DYNAMO Workshop Summary

DYNAMO[1] is the US participation in CINDY2011, an international program for the study of MJO initiation processes in the Indian Ocean in 2011. The first DYNAMO planning workshop was held April 13-14, 2009 in the NOAA/ESRL, Boulder, CO. The objective of the workshop was to identify:

(a) Observation and modeling requirements to advance our understanding of critical processes in MJO initiation and to improve numerical simulations and prediction of MJO initiation, and

(b) Issues that have to be addressed to move forward the DYNAMO planning process.

The workshop covered a variety of topics, including scientific issues related to MJO initiation from viewpoints of forecast and numerical simulations, hypotheses on MJO initiation process, field observations, modeling-observation synergy, logistic and operational support, and potential partner programs in 2011. The workshop agenda is given in Appendix A. More than thirty-four people from universities and federal laboratories attended, including two scientists from JAMSTEC, representing CINDY2011. Appendix E lists the workshop participants. A complete set of presentations is available at http://www.eol.ucar.edu/projects/dynamo/meetings/200904/.

1. Scientific issues

There is currently a broad range of users of MJO prediction products, highlighting the importance of accurate MJO prediction to the society. However, tropical weather prediction suffers from particularly low skill in two stages of the MJO life cycle: its initiation in the Indian Ocean and its propagation across the Maritime Continent. The MJO initiation problem is difficult to solve because it may involve many mechanisms. They include (i) slow energy recharge in the troposphere due to sea surface fluxes, moisture advection and convergence, moistening of the lower troposphere by shallow convection, and radiative cooling, (ii) forcing from extratropical perturbations due to Rossby waves, cold surges, global wind oscillation and eddy momentum transport, etc., (iii) forcing from upstream due to previous circumnavigating MJO events, and (iv) dynamical response to tropical and extratropical stochastic processes. These possible mechanisms all operate under the influence of short-term climate variability, such as ENSO and IOD.

Understanding and forecasting the MJO in the Indian Ocean, especially its initiation, pose a great challenge. To a large extent, our current observational knowledge of the MJO is based on data from the western Pacific, where the in situ observations of TOGA COARE in 1992-93 captured three MJO cycles and the long record of the TAO mooring array provides reliable MJO statistics at the surface and in the upper ocean. In contrast, there are no in situ atmospheric observations covering the life cycle, including the initiation, of the MJO in the Indian Ocean. Time series of air-sea processes in the

[1] Acronyms are listed in Appendix F.

Indian Ocean is extremely limited from the RAMA array that has yet to be completed. None of the past field campaigns in the Indian Ocean (INDOEX, JASMINE, MISMO, Vasco-Cirene) captured MJO initiation. In addition, many global models that are capable of producing MJO signals suffer from a lack of MJO strength in the Indian Ocean.

The structures of the MJO and its embedded synoptic-scale perturbations vary in longitude from the Indian Ocean to the western Pacific, and what we know about the MJO in the western Pacific cannot be readily applied to the Indian Ocean. Mechanisms for MJO initiation in the Indian Ocean can be different from those for its propagation in the western Pacific. The large-scale dynamical component of the MJO always interacts with the convective component to provide a mechanism to maintain the MJO propagation in the western Pacific. Such a dynamical factor may or may not exist for MJO initiation in the Indian Ocean. One unique climatic feature of the Indian Ocean is the Seychelles-Chagos thermocline dome with a shallow mixed layer. Over this dome, SST perturbations in the intraseasonal frequency band are extraordinarily large, signaling that the air-sea interaction process during the MJO initiation stage could be different from that for the MJO propagation in the western Pacific where the thermocline is much deeper. As an important player in air-sea interaction, the detailed upper-ocean mixing profile in the equatorial Indian Ocean with its unique shear structure has never been systematically observed and analyzed. The same can be said to its counterpart of turbulence mixing in the atmospheric boundary layer. In summary, there is gaping hole in our observations and knowledge of the physical processes related to the MJO in the Indian Ocean.

2. Field campaign in 2011

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 in 2011 to collect in situ observations to meet this need. Numerical model experiments have led to several hypotheses on possible mechanisms for MJO initiation. These hypotheses include lower-tropospheric moistening, shallow convective heating, scale interaction, boundary-layer drying and recovery, upper ocean heat content, among others. Further testing these hypotheses would substantially benefit from in situ observations of surface fluxes, profiles of diabatic heating and moistening, cloud structure and population, precipitation characteristics, upper-ocean and atmospheric boundary-layer structure and mixing, etc. In addition, possible effects of Asian continental pollution aerosol to cloud and precipitation associated with MJO initiation are currently unknown. 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. This infrastructure will provide real time support for the field operation and its archived data will be used to quantify prediction improvement that may partially result from the field campaign. 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). Lastly, but most importantly, international cooperation and other US partnership programs will be in place in late 2011 to provide a comprehensive suite of observations across a large region of the Indian and western Pacific Oceans, as briefly described below (Fig. 1). 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 a critical time for DYNAMO.

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 Southern Surveyor, with radiosondes, surface and upper ocean observations). Enhanced radiosonde observations will be conducted at Seychelles during CINDY2011, in addition to the operational sounding launched in the region. A field experiment on meso- and synoptic-scale air-wave-sea interaction, to be sponsored by the ONR, is being planned for the Indian Ocean during the time period of CINDY2011 (late 2011). A French program TRIO may be conducted in 2011 with a focus on air-sea interaction over the Seychelles-Chagos thermocline dome. The ARM Program is considering a proposal to have an enhanced observational period of six months (AMIE) embedding the CINDY2011 period to document the MJO over the western Pacific. The enhanced observations are anticipated to include a new C-Pol radar and increased frequency of radiosondes in addition to the standard radiation package at the Manus Island site. Between the CINDY2011 site in the central equatorial Indian Ocean and the AMIE Manus site at the eastern end of the Maritime Continent there 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. Finally, a large NASA regional field effort, the Pacific Atmospheric Composition, Cloud, and Climate Experiment (PAC^3E), will take place over the Maritime Continent in the 2011 - 2012 timeframe. While PAC^3E will have comprehensive atmospheric chemistry and radiation components, one of its primary foci is the role of convection in pumping and evolving boundary layer air into the free troposphere. It is anticipated that the PAC^3E mission will utilize surface, shipboard, and aircraft measurements of aerosol and meteorology. By joining this suite of field programs in late 2011, 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 would probably not come again in the foreseeable future.

3. Field observations

To assist model validation, comparison, improvement and development as well as hypothesis testing, the following observations/instruments were recommended for the DYNAMO field campaign:

Ship-based (R/V Ron Brown and/or a UNOLS ship): radiosondes, a scanning Doppler precipitation radar, air-sea fluxes, surface and boundary layer, lidar, aerosol, high-resolution profiles of the upper ocean (including mixing), drifters gliders, and rapid profilers

Land-based (Diego Garcia and/or Maldives islands): radiosondes, C-Pol SMART radar, S-Pol radar, AMF2, lidar, and other surface flux and meteorology measurements

Mooring-based: mixing profiles (supplement to RAMA), additional upper ocean/surface meteorology moorings

Aircraft-based: observations of atmospheric boundary layer

Possible DYNAMO observations, tentative PIs, and potential funding sources are listed in Appendix B.

Before the experimental design can be finalized, several issues have to be addressed:
(a) Ship time of R/V Ron Brown has been requested (primary time window September-October 2011, secondary time window January-February 2012, with 25 days on station and 31 days total). However, the availability of the Ron Brown is uncertain and will not be known for some time. A request for a UNOLS ship needs to be made. The NASA TOGA radar needs to be installed on a UNOLS ship.
(b) It is desirable to include Diego Garcia (7.3S, 72.5E) as a land sounding/radar site so the sounding array is closer to the Seychelles-Chagos thermocline dome (centered near 7S). But the permission to do so will have to be given by the US Navy base there, which may not come as soon as desired.
(c) Because of the uncertainties in the ship availability and the permission to operation on Diego Garcia, several options were suggested for the sounding-radar array, including both triangle and rectangular designs. Because the arrays involve ships, there are tradeoffs between triangular and rectangular designs: a triangular array would allow for a longer sampling period thereby enhance the probability of capturing at least one MJO event, while a rectangular array improves the accuracy of the divergence field in atmospheric budgets. For the same reason, the exact locations of the land radars (Diego Garcia and/or Maldives islands) will have to be determined after the permission from Diego Garcia is given or denied.

It is anticipated that the DYNAMO field campaign will be supported by NCAR EOL in terms of operation and data management, among others.

4. Modeling

Modeling contributions to DYNAMO and model-observation synergy were obvious at the workshop. Low prediction skill for MJO initiation by numerical models and hypotheses proposed from model simulations and experiments to explain it motivate the DYNAMO field campaign. Model experiments have been used to help optimize the experiment design. In situ observations from the field campaign are needed to further test the hypotheses using numerical models. There is a hierarchy of models that have been and will continue to be used to investigate the MJO initiation problem in the context of DYNAMO. They include global and regional operational models (NCEP CFS, Navy NOGAPS and COAMPS), global and regional research models (NCAR CAM and NRCM, UH HcGCM, IPRC IROAM), and cloud resolving model (ISU CRM). A DYNAMO modeling working group was formed of scientists from NOAA/NCEP, NRL, and universities. They started active discussions immediately after the workshop on how models can further assist the DYNAMO field campaign, what common model experiments should be planned to quantify model uncertainties and to identify model deficiencies, and how field observations can be used for hypothesis testing, model validation, comparison, improvement and development. Their initial discussions are summarized in Appendix C.

At the end of the workshop, a list of action items was discussed, which will be pursued to move the DYNAMO planning forward. This timeline for DYNAMO planning is given in Appendix D.

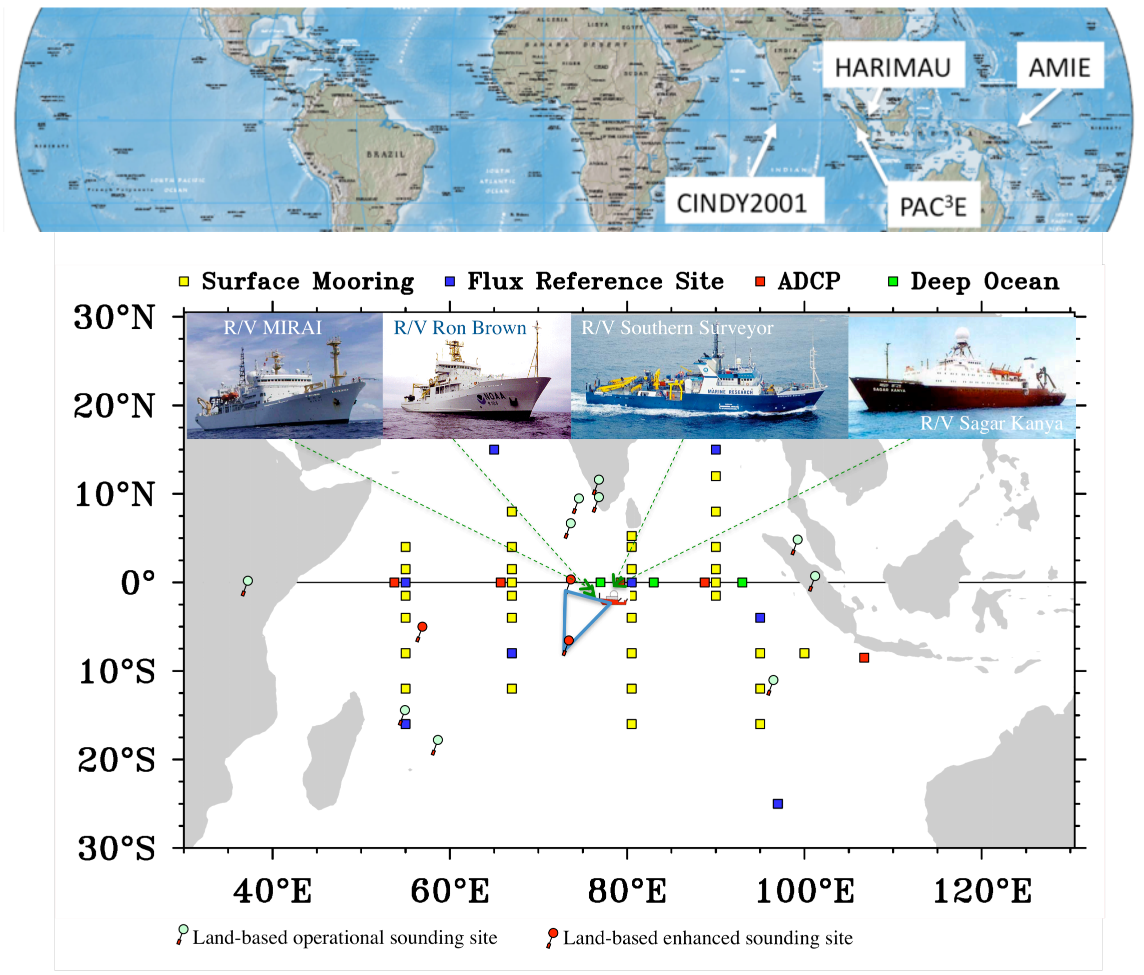

Figure 1 Top panel: Global perspective of CINDY2011/DYNAMO. Bottom Panel: CINDY2011 observing network. The triangle illustrates one option of the sounding-radar array formed by Gan Island, Diego Garcia, and four ships on station in relay. Squares are IndOOS and RAMA moorings.

Appendix A   Workshop Agenda

Monday, April 13 (starting 9 am)

Logistics information (Fairall)

1. Background on DYNAMO and meeting objectives (C.Zhang) **10 min**

2. Scientific issues (convener: Fairall)
MJO initiation problem: Mechanisms/MISMO (Johnson/Katsumata) 15 min
MJO initiation problem: Forecast/MJO prediction experiment (Vintzileos/Weickmann/Gottschalck) 45 min
Structures of atmospheric perturbations associated with the MJO (Kiladis) 15 min
Indian Ocean climate and observing systems (McPhaden) 15 min
PBL in convectively active and inactive periods (Wang) 15 min

3. Planning for 2011(convener: Johnson)
CINDY2011 (Yoneyama) 15 min
DYNAMO (C.Zhang) 15 min
DOE AMIE (Long) 15 min
TRIO (McPhaden) 15 min
ONR air-sea interaction experiment (Eleuterio/Harper) 15 min
YOTC and YOTC2 (Moncrieff) 15 min

4. DYNAMO observations (convener: C. Zhang)
GPS sondes (Johnson) 15 min
Seagoing lidar (Brewer/Tucker) 15 min
Aerosol (Bates/Fairall) 10 min
Surface flux/AMF2 (Fairall/Long) 15 min
Enhanced RAMA moorings (McPhaden) 15 min
Ocean mixing measurement (Moum) 15 min
Ship radar (Rutledge) 15 min
Land radar (Schumacher/Katsumata) 15 min

5. Field operation (convener: McPhaden)
ship time request (Fairall) 15 min
Integration of field components (Johnson) 15 min
field operation support (Meitin) 15 min
data management (Williams/C.Zhang) 15 min

Adjourn

Tuesday, April 14 (starting 8:30 am)

6. Modeling component and hypothesis testing (convener: Fairall)
NCEP CFS (Vintzileos) 15 min
NCAR CAM (Maloney/G.Zhang) 30 min

Regional model (Li) 15 min
Regional coupled model (Small/Xie) 15 min
Coupled COAMPS (Chen/Small) 15 min
NOGAPS (M.Flatau) 15 min
NRCM (Moncrieff) 15 min
CRM (Wu) 10 min

7. ***Action items*** (convener: C. Zhang)
form a science steering committee
expand the white paper into a science and implementation plan
seek broader support and involvement
inter-agency briefing
NOAA Climate Board briefing
others

End (12:30 pm)

Appendix B DYNAMO Observations

Observation/Instrument	PI (Institution)	Funding Agency
Ship-based (Ron Brown and/or UNOLS ship):		
soundings	R. Johnson (CSU)	NSF
NASA TOGA radar	S. Rutledge (CSU)	NSF, NASA
air-sea flux	C. Fairall (NOAA/ESRL)	NOAA
lidar	A. Brewer (NOAA/ESRL)	NOAA
aerosol	T. Bates (NOAA/PMEL)	NOAA
high-resolution mixing	J. Moum (OSU)	NSF, ONR
drifters	R. Lumpkin (NOAA/AOML)	NOAA
gliders, rapid profilers	P. Flatau (UCSD)	NSF, ONR
Land-based (Gan, Hulhule, and/or Diego Garcia):		
ISS/soundings	R. Johnson (CSU)	NSF
SMART radar	C. Schumacher (Texas A&M)	NSF, JAMSTEC
AMF2	C. Long (PNL)	DOE
S-pol radar	S. Medina (UW)	NSF
turbulence	Q. Wang (NPS)	NSF
lidar, surface fluxes	P. Flatau (UCSD)	NSF
Mooring-based:		
upper ocean/ surface meteorology moorings	M. McPhaden (NOAA/PMEL)	NOAA
mixing profiles on RAMA moorings	J. Moum (OSU)	NSF, NOAA
high-resolution wave-propagation mixing moorings	R-C. Lien (UW)	NSF, ONR
Aircraft-based (NOAA P-3):		
atmospheric boundary-layer turbulence	Q. Wang (NPS)	NOAA, ONR

Appendix C DYNAMO Modeling Activities

a. Experiments by operational forecast models

Revisiting the MISMO period (October-November 2006) through reforecasting will be the first task of the forecasting group. This will establish the skill that modern models have in forecasting variables that were helpful for MISMO and by consequence will be helpful for DYNAMO/CINDY2011. These reforecasts, coupled or uncoupled, are preferably 35-days in length. Reforecasts for a longer period will allow calibrating the forecasts and establish the baseline forecast statistics. Forecast should be initialized at least daily to provide a continuous picture of the representation of the MJO as a function of lead time and allow the generation of lagged ensembles. Additionally, recovering from the archives real time operational weather forecasts during the MISMO period will also be valuable. The reforecasts of the global models will provide initial and boundary conditions for higher resolution forecast based on regional models.

Diagnostics proposed by the US CLIVAR MJO Working Group will be adapted to validate the reforecasts. For high-resolution limited area models, a metric to evaluate the success of the forecast needs to be established during the virtue campaign phase. Investigating the root causes of poor forecast skill will be a key task to help set observational priorities for the field campaign. Virtual campaigns will use the comprehensive high-resolution database of YOTC as the ‘truth’ in combination with reforecasting in order to explore optimal observational grids. Data denial experiments during the MISMO period will try to define the most sensitive geographical locations and observation times. Currently, models show a variety of behaviors in their MJO related forecasts. We expect that the forecast products specifically tailored for DYNAMO will be multivariate. Reforecasting will establish a base for pursuing the possibility of a multi-model ensemble forecast approach for the MJO.

Data collected during CINDY/DYNAMO in combination with previous model simulations and forecasts will allow better understanding of the physical processes related to MJO. This better understanding may lead to the improvement of existing parameterizations. These new parameterization schemes will be tested in a series of reforecasts that will be compared with the baseline reforecasts conducted before the campaign. The necessary computing time that will ultimately prove the value of the campaign should be one of the requests of DYNAMO. In addition, the sensitivity of the forecast skill to special field data can be examined using the data denial technique in the reforecast data assimilation runs.

NCEP: EMC and CTB will provide hindcasts with the intermediate version of the CFS initialized by the operational GDAS instead of Reanalysis-2 for the period October to December 2002 to 2006; this will cover the MISMO campaign. EMC is providing forecasts to YOTC. EMC is currently computing a new reanalysis and a new series of hindcasts (1980 to 2009) with the next version of the CFS. These will be available towards the end of 2010. NCEP/EMC is also committed to provide operational forecasts during the campaign with the GFS and GEFS.

CPC will coordinate the virtual map room and organize materials for daily briefings. This will include realtime evaluation and assessment of the US CLIVAR MJO index model forecasts.

NRL: High-resolution forecasts for the MISMO period will be conducted using COAMPS, with data denial experiments retaining selected MISMO observations from the experimental analysis.

NASA: A new series of 6 months hindcasts with the GEOS-5 coupled model is being computed. These daily hindcasts have already covered the period 1980 to 2004. It is expected that these hindcasts will cover the MISMO period. NASA is also providing YOTC with high-resolution forecasts.

There will be strong interaction with the modeling experiments by research climate models in the investigation of the reasons for low forecast skill, in defining additional diagnostics when necessary and on setting observational priorities.

b. Experiments by research climate models

Climate and forecasting models traditionally have difficulties simulating MJO initiation, as well as maintaining the amplitude of strong MJO events that are already in progress. Recent modeling and observational studies have presented hypotheses for why some models are deficient at simulating MJO initiation, while other models do significantly better. Such variance in model behavior may also provide insight into the processes that regulate initiation of MJO convection in the Indian Ocean. Good models appear to allow atmospheric preconditioning before deep MJO convection occurs, as well as realistically simulate convective triggering processes and upper ocean SST and heat content variability (including diurnal cycle). Shallow convection, horizontal advection, surface latent heat fluxes, and ocean coupling were hypothesized as important processes for regulating model MJO preconditioning in advance of Indian Ocean MJO events.

Appropriate measurements to be collected during the DYNAMO field phase can be used to test these model-derived hypotheses. Research modeling efforts can help guide DYNAMO observational priorities, with the resulting observations providing potentially important feedbacks that highlight model and parameterization deficiencies. Common MJO initiation diagnostics will be developed to allow direct comparison among models and DYNAMO field observations. This effort will be strengthened by leveraging strong linkages to other programs such as the CLIVAR MJO Working Group and YOTC. For example, support for the YOTC virtual field campaign and extension of the CAPT forecasting efforts through the DYNAMO time period may be mutually beneficial to both YOTC and DYNAMO. DYNAMO can also support an extension of CLIVAR MJO Working Group activities to develop MJO initiation diagnostics. Careful evaluation of the DYNAMO field observations as well as complementary data sets can be used to evaluate a hierarchy of models and improve parameterizations.

It is suggested that the experimental modeling group start formulating requests for computing support as well as human resources to assist in modeling activities supporting DYNAMO.

Appendix D DYNAMO Timeline:

(Coordinated partner programs are in parentheses)

October 2011: field campaign starts

July 2011: finalize the Operations Plan and Data Management Plan

April 2011: operations planning meeting; project safety review

January 2011: implementation starts

January 2011: NSF decision on individual proposals

November 2010: facility request review by OFAP

October 2010: facility and science coordination meeting

September-October 2009: preliminary site survey to provide feasibility to OFAP

August 1, 2010: submit facility request to OFAP

June 2010: submit individual proposals to NSF

May 2010: EDO review by the OFAP

January 2010: submit AMF2 proposal to ARM

January 2010: submit SPO and EDO to NSF

(December 2009: Request/LOI for NOAA aircraft flight hours)

December 2009: request preliminary cost estimates from EOL (no later than 1 Dec)

August 2009: request UNOLS ship time

July 15-17, 2009: presentation at the US Clivar Summit

(July 1, 2009: ONR DRI full proposals due)

July 1, 2009: send drafts of SPO and EDO to the US Clivar PSMIP

May 15, 2009: Letter of Intent to EOL

May 2009: finalize planning workshop summary and update the white paper; estimate field program budget

Now ————————————————————————————————

(May 1, 2009: AMIE proposal to ARM submitted)

April 2009: science steering committee (SSC) formed

(April 17, 2009: ONR DRI planning letters due)

April 13-14, 2009: first planning workshop; modeling working group formed

April 2009: ship time of R/V Ron Brown requested for DYNAMO

Spring 2009: The US Clivar PSMIP supported the DYNAMO initial plan

July 2008: a white paper of DYNAMO written and presented to the US Clivar Summit

Spring 2008: invitation from CINDY2011 for the US to participate in the 2011 Indian Ocean field experiment

Appendix E Participant List

Alan Brewer (NOAA/ESRL)
Sue Chen (NRL)
Paul Ciesielski (CSU)
Rob Cifelli (CSU)
Mike Daniels (UCAR/EOL)
Dan Eleuterio (ONR)
Chris Fairall (NOAA/ESRL)*
Maria Flatau (NRL)
Piotr Flatau (UCSD)
Jon Gottschalck (NOAA/NCEP/CPC)
Scott Harper (ONR)
Richard Johnson (CSU)*
Masaki Katsumata (JAMSTEC)
George Kiladis (NOAA/ESRL)
Timothy Lang (CSU)
Tim Li (UH)
Chuck Long (DOE/PNNL)
Eric Maloney (CSU)
Mike McPhaden (NOAA/PMEL)*
Socorro Medina (UW)
Jose Meitin (UCAR/EOL)
Mitch Moncrieff (NCAR/MMM)
James Moum (OSU)
Steve Rutledge (CSU)
Justin Small (NRL)
Sara Tucker (NOAA/ESRL)
Augustin Vintzileos (NOAA/NCEP/EMC)
Qing Wang (NPS)
Klaus Weickmann (NOAA/ESRL)
Steve Williams (UCAR/EOL)
Xiaoqing Wu (ISU)
Kunio Yoneyama (JAMSTEC)
Chidong Zhang (UM)*
Guang Zhang (UCSD)

*Organizing Committee

Appendix F Acronym List

ACRF	ARM Climate Research Facility
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
CTB	Climate Test Bed
EDO	Experimental Design Overview
EMC	Environmental Modeling Center
EOL	Earth Observing Laboratory
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
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
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
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
SMART-R	Shared Mobile Atmosphere Research and Teaching Radar
SPO	Science Planning Overview
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