Discussion Summary for Air-Sea Interactions and Warm Season and Monsoon Climate Variability.
Chairs: Chris Bretherton, Dick Johnson, Eric Maloney, and Roberto Mechoso

A. Gaps in Knowledge

The following questions were broached, and issues raised:

1) To what extent is climate variability in the Intra-America Seas and the warm-season Americas internally versus externally forced?

• The IAS region is associated with strong intraseasonal variability in SST, winds, and precipitation. Can this strong variability exist in isolation from the global MJO? If so, does it phase lock to the MJO due to a similar timescale?

It was noted that this question has large consequences for intraseasonal prediction in the Americas. Support was voiced for further study of MJO impacts on hurricane statistics, and the consequences for prediction. The consensus view was that we need to better understand the role of nonlocal effects (e.g. MJO) vs. local coupled ocean-atmosphere processes on intraseasonal timescales for convection, SST, TCs.

• Can tropical synoptic-scale disturbances be generated in-situ from the east Pacific, without being seeded from African easterly waves?

It was noted that wide discrepancies exist in estimates of the fraction of African easterly waves that cross the Isthmus of Panama and reach the east Pacific. East Pacific easterly waves often develop into tropical cyclones (itself a difficult and imperfectly understood forecast problem). Experience from EPIC showed that it was difficult to determine which (if any) Atlantic easterly waves might redevelop into easterly waves and/or tropical cyclones in the East Pacific. It was also noted that pathways might exist for local generation of easterly waves in the Caribbean and Pacific, in isolation from easterly wave propagation from Africa, although debate still exists about how important this is.

• Some models produce a strong interannual precipitation and wind response in the IAS region, while others do not. Which are realistic? Are our models good enough yet to study IAS and North American warm seasonal variability?

There are large coupled-model biases in rainfall over the IAS region, which might have significant consequences for climate prediction there. These biases point to improvements that need to be made to parameterizations of clouds and convection. Model convection in these regions might be improved by increasing the sensitivity of the schemes to free tropospheric moisture, which might also aid simulation of phenomena like the MJO. However, in many cases climate models have chosen parameters to balance between better simulations of mean rainfall and vertical atmospheric structure and better simulations of its variability, suggesting that more that parameter retuning will be required to improve both the mean structure and variability of convection over the Western Hemisphere warm oceans.
2) What are the underlying mechanisms behind the mid-summer drought (MSD)?

- In particular, which of the following regulate this mid-summer minimum in North/Central American precipitation? Possible strawman mechanisms: SST-convection-radiation feedback, land-sea temperature contrasts, variability in the North American subtropical high, similar climatological active/break cycles in Asian monsoon heating and teleconnections to the W. Hemisphere. The Caribbean low-level jet

The underlying mechanism of the MSD still remains murky. It was noted that the key to the MSD might lie in northward migration of the 200 hPa anticyclone, and associated development of a tropical upper-tropospheric trough over the Gulf of Mexico extending into Central America. The Rossby wave response to sensible and latent heating over the desert southwest and associated subsidence to the south was also mentioned as a possible MSD mechanism. Others cited the need to examine what regulates the Caribbean low-level jet. It is thought that the regulatory mechanisms for the MSD need to be examined in relation to similar processes in the Asian monsoon system, and further, the mechanisms that regulate a mid-summer minimum in precipitation in the Americas may vary on a region by region basis.

- Some years a mid-summer drought does not occur. What is responsible for interannual variability in the MSD? Possible mechanisms include: The MJO, ENSO (including its impacts on the Western Hemisphere warm pool the next spring/summer).

3) What regulates the diurnal cycle? Particular issues include:

- Details of diurnal cycle over orography
- Offshore propagation of convection (gravity waves?)
- Modulation of diurnal cycle by intraseasonal phenomena (easterly waves, gulf surges, MJO, etc.)
- Vegetation impacts – pre- and post-monsoon onset

It was noted that the IAS sea breeze might be very important for regulating the diurnal cycle of precipitation over land. Models have a particularly difficult time simulating the diurnal cycle. Diurnal variations in energy fluxes over the oceans was noted as a particular hurdle, which might be related to inability to simulate the diurnal mixed layer in coupled models, and lack of any ocean dynamics in uncoupled simulations.

4) Is it important to accurately represent the diurnal cycle in order to achieve realistic simulations of regional and mean structure of the monsoons of the Americas? Is the oceanic diurnal cycle important?

- Does diurnal cycle of SST modify sea/land breezes?
- Neale and Slingo (2003) – climate version of HadAM3: inability to simulate the diurnal cycle over the Maritime Continent leads to a systematic underestimate of
precipitation in that region, as well as regional Walker Circulation-induced precipitation biases over the Indian Ocean and modifications of the extratropical response to the Maritime Continent heat source

- Danabasoglu et al. (2006) – CCSM3: incorporation of an idealized diurnal cycle of solar forcing (as opposed to a mean diurnal cycle) leads to improvements in representation of the mean ocean boundary-layer depth, SST, and surface currents.

To what extent are the above results related to the diurnal cycle (for the eastern Hemisphere) relevant to the Western Hemisphere Warm Pool and American Monsoon region?

5) **To what extent are the monsoon systems of the North and South America coupled?**

- Are the onset and demise of the monsoon in one hemisphere linked to the demise and onset in the other?
  
  It was noted that the southern Hemisphere monsoon onset and demise are definitely accompanied by a reversal of the cross-equatorial flow in the Western Hemisphere. The monsoons may be characterized by large-scale connections between land and ocean, spanning northern and southern hemispheres, e.g. as complementary branches of overturning circulations. Where is this a useful way to think? Where is this not?

  - What are the cross-hemispheric characteristics and impacts of the Hadley circulations associated with the American monsoons?
  
  It needs to be examined what determines the vertical structure of the overturning circulations, for example the E Pacific cross-equatorial flow.

  - Does the NAO or other NH climate variability influence climate variability over South America?
  
  - Is the cross-equatorial flow in the eastern Pacific part of a larger-scale coupling between the North and South American monsoons? Is there a role in for this flow in EPAC tropical cyclone activity?

6) **What are the impacts of aerosols on climate prediction?**

The need was cited to study impact of aerosols on radiative forcing and thus monsoon transitions in the Americas. Land areas like Mexico are large aerosol sources. High priority should be placed on including these impacts in models. It was noted that including aerosol impacts in the GFDL AM3 has very large local climate impacts. Further, it would be useful to measure aerosols wherever NOAA CPPA-supported cruises go, for validation of global climate models, which are starting to include aerosol transport and cloud-aerosol feedbacks.

**B. Impact of Past Field Experiments**

- EPIC has provided insight into ocean-atmospheric coupling processes related to intraseasonal-to-interannual climate variability in the eastern Pacific and surrounding region
It was noted that EPIC observations have been documented to improve some climate models. Comparisons of EPIC data with model output from the GFDL, NCEP, NCAR, ECMWF and U. Hawaii models, as well as with high-resolution models, have been published that document particular strengths and weaknesses of these models’ simulations of boundary layer cloud and deep convective processes.

- NAME has provided detailed description of the NAM precipitation response to intraseasonal variability (MJO, easterly waves, cold surges)
- NAME has provided detailed documentation of the diurnal cycle of the boundary layer and deep convection

C. Future Near-Term Priorities and Specific Activities

- Conduct further and more detailed comparisons of climate and regional model simulations to field data from NAME, EPIC, SALLJEX, pre-VOCALS, VOCALS, and satellite datasets (e.g., boundary-layer structures, timing of diurnal cycle, low-level jets, etc.)
- Conduct modeling studies related to IAS climate variability

It was very strongly suggested that we need to better define science hypotheses around which to shape a possible IASCLiP field study. It is difficult to define a field experiment without important guiding scientific questions.

- Optimal combination of satellite data to sample diurnal cloudiness/precipitation variability, mid-summer drought, etc.

D. Paths to Improved Climate and Hydrologic Prediction

- Conduct further and more detailed comparisons of climate and regional model simulations to field data from NAME, EPIC, SALLJEX, VOCALS, and satellite datasets (e.g., boundary-layer structures, timing of diurnal cycle, low-level jets, etc.)
- Improve parameterizations in flagship climate and weather forecasting models (e.g. deep and shallow convection, stratocumulus, stratiform clouds), recognizing that many model biases involve tight interactions between several different parameterized processes that require a systemic approach to model physics improvement.
- High resolution simulations