Reproducibility of Monsoon Precipitation over the Central Himalaya in Numerical Models

論　文　内　容　要　旨

(NO. 1)

氏　　名	KADEL Indira	提出年	平成 29 年
学位論文の 題　　目	Reproducibility of Monsoon Precipitation over the Central Himalaya in Numerical Models （数値モデルによる中央ヒマラヤにおけるモンスーン降水の再現性）		

論　文　目　次

ABSTRACT

Summer monsoon season (SMS) precipitation over the central Himalaya is a lifeline of huge population which supplies water for water resources, agriculture, energy production and industry. However, inhabitants are adversely affected by precipitation–induced natural hazards such as floods, landslides and droughts that cause huge losses of life and property, impact the Himalayan environment, and ultimately obstruct the socioeconomic development. Consequently, accurate prediction of precipitation at near and far future periods is essential to support in decision making process at various sectors. This study assesses the performance of state–of–the–art numerical models (global climate models, global operational weather models and a non-hydrostatic regional model) to predict monsoon precipitation and investigates the future projections under anthropogenic climate change.

Firstly, employing 38 Global Climate Models (GCMs) participating in the Coupled Model Intercomparison Project phase 5 (CMIP5), we assess the performance of state–of–the–art GCMs to reproduce SMS precipitation over the central Himalaya at present climate and investigate the projected changes in future under anthropogenic warming climate (Representative Concentration Pathways: RCP4.5 and RCP8.5) based on the systematically selected best models. GCMs are evaluated to reproduce annual cycles of the area averaged precipitation, the spatial pattern of SMS mean climatology and the interannual variability (IAV) of the seasonal mean precipitation at the present climate. Most of the models are reliable to reproduce the annual cycle of the mean precipitation over the central Himalaya. However, simulating the spatial distribution remains the major challenge to the models, only a few models are capable to reproduce the spatial pattern of seasonal mean climatology and IAV of seasonal mean precipitation. About 66% of the total models show wet bias. The selected best models and their multi-model means project an increase of SMS mean precipitation in mid and far future periods significantly under the both warming scenarios whereas the projected changes in variability are very uncertain. Unlike, the frequency of dry days which is projected to decrease, frequencies of moderate and heavy precipitation days are projected to increase in far future period under RCP8.5 scenario. Furthermore, the frequency and the length of active spells and the frequency of break spells are projected to increase in all future periods under RCP8.5 scenario. However, the projected length of dry spell is uncertain. The increase in mean monsoon precipitation and extreme indices can be attributed to intensified low level flow from the Arabian Sea, abundant availability of moisture and enhanced convective activities in a warmer atmosphere, and is partly balanced by weakening of upper level easterly wind over the India and the Arabian Sea. Our results suggest that precipitation–induced natural disasters will likely be increased in the future since extremes indices are projected to intensify.

Secondly, we assess the predictability of precipitation in five major global operational ensemble prediction systems (EPSs) namely the China Meteorological Administration (CMA), the Canadian Meteorological Centre (CMC), the European Centre for Medium–Range Weather Forecasts (ECMWF), United States National Centers for Environmental Prediction (NCEP), and the United Kingdom Meteorological Office (UKMO) which contribute in The Observing System Research and Predictability Experiment (THORPEX) Interactive Grand Global Ensemble (TIGGE) dataset. Daily ensemble mean precipitation forecasts for Nepal from individual EPS at short to medium range time scales are evaluated in deterministic well as probabilistic sense against the Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of

water Resources (APHRODITE) project dataset during summer seasons of 2009–2012. Various verification metrics have been employed to evaluate the performance at different lead times and precipitation thresholds. Results indicate that the performance of EPSs to forecast precipitation in Nepal, a country with the complex terrain, is poor. Comparatively, the ECMWF exhibits the highest forecast skills for both quantitative precipitation forecast (QPFs) and probabilistic QPFs (PQPFs) followed by that of UKMO. Although, CMC has shown comparatively lower error, better spread-skill relationship and reliability diagram, forecasts are least sharp and the spatial correlation and discrimination ability is very poor. The skill scores to verify QPFs and PQPFs show that NCEP is the least reliable. Similarly, CMA shows large wet bias particularly for the first three lead days, and over estimates medium and heavy rain events. Furthermore, we investigate the performance of multi–model grand ensemble means by applying various methods in 2012. The results show that forecast errors are reduced in grand ensemble means than the individual EPS, with the highest improvement in bias removed grand ensemble. However, the performance of ECMWF is as good as the simple multi-model grand ensemble mean.

Thirdly, reproducibility of an extreme rainfall event that occurred on 13–15 August 2014 in Nepal in a non-hydrostatic regional model (Japan Meteorological Agency Non–Hydrostatic Model: JMA–NHM) is examined. Four experiments are performed with two sets of domain sizes (large and small) at 25km and 5km spatial resolutions. Results show that JMA–NHM is able to simulate extreme precipitation at 25km to some extent. However, the spatial coverage of the event is greatly diminished, and excessive wet bias is apparent in the eastern parts of Nepal. The large wet bias could be related to the topography, cumulus parameterization scheme, and bias inherited from the initial and boundary conditions. With the use of high resolution (5 km) model, the simulation of precipitation is not improved significantly, and even deteriorated in the case of small domain on 14 and 15 August. Additionally, the impact of domain size is insignificant in the case of 25km experiments compared to the extreme wet bias particularly in the eastern parts of Nepal. However, domain size has shown large impact in simulation in the case of 5km experiments.

In summary, precipitation over the central Himalaya is highly variable both in space and time. Most of the state–of–the–art numerical models are not sufficient to accurately reproduce the precipitation characteristics. Therefore, detail precipitation mechanisms should be understood, and numerical models need to be improved accordingly.

様式３の(3)

論　文　審　査　等　報　告　書

博士の 専攻分野	博士（理学）	ふりがな 氏　　名	カデル　インディラ KADEL, Indira
論文審査の 結果の要旨 及びその 担当者氏名	別紙のとおり 山崎　剛　（主査） 岩崎　俊樹 早坂　忠裕 青木　周司 森本　真司		
最終試験の 結果の要旨 及びその 担当者氏名	本学大学院理学研究科の選定した 下記担当者が行った試験に合格した。 論文審査委員のほかに 須賀　利雄 川村　宏 岩渕　弘信 境田　太樹		
博士論文審 査機関の名 称及び組織	名称　審査会 組織　委員５名		
修了の要件	本研究科規定の定める修了要件を満たしている。		
判定の方法	理学研究科委員会の議決による。		

備考　この報告書は、本人に記入させないこと。

別　紙

論文審査の結果の要旨

中央ヒマラヤの降水はモンスーン期に集中し，洪水や土砂災害などを引き起こしている。一方で南アジアの広範な人口集中域に河川水を供給している。本研究の目的は，中央ヒマラヤ，特にネパールにおけるモンスーン期の降水について，数値モデルによる予報可能性を明らかにすることである。降水の短中期予報は防災に，また将来予測は社会基盤整備や水資源の問題に直結するものである。ネパールをはじめとする途上国では，独自の全球予報システムを運用することは難しく，先進国の気象機関による全球数値予報を用いて，地域気候モデルを実行するのが有力な手法となる。

まず，２章では将来予測に関して，大気海洋結合モデルの相互比較プロジェクトである CMIP5 に参加した全球気候モデルから，中央ヒマラヤ域での降水再現性に優れたモデルを合理的な手法により抽出した。選ばれたモデルの結果を解析し，今世紀中ごろおよび今世紀末には降水量の増加が見込まれるが，年々変動に関してはモデルによるばらつきが大きく不確実であることがわかった。また，将来は強い雨が増えることを示した。

続いて３章では短中期予報に関して，５つの国や地域の気象機関により運用されている代表的な全球予報システムの評価を行った。その結果，降水の予報精度は概して高くなく，システム間の相違が大きかった。また，モデルアンサンブルの効果を調べ，バイアス補正を施した多数モデルのアンサンブルが，降水の予報誤差減少に有効であることを示した。

最後に４章では 2014 年 8 月のネパールにおける豪雨について，気象庁の非静力学モデル JMA-NHM を適用し，その再現性を調べた。結果は計算領域の設定，水平解像度などに強く依存し，強雨の発生域などを正確に再現することはできなかった。

中央ヒマラヤのような極めて地形が複雑な地域における降水の予報，予測には，モデルそのものの改良も含めて課題が多いことが明らかになった。本論文はこれらの課題の明確化により，ネパールでの降水の予報，予測の向上への道筋をつけるものであり，本人が自立して研究活動を行うに必要な高度の研究能力と学識を有することを示している。したがって，KADEL, Indira 提出の博士論文は，博士（理学）の学位論文として合格と認める。