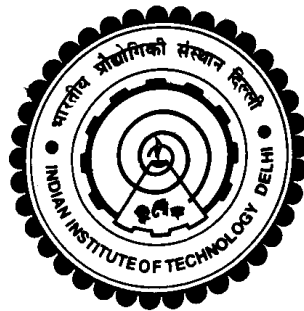


ASSESSING UNCERTAINTIES IN SIMULATING STREAM FLOW PROJECTIONS UNDER CLIMATE CHANGE FOR UPPER YAMUNA RIVER BASIN

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by

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Submitted

in fulfilment of the requirements of the degree of Doctor of Philosophy
to the



Indian Institute of Technology Delhi

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CERTIFICATE

This is to certify that the thesis entitled “**Assessing Uncertainties in Simulating Stream Flow Projections Under Climate Change for Upper Yamuna River Basin**” being submitted by **Ms Jayshri Patel** to the Indian Institute of Technology Delhi for the award of the degree of Doctor of Philosophy is a bona fide record of research work carried out by her under my supervision and guidance. The thesis work, in my opinion, has reached the requisite standard fulfilling the requirements for the said degree.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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Jayshri

ABSTRACT

This study focuses on the assessment of uncertainties in simulating hydro-climatic projection using multi model ensemble framework that consists of five global climate models, three Representative Concentration Pathways (RCP 2.6, RCP 4.5 and RCP 8.5) for two future periods (2020-2049) and (2070-2099) for Upper Yamuna River Basin, India. Changes in projected climatology and simulated stream flow are presented with respect to the reference period from 1970 to 1999. Assessment of climate change impacts especially in the context of future water availability is necessary for policy makers and water managers to identify and design suitable adaptation strategy.

Performance of the suite of fourteen Global Climate Models that have been covered under Coupled Model Inter-comparison Project (CMIP5) was evaluated in reproducing spatially averaged basin precipitation for the reference period (1970-1999). Based on significance of the individual model performance, the list was pruned down to a select five Climate Models as candidate models to be adopted in the study to assess future climate scenarios. Bias-corrected daily time series of precipitation and air temperature using three bias correction approaches for each of the selected five GCMs under three RCPs were used to drive Soil and Water Assessment Tool (SWAT) hydrological model to simulate hydrologic stream flows for historical as well as the two future study horizons and designated in this research as Near Future Period and Distant Future Period. The Soil and Water Assessment Tool (SWAT) hydrological model was calibrated to obtain reasonable reconstructions of monthly stream flows for two stations in the study area for the reference period. The calibrated model was then subjected to a systematic investigation for its performance over an independently observed time horizon for model validation.

Behavioural hydrological parameter sets are chosen using the Generalized Likelihood Uncertainty Estimation (GLUE) and, in order to assess the contribution of uncertainty from

each component of model ensemble, ANOVA was performed. For each scenario, future streamflow simulations were obtained using selected GCMs using three bias correction approaches under three RCPs and behavioural parameter sets obtained during the reference period. Resulting change in streamflow were used to compute a qualitative assessment of the relative importance of uncertainties coming from each source.

Under the three RCPs scenario change in annual precipitation ranges from -0.65 to 6.5% (5.38 to 17.14%) and annual temperature from 1.31 to 1.52 °C (1.61 to 3.22 °C) will lead to a projected annual stream flow ranging from -0.77 to -8.57% (-9.29 to 7.90%) % for Near Future Period (Distant Future Period) respectively compared to the historical period at Baghpat streamflow gauge station in Upper Yamuna River Basin.

The scenario ensemble mean under three scenario indicates increase in temperature for all season, whereas precipitation and streamflow projection variability depends upon the selected global climate model. The Uncertainty assessment based on ensemble used in hydrologic projection shows key uncertainty results from GCM structure followed by RCPs, Bias correction approaches and hydrological model parameterization in projecting mean monthly streamflow. However choice of bias correction method and hydrologic parameterization substantially affects in projecting extreme low flow and high flow. The variance decomposition shows that GCM inter model variability has the largest contribution to the overall projection variance for both future period.

सार

यह अध्ययन दो भविष्य की अवधि (2020-2049) के लिए पांच वैश्विक जलवायु मॉडल, तीन प्रतिनिधि एकाग्रता पथ (आरसीपी 2.6, आरसीपी 4.5 और आरसीपी 8.5) के साथ बहु मॉडल आभूषण ढांचे का उपयोग करके जलविद्युत प्रक्षेपण को अनुकरण करने में अनिश्चितताओं के आकलन पर केंद्रित है। और (2070-2099) ऊपरी यमुना नदी बेसिन, भारत के लिए। अनुमानित जलवायु विज्ञान और अनुरूपित धारा प्रवाह में परिवर्तन 1970 से 1999 तक संदर्भ अवधि के संबंध में प्रस्तुत किए जाते हैं। विशेष रूप से भविष्य में पानी की उपलब्धता के संदर्भ में जलवायु परिवर्तन प्रभावों का आकलन नीति निर्माताओं और जल प्रबंधकों के लिए अनुकूल अनुकूलन रणनीति की पहचान और डिजाइन करने के लिए आवश्यक है।

युग्मित मॉडल इंटर-तुलना परियोजना (सीएमआईपी 5) के तहत कवर किए गए चौदह वैश्विक जलवायु मॉडल के सूट का प्रदर्शन संदर्भ अवधि (1970-1999) के लिए स्थानिक रूप से औसत बेसिन वर्षा को पुनः पेश करने में मूल्यांकन किया गया था। व्यक्तिगत मॉडल प्रदर्शन के महत्व के आधार पर, भविष्य में जलवायु परिदृश्यों का आकलन करने के लिए अध्ययन में उम्मीदवार मॉडल को अपनाया जाने वाला उम्मीदवार मॉडल चुनिंदा पांच जलवायु मॉडल में दिखाया गया था। तीन आरसीपी के तहत चयनित पांच जीसीएम में से प्रत्येक के लिए तीन पूर्वाग्रह सुधार दृष्टिकोणों का उपयोग करके वर्षा और वायु तापमान की बाईस-सही दैनिक समय श्रृंखला का उपयोग ऐतिहासिक और साथ ही ऐतिहासिक के लिए जलविद्युत प्रवाह प्रवाह को अनुकरण करने के लिए मृदा और जल आकलन उपकरण (एसडब्ल्यूएटी) जलविद्युत मॉडल चलाने के लिए किया जाता था। भविष्य के अध्ययन और दूर भविष्य अवधि के रूप में इस शोध में दो भविष्य के अध्ययन क्षितिज और नामित। संदर्भ अवधि के लिए अध्ययन क्षेत्र में दो स्टेशनों के लिए मासिक धारा प्रवाह के उचित पुनर्निर्माण प्राप्त करने के लिए मृदा और जल आकलन उपकरण (एसडब्ल्यूएटी) जलविद्युत मॉडल को कैलिब्रेटेड किया गया था। कैलिब्रेटेड मॉडल को मॉडल सत्यापन के लिए स्वतंत्र रूप से मनाए गए समय क्षितिज पर अपने प्रदर्शन के लिए एक व्यवस्थित जांच के अधीन किया गया था।

व्यवहारिक हाइड्रोलॉजिकल पैरामीटर सेट सामान्यीकृत लिकेलहुड अनिश्चितता अनुमान (जीएलयूई) का उपयोग करके चुने जाते हैं, और मॉडल के प्रत्येक घटक से अनिश्चितता के योगदान का आकलन करने के लिए, एनोवा किया गया था। प्रत्येक परिदृश्य के लिए, तीन आरसीपी के तहत तीन पूर्वाग्रह सुधार दृष्टिकोण और संदर्भ अवधि के दौरान प्राप्त व्यवहार पैरामीटर सेट का उपयोग करके चयनित जीसीएम का उपयोग करके भविष्य में स्ट्रीमफ्लो सिमुलेशन प्राप्त किए गए थे। स्ट्रीमफ्लो में परिवर्तन का परिणाम प्रत्येक स्रोत से आने वाली अनिश्चितताओं के सापेक्ष महत्व के गुणात्मक मूल्यांकन की गणना करने के लिए किया गया था।

सालाना वर्षा में तीन आरसीपी परिदृश्य परिवर्तन के तहत -0.65 से 6.5% (5.38 से 17.14%) और 1.31 से 1.52 ° सी (1.61 से 3.22 ° सी) तक वार्षिक तापमान -7.77 से अनुमानित वार्षिक प्रवाह प्रवाह का कारण बनता है ऊपरी यमुना नदी बेसिन में

बागपत स्ट्रीमफ्लो गेज स्टेशन की ऐतिहासिक अवधि की तुलना में निकट भविष्य अवधि (दूरस्थ भविष्य अवधि) के लिए - 8.57% (-9.2 9 से 7.90%)।

परिदृश्य के रूप में परिदृश्य का मतलब तीन परिदृश्यों के लिए तापमान में वृद्धि दर्शाता है, जबकि वर्षा और प्रवाह प्रवाह प्रक्षेपण भिन्नता चयनित वैश्विक जलवायु मॉडल पर निर्भर करती है। हाइड्रोलॉजिक प्रोजेक्शन में उपयोग किए जाने वाले कलाकारों के आधार पर अनिश्चितता मूल्यांकन जीसीएम संरचना से मुख्य अनिश्चितता के परिणाम दिखाता है जिसके बाद आरसीपी, बाईस सुधार दृष्टिकोण और हाइड्रोलॉजिकल मॉडल पैरामीटरेशन का मतलब मासिक प्रवाह प्रवाह प्रक्षेपण होता है। हालांकि पूर्वाग्रह सुधार विधि और हाइड्रोलॉजिक पैरामीटर का विकल्प अत्यधिक कम प्रवाह और उच्च प्रवाह प्रक्षेपण में काफी हद तक प्रभावित होता है। भिन्नता विघटन से पता चलता है कि जीसीएम इंटर मॉडल परिवर्तनशीलता दोनों भविष्य की अवधि के लिए समग्र प्रक्षेपण भिन्नता में सबसे बड़ा योगदान है।

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ACRONYMS

ANOVA	Analysis of Variance
ARS	Agricultural Research Service
CMIP3	Climate Model Intercomparison Project Phase 3
CMIP5	Climate Model Intercomparison Project Phase 5
CN	Curve Number
CO ₂	Carbon dioxide
DEM	digital Elevation Model
ECDF	Empirical Cumulative Distribution Function
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
GCM	Global Climate Model
RCM	Regional Circulation Models
GHG	Greenhouse Gas
GIS	Geographical Information System
GLUE	Generalized Likelihood Uncertainty Estimation
HRU	Hydrological Response Units
LH-OAT	Latin Hypercube One factor At a Time
MME	Multi Model Ensemble
NSE	Nash Schiff efficiency
PBIAS	Percentage Bias
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PET	Potential evapotranspiration
PPU	Percentage Predictive Uncertainty
QM	Quantile Mapping
RCP	Representative Concentration Pathway
RMSE	Root mean square error
RMSE	Root mean squared error
SCS	Soil Conservation Service
SRES	Special Report on Emissions Scenarios

SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
TAR	Third Assessment Report
USDA	US Department of Agriculture
UTM	Universal Transverse Mercator coordinate system
UYRB	Upper Yamuna River Basin
W/m ²	Watts per square meter