Interactive Desktop Tool for Nonstationary Intensity-Duration-Frequency Curves under Climate Change

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PROPOSAL DETAILS

(SRG/2019/001251)

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Technical Details :

Scheme :	Start-up Research Grant		
Research Area :	Earth and Atmospheric Sciences (Earth & Atmospheric Sciences)		
Duration :	24 Months	**Contact No :**	+919750447774
Date of Birth :	09-Jan-1979		
Nationality :	INDIAN	**Total Cost (INR) :**	16,47,000

Project Summary :

Urban watershed management has become one of the key factors for sustainable development and management of water infrastructure. The precipitation based intensity-duration-frequency (IDF) curves are used for planning, design, and operations of water supply systems, flood management, and other hydraulic structures. These IDF curves are derived from extreme precipitation events and the variation of extreme precipitation over time is usually assumed to be stationary. However, recent studies have indicated that these events are increasing in frequencies and magnitude due to the effect of climate change. This may lead to an increase in greater risk and failure of infrastructure and other engineering structures. Extremes changing with time are termed as nonstationary and addressing nonstationary in the context of changing climate is important for developing future Intensity-Duration-Frequency (IDF) relationships. The purpose of this project is two-fold: (i) to develop a new framework for nonstationary IDF curves under climate change and assess the skill scores of GCM outputs; and (ii) to develop an interactive desktop tool for IDF update under changing climatic conditions. The tool will be disseminated and made available to municipalities in India. This is the simplest principle this project will apply to increase the existing application of the research to the municipalities. In this project, annual extreme precipitation is modelled using non-stationary based on Generalized Extreme Value (NS-GEV). The parameters of the non-stationary GEV are assumed to be time-dependent and are estimated using the maximum likelihood method. The time-dependent function for the parameters of the nonstationary IDF curves is derived from the GCM outputs. The assessment of GCM skill provides the understanding of structural uncertainty and confidence in future projections from the climate models, which are important for regional hydro-climatological studies. This study proposes a new skill score for GCM’s based on the performance of the NS-GEV. The availability of computer tool provides an effective adaptation of research outcomes which are useful in decision making for policy makers/stakeholders by examining various alternate strategies, especially under climate change. In this project, a stand-alone interactive desktop tool will be developed for the implementation of the NS-GEV under climate change. The dissemination of the tool is carried out through documentation and workshop/training session. It is expected that the proposed project and its outcome will meet the needs of municipalities for the implementation of the existing knowledge and maximize its implementation.

Objectives :

- To develop a new framework for nonstationary IDF curves under climate change by integrating extreme precipitation and GCM outputs.
- To assess the skills scores of GCM outputs for nonstationary IDF curves.
- Development of an interactive desktop tool for the implementation of the nonstationary IDF curves.
- Dissemination of the tool by providing necessary training.

Keywords :
Non-stationary, IDF Curves, Global Circulation Model, Representative Concentration Pathways, Precipitation, Interactive Desktop Tool

Expected Output and Outcome of the proposal :

The proposed project will directly contribute to SMART CITIES MISSION by Government of India, for advancing the capabilities in decision making for policy makers/stakeholders (such as municipalities or water authorities or urban development planners). The project outcome will include: 1) The modified methodology for nonstationary IDF curves under climate change; 2) the interactive desktop tool for nonstationary IDF curves; 3) The technical documentation for the tool use; 4) Dissemination of tool implementation through the workshop or presentations, or training sessions; 5) Research publications in reputed international journals.

Technical Document

1. State of the Art

Background: Anthropogenic activities are one of the major factors resulting in the modification of global terrestrial temperature variability, which in turn leads to changes in global and local climatic conditions. The rise in global temperatures is expected to increase the water vapor content in the atmosphere, resulting in spatial-temporal variations of frequencies and magnitude of extreme precipitation events. An Intensity-Duration-Frequency (IDF) relationship of such extreme events plays a vital role in planning and design of water infrastructure such as storm sewer, culverts, spillways, etc, integrated watershed management and understanding the socio-economic impacts.

Nonstationary IDF Curves: Coles (2003) introduced a generalized statistical framework for non-stationary extremes by assuming the extreme value distribution as a function of time and other dependent variables (also known as covariates). Later several studies were carried out based on this approach addressing the parameter estimation method, a function representing the trends in parameters and selection of covariates (Adlouni et al., 2007; Yilmaz and Perera, 2013; Mondal and Mujumdar, 2015; Agilan and Umamahesh, 2018; Ouarda et al. 2019). The nonstationary IDF curves are developed based on the observed timelines and extended to future time periods. These studies are do not incorporate the modeling with respect to GCMs.

Skill scores for GCM: Recently studies indicate that the uncertainty arising due to GCM outputs is significant when compared to model/parameter uncertainties (Woldemeskel et al. 2012; Her 2019). Further, the regional-scale dynamics for each GCM is simulated differently in terms of feedback processes and hence not all the GCMs replicate the local conditions. In addition, the computational burden increases with the use of all the GCMs in hydroclimatic studies. Alternatively, skill scores for GCMs were proposed to reduce the uncertainty. These skill scores are adopted to rank the GCM models, which in turn assists the modeler to reduce the degree of uncertainty (Perkins et al. 2007; Gleckler et al. 2008; Yokoi et al. 2011).

Tools for IDF Curves

Sl. No.	Software	Year	Source	Limitation
1	NEVA	2014	Cheng et al. (2014)	Applicable only when time is a covariate
2	CAPRA	2018	Cardona et al. (2012)	Limited access and not compatible with all the operating systems. Assumption of stationarity.
3	IDF R Package	2017	Ritschel et al (2017)	Assumption of stationarity.
4	HydroCad	1986	HydroCAD Software Solutions LLC	Assumption of stationarity.
5	IDF CC tool_3	2018	Simonovic et al (2016)	Applicable only for Canada, Assumption of stationarity.
6	Storms 2010 V_3	2010	JFSA water resources and environmental consultants	Assumption of stationarity.

In summary, the current works lack in the following aspects:

1. There are limited studies implementing the non-stationary IDF curves under climate change.
2. The uncertainty due to the GCM outputs has to be quantified for decision making. The skill scores for the GCMs will improve the confidence in the model implementation.
3. Non-availability of free desktop tools for implementation of nonstationary IDF curves.
4. The lack of knowledge in implementation of latest advances in hydrologic models is a major drawback in municipalities.

2. Origin of the Proposal:

Most of the previous works have been devoted to the development of alternative methodologies to update the current IDF curves under changing climate scenarios, wherein the model parameters remain constant for future time periods. However, under climate change, the assumption of stationarity for parameters are not valid. Recent studies have focused on developing nonstationary IDF curves using nonstationary generalized extreme values distribution, wherein the parameters of the distribution vary with time. However, these are limited to the variation of parameters with respect to time or attributes related to teleconnections or local physical conditions. Further few studies have been carried out in the implementation of IDF curves under climate change and verifying the same through various municipalities. This has led the investigator to explore the following opportunity in the proposed project

- There is a prospect to develop a new framework for non-stationary IDF curves using GCM models
- Identify or rank the GCM outputs to improve the confidence of the IDF curves for implementation.
- Most of the municipalities in India are yet to implement the use of updated IDF curves that incorporate climate change.
- The municipalities do not have enough expertise to develop the updated IDF curves under climate change.
- There is a need for an interactive computer tool that will help the decision makers to update the IDF curves.

This has inspired the investigator to (i) develop a new framework for nonstationary IDF curves under climate change; (ii) reduce the uncertainty associated with GCM outputs. The lack of computer tools for the municipalities in modelling of non-stationary IDF curves has also motivated the investigator to develop an interactive desktop tool. Moreover, it is envisaged that necessary training is to be provided to increase the expertise in the municipalities and proper implementation of the tool.

3. Research Plan

The project outcomes will include:

- The modified methodology for IDF update under climate change
- The computerized tool for IDF update
- The technical documentation for the tool use
- The training of sessions
- The feedback collection.

Updating the IDF curve

The details for updating the IDF curve is presented in Figure 1. The modelling framework of nonstationary IDF curves is classified into two major components:

1. Developing nonstationary generalized IDF curves using historical observed precipitation and GCM output.
2. Ranking of GCM outputs to identify the class of models relevant to observed data.
3. Generating the updated ensemble IDF curves for relevant future time-periods and accessing the changes in the extreme precipitation.

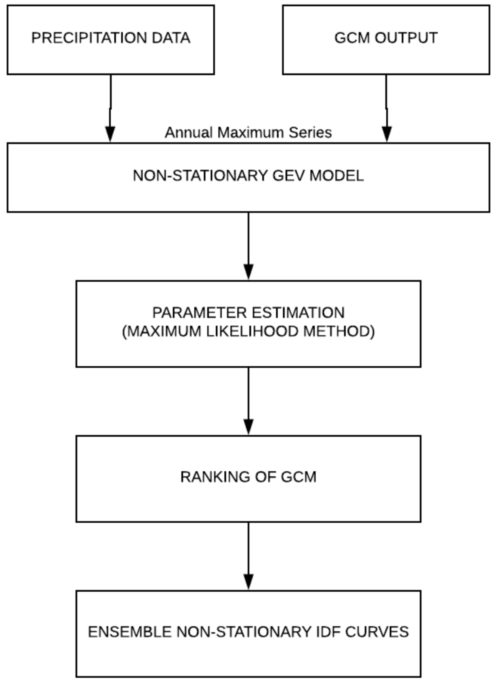

Figure 1: The flowchart for developing nonstationary IDF curves under climate change

Stand-alone Interactive Desktop Tool

The computerized tool for IDF curves update is intended to assist the user in the development of IDF curves that will capture the changes in the precipitation regime caused by climate change. The major components of the computerized tool are shown in Figure 2 and include:

1. User Interface: User data, data management tools, selection of mathematical tools, and output tools for plotting and saving the results.
2. Models: statistical data analysis, nonstationary IDF curves model, a ranking of GCM models
3. Output: statistical inferences, plots, and saving of results in various formats.

The standalone interactive desktop tool will avoid the need for internet or cloud storage unlike the web-based tools, easy to maintain in local machines as well as over any incompatibilities for the user with different computer operating systems. The tool will also include all the basic statistical analysis on station data and generate updated IDF curves under climate change.

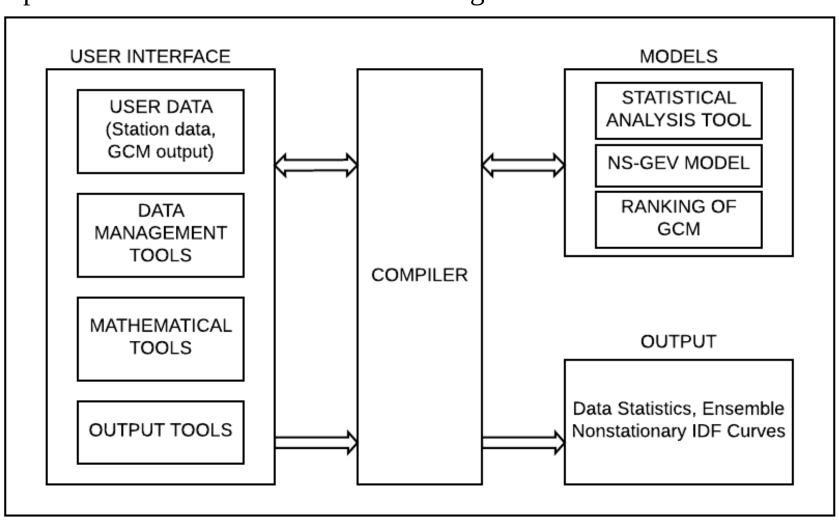

Figure 2: The standalone Interactive Desktop Tool for Generation of IDF curves

Documentation and Workshop/Training Session

The Interactive Desktop tool contains help manuals for execution and detail explanation about the methods employed. Further, it is envisaged that for better implementation of the proposed desktop tool and training of water authorities a workshop/training session will be organized. The workshop will provide hands-on training for the end-users. The training sessions will also be useful in having a feedback session for its usability and improvements.

Activities

The project implementation time is planned to be 24 months. The project research plan presented below is proposed to maximize the knowledge implementation and use and provide feedback to the investigator. It is expected that by the project completion time the first draft version of the tool will be tested and verified, the final version of the tool and documentation will be completed, the training sessions will be organized, and the feedback from the tool use will be obtained from the selected municipalities analyzed for potential future tool improvement.

Project research plan and milestones:

1. Project start	starting day X
2. Completion of the methodology	X + 6 months
3. Milestone 1 – submission of methodology paper for possible publication	X + 6 months
4. Completion of the system database	X + 9 months
5. Completion of the model base and user interface	X + 15 months
6. Milestone 2 – submission of the tool paper for possible publication	X + 15 months
7. Testing the system using data from the cities	X + 18 months
9. Milestone 3 – desktop tool launch of the system	X + 18 months
11. Preparation of the system documentation	X + 21 months
12. Milestone 4 – posting of the system documentation	X + 21 months
14. Workshop/Traning sessions	X + 22 months
15. Milestone 5 – Submission of project report	X + 24 months

4. Key publications of the Investigator during the last 5 years

1) Bhatia, N., Srivastav, R., & Srinivasan, K. (2018). Season-dependent hedging policies for reservoir operation-a comparison study. *Water (Switzerland)*, *10*(10), 1–17.
2) Irwin, S., Srivastav, R. K., Simonovic, S. P., & Burn, D. H. (2016). *Delineation of Precipitation Regions using Location and Atmospheric Variables : The role of Attribute selection. Hydrological Sciences Journal, 62(2), 191-204*.
3) Srivastav, R., Srinivasan, K., & Sudheer, K. P. (2016). Simulation-optimization framework for multi-site multi-season hybrid stochastic streamflow modeling. *Journal of Hydrology*, *542*. https://doi.org/10.1016/j.jhydrol.2016.09.025
4) Sandink, D., Simonovic, S. P., Schardong, A., & Srivastav, R. (2016). A decision support system for updating and incorporating climate change impacts into rainfall intensity-duration-frequency curves: Review of the stakeholder involvement process. *Environmental Modelling and Software*, *84*. https://doi.org/10.1016/j.envsoft.2016.06.012
5) Simonovic, S. P., Schardong, A., Sandink, D., & Srivastav, R. (2016). A web-based tool for the development of Intensity Duration Frequency curves under changing climate. *Environmental Modelling & Software*, *81*, 136–153.
6) Mandal, S., Srivastav, R. K., & Simonovic, S. P. (2016). Use of beta regression for statistical downscaling of precipitation in the Campbell River basin, British Columbia, Canada. *Journal of Hydrology*, *538*. https://doi.org/10.1016/j.jhydrol.2016.04.009
7) Srivastav, R. K., & Simonovic, S. P. (2015). Multi-site, multivariate weather generator using maximum entropy bootstrap. *Climate Dynamics*, *44*(11–12). https://doi.org/10.1007/s00382-014-2157-x

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5. Bibliography

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Cardona O.D. et al., (2012). CAPRA – Comprehensive Approach to Probabilistic Risk Assessment: International Initiative for Risk Management Effectiveness, 15 WCEE, Lisboa.

Coles, S. (2001). An introduction to statistical modeling of extreme values, Springer, London.

Gleckler PJ, Taylor KE, Doutriaux C (2008) Performance metrics for climate models. J. Geophys. Res., 113, D06104, doi:10.1029/2007JD008972

Her, Y., Yoo, S.-H., Cho, J., Hwang, S., Jeong, J., & Seong, C. (2019). Uncertainty in hydrological analysis of climate change: multi-parameter vs. multi-GCM ensemble predictions. *Scientific Reports*, *9*(1), 4974. https://doi.org/10.1038/s41598-019-41334-7

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Ritschel Christoph, Carola Detring, Sarah Joedicke (2017). Estimation and Plotting of IDF curves, R Package IDF. Version 1.1.

Woldemeskel FM, Sharma A, Sivakumar B, Mehrotra R (2012). An error estimation method for precipitation and temperature projections for future climates. Journal of Geophysical Research-Atmospheres, 117, D22104, doi:10.1029/2012JD018062

Yilmaz, A. G., Perera, B. J. C. (2013). Extreme Rainfall Nonstationarity Investigation and Intensity–Frequency–Duration Relationship. Journal of Hydrologic Engineering, 19(6), 1160–1172. https://doi.org/10.1061/(ASCE)he.1943-5584.0000878

Yokoi S et al. (2011) Application of Cluster Analysis to Climate Model Performance Metrics. Journal of Applied Meteorology and Climatology, 50, 1666-1675

6. Equipment available with the Institute/ Group/ Department/Other Institutesfor the project

Equipment available	Generic Name of Equipment	Model, Make & year of purchase	Remarks including accessories available and current usage of equipment
PI & his group	All-in-One	Dell AIO, 2017	The equipment is low powered used for non-computational purposes and mostly for official documentation, digital classroom tools, and internet
PI's department	Not applicable	Not applicable	Not applicable
Other Institute(s) in the region	Not applicable	Not applicable	Not applicable

Budget Details

Institution wise Budget Breakup :

Budget Head	Indian Institute of Technology Tirupati	Total
Consumables	1,00,000	**1,00,000**
Travel	1,00,000	**1,00,000**
Equipment	11,73,000	**11,73,000**
Contingencies	1,00,000	**1,00,000**
Overhead	1,49,000	**1,49,000**
SSR Budget	25,000	**25,000**
Total	**16,47,000**	**16,47,000**

Institute Name : *Indian Institute of Technology Tirupati*

Year Wise Budget Summary (Amount in INR) :

Budget Head	Year-1	Year-2	Total
Consumables	50,000	50,000	**1,00,000**
Travel	50,000	50,000	**1,00,000**
Equipments	11,73,000	0	**11,73,000**
Contingencies	50,000	50,000	**1,00,000**
Overhead	74,500	74,500	**1,49,000**
SSR Budget	25,000	0	**25,000**
Grand Total	**14,22,500**	**2,24,500**	**16,47,000**

Consumable Budget Detail (Amount in INR) :

Justification	Year-1	Year-2	Total
Since the nature of the project is data intensive, it requires: data transfer devices such as hard drives and pen drives in addition to regular requirements such as printer toners, paper, stationery	50,000	50,000	**1,00,000**

Travel Budget Detail (Amount in INR) :

Justification (Inland Travel)	Year-1	Year-2	Total
A few trips are envisaged to discuss the problem with the experts working in this area and attending conferences/symposium for the dissemination of the result.	50,000	50,000	**1,00,000**

Equipment Budget Detail (Amount in INR) :

Generic Name ,Model No. , (Make)/ Justification	Quantity	Spare time	Estimated Cost
Workstation (CPU only) Precision 7920 (Dell) *This project will require extensive computational modeling, maintenance of large data and data analysis. In this regard, it is requested for workstation DELL Precision 7820 (which is mid-range robust workstation) sufficient for executing the current project. Currently, the PI doesn't have any explicit computational facility to carry out the modeling exercise. Note: the workstation doesn't come with a monitor, keyboard, mouse, operating system (default DOS) and basic documenting software.*	1	100 %	**6,00,000**
Uninterrupted Power Supply (UPS) APC UPS Br1000g (APC) *The workstation, NAS storage, and data logger require an uninterrupted power supply to avoid any damages caused due to power fluctuations and avoid malfunctioning of hard drives. Frequent power cuts and fluctuations in voltage are expected at the temporary campus of IIT Tirupati. This could lead to loss of both the data and the equipment. Hence it is requested to have a UPS for the equipment.*	1	0 %	**19,000**
Data Logger XPS 13(9380) (DELL) *The project requires the use of data logger with NAS storage for frequent monitoring the NAS data, field data collection, ability to carry out the simulations and modeling for presentations to expert, and in conferences, conducting workshop training programs, and meetings for the demonstration of the proposed desktop tool.*	1	100 %	**2,00,000**
Monitor P2719H (Dell) *The workstation budget presented in the equipment list doesn't include the monitor. The project requires the simultaneous use of multiple windows for tool development, simulation, plotting of large-scale statistics and for other official works. Dual monitor setup essentially helps to get the work faster and efficiently. The two screens are certainly required to help and efficiently manage simultaneous development of tool on one screen and carrying out the research and official work on another*	1	100 %	**30,000**
Network Attached Storage Expandable 20TB (Seagate/NetGear/HP) *The project involves extensive use of General Circulation Model (GCM) output from various institutes across the globe. The data output files for each model and the hydroclimatic variable is large in size (1 to 1.5 GB per file) and contains a number of files (25 to 40 for each GCM realizations and future scenarios RCPs). The storage capacity of the proposed workstation will be not enough to process the entire data and hence it is requested for NAS storage to develop the interactive desktop tool.*	1	100 %	**3,00,000**
Printer M1005 (HP) *The project requires frequent printing of project results for manual inspection (also discussion with experts), printing for workshop/training materials, technical materials, journal papers, and project reports.*	1	50 %	**24,000**

Contingency Budget Detail (Amount in INR) :

Justification	Year-1	Year-2	Total
For maintenance of equipment purchased for this project and conference registration fees, a contingency of Rs. 50000 is budgeted every year.	50,000	50,000	**1,00,000**

Overhead Budget Detail (Amount in INR) :

Justification	Year-1	Year-2	Total
Institutional overhead charges are necessary to part-finance the basic infrastructure such as office space including furniture, electricity and other utilities, computing facilities, internet facility, library, secretarial support, accounting staff, etc required for carrying the project work envisaged.	74,500	74,500	**1,49,000**

SSR Budget Detail (Amount in INR) :

Category/Justification	Year-1	Year-2	Total
Workshop to faculty of other colleges	25,000	0	**25,000**

PROFORMA FOR BIO-DATA

1. Name and full correspondence address

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+91-9750447774
+91-877-2503165

3. Institution
Indian Institute of Technology Tirupati

4. Date of Birth
January 9, 1979

5. Gender (M/F/T)
Male

6. Category Gen/SC/ST/OBC
General

7. Whether differently abled (Yes/No)
No

8. Academic Qualification (Undergraduate Onwards)

	Degree	Year	Subject	University/Institution	% of marks
1.	Bachelor of Engineering	2002	Civil Engineering	University College of Engineering, Hyderabad, Osmania University	74.25%
2.	Master of Technology	2004	Water Resources Management	Motilal Nehru National Institute of Technology, Allahabad	10.00 (CGPI)
3.	Ph.D.	2011	Water Resources Engineering	Indian Institute of Technology Madras	

9. Ph.D thesis title, Guide's Name, Institute/Organization/University, Year of Award.
Ph.D. thesis title: Simulation-Optimization Framework for Hybrid Stochastic Streamflow Modeling
Guides: Dr. K. Srinivasan and Dr. K.P. Sudheer
Institute: Indian Institute of Technology Madras
Year: 2011

10. Work experience (in chronological order).

S.No.	Positions held	Name of the Institute	From	To	Pay Scale
1	Assistant Professor (Temporary)	VIT University	February 2010	July 2011	Basic Rs. 23500.00
2	Associate Professor (Temporary)	VIT University	August 2011	January 2013	Basic Rs. 31,500.00
3	Post Doctoral Fellow	Western University, Canada	February 2013	March 2015	$42000 per annum
4	Associate Professor (Temporary)	VIT University	April 2015	June 2018	Basic: Rs 38,500.00
5.	Assistant Professor	Indian Institute of Technology Tirupati	June 2018	Till date	Basic: Rs 1,35,000 (13A1, Cell 2)

11. Professional Recognition/ Award/ Prize/ Certificate, Fellowship received by the applicant.

S.No	Name of Award	Awarding Agency	Year
1	MITACS Accelerate Fellowship	MITACS, Canada	2013
2	Berkner Fellow	American Geophysical Union, USA	2009
3	Institutional Silver Medal	MNNIT Allahabad	2004
4	PhD Fellowship	MHRD	2004
5.	Graduate Fellowship	MHRD	2002

12. Publications *(List of papers published in SCI Journals, in year wise descending order).*

S.No.	Author(s)	Title	Name of Journal	Volume	Page	Year
1	N Bhatia, R Srivastav, K. Srinivasan	Season-Dependent Hedging Policies for Reservoir Operation—A Comparison Study	Water	10	17	2018
2	S Irwin, R Srivastav, S Simonovic, DH Burn	Delineation of precipitation regions using location and atmospheric variables in two Canadian climate regions: the role of attribute selection	Hydrological Sciences Journal	62	191	2017
3	R Srivastav, K Srinivasan, KP Sudheer	Simulation-optimization framework for multi-site multi-season hybrid stochastic streamflow modeling	Journal of Hydrology	542	506	2016
4	D Sandink, SP Simonovic, A Schardong, R Srivastav	A decision support system for updating and incorporating climate change impacts into rainfall intensity-duration-frequency curves: Review of the stakeholder involvement process	Environmental modelling & software	84	193	2016
5	S Mandal, RK	Use of beta regression for	Journal of	538	49	2016

	Srivastav, SP Simonovic	statistical downscaling of precipitation in the Campbell River basin, British Columbia, Canada	Hydrology			
6	SP Simonovic, A Schardong, D Sandink, R Srivastav	A web-based tool for the development of intensity duration frequency curves under changing climate	Environmental modelling & software	81	136	2016
7	RK Srivastav, SP Simonovic	Multi-site, multivariate weather generator using maximum entropy bootstrap	Climate Dynamics	44	3431	2015
8	RK Srivastav, A Schardong, SP Simonovic	Equidistance quantile matching method for updating IDFCurves under climate change	Water resources management	28	2539	2014
9	RK Srivastav, SP Simonovic	An analytical procedure for multi-site, multi-season streamflow generation using maximum entropy bootstrapping	Envrionmental Modelling & Software	59	59	2014
10	RK Srivastav, K Srinivasan, KP Sudheer	Multi-site, multivariate weather generator using maximum entropy bootstrap	Journal of hydrology	404	209	2011
11	RK Srivastav, KP Sudheer, I Chaubey	A simplified approach to quantifying predictive and parametric uncertainty in artificial neural network hydrologic models	Water Resources Research	43	5352	2007

13. Detail of patents.

S.No	Patent Title	Name of Applicant(s)	Patent No.	Award Date	Agency/Country	Status

14. Books/Reports/Chapters/General articles etc.

S.No	Title	Author's Name	Publisher	Year of Publication
1	Instructions for Operating the Proposed Regionalization Tool "Cluster-FCM" Using Fuzzy C-Means Clustering and L-Moment Statistics ISBN: (print) 978-0-7714-3101-2	Sarah Irwin, Roshan K. Srivastav and Slobodan P. Simonovic	Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada	2015
2	Simulation of Dynamic Resilience: A Railway Case	**Roshan K. Srivastav** and Slobodan P. Simonovic	Facility for Intelligent Decision Support,	2014

	Study. ISBN: (print) 978-0-7714-3089-3		Department of Civil and Environmental Engineering, London, Ontario, Canada	
3	Computerized Tool for the Development of Intensity-Duration-Frequency Curves under a Changing Climate: Technical Manual v.1 ISBN: (print) 978-0-7714-3087-9	**Roshan K. Srivastav**, Andre Schardong and Slobodan P. Simonovic	Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada	2014
4	Computerized Tool for the Development of Intensity-Duration-Frequency Curves under a Changing Climate: Users Manual ISBN: (print) 978-0-7714-3085-5	Andre Schardong, **Roshan K. Srivastav** and Slobodan P. Simonovic	Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada	2014
5	Instruction for Watershed Delineation in an ArcGIS Environment for Regionalization Studies. ISBN: (print) 978-0-7714-3071-8	Sarah Irwin, **Roshan K. Srivastav** and Slobodan P. Simonovic	Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada	2014
6	Generic Framework for Computation of Spatial Dynamic Resilience ISBN: (print) 978-0-7714-3067-1	**Roshan K. Srivastav** and Slobodan P. Simonovic	Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada	2014

15. Any other Information (maximum 500 words)

Certificate from the investigator

Project Title:

Interactive Desktop Tool for Nonstationary Intensity-Duration-Frequency Curves under Climate Change

It is certified that

1. The same project proposal has not been submitted elsewhere for financial support.

2. I undertake that spare time on equipment procured in the project will be made available to other users.

3. I agree to submit a certificate from institutional Biosafety Committee, if the project involves the utilization of genetically engineered organisms. I also declare that while conducting experiments, the Biosafety Guidelines of Department of Biotechnology, Department of Health Research, GOI would be followed in toto.

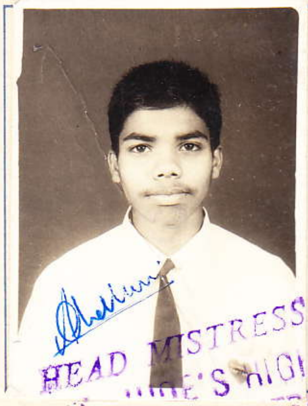
4. I agree to submit ethical clearance certificate from the concerned ethical committee, if the project involves field trails/experiments/exchange of specimens, human & animal materials etc.

5. The research work proposed in the scheme/project does not in any way duplicate the work already done or being carried out elsewhere on the subject.

6. I agree to abide by the terms and conditions of SERB grant.

(Roshan Karan Srivastav)
Name and signature of Principal Investigator:
Date: April 25, 2019
Place: Tirupati

BOARD OF SECONDARY EDUCATION
ANDHRA PRADESH



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सत्यमेव जयते

SECONDARY SCHOOL CERTIFICATE

PC/04/0020920/3

HEAD MISTRESS
ST. JUDE'S HIGH SCHOOL
MOULALI, HYDERABAD-40

Certified that ROSHAN KARAN SRIVASTAV bearing

R.No. 0056895 Son/XXXXXXX of INDER KARAN SRIVASTAV

and belonging to ST JUDE'S H S MOULALI appeared

at the SSC EXAMINATION held in MARCH 1994. and PASSED the EXAMINATION in

FIRST division with ENGLISH as the medium of instruction.

The Date of Birth of the Candidate is

DATE OF BIRTH	DAY		MONTH	YEAR			
09/01/1979	ZERO	NINE	JAN	ONE	NINE	SEVEN	NINE

The Candidate Secured the following Percentage of marks

FIRST LANG.	MARKS	THIRD LANG.	MARKS	MATHEMATICS	MARKS
HINDI	72	ENGLISH	63	MATHEMATICS	81
GENERAL SCIENCE	63	SOCIAL STUDIES	54	TOTAL (in figures)	333

TOTAL (in words) * THREE HUNDRED AND THIRTY THREE *

SECOND LANGUAGE (ENGLISH * SEVENTY THREE *) 73

Marks of Identification
1. A mole on the left cheek
2. A mole on the left hand.

Head of Institution

HEAD MISTRESS
ST. JUDE'S H. SCHOOL
MOULALI, HYDERABAD-40

Date of Issue 05/1994

HYDERABAD

SECRETARY
BOARD OF SECONDARY EDUCATION

Any corrections in the Certificate will not be entertained after three years from the date of issue.

Any corrections in the Certificate will not be entertained after three years from the date of issue

भारतीय प्रौद्योगिकी संस्थान तिरुपति
TIRUPATI

INDIAN INSTITUTE OF TECHNOLOGY TIRUPATI
भारतीय प्रौद्योगिकी संस्थान तिरुपति
Renigunta Road, Settipalli Post, Chittoor District, Tirupati - 517506

Endorsement Certificate from the Host Institute

This is to certify that:

I. The applicant **Dr. Roshan Karan Srivastav** is working as **Assistant Professor** in this Institute. He joined the institution on **27 June 2018**. We endorse his participation in the Project titled: **Interactive Desktop Tool for Nonstationary Intensity-Duration-Frequency Curves under Climate Change**.

II. The applicant is in regular position as defined by the term "Regular" in SRG guidelines.

III. The applicant will assume full responsibility for implementing the project as Principal Investigator.

IV. The date of start of project is on the day when the Institution receives the first release of grant by RTGS transfer.

V. The grant-in-aid by the Science & Engineering Research Board (SERB) will be used to meet the expenditure on the project and for the period for which the project has been sanctioned as indicated in the sanction letter/ order.

VI. No administrative or other liability will be attached to the Science & Engineering Research Board (SERB) at the end of the Research Award.

VII. The Institution will provide basic infrastructure and other required facilities to the investigator for undertaking the research objectives.

VIII. The Institution will take into its books all assets received under this sanction and its disposal would be at the discretion of Science & Engineering Research Board (SERB).

IX. The Institution will assume to undertake the financial and other management responsibilities of the project.

X. The Institution shall settle the financial accounts to the SERB as per the prescribed guidelines within three months from the date of termination of the Research Award.

Dated: 29-04-2019

Signature of the Head of Institution

Seal of Institution

Dr. Pranawa C. Deshmukh
Professor of Physics
Dean, Sponsored Research & Consultancy
Indian Institute of Technology Tirupati