Summary of the Panel Discussion of the Eighth WMO International Workshop on Monsoons (IWM-8) held on 21st March 2025

Panel Discussion of IWM-8

Monsoons in a Changing Climate: Integrating Science, Prediction, and Societal Preparedness

Time: 16:30-17:30, 21 March 2025
Panelist: Drs. Smrutishree Lenka, Kunio Yoneyama, Thara Prabhakaran, R. Krishnan, Matthew Collins.
Facilitators: Drs Hindumathi Palanisamy and Liye Li
Note takers: Lian Xue and Liye Li

Session Overview: This panel discussion synthesized key insights and outcomes from the IWM-8 workshop (17–21 March 2025), drawing on the latest research, case studies, and technological advancements presented throughout the week. It provided a platform for panelists, including an ECR and audience to discuss how emerging scientific knowledge can be translated into improved monsoon predictions, disaster preparedness, and climate resilience strategies.

1. **Advancing Observations through Field Experiments & Multi-Platform Data**:

   Key Questions:

   How can field campaigns be better designed to capture key process of monsoon in multiscale and across regions. What strategies can improve coordination and data integration across international observational programs (e.g., GPEX, Asia-PEX)? How can access to multi-source, multi-scale observational data be improved, especially for early-career researchers?

   Key Points:

   - Coordinated multi-region field campaigns that integrate various atmospheric, oceanic, and land-surface processes are essential for capturing the complexity of monsoon processes. International organizations are expected to take a role in fostering collaboration across regions and globally.
   - Emerging technologies (e.g., microphysics sensors) offer new opportunities to study fine-scale phenomena linked to large-scale variability.
   - Data fragmentation and lack of discoverability were cited as significant barriers, especially for young scientists. A unified "single window" platform was proposed to consolidate datasets and metadata from past campaigns.

2. **Monsoon Variability, Change, and Extremes in a Warming Climate**:

   Key Questions:

   How are remote drivers such as ENSO, IOD, AMOC, and MJO evolving in their influence on regional monsoon systems? What is the role of thermodynamic versus dynamic controls in shaping regional monsoon characteristics? What are the mechanisms driving increases in extreme rainfall and other compound weather events across monsoon regions?

   Key Points:

   - There is growing evidence that ENSO influence may be weakening, while Indian Ocean warming and other drivers are gaining importance.
   - Teleconnection pathways involving convective heating, dry air intrusions, and midlatitude influences are complex and merit more extensive investigation.
   - Sudden and high-impact events, sometimes in previously unaffected areas, are increasing, and current models often fail to capture their spatial or temporal characteristics.
   - Regional monsoon systems have unique propagation and variability patterns that require localized investigation.

3. **Enhancing Monsoon Prediction & Modeling Capabilities**:

   Key Questions:

   What are the root causes of long-standing model biases, particularly in moisture transport, precipitation distribution, and ocean–land gradients? How can high-resolution modeling, improved physical parameterizations, and process-informed diagnostics improve seasonal and sub-seasonal forecasts? What is the role of artificial intelligence and machine learning in enhancing prediction skill, and how can hybrid AI–physics approaches be developed responsibly?

   Key Points:

   - Persistent biases across CMIP generations point to unresolved issues in physical parameterizations and inadequate representation of key processes (e.g., boundary layer, vertical moisture transport). Process diagnostics such as vertical profiles were recommended to better identify and address model failures.
   - AI and ML are showing value in post-processing and bias correction, especially when integrated with physical models. There was consensus that while AI is promising,

physical understanding must remain central, and hybrid modeling approaches should be prioritized.

- Access to computing infrastructure—including cloud-based modeling tools—was identified as a potential game-changer for lower-resource regions.

4. **Bringing Research into Operations & Decision-Making for Strengthening Societal Preparedness and Resilience**:

   Key Questions:

   How can the gap between research outputs and operational forecasting be reduced? What institutional mechanisms can foster sustained collaboration between researchers and operational agencies? How can scientific knowledge be effectively translated into tools and services that empower local communities and support policy?

   Key Points:

   - There is a disconnect between academic research and the practical needs of forecasters; embedding researchers in operational settings and co-designing projects with forecast agencies was widely recommended.
   - Impact-based forecasting, especially in urban centers, requires high-resolution data, reliable nowcasting systems, and understanding of how communities perceive and respond to warnings.
   - The lack of resources and data-sharing at the local level limits the ability of municipal governments and community institutions to act on climate information.
   - The need to bring science to the "last mile" is emphasized, suggesting collaboration with local governance bodies, NGOs, and development sectors to deliver tailored and actionable climate services.