National Institute of Technology Rourkela

Synopsis Seminar

Seminar Title	: Role of changes in the regional climate forcings in governing Indian summer monsoon variability after the late 1990s
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Abstract	: This thesis investigates the significant shifts in Indian Summer (South Asian) Monsoon rainfall patterns observed since the late 1990s, with particular emphasis on the changing regional climate forcings that govern this variability. Through a comprehensive analysis of synoptic-scale systems such as Monsoon depressions (MDs), tropical and mid-latitude dynamical interactions, and teleconnections, this research documents and explains the recent dramatic shifts in rainfall patterns, with northwest India experiencing a 24.6% increase while rainfall in the Indo-Gangetic Plain has decreased 4.4%. This dipole pattern is not reproduced in historical climate model simulations, and its physical drivers remain poorly understood. Synthesising observational and assimilated data and climate model simulations, we show that this dipole is driven by North Atlantic sea surface temperature (SST) changes, which are transmitted through a barotropic governor mechanism and operate to control Asian jet stream dynamics. Enhanced barotropic energy conversion after 1999 created momentum focusing in the jet core while weakening east-west flanking regions, which fundamentally altered the monsoon circulation by modulating the local Hadley cell, resulting in a 1.37 shift of the low-level monsoon jet. These circulation changes subsequently induced warming in the northern Arabian Sea by altering regional ocean dynamics. Hence, increased formation of MDs over the northern Arabian Sea in the recent decade. This barotropic governor activation coincides with the North Atlantic &ldquocold blob&rdquo attributed to a slowdown in the Atlantic Meridional Overturning Circulation(AMOC). Coupled climate models driven over the historical era systematically fail to reproduce North Atlantic SST changes, and so this atmospheric dynamical mechanism instead shows reversed barotropic energy conversion patterns and misses this key teleconnection mechanism. Prescribed SST experiments using observed North Atlantic SST changes validate the proposed mechanism, thereby successfully reproducing both observed jet dynamics and rainfall trends. The identification here of a North Atlantic-Asian teleconnection pathway modulated by the barotropic governor effect directly links the behaviour of the AMOC and monsoon tipping elements to each other. This research fundamentally transforms our understanding of monsoon predictability by establishing how North Atlantic Ocean conditions influence South Asian precipitation through previously unknown atmospheric pathways, explaining why current climate models fail to capture these critical teleconnections and providing essential insights for enhancing water security, improving agricultural productivity, informing climate adaptation planning, and developing new pathways for improving seasonal monsoon forecasts and climate change projections across South Asia. Keywords: Indian Monsoon Monsoon depressions Rossby Waves Low-Level Jet jet stream dynamics Atlantic-Asian teleconnections barotropic governor AMOC Arabian Sea warming.