Modeling LOIs

- At least 19! Most propose integrated modeling and observational analysis
- Participation from three national centers (NCAR, NCEP, NRL)*
- Suite of modeling tools to be used for parameterization development and process studies:
  - Single column models
  - limited domain CSRM
  - conventional AGCMs and coupled models
  - high resolution non-hydrostatic global models and tropical channel models
  - regional high resolution coupled models
  - high resolution OGCMs and single column models
  - data assimilation

*Want to extend linkages

1) Development of Process-Oriented Diagnostics using DYNAMO Observations*

- Test DYNAMO hypotheses on MJO initiation
- Diagnose successes and deficiencies from SCM, limited domain CSRM, conventional GCMs, and high resolution models*.
- Data-driven prediction and modeling

Field data supplemented by YOTC databases for model development, and other satellite and data assimilation products

*Possible extension of activities of WCRP/YOTC MJO Task Force

* More on this below

2) Single Column Modeling and limited domain Cloud System Resolving Models (CSRM)

Forcing generated using DYNAMO field obs.

- Conventional forcing methods
- Weak temperature gradient (i.e. parameterized dynamics)

Uses of SCMs and CSRMs

1) Process studies to support DYNAMO hypotheses.

2) Parameterization development*

* If CSRM simulations are to be used for parameterization development, then they must be validated against suitable high resolution DYNAMO observations from RADAR and aircraft(?) datasets. Further, the data requirements for direct comparison of conventional models versus DYNAMO obs. need to be better defined.

3) Parameterization Improvements

Parameterizations and their modifications will be tested in SCMs and full GCMs

- Validated against CSRMs, high resolution non-hydrostatic simulations, and DYNAMO observations (e.g. cloud statistics, isotope information) and auxiliary datasets*
- Examples of parameterization modifications*:
  - entrainment
  - triggering
  - stochastic component
  - boundary layer
  - rain evaporation
  - boundary layer and large-scale cloudiness

*The data requirements for direct comparison of conventional and high resolution models versus DYNAMO obs. (e.g. RADAR) need to be better defined.

*Participation from more modeling centers may be useful.

4) Forecast/Hindcast experiments

- Transpose AMIP-type experiments (e.g. CAPT) for DYNAMO period
  - -context of parameterization improvement
  - -also, diagnose existing models to determine which ones are most successful
  - - assess predictability of MJO initiation
- Hindcast experiments with data assimilation (including high resolution atm. models and coupled models)
  - high resolution models may provide diagnostic fields to test DYNAMO hypotheses and conventional models
- Serial forecasting experiments before, during, and after MJO events. Real time capability.
- Operational forecast support from NCEP

5) High Resolution and Non-Conventional Global Models

Process-oriented diagnosis of such simulations used in testing DYNAMO hypotheses and testing conventional models

Data assimilation capabilities for some of these models will be employed that will ingest DYNAMO field observations

Particularly when data assimilation is exploited, help set large-scale context for DYNAMO field phase

Models:

- Global WRF
- Tropical channel WRF
- SP-CAM
- NICAM

Real-time forecast capability might be exploited in some cases

6) Coupled Modeling

- Process-oriented observational diagnosis of coupled and ocean mixed layer processes using DYNAMO observations, satellite and assimilation datasets
- hindcast experiments will be carried out using the GFDL MOM4 ocean model and ROMS to engneder an improved CFS at NCEP.
- Comparison of global coupled and uncoupled simulations, including hindcast/forecast simulations, to assess the importance of ocean processes to MJO initiation*
- High resolution regional coupled runs (COAMPS) and OGCM (HYCOM) runs to assess importance of coupled and oceanic processes to MJO initiation*
- One-dimensional ocean modeling

* Data requirements to validate ocean models against DYNAMO observations need to be better defined i.e. What data do we need to validate models?

Letters of Intent

Back

Flatau and Shinoda

Kim and Sobel

Kuang

Li, Yoneyama, Nasuno

Maloney

Moncrieff

Neale, Williamson, Hannay

Noone, Risi, and Galewsky

Shinoda, Wang, and Han

Sobel and Wang

Tung and Gao

Vintzileos and Gottschalck

Vintzileos, Murtugudde, Huang, Behringer, Xue

Waliser, Lee, Halkides

Waliser, Wang

Webster

Wu and Moncrieff

Zhang and Song

Modeling MJO Initiation with a GCM

PIs: Eric Maloney, Colorado State

Objectives/Goals

1) Modeling and data analysis to address Hypothesis I the role of moisture and moistening processes in MJO initiation.
2) Parameterization modifications optimized with SCM simulations and transpose-AMIP experiments.
3) Role of ocean coupling in MJO initiation

Approach

1) Use processes-oriented diagnostics on MJO initiation as developed from DYNAMO observations (in conjunction with Adam Sobel and Zhiming Kuang) to test whether the initiation process in a GCM is realistic
2) SCM version of GCM forced by and validated against DYNAMO observations and CRM (Zhiming Kuang) will help optimize convection parameterization, including treatments of entrainment and rain evaporation.
3) Coupled and uncoupled simulations will be conducted with optimized parameterizations and variability about these values to assess the MSE and moisture budgets in the context of MJO initiation, including the role of ocean heat content.
4) Transpose AMIP reforecast exercises will be conducted with the climate model for the DYNAMO period to diagnose where model errors and physical deficiencies most rapidly develop in advance of MJO initiation, as well as the sensitivity of error growth to details of the convection scheme and the strength of its moisture sensitivity (initial conditions provided by Rich Neale at NCAR)

Improving MJO Forecasts with Physical and Resolution Sensitivity Studies Using CAM

Richard Neale, Dave Williamson and Cecile Hannay (NCAR)

A configuration of the NCAR Community Atmosphere Model is enabled to provide short-term forecasts (several days to weeks) of targeted atmospheric phenomena through the Cloud Associated Parameterization Testbed (CAPT) framework

1. Initiation and maintenance
   - ✓ The evolution of the forecasts will be validated using the spectrum of in-situ DYNAMO observations
   - ✓ Forecast spread and accuracy will be investigated as a function of reanalysis, phase initialization and the ingesting of in-situ DYNAMO observation
2. Vertical and horizontal resolution dependence
   - ✓ CAM will be integrated with different resolutions varying from 26 to 80 levels in the vertical
   - ✓ In the horizontal we will investigate sensitivity to resolutions varying from 2 to 0.25 degrees
   - ✓ At 0.25 degrees we will contrast simulations with and without the parameterization of deep convection
3. *Sensitivity to boundary layer and large-scale cloud processes*
   - ✓ With a more advanced representation of physical processes in CAM5 we will perform forecasts investigating the sensitivity to particular phenomenon
   - ✓ Lower tropospheric moisture pre-conditioning (Tian et al. 2009)
   - ✓ Cirrus anvil shield (Lin et al. 2004)

DYNAMO Hypothesis Testing in a Multi-Model MJO Hindcast Experiment

PIs: Duane Waliser[1], Bin Wang[2]
[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA
[2]U Hawaii

Objectives/Goals

To evaluate MJO prediction skill and predictability measures, a unique multi-model hindcast experiment is being conducted with completion of most model contributions expected by mid 2010. What do the “better MJO” models exhibit regarding atmosphere-ocean processes and how they are parameterized relative to those that do not perform well with the MJO?

Approach

1) Analyzing the model archive independent of the field program for information regarding the proposed DYNAMO hypotheses.
2) Obtaining the relevant data and process-oriented diagnostics from the DYNAMO field program to compare to the analysis of the models.
3) Comparing the IOP case study phenomena with the model analysis

Understanding the mechanisms of MJO initiation and propagation using a hierarchy of models and DYNAMO observations

PI: Zhiming Kuang (Harvard)

- Forecasts and hindcasts of the MJO events during DYNAMO with a high-resolution global version of the WRF model and the SPCAM model. We will exploit the data assimilation capability of WRF.
- The column MSE budget for these events will be analyzed to quantify processes that generate the initial column MSE anomaly and those that maintain and propagate the anomaly.
- Experiments with single column models and limited domain cloud-resolving models (with feedbacks from the large-scale flow) will then be designed to isolate and understand the processes that contribute to the MSE budget. A key target will be variations of the gross moist stability with the large-scale conditions.

Data assimilation, real-time forecasting and high-resolution simulation during the 2011 Indian Ocean field campaign

PI: Tim Li (UH), Co-PIs: Kunio Yoneyama, Tomoe Nasuno (JAMSTEC)

- Real time observational support
  - MJO prediction using U. Hawaii hybrid coupled GCM
  - Hindcast MJO forecast experiments during 2004-2008 have been conducted (Fu et al. 2010) and results are encouraging.
- Variational data assimilation during the observational campaign period
  - A similar attempt during TCS-08 observational campaign was conducted using WRF 3DVar/4DVar (Li et al. 2009)
  - Strategy: Combining in-situ observations with remotely sensing satellite measurements
- NICAM global cloud-resolving (3.5km ~ 7 km) simulations
  - Real-case simulations with initial condition from the data assimilation products (the model will be run at the Earth Simulator)
  - Process-oriented study to reveal mechanisms responsible for convection initiation in the equatorial Indian Ocean (e.g., extratropical forcing vs. local PBL processes)

Multiscale Simulation in Support of DYNAMO

Mitch Moncrieff, Climate & Global Dynamics Division, NCAR

- **Large-scale context for DYNAMO field phase**
  - Evolution of mesoscale systems during MJO onset into organized synoptic-to-large scale systems
  - Convective parameterization at 10-km-grid- spacing (global NWP, climate models by 2020)
  - Representation of mesoscale convective organization in global models

- **Multiscale convective dynamics**
  - Upscale evolution, transport, scale interaction
  - Scale invariant dynamics (cumulonimbus, MCS and superclusters)
  - Effects of organized convection on the MJO, including convective momentum transport, convectively-generated gravity waves

- **Numerical simulation (WRF)**
  - ECMWF analysis (15 km grid) supply initial/lateral boundary conditions for nested fine-scale experiments, tropical channel model for large-scale experiments
  - YOTC databases for model evaluation, e.g., YOTC-GS , YOTC-ARM/TWP

Modeling MJO modulation of tropical deep convection under the weak temperature gradient approximation (WTG)

(Adam Sobel, Shuguang Wang, Columbia University)

- Conventional use of CRMs to model convection

large scale forcings → convection

- Using WRF under WTG (WRF-WTG): convection feeds back to large scale forcings

parameterized large scale forcings ⇄ convection

- Preliminary tests indicate broad consistency between WRF-WTG and other SCMs and CRMs

- DYNAMO field observations will be used in both approaches to understand the following effects on tropical convection: surface fluxes, SST, horizontal advection of moisture, wind shear, etc.

- Outcome: deepen our understanding of convection during MJO events; compare CRMs and field observations at a new level; further explore model strengths and weaknesses under WTG

Stochastic parameterization of moist convection using DYNAMO field observation

PI: Daehyun Kim (LDEO), Co-PI: Adam H. Sobel (CU, LDEO)

- Convective parameterizations should be stochastic rather than deterministic, but research on the stochastic nature of moist convection has been limited. The development of stochastic convective parameterizations is limited in part by a lack of adequate observational data to constrain the statistical distributions of key cloud-scale and mesoscale quantities.
- The DYNAMO field experiment will provide a unique set of observations that will be invaluable for this purpose. The multiple radars, in particular, deployed in a tropical oceanic environment, will be particularly useful in constraining (directly or indirectly) the statistical distributions of key quantities such as updraft vertical velocity, cloud liquid water, etc.
- Ways to represent stochastic behavior in convective schemes will be developed, to use DYNAMO observations to constrain the statistical distributions, and to test (in SCM framework) the resulting schemes against DYNAMO observations on the large scale.
- Long-term integration and short-term (~up to 30 days) ensemble forecast experiments will be conducted to examine the impact of stochastic cumulus parameterizations on simulation and prediction of cloud properties over the tropics.
- Stochastic representation of the moist convection is important practically in a high resolution modeling framework in where the assumption of equilibrium starts to break and in ensemble prediction systems which should sample model uncertainties in the spread of ensemble.

Cloud-Resolving Model Simulations of MJO Convection over the Indian Ocean and Western Pacific

Xiaoqing Wu (Iowa State University) and Mitch Moncrieff (NCAR)

* **Perform long-term (covering two or more MJO events) cloud-resolving model (CRM, 1-km resolution) simulations forced by the large-scale forcing observed during DYNAMO and TOGA COARE**

* **Examine and compare MJO convection properties including deep and shallow convection, convective and stratiform precipitation, heating and drying rates over the Indian Ocean and western Pacific**

* **Conduct sensitivity experiments to investigate the relationship between the MJO convection, large-scale moisture, surface latent heat flux and lower-tropospheric vertical wind shear over both Oceans**

* **Improve the convection trigger condition using the CRM simulations and assess its impact on the MJO simulation in NCAR GCM**

Spatio-temporal chaotic features of the Madden-Julian Oscillation

PI: Wen-wen Tung, Co-PI: Jianbo Gao

- Observational data-driven modeling and prediction of the MJO
  - Perform spatio-temporal chaotic analysis of MJO
  - Develop, from observational data, a method to determine quantitatively the initiation of the MJO.
    - Simple models such as Majda and Stechmann (2009) may play an important role for the deterministic component of this model, in addition to stochastic modeling of shorter-time/smaller-scale processes.
  - Chaos-based prediction to project observational data into future
    - Validate the prediction when observations become available to determine empirically a prediction time and its relation to the states at the initiation.
- Radar sea clutter modeling and air-sea interaction signal extraction
  - Spatial and temporal multifractal, fractal, wavelet-based analysis of radar sea clutter to assist determination of sea/atmosphere states
  - Distributional analysis of sea clutter for clutter removal/denoising of radar backscatter

A Global Model Investigation of MJO Initiation for DYNAMO

PI: Guang Zhang, Co-I: Xiaoliang Song
Scripps Institution of Oceanography

Scientific Issues:

- *What are the factors determining the initiation of MJO in the Indian Ocean?*
- *How does the cloud population interact with the MJO circulation during MJO initiation?*
- *Can the NCAR CAM reproduce the observed cloud population?*

Model

- *NCAR CAM4 or CAM5 with revised Zhang-McFarlane convection scheme*

Data

- *DYNAMO field observations, ECMWF/NCEP reanalyses products, YOTC data*

Tasks

- *Multi-year simulation; forecasts using CAM4/5 in prediction mode*
- *Analysis of cloud population evolution in model and observations*
- *Budget analysis and comparison with observations*

MJO initiation, moisture-convection feedback and convective pattern formation

PI: Larissa Back, University of Wisc.-Madison

1. Analyze moisture variability using soundings, surface fluxes, radar and using CSRM as tool.
   - focus on process-level understanding of moisture budget, e.g. relative role of moistening by shallow cumulus detrainment, moisture convergence, local surface fluxes, etc.
   - compare to NOAA SCM and perform basic sensitivity analyses
2. Examine organization of convection, cloud properties in radar, CSRM simulations and satellite data.
   - focus on scales of organization, and mechanisms for organization at these scales, updraft characteristics
3. Develop and test simple, physically-based models of convective pattern formation. Questions to answer:
   - Why destabilization at spatio-temporal scales observed?
   - Role of stochastic forcing? Hypothesis: widens range of environments that can lead to pattern formation
   - Unique features of Indian Ocean Basin that lead to initiation there?

Multi-model simulation/prediction of the DYNAMO Observing Period

PI: Peter Webster, G. Tech

Objectives:

Serial forecast/hindcast experiments for the DYNAMO observing period that provide real time support for DYNAMO as well as archived forecasts that provide diagnostic fields and initial conditions

Methods:

1) ECMWF operational VarEPS: 2 times daily, 51 ensembles, 25 km for the region.
2) ECMWF weekly VarEPS (coupled after 10 days) extended for 32 days.
3) ECMWF System 3 (maybe 3.1): 6 month 41 ensembles initialized daily, usually available 15th of the month but we can try and get the data as the integrations are done.

Using Satellite Data and ECCO Ocean Analysis In Support of CLIVAR/DYNAMO: Model Evaluation and Hypothesis Testing

PIs: Duane Waliser[1], Tong (Tony) Lee[1], Daria Halkides[2]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA [2]Joint Institute for Regional Earth System Science and Engineering, U. of California, Los Angeles

Objectives/Goals

1) Address whether the barrier-layer, wind and shear driven mixing, shallow thermocline, and mixing-layer entrainment all play essential roles in MJO initiation in the Indian Ocean by controlling the upper-ocean heat content and SST, and thereby surface flux feedback.

2) Address hypothesis that the MJO plays a major role in the strength and character of the cross-equatorial heat transport

Approach

1) develop a satellite and ocean analysis (ECCO-JPL) characterization of MJO initiation and the subsequent evolution process in the Indian Ocean, and put DYNAMO period in context

2) Evaluate the ocean-atmosphere interaction representation and related mixed-layer physics associated with MJO initiation and evolution in the Indian Ocean in a suite of coupled models participating in a CLIVAR-relevant, NOAA-supported multi-model hindcast experiment

The influence of atmosphere-ocean interaction on MJO development and propagation

PIs: Dr .Maria Flatau, NRL Monterey, Dr Toshiaki Shinoda, NRL Stennis (already funded under ONR)

Objectives/Goals

The objective of this research is to examine the atmosphere-ocean interaction processes responsible for initiation and propagation of Madden–Julian Oscillation in the Indian Ocean and Maritime Continent and to improve the forecasting capabilities of NRL Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) through better representation of MJO. Work supports the ONR-DRI field campaign that will take place in the Indian Ocean in the third year of the project.

Approach

1) The role of SST, ocean Mixed Layer (ML) processes, ocean dynamics, and air-sea interaction in the MJO cycle will be assessed utilizing 3-dimensional, high resolution ocean, atmosphere, and wave models (the coupled COAMPS/NCOM/SWAN system in regional mode).

2) investigate the air sea interaction in the Indian Ocean and the role of high upper ocean heat content and the effect of the barrier layer in MJO development

3) coordinate hindcast experiments with the DYNAMO modeling group and to use data gathered during the DYNAMO field phase in forecast validations.

Upper ocean processes associated with the Madden-Julian oscillation in the Indian Ocean

PIs:Toshiaki Shinoda (NRL-Stennis), Chunzai Wang (NOAA/AOML), Weiqing Han (U. Colorado)

Objectives/Goals

Improve our understanding of upper ocean processes that control SST variability in the central Indian Ocean on the diurnal to intraseasonal time scales, which may play an important role in the initiation of MJO

Approach

Ocean general circulation model (OGCM) and one-dimensional ocean model experiments

OGCM experiments

(1) Model: HYbrid Coordinate Ocean Model (HYCOM)

Note: NOAA/NCEP plans to adopt the 1/12° global HYCOM (currently running at NRL) for the Real Time Ocean Forecast System in collaboration with NRL

(2) Analysis of existing model output in advance of DYNAMO field observations

Indo-Pacific basin HYCOM (55N-55S), Horizontal resolution: 1/3° , Period: 1960-2008 (includes a number of ENSO and IOD events)

Global HYCOM, Horizontal resolution: 1/12° and 1/25° , Period: 2003-2007

Emphasis: Regional difference of various processes

(3) Model experiments that cover the period of DYNAMO observations

Validate the model performance and surface fluxes based on the comparison with DYNAMO observations

One-dimensional ocean model experiments

(1) Model: General Ocean Turbulence Model (GOTM)

The model code includes the vast number of the state-of-the-art turbulence models and algorithms.
It is designed such that it can easily be coupled to 3-D circulation models such as HYCOM.

(2) Experiments

Models will be forced with accurate surface fluxes obtained from DYNAMO observations.
Evaluate the upper ocean mixing scheme based on the comparison with DYNAMO observations (e.g., Turbulent dissipation rate based on microstructure measurements)

(3) Results will be discussed with scientists who are working on global HYCOM development at NRL and NOAA.

Real-time forecast support for the DYNAMO campaign

PIs: Augustin Vintzileos and Jon Gottschalck, ESSIC - CPC/NCEP

Objectives/Goals

The purpose of this project is to outline, develop, stage, and implement real-time operational forecast support during the DYNAMO field campaign.

Approach

(1) comprehensive real-time briefing materials for variables and products relevant to tropical weather forecasting

(2) operational forecast briefings by CPC staff focusing on extended range (Weeks 1-4) forecasts for the status of the MJO and other coherent tropical variability, hazardous rainfall, and tropical cyclone potential

(3) comprehensive diagnostic analyses of the US CLIVAR MJO operational forecasts and the YOTC database to improve understanding for when the greatest accuracy can be achieved.

Deducing moistening and dehydration mechanisms in the region of convection from isotopic measurements for DYNAMO

PIs: David Noone, Camille Risi, Joe Galewsky

Objectives/Goals

Provide isotope data that can be used to evaluate and improve climate models via testing parameterization of cloud processes associated with the initiation and maintenance of convection in the Indian Ocean. Assessment of surface exchange and rain evaporation processes during MJO initiation, including role of downdrafts.

Approach

1) Deploy an array of isotopic analyzers and precipitation samplers at island sites and on Australian, Japanese and US ships (with JAMSTEC and CAWCR partners)

2) Coordinate collection and analysis of surface sea water samples from CINDY/DYNAMO ships

3) Make eddy covariance measurements of isotopic gas exchange in coordination with the air-sea flux system on R/V Ron Brown

4) Contribute to coordination of rainfall collection (with Dr. Kurita at JAMSTEC)

5) Collect profile measurements of water vapor and cloud particle isotopic composition from NOAA P3 aircraft

6) Single column model intercomparison that will help to optimize cloud and surface exchange parameterizations for use in global models (inc. Sandrine Bony).