## DYNAMO

# **Dynamics of the MJO** EXPERIMENTAL DESIGN OVERVIEW

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#### **Executive Summary**

There is considerable evidence for the importance of the MJO in weather and climate (e.g., hurricane activity, U.S. West Coast flooding events, and ENSO), and in their seamless prediction. But our ability of simulating and predicting the MJO is severely limited due to model misrepresentation of processes key to the MJO. Development, improvement, validation of parameterizations for weather and climate models critically rely on in situ observations. A lack of in situ observations in the region of the tropical Indian Ocean has impeded the progress on the study of MJO, especially its initiation. All these point to an urgent need of a field observation campaign in the tropical Indian Ocean region to study the tropical intraseasonal variability with a focus on the MJO.

The US research, operations and applications communities are poised to join CINDY2011, an international field program that will take place in the central equatorial Indian Ocean in late 2011 – early 2012 to collect in situ observations to advance our understanding of MJO initiation processes and to improve MJO prediction. DYNAMO is the program that organizes the US interest of partaking in CINDY2011. The DYNAMO/CINY2011 campaign will coordinate with other field programs (AMIE, HARIMAU, PAC<sup>3</sup>E-SA/7SEAS, ONR air-sea interaction) also planned to take place in late 2011 – early 2012. The integrated observation data set from these programs will cover MJO events at different stages of their life cycle with complimentary observational emphases. The opportunity to be an integrated part of these coordinated programs to maximize the value of observational products makes the timing of late 2011 – early 2012 critical for DYNAMO.

The field campaign of DYNAMO/CINDY2011 consists mainly of a sounding-radar array formed by research vessels and island sites and enhanced moorings inside and near the array. The design of the field campaign and the selection of observational objectives (e.g., vertical profiles of moistening and heating, structure and evolution of cloud and precipitation systems, surface fluxes, atmospheric boundary-layer and upper-ocean turbulence and mixing) have been and will continue to be guided by the DYNAMO modeling activities, which provide hypotheses on potentially crucial processes of MJO initiation. DYNAMO field observations will serve as constraints and validation for models to quantitatively test these hypotheses. This integrated modeling-observational approach will be pursued by a proposed climate process team (CPT) and will lead to targeted information to assist model improvement.

The expected outcome of DYNAMO will be (i) a unique in situ data set available to the broader research and operations communities, (ii) advancement in understanding of the MJO dynamics and initiation processes necessary for improving MJO simulation and prediction, (iii) identification of misrepresentations of processes key to MJO initiation that are common in models and must be corrected to improve MJO simulations and predictions, (iv) provision of baseline information to develop new physical parameterizations and quantify MJO prediction model improvements, and (v) enhanced MJO monitoring and prediction capacities that deliver climate prediction and assessment products on intraseasonal timescales for risk management and decision making.

#### 1. Motivations, Objectives and Hypotheses

Detailed descriptions of the scientific background, rationale, and hypotheses of DYNAMO are given in the DYNAMO Scientific Program Overview (SPO). In short, DYNAMO is motivated by the urgent need to improve the capability of state-of-the-art climate models to reproduce the MJO for increasing our confidence in the model fidelity and to improve dynamical MJO prediction skill for the societal benefit. The overall goal of DYNAMO is to expedite the progress of advancing our understanding of MJO initiation processes and improving our ability to simulate and forecast the MJO. This goal shall be reached in coordination with DYNAMO's international and national partner programs following an integrated observation-modeling-analysis-forecasts approach. The scientific objectives of DYNAMO are:

(1) to collect in situ observations from the equatorial Indian Ocean region that are urgently needed to advance our understanding of the processes key to MJO initiation and to improve their representations in models;

(2) to identify critical deficiencies in current numerical models that are responsible for the low prediction skill and poor simulations of MJO initiation and to assist the broad community effort of improving model parameterizations.;

(3) to provide guiding information to enhance MJO monitoring and prediction capacities that deliver climate prediction and assessment products on intraseasonal timescales for risk management and decision making over the global tropics.

Through DYNAMO activities, the following hypotheses will be tested:

**Hypothesis I**: Convective suppression prior to MJO initiation is prolonged because, in the absence of external influences, the moisture source through surface evaporation over warm sea surface with weak to moderate surface wind is insufficient to support precipitating systems on the MJO scales. The timescale of the suppressed phase prior to MJO initiation is determined by the low efficiency of lower-troposphere moistening by shallow convection alone.

**Hypothesis II**: Population of shallow convection plays a two-stage role in the transition period of MJO initiation: when the precipitation efficiency is low, the moistening effect in the lower troposphere dominates, which slowly creates a favorable condition for deep convection; when the precipitation efficiency becomes high, the low-level heating effect dominates, which induces surface and low-level moisture convergence as an energy source for deep convection and accelerates the initiation process.

**Hypothesis III**: A balance between precipitating shallow, deep, and stratiform precipitation is needed to sustain convective period over the MJO space scale. In the absence of pre-existing large-scale influences, the time scale of the active phase of the MJO is determined by a graduate shift from this balance to a dominance of stratiform precipitating systems on the MJO spatial scale.

*Hypothesis IV*: Upper-ocean processes contribute to MJO initiation through maintaining high SST prior to the initiation and rapid surface cooling during the transition and early

active periods. Turbulent mixing plays a critical role in these because of the shallow mixed layer associated with the SCTR, the current shear associated with the Wyrtki jets, and their intraseasonal variability.

**Hypothesis** V: External (extratropical and upstream) perturbations, with their largescale ascents and low-level convergence, play an activating role to accelerate MJO initiation primed by internal processes.

These hypotheses will be tested through an integrated approach consisting of four main components: field campaign, modeling, analysis, and forecast. The DYNAMO field campaign is designed under the guidance provided by the DYNAMO modeling activities. Measurement will target quantities identified by modeling exercises as potentially important to MJO initiation and its prediction and simulation.

#### 2. Readiness and Expected Outcomes

The need for advancing our understanding of the processes governing MJO initiation in the Indian Ocean and improving our ability of forecasting MJO initiation is beyond doubt, and time is ripe for a field campaign in the Indian Ocean to collect in situ observations to meet this need. The ongoing YOTC activities will provide experience and organizational infrastructure for an international observation-modeling-analysis-forecast integrated approach to tackle the problem of MJO initiation. MJO prediction has been practiced in an organized way under the guidance of the US CLIVAR MJO Working Group. These research-operation infrastructures will pave the road to directly connect field observations to modeling and forecasting activities. By 2011, the IndOOS and RAMA mooring array will be nearly completed, providing climatic background information for the field campaign on basin- and multi-year scales. Since TOGA COARE, observing technology has been greatly advanced to make measurement at either unprecedented accuracy (e.g., GPS sondes, shipboard Doppler current profiles) or relatively low cost (mixing profiles in the upper ocean), and make new observations unavailable previously (e.g., cloud microphysics and boundary-layer moisture from S-Polka dual-polarimetric and K-band capabilities). Lastly, but most importantly, international cooperation and other US programs will be in place in late 2011 – early 2012 to provide a comprehensive suite of observations across a large region covering the equatorial Indian Ocean, Maritime Continent, and western Pacific Ocean, as briefly described below. The resulting synergy will make the DYNAMO field campaign much more productive than it would be as a stand alone project. This makes late 2011 - early 2012 a critical time for DYNAMO.

Figures 1 illustrates potential DYNAMO partner programs that are being planned for late 2011 – early 2012. Committed international participations in CINDY2011 include Japan (50-day ship time of Mirai with a Doppler precipitation radar, radiosondes, and surface and upper-ocean observations) and India (30-day ship time of Sagar Kanya with radiosondes). Australian scientists are planning to join the campaign (30 day ship time of



Figure 1 Global perspective of DYNAMO/CINDY2011 and their partner programs. The exact location of the ONR Air-Sea experiment has yet to be determined.

Southern Surveyor, with radiosondes, surface and upper ocean observations). French scientists are proposing for ship time that will contribute to CINDY2011. Enhanced radiosonde observations will be conducted at Seychelles during CINDY2011, in addition to the operational sounding launches in the region. An ONR supported field experiment on meso- and synoptic-scale air-wave-sea interaction in the Indian Ocean will take place for the time period of CINDY2011 (late 2011). A proposal has been submitted to the ARM Program to conduct an enhanced observational period of six months (AMIE) embedding the CINDY2011 period to document the MJO on the east side of the Maritime Continent. Between the CINDY2011 site in the central equatorial Indian Ocean and the AMIE Manus site is an observational network of Doppler radars and wind profilers over the Indonesian Archipelagos (HARIMAU) to document the propagation of the MJO over the Maritime Continent. In late 2011, a proposed NASA interdisciplinary atmospheric sciences program to study the interactions of pollution with regional meteorology, particularly with clouds, the Seven SouthEast Asian Studies (7SEAS), and an intensive field campaign, the Pacific Atmospheric Composition, Cloud, and Climate Experiment -Southeast Asia (PAC<sup>3</sup>E-SA), will be in place over the Maritime Continent. By joining this suite of field programs in late 2011 - early 2012, the DYNAMO observations will be part of an integrated data set to monitor the MJO from its birthplace in the Indian Ocean to it mature stage over the western Pacific. Such an opportunity to capture the whole life cycle of the MJO and its interaction with the ocean, land and aerosol as it propagates from the Indian Ocean over the Maritime Continent into the western Pacific would probably not come again in the foreseeable future.

The data to be collected by the DYNAMO field campaign will be made available to the broad community. They will be a unique contribution to the existing pool of in situ observations from previous field programs (GATE, TOGA COARE, NAME, TWP-ICE, etc.). This pool of in situ data has served an irreplaceable role in the painstaking and persevering effort by the research and operations communities to improve, develop and test model parameterizations. While no single program can completely solve the parameterization problem, these data have collectively allowed the improvement of model parameterizations to make slow but persistent progress. By filling the gap in the existing pool of in situ data, DYNAMO observations will make it possible for the effort of parameterization improvement to reach a higher level.

The transition of knowledge from DYNAMO to modeling and operational centers will be facilitated by several collaborative and coordinated activities. The participation in the DYNAMO modeling working group by scientists from modeling and operational centers (NCEP, NRL, NASA, GFDL) in the form of a climate process team (CPT) will make modeling research of DYNAMO transparent to these centers and its results directly accessible for the centers to absorb into their modeling improvement efforts. The forecast component of DYNAMO will further expose the prediction barrier of the MJO, help understanding and predicting linkages between the MJO, weather (including extremes) and long-term climate fluctuations. Its real-time monitoring of the MJO, including all essential climate variables, and its delivery of climate prediction and assessment products on intraseasonal timescales will be enhanced and extended. Its forecast validation will be further advanced to establish the baseline to quantify model improvement in terms of MJO prediction. DYNAMO activities are particularly relevant to improvement of the NOAA/CPC operational Global Tropics Hazards/Benefits Assessment, whose weekly

product is disseminated to a growing international audience.

#### **3. Field Experiment Design**

The DYNAMO field campaign is an integrated element of CINDY2011, the 2011-2012 international field program in the equatorial central Indian Ocean. Thus, it is appropriate to describe the DYNAMO field campaign together with CINDY2011. The general plan of CINDY2011 is to conduct an intensive observing period (IOP) for 3 – 4 months in late 2011 – early 2012 aiming to capture the initiation of at least one major MJO event and its full life cycle with a possibly maximum observing capacity. The IOP will be embedded in an extended observing period (EOP) of 6 months or longer that, with reduced observing capacity, will cover more than one MJO events. The climatological background for the DYNAMO/CINDY2011 field observations is provided by the long-term monitoring networks of IndOOs and RAMA.

The choice of the equatorial central Indian Ocean as the location and boreal late fall and winter as the time window for the DYNAMO/CINDY2011 field campaign is based on MJO statistics. Figure 1 in the SPO shows that canonical MJO precipitation anomalies start in the Indian Ocean. Matthews (2007) suggested that 40% of MJO initiation is independent of any previously existing circumnavigating MJO event occurs in the Indian Ocean. Figure 2 shows the number of major MJO initiation (OLR anomalies < -10 Wm<sup>2</sup>) as a function of longitudes (in 10° bin) and calendar months during 1979 - 2007. It is clear that major MJO initiation in the Indian Ocean concentrated in October - January. Probabilities of capturing major MJO initiation within the domain of  $60 - 90^{\circ}E$  and  $7.5^{\circ}S - 7.5^{\circ}N$  in each month of September – January and their combination are shown in Fig. 3. A field campaign in that region lasting 30 days within this period will have about 20-40% probability to capture a major MJO initiation. This probability increases to 80-90% if the field campaign spans 3 - 4 months in October – January. The planned campaign length of 3 - 4 months is therefore crucial to its success. Figure 3 also shows that the probability of capturing a major MJO initiation in that region and time window is modulated by ENSO.



Figure 2 Numbers of major MJO initiation (OLR anomalies  $< -10 \text{ Wm}^2$ ) within 10° longitudes and each month during 1979 – 2007) (Courtesy of Kunio Yoneyama)



Figure 3 Probability of capturing major MJO initiation (OLR anomalies <  $-10 \text{ Wm}^2$ ) within 60 – 90°E, 7.5°S – 7.5N during each month of September – January and their combinations for 1979 – 2007 and its normal, warm, and cold ENSO years. (Courtesy of Kunio Yoneyama)

Major MJO initiation events tend to move south (north) during ENSO warm (cold) years. A possible timeline for the DYNAMO/CINDY2001 field campaign is illustrated in

Fig. 4. It is currently planned that DYNAMO will contribute to the CINDY2011 IOP at the beginning of the field campaign (October – November 2011) and to the entire EOP.



Figure 4 Proposed CINDY2011 Field Campaign timeline.

#### 3.1a Intensive Observing Period (IOP)

The CINDY2011 IOP will be an international cooperative effort by Japan, Australia, Seychelles, India, French, and the US. At center of the DYNAMO/CINDY2011 IOP is a sounding-radar array over the central Indian Ocean embedded in the long-term monitoring network of the Indian Ocean (Fig. 5). This sounding-radar array will be formed by two islands and two research vessels. In addition to this sounding-radar array, enhanced and routine soundings from operational sites in the region will also be part of the IOP.



Figure 5 CINDY2011 observing network. The rectangle illustrates one option of the sounding-radar array formed by Gan Island, Diego Garcia, and four ships on two stations in relay. Squares are IndOOS and RAMA moorings. <u>Sounding array</u>: Sounding data of DYNAMO will provide vertical structures and variability of diabatic heating and moisture sink (Q1 and Q2) profiles. Such profiles are essential to describe convective effects on the large-scale circulation, to validate numerical models, and to constrain models for numerical experiments to test hypotheses regarding MJO initiation processes. It is planned to have 6 soundings per day. The sounding data will be transferred automatically to GTS and available to operations centers around the world.

<u>Radar array</u>: The coinciding array of Doppler precipitation radars is a unique feature of DYNAMO. The necessity of multiple radars resides in the need of spatial coverage beyond single radar coverage that will provide sufficient data for reliable statistics of the structures and variability of clouds of different types in different MJO phases. Such statistics are at the center of some DYNAMO working hypotheses (I – III). Rainfall estimates by the radars, together with surface flux and precipitation data collected by upper-ocean and surface meteorology moorings in the center of the array, are needed to help close the budget estimate based on the sounding data.

The three radars proposed for DYNAMO are: NASA TOGA C-band radar (ship based), NCAR S-Polka radar (island based), and SMART C-band Doppler radar (SMART-R, island based). These radars together with a ship-borne C-band radar on the Japanese vessel Mirai will form the CINDY2011 radar team. The CINDY2011 radars will be part of a radar constellation panning the Indian to western Pacific Ocean during late 2011 – early 2012. Other radars are six land-based C- and X-band Doppler radars deployed in the Maritime continent as part of HARIMAU, and a C-band dual-polarimetric radar to be deployed on the Manus Island ARM site as part of AMIE (Figure 1). Data to be collected from this radar constellation will capture cloud and precipitation structure and variability through different phases of the MJO starting from its initiation in the Indian Ocean.

The C- and S-band capability can map the whole spectrum of precipitating convection (e.g., shallow, congestus, and deep convection and stratiform rain); in particular to determine its three-dimensional structure, life-cycle, relationship to satellite-observed cloud characteristics, diurnal cycle, rain rate and convective-stratiform rain ratio, and diabatic heating profiles. Although the radars will not overlap their coverage, the close connection between the microphysics of convection and the air motion patterns within convective systems allow the detection of the airflow patterns within storm updrafts from single-Doppler radar measurements, as demonstrated by shipboard single-Doppler radar data in TOGA COARE (Houze et al. 2000). Similar methods can be used to determine the internal airflow patterns of MJO convection in DYNAMO simultaneously at the different radar sites.

#### TOGA C-band:

<u>NCAR S-PolKa</u>: The unique dual-polarimetric dual-wavelength (S- and  $K_a$ -band) capability the NCAR S-Polka radar will be useful to (i) document the microphysical

structure of oceanic tropical convection, particularly above the 0°C level, which is not well known in under sampled tropical ocean regions (Vivekanandan et al. 1999), (ii) provide information of the distribution of the boundary layer moisture, and (iii) detect small cumulus population during the suppressed and transition phases of the MJO.

SMART-R: 3-D observations of the evolution of the spectrum of convection will be made within 150 km of the radar. Surveillance scans out to 250 km will be run every ten minutes to provide a larger view of the convective activity in and around the sounding array.

Air-sea flux measurement: This is crucial to DYNAMO/CINDY2011 for two reasons. First, as stated earlier, closing budget estimates based on soundings needs accurate information of surface fluxes. Second, the role of air-sea interaction in MJO initiation remains unclear. To fully understand the potential role of air-sea interaction in MJO initiation, measurements of high-resolution mixed profiles of the upper ocean and atmospheric boundary-layer turbulence are needed as well as surface fluxes. These measurements can take place from ships (air-sea fluxes, upper ocean mixing, atmospheric boundary layer) and additional moorings (air-sea fluxes, upper ocean mixing) inside the sounding-radar array. Various modern instrument with unprecedented accuracy and relatively low cost can be deployed, such as lidar, high-resolution ADCPs, gliders, rapid profilers, and  $\chi$ pod. To facilitate the budget estimate for the sounding array, it is necessary to deploy additional moorings within the sounding-radar array to measure surface precipitation and air-sea fluxes.

Aerosol measurement: Aerosol observations from a ship will help investigate its possible role in cloud and precipitation formation in the context of the MJO initiation and life cycle. Continuous time series of physical, chemical, optical, and cloud nucleating properties of aerosols, in combination with the ship-borne precipitation and cloud radars, can be used to elucidate the processes and cause-and-effect relationships between aerosols, cloud physics, and precipitation and to constrain numerical models to quantify such relationships. This aerosol time series will be a supplementary and comparative dataset for the aerosol measurement downstream by PAC<sup>3</sup>E-SA/7SEAS near Indonesia (section 4).

At this stage, the detailed design of the sounding-radar array has to be made with two issues remaining unresolved. One is the availability of ship time from the US and French, the other is the permission from the US Navy base to use Diego Garcia as an observation site. Because of these uncertainties, two alternative sounding-radar arrays are proposed with and without the availability of Diego Garcia to DYNAMO. Also two optional timelines are proposed, one include French ship, the other does not. Figure 6 illustrates the two designs of the sounding-radar array in comparison to the sounding arrays of TOGA COARE and MISMO. Figure 7 shows the two lineups of ships with and without the French contribution.

The first choice of the sounding-radar array (Plan A) is formed by Gan Island of Madives (0.7°S, 73.2°E), Diego Garcia (7.3°S, 72.5°E), and two research vessels

stationed at 0, 79°E and 8°S, 79°E, respectively. This array will be referred to as the Southern Array. Gan Island was use as an observational site to form a triangular array for MISMO is 2006. There is an international airport and other facilities adequate to establish an observational site for DYNAMO. The main issue at hand is to get permission from the US Navy base at Diego Garcia to set up an observational site of DYNAMO. This issue will be addressed through ONR.



Figure 6 Proposed sounding-radar arrays, with the sounding arrays of TOGA COARE and MISMO in comparison. (Courtesy of Kunio Yoneyama)

In case Diego Garcia is not available, the sounding-radar array will be formed by Gan Island and Hanimaadhoo Island (6.5°N, 73.9°E) and two research vessels at 0, 79°E and 6.5°N, 79°E, respectively (Plan B). This array will be referred to as the Northern Array. Hanimaadhoo Island hosts the Maldives Climate Observatory and a Super Observatory of Asian Brown Cloud Project, and should be able to host an observational site of DYNAMO.

Another possibility is to form a triangular array of two islands and one research vessel as in MISO (Fig. 6, lower right panel). The main advantage of this configuration is that, with all available ships (see discussion below) on one station in relay, the IOP can be extended for a longer period to guarantee a better chance to capture a major MJO event. The major disadvantage is that the triangular array would suffer from large errors in estimate of divergence associated with the equatorial Rossby wave, which is an intrinsic component of the MJO. For this reason, CINY2011 will not pursue this configuration unless neither the US nor France ship will be available.

Ships available for CINDY2011 include R/V Mirai of Japan (50 days on station committed), R/V Saga Kanya of India (30 days on station committed), RV Southern Surveyor of Australia (30 days on station proposed), R/V Ron Brown or a UNOLS ship from the US (40 - 50 days on station to be proposed), and possibly a ship from France (30 days on station to be proposed). The ship lineups Fig. 5 are proposed to maximize the

length of the IOP with considerations of available ship ferry and on station time.

The Southern Array is preferred over the Northern Array. The Southern Array is closer to the Seychelles-Chagos thermocline dome and would be more relevant to study air-sea interaction associated with the shallow mixed layer there during MJO initiation.

#### 3.1b Extended Observing Period (EOP)

The major component of the EOP of DYNAMO is the SMART C-band radar bundled with AMF2. This combination would form an almost identical package as the facility of DOE ARM site on Manus Island, where a C-band radar is planned to be deployed in early 2011 to be part of AMIE. This pair of radiation-radar observations will provide unique comparisons of the MJO at two distinct stages of its life cycle. Additional surface meteorology and upper ocean (including high-resolution mixing profiles) moorings to be deployed inside the sounding-radar array will be another component of the EOP. Drifters to be deployed before and at the beginning of the CINDY2011 IOP also contribute to the EOP. These drifters can fill undersampled regions in the tropical Indian Ocean and provide additional information of surface temperature, salinity, and current.

#### 3.1c Long-Term Monitoring

Long-term monitoring is not a direct component of DYNAMO/CINDY2011, even though drifters deployed by DYNAMO will contribute to it. The existing long-term monitoring network in the Indian Ocean, namely, the IndOOS and RAMA will be nearly completed by 2011 and thus provide basin-scale and multiyear background information for DYNAMO/CINDY2011. Regular continuous measurement at ARM sites of Darwin, Nauru and Manus also provide long-term background information of surface radiation/energy flux and cloud evolution associated with the MJO.

4. Project management and operational support

5. Data policy and management

### Appendix B DYNAMO Observations

Observation/Instrument (observation period)	PI (Institution)	Funding Agency
Ship-based (Ron Brown and	Vor UNOLS ship):	
soundings (IOP)	R. Johnson (CSU)	NSF
NASA TOGA radar (IOP)	S. Rutledge (CSU)	NSF, NASA
air-sea flux (IOP)	C. Fairall (NOAA/ESRL)	NOAA
	S. DeSzoeke (OSU)	NSF
lidar (IOP)	A. Brewer (NOAA/ESRL)	NOAA
aerosol (IOP)	T. Bates (NOAA/PMEL)	NOAA
high-resolution mixing (IOF	P) J. Moum (OSU)	NSF, ONR
drifters (EOP)	R. Lumpkin (NOAA/AOML)	NOAA
Land-based (Gan, Hulhule,	and/or Diego Garcia):	
ISS/soundings (IOP)	R. Johnson (CSU)	NSF
SMART radar (EOP)	C. Schumacher (Texas A&M)	NSF, JAMSTEC
AMF2 (EOP)	C. Long (PNNL)	DOE
S-PolKa radar (IOP)	S. Medina (UW)	NSF
Mooring-based:		
upper ocean/	M. McPhaden (NOAA/PMEL)	NOAA

surface meteorology moorings

(EOP)

(LOI)		
mixing profiles on	J. Moum (OSU)	NSF, NOAA
RAMA moorings (EO	P)	
high-resolution wave-	R-C. Lien (UW)	NSF, ONR
propagation mixing m	oorings (EOP)	

## Appendix C Acronym List

ACRF	ARM Climate Research Facility
AIRS	The Atmospheric Infrared Sounder
AMF2	ARM Mobile Facility 2
AMIE	ACRF MJO Investigation Experiment
ARM	Atmospheric Radiation Measurement
CAM	Community Atmosphere Model
CAPT	CCPP-ARM Parameterization Testbed
CCPP	Climate Change Prediction Programs
CFS	Coupled Forecast System
CINDY2011	Cooperative Indian Ocean Experiment on Intraseasonal Variability in
	the Year 2011
COAMPS	Coupled Ocean-Atmosphere Mesoscale Prediction System
CPC	Climate Prediction Center
CRM	Cloud Resolving Model
CSU	Colorado State University
СТВ	Climate Test Bed
ECMWF	European Centre for Medium-Range Weather Forecasts
EDO	Experimental Design Overview
EMC	Environmental Modeling Center
EOL	Earth Observing Laboratory
EOP	Extended Observing Period
DRI	Departmental Research Initiative
DOE	Department of Energy
DYNAMO	Dynamics of the MJO
ENSO	El Niño – Southern Oscillation
ESRL	Earth System Research Laboratory
GDAS	Global Data Assimilation System
GEFS	Global Ensemble Forecast System
GEOS-5	Goddard Earth Observing System Model Version 5
GPS	Global Position System
HARIMAU	Hydrometeorological Array for ISV-Monsoon Automonitoring
HcGCM	Hybrid coupled GCM
INDEOX	The Indian Ocean Experiment
IndOOS	Indian Ocean Observing System
IOD	Indian Ocean Dipole
IOP	Intensive Observing Period
IPRC	International Pacific Research Center
IROAM	IPRC Regional Ocean-Atmosphere Model
ISU	Iowa State University
ISV	Intraseasonal Variation
JASMINE	Joint Air-Sea Monsoon Investigation
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JPL	Jet Propulsion Laboratory
LOI	Letter of Intent

MISMO	Mirai Indian Ocean cruise for the Study of MJO-convection onset
MJO	Madden-Julian Oscillation
MMM	Mesoscale and Microscale Meteorology
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NOAA	National Ocean and Atmosphere Administration
NOGAPS	Navy's Operational Global Atmospheric Prediction System Model
NPS	Naval Postgraduate School
NRCM	NCAR Nested Regional Climate Model
NRL	Navy Research Laboratory
NSF	National Science Foundation
ONR	Office of Navy Research
OSU	Oregon State University
PAC <sup>3</sup> E-SA	Pacific Atmospheric Composition, Cloud and Climate Experiment -
	Southeast Asia
PNNL	Pacific Northwest National Laboratory
PSMIP	Process Study and Model Improvement Panel
RAMA	Research Moored Array for African-Asian-Australian Monsoon
	Analysis and Prediction
R/V	Research Vessel
7SEAS	The Seven SouthEast Asian Studies
SMART-R	Shared Mobile Atmosphere Research and Teaching Radar
SPO	Science Planning Overview
THORPEX	The Observing System Research and Predictability Experiment
TRIO	Thermocline Ridge of the Indian Ocean
TOGA COARE	Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere
	Research Experiment
UCSD	University of California at San Diego
UH	University of Hawaii
UM	University of Miami
UW	University of Washington
UNOLS	University-National Oceanographic Laboratory System
YOTC	Year of Tropical Convection
WCRP	World Climate Research Program
WWRP	World Weather Research Program