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Ensemble climate projections of mean and extreme rainfall over Vietnam

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ABSTRACT

A systematic ensemble high resolution climate modelling study over Vietnam has been performed using the PRECIS model developed by the Hadley Center in UK. A 5 member subset of the 17-member Perturbed Physics Ensembles (PPE) of the Quantifying Uncertainty in Model Predictions (QUMP) project were simulated and analyzed. The PRECIS model simulations were conducted at a horizontal resolution of 25 km for the baseline period 1961–1990 and a future climate period 2061–2090 under scenario A1B. The results of model simulations show that the model was able to reproduce the mean state of climate over Vietnam when compared to observations. The annual cycles and seasonal averages of precipitation over different sub-regions of Vietnam show the ability of the model in also reproducing the observed peak and magnitude of monthly rainfall. The climate extremes of precipitation were also fairly well captured. Projections of future climate show both increases and decreases in the mean climate over different regions of Vietnam. The analyses of future extreme rainfall using the STARDEX precipitation indices show an increase in 90th percentile precipitation (P90p) over the northern provinces (15–25%) and central highland (5–10%) and over southern Vietnam (up to 5%). The total number of wet days (Prcp) indicates a decrease of about 5–10% all over Vietnam. Consequently, an increase in the wet day rainfall intensity (SDII), is likely inferring that the projected rainfall would be much more severe and intense which have the potential to cause flooding in some regions. Risks due to extreme drought also exist in other regions where the number of wet days decreases. In addition, the maximum 5 day consecutive rainfall (R5d) increases by 20–25% over northern Vietnam but decreases in a similar range over the central and southern Vietnam.
These results have strong implications for the management water resources, agriculture, bio diversity and economy and serve as some useful findings to be considered by the policy makers within a wider range of climate uncertainties.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that global surface temperatures may rise to about 1–2 °C by the year 2050 and to about 2–5 °C by the end of the 21st century, depending on how much of the anthropogenic Green House Gases (GHG) will be emitted to the atmosphere in the coming decades. The latest findings from the IPCC show many evidences that climate change has already affected many regions in Southeast Asia, one of the highly climate vulnerable regions in the world (IPCC, 2007, 2013). It is high time that more research into climate science is necessary as far as Southeast Asia is concerned, not just in understanding the climate and its change but also be able to understand the climate impacts and its severity so that all countries in Southeast Asia can prepare themselves adequately to adapt to such changes.

The IPCC's Fifth Assessment Report (AR5) mentioned that significant changes in rainfall patterns and increased global sea-level rise may be expected by 2100 (IPCC, 2013). The report also mentioned that it is certain that global mean surface temperature has increased since the late 19th century and the decade of the 2000′s has been the warmest with the global combined land and ocean temperature data showing an increase of about 0.89 °C during the period 1901–2012. With respect to precipitation changes, the report indicated that future increases in precipitation extremes related to monsoons is very likely in South America, Africa, East Asia, South Asia, Australia and Southeast Asia. Temperatures are likely to increase by 3 °C and rainfall increases up to 40% are also likely by the end of the century, over Southeast Asia. Overall, many of the reported climatic changes and projections have been found to be consistent with its earlier assessment report AR4 (IPCC, 2013).

These climatic changes are significant as most of the economically weaker countries in Southeast Asia are highly vulnerable to climate change and are in need of both scientific expertise and the economic means to combat climate change (ADB, 2009). Over the past two decades, decreasing trends in precipitation as well as rising trends in sea

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level (1–3 mm/year) have also been noted. The number of extreme weather events such as hot days/warm nights or number of heavy storm events and tropical cyclones has also increased. These climate changes have shown impacts on other physical systems - increasing temperatures and increasing extreme weather events also led to the decline of crop yield in many Southeast Asian countries (Thailand, Vietnam and Indonesia), massive flooding in Hanoi, Hue (Vietnam), Jakarta (Indonesia), Vientiane (Laos) and landslides in Philippines and droughts in many other parts of the region (ADB, 2009). Water shortage, agriculture constrains, food security, infectious diseases, forest fires and degradation of coastal and marine resources have also been increasing (IPCC, 2007). The strongest and most consistent increases are seen over northern Indonesia, Singapore and Malaysia in June, July, August (JJA) and over southern Indonesia and Papua New Guinea in December, January, February (DJF). Some other studies (Kharin et al., 2007; Lenderink and Van Meijgaard, 2008) have also shown that precipitation extremes are expected to increase both in intensity and frequency over many regions in the world due to global warming.

In this context of climate change over Southeast Asia, the PRECIS (Providing Regional Climates for Impacts Studies) regional climate model was used in this study to assess future climate changes in rainfall over Vietnam. PRECIS was developed by the Hadley Center in UK and has been used in various regional climate studies around the globe. Rao et al. (2014) applied PRECIS model to assess the mean and extremes of rainfall over India for a suit of 5 ensemble PPE boundary conditions. They found out that changes in extreme rainfall events and dry spells suggesting not only shifts but also substantial increase in the spread of the precipitation distribution, with an increased probability of the occurrence of events conducive to both floods and droughts. Kumar et al. (2011) performed simulations from a 17-member Perturbed Physics Ensemble (PPE) generated using the Hadley Center Coupled Model (HadCM3) for the "Quantifying Uncertainty in Model Predictions" (QUMP) project which were used to drive the PRECIS for period of 1961–2098. The model showed reasonable skill in simulating the monsoon climate over India. The authors reported that the summer monsoon rainfall over India was expected to increase by 15% in the 2080s compared to the baseline period. In addition, the rainy days were projected to be less frequent and more intense over central India. Alves and Marengo (2010) used the PRECIS to evaluate the accuracy and skill in describing the seasonal variability of the main climatological features over South America and adjacent oceans in their 30 year (1961–1990) simulations. It was reported by the authors that precipitation and temperature patterns as well as the main general circulation features were well simulated by the model. In another study, Marengo et al. (2009) also used the PRECIS model to analyze the distribution of extremes of temperature and precipitation in South America over the past (1961–1990) and in the future (2071–2100) climate under the IPCC A2 and B2 emissions scenarios. It was shown that the PRECIS model was able to reproduce the spatial and temporal patterns of precipitation and temperature and the main features of the large circulation reasonably well. It was reported that these trends were consistent with those from the GCM HadAM3P model that was used to drive PRECIS and some detailed climatic features were captured at finer scales than those resolved by the global model. The study suggested that the model simulated the spatial distribution of extreme temperature and rainfall events well enough although temperature distributions were more realistic than rainfall. This finding along with the others mentioned earlier also indicated that compared to temperatures, precipitation is a difficult variable to be simulated accurately due to its large variability in space and time. Other studies that have applied PRECIS are those of Karmalkar et al. (2011), Duliere et al. (2011), Mileham et al. (2009), Islam et al. (2009), Bloom et al. (2008), Buonomo et al. (2007) and Kumar et al. (2006), to name a few.

Very few climate change studies exist over Vietnam. McSweeney et al. (2012) applied the 17-member PPE in developing high resolution climate scenarios over Vietnam using a subset of 5 ensemble members

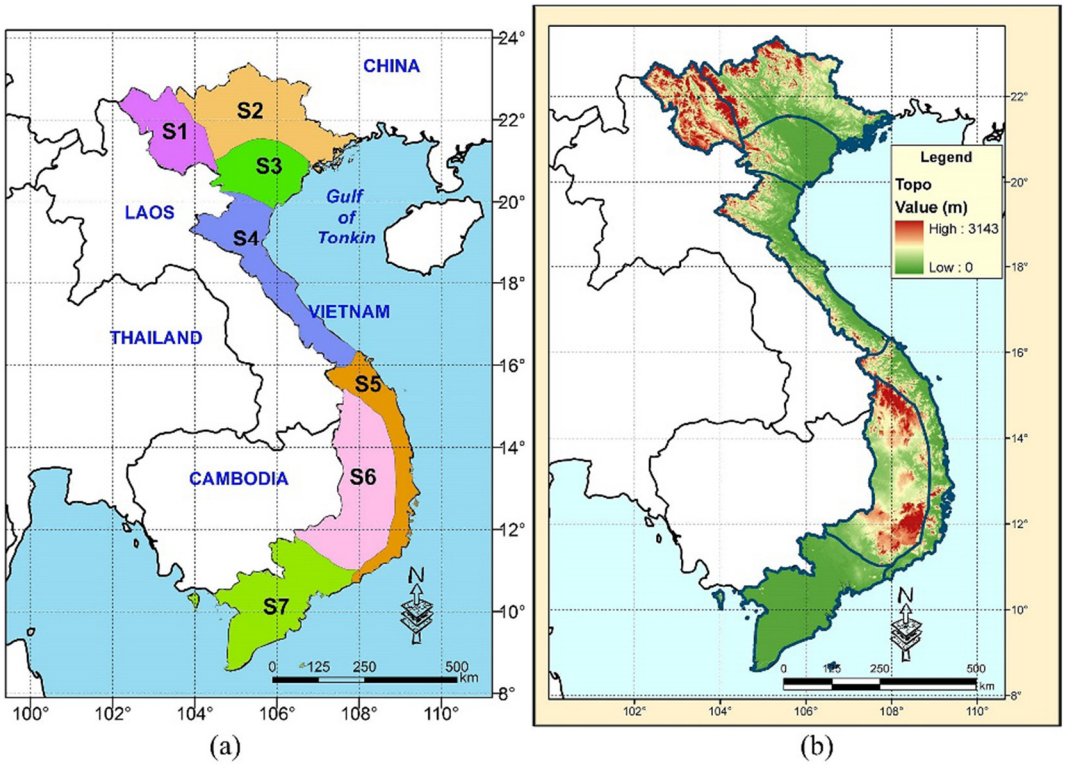

Fig. 1. (a) Seven climate sub-regions of Vietnam, (b) Vietnam topography by SRTM.