IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	**The thermodynamics of global monsoons**	
Project Number	**IMURA1088**	
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Monash Co-supervisor(s) (Name, Email Id, Phone)	None	
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IITB Co-supervisor(s) (Name, Email Id, Phone)	None	*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof. Subimal Ghosh, head.climate@iitb.ac.in	*Full name, email*
IITB Department:	IDP in Climate Studies	

Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address?
*(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*

1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	*Math, CFD, Modelling, Manufacturing*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*
5	***Earth Sciences and Civil Engineering (Geo, Water, Climate)***
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
	HSS, Design, Management

Research Themes:

Highlight which of the Academy's Theme(s) this project will address?
(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1	***Artificial Intelligence and Advanced Computational Modelling***
2	*Circular Economy*
3	*Clean Energy*
4	*Health Sciences*
5	*Smart Materials*
6	*Sustainable Societies*
7	*Infrastructure*

The research problem

Statement:

Monsoons are one of the fundamental ingredients of the tropical climate influencing the lives of billions (Wang and Ding, 2008). They have a deep-rooted influence on the planning across sectors such as logistics, agriculture, travel, tourism, the economy and so on. Monsoons are characterised by rapid onset, slow retreat and feature sub-seasonal variability (Geen et al., 2020). While a vast literature exists regarding the observational characterisation, numerical simulation, and prediction of these features, we still lack a basic understanding about the physics of monsoons (Biasutti et al. 2018). The recent advancement in computation allows for designing simulations that can resolve the details of convection to evaluate the physical assumptions encoded in Climate Models that have large errors in simulating monsoons.

The representation of convection in climate models centrally relies on the convective quasi-equilibrium (CQE) hypothesis which proposes that the conditions in the atmospheric boundary layer (as measured by the boundary layer equivalent potential temperature) largely control the latitudinal extent, intensity and spatio-temporal features of monsoons (Nie et al. 2010, Hill 2019). This project will explore the limits of CQE in explaining rapid onset, slow retreat and sub-seasonal features of monsoon variability and evaluate possibilities to extend the CQE hypothesis. A set of idealised simulations will be carried out to generate a physically consistent high-resolution version of convective structures during monsoons. The understanding gained of the limits of CQE theory will be used to suggest improvements in representation of convection in climate models.

References:

1. Biasutti, Michela, et al. "Global energetics and local physics as drivers of past, present and future monsoons." *Nature Geoscience* 11.6 (2018): 392-400.
2. Geen, Ruth, et al. "Monsoons, ITCZs, and the concept of the global monsoon." *Reviews of Geophysics* 58.4 (2020): e2020RG000700.
3. Hill, Spencer A. "Theories for past and future monsoon rainfall changes." *Current Climate Change Reports* 5.3 (2019): 160-171.
4. Nie, Ji, William R. Boos, and Zhiming Kuang. "Observational evaluation of a convective quasi-equilibrium view of monsoons." *Journal of Climate* 23.16 (2010): 4416-4428.
5. Wang, Bin, and Qinghua Ding. "Global monsoon: Dominant mode of annual variation in the tropics." *Dynamics of Atmospheres and Oceans* 44.3-4 (2008): 165-183

Project aims

1. Develop a climatology of thermodynamic and dynamic state during onset, retreat and different sub-seasonal features of monsoon variability with the help of high-resolution cloud resolving model experiments.

2. Evaluate how CQE is relaxed in these different states and identify how it can be modified for better understanding.

3. Use modified CQE to suggest improvements in representation of convection in Climate models.

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash

While in IITB the student will develop a background in Climate Sciences as well as get an exposure to the wider questions of Climate Mitigation, Adaptation and Policy. The student will phrase the science question and will identify its impacts. At Monash University, he will work on the theoretical aspects of the problem and will undergo training specific to understanding the nuances of the problem. The idealised modeling will be carried out both at IITB and Monash.

Expected outcomes

Highlight the expected outcomes of the project

1. Advancement in the fundamental understanding of monsoonal climates across the world.

2. Development of a tool to segregate different sub-seasonal features of monsoonal variability.

3. A generic set of high resolution – regional simulations (3 km x 3 km) and low resolution - global climate model simulations (~ 100 km x 100 km) that resolves sub-seasonal features of monsoons that can be used to improve the representation of convection in Climate Models with an ultimate aim to improve monsoon prediction.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

1. High resolution cloud resolving model employs state of the art developments in computational modeling

2. The parallel data processing toolkit used and developed to process Big Data will also involve use of high-end computational methods.

3. This project will explore possibilities of using high-resolution climate data to suggest improvements in representation of convection using modern AI / ML techniques.

How well the IITB and the Monash supervisor(s) know each other

Provide details of previous collaborations (if any). For new collaborators, have you had a chance to meet each other in person or through VC or Skype?

The supervisors have known each other for over 5 years since Dr. Dixit's postdoctoral stint in UNSW Sydney. While they do not yet have joint papers, they have had many scientific discussions, both in-person and online, and their research is well aligned. For example, in Bao et al. (2022), Dr Dixit used a prior theory of the tropical thermodynamic structure introduced in Singh & O'Gorman (2013) to help explain results of idealised simulations of tropical circulations.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

Monash:
Prof. Michael Reeder – expert on atmospheric dynamics and influence of midlatitude processes on monsoons
Prof. Steve Siems – expert on atmospheric modelling, including high-resolution cloud resolving modelling. Prof Siems has also participated in the IITB-Monash program as a supervisor.

IITB:
Prof. Subimal Ghosh – Expert in Hydro-Climatology of Global monsoons. He was involved in adding "Earth Sciences and Civil Engineering" research cluster in IITB-Monash academy.
Prof. Karthikeyan Lanka – Expert in Land-Atmosphere interactions during Indian Monsoon

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

An ideal student would have a strong background in physics, mathematics or related disciplines. Previous coding experience and background in meteorology or atmospheric science is beneficial but not necessary.

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

Introduction to Climate Science
Atmospheric and Oceanic Dynamics
Atmospheric Thermodynamics
Monsoons and Tropical Climate

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Monash:
Prof. Christian Jakob – expert in atmospheric convection and convection parameterisation in models. Prof Jakob may have an interest in collaborating with us on developing ideas for improving convection parameterisations in climate models.

Prof. Ashwin Seshadri (IISc Bangalore) – An expert in theoretical climate modeling. His work on simple monsoon models could be relevant to this PhD proposal.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

1. **Modelling and Simulation,**
2. **water, climate change**
3. **Computational fluid dynamics**