CLIVAR Grand Challenge #1: Intraseasonal, seasonal and interannual variability and predictability of monsoon systems

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Description

Monsoon systems represent the major mode of annual climate variability on the planet and supply the majority of rainfall to often vulnerable and developing nations. At intraseasonal and interannual levels, being able to predict monsoon variability is of vital importance to food security, water supply and economy. Yet current models are often poor at simulating and predicting these aspects of the monsoon (Gutzler *et al.*, 2009; Wang *et al.*, 2008; 2009; Zhou *et al.*, 2009; Dominguez *et al.*, 2010; Turner *et al.*, 2011; Sperber *et al.*, 2012; Turner and Annamalai, 2012), and seasonal prediction efforts often yield low levels of skill (Langford and Hendon, 2013; Rajeevan et al., 2012).

The overarching goal of this challenge is thus to *enable better predictions of the intraseasonal to interannual variability of monsoons* at a regional and local level.

Processes:

- Can we make links between modes of monsoon variability? For example, do large-scale drivers such as ENSO affect the statistics of monsoon intraseasonal variability in addition to the seasonal mean, offering a *cascade of predictability*? Does this extend to modulation of monsoon synoptic, intraseasonal, seasonal and interannual behaviour by decadal variability and mean state change?
- What can be gained in terms of predictive skill in terms of consideration of the global monsoon and its relationship to large-scale drivers? To what degree do cross-hemispheric forcings contribute to variability in the timing and strength of the monsoon systems? Are regional monsoons across the global monsoon domain driven by the same drivers at interannual and interdecadal time scales?
- What can be learnt from teleconnections and other dynamics linking monsoon regions to remote forcing from other modes of climate variability and mid-latitude interactions? For instance how does the NAO/AO/AAO and PSA affect the monsoons?

Characterising and observing:

- Are there opportunities to reconcile some of the large differences between analysis products and observational datasets to provide a

more consistent framework for monsoon analysis? If so, what are the priority observations not currently in existence or being made available?
- How does the relative importance of different spatio-temporal modes of monsoon variability differ from one monsoon to the next?
- What are the commonalities and differences in forcing mechanisms amongst the various regional monsoons? For a given regional monsoon (e.g., North American, South American, African, Indian) what are the relative influences of large-scale and local forcing mechanisms?

Modelling and prediction:

- How predictable *is* summer monsoon rainfall or winter monsoon temperature in various regions and on various time scales from intraseasonal to interannual?
  - How can representation of monsoon synoptic and intraseasonal variability be improved and does this yield concomitant improvements in the mean state and seasonal forecasting capability?
  - Is adequate attention being paid to the diversity of variability in the low-frequency lower boundary conditions including marine and land surfaces, such as canonical East Pacific El Niño versus El Niño Modoki?
  - What are the major missing observational elements that can be used to improve initialised forecasts of the monsoon? (For example: the land surface; atmospheric composition including aerosol.)
- How can we improve model performance and predictability by using satellite and other remote sensing data?
- How important are precipitation errors developing within the first days of a forecast to the overall predictive skill and what role does resolution play in this regard?

The major themes (primed for progress in the next 5-10 years)

- Better constraint of modelled monsoon variability and change based on observation-informed process studies and the development of more reliable reanalysis products;
- Improve models and data assimilation systems to better represent the key processes involved in monsoon intraseasonal, seasonal and interannual variability, including ENSO and the IOD;
- Extend efforts to improve predictions of monsoon variability and change using land surface modelling and incorporation of improved land surface initialisation;
- Continued improved physical understanding of monsoon variability in the context of natural (decadal) variability and anthropogenic change;

- High-level efforts to make observed in-situ data more available to the global community and enhance observing systems over the monsoon regions, particularly to better constrain surface fluxes and atmospheric composition fields including aerosol;
- Enhance ties to users of the variety of monsoon forecasts and aid development of products geared to specific societal use.

The way forward

- Engage with the other CLIVAR Grand Challenges in order to embrace cross-cutting issues (particularly decadal variability);
- Maintain international collaboration in coordinated experiment design (such as intraseasonal or seasonal hindcast experiments, observing systems and data sharing and in identification of future research foci) and in efforts such as the S2S[1] initiative;
- Improve links between the (current) CLIVAR regional monsoon panels and under the proposed new PMAP[2] for better synergy;
- Embrace programmes such as GEWEX (including GLASS[3]) and iLEAPS for exploiting knowledge of convective and land surface processes;
- Ensure international coordination on efforts to perform computationally expensive high resolution research.
- A WCRP-led report on the current state-of-affairs of monsoon seasonal prediction skill, incorporating DEMETER, ENSEMBLES etc.

Capacity building (see SSG-19 report Appendix.)

- Encourage WCRP CLIVAR input into regionally coordinated forecast assessment and sharing activities (such as the Climate Outlook Fora) in order to improve methodologies.
- Encourage participation of developing nations within the monsoon domain to engage in coordinated science and in particular to invest in young scientists (requires high-level WCRP support).

Communication challenges

Perhaps the largest challenge in communicating with end-users is the perceived relevance of the information given, particularly at the climate timescales, which are often discounted. There is a potential synergy in linking the scales of variability such that climate projections can be explained in terms of changes to day-to-day rainfall variability.

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[1] Subseasonal to Seasonal Prediction Initiative, http://www.wmo.int/pages/prog/arep/wwrp/new/S2S_project_main_page.html.
[2] The proposed Pan-WCRP Monsoon Advisory Panel (PMAP).
[3] GEWEX Global Land/Atmosphere System Study, http://www.gewex.org/glass.html.

Summary

Monsoon systems truly represent a Grand Challenge to the CLIVAR community, particularly in tapping expertise in other areas, to benefit predictability through better understanding of land-atmosphere interactions, for example. The other major area to benefit from coordination is in bringing together the wealth of observational information in order to better constrain our models and understand monsoon processes.

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