Dynamic Downscaling to Study Climate Change Impacts on Water Resources in India

under

National Water Mission

Proposal

Submitted to

Ministry of Water Resources, New Delhi

By consortium of:

IIT Delhi
IIT Madras
Anna University, Chennai
Banaras Hindu University, Banaras

Centre for Atmospheric Sciences
Indian Institute of Technology Delhi
Hauz Khas, New Delhi - 110 016

October 2015

Proforma of Application for Research Grants

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4. Brief Bio-data of the Investigators

Please see Appendix 1.

5. Project Title (keep it as short as possible)

Dynamic Downscaling to Study Climate Change Impacts on Water Resources

6. Track Record and Workload Assessment of the PI

List all the research and consultancy schemes, whether funded by MoWR or any other agency, in which the present PI is/was Principal Investigator, in following groups.

a. Schemes completed

b. Schemes foreclosed with reasons for foreclosure

c. Schemes ongoing

Please see Appendix 2.

7. If the scheme is sanctioned, in whose name the cheque is to be issued. (write precise title of the account)

Registrar, Indian Institute of Technology Delhi

8. Category of R&D activity (Tick those which are applicable)

a. Basic Research

b. Applied Research √

c. Action Research
d. Education & Training √
e. Mass Awareness Programme
f. Infrastructure Development √
g. Creation of Centres of Excellence

9. Description of the Proposal

(Describe the research proposal, the background, how the idea originated etc.)

This proposal originates from the Indian National Committee on Climate Change (INCCC, the R&D Programme of Ministry of Water Resources) request for proposals for Dynamic downscaling with IIT Delhi as lead institution. The dynamical downscaling approach is being proposed with the intention of providing an alternate to statistical downscaling as a means for getting high resolution climate information for the future that are required by the impact studies.

Climate change has been shown to be ocurring as a result of human activities (IPCC 2014) and is expected to impact the hydrological cycle. Coupled Atmosphere-Ocean-Sea-ice General Circulation Model (AOGCM) simulations indicate that the hydrological cycle will strengthen in the future under various emission scenarios. Understanding implications of projected climate change on the impact of these changes especially as they relate to water resources is essential to devise better strategies for management and conservation of vulnerable water resources.

Projections of future climate change involve computer numerical simulations of various scenarios of future climate. This requires the use of Coupled Atmosphere-Ocean General Circulation Models (AOGCMs or CGCMs) that can only be run on powerful supercomputers. While the increasing computing power has made these simulations easier to perform, most AOGCMs used to produce climate change projections (e.g. for the CMIP3 ensemble, Meehl et al., 2007) are still run at horizontal resolutions of ~250 km, which is too coarse to produce fine-scale climate change information for use in most impact assessment studies. This resolution also precludes the accurate simulation of extreme weather events, which is fundamental to assess many impacts of climate change.

The evolution of modeling has been partially constrained by the availability of computing power. The CGCMs that are in use today to simulate climate typically employ grid cells bigger than 100kmx100km on the side. This is an improvement from the previous generation of climate models that were of much coarser resolution (> 250km x 250km). Computing power is the main bottleneck in our ability to model the climate at higher resolutions. The climate models of today have reasonable skill at continental and larger spatial scales – typically thousands of square kilometers. When one comes to relatively smaller (watershed/at-site) scale that is of interest to hydrologists for modeling hydrological processes in a river basin, the skill of the models is quite poor since these models do not resolve the fine scale features of land-surface processes and orography.

In order to get around the lack of climate projections at the finer scales of interest to hydrologists, downscaling methodologies have been developed that take the coarse resolution CGCM outputs from simulations of future climate and increase the resolution of the simulated variables. The two main approaches to this are dynamic and statistical downscaling. Statistical downscaling utilizes the observed statistical relationships between observed and modeled climate variables in the recent past to provide fine-scale information for the future. The primary criticism of the statistical downscaling approach is that it presumes the statistical relationships at various spatial and temporal scales to be unchanging under climate change. Therefore, since the late 1980s and early 1990s, different "regionalization" techniques have been developed to spatially refine the information produced by AOGCMs and provide data usable for impact assessment studies (Giorgi et al., 2001). These strategies are described in more detail below.

Nested Regional Climate Model

Dynamical high resolution Regional Climate Models (RCMs) have been nested into global models and forced at their lateral boundaries by AOGCMs (Giorgi and Mearns, 1991, Giorgi and Mearns, 1999). This is becoming an increasingly popular technique for carrying out regional climate studies. These regional models have the advantage that affordable very high-resolution simulations can be performed for a certain region of interest for a particular time, but have the disadvantage that they encounter severe problems at the boundaries. The simulations tend to be sensitive to the nesting levels as well as location (Giorgi, F., and M.R. Marinucci, 1991). The other problem is that they are currently coupled only one way, i.e. the global model drives the regional model but an interaction of the regional scale with the global scale is not possible.

Variable resolution AOGCMs

The Variable resolution AOGCM (VarGCM) or "stretched grid" approach consists of running a global model with gradually increasing horizontal resolution towards a given region of interest (e.g. Deque and Piedelievre, 1995). These models are therefore simulating some areas of the globe at coarse resolution while simulating the domain of our interest at very high resolution. A problem that arises with such models is that the physical parameterizations used by such GCMs need to operate at a wide range of spatial scales, which, in some cases, may break the limits of the applicability of the schemes. Today, several VarGCMs are available for climate simulation at refined regional resolutions reaching a few tens of kilometers and a VarGCM intercomparison project has recently been initiated (Fox-Rabinowitz et al., 2006).

Time-slice Technique

A time-slice experiment involves model simulation of two slices of time, one for the present and one for the future (Cubasch et al., 1995; U. Cubasch, J. Waszkewitz, G. Hegerl and J. Perlwitz ,1995). The boundary conditions for sea surface and ice for the historical run are based on observational data, and boundary conditions for the scenario run are derived by perturbing the same observed sea-surface temperature and ice data by an amount based on the results of a lower-resolution run of the full AOGCM. The time-slice technique is useful because this method can give satisfactory answers to most of the problems of the previous methods and can be run at high resolution (Giorgi et al., 2001). The main advantages of time-slice technique are:

i. The atmospheric component of an AOGCM is run without the full-coupled ocean component of the model. Because the ocean model is omitted, the computational requirements of the simulation are much lower.
ii. Because AGCM is running in standalone it can be run at higher resolutions. In fact, recent AGCM time-slice experiments have been run at resolutions of a few tens of kilometers, clearly showing an improvement in the model performance with increasing resolution.

Given the multiplicity of approaches - each valid in its own right - there remains an element of choice based on convenience and resource availability. As long as high resolution AOGCMs remain computationally expensive, one of the downscaling methods will have to be adopted. The reliability of these downscaling methods over the Indian domain as well as the additional uncertainty introduced by the models are topics of current research.

10. Objectives (Classify the objectives of proposed research under one or more of following and explain the objectives briefly)

The objectives of the proposed project are as follows:

(i) *The primary objective of the proposed project is to produce the downscaled climate data (at less than 50km) under future scenarios to carry out river basin impact studies*. These are specifically to enable the studies that will carry out impact assessments on river basin scales.

(ii) *A second objective is to build capacity within the country to carry out dynamical downscaling.* There are quite a few institutions where expertise exists to carry out dynamical downscaling but that are either hampered by lack of resources or by not having end users for the downscaled output to be readily utilized.

(iii) *The third objective is to train manpower in the country to be able to perform dynamical downscaling as well as make use of downscaled output.* Recent years have seen both an increase in computing power available at reasonable costs as well as easy availability of models to carry out mesoscale studies as well as regional climate studies. However, the quality and quantity of available manpower has not kept pace. There is an urgent need to train manpower and educate end-users at various levels. For this purpose, workshops will be conducted.

11. Contribution to Water Resources Department

(Describe very briefly the contribution envisaged to be made by the proposed R&D activity to the Water Resources Sector)

The proposal originates from the INCCC's (R&D programme of the Ministry of Water Resources in support of the National Water Mission under Government of India's NAPCC) request to submit proposals to carry out Dynamic Downscaling with IIT Delhi as the lead institute. The proposed work will be critical for carrying out the impact studies at the basin scale as envisaged under the National Water Mission.

12. Putting the Research to Use

a. Identify the possible end-users for the results of proposed research.

b. List the actions that will be necessary to put the results to use.

c. List the difficulties/problems that may be encountered in putting the results to use.

d. Are the possible end users being involved in the research ? If yes then describe how, if not then explain why not.

a) The primary goal of the proposed project is to produce the dynamically downscaled climate data for future scenarios to carry out the river basin impact studies that are funded under the same request for proposals in TOR 2. This project will also benefit impact studies in hydrology and other sectors that may be carried out at a later date.

b) There will have to be a concerted effort made to publicise and make the data available to researchers. This needs to be done both in terms of having data servers and network from which to distribute the data but also in educating end users on how to use and interpret the data.
c) The difficulties that may be encountered in using the results are in terms of understanding and accounting for the limitations of the AOGCM simulations that are being downscaled and the added layer of uncertainty that the downscaling model introduces.
d) The partner institutions are actively involving hydrologists in the research both in order to provide better understanding of the model output and also to gauge the requirements of the end users.

13. Present State of Art

a. Describe the work that has already been done at International Level

b. Describe the work that has already been done at National Level

c. Explain how the work proposed to be done by you will be different from the work already done by others at National and International levels.

d. List the references examined by you to reply to a) and c) above

(a) International Status

The climate change impact assessment on water resources requires the downscaling of the precipitation and other variables such as temperature, relative humidity, solar radiation, wind direction and wind speed from the global scale to the regional scale. The downscaling efforts internationally make use of all three techniques described previously namely; nested RCMs, variable resolution AOGCMs and time-slice methods. The models required for such downscaling efforts are developed by groups outside India and are typically by the same modelling groups that develop the AOGCMs used to simulate future climate. There are efforts internationally to perform coordinated downscaling experiments such as CORDEX (Giorgi et al 2008) that systematically examine the effects of downscaling by using a suite of RCMs and AOGCM data. This is being performed over numerous pre-defined domains representing the major continental regions of the world.

(b) Work done at the National Level

The CORDEX experiment also covers the South Asian domain for which simulations are being performed in IIT Delhi as well as at IITM Pune. Previously, the dynamic downscaling efforts to inform impact studies over India have been carried out at the IITM Pune using the UK Met Office Hadley Centre's PRECIS regional model (Rupakumar & Krishnakumar). These have been useful for the NATCOM process. However, the current generation of AOGCM simulations are not being downscaled using the PRECIS but with the LMDZ variable resolution AGCM at IITM Pune and the RegCM4 at IIT Delhi.

(c) Importance of proposed work

The proposed work is crucial to enable the climate change impact studies in different river basins envisaged under the National Water Mission. As previously described, the shortcomings of statistical downscaling methods resulting from the assumption of stationarity can only be avoided by the dynamical downscaling approach. This project will deliver dynamically downscaled output at less than 50km resolution for the entire country. In addition to providing such output from a range of approaches from time-slice to RCMs, the project will give an understanding of which approach / model will give the best results for Indian conditions. This will help in planning for future impact studies.

Another important outcome of this project will be in building the capacity of multiple groups within the country to perform downscaling. This is a vital need that will help produce not only the required climate model output but will encourage further impact studies and collaborations between atmospheric scientists/modellers and hydrologists/impacts communities. These institutions will also be performing the manpower training that will build critical mass of researchers required by the country.

(d) References

- Coppola, E., and Giorgi F., 2005, Climate change in tropical regions from high-resolution time-slice AGCM experiments. Q. J. R. Meteorol. Soc., 131, pp. 3123–3145
- Cubasch, U., J. Waszkewitz, G. Hegerl and J. Perlwitz, 1995, Regional climate changes as simulated in time-slice experiments, Climatic Change, 31, 273-304.
- Giorgi, F., and L.O. Mearns, 1991, Approaches to regional climate change simulation: A review, Rev. of Geophys., 29, 191-216.
- Giorgi, F., and M.R. Marinucci, 1991, Validation of a regional atmospheric model over Europe: Sensitivity of wintertime and summertime simulations to selected physics parameterizations and lower boundary conditions, Quart. J. Roy. Meteorol. Soc., 117, 1171-1206.
- Giorgi, F., and L. O. Mearns, 1999, Introduction to special section: Regional climate modeling revisited, J. Geophys. Res., 104, 6335-6352.
- Giorgi, F., et al, 2001, Regional climate information – Evaluation and projections. In: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 583–638.
- Giorgi, F., *et al.* (2008), The Regional Climate Change Hyper-Matrix Framework, Eos Trans. AGU, 89(45), 445–446, *doi:*10.1029/2008EO450001.
- IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
- Wilby, R.L., Wigley, T.M.L., 1997. Downscaling general circulation model output: A review of methods and limitations. Progress in Physical Geography 21, 530–548.

14. Methodology

(Describe clearly the experiment; observations and data collection; and analysis)

To achieve the above objectives, the following methodology is proposed for the present study:

- Time-slice technique
- Nested Regional Models (RCMs)

The multiple approaches (in addition to the statistical downscaling being carried out with IIT Bombay's coordination) will provide us with a true representation of the uncertainties in regional climate change. These approaches to dynamical downscaling along with the particulars of models and scenarios chosen are described in greater detail below. Table 1 summarizes the different models, scenarios, resolutions and domains chosen for downscaling by the various groups.

14.1 Time-Slice Approach

As described previously, the approach of using an AGCM in time-slice mode involved running an global atmospheric model with boundary conditions given by the AOGCM simulation of future scenario. This has the advantage of not being constrained by imposing artificial boundaries for the domain which can affect the simulation. A time-slice experiment involves model simulation of two slices of time, one for the present and one for the future (Cubasch et al., 1995). The boundary conditions for the present period run are based on observational data, and boundary conditions for the future period run are derived by perturbing the same observed sea-surface temperature and sea-ice data by an amount based on the results of a lower-resolution run of a fully coupled AOGCM. The main conceptual assumption underlying the use of time-slice AGCMs is that the SST and sea-ice concentration forcing obtained from the AOGCM is consistent with the climatology of the high-resolution AGCM. Since this may not always be the case, such inconsistencies should be evaluated in the analysis of the results. The main advantage of time-slice AGCMs is their global coverage and their ability to simulate teleconnection patterns across remote regions. However, time-slice AGCMs are the most expensive of the regionalization tools and need to be run on large computing platforms in order to achieve high resolution.

In order to have a baseline for estimating the future change in climate, the first time-slice is chosen to be a recent period with sufficient observations and is referred to as "Present". The "present-day" period chosen for this study is 1971-2010. For the future period that we are interested in, 2011-2100 (hereafter referred at as "Future" time-slice), we will use multiple AOGCMs from the CMIP5 database and use multiple RCP scenarios as required under the TOR-1. We will make use of the AOGCM simulations of the "Present-day" period (in the 20^{th} Century or historical runs) to provide the baseline for calculating changes in the boundary conditions for the "future" time-slice.

The IIT Delhi group will follow the time-slice approach and simulations for "present day" and "future" will be carried out with an AGCM running at a higher resolution (~50km). For this purpose we have chosen the National Center for Atmospheric Research (NCAR) Community Atmospheric Model version 5.2 (CAM5). Version 5.2 of the Community Atmosphere Model (CAM) is the sixth generation of the NCAR atmospheric GCM and has again been developed through a collaborative process of users and developers in the Atmosphere Model Working Group (AMWG) with significant input from the Chemistry Climate Working Group (Chem-Clim WG) and the Whole Atmosphere Working Group (WAMWG). The Atmosphere Model Working Group1 (AMWG) of the Community Climate System Model2 (CCSM) project guides the current development of CAM. CAM is used as both a standalone model and as the atmospheric component of the CCSM.

As required in the TOR, the downscaling is proposed for at least five CMIP5 AOGCMs and 2 scenarios (RCP4.5 and RCP8.5). This will mean a minimum number of about 1500 model years to be simulated. Additional scenarios (RCP3 and RCP6) can be added on depending on the availability of resources and users.

14.2: Nested Regional Climate Model (RCM) Approach

This approach to downscaling is highly popular because of the relatively inexpensive computational cost and also because of a strong user base helping to develop this class of models. These models have typically grown out of numerical weather prediction models and have been used for meso-scale studies. Many approaches exist in formulating and developing these models and this has led to many RCMs that are currently in use. In the current proposal, many different RCMs have been selected to carry out dynamic downscaling of future climate scenarios. The multiple models in use should provide comprehensive coverage of the entire country and a range of scenarios and AOGCMs on which downscaling is carried out. Downscaling a single AOGCM projection can provide us with some information about what type and magnitude of changes we might expect under a given emissions scenario for our region of interest, but it does not provide us with much information about how confident we should be in that projection. Exploring the range or spread of projections from different AOGCMs enables us to gain a better understanding of the uncertainties in climate change scenarios that arise from differences in model formulation. The models used and approaches taken are described below.

14.2.1: WRF (CWRF)

The Weather Research and Forecasting (WRF) model is a numerical weather prediction and atmospheric simulation system designed to resolve this interaction at regional scale. WRF has been used earlier to investigate the downscaling methodology allover the Globe, specially United States. This model has been chosen by the IIT Madras group to carry out the dynamical downscaling. The goal of the IIT Madras group is to attempt dynamic downscaling for the entire country at a resolution of 25km (approximately 0.25° × 0.25°) for the purpose of hydrological modelling and assessment of impact of climate change on the water resources of Indian river basins. The Geophysical Fluid Dynamics Laboratory Coupled Physical Model (GFDL-CM3) output data will be used for lateral forcing for one historical run and four scenarios. The historical run is with the GFDL forcing for the period 1971-2005. The four future scenarios will be:

i. RCP 2.6 from 2006-2100
ii. RCP 4.5 from 2006-2100
iii. RCP 6.0 from 2006-2100
iv. RCP 8.5 from 2006-2100

The downscaling will be done on the IIT Madras Virgo super computer. Virgo is one of the fastest cluster in India with 292 computer nodes having a total computer power of 97 TFlops. The deliverables will be the hourly and daily average weather data of climate variables such as precipitation, maximum and minimum temperatures, relative humidity, wind speed and incoming solar radiation needed to run the hydrology models. The downscaled weather data will be validated with observations from possible networks of meteorological weather stations. Further, gridded weather data such as IMD 0.5º × 0.5 º rainfall data and APHRODITE 0.25 º × 0.25 º rainfall data will also be used to verify and adjust for any bias in the downscaled rainfall data. Similar gridded temperature data from IMD will be used for validation and bias adjustment.

14.2.3: PRECIS

The Anna University proposes to run the PRECIS model to downscale the future climate scenarios. PRECIS: One of the key successes of climate modeling in the International level is the development of the regional climate modeling system PRECIS at UK Met office. PRECIS was developed by the U.K Met Office in order to help generate high-resolution climate change information for as many regions of the world as possible. HadAM3P is a global atmosphere-only model with a resolution of order 150km, forced by surface boundary conditions (sea-surface temperature and sea-ice fraction) from HadCM3 and observations. It has been run for two "time slices": 1960-1990 and 2070-2100. The Hadley Centre has run a suite of climate change experiments, sampling a range of scenarios from the IPCC Special Report on Emissions Scenarios (SRES), using HadAM3P. Boundary data from a 17-member perturbed physics ensemble are now available for use in PRECIS experiments. This allows PRECIS users to explore the model uncertainty in the projections of future climate change in their region. The 17 models are based on the Hadley Centre's HadCM3 model. The Met Office Hadley centre provides boundary data from our 17-member perturbed-physics ensemble (HadCM3Q0-Q16, known as 'QUMP') for use with PRECIS in order to allow users to generate an ensemble of high-resolution regional simulations. Running 17 PRECIS experiments may be beyond the computing capacity of many institutions, in which case users might select a smaller sub-set from the 17. The PRECIS model has previously been used by the IITM, Pune to downscale the HadCM3 model output as part of the NATCOMM effort to inform impact assessment studies. The limitation of the PRECIS is that it is designed to only take inputs from the Hadley Centre models.

Met Office Hadley centre is now able to provide boundary data from 17-member perturbed-physics ensemble (HadCM3Q0-Q16, known as 'QUMP') for use with PRECIS in order to allow users to generate an ensemble of high-resolution regional simulations. PRECIS is an atmospheric and land surface model of high resolution (up to 25 km) and limited area which can run with boundary data of HADCM3Q from 1950 to 2100 continuously. Comparison of the range of physically plausible outcomes simulated by the QUMP PPE with those simulated by the CMIP3 MME demonstrated some differences between the two ensembles. While both ensembles consistently indicate increases in wet season (JJAS) rainfall over the whole region, consistent with an increase in monsoon intensity, in DJF the QUMP models generally project a decrease whilst the CMIP3 models indicate increases. This leads to a difference in the consensus achieved between the two ensembles in total annual rainfall change. Ensemble members will be selected based on the model performance and the variety of changes in precipitation patterns. The selection of a sub-set of the 17 available QUMP members for India have to be done by examining simulations from each of the GCMs against the following criteria: (a) Performance in simulating key aspects of the regional climate in baseline simulations , when compared with observational datasets. Specifically, we will consider the behavior of the Indian summer monsoon as the major driver of the timing, magnitude and variability of wet-season rainfall and its extremes to access the impact on the water resources; (b) Regional projections: Simulations of climate for the period 2070-2100 were examined to look at the range of magnitudes and patterns of response in south-India to forcing from the A1B emission scenario (Carol et al 2010). As per the requirement, we will include other scenarios like A2 and B1 simulated by other GCMs in future. Specifically, we are interested in the magnitude of temperature changes, the magnitude and direction of rainfall changes, and changes in the timing or magnitude of the Indian summer monsoon. The output of PRECIS is post processed and used for hydrological impact studies.

14.2.4: RegCM4

The Regional Climate Model Version4.0 (RegCM4.0) developed at ICTP, Italy, will be used in dynamical downscaling by BHU. In this component, the BHU group propose to downscale using Regional Climate Model (RegCM4..3, Giorgi and Anyah, 2012; Giorgi et al., 2012) for

RCP4.5 and RCP8.5 scenarios. Projections will be carried out for near future (2015-2040), and distant future (2040-2070) over the entire country at 50km resolution.

14.3: Bias Correction and Uncertainty Analysis

Numerous gridded weather data are available from sources such as IMD (0.25 º × 0.25 º and 0.5º × 0.5 º for rainfall; 1.0 º × 1.0 º for temperature) and APHRODITE (0.25 º × 0.25 º and 0.5 º × 0.5 º rainfall data). These datasets will be used to verify and adjust for any bias in the daily average downscaled data and quantify the uncertainty. For hourly data, the bias correction is not possible as the availability of long-term measurements at such high frequency is not available. Therefore, the hourly output data is provided "as is" and should be considered "experimental" as no real validation has ever been carried out for model output at these frequencies.

Table 1: Summary of downscaling simulations proposed to be carried out.

S. No.	Institution	Lead	Downscaling Model	Downscaled Resolution	CGCM to be downscaled	Scenario Runs planned	Years	Basins Selected
1	IIT Delhi	Dr. Krishna AchutaRao	CAM	50km	All Available (minimum 5)	Historical, RCP4.5 & RCP8.5	1971-2100	Entire Globe
2	IIT Madras	Prof. C. Balaji	WRF/CWRF	25km	GFDL-CM3	Two or more of the future RCP scenarios	130 years (1971 to 2100)	Entire Country
3	Anna University	Dr. K. Palanivelu	PRECIS	25 km	HadCM3Q	A1B, (A2 & B1)	1950-2100	Entire Country
4	BHU	Dr. R. K. Mall	RegCM4	50 km	HadGEM2	RCP4.5, RCP8.5	20c3m: 20th century (1980-2005), near future (2015-2040), and distant future (2040-2070)	Entire Country

15. Cost Estimates

15.1. Total Cost of the project (Sum Total of all participating institutions but excluding data cost).

Subhead	**Amount (Rs.)**
Salary	88,20,800
TE	13,00,000
Infrastructure /Equipments	1,14,50,000
Consumables	5,50,000
Experimental Charges	1,08,00,000
Sub Total	3,29,20,800
Add Contingency 5 %	15,50,720
Total	3,44,71,520
Institutional over heads capped as per DST rules	**15,00,000**
Grand Total	**3,59,71,520**

Budget – IIT Delhi

Subhead wise Abstract

Subhead	Amount (Rs.)
Salary	23,08,800
Travel Expenditure	2,80,000
Infrastructure /Equipment	30,00,000
Consumables	50,000
Experimental Charges	93,00,000
Sub Total	1,49,38,800
Add Contingency 5 %	7,46,940
Total	**1,56,85,740**
Institutional overheads (10%) or capped as per DST rules	6,82,552
Grand Total	**1,63,68,292**

(Note: In this table of abstract, it is not necessary to indicate year wise provisions. The release of funds will be tied down with milestones of progress and not with passage of time)

i. Justification for Institutional Overhead charges

As per the Institute rules, overhead charges at the rate of 20% of the total project cost should be paid, for providing basic infrastructure facilities, such as water, electricity, internet, office, computing facilities, library, etc. The amount requested is capped at 10% (or 15 Lakhs, whichever is less), to conform to MoWR / DST guidelines.

ii. Amount sought to be released at the start of the work with justification

The amount to be released at the start of the work shall be 20 Lakh rupees only. (Rs. 20,00,000 /-). This will be used for salaries, purchasing equipment and establishing other infrastructural facilities necessary for smooth running of the project.

iii. Subheads wise details

Designation	Year1			Year2		
	Rate/ month	Months	Amount	Rate/ month	Months	Amount
Research Associates (2)	36000 + 30% HRA	12	11,23,200	38000 + 30% HRA	12	11,85,600
Grand Total for Salary Rs. 23,08,800/-						

Two Research Associates (As per DST payscales of 36000+30% HRA for first year and 38000+30%HRA for second year) are included in the budget.

iv. Travel Expenditure

(Give the break-up for the provision for TE indicating the places to be visited, purpose, number of visits to each place by air/ rail/ road with approximate fares for each type of journey and provision for DA. The mode of journey allowed (air/rail/road) will be as per the TE entitlement rules of the host institute.)

Funds are required for the project staff to visit the co-Pis and to attend training sessions/conferences/workshops/meetings. Travel budgeted for 4 visits per year at Rs. 35,000/- per trip.

v. Infrastructure *(Purchased items of a permanent nature like equipment, software or data; construction of any buildings etc.)*

Infrastructure		
S. No	Name of the Equipment	*Total estimated cost (Rupees)*
1	Storage Server with about 200TB raw capacity and 40 core processing capacity	20,00,000
2	4 workstations (@ 200,000 each)	8,00,000
3	Printer-scanner, 6 3-TB portable hard-disks, 2-laptops	2,00,000
	Total	**28,00,000**

vi. Experimental/Workshop Charges

The major expenditure in this category is for Computer time on the PARAM YUVA-II HPC at CDAC Pune or if already online, the IIT Delhi Supercomputer (the new HPC facility is expected to be fully functional by December 2015). A total of 3 million core hours is estimated for carrying out the downscaling using the NCAR CAM model for a total of Rs. 90 Lakhs (@ Rs.3 per core hour). Additional charges levied by CDAC amount to nearly 1 Lakh.

One capacity building and data usage workshop for scientists is envisaged as also one meeting of co-Investigators for coordination. For this purpose, a request of Rs. 2 Lakhs is included.

S.No.	**Description of Activity**	**Time duration (months)**	**I year**				**II year**			
			I	II	III	IV	I	II	III	IV
1.	Setting up model	**3**	■							
2.	Deployment of Project Personnel	**6**	■	■						
3.	Purchase of equipment	**9**	■	■	■					
4.	Preliminary model runs for validation and testing	**6**		■	■					
5.	Model Simulations	**18**			■	■	■	■	■	■
6.	Bias Correction and Data Distribution	**15**				■	■	■	■	■
7.	Final report preparation	**3**								■

Budget – IIT Madras

	Amount (Rupees)
Salary (Two SRF's) Rs.28,000/month + 30% HRA	17,47,200
Travel	4,20,000
Infrastructure /Equipment /Data Charges	1800000
Experimental Charges	300000
Sub-Total	**42,67,200**
Contingency (5%)	2,13,360
Total	**44,80,560**
Institutional over heads (10%) or capped as per DST rules	1,94,968
Grand Total	**46,75,528**

Subheads wise Details

i. Salary

Designation	Number of personnel	Year 1			Year 2			Total amount for 2 years
		Rate/ Month	Months	Amount (Rs)	Rate/ Month	Months	Amount (Rs)	
SRF**	2	28000+ 30% HRA	12	8,73,600	28000+30% HRA	12	8,73,600	**17,47,200**

** staff recruited at the SRF level will be eligible to register for PhD.

ii. Travel Expenditure

S. No	Purpose of visit	Number of visits	Mode of travel	Amount (Rs.)
1	Visit for meetings, trainings, conference, workshop at partnering and lead centre	Total 6 visits in two years for two	Rs.35,000/ visit by Air	**4,20,000**

		personnel		

iii. Infrastructure

S. No	Name of the Equipment	Total estimated cost (Rs)
1	Weather data from IMD (20 years of precipitation data for 200 stations and 20 years of surface parameters from 100 stations for 20 years)	14,60,000
2	Computers and its accessories (2 no. of Desktops + UPS)	3,00,000
3	Books, Journals, Reports and publications	40,000
	Total	**48,00,000**

* The desktop HPC is needed to test the job locally for the smaller domain and check for the short run simulation and to rectify the problems before submitting the job at IITM HPC.

iv. Experimental Charges

S. No	Items	Amount (Rs)
1	Stationeries, interim and final report preparation and capacity building for the scientists (workshop).	**3,00,000**

Budget – Anna University, Chennai

Total Budget including overhead charges: Rs. 90,27,040.00

Subhead wise abstract:

Non-Recurring	**Amount (Rs.)**
See table below	**34,00,000**

Infrastructure/Equipments/Data Charges	**Cost @ Rs.**	**Amount Rs.**
Workstation with 16 cores and 10TB storage capacity (6 nos.)	2,00,000.00	12,00,000.00
NFS storage box with 12TB Storage capacity(6.nos)	1,00,000.00	6,00,000.00
Laboratory Establishment(for 2 years)	2,00,000.00	4,00,000.00
Software and database packages(for 3 licensed users)	2,00,000.00	6,00,000.00
Data Processing and Analysis tools	6,00,000.00	6,00,000.00

Recurring	
Salary	**28,06,400**

Designation	**Year 1**			**Year 2**		
	Rate/ Month	**Month**	**Amount (Rs.)**	**Rate/ Month**	**Months**	**Amount (Rs.)**
Research Associate (1)	46,800	12	5,61,600	49,400	12	5,92,800
SRF (1)	36,400	12	4,36,000	36,400	12	4,36,000
JRF (1)	32,500	12	3,90,000	32,500	12	3,90,000

Sub Total(Rs)	**62,06,400**
Recurring	**Amount(Rs)**
Consumables	**5,00,000**

Experimental/Workshop	**8,00,000**
Travel	**4,00,000**
Contingency	**3,00,000**
Sub Total(Rs)	**82,06,400**
Institutional Overheads (10%) or capped as per DST rules	**3,57,095**
Grand Total (Recurring + Non-Recurring) in Rs.	**85,63,495**

i. **JUSTIFICATION**

A. **Salary:** One Research Associate, one Senior Research fellow and one Junior Research Fellow will be employed to carry out the overall work(Down Scaling ,Analysis, and Data processing) as per norms.

B. **Equipments:** As per the application requirements, high performance and heavy workloads, our centre needs required number of work stations to increase the productivity and reduce the computational complexity. Taking all of these advantages into account, workstations with architectural support to 16 core and support for up to 10 TB storage capacities is highly recommended.

C. **Software:** The whole curriculum module deals with the elicitation, analysis, specification, and validation of requirements for software. A reliable **data warehouse** server is required to integrate different components of **data warehouse** architecture. This module supersedes various software packages like oracle, SQL which are presently leading in worldwide data warehouse management software. We present some of the analysis tools like FERRET, R, Grads, and SDSM etc. that perform wide range of best practice for statistical analysis. There are other software like IDRISI and IDL etc. which are required to assess different climate change impacts and adaptation research.

D. **Experimental Charges & Workshop:** The consumables and data storage etc are necessary for the daily routine of research and official work. Telephone and separate hi-speed internet connection charges, Honorarium for assistant for compilation of reports and preparation of manuscripts etc. To conduct regional workshop inviting partners, MoWR officials, local govt. /NGOs and other water resources managers / stakeholders.

E. **Travel:** Guest faculty from foreign organizations will be invited for providing training on models in different areas of climate change. Expertise in each social and scientific sector will be invited in contributing to the regular updating of information and knowledge as an input to Hydrology that demands extensive travel expense within and outside the country. Moreover, to gain practical expertise on meteorology and climate predictions, our faculties will also be trained suitably within India and abroad.

F. **Justification for institutional over head charges::** As this is a research project, the investigators will not be paid with any remuneration. As the investigators are paid by the University for their Monthly Salary, their contribution of time and effort to this project will be compensated in the form of such University overhead charges. In addition, some of the university facilities like space for doing research, electricity charges and efforts of some of the permanent staff involved in this work will be accounted in this aspect

G. **Justification for the Infrastructure:** The high-resolution RCM (RegCM 4.3) simulations for 100 years (climate and other data) for the study area are very time consuming and it is desirable to have a dedicated high power server for the above purpose. The super-computing facility i.e. IBM/ SUN blade Series server, because of its high speed and large memory space, will be able to run the climate model over the region and resolution of interest within a reasonable time interval. The Computers (also Higher-end desktops and laptop) with its accessories, printer and software will be also used for simulation, computation, running of Graphics software, GIS, data collection etc. Project staff employed for the project will also use the Computer. AC and UPS is needed for smooth functioning of Server.

Budget – Banaras Hindu University, Varanasi

Subhead wise Abstract

Subhead	Amount (Rs.)
Salary	19,58,400
Travel Expenses	2,00,000
Equipment	32,50,000
Experimental Charges and Workshop	4,00,000
Sub Total	58,08,400
Add Contingency 5 %	2,90,420
Total	60,98,820
Institutional over heads (10%) or capped as per DST rules	2,65,385
Grand Total	**63,64,205**

(Note: In this table of abstract, it is not necessary to indicate year wise provisions. The release of funds will be tied down with milestones of progress and not with passage of time)

i. **Justification for Institutional Over Head charges**

(Institutional over head charges, if sanctioned, will be actually paid only on successful completion of the project)

As per the Institute rules, overhead charges at the rate of 20% of the total project cost should be paid, for providing basic infrastructure facilities, such as water, electricity, internet, office, computing facilities, library, etc.

ii. **Amount sought to be released at the start of the work with justification**

The amount to be released at the start of the work shall be **Fifty Five Lakh rupees only. (Rs. 55,00,000 /-).**

The amount sought at the start of the work will be used for salaries, purchasing of equipment, software's etc and establishing other infrastructural facilities necessary for smooth running of the project.

iii. **Subheads wise details**

Designation	**Year1**			**Year2**		
	Rate/ month	Months	Amount	Rate/ month	Months	Amount

Research Associate (1)	Rs. 40000 + 20% HRA	12	5,76,000	Rs. 40000 + 20% HRA	12	5,76,000
SRF (1)	Rs 28000 + 20% HRA	12	4,03,200	Rs 28000 + 20% HRA	12	4,03,200
					Grand Total for Salary	19,58,400

iv. **Travel Expenditure**

(Give the break-up for the provision for TE indicating the places to be visited, purpose, number of visits to each place by air/ rail/ road with approximate fares for each type of journey and provision for DA. The mode of journey allowed (air/rail/road) will be as per the TE entitlement rules of the host institute.)

Funds are required for the project staff to visit the site and departments concerned, for the collection of data. Travel grants are also required to attend R& D sessions, conferences/workshops and meetings.

v. **Infrastructure** *(Purchased items of a permanent nature like equipment, software or data; construction of any buildings etc.)*

Items	**1st year***
One High Performance Computer (Blade Server, Intel Xenon eight core processor, high cache memory, high memory and heavy storage capacity, Optical drive)	24,00,000
Intel Fortran compiler version 12.2 (server version)	2,00,000
Higher-end desktop (2 Nos.), Laptop (1 Nos.), Laserjet printer, scanner etc., and Hard disks	2,50,000
2 Split AC (2 Tons)+ installation	60,000
UPS for Linux Cluster	90,000
Hydro-Meteorological Data (from IMD & others)	1,50,000
Infrastructure development for High Performance Computer	1,00,000
Total	**32,50,000**

*Prices includes all taxes, which is not included in the quotation

The high-resolution RCM (RegCM 4.3) simulations for 100 years (climate and other data) for the study area are very time consuming and it is desirable to have a dedicated high power server for the above purpose. The super-computing facility i.e. IBM/ SUN blade Series server, because of its high speed and large memory space, will be able to run the climate model *over the region and resolution of interest within a reasonable time interval*. The Computers (also Higher-end desktops and laptop) with its accessories, printer and software will be also used for simulation, computation, running of Graphics software, GIS, data collection etc. Project staff employed for the project will also use the Computer. AC and UPS is needed for smooth functioning of Server.

vi. Experimental charges and Workshop: List the items and estimated cost.

The consumables and data storage etc are necessary for the daily routine of research and official work. Telephone and separate hi-speed internet connection charges, Honorarium for assistant for compilation of reports and preparation of manuscripts etc. To conduct regional workshop inviting partners, MoWR officials, local govt. /NGOs and other water resources managers / stakeholders.

Appendix 1
Brief Bio-data of the Investigators

Krishna AchutaRao

Associate Professor, Centre for Atmospheric Sciences
Indian Institute of Technology Delhi,
Hauz Khas, New Delhi 110016.
Phone: (+91)-11-2659-6278 Mobile: (+91)-99-7164-1104
E-mail: akrishna@cas.iitd.ernet.in *or* Krishna.achutarao@gmail.com

Educational Qualifications:

- Tulane University, New Orleans, Louisiana, U.S.A. *M.E.* Mechanical Engineering, (May 1990) and *Ph.D., (*December 1994)
- Birla Institute of Technology and Science (BITS), Pilani, India, *B. E. (Hons*) Mechanical Engineering and *M. Sc (Hons)* Mathematics (June 1986)

Work Experience:

- June 2007-Present: Associate Professor, Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India.
- October 2000-May 2007: Research Scientist, Program for Climate Model Diagnosis and Intercomparison (PCMDI), Lawrence Livermore National Laboratories, Livermore CA, U.S.A. (*Key member of team responsible for CMIP-2 and CMIP-3*).
- May 1998-September 2000: Postdoctoral Research Scientist, PCMDI, Lawrence Livermore National Laboratories, Livermore CA, U.S.A.

Research Experience and interests:

- Extensive research experience in climate change, interannual-to-decadal scale climate variability and climate model validation.

Professional Activities:

- Member, CLIVAR Scientific Steering Group.
- Lead Author, Chapter 10, WG-1, Fifth Assessment Report (AR5) of the IPCC.
- Contributing Author: WG-1, Third and Fourth Assessment Reports (TAR and AR4) of the IPCC.
- Invited Expert and Contributing Author to UNEP Panel on "Asian Brown Cloud".
- Reviewer for Journals: *Climate Dynamics*, *J. Climate*, *GRL*, *Tellus*, *BAMS, Current Science, INSA.*
- Reviewer for Funding Agencies*: NSF (USA), NOAA (USA), INCOIS (Ministry of Earth Sciences, India), and NERC (UK).*

Selected Publications:

- P. J. Gleckler, B. D. Santer, C. M. Domingues, D. W. Pierce, T. P. Barnett, J. A. Church, K. E. Taylor, K. M. AchutaRao**,** T. P. Boyer, M. Ishii & P. M. Caldwell 2012: "Human-induced global ocean warming on multidecadal timescales" *Nature Climate Change* 2, 524-529, doi:10.1038/nclimate1553
- AchutaRao, K.M., M. Ishii, B.D. Santer, P.J. Gleckler, K.E. Taylor, T.P. Barnett, D.W. Pierce, R.J. Stouffer, and T.M.L. Wigley, 2007: "Simulated and observed variability in ocean temperature and heat content", *PNAS*, 104, doi:10.1073/pnas.0611373104.
- Santer, B.D., T.M.L. Wigley, P.J. Gleckler, C. Bonfils, M.F. Wehner, K. AchutaRao, T.P. Barnett, J.S. Boyle, W. Brüggemann, M. Fiorino, N. Gillett, J.E. Hansen, P.D. Jones, S.A. Klein, G.A. Meehl, S.C.B. Raper, R.W. Reynolds, K.E. Taylor, and W.M. Washington, 2006: Forced and unforced ocean temperature changes in Atlantic and Pacific cyclogenesis regions*. PNAS*, 103, 13905-13910.
- Gleckler, P. J., T.M.L. Wigley, B.D. Santer, J.M. Gregory, K. M. AchutaRao and K.E. Taylor, 2005: "Krakatoa's signature persists in the ocean", *Nature*, V. 439, 9 February 2006, doi:10.1038/439675a
- AchutaRao, K. M., and K. R. Sperber, 2006: "ENSO Simulation in Coupled Ocean-Atmosphere Models: Are the Current Models Better?" *Climate Dynamics*, Vol. 27: 1-15, DOI: 10.1007/s00382-006-0119-7.
- Barnett, T. P., D. W. Pierce, K. M. AchutaRao, P. Gleckler, B. Santer, J. Gregory, W. Washington, 2005: "Penetration of a Warming Signal into the World's Oceans: Human Impacts", *Science,* Published online June 2, 2005; 10.1126/science.1112418.

Dilip Ganguly
Assistant Professor, Centre for Atmospheric Sciences (CAS)
Indian Institute of Technology Delhi Hauz Khas, New Delhi 110016, INDIA
Phone: 91 11 26596401 (office), Fax: 91 11 26591386
Email: dilipganguly@cas.iitd.ac.in

Education, Training and Professional Positions

B.Sc.	Physics	1996-1999	University of Calcutta, Kolkata, India
M.Sc.	Physics	1999-2001	Banaras Hindu University, Varanasi, India
Ph.D.	Physics	2001-2006	Physical Research Laboratory, Ahmedabad,
Postdoc.	Atmospheric Sciences	2006-2007	Physical Research Laboratory, Ahmedabad,
Postdoc.	Atmospheric Sciences	2007-2010	Princeton University, Princeton, NJ, USA

Research Scientist	Jun 2010 - Aug 2012	Pacific Northwest National Laboratory, Richland
Visiting Scientist	Sep 2012 - Feb 2013	Indian Institute of Tropical Meteorology, Pune
Assistant Professor	Feb 2013 - till date	Indian Institute of Technology Delhi, New Delhi

Areas of Research Interest

Aerosol-cloud-precipitation interactions, Cloud parameterizations, Radiative Forcing and Climate Change, Climate sensitivity and feedback processes, Climate Diagnostics using model output and observations, Monsoon Dynamics

Selected Peer Reviewed Publication in Journals

- **Ganguly, D**., Philip J. Rasch, Hailong Wang, and Jin-ho Yoon (2012), Fast and slow responses of the South Asian monsoon system to anthropogenic aerosols*, Geophys. Res. Lett., 39, L18804, doi:10.1029/2012GL053043.*
- **Ganguly, D.**, Philip J. Rasch, Hailong Wang, and Jin-ho Yoon (2012), Climate response of the South Asian monsoon system to anthropogenic aerosols, *J. Geophys. Res., 117*, D13209, doi:10.1029/2012JD017508.
- **Ganguly, D.**, P. Ginoux, V. Ramaswamy, D.M. Winker, B.N. Holben, and S.N. Tripathi (2009), Retrieving the composition and concentration of aerosols over the Indo-Gangetic basin using CALIOP and AERONET data, *Geophys. Res. Lett., 36*, L13806*,* doi:10.1029/2009GL038315.
- **Ganguly, D.**, A. Jayaraman, T. A. Rajesh, H. Gadhavi (2006), Wintertime aerosol properties during foggy and non-foggy days over urban center Delhi and their implications to Short Wave radiative forcing, *J. Geophys. Res.,* 111, D15217, doi:10.1029/2005JD007029.

Awards and Recognitions

- Dr. Sudhansu Kumar Banerji Outstanding Young Faculty fellowship, 2013.
- Best Research Poster award at the European Research School on Atmospheres-2005,
- Qualified the National Eligibility Test (NET) for research fellowship and lectureship in Physics, conducted by Council of Scientific and Industrial Research, Govt. of India, 2001.

Chakravarthy Balaji

Professor
Department of Mechanical Engineering, Indian Institute of Technology
Chennai – 6003036. Tamil Nadu, INDIA.
E-mail: balaji@iitm.ac.in; Ph: +91-44-2257 4689 ; Mobile : 9790789362

Education

Humboldt Fellowship, Asymptotics heat transfer, Hamburg University of Technology, Germany. 2005.
Ph.D. Heat Transfer, IIT Madras, India. 1995.
M.Tech. Heat Transfer, IIT Madras, India. 1992.
B.E. Mechanical Engineering, Anna University, Chennai, India. 1990.

Professional Experience

Mar 2009 – present	**Professor**	Department of Mechanical Engineering, IIT Madras.
Jan 2004 – Mar 2009	**Associate Professor**	Department of Mechanical Engineering, IIT Madras.
Oct 1998 – Jan 2004	**Assistant Processor**	Department of Mechanical Engineering, IIT Madras.
Jan 1997- Oct 1998	**Senior Project Manager**	NIOT, IIT Campus, Madras.
June 1996 – Jan 1997	**Visiting Scientist**	NIOT, IIT Campus, Madras.
Sep 1994 – May 2004	**Lecturer**	NIT, Trichy.

Research Interests

- Developing the algorithms to retrieving the atmospheric parameters from micro wave and Infra red Satellites.
- Impact of multi satellite radiance assimilation into the regional weather models.
- Tracking the cyclones path in North Indian Oceans.

Selected Refereed Publications

1. Srinivasa Ramanujam. K, Chandrasekar. R, Balaji. C "A new PCA-ANN algorithm for retrieval of rainfall structure in a precipitating atmosphere" International Journal of Numerical Methods for Heat and Fluid Flow, (21), 2011:1002-1025.
2. Srinivasa Ramanujam. K,Balaji. C "Radiative Transfer Simulations for the MADRAS Imager of Megha-Tropiques" Journal of Earth System Science,(120), 2011:1-17.
3. Srinivasa Ramanujam, R. Chandrasekar, Deepak Subramani, C. Balaji "On The Effect Of Non-Raining Parameters In Retrieval Of Surface Rain Rate Using TRMM PR And TMI Measurements" IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2012, (in press).
4. Praveen Krishnan, K. Srinivasa Ramanujam, C. Balaji "An Artificial Neural Network Based Fast Radiative Transfer Model for Simulating Infrared Sounder Radiances" Journal of Earth System Science, 2012, (in press).
5. R.Chandrasekar, C. Balaji "Sensitivity of Tropical Cyclone Jal simulations to Physics Parameterizations" Journal of Earth System Science, 2012, (in press).

Awards

1) **Young Faculty Recognition Award** at IIT Madras for excellence in Teaching and Research, 2007.
2) **Prof.K.N.Seetharamu Medal** and Prize for excellence in research, 2008 awarded by the Indian Society for Heat and Mass Transfer.
3) **Humboldt Fellowship** - Alexander Von Humboldt foundation, Germany, 2005-2006.
4) **Swarna Jayanthi Fellowship** - Govt of India, in Earth and atmospheric sciences, 2008-2013.
5) **Tamil Nadu Scientist Award** - Govt of Tamil Nadu, in Engineering and sciences, 2010.

Balaji Narasimhan

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Chennai – 6003036. Tamil Nadu, INDIA.
E-mail: nbalaji@iitm.ac.in; Ph: +91-44-2257 4293 ; Mobile : 9962466161

Education

Ph.D. Biological and Agricultural Engineering, Texas A&M University, 2004.
M.S. Biosystems Engineering, University of Manitoba, Winnipeg, Canada. 1999.
B.E. Agricultural Engineering, Tamil Nadu Agricultural University, Trichy, India. 1997.

Professional Experience

August 2014 - Present	**Associate Professor**	Department of Civil Engineering, Indian Institute of Technology Madras (IIT Madras), INDIA.
October 2007 – July 2014	**Assistant Professor**	Department of Civil Engineering, Indian Institute of Technology Madras (IIT Madras), INDIA.
May 2006 – September 2007	**Research Assistant Professor**	Spatial Sciences Laboratory, Texas A&M University, USA.
June 2004 – April 2006	**Post-Doctoral Research Associate**	Spatial Sciences Laboratory, Texas A&M University, USA.

Research Interests

- Modeling the impact of landuse and climate change on hydrology, in-stream and reservoir water quality
- Energy fluxes/Evapotranspiration/Soil moisture from thermal remote sensing data for irrigation water management and drought assessment
- Development of operational flood and drought assessment/forecast system using GIS, remote sensing and hydrologic/hydraulic models

Selected Refereed Publications

1. Kaushal K. Garg, L. Bharati, A. Gaur, B. George, S. Acharya, K. Jella, and B. Narasimhan. 2011. Spatial Mapping of Agricultural Water Productivity using SWAT model in Upper Bhima Catchment, India. *Irrigation and Drainage*, 60: n/a. doi: 10.1002/ird.618.
2. *Narasimhan, B*., R. Srinivasan, S. Bednarz, M. Ernst, and P. M. Allen. 2010. A Comprehensive Modelling approach for reservoir water quality assessment and management due to point and non-point source pollution. *Transactions of the ASAE.* (In press).
3. Stratton, B. T., V. Sridhar, M. M. Gribb, J. P. McNamara and *B. Narasimhan*. 2009. Modelling the spatially varying water balance processes in a semiarid mountainous watershed of Idaho. Journal of the American Water Resources Association. 45(6):1390-1408.
4. *Narasimhan, B*., and R. Srinivasan. 2005. Development and evaluation of soil moisture deficit index (SMDI) and evapotranspiration deficit Index (ETDI). *Agricultural and Forest Meteorology* 133:69-88.
5. *Narasimhan, B*., R. Srinivasan, J. G. Arnold, and M. Di Luzio. 2005. Simulation of long-term soil moisture using a distributed parameter hydrologic model. *Transactions of the ASAE* 48(3):1101-1113.

Book Chapter

1. Narasimhan, B., Pei-yu Chen, J. H. Jacobs, and R. Srinivasan. 2006. Real-Time Modeling of Natural Resources Using the Spatial Sciences. In Modeling and Remote Sensing Applied to Agriculture (U.S. and Mexico). USDA-ARS and INIFAP. 51-69.

Selected Training/Workshops Conducted

1. Sep 16-18, 2011. Advanced SWAT workshop. Along with Dr. R. Srinivasan from Texas A&M University. Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, INDIA.
2. Jan. 31 - Feb.5, 2011. QIP short-term course on "GIS and Remote Sensing Techniques for Water Resources Assessment (Using Open Source Tools)". Along with Dr. K. P. Sudheer, Dept. of Civil Engineering, IIT Madras, INDIA.
3. Dec. 1-3, 2010. Introductory SWAT workshop. Along with Dr. R. Srinivasan from Texas A&M University. IIT Madras, INDIA.

SACHIN S. GUNTHE

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Web : www.sachingunthe.com

Professional Experience

10/2011 – :Assistant Professor, EWRE Division, Dept. of Civil Engineering, Indian Institute of Technology, Madras, India

07/2006 – 10/2011 :Post doctoral researcher, Dept of Biogeochemistry, Max Planck Institute for Chemistry, Mainz, Germany (– Ulrich Pöschl, Director: M. O. Andreae)

Current scientific focus areas

- Aerosol-cloud-precipitation interactions with special emphasis on Indian summer Monsoon
- CCN properties of aerosols (filed campaign, laboratory studies, and numerical modeling), Measurements of biological aerosol particles

Fellowships and Awards

- Head Max Planck partner institution at IIT Madras (2013 – 2016)
- Marquis Who's Who for Science and Engineering (for aerosol research) 2010
- Five "Highly Cited Papers" (Top 1% in their journal) – ISI web of knowledge
- Junior research fellowship awarded by Defense Research Development Organization (DRDO),Govt. of India
- Junior research fellowship by Dept. of Science and Technology, Govt. of India.
- Senior research fellowship by Indian Institute of Tropical Meteorology, Pune, India
- Research assistantship by Indian Institute of Tropical Meteorology, Pune, India
- Post doctoral assistantship by Max Planck Institute for Chemistry, Germany

Sponsored scientific projects (includes proposed projects)

- The National Carbonaceous Aerosol Program (in review with MoEF; Rs. 1100 Lakh)
- Size-resolved CCN measurement over Indian continental and marine region (in review with MoES; Rs. 110 Lakh)
- Characterizing properties of atmospheric aerosols for climatic and health impact over Indian tropical region (in review with DST; Rs. 100 Lakh)
- Characterizing properties of atmospheric aerosols in south Indian region (IITM seed grant; Rs. 18 Lakh)

Scientific projects involvement

- **A**mazonian **T**all **T**ower **O**bservatory (ATTO): Sampling of trace gases and aerosols from 320 meters tall tower in middle of Amazon north of Manaus, Brazil. 2011 – 2012, Brazil
- **Zot**ino **T**all **To**wer (ZOTTO): Aerosol sampling for SEM and TEM analysis of aerosol to characterize physical and chemical properties of pristine air masses. Sep – Oct 2009, Zotino, Krasnoyarsk Krai, Siberia, Russia
- Amazonian Aerosol Characterization Experiment (AMAZE-08), Jan –Mar 2008, Amazon Forest, Manaus, Brazil

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Education

- Ph.D., (1992) IIT Madras, Tamil Nadu, India
- M.Sc., Chemistry, Annamalai University, Tamil Nadu, India
- B.Sc., Chemistry(1980-1983) Madras University, India

Professional Experience

Feb. 2014- till date: Director, CCA&R, Anna University
Nov.1992- till date: Lecturer & Professor, Centre for Environmental Studies, Anna University

Major Research Fields

Carbon sequestration, Climate change impacts on natural resources, Greenhouse gases and Air pollution inventories, Waste treatment

No of Journal Publications- 114

Selected recent Publications:

1. Recovery of Sodium Bicarbonate from Textile Dye Bath Effluent using Carbon Dioxide Gas" Krishnaveni, Vel; Palanivelu, Kandasamy, Industrial & Engineering Chemistry Research(ACS) , 2013, 52 (47), pp 16922–16928.
2. Absorption of carbon dioxide in alkanolamine and vegetable oil mixture and isolation of 2-amino-2-methyl-1-propanol carbamate, A.Umamaheswari and K. Palanivelu, Journal of CO2 Utilization(Elsevier), 6 (2014) 45–52.
3. 'Climate portfolio' of Pichavaram mangrove region of Tamil Nadu coast, India: an add-on information for adaptation policy planning ,A. Saleem Khan, A. Ramachandran, P. Malini and K. Palanivelu, Journal of Integrative and Environmental Sciences, 2014,11(3-4) 173-186
4. An Assessment of Perceptions and Autonomous Adaptation among the Farmers of North East Tamil Nadu, under the Purview of Climate Change, Dhanya P, Ramachandran A and Palanivelu K, Journal of Studies in Dynamics and Change (JSDC), Vol. 1, No. 8, December 2014,309-319.

Awards and Recognitions

- Brain Korea 21- Teaching cum research Fellowship (2007),CNU,South Korea
- Hiyoshi Corporation (Japan) Ltd.,Think of Ecology award,2009
- Awarded INDIA4EU- EMECW EU fellowship(2010),University of ologna,Italy
- Best Environmental Research Paper Award (2010), Department of Environment, Government of Tamil Nadu
- Active Researcher Award 2014 in Environmental Studies, CTDT, Anna University, Chennai.

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April 2011-present	**Associate Professor**, Institute of Environment & Sustainable Development, Banaras Hindu University, Varanasi – 221 005
2008-2011	**Associate Professor (On Deputation),** *National Institute of Disaster Management (NIDM)*, Min. of Home Affairs, GOI, New Delhi – 110 002
2005 -2008	**Assistant Professor,** *Department of Geophysics,* Banaras Hindu University, Varanasi – 221 005, INDIA
2000-2005	**Scientist** (Group A, Gazetted), Central Ground Water Board, Min. of Water Res, Govt. of India, New Delhi
1998 -2000	**Research Scientist,** *Indian Agricultural Research Institute*, New Delhi- 110012
1996 -1998	**Project Scientist,** *Indian Institute of Technology*, New Delhi – 110016

EDUCATION: *Ph.D., Geophysics (Meteorology), 1996, B.H.U., Varanasi*
M. Tech, Geophysics 1991, B.H.U., Varanasi

DISTINCTIONS/ AWARDS/ MEDALS/ HONORS/ RECOGNITION:

- Senior Associate Award in 2012 (2012-2017) from ICTP-ITALY (A UNESCO and IAEA organization)
- CAS-TWAS Visiting Scholar Fellow Award-2006 (A Chinese Academy of Sciences & the Academy of Sciences for the Developing World Award)
- Regular Associate Award in 2004 (2004-2012) from ICTP-ITALY (A UNESCO and IAEA organization)
- Visiting Professor, ICTP, Trieste, ITALY in 2007.
- Member of "Expert Research Committee on climate change" Central Ground Water Board, MoWR, New Delhi.
- Consultant (Climate Change) for SAARC Disaster Management Centre, New Delhi and Expert for SAARC countries
- Invited as SAARC countries expert to participate in 5th Asian Ministerial Conference on Disaster Risk reduction (5th AMCDRR), 21-25 Oct. 2012, Yogyakarta, Indonesia
- Expert Member of SERB School Planning Committee (DST-New Delhi).

PROJECTS CARRIED OUT/ ONGOING

1. **Consultant/ PI: UN-ISDR and SAARC** Disaster Management Centre-New Delhi funded "Operationalizing the Thimphu Statement on Climate Change: Action, Planning for DRR-CCA integration in South Asia ", US $ 1,20,000, Since Dec 2012.
2. **Principal Investigators, CGWB, Min. of Water Resources Funded-** Impact of Climate change on groundwater resource in Sai- Gomti Interflue, Central Ganga Plain, Uttar Pradesh, India", Rs 56.60 Lakhs, Jan 2013
3. **Consultant/ PI: SAARC** Disaster Management Centre-New Delhi funded "Development of a Compendium on Lessons learnt and best practices of Climate Change Adaptability (CCA) in SAARC countries", US $ 10,000, Since July 2012.

PUBLICATIONS

Book/ Chapter/ Outcome /Contribution in Govt. Documents:	***5 (Five)***
Referred International / National journals:	***36 (Thirty Six)***
Recent Papers in Proceedings /Conferences / Symposia/ Workshop:	***14 (Fourteen)***

Appendix 2

Track Record and Workload Assessment of the PI

1. Schemes completed

Name of the Investigator	*Title of the project and duration*	*Amount sanctioned*	*Funding Agency*
Krishna AchutaRao (Co-PIs: Dr. A. S. Unnikrishnan, NIO, Goa & Prof. A. D. Rao, IIT Delhi)	"Current and future sea-level rise around coastal India." Start: Dec 2008. Ended Dec 31, 2012. Final report under preparation.	34.67 Lakhs (IITD component)	INCOIS (MoES) under INDOMOD Program.
Krishna AchutaRao	"Development of a Framework for Systematic Model Diagnosis" December 2009 -2013 (4Yrs)	53.702 Lakhs	Ministry of Earth Sciences
Krishna AchutaRao	Ocean heat uptake and thermosteric sea-level rise in the Northern Indian Ocean. April 2010 – 2013 (3Yrs) (Has just been extended to 2016.)	22.02 Lakhs	SAC (ISRO) under SARAL-Altika Utilization Programme

2. Schemes foreclosed with reasons for foreclosure

Name of the Investigator	*Title of the project and duration/ Date of start*	*Amount sanctioned*	*Funding Agency*
	Nil		

3. Schemes ongoing

Name of the Investigator	*Title of the project and duration/ Project status*	*Amount sanctioned*	*Funding Agency*
Krishna AchutaRao (Lead PI from India) (Prof. Mat Collins of Univ. Exeter as Lead PI from UK).	"South Asian PRecIpitaton: A SEamless Assessment - SAPRISE" September 2011- March 2016 (Initial 3 Years was extended)	Total Funds: India Component of Rs 347.39 Lakhs (IIT Delhi component 46.12 Lakhs)	MoES/NERC (UK) Changing Water Cycle Program