Project: **981**
Project title: **Sensitivity and Response of the Treeline Ecotone in Rolwaling Himal, Nepal, to Climate Warming (TREELINE)**
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Report period ending: **2019-01-01 to 2019-12-31**

As detailed in submitted research plans, a fully-compressible non-hydrostatic, Weather Research and Forecasting (WRF) model in its latest version (3.9.1.1) has been compiled in DKRZ HPC Mistral. It is a widely used model for meso/micro-scale climate simulations due to its features to use large number of physical parameterizations for downscaling climate variables across a variety of horizontal and vertical scales.

Utilizing both the existing WRF setup in DKRZ as well as the old set up in University of Hamburg, Regionales Rechenzentrum (RRZ) server, we completed the one year simulations in three nested domain D1, D2 and D3 configured at 25, 5 and 1 km horizontal grid spacing (with default land use and topography), respectively using ERA Interim forcing in 2017. The simulated outputs were validated against the 7 in-situ meteorological stations established under the same project and other stations from several other organizations. These simulation results are already published in the form of a research article in the Journal Earth System Dynamics (Karki et al. 2017, https://www.earth-syst-dynam.net/8/507/2017/) in 2017. The results from this set up were already included in the last years report, thus is excluded here.

In the second WRF work published recently in Climate Dynamics (**Karki et al. 2019**), a new WRF model configuration at 1 km (15, 3, 1 km) with updated land cover is used to investigate the factors and processes controlling the temperature distribution and lapse rate of temperature (LRT) in different seasons over complex Himalayan terrain (Fig. 1). The temperature lapse rate is controlled by surface characteristics (snow, glacier, forest etc), local and large scale wind flows, cold air pooling and inversion phenomena, and moisture and latent heat release process but with dominancy of different factors in different seasons. Therefore, the dominant drivers for different seasons are identified in this research by means of one year of WRF simulation as well as sensitivity experiments with modified land cover and terrain characteristics. Our results indicate the dominant role of surface characteristics (snow cover and snow free) during pre-monsoon and early post-monsoon season (Fig. 2). Likewise, strong large-scale westerlies prevent the local anabatic flow to reach the high mountain slopes in these months. The cooling effect by westerlies at higher elevation and prevention of warm up valley wind further contributes for steeper LRTs during these seasons (Fig. 3). In contrast, upslope flow is stronger during monsoon, which reduces the temperature contrast between lower and higher elevations. Different type of inversions including shallow inversion associated with cold air pooling in valley floors play a dominant role for Nov-Dec shallowing of LRT (Fig. 4).

In the third WRF work (**Karki et al. 2018, published in Atmospheric research Journal** https://www.sciencedirect.com/science/article/pii/S0169809518301844?via%3Dihub), we analyse the extreme precipitation using WRF model to identify the meso- and micro-scale dynamical mechanisms and the interactions between the atmosphere and the underlying topography (Fig. 5). In synoptic scale, extreme rainfall events in Nepal are often associated with the interaction of large scale westerly and monsoon circulations near the first mountain range (foothills) of Himalayas. However, cross barrier flow towards the foothills and consequent orographic upliftment triggers the extreme precipitation of Himalaya (Fig. 6). Amount, location and timing of precipitation during the event were highly sensitive to the chosen microphysics scheme in the model configuration. The findings suggest that the selection of an appropriate microphysics scheme and near realistic representation of terrain is crucial for the reliable prediction of intense convective rainfall events by means of CPS NWP models.

Besides these, using the allocated resources in previous years, we have simulated 3 km WRF run covering entire Nepal and 600 m run covering Everest region for 3 years (2013 -2016). The preliminary evaluation of 600 m simulation did not show significant improvement compared to 1 km simulation but we are further analysing this with several modifications. In addition, 3 km WRF run which covers entire Nepal is also planned for evaluation across whole Nepal.

Publications from WRF set up in DKRZ Mistral:

Karki, R., Hasson, S., Gerlitz, L., Schickhoff, U., Scholten, T., and Böhner, J.: Quantifying the added value of convection-permitting climate simulations in complex terrain: a systematic evaluation of WRF over the Himalayas, Earth Syst. Dynam., 8, 507-528, https://doi.org/10.5194/esd-8-507-2017, 2017.

Karki, R., Hasson, S., Gerlitz, L., Schenk, E., Talchabhadel, R., Schickhoff, U., Scholten, T., Böhner, J. 2018a. WRF-based simulation of an extreme precipitation event over the Central Himalayas: Atmospheric mechanisms and their representation by microphysics parameterization schemes. Atmos. Res. 2018, doi:10.1016/J.ATMOSRES.2018.07.016

Karki, R., Hasson, S., Schickhoff, U., Scholten, T., Böhner, J., Gerlitz, L., 2018b. Near surface air temperature lapse rates over complex terrain: A WRF based analysis of controlling factors and processes for the Central Himalayas. Climate Dynamics, 2019. https://doi.org/10.1007/s00382-019-05003-9

Figures:

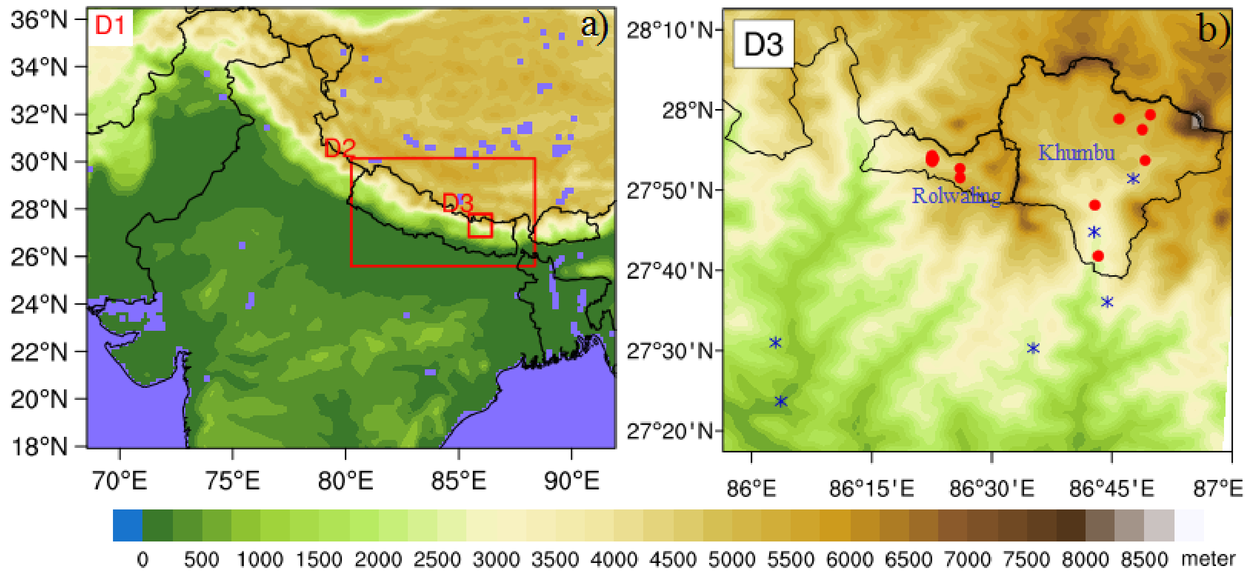

Figure 1 a) WRF domain boundary for three WRF resolutions -15 km (D1), 3 km (D2), and 1 km (D3) b) topography of the study area from WRF D3 including Rolwaling and Khumbu catchments. Political boundary of Nepal is delineated and stations are marked with • for Temperature, relative humidity and precipitation measurement and * for precipitation measurement only. Rolwaling hosts 7 stations but all stations are not visible due to dense network.

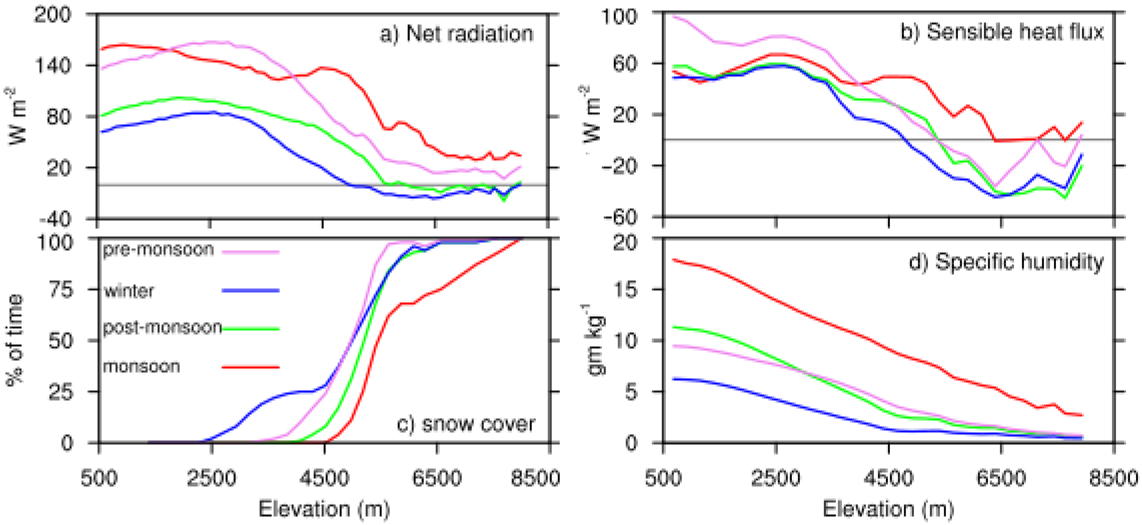

Figure 2 WRF simulated seasonal and elevational variations of a) net radiation b) sensible heat flux, c) snow cover at the surface (% of total duration) and d) specific humidity at 2 m

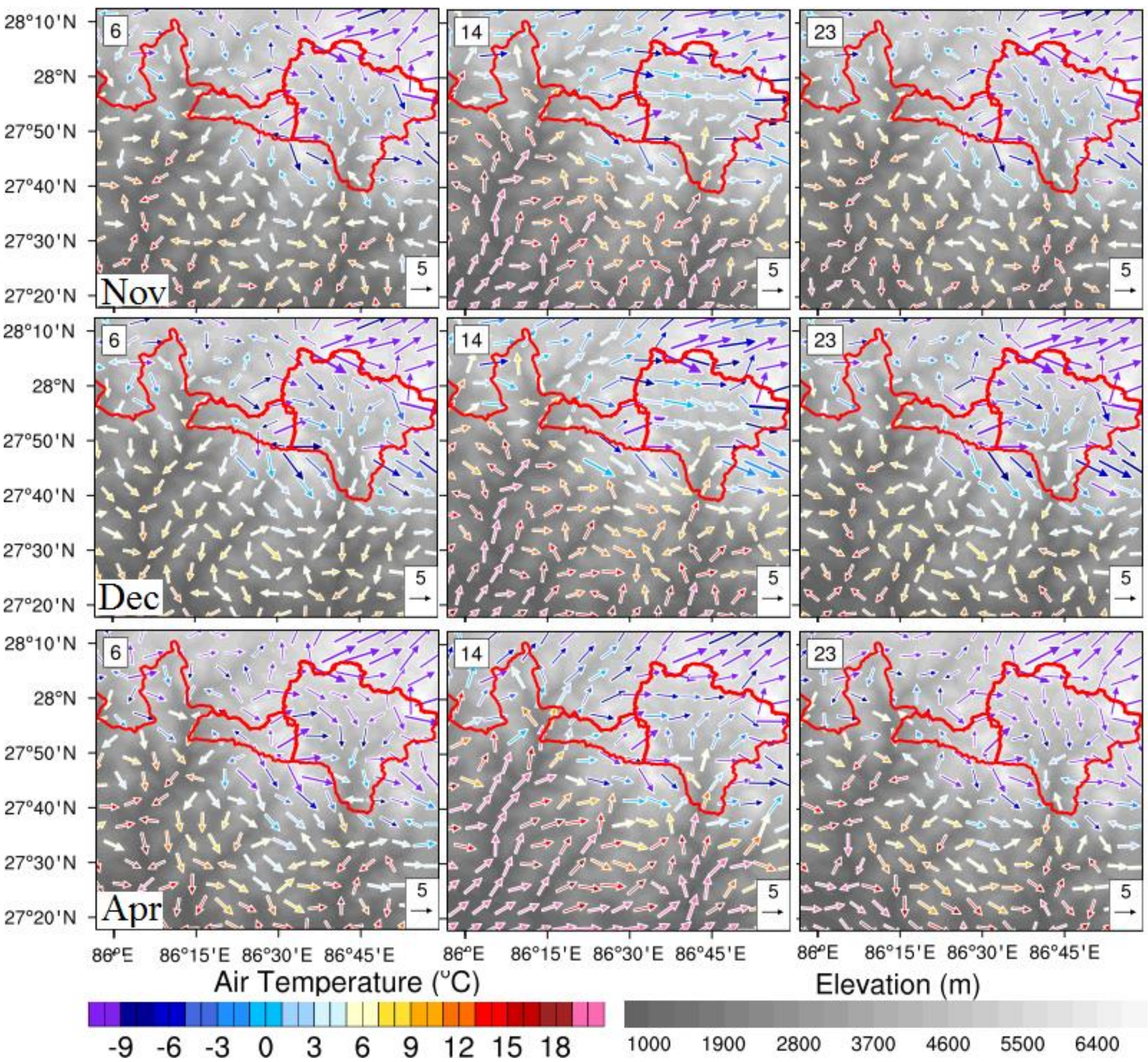

Figure 3 WRF simulated surface wind (10 m) vector for dry periods during selected months. Vectors are colorized by 2 m air temperature during different hours (local time is indicated in each plot)

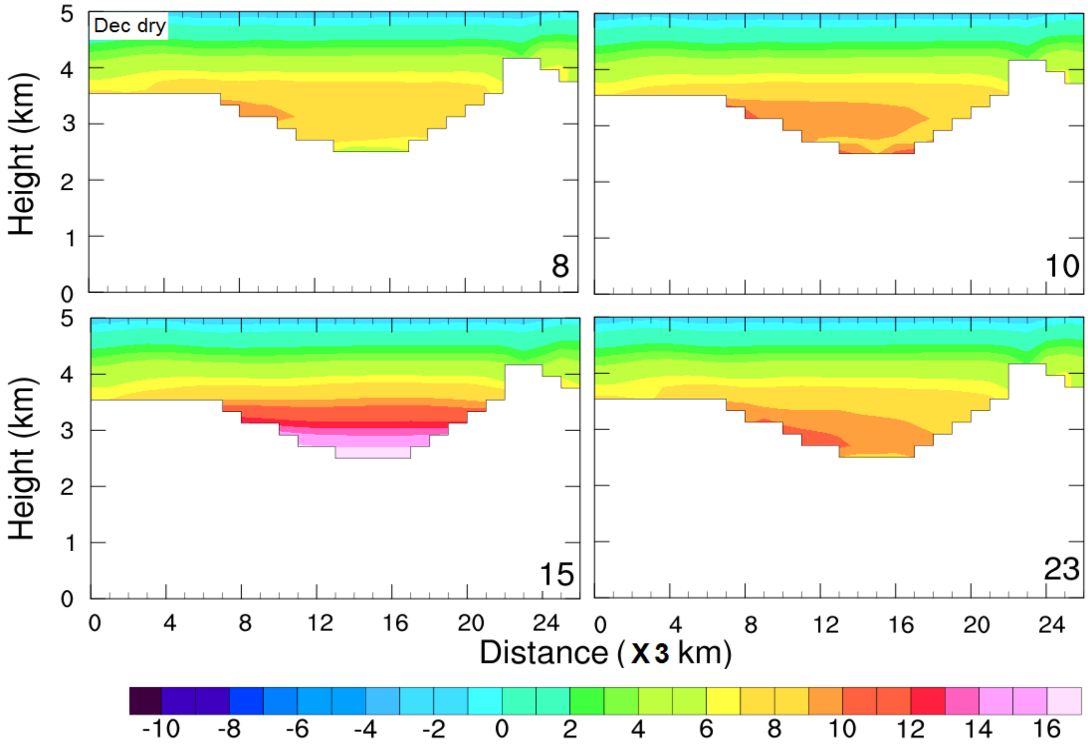

Figure 4 Cross sectional profile of hourly average air temperature (ºC) in the ideal lower valley (section W-E) for different local hours of dry days of 2 – 9 December, 2014

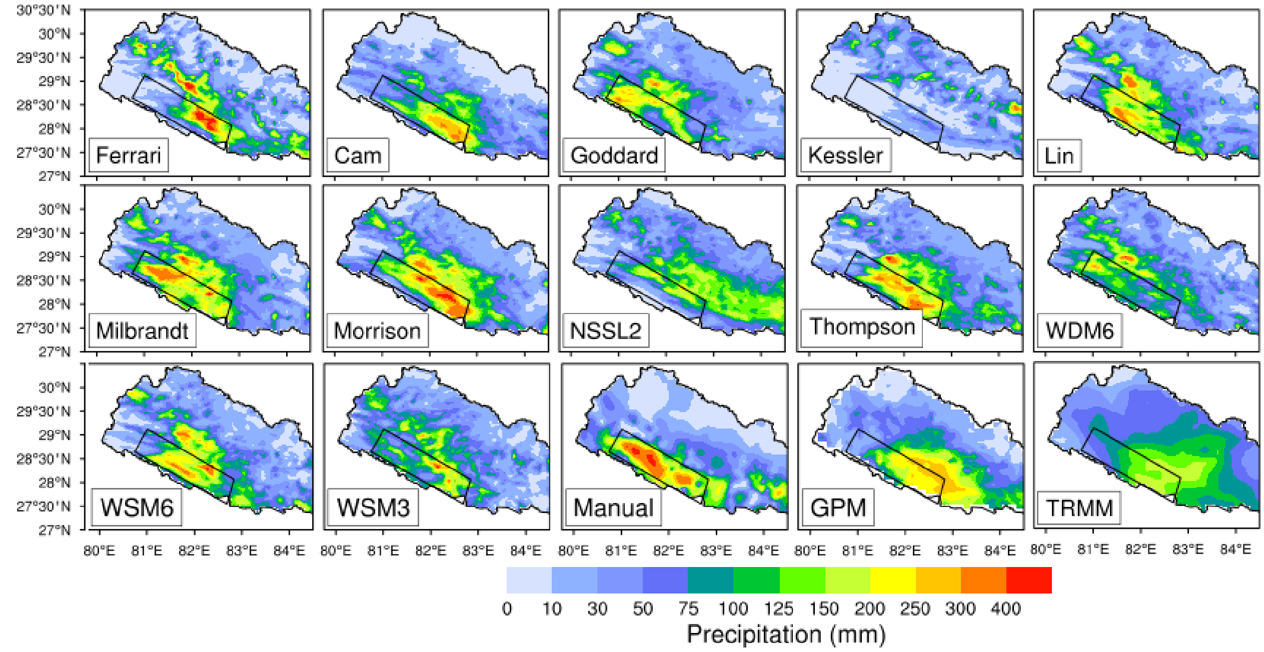

Fig.5 Daily precipitation total simulated by different WRF microphysics and observations.

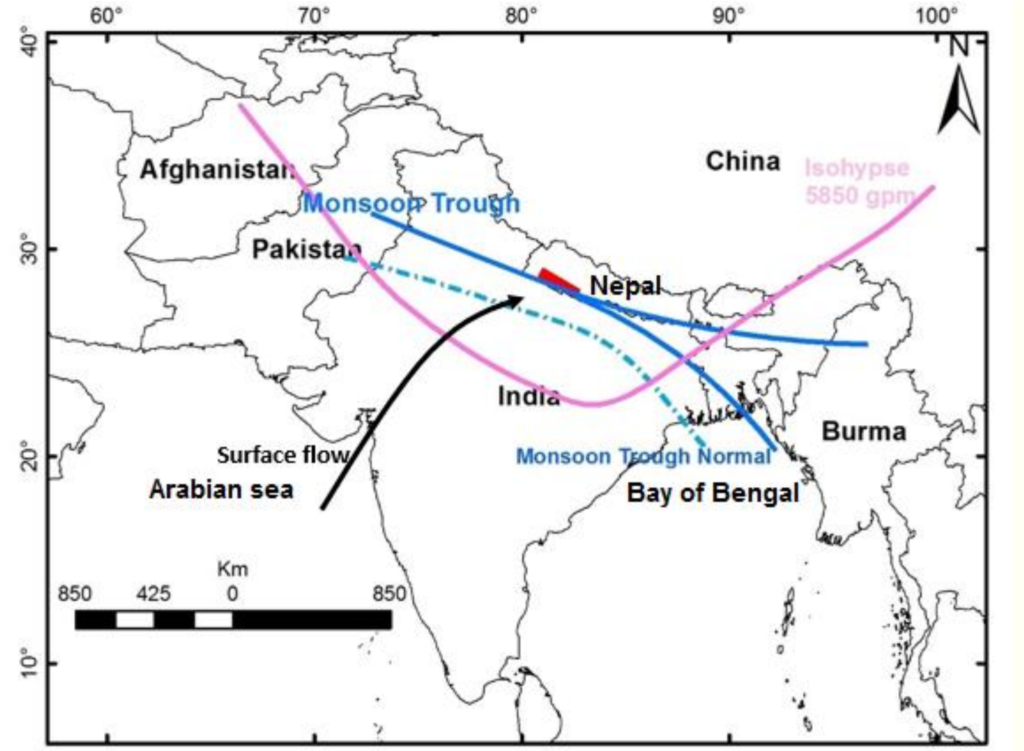

Figure 6. Schematic overview of the synoptic conditions during the extreme rainfall event (zone of maximum precipitation in Nepal is marked with red shade). The 5850 gpm isohypse (violet line) reflects the intruded 500 hPa trough. The northward shift of monsoon trough is indicated in solid blue. The cross barrier low-level flow from the Arabian Sea is illustrated by the black arrow.