Breakout 3: Atmospheric Convection

Objective: To identify opportunities for integrating convection modeling and Observations

Discussion Questions:

1. What are the main progress during the past decade and key remaining gaps in observing, understanding, and modeling of tropical convection over the ocean?
2. What new technological tools are available that need to be developed to further model-observation integration to advance understanding, modeling, and prediction of tropical convection over the ocean? How to combine studies on tropical convection and air-sea interaction in a way that is impossible in the past?
3. Which existing coordinated activities could be leveraged to address these challenges and what new ones could be put together that will further model observation integration to advance understanding, modeling, and prediction of tropical convection over the ocean?
4. What are the key lessons learned from past activities regarding the separation and integration of studies on modeling and observations of convection and studies on convection and air-sea interaction that could potentially benefit future activities?

Breakout 3, Group 1

Lead: Angel Francisco Adames-Corraliza

Co-Chairs: Hyodae Seo and Elizabeth Thompson

#1. Progress and Gaps

Progress:

Better understanding of cloud processes, including microphysics.

Development of “Process “ oriented diagnostics” for different climate models that highlight physical processes in simulations

Gaps:

Need to improve understanding of the behavior of *ensemble* of convection, rather than individual convective cells.

We need to elucidate the role of waves –under high wind conditions– in air-sea fluxes, and their role in convective onset.

Need to better understand convection organization in time and the mechanisms of convective initiation/transition.

#2. Technological tools

High-resolution regional climate models with explicit convection to examine the mechanisms and processes.

Need for high spatial and temporal coverage of the boundary layer and the ocean.

Need a more robust description of boundary layer processes with the use of, for example, saildrones.

A network of vertically pointing WV dials to understand water vapor variations in space and time of q in space and time.

Combining drone data with soundings.

Vertical wind profilers to to calculate the vertical velocity of convective systems. Need observations with good spatial resolution to validate model vertical winds.

Need to better understand diversity of available datasets, their uses and limitations.

#3. Existing activities

Coordinated activities through NCAR, CLIVAR, GEWEX.

Emphasis needs to be placed on measuring convective cloud velocities.

Radar - satellite obs coordinated activities have helped us understand the limits of satellite rain products.

Concern about the reduced used of aircraft measurements, concerns about costs of in-situ observations. Cost is increasing and fund availability scarce.

Field campaigns in the future need to be led with science questions, and it needs to meet gaps in learning, and have logical next steps

Explore an area where ocean/atmosphere can both play roles in convection and air-sea interaction. Eg, TPOS eastern edge of the western Pacific Warm pool.

Identify the forecast skill over the target region with pre-modeling experiments or evaluate the existing S2S database.

Satellites (e.g. TRMM): can describe the 3D structure of convection, but need technologies that reveal dynamical processes.

#4. Key Lessons

Early preparation is the key.

Need to know what has been already done and what is routinely measured etc in the region.

Improved coordination between observational and modeling community is needed. A virtual campaign could help improve communication amongst communities

Breakout 3: Convection modeling and observations (Group 2)

Recent progress over last decade:

Observational

- Capability to simultaneously remotely sense various parts of the tropical cloud population (from shallow precipitating and non-precipitating to deep convection) using multi-frequency radar platforms
- Realization of the importance of shallow clouds to dynamics in variety of environmental regimes and on a variety of spatio-temporal scales

Modeling

- Ensemble data assimilation
- Stochastic parameterization of sub-grid scale variability
- Increased computational capability == increases in model resolution

Remaining Gaps:

- Observations and modeling of the pre-convective boundary layer and subsequent shallow convection (even though the technology is available to do so!)
- Vertical velocity in convection, especially over oceans. (Current dual-Doppler retrievals have very large uncertainty.)
- 3D observations of boundary layer and shallow clouds using remote sensing techniques (e.g. scanning cloud radars and lidars)
- Coupled reanalyses and coupled data assimilation
- Comprehensive knowledge of structural errors in models
- Data management for observations globally, making query and access of data easy for users. Having a central repository of data with advanced search capabilities. Will this require collaboration/integration with private sector?

Breakout 3: Convection modeling and observations (Group 2)

Technological Advances:

- Ship-based SEAPOL (dual-polarimetric sea-going radar) permits observations or derivations of cloud kinematics and microphysics. Rain rate estimates also provide information about fresh water on ocean surface.
- Satellite passive microwave retrievals of temperature and humidity in lowest 1 km of atmosphere (~15 km horizontal and ~1 km vertical grid spacing)
- Scanning cloud radars, lidars to complement vertically pointing instruments at similar frequencies
- Future satellite data might provide some information on vertical mass fluxes at observable spatial scales
- UAVs can directly sample boundary layer and cloud environment (Difficult with strong wind however!)
- GPUs for modeling and Machine Learning?

Challenges/remaining questions:

- For LES modeling, parameterized turbulence and cloud physics, and treatment of surface conditions. Also, current domain size of typical LES is too small to contain MCSs
- “Super-parameterization” in CRM using 2D LES to replace shallow-cloud parameterization in CRM
- What are the spatial scales of the observations we need? These depend on the processes we seek to understand, but processes that occur on O(100-1000) km feedback onto processes that occur on O(0.1) km and vice versa. Scientific questions should be clearly identified to guide this question.
- From a DA perspective, the model scale is the largest spatial scale we want for observations, but we have a wide range of model spatial scales!

Recommendations:

- Regardless of spatial scale, any observations of clouds should be accompanied by observations of the cloud environment (e.g. T, q, u, v).
- DYNAMO legacy dataset could be a blueprint for improving field data management.
- Furthermore, data management should be actively considered in the planning stages of observational collection.
- Integrated modeling activity should also be considered at early stage of planning for collecting observations as well. Models’ grid sizes should be consistent with the scale(s) of the physical process(es) targeted by the obs.

Breakout 3, Group 3

Juliana Dias

Breakout 3: Convection modeling and observations session

Observations

“New” technology

Dual-polarization radar measurements;

satellite products (TRMM/GPM, CloudSat, MODIS, Aeolus – wind profiles)

Gaps:

radar measurements are still very expensive

vertical profiles in the tropical atmosphere (heating, mass fluxes);

Modeling

“New” technology:

Global high resolution (cloud permitting, fully coupled) are now possible.

Coupled data assimilation

Gaps:

how to use observations and high resolution coupled model simulations of tropical convection to inform model development?

comparison between models and actual, not gridded, sparse in-situ data are difficult*

**DYNAMO legacy dataset provides gridded data*

Breakout 3: Convection modeling and observations session

“key scientific problems in tropical convection and/or air-sea interaction”

- Interactions of convection with surface fluxes are not well understood
(boundary layer problem)

“the innovative integration and modeling and/or observational technology/methodology for addressing them"

- Importance of having obs and modelers work together on development of field campaigns “from day 1”
- It is also important to have a few common science questions that the community wants to address.
- Need for improved observations of boundary layer processes
- Inform physical parameterizations by using “new” statistical tools that take advantage of those observations in combination with fully coupled reanalysis data

Breakout 3, Group 4

Lead: Simon de Szoeke

Co-Chairs: Samson Hagos and Kevin Reed

Convection Parameterization

- Reframing convection parameterization:
  - Represent by distributions of *observable properties*, rather than by the nonphysical parameters of entraining plume parameterization:
    - alternative approaches: stochastic models, superparameterization, cloud population models, machine learning.
  - Consider models’ degrees of freedom vs. their structural complexity.
  - Assess feasibility and readiness for these approaches.
  - Machine learning offers opportunities to improve modeling, but might not help in specific understanding of convective processes.
- Classify process scales and model resolution and to identify effective observations and parameterization approaches.
  - Identify *gray scales** of present and upcoming numerical models.
    - *gray-scale model resolution is too coarse to resolve individual convective clouds, yet too fine represent convection statistically.
  - Partial coupling approaches to advance of air-sea-convection interactions with modeling.
  - superparameterization, scale aware parameterization

Convection observations

- Observe and model covariances:
  - air-sea interaction: SST, surface wind, precipitation, solar radiation, vertical velocity
  - phasing among different surface fluxes, and their components.
  - mass fluxes, vertical velocity fluctuations, buoyancy and moisture flux, aerosol mass fluxes.
- Observe variety of convective conditions, and convection cases in marginal: half depth convection.
- Observations facilitated by new technology:
  - turbulence in clouds and the subcloud boundary layer: remote sensing of velocities and density variations
  - multiple phased array Doppler radar/lidar,
  - cloud penetrating aircraft and/or UAVs
  - multiple field experiments, and super-site for long term observations and modeling