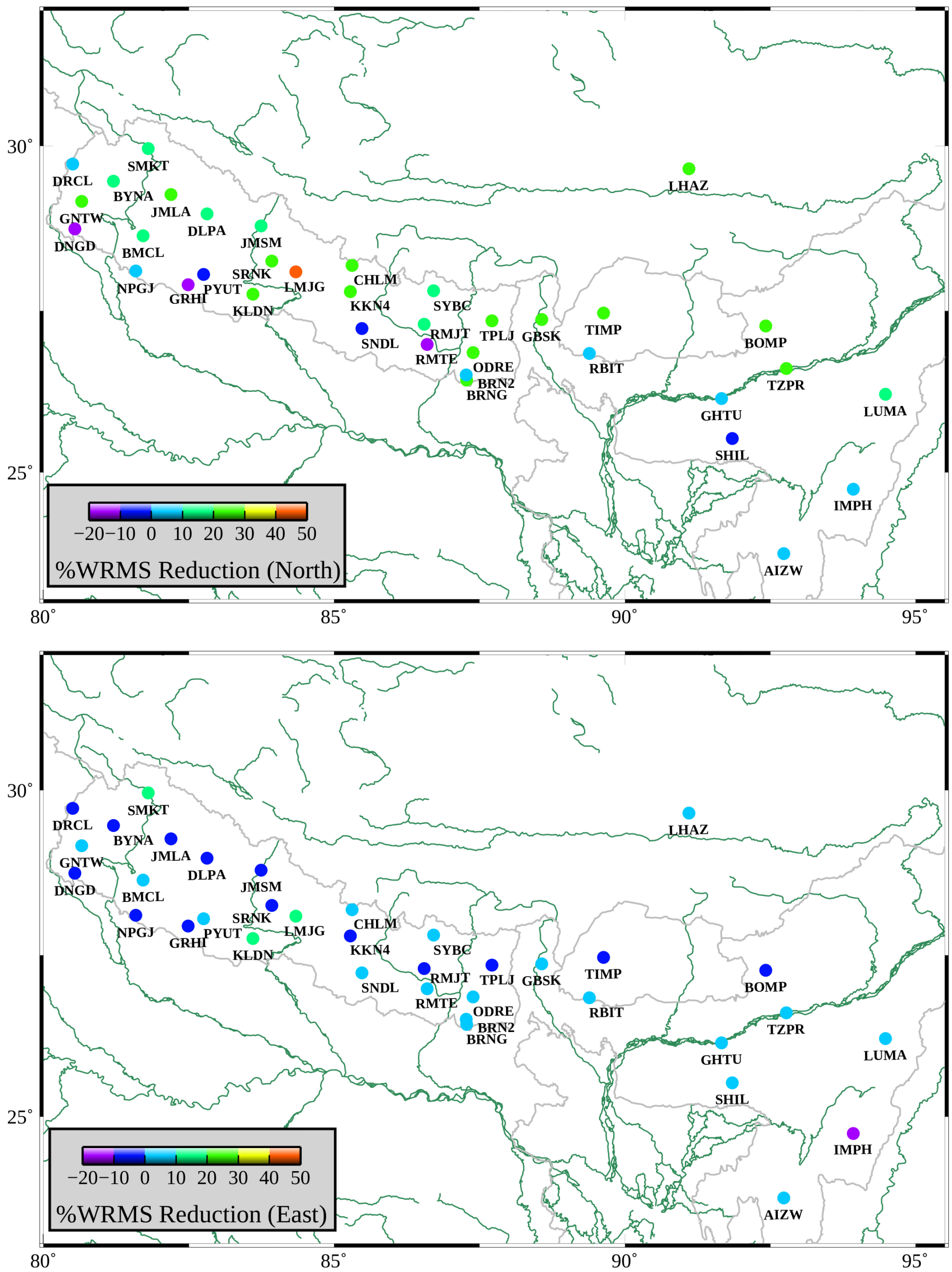


Figure 4.1: The WRMS reduction obtained after reducing the seasonal deformations obtained from GRACE data from the seasonal deformations determined from GPS data.

elevation observations and capable of detecting tsunamis propagating as far as 800 km away from the coast using inland GPS receivers. The locations of the ionospheric perturbations obtained from GPS observations using SPLA matches well with the simulated 26th December 2004 Indian Ocean tsunami (Figure 4.2). The results obtained in this study indicate that the potential of ionospheric observations for tsunami early warning.

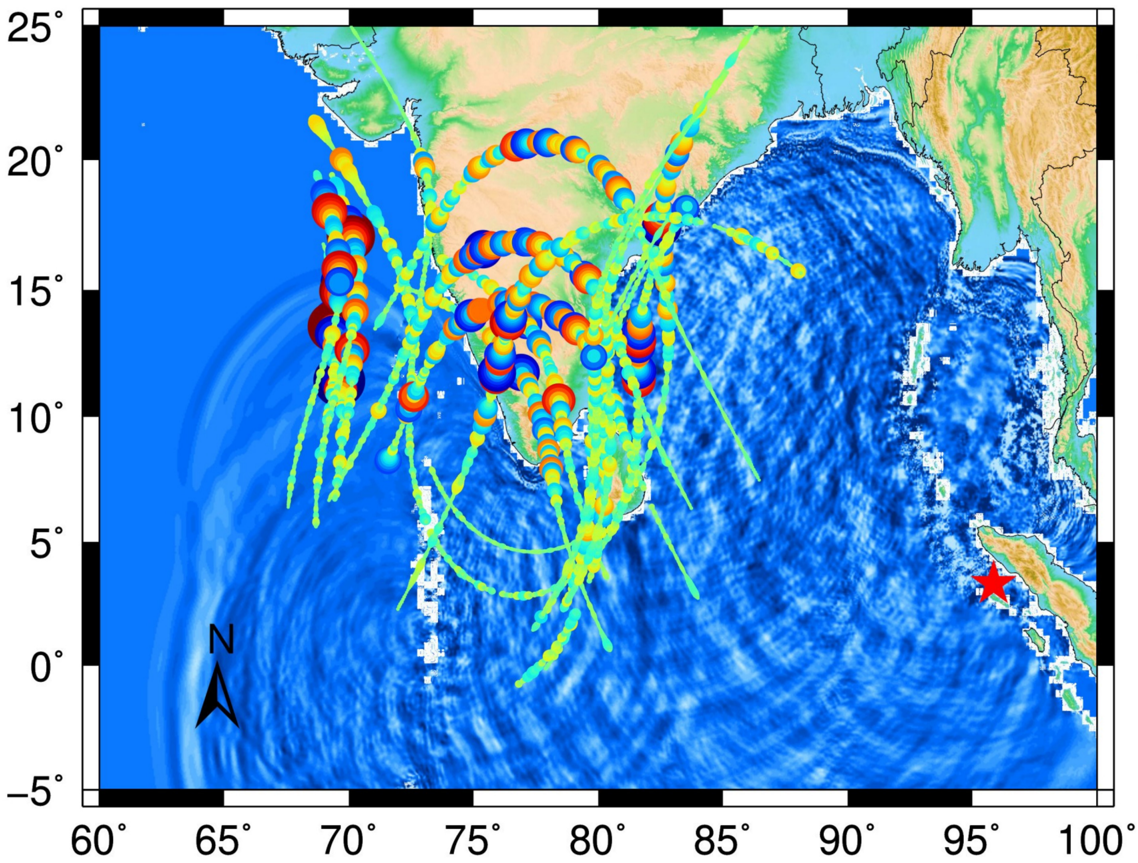


Figure 4.2: Ionospheric perturbations induced by 26th December 2004 Indian Ocean tsunami. The ionospheric perturbations detected at a height of 350 km above the ocean surface are plotted over the numerically simulated tsunami.

## 4.6 Stream gradient indices and the active tectonics of the Central Himalaya

The evolution of the landscape is generally considered to be associated with active tectonic processes and erosion. Our understanding on the topographic evolution of a convergent orogen can be looked through the river drainage network of that region. The 2500 km long Himalayan arc orogen sets an ideal region to study the active tectonic orogenic process using river channel morphological analysis. For this rivers from the central Himalayan region, like the Yamuna, Bhagirathi, Sharda, Ghagra and Kali Gandaki are selected. For this we computed the normalized steepness index and river knick points distribution. The longitudinal profile of the transient stream typically shows convexity whereas the graded stream show concave up. High normalized steepness index values indicate faster surface uplift. Areas that are undergoing faster surface uplift are identified by high normalized steepness index (Ksn) values (Figure 4.3). This study indicates that the regional river channel profiles represent a uplift tectonics in a compressional environment.

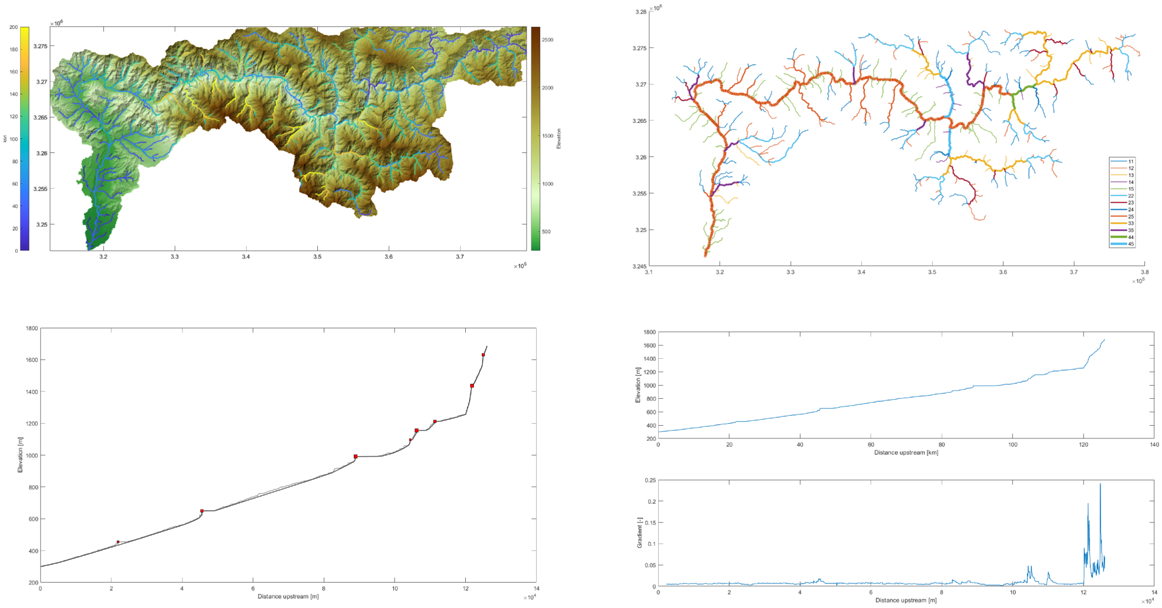

Figure 4.3: Digital elevation model of Kosi river and tributaries indexed with normalized steepness index (Ksn) values. (Top left), Drainage side branching used in the analysis (Top right), Knick points along the river profile (Bottom left) and the stream line gradient index (Right bottom).