Abstracts

Banff Workshop: Stochastic and organization of tropical convection

Ajayamohan
Title: Simulation of monsoon intraseasonal oscillations and low pressure systems in a coarse-resolution aquaplanet GCM

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Abstract: The skill of the global climate models (GCMs) to realistically simulate the monsoon intraseasonal oscillations (MISOs) is related to the sensitivity of their convective parameterization schemes. Our earlier studies has revealed that by coupling a simple multicloud parameterization to a coarse-resolution aquaplanet GCM, low frequency oscillations in the atmosphere like Madden-Julian Oscillations (MJO) and MISOs can be simulated. Here, we conduct three different simulations with a fixed nonhomogeneous sea surface temperature mimicking the Indian Ocean/western Pacific warm pool (WP) centered at the three latitudes 5N, 10N, and 15N, respectively, to replicate the seasonal migration of the Tropical Convergence Zone (TCZ). This results in the generation of mean circulation resembling the monsoonal flow pattern in boreal summer. Succession of eastward propagating MJO disturbances with phase speed, amplitude, and structure similar to summer MJOs are simulated when the WP is at 5N. When the WP is located over 10N, northward and eastward propagating MISOs are simulated. This case captures the meridional seesaw of convection between continental and oceanic TCZ observed during boreal summer over South Asia. Westward propagating Rossby wave-like disturbances are simulated when the WP is over 15N congruous with the synoptic disturbances seen over the monsoon trough. The initiation of intraseasonal oscillations in the model can occur internally through organization of convective events above the WP associated with internal dynamics. Sensitivity of various cloud related parameters like formation and residence time of startiform and deep clouds to the monsoon trough are also explored.

Phil Austin
Title: Cloud entrainment and detrainment in high resolution simulations of
tropical convection.

Abstarct: We use high resolution simulations of shallow and deep convection to directly estimate entrainment and detrainment rates of thousands of individual clouds tracked over their life-cycle. Our simulations allow us to mapthe impact of cloud and environmental properties (height above cloud base, vertical velocity, critical mixing fraction, environmental lapse rate and buoyancy) on entrainment and detrainment rates of a passive tracer and vertical momentum. Paired correlations and measures of the mutual information point to the buoyancy and the environmental stability as the primary controls for entrainment, while vertical velocity and the critical mixing fraction control detrainment. We compare the entrainment and detrainment rates found from these direct calculations with bulk estimates from the moist static energy budget, and look at the implications for the development of large-scale parameterizations of convective mixing.

Hugo Bellenger (JAMSTEC)
Title: Diagnostic of small-scale processes and of their role in low-tropospheric moisture budget from in situ observations: the cases of shallow convection and turbulence.

Abstarct: Lower-tropospheric (1-4 km height) moisture is a key factor for tropical climate variability and in particular for the triggering of a convective phase of the MJO. The important role of large-scale advections in moisture budget is largely admitted. However, the role of small-scale processes (usually parameterized in global models) is still debated, as for shallow convection, when not simply neglected, as it is the case for turbulence. Using observations from the 2011-2012 CINDY/DYNAMO campaign in the Indian Ocean, we present first attempts (1) to directly quantify shallow convection impact on the scale of the cloud and its resultant on mesoscale using high-frequency Raman lidar observations and (2) to diagnose the impact of clear air turbulence on the diffusion of moisture during suppressed phase of the MJO. The role of these processes in moisture budget and the associated uncertainties are discussed and compared to large-scale tendencies diagnosed from ECMWF reanalysis:

(1) Within a few tens of minutes and near shallow convection occurrences, we observed moisture anomalies of ~0.25–0.5 g kg^{-1} that correspond to tendencies of ~10–20 g kg^{-1} day^{-1}. On the scale of a few hours, the resultant mesoscale effect of the population of shallow convective clouds consist in anomalies of ~0.5–1 g kg^{-1} that correspond to tendencies of ~1–4 g kg^{-1} day^{-1}. Large-scale advective tendencies can be stronger than the moistening by shallow convection; however, the latter is a steady moisture supply whose importance can increase with the time scale.

(2) Turbulent patches of ~100 m depth are observed (by Thorpe technique on sounding data) in relation with large vertical gradients of specific humidity. Intense mixing is diagnosed within these intermittent patches. Three approaches are used to diagnose the overall effect of this intermittent turbulence. Large uncertainties on the corresponding eddy diffusivity coefficient arise from parameters hard to experimentally constrain. However, dry conditions are associated with steep moisture vertical gradients above the boundary layers. Owing to the uncertainties on the eddy diffusivity, these gradients can correspond to negligible or to significant moisture tendencies (~0.5-1 g kg^{-1} day^{-1}) during the recovery following a dry intrusion or the preconditioning stage of an MJO.

Steef Böing

Title: Convective cold pools and their effects on cloud formation

Abstract: Previous LES studies have identified a positive feedback between cloud size and convective cold pools (i.e. the cold outflows that form under a cloud due to the evaporation of hydrometeors). The formation of cold pools leads to the formation of wider and deeper clouds, which in turn leads to more precipitation. Cloud size is not only related to precipitation, but also to the rate at which clouds mix with their environment. Here, it is argued that explicitly accounting for variations in cloud size would benefit the representation of clouds in a convective parameterization. In particular, a parameterization that takes these differences into account could have a more realistic representation of in-cloud properties of convection.

It is also shown that the feedback between cold pools and subsequent cloud formation is modulated in the presence of surface features, and in particular topography. In the presence of topography, cold pools travel downslope and interact with warm air that ascends along the slope. This weakens the formation of clouds at the hill top, but the convergence between the cold pools and the upward slope flows also induces convection on the slopes.

Noah D. Brenowitz

Title: Enhanced persistence of equatorial waves via convergence coupling in the stochastic multicloud model

Authors: Noah D. Brenowitz, Yevgeniy Frenkel, and Andrew J. Majda

Abstract:Recent observational and theoretical studies show a systematic relationship between tropical moist convection and measures related to large-scale convergence. Peters, et. al. 2013 suggested that cloud fields in the column stochastic multicloud model compare better with observations when using predictors related to convergence rather than moist energetics (e.g. CAPE). Here, this work is extended to a fully prognostic multicloud model. A convergence coupled formulation of the stochastic multicloud model is implemented without wind-dependent surface heat fluxes. In a series of idealized Walker cell simulations, this convergence coupling enhances the persistence of Kelvin wave analogs in dry regions of the domain while leaving the dynamics in moist regions unaltered. These persistent waves are associated with a increase in the low-frequency variability of the Walker circulation on a time scale of 50 days. In essence, this method provides a soft convergence coupling that allows for

increased interaction between convection and the large-scale circulation, but does not suffer from deleterious wave-CISK behavior of the Kuo-type moisture budget closures.

Nan Chen
Title: Predicting the cloud patterns of the Madden-Julian Oscillation through a low-order nonlinear stochastic model

Abstract: We assess the limits of predictability of the large scale cloud patterns in the boreal winter Madden-Julian Oscillation (MJO) as measured through outgoing longwave radiation (OLR) alone, a proxy for convective activity. A recent advanced nonlinear time series technique, Nonlinear Laplacian Spectral Analysis, is applied to the OLR data to define two spatial modes with high intermittency associated with the boreal winter MJO. A recent data driven physics constrained low-order stochastic modeling procedure is applied to these time series. The result is a four dimensional nonlinear stochastic model for the two observed OLR variables and two hidden variables involving correlated multiplicative noise defined through energy conserving nonlinear interaction. Systematic calibration and prediction experiments show the skillful prediction by these models for 40, 25 and 18 days in strong, moderate and weak MJO winters, respectively. Furthermore, the ensemble spread is an accurate indicator of forecast uncertainty at long lead times.

Shengqian Chen
Title:Multiscale asymptotics for MJO skeleton and Tropical–Extratropical Interactions

Abstract: Mechanisms of MJO initiation/termination remain unclear. One triggering factor could be the barotropic Rossby wave which plays an important role in tropical-extratropical interactions. Here an energy-conserved model is proposed to include the barotropic and first baroclinic mode with moisture and convective envelope. The method of multiscale asymptotics is used with two time scales: the intraseasonal time scale of the MJO and a longer time scale for tropical-extratropical interaction. The model is then analytically reduced to an ODE system which allows for explicit illustration of multi-wave interactions. Numerical results from the ODE can be used to investigate the role of baroclinic Kelvin and/or Rossby waves and/or barotropic Rossby waves for MJO initiation and termination.

Shuyi Chen
Title: Stochastic Ensemble Modeling of Scale-Dependent Error Growth and Multiscale Interaction in Tropical Convective Systems
Shuyi S. Chen, Falko Judt, Ajda Saravin, and Brandon Kerns
RSMAS/University of Miami

Abstract: Prediction of tropical cyclones (TCs), especially the TC intensity, has not improved significantly over the last two decades. It is a challenging problem in part because of the multiscale processes governing TC intensity, which are not well understood. Like most non-linear, chaotic systems in the atmosphere and ocean, TCs have an intrinsic predictability limit. A systematic study of the intrinsic predictability of TC intensity is conducted using a set of cloud-resolving (1.3 km grid spacing) Weather Research and Forecast (WRF) model ensemble predictions. The ensembles are perturbed with a stochastic kinetic-energy backscatter scheme (SKEBS). Scale-dependent error growth is investigated by imposing stochastic perturbations with various spatial scales (from convective-synoptic) on the TC and its environment. This study aims to better understand the dynamic and physical processes contributing to the TC predictability and to assess uncertainty in TC prediction. The results show that, while the high-frequency error growth saturates within 1-2 days, the large-scale TC environmental circulation provides the source of predictability of TC mean vortex and wavenumber 1 asymmetry beyond 7 days for long-lasting, non-landfalling major TCs. The stochastic ensembles allow us to investigate the influence of TC internal dynamics, environmental circulation, and scale-dependent error growth TC intensity change and uncertainty in TC predictions.

A similar approach is used for better understanding of the large-scale convective initiation of the Madden-Julian Oscillation (MJO) over the tropical Indian Ocean. Observations from the Dynamics of MJO (DYNAMO) field

campaign showed that a complex multiscale interaction among convective cloud systems and their large-scale environment on time scales from hours to weeks, e.g., from convective cold pools to dry air intrusions associated with synoptic disturbances and to ITCZ, may be a key to the MJO initiation. However, the predictability of multiscale interactions, especially convective cloud systems and their upscaling influence on MJO, has not been studied systematically. Although the predictability of individual convective cloud systems is likely to be less than 1-2 days, the predictability of MJO initiation over the Indian Ocean could be much longer if the large-scale atmosphere and ocean processes are dominant factors. We conduct modeling experiments using the coupled atmosphere-ocean (WRF-HYCOM) developed at the University of Miami to better understand the physical processes and multiscale interaction. The coupled model is first evaluated using coupled air-sea observations (e.g., airborne GPS dropsondes and AXBTs, ship and buoy data) collected during DYNAMO to remove model biases. Stochastic ensembles will then be generated using SKEBS.

Hannah Christensen
Title: Stochastic Parametrisation: Representing Model Uncertainty in Earth-System Modelling

Hannah Christensen, Judith Berner, Dani Coleman and Tim Palmer

Stochastic parametrisations have been used for more than a decade in atmospheric models. They provide a way to represent model uncertainty through representing the variability of unresolved sub-grid processes, and have been shown to have a beneficial effect on the spread and mean state for medium- and extended-range forecasts (Buizza et al. 1999, Palmer et al. 2009). There is also increasing evidence that stochastic parametrisation of unresolved processes could be beneficial for the climate of an atmospheric model. There is evidence that including stochastic physics can reduce model biases through noise-induced drift (nonlinear rectification) (Berner et al. 2008), and that including stochastic physics enables the climate simulator to explore other flow regimes (Christensen et al. 2015; Dawson and Palmer 2015). It is also possible that, through representing the variability of unresolved sub-grid processes, stochastic parametrisation schemes could improve the internal variability of a model's climate.

We start by giving an overview of the variety of research being carried out by the Predictability of Weather and Climate Group at the University of Oxford. We then present results showing the impact of including the Stochastic Kinetic Energy Backscatter Scheme (SKEBS) and the Stochastically Perturbed Parametrisation Tendencies scheme (SPPT) in coupled runs of the National Center for Atmospheric Research (NCAR) Community Atmosphere Model, version 4 (CAM4) with historical forcing. Both schemes have a beneficial impact on the model climate. The SKEBS scheme significantly reduces mean biases in several fields whereas SPPT results in a significant improvement in the variability of the modeled climate. In particular, SPPT results in a significant improvement to the representation of the El Nino-Southern Oscillation in CAM4, improving the power spectrum, as well as both the inter- and intra-annual variability of tropical pacific sea surface temperatures.

Michel De La Chevrotiere
Title: Bayesian Inference for the Stochastic Multicloud Model using the Giga-LES Dataset

Abstract: The stochastic multicloud model (SMCM) was recently developed (Khouider, Biello, and Majda, 2010) to represent the missing variability in general circulation models due to unresolved featuresof organized tropical convection. In the SMCM parameterization scheme, convective elements areviewed as Markov processes with state transition probabilities that are conditioned on the largescale environment, and scaled by cloud transition time parameters. We develop a robust calibration methodology for the SMCM to estimate these cloud timescale parameters from simulated and in situ data. The calibration problem is formulated within a Bayesian framework to derive the posterior distribution over the model parameters. The model likelihood function involves the repeated calculation of large matrix exponentials, which we maintain computationally feasible using a parallel version of a preconditioning technique known as the uniformization method. Sampling of the high dimensional posterior distribution is achieved using the Markov Chain Monte Carlo technique. In this talk, I will present inference results for the SMCM cloud transition times based on the Giga-LES dataset (Khairoutdinov et al., 2009), an idealized GATE Large-Eddy Simulation of deep convection over the tropical Atlantic.

Qiang Deng
Title: The Role of Stratiform Heating in Simulating MJOs in a Stochastic Multicloud GCM

Qiang Deng (New York University Abu Dhabi)
Boualem Khouider (University of Victoria)
Andrew Majda (New York University and New York University Abu Dhabi)
R.S. Ajayamohan (New York University Abu Dhabi)

Abstract: The eastward propagating Madden-Julian Oscillations (MJOs) play a crucial role in determining the rainfall over the tropics and also influence the weather patterns around the Globe, but the realistic representation of MJOs in climate models is still a challenge due to inadequate representation of different clouds and their transition.

To have an adequate treatment of convection and the associated interaction across scales in the cumulus parameterization schemes, a stochastic multicloud model (SMCM) is developed. The convection heating rates in SMCM are set proportional to the area fractions of the three cloud types (congestus, deep and stratifrom), which are modeled through a judiciously constructed Markov birth-death process derived from a particle interacting lattice model.

The SMCM is coupled to a High-Order Methods Modeling Environment (HOMME) NCAR General Circulation Model (GCM). Simulations successfully reproduce the observed characteristics of MJOs over the Indo-Pacific warm pool. Further, SMCM-HOMME has been used to explore the cold-pool effect of stratiform heating on the planetary-scale organization of tropical convection, like MJOs.

Dimitris Giannakis
Title: Kernel analog forecasting of intraseasonal oscillations

Abstract: We discuss nonparametric forecasting of the MJO and the boreal summer intraseasonal oscillation (BSISO) in brightness temperature data. First, we extract eigenmodes representing the dominant ISOs from the CLAUS archive using the nonlinear Laplacian spectral analysis (NLSA) algorithm. We then apply a recently developed nonparametric technique that modifies the traditional analog forecasting approach to create weighted ensemble analog forecasts with weights computed from the similarity kernels employed in NLSA. We find significant skill extending up to ~50 days in MJO and BSISO hindcasts over the period July 2006 to February 2009. This work is in collaboration with Romeo Alexander, Jane Zhao, Eniko Szekely, and Andrew Majda

Bityut Goswami
Title: Is Superparameterization capable of breaking the “deadlock” ? ... seeking the answer in Superparameterized CFSv2 664 day climate

B. B. Goswami, R. Phani, P. Mukhopadhyay, M. Khairoutdinov and B. N. Goswami

We present here the analysis of the 664-day (from 21 May 2008 to 15 March 2010) free run of the first time implemented superparameterized (SP-) Climate Forecast System (CFS) version 2 (CFSv2) (SP-CFS) at T62 resolution. The SP-CFS simulations are evaluated against observations and traditional convection parameterized CFSv2 simulations at T62 resolution. The metrics to evaluate the model performance are chosen in order to address mainly the improvement of systematic biases observed in the CFSv2 documented in earlier studies. This study emphasizes the simulation of the Indian summer monsoon (ISM) by the SP-CFS model. However. as the challenges of simulating ISM intra-seasonal oscillations (ISO) are similar to those of simulating MJO in a climate model, we believe our results will provide a good learning lesson for the MJO simulation.

Compared to CFSv2, SP-CFS simulates:
• improved precipitation distribution over the globe;
• better temperature structures both spatially and vertically;

• improved relative distribution of variance for the synoptic and low-frequency tropical intraseasonal oscillation (ISO) scale.
•improved convectively coupled equatorial wave spectra

We demonstrate that the climate system simulated by SP-CFS appears to be better compared to that by CFSv2. The results presented here need to be established for a longer climate simulation; nevertheless the results are surely exciting and superparameterization surely shows the promise to break the “deadlock”.

Richard H. Johnson
Title: MJO Initiation Processes Inferred
from DYNAMO

Abstract: Two prominent MJOs occurred over the Indian Ocean in October and November during the 2011 DYNAMO/CINDY/AMIE field campaign. At least in part, both events were linked to global-circumnavigating, upper-tropospheric disturbances. In addition, however, a number of local processes played a role in the initiation of the MJOs as revealed by atmospheric soundings and other in situ DYNAMO data.

Prior to the development of deep convection, dry conditions in the midtroposphere inhibited the growth of convection, resulting in a prevalence of shallow cumulus and congestus clouds. During these suppressed periods, winds were generally light and the SST exhibited a diurnal cycle of up to 1-3 C. Correspondingly an afternoon maximum in cumulus and congestus clouds occurred, which existed in addition to a weak nocturnal peak in precipitation. Typically, the afternoon shallow clouds were organized into mesoscale open cellular patterns, à la Benard convective cells, having horizontal dimensions of 20-40 km. As a consequence, the moistening of the lower troposphere during the MJO build-up phases exhibited a pronounced diurnal modulation.

Observations also show an increase in cirrus clouds during the suppressed periods leading up to the active MJO phases. The cirrus developed in association with cool anomalies generated by a large-scale gravity wave in the UT/LS excited by the MJO convective envelope, as originally proposed by Kiladis et al and subsequently documented with CALIPSO data by Virts and Wallace. Based on sounding data budgets and satellite estimates, a corresponding reduction in column-integrated net radiative cooling was observed during these periods, which was accompanied by a reduction in large-scale subsidence. Correspondingly, there was a deepening of the atmospheric mixed layer prior to the occurrence of deep convection. Results from the sounding network also indicate a possible role of radiative-convective instability in the convective build-up within the MJOs.

George Kiladis
Title: Stochastic Aspects of Convection Organization by the MJO
George N. Kiladis and Juliana Dias

Abstract:
As is now well-documented, the convective envelopes that made up the MJO and “MJO-like” events during the CINDY/DYNAMO and TOGA COARE field campaigns were characterized by a wide variety of disturbances. This diversity is not only evident between events, but also within an individual event as it evolves. We investigate the convective makeup of the MJO during the historical record of satellite data going back to 1974. Three independent techniques to assess the scale and type of disturbances within the MJO are applied to the DYNAMO period and compared with results from TOGA COARE and the historical record. One approach uses a tracking algorithm that isparticularly well suited to providing a “census” of mesoscale convective systems (MCSs). This can also be adapted to track convectively-coupled equatorial waves (CCEWs) using suitably filtered data. The other technique utilizes a spatio-temporal wavelet transform that can quantify the contribution of CCEWs across an individual MJO envelope. A third technique measures the variance of various CCEWs within a given MJO event, using brightness temperature filtered for the individual modes. Results reveal that, while the MJO obviously increases the variance of disturbances within its envelope, the distribution of these disturbances across scales appears to be remarkably

uniform regardless of the technique used. To start with, while MCS characteristics vary geographically around the globe, the tracking method suggests strongly that there is nothing special about the MJO in terms of the spatial scale, lifetime, and propagation characteristics of MCSs within its envelope, other than the fact that they are more common when the MJO is active. A similar result is obtained by measuring the variance of filtered CCEW activity within the MJO envelope versus outside of it. However, although this filtering approach has been and is currently used to assess variations in CCEW activity, we show an example of how it can lead to erroneous results due to the inclusion of "background" variance that is unrelated to the modes being analyzed. Finally, the probability distribution function (pdf) of brightness temperature is analyzed with respect to the MJO. It turns out that while the MJO does modulate the pdf of brightness temperature locally, the global pdf is extremely stable regardless of whether the MJO is active or not. This suggests that the while MJO substantially alters the geographic distribution of convection, it does not necessarily impact the amount of convection on a global scale, perhaps as a result of a global convective-radiative balance on intraseasonal time scales.

Micth Moncrieff

Title: Supercluster-like Organization and an Inertial-Gravity Wave during YOTC

Mitch Moncrieff & Changhai Liu, NCAR

Abstarct: We seek to quantify the relative roles of propagating organized convection and westward-propagating waves in the MJO context. We focus on: i) a high-resolution subset (1-km-grid) of a larger cloud-system resolving simulation utilizing the Weather Research and Forecasting (WRF) model; ii) a particular 2-day wave event for 9-11 April 2009, during the Year of Tropical Convection (YOTC; May 2008-April 2010). WRF simulated many features observed by TRMM, e.g., location, propagation, life-cycle. Of special interest is a westward inertial-gravity wave of about 12-degree wave-length and 10 m/s propagation speed. The simulated perturbation fields show a westward-propagating supercluster-like system (giant MCS) tilted rearward with height, containing embedded eastward-propagating MCSs. The propagation and vertical structure of both the supercluster and the MCSs are consistent with slantwise layer overturning models of organized convection (Moncrieff 2010). We identify multi-cloud parameterization (Khouider and Majda 2006, and subsequent developments) as the framework of choice for organized convection parameterization development in GCMs.

Parthasarathi Mukhopadhya

Title: Modification of sub-grid scale and grid scale cloud and convective parameterization in CFSv2 and its impact on organized convection and improving model fidelity

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2. NCAR MMM, Boulder, Colorado, USA

Abstract: It is well established that the poor representation of cloud and convective processes are one of the principal source of uncertainties in climate model. Mostly, attempts are being made to increase the model resolution to address the issue arising from sub-grid scale cloud processes. However, higher resolution many times does not improve the physical representation of the unresolved process and thereby fails to improve the model bias. Keeping these challenges in mind, a revised SAS convection and a realistic cloud microphysics scheme is used in CFSv2. The inclusion of the revised SAS and the realistic representation of cloud microphysics, indeed are able to improve the systematic biases of CFSv2. Most importantly, it is seen to improve the seasonal mean as well as the intraseasonal variabilties. The convectively coupled equatorial waves particularly the MJO, is found to improve significantly. The CFSv2 is known to have a very weak eastward propagation of convection anomaly which has improved substantially with the revision of grid scale and subgrid scale cloud processes. Further the modified CFSv2 is found to improve the daily PDF, organized convection and most challenging the annual distribution of different cloud hydrometeors. Lastly, the climate models such as those in CMIP5 show inability in capturing the ratio of convective and stratiform rain. In the revised CFS, the convective and stratiform rain percentage has

improved. It indicates the dominant role of cloud processes in influencing the model fidelity in simulating mean as well as the intraseasonal variabilities.

Reed Ogrosky
Title: Identifying the MJO using the skeleton model.

Abstract: The MJO skeleton model, a nonlinear oscillator model, has been shown to have solutions that exhibit several features in common with observed MJOs. In a previous study, Stechmann and Majda (2015) used a new data analysis technique to identify these model solutions in observational data during periods of well-documented MJO activity. This technique does not employ temporal filtering or empirical orthogonal functions (EOFs). Here, we find new solutions to the skeleton model using observationally-based, spatially-varying forcing functions. Combining the method of Stechmann and Majda (2015) with these new solutions to identify the MJO yields results that are in good agreement with standard observational MJO indices, and offers conceptual improvements in the theoretical identification of the MJO. This data analysis technique appears to be useful in the identification of other tropical atmospheric phenomena as well; as an example, it will be shown that combining similar data analysis methods over longer timescales with an undamped Matsuno-Gill model can be used to identify the Walker circulation.

SeungBu Park
Title: A unified parameterization of dry and moist convection for general circulation models

SeungBu Park and Pierre Gentine
Department of Earth and Environmental Engineering, Columbia University, USA

Abstract: We plan to develop a unified parameterization of dry and moist convection for generalcirculation models based on a probabilistic plume model (PPM: Gentine et al. 2013a,b; D'Andrea et al. 2014) further validated with large-eddy simulation data. The PPM model uses an ensemble of plumes to represent boundary-layer growth and heat and moisture fluxes in the cloud layer. The model has recently been extended to deep convection (D'Andrea et al. 2014) and seems to correctly reproduce the diurnal cycle of convection over land regions, using a simple cold pool parameterization. This kind of unified scheme of boundary- and cloud-layer convections will be implemented on the single column version of NASA GISS ModelE (Schmidt et al. 2006). More details on our plan will be presented in the workshop.

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Hagos Samson
Title: Cloud permitting modeling of shallow-to-deep convection transitions during the initiation and propagation of Madden-Julian Oscillation

Abstract: Using observations from the 2011 AMIE/DYNAMO field campaign over the Indian Ocean and a Cloud permitting model simulation, the processes that lead to the rapid shallow-to-deep convection transitions associated with the initiation and eastward propagation of the Madden-Julian Oscillation (MJO) are examined. By tracking the evolution of the depth of several thousand individual model simulated precipitation features, the role of and the processes that control the observed mid-tropospheric moisture

buildup ahead of the detection of deep convection are quantified at large and convection scales. The frequency of shallow-to-deep convection transitions is found to be sensitive to this midlevel moisture and large-scale uplift. This uplift along with the decline of large-scale drying by equator-ward advection causes the moisture buildup leading to the initiation of the MJO. Convection scale moisture variability and uplift, and large-scale zonal advection play secondary roles.

Courtney Schumacher

Title: Mesoscale organization from an observational perspective

Courtney Schumacher
Texas A&M University

Abstract: Convective systems can be considered organized by a number of definitions: size > 100 km in horizontal extent, a linear shape, a long lifetime, or the existence of a mesoscale updraft or brightband. Regardless of one's definition, several factors are potentially important in organizing convection. These factors may include synoptic scale targets such as diurnally forced systems at the coast, convectively coupled waves near the equator, and the Madden-Julian Oscillation over the Indian Ocean and west Pacific warm pool. One may also consider more local factors in the role of convective organization, such as boundary layer conditions, low- and mid-level wind shear, cold pools, mesoscale boundaries, and gravity waves. Once convection organizes, large regions of stratiform rain and anvil often form and persist through processes such as convective sustainability, upper level shear/hydrometeor advection, mid- and upper level moisture, and radiative feedbacks. The impact of this organization on local weather and global climate is profound. Satellite-observed mesoscale convective systems account for more than 50% of the rain in many regions of the tropics and the elevated heating associated with organized convective systems can alter circulations as large as the Walker Circulation. Regional moisture and momentum budgets are also sensitive to organized convection. This talk will review, from an observational frame of reference, the definitions of convective organization, the factors that organize and maintain mesoscale convective systems, and the large-scale impacts of organized convective systems in the tropics.

Pier Siebesma

Title: A new simple, stochastic and scale-aware convection parameterization

A. Pier Siebesma

Abstarct: Convection parameterizations are usually developed under the assumption that the area for which the convective transport needs to be parameterized is large enough to assume a quasi-equilibrium between the large-scale forcing and the convective response. At resolutions that are still too coarse to resolve convection but too fine to support quasi-equilibrium, convection parameterizations have to be scale-aware and need a stochastic character

First we show how we can use conditional Markov chains trained by observational data and Large Eddy Simulation (LES) results to design a multicloud model in the spirit of Khouider and Majda (2006)and which are the most important parameters on which the Markov chains needs to be conditioned. As a next step we will show how the convective area fractions generated by a multicloud model can serve as a simple closure for the mass flux at cloud base in conventional convection parameterizations.

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Courtney Schumacher
Title: Mesoscale organization from an observational perspective

Justin P. Stachnik
Title: Sensitivities of the MJO to the Shape and Strength of the Tropical Warm Pool in the Stochastic Skeleton Model

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Abstarct: This study presents differences in the climatology of Madden-Julian oscillation (MJO) events as a function of the large-scale background forcing using the stochastic version of the MJO skeleton model. The MJO events in the skeleton model are first defined using a metric similar to the Real-time Multivariate MJO (RMM) index of Wheeler and Hendon (2004), with the resulting climatology generally matching observations. We also measure the stochasticity of MJO events in terms of the event length and amplitude distributions relative to those solutions from a deterministic version of the model. The degree to which MJO stochasticity varies in response to idealized changes in the magnitude and gradient of the tropical warm pool is discussed, along with differences in the resulting MJO climatology.

Time permitting, we also show differences in the simulated MJO events from the skeleton model using observed estimates of sea surface temperature (SST) variability including El Niño-La Niña and the Indian Ocean dipole (IOD). Corresponding changes to the observed MJO behavior as a function of tropical SSTs are also discussed.

Samuel Stechmann
Title: A Spatiotemporal Stochastic Model for Tropical Precipitation and Water Vapor Dynamics

Abstract: A linear stochastic model is presented for the dynamics of water vapor and tropical convection. Despite its linear formulation, the model reproduces a wide variety of observational statistics from disparate perspectives, including (i) a cloud cluster area distribution with an approximate power law, (ii) a power spectrum of spatio-temporal red noise, as in the ``background spectrum" of tropical convection, and (iii) a suite of statistics that resemble the statistical physics concepts of critical phenomena and phase transitions. Exact analytical solutions are available for many statistics, and numerical realizations can be generated for minimal computational cost and for any desired time step. Given the simple form of the model, the results suggest that tropical convection may behave in a relatively simple, random way. Finally, relationships are also drawn with the Ising model, the Gaussian Free Field, and the Schramm-Loewner evolution and its possible connection with cloud cluster statistics. Potential applications of the model include several situations where realistic cloud fields must be generated for minimal cost, such as cloud parameterizations for climate models or radiative transfer models.

Sulian Thual
Title: A Skeleton Model for the MJO with Refined Vertical Structure

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Abstract: The Madden-Julian oscillation (MJO) is the dominant mode of variability in the tropical atmosphere on intraseasonal timescales and planetary spatial scales. The skeleton model is a minimal dynamical model that recovers robustly the most fundamental MJO features of (I) a slow eastward speed of roughly 5 ms-1, (II) a peculiar dispersion relation with dw/dk=0, and (III) a horizontal quadrupole vortex structure. This model depicts the MJO as a neutrally-stable atmospheric wave that involves a simple multiscale interaction between planetary dry dynamics, planetary lower-tropospheric moisture and the planetary envelope of synoptic-scale activity.

Here we propose and analyse an extended version of the skeleton model with additional variables accounting for the refined vertical structure of the MJO in nature. The present model reproduces qualitatively the front-to-rear vertical structure of the MJO found in nature, with MJO events marked by a planetary envelope of convective activity transitioning from the congestus to the deep to the stratiform type, in addition to a front-to-rear structure of moisture, winds and temperature. Despite its increased complexity the present model retains several interesting features of the original skeleton model such as a conserved energy and similar linear solutions. We further analyze a model version with a simple stochastic parametrization for the unresolved details of synoptic-scale activity. The stochastic model solutions show intermittent initiation, propagation and shut down of MJO wave trains, as in previous studies, in addition to MJO events with a front-to-rear vertical structure of varying intensity and characteristics from one event to another.

Wen-wen Tung
Title:The emerging states of MJO convection initiation

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In light of recent results indicating that a build-up of lower-tropospheric moisture due to advection over the Western Indian Ocean precedes the initiation of MJO convection, here we propose an approach for detecting the local changes of atmospheric states prior to the initiation. Permutation entropy (PE), a measure of randomness capable of detecting dynamical changes in a temporal process, is used to characterize the complex time evolution of perturbation kinetic energy at 850 hPa (PKE) and specific humidity integrated from surface to 750 hPa (IWV) globally between 45 S and 45 N in ECMWF Interim reanalysis. Phase indices of MJO convective activities from 1984 to 2005 are created based on the temporal evolution of a pair of MJO modes obtained via the Nonlinear Laplacian Spectral Analysis applied to infrared brightness temperature averaged over the tropical belt. PKE- and IWV-based PE time series computed within a ~10-day window are compared with the phase indices to identify the typical dynamical configuration of states and changes which occur when nascent MJO convection is in the Western Indian Ocean. Two tiers of statistical tests bring out the spatial patterns of the emerging states. First, the Wilcoxon rank sum test determines locations where PE values in the initiative phase are significantly different from other phases. Then, 1000 synthetic Markov Chain surrogates were created for PKE and IWV, respectively, to form the null hypothesis of a two-sided significance test for the aforementioned rank sum values. Major results show that, around the time of MJO convection initiation, both PKE and IWV fields undergo significant dynamical changes toward organized activities mainly in the northern hemisphere. The changes are planetary in scale, sweeping across all three ocean basins. Especially, PKE changes over extratropical Pacific and Atlantic indicate extratropical forcing at the initiation. Moreover, upon examining the PE time series during 1992-1993, it appears that IWV changes more gradually into MJO initiation, riding on a sinusoidal background corresponding to the annual cycle, whereas PKE tends to shift from one regime to another. It is noted, however, that both PKE- and IWV-based PE over Atlantic

Ocean basin might also signal the end of a boreal MJO season. Qualitatively similar observations are found during the DYNAMO period in 2011-2012.

Micheal Waite:
Title: The spectral kinetic energy budget in dry and moist convective turbulence

Abstract: This talk will present high-resolution large eddy simulations of dry and moist convective boundary layers, with a focus on the spectral kinetic energy budget. Atmospheric kinetic energy spectra are often explained using turbulent inertial subrange ideas, which assume scale separation between the forcing and dissipation. Analysis of the full budget can be used to assess the validity of this hypothesis in simulations. Simulations are performed with the UCLA-LES with the Smagorinsky-Lilly sub-grid scale parameterization. A broad heat flux spectrum develops in both dry and moist simulations, injecting kinetic energy over a wide range of horizontal length scales. Even with grid spacings of 10 m, there is significant overlap between the buoyancy flux and sub-grid dissipation spectra. Only at very high resolutions (grid spacings of 5 m) does an explicitly resolved inertial range begin to emerge. Sensitivity tests with the TKE model show that it is more scale selective, leading to less overlap between the buoyancy flux and dissipation spectra. This is work with James Sandham (University of Waterloo).

Qiu Yang
Title: A multi-scale model for the intraseasonal impact of the diurnal cycle of tropical convection

Abstract: One of the crucial features of tropical convection is the observed variability on multiple spatiotemporal scales, ranging from cumulus clouds on the daily time scale over a few kilometers to intraseasonal oscillations over planetary scales. The diurnal cycle of tropical convection is a significant process but its large-scale impact is not well understood. Here we develop a multi-scale analytic model to assess the intraseasonal impact of planetary-scale inertial oscillations in the diurnal cycle. The appeal of the multi-scale model developed here is that it provides assessment of eddy flux divergences of momentum and temperature and their intraseasonal impact on the planetary-scale circulation in a transparent fashion. Here we use it to study the intraseasonal impact of a model for the diurnal cycle heating with two local phase-lagged baroclinic modes with the congestus, deep, stratiform life cycle. The results show that during boreal summer the eddy flux divergence of temperature dominates in the northern hemisphere, providing significant heating in the middle troposphere of the northern hemisphere with large-scale ascent and cooling with subsidence surrounding this heating center. In an ideal zonally symmetric case, the resulting planetary-scale circulation on the intraseasonal time scale during boreal summer is characterized by ascent in the northern hemisphere, southward motion in the upper troposphere, descent around the equator and northward motion in the lower troposphere. The intraseasonal impact of the diurnal cycle on the planetary scale also includes negative potential temperature anomalies in the lower troposphere, which suggests convective triggering in the tropics. Furthermore, a fully coupled model for the intraseasonal impact of the diurnal cycle on the Hadley cell shows that the overturning motion induced by the eddy flux divergences of momentum and temperature from the diurnal cycle can strengthen the upper branch of the winter cell of the Hadley circulation, but weaken the lower branch of the winter cell.

Guang Zhang
Title: Examination of Convective Parameterization Closures and Their Scale-Awareness Using Cloud Resolving Model Simulations

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Abstract: Closure is an important component of mass flux-based convective parameterization schemes and it determines the amount of convection with the aid of large-scale variables. In this talk, I will examine the relationship between commonly used closure variables and convection for a range of global climate model (GCM) horizontal resolutions. We use cloud resolving model simulations of both tropical and midlatitude convective systems from the ARM TWP-ICE and MC3E field experiments to create domain averages representing different

GCM horizontal resolutions. Results show that moisture convergence and large-scale CAPE generation (dCAPE)-based closures work well. Other closures, such as CAPE and PBL turbulent kinetic energy (TKE)-based closures do not capture the variation of convection with the large-scale fields. It is found that the correlation between moisture convergence and convective precipitation is largest when moisture convergence leads convection. This correlation weakens as the subdomain size decreases to 8 km or smaller. Although convective precipitation and mass flux increase with moisture convergence or CAPE generation by GCM grid-scale circulation at a given subdomain size, as the subdomain size increases, the rate at which they increase becomes smaller. This suggests that moisture convergence and dCAPE-based closures should scale down the predicted mass flux as GCM resolution increases, implying that scale-awareness should be factored into convective parameterization closures as GCM resolution increases.