DYNAMO Operations Plan (Darft 3)

Executive Summary

DYNAMO is a US research program motivated by two outstanding problems:

(i) Current prediction skill for the Madden-Julian Oscillation (MJO) is very limited; particularly, it is the lowest for the MJO initiation phase over the Indian Ocean.

(ii) The inability of state-of-the-art global models to produce the MJO degrades their seasonal to interannual prediction and lessens our confidence in their ability to project future climate.

The overarching goal of DYNAMO is to expedite our understanding of processes key to MJO initiation over the Indian Ocean and our efforts to improve simulation and prediction of the MJO. DYNAMO consists of four integrated components: a field campaign, data analysis, modeling, and forecasting.

The DYNAMO field campaign is proposed as the US component of CINDY2011 (*Cooperative Indian Ocean Experiment on Intraseasonal Variability in Year 2011*), an international field program planned for October 2011 – March 2012 in the equatorial central Indian Ocean region. Four countries (Australia, India, Japan, and the US) will participate. This field campaign is designed to collect observations that are necessary to test hypotheses on three key aspects of MJO initiation: the structure and evolution of cloud populations, their interaction with the large-scale environment, and air-sea interaction. It will include an atmospheric sounding network, a radar network consisting of an island "supersite" with multiple radars (NCAR S-PolKa, Texas A&M SMART-R C-band, DOE AMF2 X-, K_a- and W-bands) and shipborne C- and W-band Doppler radars, and a ship/mooring network to measure air-sea fluxes, marine atmospheric boundary-layer properties, and upper-ocean large-scale and mixing structures.

DYNAMO will target processes deemed critical to MJO initiation but poorly observed and understood, including shallow cloud moistening, convective sensitivity to environmental moisture, low- vs. upper-level diabatic heating, cloud microphysics, convective organization, large-scale moisture advection and convergence, surface evaporation, the ocean barrier layer, and upper-ocean mixing and entrainment. A better understanding of these processes is essential for improving their representations in numerical models and improving MJO simulation and prediction. The newly available observation technology (e.g., scanning K_a-band radar, dual-wavelength radar, and moored microstructure sensors) and innovative instrument combinations (e.g., at the radar supersite) will allow DYNAMO field campaign to provide unprecedented information of these processes. The field campaign will consist of three observing periods:

– Special Observing Period (SOP): 1 October - 9 November 2011

– Intensive Observing Period (IOP): 1 October 2011 - 15 January 2012

– Extended Observing Period (EOP): 1 October 2011 - 31 March 2012

The SOP is designed to sufficiently resolve the diurnal cycle with the maximum observation capacity of DYNAMO. The IOP will cover initiation of at least one major MJO event using all DYNAMO instruments with a high probability (~90%). Over the course of the EOP, this probability is nearly 100% and likely multiple MJO events will occur. The field observations will be augmented by auxiliary data with longer and broader coverage (from RAMA moorings, satellites, global reanalyses).

The DYNAMO observations will be use to calibrate and validate satellite retrievals to benefit their application to much broader areas beyond MJO-related problems. Improved model simulation and prediction of the MJO born from DYNAMO activities will enhance our capacities of delivering prediction and assessment products on intraseasonal timescales for risk management and decision making, and to strengthen confidence in climate simulation and projection.

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Chapter 1 DYNAMO Science Overview

The Madden-Julian Oscillation (MJO, Madden and Julian 1971, 1972) dominates tropical intraseasonal (20 – 100 days) variability. As it propagates eastward from the Indian Ocean to the western and central Pacific, the MJO interacts with many weather and climate systems. Because of the important roles of the MJO in weather and climate, society increasingly demands its accurate prediction. Current prediction of the MJO, however, suffers from very low skill, particularly during its initiation over the Indian Ocean and when it is about to propagate across the Maritime Continent. Meanwhile, even though improvement in MJO simulation has been shown by new capabilities in global cloud system resolving models and cloud-resolving convection parameterization, most state-of-art global climate models either under-estimate the strength of the MJO over the Indian Ocean or are unable to reproduce any salient feature of the MJO at all. Poor simulations of the MJO in climate models expose deficiencies in their cumulus parameterizations and therefore lessen our confidence in their ability to project future climate. Particularly, because of the close connections between the MJO and extreme events mentioned above, the inability of climate models to simulate the MJO and its potential response to climate change seriously limits the application of these models to predict the statistics of extreme events in the future. The limited prediction skill for the MJO and inability of state-of-the-art global models to produce the MJO motivate the research program DYNAMOM (*Dynamics of the MJO*) and its mother program CINDY2011 (*Cooperative Indian Ocean Experiment on Intraseasonal Variability in Year 2011*). CINDY2011 is an international program with participations from nine countries (Australia, France, Kenya, India, Indonesia, Japan, Seychelles, Taiwan, US). DYNAMO is the US contribution to CINDY2011. Hereafter, “DYNAMO” should be taken as “DYNAMO/CINDY2011”.

The overarching goal of DYNAMO is to expedite our understanding of MJO initiation processes and our efforts to improve simulation and prediction of the MJO. This goal will be achieved by following an integrated approach of field observations, data analysis, modeling, and forecasting in collaboration with its international partners. The specific DYNAMO objectives are to:

- Collect observations from the equatorial central Indian Ocean region that are urgently needed to advance our understanding of the processes key to MJO initiation;
- Identify critical deficiencies in current numerical models that are responsible for their low prediction skill and poor simulations of MJO initiation;
- Provide unprecedented observations to assist the broad community effort toward improving model parameterizations;
- Provide guiding information to enhance MJO monitoring and prediction capacities for delivering better climate prediction and assessment products on intraseasonal timescales for risk management and decision making over the global tropics.

A conceptual model of MJO initiation is proposed for DYNAMO. In this model, MJO initiation consists of three stages: pre-onset, onset, and post-onset. In order to understand MJO initiation, we need to determine the mechanisms that initiate each stage, sustain it for a certain time, and cause its demise. DYNAMO hypotheses emphasize three key aspects: interaction between convection and environmental moisture, the evolution of the cloud populations, and air-sea interaction. Inadequate representations of these processes in numerical models may inhibit their accurate simulation and prediction of MJO initiation. The DYNAMO hypotheses are:

Hypothesis I: Deep convection can be organized into an MJO convective envelope only when the moist layer has become sufficiently deep over a region of the MJO scale; the pace at which this moistening occurs determines the duration of the pre-onset stage.

Hypothesis II: Specific convective populations at different stages are essential for MJO initiation.

Hypothesis III: 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.

These hypotheses will be tested using DYNAMO field observations, auxiliary data (from moorings, satellites, and global reanalyses), and numerical models constrained, validated and evaluated by observations. Detailed descriptions of the scientific background, rationale, hypotheses, and program components of DYNAMO are given in the DYNAMO Scientific Program Overview (SPO). Descriptions of observing facilities and rationales for their deployment to collect data for DYNAMO hypothesis testing are discussed in the DYNAMO Experimental Design Overview (EDO). This current document provides operation guidance for the field campaign.

Chapter 2 General Planning for the Field Campaign

DYNAMO field campaign will take place in the equatorial central Indian Ocean (Fig. 1.1). It consists of four main components:

- A sounding array formed by two islands, Gan (0.7°S, 73.2°E) and Diego Garcia (7.3°S, 72.5°E), and two research vessels, one at 0°, 80°E ("northeast point" or NE) and another at 7.3°S, 80°E ("southeast point" or SE). Three ships will participate in the formation of the sounding array. They are the *R/V Mirai* (Japan), *Sagar Kanya* (India), and *R/V Roger Revelle* (US). GPS sondes will be launched from all four island and ship sites and wind profilers will operate on Gan and onboard three ships. The detailed plan for the sounding operations is given in Chapter 5.
- A radar network including a multi-radar "supersite" on Gan (with the NCAR S-Polka dual wavelength radar, Texas A&M SMART C-band radar, DOE AMF2 X-, K_a- and W-band radar system) and C- and W-band radars on the *R/V Mirai* and *Revelle* to be stationed at the NE and SE points of the sounding array (blue circles in Fig. 1.1). The detailed plan for the radar operations is given in Chapter 4.
- A network for air-sea interaction measurements. Moored buoys with instruments for surface meteorology and high vertical and temporal resolution upper-ocean temperature, salinity, current, and turbulence flux profiles will be deployed at 78°E and 0, 2, 5 and 8°S (red diamond in Fig. 1). High-resolution upper-ocean moored turbulence sensors will also be outfit to three existing RAMA moorings at 0° 80°E, 0° 90°E, and 2°S 80°E (yellow dots in Fig. 1). Air-sea fluxes, upper-ocean profiles, and atmospheric boundary-layer profiles will be measured from all ships (blue squares in Fig. 2.1). In addition, aerosol, ozone, and marine biochemical samples will be measured from ships. The detailed plan for the ship operations is given in Chapter 3.
- Two research airplanes. The NOAA P-3 will be based on Diego Garcia. Its mission objectives include the air-sea interface, atmospheric convection, and the large-scale gradient in atmospheric and oceanic dynamical and thermodynamical fields. The French Falcon will be based on Gan Island. Its objective is main cloud microphysics. The detailed plan for the aircraft operations is given in Chapter 6.

In addition, comprehensive measurement of radiation and other surface meteorology will be made at Gan Island and Diego Garcia. The detailed plan for these observing operations is given in Chapter 7.

The DYNAMO field campaign will be supported from various perspectives. Details plans for these support are given in, respectively, Chapters 8 (forecast), 9 (modeling), 10 (communication), 11 (data management), and 12 (logistics).

The general observational timeline of DYNAMO is outlined in Fig. 2. The main DYNAMO field campaign will start on 1 October 2011 and end on 31 March 2012. It will consist of three observing periods:

- Special Observing Period (SOP, 1 October – 15 November 2011, section 3.1),
- Intensive Observing Period (IOP, 1 October 2011 – 15 January 2012, section 3.2), and
- Extended Observing Period (EOP, 1 October 2011 – 31 March 2012, section 3.3).

The objective of the SOP is to sufficiently document the diurnal cycles in the vertical structures of the atmospheric large-scale environment, its embedded convective clouds, and the air-sea interaction using the maximum observing capacity of DYNAMO. GPS sondes will be launched 8 times per day from all island and ship sites. During the SOP, and only during the SOP, will all DYNAMO radars be operating simultaneously onboard *R/V Mirai* (at the SE point of the array) and R/V *Revelle (*at the NE point), and at the supersite on Gan.

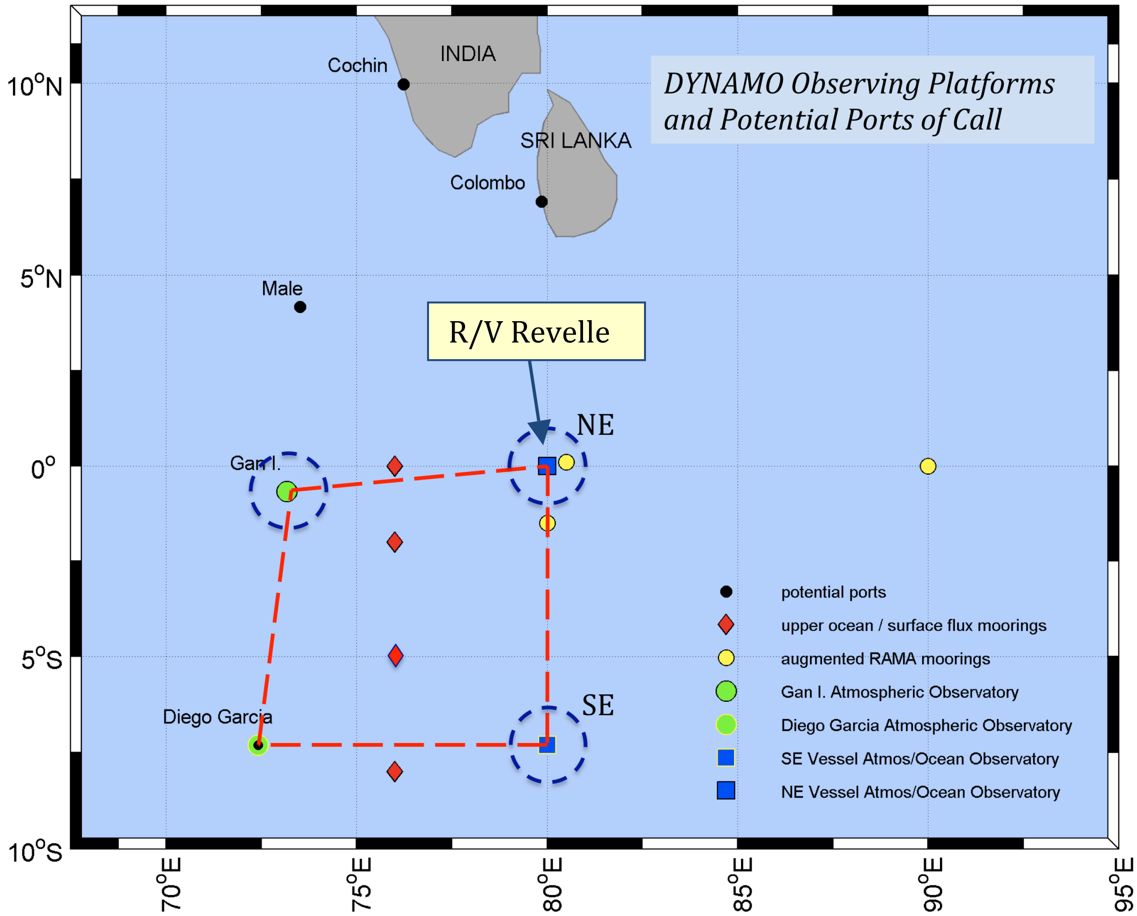

Figure 2.1 Map of DYNAMO field campaign platforms and potential ports of call. Red dashed lines mark the sounding array. Blue dashed circles indicate the radar sites.

The objective of the IOP is to document the evolution in the processes of the atmosphere, upper ocean, and their interface at all stages of MJO initiation using all DYNAMO instruments. From the end of the SOP (9 November 2011) to the end of the IOP, the sounding frequency will remain 8 times per day at Gan Island and R/V Mirai but reduce to 4 times per day at Diego Garcia and R/V Revelle. R/V Mirai will finish her mission November 28 and leaves the sounding-radar array. R/V Revelle and S. Kanya will stay to form the sounding array until the end of the IOP. Aircraft operation will take place during the IOP. DYNAMO moorings will be retrieved after the IOP.

The objective of the EOP is to expand the DYNAMO observation sample size by documenting MJO initiation of multiple events and to compare the MJO at distinct stages of its lifecycle over the Indian Ocean, Northern Australia, and the western Pacific Ocean using the same instruments. After the IOP, there will be no ship observations. Two radar systems, a sounding system, and a full radiation package (SMART-R and AMF2) on Gan will continue to operate until 31 March 2012, which is the end of EOP and the entire DYNAMO field campaign. The outfit mixing profilers on RAMA moorings will continue taking observations during part of the EOP (until the end of December 2011). During the EOP the combination of SMART-R and AMF2 on Gan would form a package nearly identical to the facilities at the ARM Darwin and Manus sites to document the same MJO events at different stages of their lifecycles. The comparison and cross-calibration among different radars at the Gan supersite and between measurements from Gan and the sounding-radar array during the IOP will provide detailed and quantitative information of how the EOP observations can be optimally interpreted.

Chapter 3 Ship Operation

3.1 Overview

R/V Roger Revelle is committed to DYNAMO operations in the Indian Ocean from August 2011 to February 2012. Three oceanographic moorings with surface meteorological components and three subsurface moorings will be deployed from Revelle at the beginning of this period and recovered at the end. During the mooring deployment cruise, a preliminary survey of upper ocean structure across the DYNAMO region will be conducted using a towed undulating SeaSoar. The primary role of Revelle will be to act as a stationary platform at 0, 80E (near the RAMA mooring at that location) for intensive boundary layer observations in both atmosphere and upper ocean, atmospheric thermodynamic soundings, lidar and radar observations of clouds.

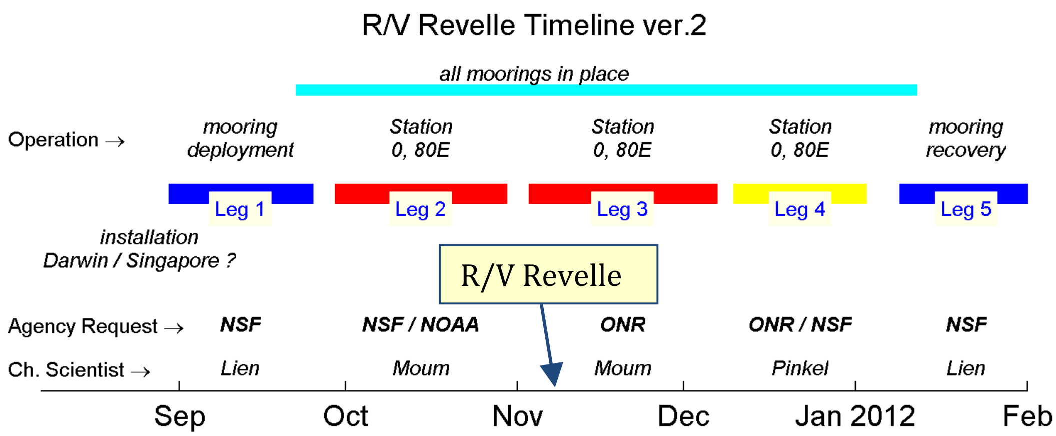

Figure 3.1 – DYNAMO timeline from R/V Revelle's perspective

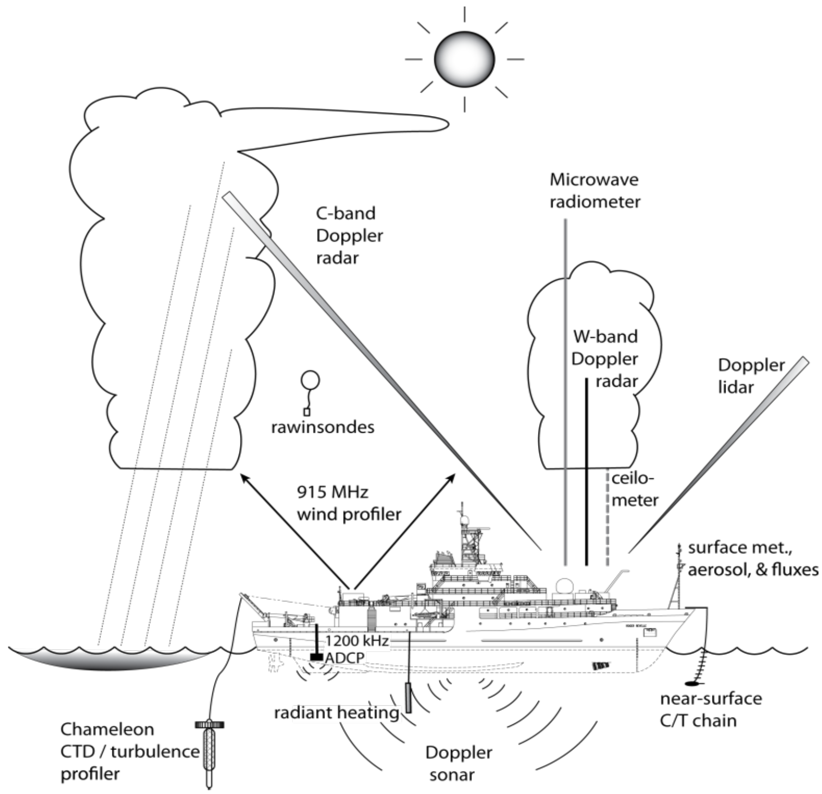

Figure 1.2 schematic of shipboard instrumentation for DYNAMO

Instrumentation

Table 3.1 Station observations on Revelle DYNAMO

Instrument/measurement		***PI***
radiosondes	3 hr (SOP) and 6 hr (IOP)	Johnson (CSU), Brown(NCAR)
surface met/bulk flux	10 min	Fairall (NOAA), Edson (UConn), deSzoeke (OSU)
turbulent flux	Continuous / 10 min avg	Fairall (NOAA), Edson (UConn), deSzoeke (OSU)
Doppler C-band radar	Continuous	Rutledge (CSU)
Doppler W-band radar	Continuous	Fairall, Brewer (NOAA), de Szoeke (OSU)
scanning Doppler lidar (HRDL)	20 min (wind, turbulence, and aerosol backscatter intensity); 10 min (clouds, precipitation, vertical velocity)	Brewer (NOAA)
wind profiler (915 MHz)	30 min winds, 1 min moments	Brown (NCAR)
Ceilometers	20 sec	Fairall, Brewer (NOAA), de Szoeke (OSU)
Solar/IR radiometers	10 min	Fairall, Brewer (NOAA), de Szoeke (OSU)
Microwave radiometer vapour/liquid	20 sec	Fairall, Brewer (NOAA), de Szoeke (OSU)
Ozone UV absorbance	1 min	Bates (NOAA)
SO_2, Pulsed fluorescence	1 min	Bates (NOAA)
Radon	13 min	Bates (NOAA)
Aerosol chemistry, Q-AMS	5 min	Bates (NOAA)
Aerosol chemistry, Impactors	4-12 hrs	Bates (NOAA)
Aerosol light scattering, TSI 3563 nephelometers	1 min	Bates (NOAA)
Aerosol light absorption Radiance Research PSAP	1 min	Bates (NOAA)
Total particle number CNC	1 sec	Bates (NOAA)
Aerosol number size distribution, DMA and APS	5 min	Bates (NOAA)
DMT CCN counter	30 min	Bates (NOAA)
Aerosol optical depth, Microtops	1 hr	Bates (NOAA)
GPS water vapor	10 min	Brown NCAR
120 kHz sounder (150m)	1 sec	Moum (OSU)
Chameleon turbulence profiler (200m)	8-10 per hour	Moum (OSU)
CTD	8-10 per hour	Moum (OSU)
ADCP	5 sec (500m)	Moum (OSU)
Bow CT chain	1 s	Moum (OSU)
Sea-Soar	upper 300 m / 1 km profile spacing	Lien (UW/APL)
Surface radiometer	10 min (3 Hz when profiling)	Ohlmann (UCSB)
Profiling radiometer	Every few hrs during day to ~40 m	Ohlmann (UCSB
water sampling (biogeochemical analysis)	1 x daily (at local noon) to ~150 m water samples at 12 depths tbd	Ohlmann (UCSB)
Scanning LIDAR (High-Resolution Waves)	Continuous; 10 kHz sampling	Zappa (LDEO Columbia)
WaMoS (Directional Waves; Existing onboard)	Continuous; 20 min avg	Zappa (LDEO Columbia)
IR Imagery (SST variability, upper ocean processes, and wave breaking.)	20 min every 30 min; 24 hours ops	Zappa (LDEO Columbia)
Visible Imagery (Wave breaking kinematics)	20 min every 30 min; daylight only	Zappa (LDEO Columbia)

Table 3.2 DYNAMO mooring observations and sampling frequency

Instrument	DYNAMO (Lien UW/APL)	RAMA (McPhaden NOAA)
Surface Meteorology (P, T, wind, humidity, rain, shortwave, longwave radiations, air-sea fluxes)	10 min (realtime)	10 min (realtime?)
χpod(turbulence mixing and flux)	1 sec	1 sec
CTD (T, S, P)	1 min (realtime)	10 min (?)
Acoustic Doppler Profilers (ocean current velocity profile)	4 sec (300 kHz ADCP) 1 min (1200 kHz ADCP) 2 min (DVS) (realtime) 1 min (75 kHz Long Ranger ADCP)	1 hr (75 kHz Long Ranger ADCP) (?)

Mooring Deployment/Recovery

Three pairs of surface and subsurface moorings will be deployed at (0, 77E), (1.65S, 77E) and (8S, 77E) (Fig. 1.1). The nominal positions and local water depths of surface moorings and subsurface moorings are shown in Table 3.3. Measurements from meteorology sensors (Weatherpak), current velocity measurements from Doppler Velocity Samplers (DVS), and measurements of temperature, conductivity, and pressure from MicroCats will be transmitted in near-realtime via Iridium Satellites (Fig. 3.3). During the mooring deployment cruise (leg 1), surface drifters (Lumpkin) will be deployed and SeaSoar survey of the upper ocean will be performed between 77E and 80E.

Table 3.3 DYNAMO mooring positions and water depths

Surface mooring			Sub-surface mooring		
Lon	Lat	Depth	Lon	Lat	Depth
77°10' E	0°00S	4760m	77°20' E	0°00S	4750m
76°51' E	1°40' S	4600m	77°01' E	1°40' S	4850m
77°01' E	8°00' S	5200m	77°11' E	8°00' S	5250m

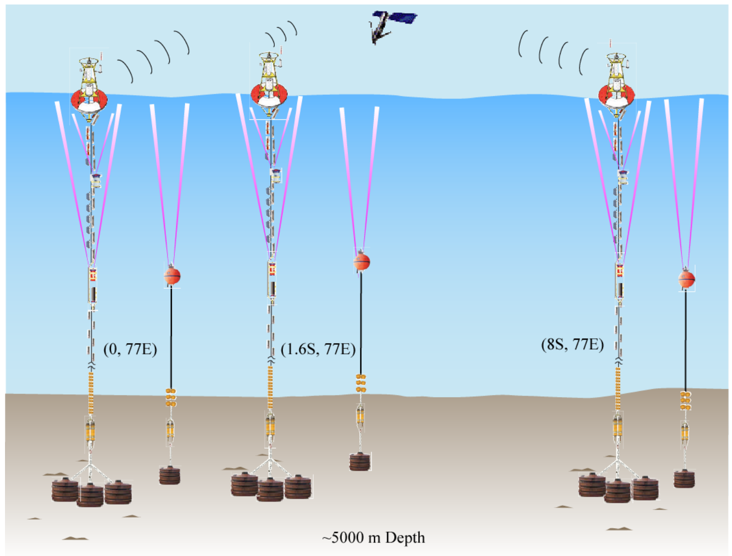

Figure 3.3 Schematic diagram of DYNAMO mooring array along 77(?)E.

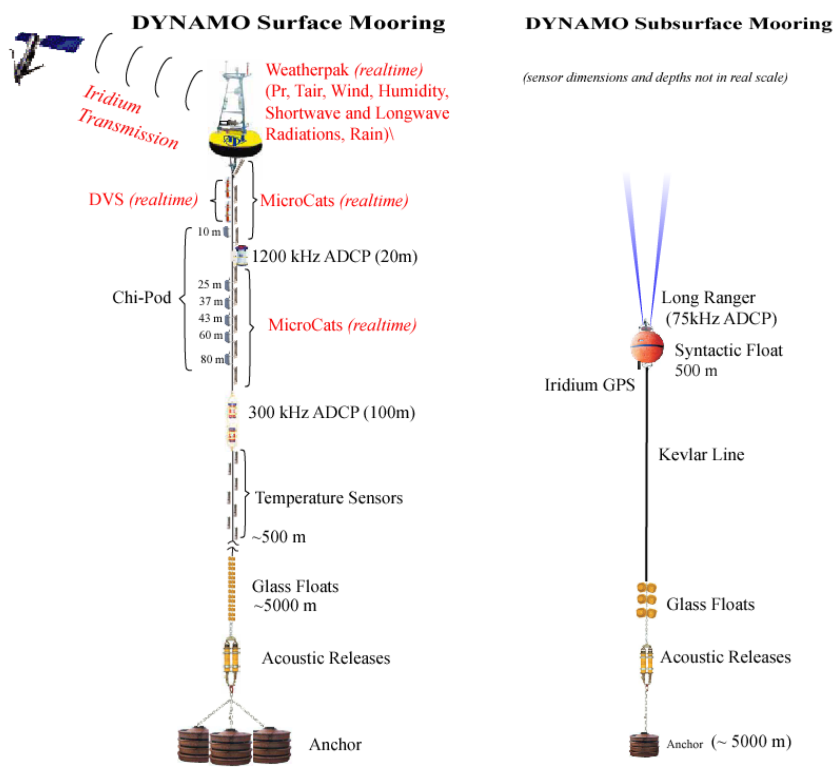

Figure 3.4 Configurations of DYNAMO surface and subsurface moorings and instrumentations on the moorings. Measurements from Weatherpak, DVS, and MicroCats will be transmitted via Iridium satellites in real time (labeled in red).

Ocean Observations (Legs 2,3)

The turbulence profiler, Chameleon, includes turbulence and CTD sensors. This will be deployed using a winch mounted beneath the A-frame on a continuous 24h basis while on station. A shelter shed (4'x8'deck footprint) will be mounted immediately forward for winch operator. This operation requires 4 people on watch (12 h shifts), 2 of whom are completely occupied with realtime operations. One of the other 2 is available to help with other operations as needed.

Chameleon profiling will be conducted as 24 ops to 200-250m, depending on conditions. This will result in 8-10 profiles per hour. Chameleon is brought to the surface to begin each new profile. The instrument will be brought on board only for repairs/maintenance. The primary consideration during this operation is to ensure the instrument remains aft of the ship. This will likely require some adjustments in ship handling as the strong equatorial current structure changes. It is likely not optimal to use DP.

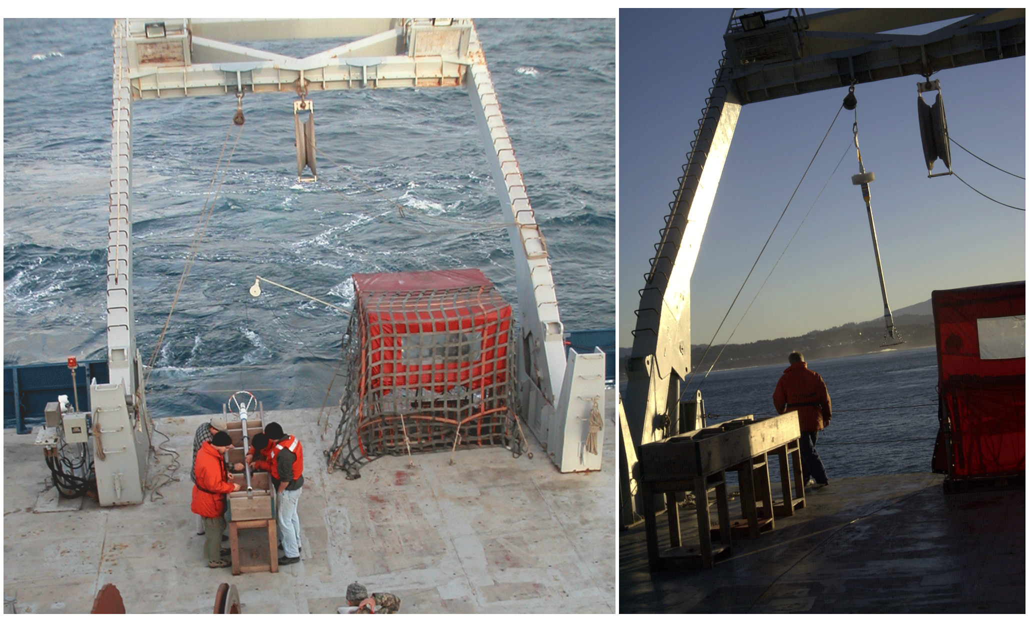

Figure 3.5 Chameleon setup on Revelle's fantail January 2003.

A temperature/conductivity chain will be deployed from the bow for continuous measurements of upper ocean TC structure. How this will be accomplished is pending discussion with SIO personnel.

Velocity profiling will be conducted using 50 and 140 kHz Doppler sonars mounted in the hull. A 1200 kHz acoustic Doppler current profiler will be mounted over the side of the ship to measure near-surface currents. We plan to deploy a 120 kHz echosounder in the transducer tube in the staging bay. We have our mounting plate that we used in 2003 in the tube.

CTD, optics and water sampling will be done from the starboard-side CTD A-frame/winch at noon daily. Seawater will be filtered and samples frozen for subsequent post-cruise analysis.

Profiling radiometer will be hand deployed to ~40m every few hours during daylight. These observations will be referenced to a surface radiometer that measures in same spectral bands as profiling radiometer.

Real-time analysis and displays of all velocity and Chameleon data will be set up in the hydrolab (aft port side) where Chameleon data acquisition ops will be situated.

Waves

Scanning LIDAR wave measurements will be made from a boom welded to the deck at the bow. The boom can swivel inboard so that instruments can be worked on easily and outboard for measurement deployment. LIDAR will run continuously and can be monitored by the LDEO team.

Visible/IR imagery of wave breaking will be performed. Also, the IR imagery would characterize SST signatures including upper-ocean convection, freshwater lenses due to rain, Langmuir circulation, ramping of near-surface stratification, etc. Visible imagery will run 20 minutes every 30 minutes during daytime hours. IR imagery will run 20 minutes every 30 minutes continuously.

WaMoS is scheduled to be on the Revelle. WaMoS will be monitored and quality controlled during cruise by the LDEO group.

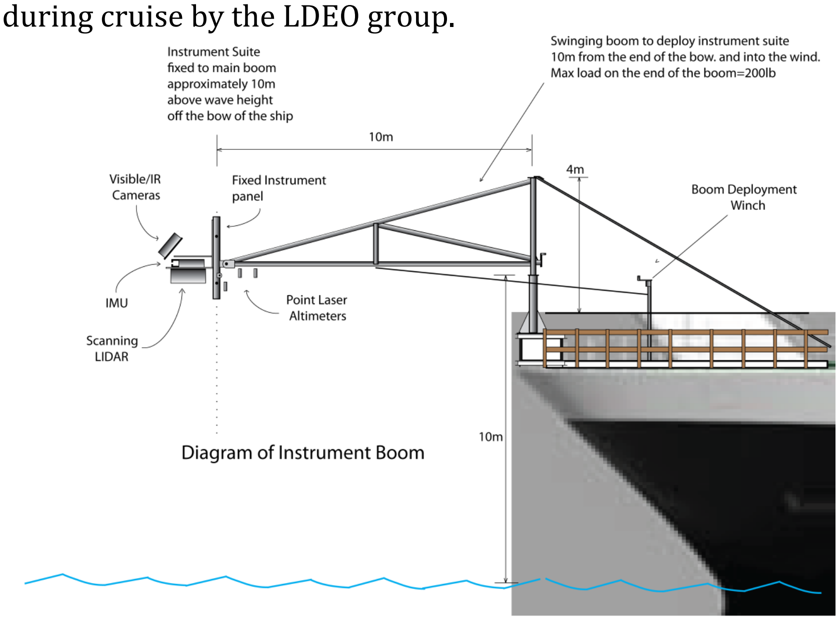

Figure 3.6 LDEO swinging boom with instrument suite including Scanning LIDAR and Visible/IR imagery. Note that base and supports of the boom are to be welded to 01 Deck at the bow of the R/V Revelle.

Air-Sea Fluxes / Surface Meteorology

Air onto the bow will be continuously sampled at 20 Hz with 2-3 systems, each consisting of a sonic anemometer/thermometer, a motion correction system, andan open-path infrared gas analyzers (IRGAs) collocated near the top of the forward mast of the ship. Observations are valid when the ship is headed into the ship-relative wind. The use of 3 systems can extend the flux observations to +/- 120^{o} from bow on relative winds. Two of the systems will also deploy new closed-path IRGAs that will sample air from near the sonic sampling volume. One these closed path sensors will be deployed on the mast while the other will draw air back to the NOAA/ERL van on the O2 deck. The optics of the open-path IRGAs are cleaned daily with a flushing system attached to the hose on the O2 deck. However, both the closed and open path may need maintenance that requires climbing the mast while at sea. Data will be recorded to sealed data loggers at various locations along the mast and sent by Ethernet cable or wireless to computers in one of the dry labs. Real-time processing of turbulence statistics and covariance fluxes will be performed daily and data displayed and shared.

Temperature, humidity, and pressure sensors will be deployed on the forward mast and will collect data to be averaged in 1- and 10-minute intervals. Some of the RH/T sensors will be aspirated to reduce self heating at low relative wind speeds. We will deployed GPS compasses to provide our own high frequency heading measurements along with estimates of pitch and/or roll. Broadband solar and IR radiometers, and rain gauges will be deployed at several locations aboard the vessel where we expect good exposure. Likely locations include the roof of the NOAA/ERL van on the O2 deck and possible an addition location where the radiometers have a relatively unobstructed view of the sky. Microwave radiometers will measure integrated water vapor and liquid water path, and need a view of zenith down to the horizon in one direction.

The flux packages and mean meteorological sensors run autonomously, but require daily maintenance and calibration, and multiple data streams require archival and processing. Two personnel will divide time between tending instruments and processing data for the W-band cloud radar and the flux and surface meteorological observations. These individuals will also assist in the rawinsonde launches.

Soundings and Wind Profiler

An atmospheric sounding system (known as an ISS or Integrated Sounding System) will be deployed on the Revelle by NCAR/EOL. Balloon-borne soundings will be carried out at varying intervals, using Vaisala RS-92 radiosondes and an NCAR GAUS receiving rack. Standard products are high-resolution temperature, relative humidity, pressure, and wind profiles, generally up to the 50-100 mb level. Soundings will be launched 8 times per day (ie, 3-hourly) during the SOP period, 4 per day during the IOP period, and twice per day during other periods. A 915 MHz wind profiler radar (a modified Radian

LAP-3000) operating on a stabilized platform, will also be deployed. Standard products are wind profiles up through the boundary layer every 30 minutes, and 30-second moment data. Two - three NCAR personnel will staff the ISS, and will request brief assistance (typically 1 or 2 helpers for 10-15 minutes) for each sounding launch. Balloons will be inflated in or near the staging bay and launched on the leeward side of the main deck.

Radar

A C-band Doppler radar (NASA-TOGA) will be operated 24/7 onboard the R/V Revelle. This radar will measure radar reflectivity, Doppler velocity and spectral width with approximate spatial resolution of 1 km out to a range of 150 km. The main use of the radar is to document the 3-D structure of precipitating clouds and relate the cloud spectrum to phase of the MJO and atmospheric moisture structure. Radar reflectivity data will be used to derive near-surface rain rates every 10 minutes. Doppler velocity will identify the basic horizontal flow patterns in mesoscale precipitation systems. The TOGA radar data will be combined with data from the W-band radar and Doppler lidar to merge the statistics of non-precipitating clouds with the precipitating clouds (the latter measured by TOGA).

W-band cloud radar will be housed in a van on a deck with a view of the sky and electrical power. Broadband and microwave radiometers in Air-Sea Fluxes can be mounted on the roof of this van.

Doppler lidar

Ops plan : 24/7 continuous operation (2 shifts). 20 minute repeating scan pattern including 10 minutes of zenith staring and 10 minutes of vertical and horizontal scanning.

Realtime Info (20 minute update time to web site) :

Vertical profiles of :

- Horizontal windspeed and direction
- Aerosol backscatter intensity
- Vertical windspeed variance

Aerosols

Continuous sampling while relative wind is favorable (i.e., forward of the beam). The data include physical, chemical, optical and cloud nucleating aerosol properties and will be available online locally at 1 second to 5 minute resolution. A subset of data will be available remotely as 1 minute averages. Chemical data will be available from an AMS and from impactor samples. The AMS data will be available every 5 minutes while the impactor samples will be taken 1 or 2 times per day and the data will be analyzed on the ship (1 to 2 day analysis time).

Leg 4 Cruise Plan

For the December Dynamo Leg there will be a physical oceanography group (approx 7 people, Pinkel: lead), an autonomous aircraft group (5 people, Ken

Melville: lead), and presently undetermined meteorology and radar teams aboard. The plan is to load two 20' containers in Tuticorin and transit to station 0^0N, 80^0E. At this point, the ship will be put in dynamic positioning mode and a ~two-km horizontal array containing ~ 10 vertically profiling floats will be deployed. One end of the array will be attached to the Revelle's fantail. It is expected that the ambient currents will stretch the array laterally. The ship's azimuth will be adjusted as conditions change.
The array will remain deployed for the duration of the leg. Profilers along the array will have to be serviced every ~3 days to change batteries and recover data. The Revelle's workboat or rescue boat will be deployed to service the array. Assistance from the crew in small boat operations is requested.

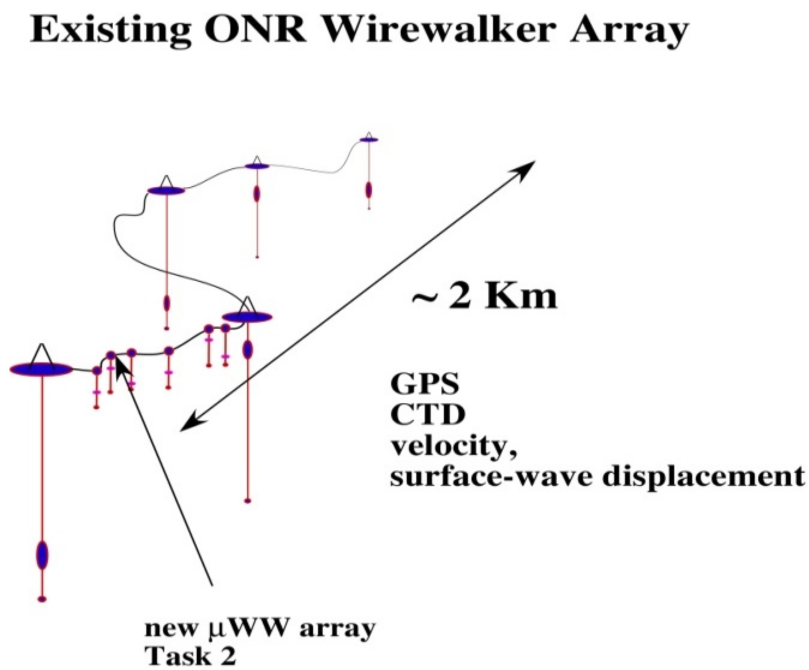

Figure 3.7 Pinkel wire-walker array – Leg 4

With the array deployed, the oceanography team will deploy and test a 64-beam phased array Doppler Sonar (Dr. Jerry Smith: lead). This system weighs ~250 lbs and is delicate. Assistance from the crew and techs in deployment operations is requested. The potential scenario is to deploy the device in the morning & recover in the evening. In moderate weather, it might be left over the side for periods of several days.
In parallel, the AAV group will launch and recover aircraft several times per day. The aircraft launcher it tentatively planned for installment on the ship's foredeck. Aircraft will be recovered by a "snare" deployed outboard from the ships fantail. Personnel are required to clear the fantail during recovery.
On the final day on station, the horizontal array will be recovered. Containers will be offloaded in Tuticorin for return shipment to the US.

Realtime Data Products

Practical upload data speed is 96 kbits/s max, 70 typical, or < 10 kbytes/s. (1000 s for a 10 Mbyte file). Link download speed is 1/2 Mbit/sec shared over all the UNOLS ships on that satellite. This could end up being be a little better than the upload from the ship.

The TOGA radar will upload to the internet a .gif image (estimated max file size 35 kB) of low level reflectivity every 10 minutes.
NCAR ISS will upload parsed data-sets (approx 1-2MB/day and 50kB/sounding).

a. Directional Wave Spectra from WaMoS.
b. High-resolution Significant Wave Height from Scanning LIDAR.
c. SST including maps of upper ocean processes outlined above (would help in targeted process studies during cruise).
d. Breaking wave statistics.

A subset of select aerosol parameters will be transmitted off the ship every 60 minutes. The data are 1 minute averages and will be available for plotting on our server at PMEL.

Requirements for Coordination with rest of DYNAMO

Notification of systems moving E toward ship station from satellite observations.
Communication with aircraft. Timing of aircraft and coordination with soundings.
Coordination of data I/O from ship – maintain ship ftp site to limit downloads.
0 80.5E met sensor – comparison / realtime data availability / can we add GPS to buoy?
Will compile daily reports to distribute
Weekly chat sessions
Need for satellite phone

SIO Contacts

Shipboard Technical Support: http://sts.ucsd.edu/t/sts/
Bud Hale bhale@ucsd.edu computing
Woody Sutherland wosutherland@ucsd.edu STS manager 858-603-1860
Zoltan Kelety - ship operations 858-534-1643
Rose Dufour & Liz Brenner - ship schedules 858-534-1841

Personnel

DYNAMO Leg 1 – Mooring Deployment / Seasoar surveys

Darwin– Cocos Keeling instrument shakedown

Ch.Sci - Lien PIs – Fairall, Edson, Zappa, DeSzoeke, Brewer, Lang

Ocean Obs	Surface Fluxes	Soundings	Radar	Doppler Lidar	Aerosols
Lien (UW/APL)	Fairall (NOAA)	Brown (NCAR)	Tim Lang(CSU)	Brewer	
	Edson	Brad Linseth (NCAR)	N.Guy(CSU)	Sandberg	
	Pezoa (NOAA)	Darek Baranowski (U.Warsaw)	R.Bowie(CSU)		
	Ken Moran (NOAA)				
	Zappa		G.King (NASA)		
	Edson stud				
	deSzoeke				

Fluxes

Chris.Fairall@noaa.gov

Sergio Pezoa Sergio.Pezoa@noaa.gov

Ken Moran Ken.Moran@noaa.gov

William Otto William.D.Otto@noaa.gov

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james.edson@uconn.edu

lien@apl.washington.edu

wbrown@ucar.edu

tlang@atmos.colostate.edu

Alan.Brewer@noaa.gov

COCO Keeling – Tuticorin mooring deployment
Ch.Sci - Lien PIs – Lien, Lang

Ocean Obs	Surface Fluxes	Soundings	Radar	Doppler Lidar	Aerosols
Lien (UW/APL)	Pezoa (NOAA)		Lang	Brewer	
Ma (UW/APL)	Edson stud	Brad Linseth (NCAR)	Guy	Sandberg	
Johnson(UW/APL)		Darek Baranowski (U.Warsaw)	Bowie		
Hsu (UW)			King		
Chi (UW)					
Aguilar (UW/APL)					

DYNAMO Leg 2 – Atmosphere/Ocean Observations
Ch.Sci - Moum PIs – DeSzoeke, Ohlmann, Brown, Smyth, Brewer, Zappa

Ocean Obs	Surface Fluxes	Soundings	Radar	Doppler Lidar	Aerosols	Waves
Moum (OSU)	DeSzoeke OSU	Kurt Knudson (NCAR tech)	A.Rowe CSU	Brewer	Coffman PMEL	Zappa (Colum)
Kenneth Fairbarn (UCSB)	Schuster OSU Student	Jen Standridge (NCAR tech)	T.Meyer CSU	Alvarez	Schulz(/F)	Zappa2
Smyth(OSU)	Dan Wolfe NOAA	John Dwyer (Stud, Colum.)	Nathan Gears (NASA)		Dewitt(/F)	
NeeleyBrown, M.(OSU)						
Kreth(OSU)						
NeeleyBrown, L. (OSU)						
Perlin(OSU)						
McHughOSU/F						
Moulin(OSU/F)						
Brown(OSU/F)						

Total – 26

moum@coas.oregonstate.edu
carter@eri.ucsb.edu
bsmyth@coas.oregonstate.edu
ritabrown223@gmail.com
mnb@coas.oregonstate.edu
kreth@coas.oregonstate.edu
aperlin@coas.oregonstate.edu
elillicoi@hotmail.com
amoulin@coas.oregonstate.edu
Alan.Brewer@noaa.gov (lidar)
wbrown@ucar.edu (soundings)
sdeszoek@coas.oregonstate.edu (fluxes)
rutledge@atmos.colostate.edu (radar)
Derek.Coffman@noaa.gov (aerosols) Kristen.Schulz@noaa.gov
helen.dewitt@noaa.gov

zappa@ldeo.columbia.edu (waves)

DYNAMO Leg 3 – Atmosphere/Ocean Observations
Ch.Sci - Moum PIs – Edson, Brown, Smyth, Ohlmann, Zappa

Ocean Obs	Surface Fluxes	Soundings	Radar	Doppler Lidar	Aerosols	Waves
Moum (OSU)	Edson (UConn)	Tim Lim (NCAR tech)	E.Thompson (CSU)	Alvarez	Coffman(PMEL)	Zappa (Colum)
Kenneth Fairbarn (UCSB)	L. Bariteau (NOAA/CU)	Lou Verstraete (NCAR tech)	O.Shieh(Hawaii)	Weickman(/F)	Schulz(/F)	Zappa2
Smyth(OSU)	Edson stud	Jonathan Smith (Student, Howard Uni).	Michael Watson (NASA)		Dewitt(/F)	
Neeley-Brown(OSU)						
Kreth(OSU)						
Osborne, J (OSU)						
Perlin(OSU)						
McHugh(OSU/F)						
Moulin(OSU/F)						
Brown(OSU/F)						
Hams,J(LAVC)						

Total – 26

moum@coas.oregonstate.edu
carter@eri.ucsb.edu
bsmyth@coas.oregonstate.edu (also Rita Brown)
mnb@coas.oregonstate.edu
kreth@coas.oregonstate.edu
aperlin@coas.oregonstate.edu
elillicoi@hotmail.com
amoulin@coas.oregonstate.edu
wbrown@ucar.edu (soundings)
sdeszoek@coas.oregonstate.edu (fluxes)
rutledge@atmos.colostate.edu (radar)
Derek.Coffman@noaa.gov (aerosols) Kristen.Schulz@noaa.gov
helen.dewitt@noaa.gov
zappa@ldeo.columbia.edu (waves)

DYNAMO Leg 4 – Atmosphere/Ocean Observations
Ch.Sci - Pinkel PIs – Smith

Ocean Obs	Surface Fluxes	Soundings	Radar	Doppler Lidar	AAV
Pinkel (SIO)	Bill Otto (NOAA)	Laura Tudor (NCAR tech)	M.Igel		1
Smith (SIO)		Nicole Colasacco-Thumm (Student, Uni Wisconsin)	A.Lichtenberger(CSU)		2
3			Gary King (NASA)		3
4					4
5					5
6					
7					

DYNAMO Leg 5– Mooring Recovery
Ch.Sci - Lien PIs – Lien

Ocean Obs	Surface Fluxes	Soundings	Radar	Doppler Lidar	Aerosols
Lien (APL/UW)	None	Chris Golubieski (NCAR tech)			
Ma (APL/UW)					
Johnson(UW/APL)					
Aguilar (UW)					

Revelle Schedule / UNOLS format please refer to UNOLS website for updates

Arr: 23 Aug 11 Port Darwin 0N/0E Transit
Dmo: 23 Aug 11

DYNAMO instrumentation installation 24 – 29 Aug Darwin Australia

DYNAMO Leg 1 – Mooring Deployment / Seasoar surveys
==
==
Lien, R/UW_APL DYNAMO Moorings 1029488 26/NSF-OCE-PO/F
Moum, J/OSU_COAS DYNAMO Fluxes 4/NAVY-ONR/T
Lien, R/UW_APL 4/NOAA/P
Moum, J/OSU_COAS DYNAMO Fluxes 1029265 0/NSF-OCE-PO/F
---------------------- -------------------- ---------------- ------------------
Mob: 24 Aug 11 Indian Ocean
Dep: 29 Aug 11 Port Darwin IN04 0N/76E Ren-Chieh Lien 27/34
Arr: 26 Sep 11 Tuticorin IN04 2S/76E
Dmo: 27 Sep 11
Notes: Radar installation and load out for DYNAMO. Personnel pickup in Cocos
Keeling.

DYNAMO Leg 2 – Atmosphere/Ocean Observations 0, 80E
==
==
36/NOAA/P
Moum, J/OSU_COAS DYNAMO Fluxes 1029265 0/NSF-OCE-PO/F
Moum, J/OSU_COAS DYNAMO Fluxes 0/NAVY-ONR/T
---------------------- -------------------- ---------------- ------------------
Mob: 28 Sep 11 eq. Indian Oc.
Dep: 29 Sep 11 Tuticorin IN04 0N/80E Jim N. Moum 33/36
Arr: 31 Oct 11 Tuticorin IN04 0N/80E
Dmo: 02 Nov 11
Clearances: India(T)
Notes: It is critical to be on site 80E on or before 1 October.
Helium container pickup in Cohcin.

DYNAMO Leg 3 – Atmosphere/Ocean Observations 0, 80E
==
==
Moum, J/OSU_COAS Indian Ocean Fluxes 40/NAVY-ONR/F
---------------------- -------------------- ---------------- ------------------
Mob: 03 Nov 11 eq. Indian Oc.
Dep: 05 Nov 11 Tuticorin IN04 0N/80E Jim N. Moum 36/40
Arr: 10 Dec 11 Tuticorin IN04 0N/80E
Dmo: 12 Dec 11
Clearances: India(T)

DYNAMO Leg 4 – Atmosphere/Ocean Observations 0, 80E
==
==
Pinkel, R/SIO Stability of the DSL 13/NAVY-ONR/F
Smith, J/SIO EquatorMixSP 0961801 7/NSF-OCE-PO/F

---------------------- -------------------- ---------------- ------------------
Mob: 13 Dec 11 Indian Ocean
Dep: 14 Dec 11 Tuticorin 0N/0E Robert Pinkel 23/26
Arr: 05 Jan 12 Tuticorin 0N/0E
Dmo: 07 Jan 12
Notes: 6 Navy days fall in 2012

DYNAMO Leg 5– Mooring Recovery
===
==
Lien, R/UW_APL DYNAMO Moorings 1029488 0/NSF-OCE-PO/F
---------------------- -------------------- ---------------- ------------------
Mob: 07 Jan 12 Indian Ocean
Dep: 10 Jan 12 Tuticorin IN04 0N/76E Ren-Chieh Lien 37/42
Arr: 15 Feb 12 Cape Town IN04 2S/76E
Dmo: 17 Feb 12
Notes: Recover moorings and Seasoar suveys
New transit calculated from last mooring site to Cape Town.

Bow deck

Pieces necessary for the building of the swinging and CTD booms on the bow of the ship. Deck plan for swinging boom deployments from the bow. Zappa (LDEO) has a primary and secondary boom deployment preference. Moum (OSU) CTD boom is also shown. All booms require welding of the base and supports to the deck.

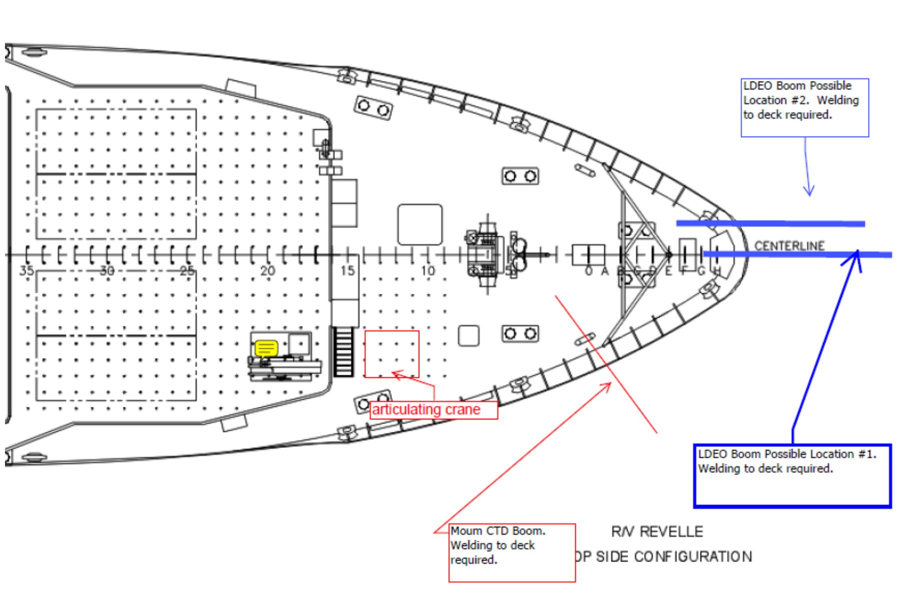


Figure 3.8 Deck plan for boom deployments from the bow. LDEO has a primary and secondary boom deployment preference. The Moum CTD boom is also shown. All booms require welding of the base and supports to the deck.

Sea container specs

a) PMEL 1 (AeroChem Van)
wt 13,500 lbs
size 8' x 20'
power 50 amp 480 v three phase
location outboard port side 02 level, sampling line connected to PMEL 2
Needs phone connection.

b) PMEL 2 (AeroPhys Van)
wt 17,000 lbs
size 8' x 20'
power 50 amp 480 v three phase
location inboard port side 02 level, sampling mast mounted on roof
Needs phone connection.

** PMEL 1 and 2 can share a single 70 amp (or greater) 480V 3 phase service through the use of a splitter box **

The exhaust vents forward of the PMEL 1 and 2 need to be rerouted via eight large tubes (8 inch diameter). They will be run around the outboard side of PMEL 1 and terminate near the aft end of the 02 van deck. We have plates that should mount over exhaust port that we have used many times on the Ron Brown and once on the Atlantis.

c) PMEL 3 (Chemistry van)
wt 11,500 lbs
size 8' x 20'
power 30 amps 480 v three phase
location outboard port side 01 level
Needs freshwater line, Ethernet connection and phone.

d) PMEL 4 (spare parts/storage van)
wt 12,000 lbs
size 8' x 20'
power none
location inboard port side 01 level

e) ESRL-CSD HRDL van
wt 16,000 lbs
size 8'x20'
power - 70amp 480v three phase (only drawing from a single phase)
location - O2 deck Starboard side inboard
Needs phone connection and RS422 serial line from the ship's Seapath INU

f) ESRL-PSD W-band radar van
wt 16,000 lbs
size 8'x20'
power - 70amp 480v three phase
location – 02 behind PMEL vans
Needs phone connection and RS232 serial line from the ship's met obs

g) TOGA Radar van

h) OSU van
wt 18,000 lbs
size 8'x20'
power – none required
location - main deck port side aft

i) UW/APL van
wt 14,000 lbs
size 8'x20'
power –none required
location – main deck port side aft

j) NCAR Helium container (leg 2 onwards only)
wt 30,000 lbs
size 8'x20'
power – none
location – main deck

Other deck cargo

Mooring gear (APL/UW)
estimate of mooring gear weight on fantail is 51,000lb
includes anchors, mooring lines, surface buoys, subsurface buoys.

PMEL
Frames to secure vans on O2 deck – 9000lbs
Radon system, O3 deck forward, 3' x 10', 200 lbs
Exhaust vent tubes for O2 deck vents – 1000 lbs

NCAR
Wind profiler radar on aft 02 deck (adjacent to winches) 12'x12' ~ 1500 lbs
Helium cylinder racks (two 2'x5' racks) main deck near staging bay ~ 2500 lbs
(assumes Helium container loading in Tuticorin after leg 1 – if not then approx 15 more racks will need to be loaded and stored).

Van Schedule

van	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5
PMEL 1	x	x	x		
PMEL 2	x	x	x		
PMEL 3	x	x	x		
PMEL 4	x	x	x		
APL	x				x
OSU	x	x	x		
ESRL lidar	x	x	x	x	
ESRL Wband	x	x	x	x	
TOGA radar	x	x	x	x	
NCAR He					x
Pinkel				x	

Deck Layouts

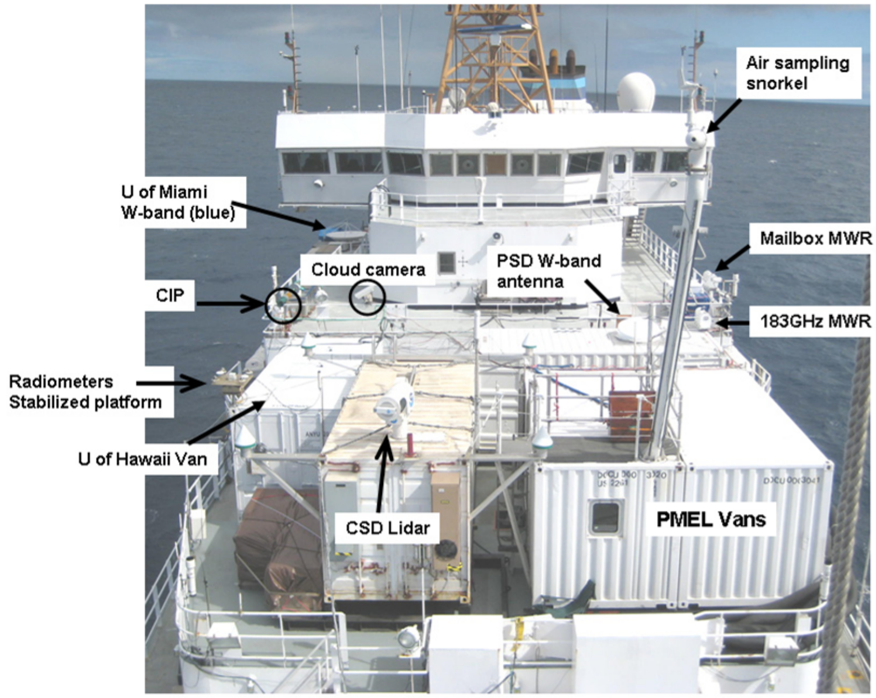


Figure 3.9 Example setup of on Brown during the VOCALS experiment

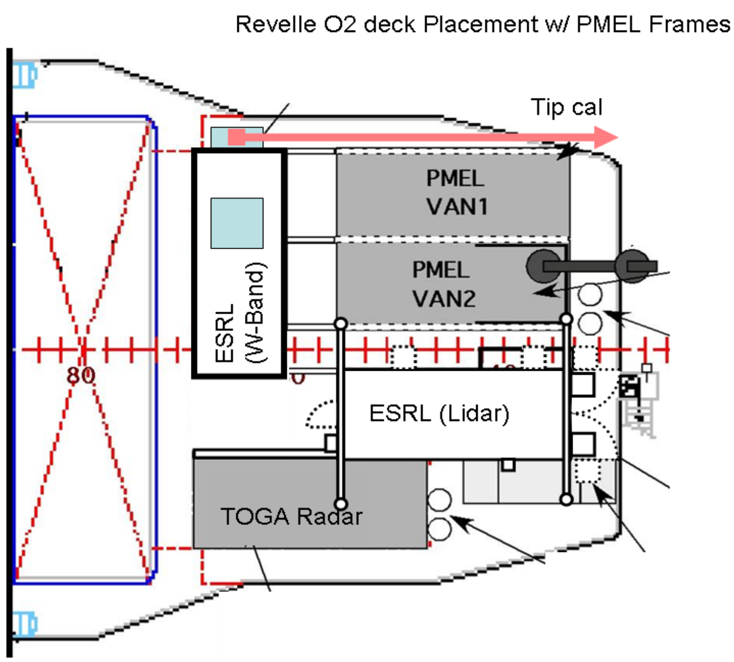


Figure 3.10 Proposed van placements on Revelle 02 deck ahead of pilot house

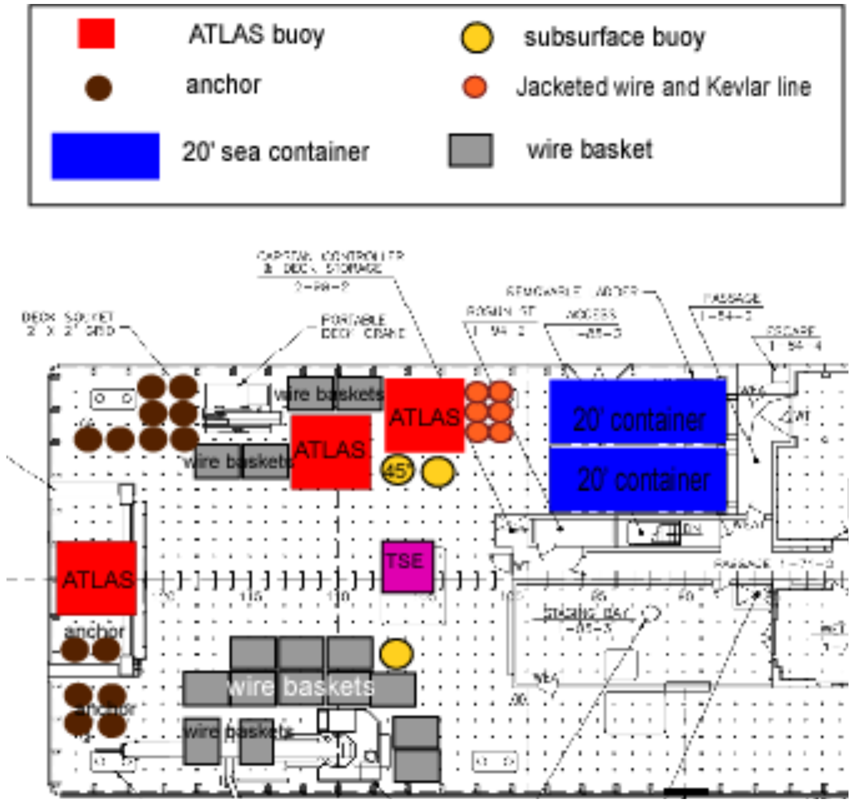


Figure 3.11 Proposed van placements on Revelle main deck – Leg 1

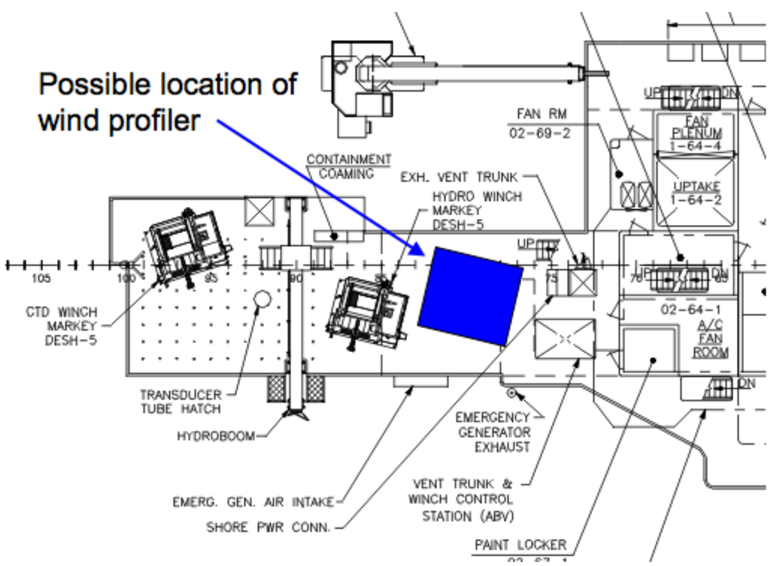


Figure 3.12 Proposed wind profiler placement

Lab Setups

Moorings
Moorings will be staged from Main Lab during Leg 1. This lab will be cleaned up and available following Leg 1.

Chameleon
Chameleon ops will be set up in the hydrolab. This will include electronics and mechanical repair stations, and all data acquisition for profiler, adcp, ship das and bow chain. This lab will be set up prior to Leg 1 and taken down and emptied following Leg 3. Container will be shipped home from Tuticorin following Leg 3.

NCAR
ISS sounding and wind profiler require approx 8'-10' feet of bench space either in the hydro lab or aft-half of the main lab. Sounding computer station should have easy access to main deck. Power requirements are clean 110V 20A circuits only. Storage area in lab (eg under benches) or science holds for radiosondes and parts also required.

Loading Plans (01, 02, 03 decks and radar)

We will need a dockside crane to load frames and vans on the 02 and 01 decks and install the radome on the first day we have access to the ship. We anticipate one full day of crane time. Once the vans are in place, the next priority will be to get electrical power to the vans. Other priorities will include the installation of instruments on the jackstaff and the mounting of a boom off the bow for the installation of additional instruments.

Crane Operations

The size of the crane required for loading of the vans will be determined by how far the crane will have to reach (i.e., how far away the boat is from the dock and the height of the dock). In the past we have used cranes in the 120-180 ton range to load the 02 deck. That size range should be sufficient to install the radome as well. The reach should be sufficient to lift the radome more than 30 ft above the newly installed radar platform.

Question: What is the preferred procedure for ordering a crane? Would the ship prefer to order the crane through the ship's agent and bill the scientific party or would they rather the scientific party order the crane themselves?

ON THE DOCK

- Lift PMEL 4 (Storage) van to dock for unloading of aerosol sampling inlet and miscellaneous items – estimated time needed for unloading: 1 hour
- Lift both TOGA vans to dock for unloading of the antenna and radome. The pieces will need to be assembled on the dock (needs a clear space to do

this). Estimated time for unloading and assembly: 4-5 hours

02/03 DECKS

ii) Move small ship's crane to bow (01 deck) if not already moved.
iii) Load frames and secure. The frames have been installed on Ron Brown and Atlantis and will hopefully fit the deck bolt pattern on Revelle. We will need to be prepared to have modifications done to the footer plates if the holes don't line up and to the breech base sockets. This is especially true for the PSD van that spans the two frame assemblies.
iv) Load vans in most expedient manner. All but the TOGA van will be secured to the frames via breech base twistlock fittings. The TOGA van will need to be secured to deck by the Revelle crew (or as instructed by the deck crew).
v) Additional lifts to the 02/03 deck(s):
   a. Radon tank lifted to 03 deck
   b. Aerosol sampling inlet installed on PMEL 2 (AeroPhys) van
   c. Miscellaneous pieces for PMEL 2 van (roof deck, railings, ladder)
   d. Air conditioner for TOGA Radar van

Questions:

1. Will the ship supply bolts for securing the frames in the deck sockets?
2. Will ship be able to supply a welder to grind off and re-weld the sockets if necessary?

01 DECK (PORT SIDE)

1. After PMEL 4 (Storage) van is unloaded, lift both PMEL 4 and PMEL 3 vans into position. The ship's crane has been used to do these lifts in the past or we can use the dock crane. This will be up to the ship.

01 DECK (BOW; SEE SECTION 17 AND FIGURE 9)

1. Pieces necessary for the building of the swinging and CTD booms on the bow of the ship.
2. Deck plan for swinging boom deployments from the bow. Zappa (LDEO) has a primary and secondary boom deployment preference.
3. Moum (OSU) CTD boom is also shown.
4. All booms require welding of the base and supports to the deck.

RADAR INSTALLATION

5. Lift the radome into place for installation. The installation process uses 20-30 foot long slings to lift the antenna/radome/platform into place. The process is anticipated to be completed with 2 lifts. The radome will require one lift. A second lift will be needed for the air conditioner.

Power

According to the ship-handbook online, the following power is available:

- 3 100 amp 480vac deck receptacles, two at the aft end of the staging bay, one at the bow, 01 deck

- 1 30 amp 480vac deck receptacle in the staging bay
- 2 30 amp 480vac deck receptacles on weather deck aft end of staging bay
- 30 amp 208vac deck receptacles and 4-30 amp 120vac 3-phase clean power deck receptacles, two of each kind aft of the hydro lab for main deck vans, and aft on the 02 deck for 01-level vans

The following scenario assumes this is still true. As can be seen in the Sea Container Specs portion of the Ops plan all the vans on the 02 deck require power. This will require at least three long runs of power cable from the 02 deck aft to the staging bay. TOGA radar will bring a power stand with 5 100 ft super vultron cables to connect it to the TOGA van plus a 100Ft of power cable to connect the air conditioner.

Questions:

1. Are all these receptacles available for use or are some of the dedicated to other things?
2. Are there any issues that would make the long power cable runs impossible? How much cable will be needed to run along an acceptable route from the 02 van deck to the receptacles near the staging bay? Similarly, how much cable is needed to run from the 01 port side van deck to the receptacles near the staging bay?
3. Will the ship provide plug ends for connection to the ship (to be removed at the end of the cruise)? If not, what type of power receptacles are on the ship?
4. Will the ship provide bolts or studs and nuts and washers to secure the TOGA radome to the platform? If not what is the hole size or required size and thread of the nuts?

02 DECK

1. PMEL 1 (AeroChem) and 2 (AeroPhys) can be powered through the use of a splitter box (used on Brown, Knorr and Atlantis) and require one of the 100A 480vac receptacles.
2. ESRL PSD and HRDL vans each require 70A 480vac 3 phase power. HRDL only draws from a single phase. It is uncertain if the same is true for the PSD van. Each would require a 100A 480vac receptacle. *Chris F. and Alan – do you both require the full 70A and is it possible for you to combine through a splitter box if necessary? Just a thought -Derek*
3. TOGA Radar van needs 208vac 100-150A. *The possibility of a 480vac to 208vac transformer was mentioned as an option in an earlier email but is not a good option given all of the 480vac requirements.*

01 DECK

1. PMEL 3 (Chemistry) van requires one of the 30A 480vac receptacles near the staging bay.

a. Phones/Speakers

All of the vans on the 02 deck and the PMEL 3 (Chemistry) van require a phone line. The vans are used as portable laboratories/workspaces and personnel spend large amounts of time in them. Experience from prior cruises has shown us it is almost impossible to hear alarms (drills or otherwise) and the phones are necessary for safety purposes. Ideally, the phone can also act as a speaker through which the alarms can be heard.

Network

Internet access to the ship's network is needed for a few of the vans

1. ESRL-CSD HRDL – Alan...do you need this?
2. ESRL-PSD – Chris...do you need this?
3. PMEL 3 (Chemistry) van – needs a single IP address (static if possible). PMEL maintains a private LAN behind this single connection.

Data

Serial data connections are needed for the ESRL vans

1. ESRL-CSD HRDL requires a RS422 serial line from the ships Seapath INU
2. ESRL-PSD requires a RS232 serial from the ship's meteorological observations

Air

PMEL 4 (Storage) van requires a compressed air line

Fresh water

PMEL 3 (Chemistry) van requires a fresh water line

Welding

1. LDEO (Zappa) swinging boom at the bow requires welding of base and supports to the deck.
2. OSU (Moum) CTD boom at the starboard side of the bow requires welding.

Chapter 4 DYNAMO/AMIE Radar Operations Plan

1. Radar characteristics, locations, and schedules

1.1 Introduction

The objective of the DYNAMO radar observations is to fully characterize the ensemble of convection associated with each stage of MJO initiation. Advancing the understanding of MJO initiation, in particular testing DYNAMO Hypotheses I and II, requires observing the full spectrum of convection, described by as many variables as possible (e.g., areas and heights of radar echoes, types and concentrations of hydrometeors, air motions internal to clouds, cloud and precipitation element movement, separation of precipitating and non-precipitating components of clouds, subdivision of precipitating clouds into convective and stratiform components, structure and organization of cloud ensembles, association with environment moisture field, and propagation characteristics, among others). To relate these observations to the larger-scale dynamics of the MJO, it is essential to determine these observed aspects of the convection statistically and to determine how the statistics of the cloud population evolve from suppressed conditions to active conditions. Surface-based radars are the only instruments that can routinely observe these features of the cloud population and resolve them in three-dimensions over a representative spatial domain over a reasonably long time.

The diversity in the size and intensity of convection during the MJO phases and the basic limitations of radar instrumentation imply that any individual radar can only document a subset of the convective spectrum. DYNAMO's approach is to use radars of a variety of wavelengths and scanning strategies, to diagnose different aspects of the convective population. Shorter (mm) wavelength radars are more sensitive to cloud particles and small hydrometeors, but are more susceptible to attenuation. Non-Rayleigh scattering effects further complicate interpretations of short wavelength radar. Longer wavelength (cm) radars are less prone to attenuation, but are unable to detect cloud particles and small hydrometeors. The most common precipitation radar wavelengths are 10 cm (S-band), 5 cm (C-band) and 3 cm (X-band), while the most common cloud radar wavelengths are ~8 mm (Ka-band) and 3 mm (W-band). Radars of all of these wavelengths will be deployed simultaneously in a supersite located on Addu Atoll (0.7° S and 73.2° E, Fig. 2.1), in the nation of the Maldives. In addition, shipboard C- and W-band radars will be deployed on the Japanese Research Vessel *Mirai* and U. S. Research Vessel *Revelle*.

1.2 The radars

1.2.1 SHIP RADARS

Onboard the *R/V Revelle* will be the NASA/NSF TOGA C-band scanning Doppler radar and NOAA's vertically-pointing (VP) W-band Doppler radar. A 915 MHz profiler is also planned for the *R/V Revelle*. The *R/V Mirai* will have scanning C-band and VP W-band Doppler radars. These radars will be stabilized for ship motions. The locations of these ships are shown in Fig. 2.1. The *Revelle* will be at the NE point.

The *Mirai* will be at the SE point when the *Revelle* is at the NE point, but at the SE point other wise. The ships will be on station according to the following schedule. Radar operations so far have only been planned for the first two on-station periods.

Mirai	1 October-28 November 2011 (radar operating continuously, on station at SE point 1-24 October and 31 October-28 November)
Revelle	28 September-30 Oct 2011 (radar operating at NE point) 4 November 2011-9 December 2011(radar operating at NE point) 13 December 2011-4 January 2012 (radar operations TBD)

1.2.2 DOE/ARM RADARS

DOE/ARM will deploy two radars on Addu Atoll. A Scanning ARM Cloud Radar (SACR) will be located at the Wharf Site (4.1) on Hithadhoo Island. It is a dual-wavelength (X- and Ka-band) radar system of unmatched beams. It is dual polarimetric and Doppler. This system will conduct three-dimensional scanning. The second radar is the vertically pointing Ka-band ARM Zenith Radar (KAZR), which will be located at Gan airport (Fig. 4.1). These radars will be deployed on Addu Atoll from October 2011 through March 2012.

Figure 4.1 Locations of radar sites on Addu Atoll

1.2.3 TEXAS A&M SMART-R

The Texas A&M Shared Mobile Atmospheric Research and Teaching Radar (SMART-R) is a truck-mounted Doppler C-band scanning radar. Its antenna is a 2.4 m diameter solid parabolic reflector with a 1.5-degree beamwidth. Its peak power is 250 kW. SMART-R will be deployed at the Spit Site (Fig. 4.1) on Hithadhoo Island from October 2011 through March 2012.

1.2.4 NCAR S-PolKa

The NCAR S-PolKa radar has matched S- and Ka-band beams to obtain simultaneous measurements of reflectivity, Doppler velocity, dual-polarimetric parameters and dual-wavelength differential attenuation. The parabolic antenna diameter is 8.5 m and the peak power is >1MW. S-PolKa will be deployed at the Wharf Site on Hithadhoo Island (Fig. 4.1) from 1 October 2011 to 15 January 2012 (107 days).

2. Scanning

2.1 General principles

Since DYNAMO and AMIE aim to document the population of clouds rather than individual storms, it has been agreed that breaking off scans to track specific phenomena would be inadvisable because it could introduce serious biases into the dataset. Therefore, the scan strategies for all radars are aimed at obtaining statistics of the cloud population as opposed to analyses of individual convective or mesoscale systems.

The statistics of the cloud population are expected to vary with respect to the phase of the MJO. The scanning strategies are designed to optimize information in all phases of the MJO without introducing biases into the statistics of the cloud population. During some phases, large-scale conditions over the DYNAMO/AMIE array will suppress deep convection while other phases favor deep convection. It is expected that both shallow and deep convection will be present in all phases of the MJO but in different proportions. The radar scans are designed to capture both deep and shallow convection in all phases of the MJO. Two of the radars (TOGA on the *Revelle* and S-PolKa) will modify their scans to obtain greater detail on shallow convection when deep convection is not present within radar range. However, these modifications will be done in a way that will not bias the long-term statistics obtained by those radars over the entire period of the project.

2.2 Terminology

The scanning mode descriptions use the following definitions:

- LLPPI: Low-level azimuthal scans at a series of low elevation angles (elevation angles will vary with radar)
- HSRHI: Horizon-to-Horizon Scan Range Height Indicator. This mode consists of a series of 0-180 degree elevation angle sweeps at an azimuthal separation of some selected large finite amount, e.g. 90 degrees or 60 degrees.
- CWRHI: A series of RHI sweeps ±30 degrees about zenith and at a fixed azimuth angle, probably north-south so as to be more or less across the prevailing zonal wind. The fixed azimuth angle is set such that the sweeps are orthogonal to the dominant wind direction at a given altitude. The

objective of CWRHI mode is to enable the study and characterization of high cloud systems.

BLRHI: A series of RHI scans from elevation 0-60 degrees conducted over an azimuthal sector. This azimuth range combines well with CWRHI.

2.3 Scanning modes

Scanning at all radars will be done on a coordinated 30 minute cycle. The sequences to be performed at each radar are summarized below.

SACR (30 minute cycle)

1 min: RHI over KAZR (unless co–located)

5 min: Some combination of LLPPI + HSRHI (Given the ~20 km max range of SACR, sweeps will likely be at elevations ≥2 degrees, so that the Ka will not be scanning below the clouds, which will have bases at ~500 m)

6 min: BLRHI (azimuthal boundaries TBD, based on blockage)

2 min: CWRHI (zenith ± 30 degrees elevation)

6 min: BLRHI (0-60 degrees elevation, to capture clouds within 20 km of radar and to combine well with CWRHI)

2 min: CWRHI

6 min: BLRHI

2 min: CWRHI

KAZR

Continuous vertically pointing

SMART-R (10 minute cycle)

1 min: RHI over KAZR and low PRF surveillance scan

9 min: Interleaved PPI volume scans of 11 angles each, repeating the lowest elevation each time. The elevation coverage will be similar to the shipborne C-band radar (deep) scan strategies.

1 min: RHI over KAZR and low PRF surveillance scan

9 min: Interleaved PPI volume scans of 11 angles each, repeating the lowest elevation each time.

1 min: RHI over KAZR and low PRF surveillance scan

9 min: Interleaved PPI volume scans of 11 angles each, repeating the lowest elevation each time.

TOGA C-band Radar on the *Revelle* (30 minute cycle)

8-9 min: PPI volume scan* to range of 150 km

1-2 min: of selected RHI's for improved vertical resolution

10 min: Repeat both scan types

8-9 min: Repeat the PPI volume scan

1-2 mins, selected RHI's plus a 0.5 degree elevation low PRF surveillance scan to range of 200 km

* A deep mode will be used when deep convection is present. A shallow mode will be used when shallow to mid-depth cells are present. The timing of both scans will be the same but the shallow scan mode will simply have a finer elevation stepping.

C-band Radar on the *Mirai*

Same as *Revelle*, except no change of the volume scan throughout the observation period. Volume scan consists of 21 elevations from 0.5 to 40 degrees. The maximum elevation aims to cover echoes reaching the tropopause at 20-km range

S-PolKa (15 minute cycle)

Deep mode:

1 min: RHI over KAZR (Note: KAZR is about 8.5 km from S-PolKa: Assuming 4/3 Earth radius)
5 min: PPI volume up to about 10 deg elevation
9 min: RHI sectors (azimuthal boundaries TBD, based on blockage)
1 min: RHI over KAZR
5 min: PPI volume up to about 10 deg elevation
9 min: RHI sectors

RHI angle limits	Max height of beam at KAZR
0 to 60 deg	7.4 km
0 to 45 deg	6.0 km
0 to 30 deg	4.2 km

Shallow mode:

1 min: RHI over KAZR
7 min: PPI volume up to about 10 deg elevation
7 min: PPI volume up to about 10 deg elevation
1 min: RHI over KAZR
7 min: PPI volume up to about 10 deg elevation
7 min: PPI volume up to about 10 deg elevation
Note: This sequence can also contain RHIs over KAZR after every PPI volume to increase the frequency of RHIs.

3. Data flow

The data flow will change after the IOP (dates?) phase of DYNAMO/AMIE end but the EOP (dates?) continues.

3.1 Data flow during IOP and SOP phases

The radar scientist at the S-PolKa site will combine all available data into a daily science summary blog, which will be a free-form summary and interpretation of each day's events in terms of the DYNAMO and AMIE objectives during the IOP and SOP phases. This blog will be made generally available over the internet. To facilitate this integrative activity and other ongoing scientific assessment of the progress of the experiment, to provide feedback to the forecast team, and to support aircraft activities, a coordinated data flow is required. In addition to data and analysis products from all the radars, this data flow will include satellite data and products, humidity analyses from the S-PolKa, sounding data, various numerical model products, and products from the DYNAMO forecast team.

The near real-time data flow of radar and other data is diagrammed in Fig. 4.2. To maintain real time experimental monitoring, data from all the radar sites will flow into a central server at the S-PolKa site, which is the primary location for radar-related scientific operations on Addu Atoll. Rawinsonde launching and most of all the other measurements besides radar will occur at the airport site. Thus there will need to be close communication and interaction between the two sites. At the S-PolKa site, data from the different radar sites and from satellite and sounding data sources will be ingested into the Zebra system. A composite overlay of satellite and radar data will be constructed on a near real time schedule. Ancillary products for polarimetric fields, dual-wavelength humidity, and soundings will also be generated. These products will be provided to the EOL data catalog.

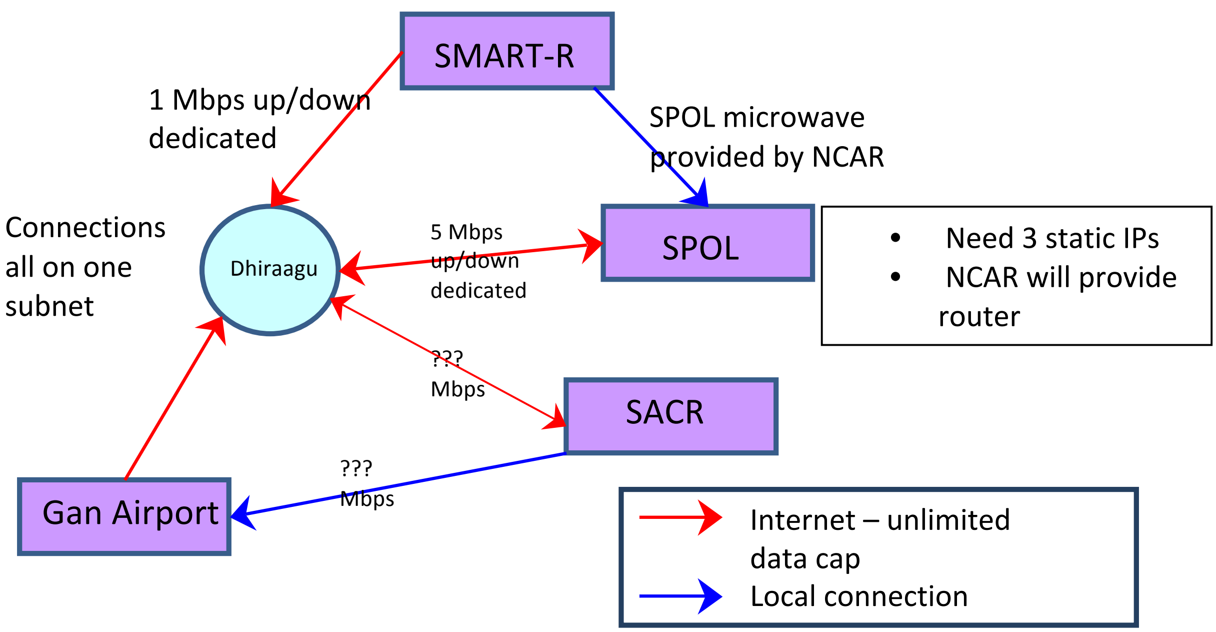


Figure 4.2 Data flow schematic for DYNAMO and AMIE radar operations. Dhiraagu is ISP for Gan.

The data from the KAZR and SACR will be provided via internet from the ARM location at Gan airport to the S-PolKa server in netcdf format for inclusion in the daily products. This information will be provided on a continuous basis.

The *Revelle* will provide gif images of the 0.5 degree elevation sweep every 30 min. They will be uploaded to a web site address at the S-PolKa site. The *Mirai* will be able to provide low-PRF long-range PPI reflectivity images (200 or 300 km range) at 6 hour intervals.

The SMART-R will provide 1 surveillance scan, 1 RHI over the ARM site at the airport, and 2 volume scans every 10 min in raw sigmet format. In addition, they will provide images made automatically by the IRIS software (the surveillance scan and lowest tilt from each of the volume scans), which will be useful for both monitoring and the EOL catalog. A dedicated internet line with a 1 Mbps bandwidth is preferred. Simultaneously, a MW link between SMART-R and S-PolKa may be set up and utilized as available while S-PolKa is on Addu Atoll.

3.2 Data flow during the EOP after the IOP and SOP phases

Once the S-PolKa team leaves after the SOP and IOP phases, the AMF2 site at the airport will become the central site for the SMART-R, SACR, and KAZR radar activities. Data will flow to the airport site via hardwired internet lines so that the DOE and SMART-R scientists can maintain the production of a daily science summary. In addition, it is requested that the local server for the EOL catalog be moved or copied to a server at the airport to assist in daily science operations during the EOP.

4. Daily science operations

In this chapter, we do not discuss the radar operations, which will be overseen by engineering and technical staff at each site. Rather, by "science operations" we mean activities that are directed toward obtaining a dataset that conforms to the scientific objectives of DYNAMO and AMIE. Science operations will vary among the radar sites. Lead investigators for each radar facility will be focused on their own specialized objectives within the broader context of DYNAMO and AMIE. At the same time these specialized objectives can best be achieved in the context of the successful achievement of broader DYNAMO and AMIE objectives. Therefore, the daily routines at each site will be carried out in such a way that real time experimental monitoring, preliminary scientific assessment, data product generation, and aircraft support can be maintained in a coordinated manner, so that both specialized and broader objectives will be achieved.

4.1 S-PolKa UW Scientists

A primary focus for integrating information coming in from the various radar sites as well as from satellite and numerical forecast products will be composite products and science summaries produced at the S-PolKa site. The University of Washington team represents both AMIE and DYNAMO through NSF and DOE/ARM grants. They will have three scientists present throughout the project with the following responsibilities:

1. Data manager: Data ingest from the radar sites, satellite, and other data sources and creation of a standard set of products composited from these

sources. These products will be sent to the EOL DYNAMO Data Catalog.

2. Polarimetric and dual-wavelength analyst: Create and analyze products from the dual-polarimetric microphysical particle identification products and from the dual-wavelength humidity profiles. This activity will be done in close coordination with the lead NCAR scientist on-site.
3. Science summary scientist: The lead S-PolKa scientist will be responsible for producing and summarizing integrated analysis of all of the information provided by the other two S-PolKa scientists' activities and prepare a daily blog of this analysis. Although the lead S-PolKa scientist (Houze or his designate) will take responsibility for this activity, it will be done in collaboration with the lead AMIE and SMART-R scientists. The daily blog will be co-authored by all who contribute to it and wish to be included. To carry out this ongoing near real-time integrated scientific assessment, certain data products from non-DYNAMO/AMIE sources are needed. These sources include NCEP and other modeling and satellite data centers. The external data products needed for scientific assessments are listed in Section 7 below.

These three activities will take place at three desks in the Annex container of the S-PolKa facility.

4.2 SMART-R Scientists

The SMART-R crew will consist of two scientists on a rotating schedule for the six months of deployment. The main duties of the two scientists will be to monitor SMART-R's operations, produce initial products (as outlined in Sec. 5.1), and contribute to the daily science summaries. The SMART-R PI (Schumacher) will also be on Addu Atoll for approximately the first two and a half months of the campaign to assist in the above activities and to provide additional support for the aircraft operations. When not at the SMART-R spit site, the SMART-R scientists will occupy one desk in the SSC container of the S-PolKa facility except when the Falcon is flying. During Falcon missions, the SMART-R scientist will occupy one desk in Container 9. After the SOP and IOP, the SMART-R scientists will occupy a desk at the AMF2 airport site when not at the SMART-R spit site.

4.3 AMIE radar scientists

The DOE/AMIE crew will consist of two technicians on a rotating schedule for the six months of the deployment, with a visiting scientist during site installation, and for a period of a month TBD either in October or November. Due to the large number and variety of instruments included in the second ARM Mobile Facility, there is no dedicated Radar Technician per se. Rather, the on-site technicians act in conjunction with the ARM Program Radar Instrument Mentors to address any problems that occur, with on-site visits by the Radar Instrument Mentors should a situation warrant. The two AMF2 technicians will primarily be stationed at the AMF2 Main airport site, with periodic visits to the X/Ka scanning radar and S-PolKa sites. The visiting scientist after the start of the campaign will primarily be stationed at the S-PolKa site near the X/Ka site and will occupy a desk in Container 9. In addition, PNNL is sponsoring a Post-Doc for a period of 4-8 weeks who will help launch sondes, and is interested in working with the other scientists regarding radar data, products, and related science issues. The exact time of this Post-Doc's on-site presence is yet TDB, and is to large extent dependent on the eventual details of the personnel available for the intensive 8/day sonde launching schedule for the duration of the 6-month EOP. We anticipate that the post-doc will share the desk in Container 9 set aside for the visiting ARM scientist.

5. Near real-time analysis products generated in field

5.1 Products for the NCAR/EOL Data Catalog

Standard analysis products will be generated at the S-PolKa site for transfer to the NCAR/EOL Data Catalog. These products will be based on all the DYNAMO radars on Addu Atoll and on the *Revelle* and *Mirai*. Some products will be integrated with satellitedata. Preliminary plans are to generate the following products hourly:

1. Integrated satellite radar map: This product will be a map over the DYNAMO ship/island domain showing low-level precipitation echo patterns around Gan, *Revelle*, and *Mirai* on a background of satellite infrared imagery from METEOSAT.
2. A map of non-precipitating clouds in the vicinity of Addu Atoll on a background of satellite infrared imagery from METEOSAT.

In addition the following products will be provided daily:

1. A time-height plot of the KAZR reflectivity and velocity data for the 24 hour period.
2. Graphs for each of the SMART-R, *Revelle*, and *Mirai* C-band radars showing hourly rain amount (total, convective, stratiform) versus time of day for the 24 h period.
3. Graphs for each of the SMART-R, *Revelle*, and *Mirai* C-band radars showing hourly areal coverage by rain (total, convective, stratiform) versus time for the 24 h period.
4. Graphs for each of the SACR and S-PolKa Ka-band radars showing hourly percent areal coverage by non-precipitating clouds for the 24 h period. This product will be of an experimental nature and may or may not be possible to produce in the field. It is nevertheless hoped that it can be produced once a day for each radar.
5. A graph showing the pdf of echo height observed over 24 h, for several dBZ thresholds for each of the following radars: S-PolKa, SMART-R, *Revelle, Mirai*, and SACR.
6. A histogram of hydrometeor type determined from the S-PolKa S-band polarimetric data accumulated over the 24 h period.
7. A mean profile of humidity determined from the S-PolKa dual-wavelength measurements over the 24 h period. Spread of the profiles determined over

the day will be shown. The profiles will be presented alongside the radar-determined profiles.

8. A plot showing the average vertical profile of latent heating (total, convective, stratiform) estimated from the SMART-R observations for the 24 period.
9. As mentioned in Sec. 3.1, a daily integrated scientific discussion will be provided in the form of a blog by the lead radar scientist at the S-PolKa site.

5.2 DOE/ARM quick look products

It is anticipated that the ARM KAZR and SACR radars will produce near real-time quick-look images of radar reflectivity and/or Doppler velocity (Examples from current AMF deployment can be seen at https://engineering.arm.gov/~widener/ARM_Radars/AMF2_SWACR_Data.html). These images will be transmitted periodically from the AMF to the S-PolKa site. Additional quick look plots from AMF instruments at the airport facility (microwave radiometer, lidar, soundings) may also prove useful to interpreting the radar measurements and will be transmitted periodically from the AMF to the S-Polka site.

6. Support of aircraft operations

Two aircraft are likely to participate in DYNAMO and AMIE: a NOAA WP-3D and the French Falcon. The NOAA WP-3D aircraft and its operational and science crews will be based on Diego Garcia. The Falcon aircraft and its operational and science crews will be based at Gan Airport on Addu Atoll.

6.1 NOAA WP-3D operations

Radar scientists at S-PolKa and SMART-R will be available to consult with NOAA WP-3D scientists on current and forecast weather conditions as seen from the perspective of the DYNAMO radars. The NOAA WP-3D scientists will notify the radar scientists at S-PolKa and SMART-R when an aircraft mission is to be flown. S-PolKa and/or SMART-R radar scientists will be available at the S-PolKa site for the first 1-2 hours of the flight to help guide the WP-3D toward the most appropriate quadrant of the DYNAMO ship/island quadrilateral. The WP-3D scientists and crew will provide real-time flight track data to the S-PolKa site. In addition, the WP-3D will transmit occasional lower-fuselage radar images or data to the S-PolKa site. The flight track and lower-fuselage data will be incorporated into the hourly integrated satellite radar map described above. The possibility of sending radar data from the island or ship radars to the aircraft will be explored. The radar scientist at Mirai and/or Revelle will be able to provide information to the aircraft as needed during flights. The mode of communication is to be determined.

6.2 French CNES Falcon operations

The Falcon scientists will notify the S-PolKa and SMART-R scientists when a Falcon flight will take off. In Container 9, at the S-PolKa site, two Falcon scientists will operate with a VHF radio and a linux machine with software for processing and visualizing the SMART-R radar data. They will pass recommended coordinates to the Falcon based on the SMART-R three-dimensional radar echo structure.

7. External products needed in near-real time for scientific assessment of observations in the field

Products needed in the field for the near real time scientific assessment of the radar component of DYNAMO (last item listed in Sec. 5.1) include:

1. All DYNAMO products provided by NCEP
2. Standard level charts of global model wind and equivalent potential temperature for 00, 24, 48, 72, and 96 hour forecasts
3. Humidity at standard levels and precipitable water maps for 00, 24, 48, 72, and 96 hour forecasts
4. Sounding data from ships and island sites
5. Satellite IR, visible, and water vapor imagery from METEOSAT every 30 min for a region to be specified.

Chapter 5: Sounding Operations

Overview and Objectives

The objective of the DYNAMO sounding network is to observe the vertical structure of the large-scale environment for convective cloud populations and their feedbacks at each stage of MJO initiation.

DYNAMO Hypotheses I and II focus on interaction between clouds, precipitation and their large-scale environment. Testing these hypotheses is possible only with accurate information of atmospheric profiles of temperature, moisture, and wind. These profiles, which describe the large-scale environment for clouds and precipitation, can be observed reliably only from soundings, including rawinsondes, lidars, dropsondes, and wind profilers. The DYNAMO sounding arrays (Fig. 5.1) are designed to provide such reliable field observations at different initiation stages of the MJO. This figure shows the network design during the first phase of DYNAMO, when there are quadrilateral sounding arrays both north and south of the equator. During the second phase (after 55 days), the SE Ship (R/V *Mirai*) will leave station and the southern array will become a triangle comprised of the NE ship (R/V *Revelle*), Gan Island, and Diego Garcia. Colombo will be operational October through November, whereas Malé will be operational October to mid-December. All rawinsonde measurements will be available to the operational centers in real time through GTS. These sounding observations will form the basis for estimating large-scale divergence profiles and atmospheric sources/sinks of diabatic heating (Q_1) and moisture (Q_2). Such observations and derived variables will be used in model and satellite validation, and in data analysis in conjunction with other DYNAMO observations, numerical model experiments, and auxiliary data.

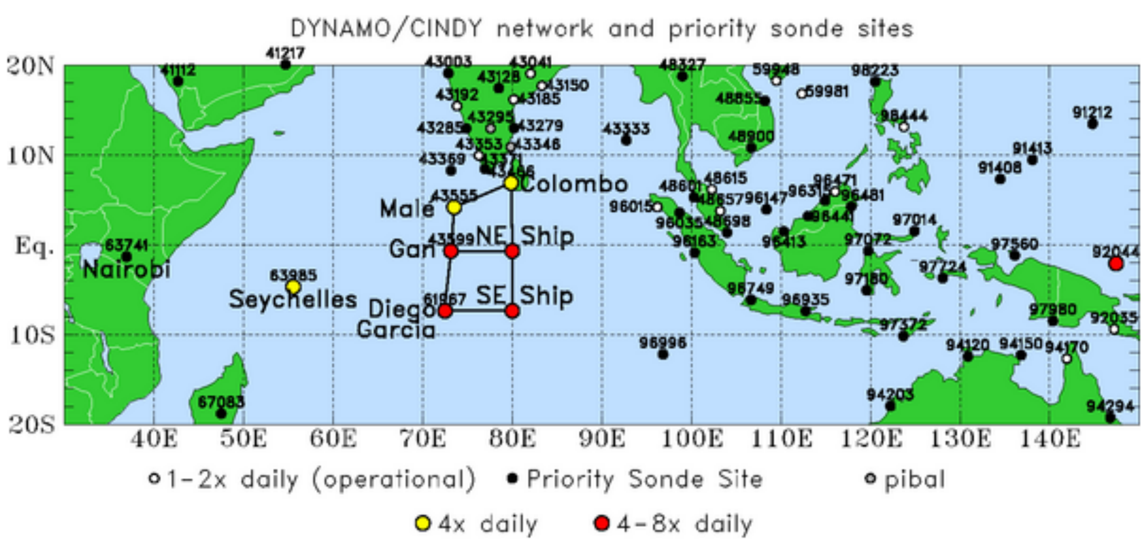


Fig. 5.1. Map of DYNAMO sounding arrays during the first 55 days of the experiment (1 October-25 November 2011) and Priority Sounding Sites in large-scale domain. Following 25 November, the SE Ship site will be discontinued.

Description of facilities (location, time, launch frequency, operations)

The primary DYNAMO sounding operations consist of a combination of sites on ships (R/Vs *Mirai, Revelle*) and islands (Diego Garcia, Gan, Malé, and Sri Lanka) as shown in Fig. 1. The periods of observations for these sites are shown in Fig. 5.2.

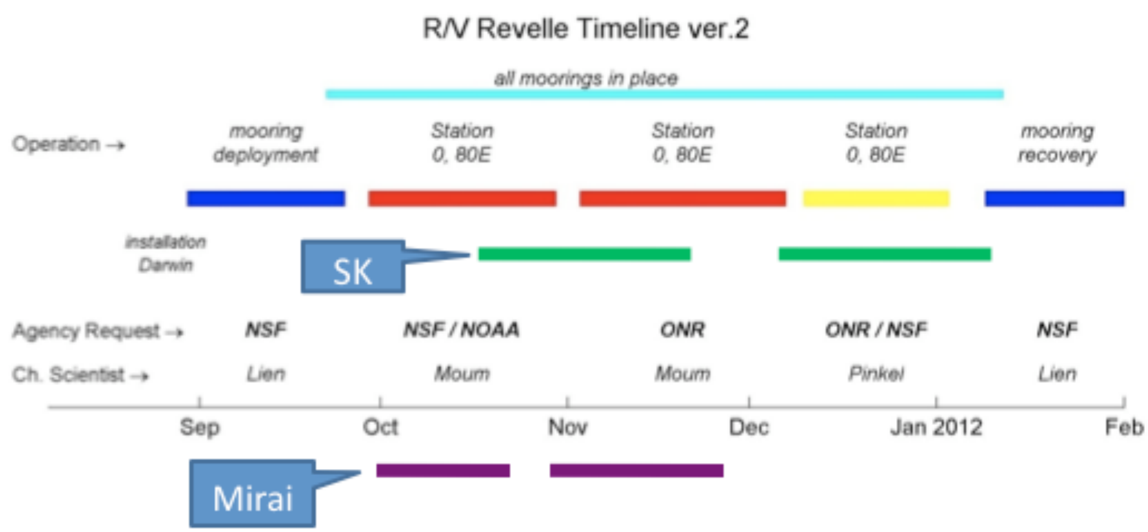


Fig. 5.2. Timeline of DYNAMO field experiment. Horizontal bars at top (blue, red, yellow) indicate R/V Revelle schedule, and purple bars at bottom the R/V Mirai schedule. (Sagar Kanya operation is uncertain.)

The entire DYNAMO field campaign is divided into three periods: an Enhanced Observing Period (EOP) extending from 1 October to the end of March, an Intensive Observing Period (IOP) extending from 1 October to 15 January, and a Special Observing Period (SOP) from 1 October to 24 November (the period of the R/V *Mirai* deployment). The R/V *Revelle* will be at 0°N 80°E (NE) throughout its on-station deployment. The R/V *Mirai* will be at 8°S 80°E (SE) throughout its on-station deployment.

During the SOP, sounding frequency from Gan Island, Diego Garcia, the *Mirai,* and the *Revelle* with be 3 hourly (8 soundings per day). Following the SOP and for the remainder of the IOP, the sounding frequency will change to 4/day, except at Gan Island (AMF2), where the frequency will continue at 8/day until the end of the EOP. Both Malé and Colombo, Sri Lanka will be at 4/day frequency for the duration of their operation. At times, some of the operational stations in the surrounding region (e.g., Seychelles, Colombo, Nairobi) will increase their frequency of launches during the IOP.

Description of sounding instrumentation and supporting measurements

Tables 5.1 and 5.2 list the sounding sites, launch frequencies, and periods of operation for land (Table 1) and ocean (Table 2) observing platforms. In addition, supporting profile and surface observations are listed along with their measurement frequency.

The surface met and flux observations, taken at many of the sites listed in the tables below, will be combined with data from the buoy networks in Indian Ocean (Fig. 5.3) to map out surface fluxes over the DYNAMO/CINDY domain. Specifically, there will be four DYNAMO/CINDY moorings inside the sounding array that will provide bulk flux estimates. The flux maps will be used to help in closing the atmosphere and oceanic budgets. The ground-based GPS systems and microwave radiometers, collocated at the several of the sonde sites, will provide PW estimates at 10-min resolution. These estimates will help in describing the temporal evolution of the water vapor field, and also provide independent estimates of PW to identify sonde moisture biases and validate their corrections.

Table 5.1. Operation period and sampling frequency of DYNAMO observations from land-based instruments.

Instrument /measurement	Gan	Diego Garcia	Nairobi	Malé / Colombo	Seychelles
Operational GPS sondes (12 hr regularly)			12 hr, IOP	6 hr, IOP	6 hr, IOP
Sonde type, software, version	Vaisala RS92	Vaisala RS92, NCAR GAUS	Vaisala RS92, MW15	Vaisala RS92/Meisei RS-06G	Vaisala RS92, MW31
ISS:		**IOP**			
GPS sondes		3 hr, SOP 6 hr, IOP			
rain gauge		1 min			
10-m surface met		1 min			
microwave radiometer		10 min			
915 MHz wind profiler		30 min			
RASS		30 min			
GPS water vapor		10 min			
AMF2:	**EOP**				
GPS sondes	3 hr				
rain gauge	10 min				
10-m surface met	10 min				
micropulse lidar	10 min				

microwave radiometer	20 sec				
ceilometer	20 sec				
915 MHz wind profiler	10min				

Table 5.2 Sampling frequency of DYNAMO observations from ship-borne instruments

Instrument/measurement	*R/V Revelle*	*Mirai*
radiosondes	3 hr (SOP) and 6 hr (IOP)	3 hr
sonde type, software, version	Vaisala RS92, NCAR GAUS	Vaisala RS92, MW31, v3.64
surface met/bulk flux	1 min	10 min
turbulent flux	10 min	10 min
scanning Doppler lidar (HRDL)	20 min (wind, turbulence, and aerosol backscatter intensity); 10 min (clouds, precipitation, vertical velocity)	
Mie-scattering Lidar	Continuous	Continuous
wind profiler (915 MHz)	10 min	
water vapor radiometer	20 sec	
ceilometer	20 sec	1 min
Solar/IR radiometer	10 min	10 min
Microwave radiometer	20 sec	
GPS water vapor	10 min	10 min
video sondes		15 times
ozone sondes		15 times
SST		10 min

An important extension of the DYNAMO/CINDY sounding array with respect to supporting surface measurements will be provided by the Indian Ocean RAMA array (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction). The configuration of this network is shown in Fig. 5.3.

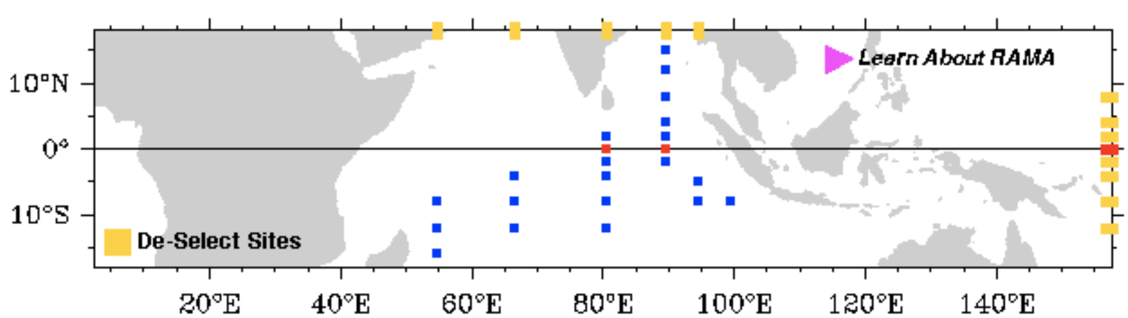


Fig. 5.3. The Indian Ocean RAMA mooring array (as of February 2011).

The RAMA array provides surface meteorological observations and upper-ocean measurements. These data are available in real time from the PMEL website (http://www.pmel.noaa.gov/tao/disdel/disdel.html). These observations can be used to estimate surface fluxes using the bulk flux algorithm.

Sounding operations for the DYNAMO sites

- ***Malé, Maldives***

The position of Malé in the sounding array is shown in Fig. 5.1. Sonde operations at Malé will cover the period from 1 October to 15 December 2011. After mid-December the ITCZ shifts southward, and convection typically becomes less frequent north of the equator. During this 76-day deployment, sounding frequency from Malé will be 6 hourly (4 soundings per day) to coincide with synoptic times of 00, 06, 12, 18 UTC. Sonde launches will be conducted 30 minutes prior to these nominal times or at 0430, 1030, 1630 and 2230 LT.

Based on experiences during MISMO, we are requesting permission from the Maldives Meteorological Service (MMS) to launch sondes from their National Meteorological Center (NMC) site near the Malé International Airport on Hulhule Island. This site will provide us easy access to surface observations from the NMC instrumentation to baseline collocated sonde observations.

To support the 4/day sonde launches we propose to staff daily operations with 2 sonde teams and 2 persons per team. Each team will be responsible for 2 launches per day. Currently we have personnel coming from Colorado State University (CSU), Japan and Taiwan. The CSU staffing will be provided by 3 persons with each taking a 4-week shift. A similar rotation will likely be used by the other countries involved. The current staffing commitment provides 3-4 persons per day coverage. We will be using a launch tent which, if necessary, allows a single person to do a launch (although two persons per launch are recommended and for safety reasons are required for nighttime launches). We will also need the assistance of the NMC staff to alert the airport authorities and obtain permission for all four launches each day.

For Malé sonde operations we are proposing to bring the Digicora MW21 sounding system from Colorado State University. The software on this system was recently upgraded in April 2011 to V3.64.1 which provides a correction to the Vaisala RS92 daytime dry bias. The CSU system and expendables (Vaisala RS92 sondes, 200 g balloons, cylinders of helium) will be shipped by NCAR EOL. As a backup system, the National Central University (NCU) of Taiwan will be bringing a Digicora MW31 system and their automated weather station (AWS) to obtain surface observations. We would like to request some indoor space at or near the NMC Malé site with a desk or two to set up our sonde hardware (including a Dell laptop computer, SPS220 processing box, and a Vaisala calibration/ground check system). This hardware will be connected to two antennae (UHF and GPS) with 30 meter long cables. We will require a small hole (diameter of 3-4 cm) in the outside wall near our ground station hardware to allow us to connect our sonde hardware to the antennae. The antennae need to sited somewhat (20m or so) away from buildings to provide a good line-of-sight with the launched sondes. We also request some indoor storage space for sonde expendables (i.e, balloons and sondes). Ideally the shipping container with the helium cylinders can be sited close to the balloon-filling tent. If not, we request indoor storage space near the balloon-filling tent for the helium cylinders.

A ground based GPS receiver was set up at NMC by the Japanese research team during MISMO. If possible, we would like to operate this GPS receiver during the DYNAMO project to obtain an independent estimate of column-integrated water vapor. Finally, digital photographs of the cloud field and subjective cloud observations will be made in conjunction will all daytime sonde launches. The digital camera (i.e, a Sony Cyber-shot DSC-WX9) will be provided by CSU.

To meet the near real-time numerical modeling objectives of DYNAMO, it is quite important that the Malé sonde data be received at the operational weather centers (NMC, ECMWF, etc) within a few hours after launch. To accomplish this we are requesting the support of the Maldivian Met Service to help us transmit the sonde data onto the Global Telecommunication System (GTS). The Digicora ground station will automatically produce a properly coded message for this purpose. As a backup plan, we will look into an alternative method for getting the data onto the GTS via email relay through the NCAR Earth Observing Laboratory (EOL). High-resolution sonde data will be routinely backed up after every sonde launch. Sonde data will be saved in several formats but most importantly the raw dc3db files will be saved. These dc3db files contain the necessary information to reconstruct all sonde data fields, which may be necessary if further data corrections are needed.

- ***Gan Island, Maldives***

Balloon Launch Procedures – AMF2-GAN

Table 5.3 **Launch Times**

Actual Launch Time (UTC)	Nominal Launch Time (UTC)	Relaunch Before Time (UTC)	Terminate at Time (UTC)
2330	0000	0100	0200
0230	0300	0400	0500
0530	0600	0700	0800
0830	0900	1000	1100
1130	1200	1300	1400
1430	1500	1600	1700
1730	1800	1900	2000
2030	2100	2200	2300

Fig. 5.4 **Sonde Frequency Tuning Schedule**:

Sonde Frequency Tuning Schedule	**Launch Time "A" 0230, 0830, 1430, 2030 UTC**	**Launch Time "B" 0530, 1130, 1730, 2330 UTC**
Initial	DEFAULT (factory setting)	404.0 MHz
Relaunch (if Initial fails)	401.0 MHz	402.0 MHz

Launch Sequence:

- **Before** starting launch procedures:
  - **Confirm** there is at least 500psi in one of the helium tanks.
  - **DO NOT** launch if wind speed is greater than 15 m/s. **Record** "no launch" and the wind speed in log book.
  - **DO NOT** Launch if there is **severe weather** in the area or any **safety concern.**

- **Check** Power / Status Light on SPS 311.
  - If Standby Light is Yellow press the Power Button.
  - If Power / Status Light is Green the SPS is ready for use.

- **Insert** Sonde in the GC25 (Ground Check Station) and **connect cable** to Sonde.
- **Power up** the GC25 (Ground Check Station).
- The GC25 will identify the Sonde Type and will ask to "Recond U-Sensor".

DO NOT Press any Buttons on the GC25
until it is time to remove the Sonde from the GC25.

On DigiCORA-III Computer:

- Double Click the **DigiCORA icon** if application is not already running.
- Single Click on **New Sounding Button** (upper left under icons).
- After the coefficients are read from the Sonde and the Sonde SN# is displayed select **Next (If the SN# does not match, get a new sonde).**
- Select Wind Type: **GPS - DCC** and select **Next.** Note: This will be a drop down menu selection.
- Re-tune sonde if necessary.

- Enter the **Sounding ID Number** in the following format (75mmddyy launch#) and select **Next.** (Check log book to see consecutive launch #)
- Select **Record**. Note: Reconditioning will take 3 minutes and then Sonde Sensor Stabilization will take 2 minutes.
- When Sonde Reconditioning is finished, select **Next.**
- At the GC Request Window, select **Perform GC, wait for white box.**
- At the Conditions Stabilized Window, **Enter the Pressure** that is displayed just above in black next to the "P". select **Next.**
- At the Correction Values Window, select **Next.**
- Click on the RawPTU tab to display the Sonde Values.
- When you get a "Ready for Sonde Release", **Power off the Ground Check Station and Remove the Sonde package**. **Connect the Battery** to the Sonde Package. Push silver boom into holder at angle.
- Take sonde outside.
- Prepare Balloon for launch.
- Attach Sonde to Balloon.
- Launch Sonde at designated launch time (0230, 0530, 0830, 1130, 1430, 1730, 2030, 2330 UTC balloon release).
- Record the **Temperature**, **Humidity**, **Pressure**, **Wind Speed** and **Wind Direction** from the surface met station **Window** located in the green box in upper right on desktop, select **Next.**
- Remember to **record** in the **Log Book**.

    - ***Diego Garcia***

Diego Garcia ISS

NCAR / EOL will be operating an ISS (Integrated Sounding System) on the island of Diego Garcia, British Indian Ocean Territories (BIOT). Diego Garcia is a joint U.S./U.K. military base and access to the island is restricted. All personnel visiting the island have to be cleared by U.S. and U.K. authorities. Transfer of personnel and equipment to Diego Garcia will be via U.S. military transport, requiring an extensive clearance procedure. Logistical support is being provided by the Navy, Air Force, and military contractors. Accommodation will be in the Chagos Inn (part of the Navy Gateway Inns & Suites chain) in the village, approx 6 miles north of the site. Services such as dining mess, fast food, post office, banks, a general store, and various others are available nearby.

The ISS will be sited near the Diego Garcia airport. The ISS will consist of a radiosonde balloon sounding system, boundary layer wind profiler radar, ceilometer, GPS Integrated Water Vapor receiver, and surface meteorological instruments such as a 10-meter tower, tipping bucket rain gauge, and solar radiation sensors, (see table). The ISS will be shipped in an container that also serves as lab/office space. A second container will contain Helium to support

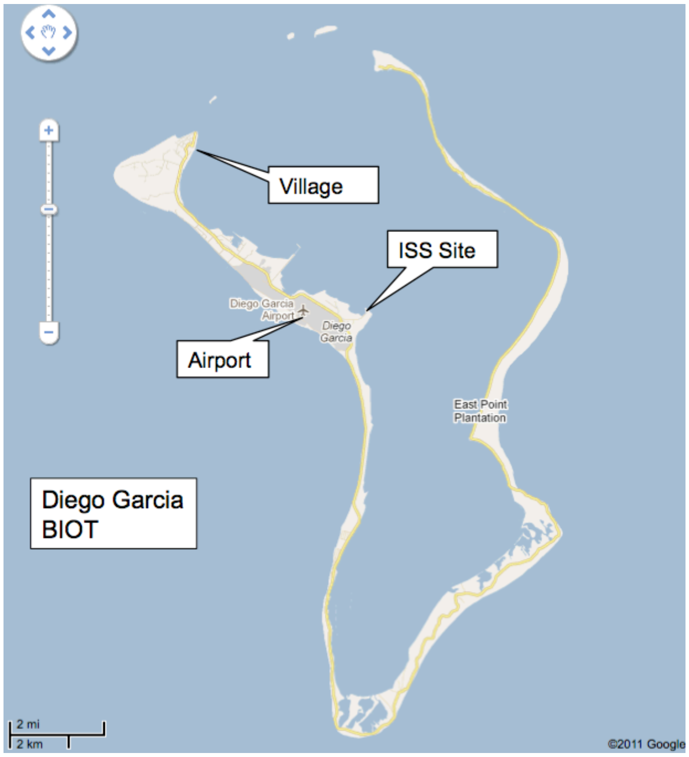


Fig. 5.4 Map of Diego Garcia

sounding operations. Power, network and phone service will be provided by the military and local contractors.

Soundings will be carried out every 3 hours during the SOP (Oct 1 to Nov 27), and every 6 hours for the remainder of the deployment (Nov 28 to Jan 15). Approximately 660 soundings will be launched. The wind profiler and other instruments will operate continuously. The wind profiler generates wind and virtual temperature profiles every 30 minutes, and Doppler moment data every 30 seconds. Quick look plots from most instruments will be posted on the web in near real time, however the limited network bandwidth from the island may require some parsing of the data. Significant level sounding data will be submitted to the GTS.

Table. 5.5 Instrument on Diego Garcia

Instrument	**Manufacturer / Model**	**Purpose / Measurement**
Soundings	Vaisala RS92 radiosondes	Sounding of temperature, humidity, pressure, and winds (approx to tropopause)
Boundary Layer Wind Profiler Radar with RASS	Vaisala Radian LAP3000 (915 MHz, DBS)	Profiles of wind (every 30 minutes, to 2 or 3 km altitude) and virtual temperature (to 1 km); precip Doppler spectra (30 second beams)
Anemometer	R.M. Young 5103 Wind	Wind speed and direction on 10 m

	Monitor	tower
Temperature, Humidity	Vaisala 50Y humitter	2 m level temperature and relative humidity
Pressure	Vaisala PTA427	Barometric pressure (2m)
Solar radiometer	Eppley PSP pyranometer	Incoming solar radiation
IR radiometer	Eppley PIR pyrgeometer	Infrared radiation
Net radiometer	REBS Inc Fritschen net radiometer	Sum of incoming and outgoing radiation
Rain gauge	Texas Electronics TE525 tipping bucket	Rain rate
Weather sensor	Vaisala WXT 510	Winds, temperature, humidity, rain-rate, pressure
Ceilometer	Vaisala CL31	Cloud ceiling, vertical visibility
GPS Water vapor	Trimble 4700	Integrated water vapor
Data logger	Campbell Scientific CR10x	Records data from sensors

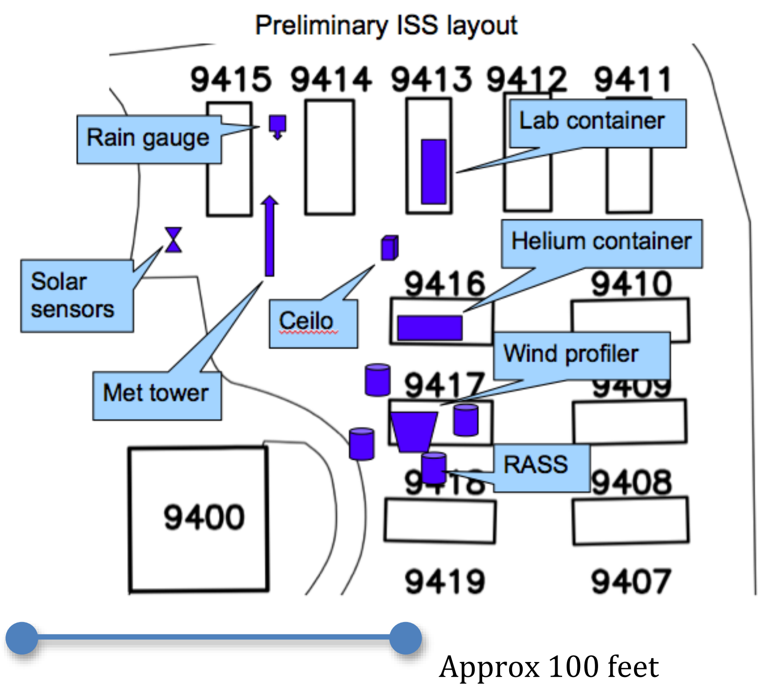


Fig. 5.5 ISS layout.

The preliminary staffing and sounding schedule is given in the following table, although the actual staffing dates are likely to change. During operations there will generally be one NCAR staff member and 2 or 3 students.   Four staff will set-up and tear-down the system, and we anticipate one or two maintenance visits.

The principle contact for the ISS is Bill Brown at NCAR/EOL (wbrown@ucar.edu).

Table. 5.5

Diego Garcia staff schedule chart

Sep 2011	Oct	Nov	Dec	Jan 2012

SOP (1 Oct - 27 Nov) IOP (28 Nov - 15 Jan)

Soundings per day :	*2*	*8*	*4*	

CREW	STAFF	Approx. Dates
Set-up	4 Staff	17 - 30 Sept 2011
Ops-1	1 staff + 3 students	29 Sep - 26 Oct 2011
Ops-2	1 staff + 3 students	25 Oct - 21 Nov 2011
Ops-3	1 staff + 2 students	20 Nov - 17 Dec 2011
Ops-4	1 staff + 2 students	16 Dec 2011 - 15 Jan 2012
TD (Tear-Down)	4 Staff	14 Jan - 22 Jan 2012
I (Inspection and Maintenance team)	2 Staff	TBD : Two 3-5 day visits during the Oct - Jan operations period

- ***R/V Revelle (ISS)***

An atmospheric sounding system (known as an ISS or Integrated Sounding System) will be deployed on the Revelle by NCAR/EOL. Balloon-borne soundings will be carried out at varying intervals, using Vaisala RS-92 radiosondes and an NCAR GAUS receiving rack. Standard products are high-resolution temperature, relative humidity, pressure, and wind profiles, generally up to the 50-100 mb level. Soundings will be launched 8 times per day (ie, 3-hourly) during the SOP period, 4 per day during the IOP period, and twice per day during other periods. A 915 MHz wind profiler radar (a modified Radian LAP-3000) operating on a stabilized platform, will also be deployed. Standard products are wind profiles up through the boundary layer every 30 minutes, and 30-second moment data. Two - three NCAR personnel will staff the ISS, and will request brief assistance (typically 1 or 2 helpers for 10-15 minutes) for each sounding launch. Balloons will be inflated in or near the staging bay and launched on the leeward side of the main deck.

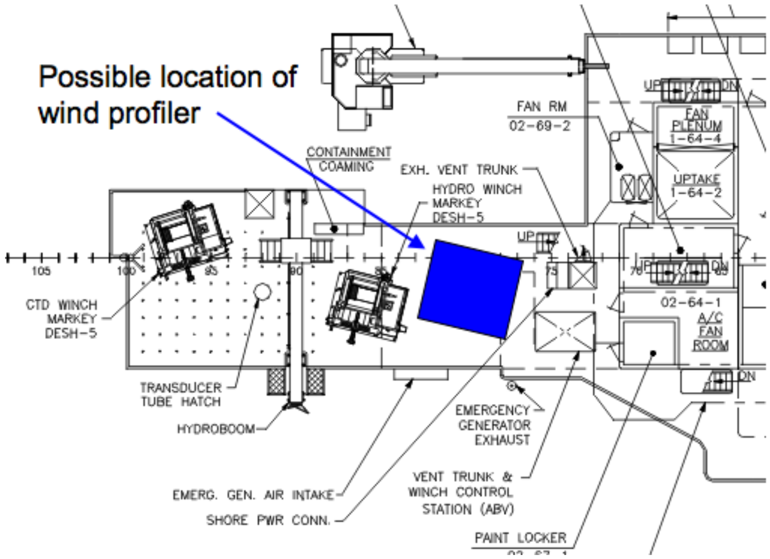


Figure 5.6. Proposed wind profiler placement

Lab Setup

ISS sounding and wind profiler require approx 8'-10' feet of bench space either in the hydro lab or aft-half of the main lab. Sounding computer station should have easy access to main deck. Power requirements are clean 110V 20A circuits only. Storage area in lab (eg under benches) or science holds for radiosondes and parts also required.

Sea container specs

NCAR

Wind profiler radar on aft 02 deck (adjacent to winches) 12'x12' ~ 1500 lbs
Helium cylinder racks (two 2'x5' racks) main deck near staging bay ~ 2500 lbs
(assumes Helium container loading in Tuticorin after leg 1 – if not then approx 15 more racks will need to be loaded and stored).

REVISED: NCAR Helium container will be loaded in Darwin and will remain on until the end of leg 5 (Cape Town).

Recommended DYNAMO/CINDY sonde operation procedures

To ensure that high-quality sonde observations will be taken to meet the scientific objectives of the experiment, the following is a list of recommended launch procedures that should be followed at all sites in the enhanced sonde network:

(1) Relatively new sondes (less than 1 year from manufacturing date) should be used and the sonde serial number (which contains age information) should be recorded in meta data (see item 2).

(2) A sonde launch log should be kept and updated for every launch. Recorded information should include: sonde serial number, operator name, nominal launch time, transmission frequency, sonde surface PTU values, independent surface PTU values, surface wind speed and direction, actual release time and duration, max sonde altitude (optional: cloud coverage and type, significant weather, operator comments).

(3) Sondes should be properly ventilated prior to launch so that sensors can equilibrate to the ambient environment.

(4) Independent surface observations, to be used as a check on the surface values in the sounding, should come from well-calibrated instruments measuring the surface pressure, 2-m T and RH, and 10-m winds, all collocated with the sonde launch site. Surface values should be recorded with one decimal place of precision.

(5) The desiccant should be changed and the seal checked in the Vaisala ground check (GC) chamber if RH values > 1% are measured during GC procedures. RH values > 2% indicate a faulty GC procedure or a bad sonde.[1]

(6) Radio frequency for sonde data transmission should be coordinated among the sites. This will be particularly important for ship-to-ship intercomparisons.

(7) Operators can choose to use research mode only for sondes relaunched into heavy weather conditions. Otherwise standard "operational mode" should be used which filters the data and removes apparent "bad" values (which is not done in research mode). Filtered data are better for operational centers which use GTS resolution data in their analyses.

(8) 200 gr balloons should be adequate for DYNAMO. Past studies have shown that 95% of balloons this size will reach 50 hPa (~21 km) before bursting. (See figure below from Masaki Katsumata).

(9) Sonde launch time should be H-30 min from nominal time (H) and, in general, should not fall outside the time range H-45 min to H. (See exceptions in items 10 and 12). This nominal 30-minutes-prior launch time will match operations with other surrounding countries. At times air traffic at nearby airports may cause launches to be delayed (e.g., at Male' and Diego Garcia). Such sites will need to routinely check with aviation authorities for permission to launch.

[1] NCAR ISS systems use a different ground check procedure.

(10) Criteria for re-launch include: sonde not reaching 500 hPa, substantial missing winds or PTU in first 30 minutes or premature termination within this time window, no more than one re-launch attempt, cutoff time for re-launch should be H+60 min from nominal time (H). Note: for relaunch operator should select a different sonde frequency from 1st sonde to avoid possible interference between sondes.

(11) Operator judgment should be exercised, with the option of postponing the launch, when releasing sondes into strong convective storms (i.e., for safety reasons, balloon icing issues and poor representation of large-scale environment).

(12) In the event a launch is delayed due to severe weather where operator safety is a concern, launch should be attempted when safety concerns have passed but only if within H+60 minutes of nominal launch time (H).

(13) The amount of gas used in the balloon should aim for an ascent rate of 4 m/s with a minimum rate of 3.5 m/s. Note: the automatic launcher on the *Mirai* limits the amount of helium used to 1.17 m^3, which yields a typical ascent rate of 3.8 m/s. Limited helium supply at ISS sites may limit ascent rates to minimal values.

(14) Data sampling rate should be set at 1-2 observations per second.

(15) To meet the near real-time numerical modeling objective of DYNAMO, it is crucial that the upper-air sonde data be received at the operational weather centers (NCEP, JMA, ECMWF, etc) roughly 2 hours after nominal launch times. To achieve this objective sondes should be allowed to take data until balloon burst and only be terminated 2 hrs after nominal time (e.g., terminate at 1400 UTC for 1130 UTC launch) if balloon has not burst. [2]

(16) After balloon burst, WMO TEMP coded data should be sent to GTS.

(17) All systems should have a means to backup their data in case primary computer fails. Backups of data files should be done on a daily basis.

(18) Raw data (dc3db files on Digicora III systems) and standard processed files (e.g., edt format) should be saved and submitted to data archival centers at the end of each month and at end of experiment.

(19) Each site should plan to execute a number of test launches a few days prior to the beginning of the experiment. These launches should include 00 and 12 UTC

[2] *Special consideration for sites with Integrated Sonde Systems (ISS):* ISS sites have limited personnel, especially on the *Revelle*, and have proposed to do every other launch until burst with intermediate sondes being terminated at 100 hPa. Because of the importance of 00, 06, 12, and 18 UTC to operational models, during the SOP (with 8/day launches) sondes launched at ISS sites at these nominal times should use the above policy, while launches at intermediate times may be terminated at 100 hPa. If resources (e.g., personnel and helium) are adequate, sondes launched after the SOP (with 4/day launches) should use the above policy (i.e., terminate at burst or 2 hr after nominal time) at all times of day.

nominal times since these are common times for real-time data assimilation systems to ingest sonde data. These launches will ensure that all systems are fully operational and able to transmit their data onto the GTS in a timely fashion.

Other considerations:

- 200 g balloon will used at all sites except Gan where they will use 350 g balloons.
- Balloons should be filled such that ascent rates are at least 3.5 m/s while between 4-5 m/s is preferred.
- Average burst height of 200 g balloon is 24 km; 350 g balloon is 27 km (from Masaki Katsumata).
- With an ascent rate of 3.5 m/s, 200 g balloons should reach 100 hPa (or 16.5 km) in ~80 minutes and 30 hPa (or 24 km) in ~114 minutes. Rarely will balloons not burst by 2.5 hours (~31.5 km) after launch. Longer delays in bursts may only be an issue at Gan which is using larger balloons.

Real-time data products, display and diagnosis

During the DYNAMO field phase, a sonde monitoring and analysis system will be set up as in past field experiments (TOGA COARE, SCSMEX, NAME, TiMREX). Scientists from different agencies and institutions (DOE, NCAR EOL, CSU, etc.) will work together to ensure that sounding data gets onto the GTS and are therefore available in near real time to be accessed and analyzed. Scientists at CSU will conduct quality control (QC) of the sonde data so that field operators can be informed of problems as they develop (e.g., errors in pre-launch calibration, obvious measurement biases, etc.) so that efforts can be made to correct procedures and/or instrumentation in a timely fashion. The data and several analysis products will then be prepared at CSU and made available on a website for DYNAMO investigators to be used for planning of aircraft missions, radar operations, and general operations of the experiment. Planned products are skew-Ts; station time series sounding plots of humidity and winds; maps of divergence, vorticity and streamlines; time series of network-averaged divergence, vertical motion, and apparent heating and drying; and plots of surface fields. A susbset of these products will sent to the DYNAMO field catalog. Efforts will be made to display PW measurements from ground-based GPS systems. In addition, NCAR EOL will provide real-time displays of profiler, RASS and surface data from their ISS systems at Diego Garcia and the R/V *Revelle*. Sounding and other data will also be provided from the EOL DYNAMO Field Data Catalog.

It is critical to get the CINDY/DYNAMO sounding data onto the GTS so that the data can be assimilated into operational models. It is not sufficient just to get data onto the GTS; the operational centers must be able to recognize the messages so they can be incorporated into the assimilation cycle. Information on GTS routing for the various CINDY/DYNAMO observations is given in Table 5.6 (see Appendix A).

Coordination requirements with the rest of the project

Sounding frequency is fixed for EOP, IOP, and SOP. Dropsonde missions will be coordinated with radar operations and other requirements of project.

Personnel rotation schedule (Malé, Gan – AMF2, Diego Garcia R/V Revelle)

- ***Malé***

CSU personnel:

Todd Jones (28 September – 24 October)
Paul Ciesielski (22 October – 20 November)
Alex Gonzales (18 November – 17 December)

JAMSTEC personnel:

Dr. Kazuaki Yasunaga (27 September - 04 October)
Dr. Hiroyuki Yamada (27 September - 18 October)
Dr. Qoosaku Moteki (15 October – 06 November)
Dr. Biao Geng (04 November – 27 November)
Dr. Ryuichi Shirooka (24 November – 17 December)

Taiwanese personnel:

Chen, Teng-Ching (28 September – 25 October)
Chiu, Szu-Han (28 September – 25 October)
Yu, Hung-Jui (24 October – 19 November)
Chen, Tse-Chun (24 October – 19 November)
Tseng, Kai-Chih (18 November - 16 December)
Lin, Wen-Lin (18 November – 16 December)

CSU, JAMSTEC and Taiwanese personnel will be staying at Dace Hotel in Malé. Travel between Malé and Hulhule Island, where sonde observations will be conducted, will be provided by small public boats called dhonis. Once travel plans are finalized for all participants, detailed arrival information and copies of passports will be sent to MMS.

- **ISSs**

Table 5.7. DYNAMO Participants Schedule

Last Name	First Name	Destination	Organization	Arrival Date	Departure Date
Verstraete	Lou	Revelle	NCAR	16-Aug-11	30-Aug-11
Brown	William	Revelle	NCAR	18-Aug-11	5-Sep-11

Granger	Gary	Revelle	NCAR	18-Aug-11	30-Aug-11	
Lindseth	Brad	Revelle	NCAR	18-Aug-11	30-Aug-11	
Semmer	Steve	Revelle	NCAR	18-Aug-11	30-Aug-11	
Standridge	Jen	Revelle	NCAR	18-Aug-11	30-Aug-11	
Baranowski	Darek	Revelle	Student	25-Aug-11	29-Sep-11	
Lindseth	Brad	Revelle	NCAR	4-Sep-11	28-Sep-11	
Verstraete	Lou	Diego Garcia	NCAR	15-Sep-11	3-Oct-11	
Brown	William	Diego Garcia	NCAR	19-Sep-11	17-Oct-11	
Lim	Tim	Diego Garcia	NCAR	19-Sep-11	3-Oct-11	
Martin	Charlie	Diego Garcia	NCAR	19-Sep-11	30-Sep-11	
Paulus?	Matt?	Revelle	Student	27-Sep-11	31-Oct-11	
Knudson	Kurt	Revelle	NCAR	27-Sep-11	2-Nov-11	
Standridge	Jen	Revelle	NCAR	27-Sep-11	2-Nov-11	
Roy	Gavin	Diego Garcia	Student	29-Sep-11	25-Oct-11	
Ruppert	James	Diego Garcia	Student	29-Sep-11	25-Oct-11	
Rydbeck	Adam	Diego Garcia	Student	29-Sep-11	25-Oct-11	
Militzer	John	Diego Garcia	NCAR	12-Oct-11	28-Oct-11	
Davis	Adam	Diego Garcia	Student	23-Oct-11	20-Nov-11	
Lee	Jared	Diego Garcia	Student	23-Oct-11	20-Nov-11	
McCrary	Rachel	Diego Garcia	Student	23-Oct-11	20-Nov-11	
McIntyre	Heather	Diego Garcia	NCAR	26-Oct-11	2-Dec-11	
Lim	Tim	Revelle	NCAR	1-Nov-11	14-Dec-11	
Verstraete	Lou	Revelle	NCAR	1-Nov-11	14-Dec-11	
Smith	Jonathan	Revelle	Student	3-Nov-11	10-Dec-11	
Hannah	Walter	Diego Garcia	Student	18-Nov-11	15-Dec-11	
Slade	Stephanie	Diego Garcia	Student	18-Nov-11	15-Dec-11	
Cohn	Steve	Diego Garcia	NCAR	30-Nov-11	16-Dec-11	
Colasacco-Thumm	Nicole	Revelle	Student	12-Dec-11	5-Jan-12	
Tudor	Laura	Revelle	NCAR	12-Dec-11	10-Jan-12	
Alaka	Gus	Diego Garcia	Student	13-Dec-11	7-Jan-12	
Clark	Johnathan	Diego Garcia	Student	13-Dec-11	7-Jan-12	
Standridge	Jen	Diego Garcia	NCAR	14-Dec-11	20-Jan-12	
Golubieski	Chris	Revelle	NCAR	9-Jan-12	20-Feb-12	
Brown	William	Diego Garcia	NCAR	12-Jan-12	20-Jan-12	
Kidd	Patti	Diego Garcia	NCAR	12-Jan-12	24-Jan-12	
Verstraete	Lou	Diego Garcia	NCAR	12-Jan-12	24-Jan-12	
Brown	William	Revelle	NCAR	16-Feb-12	23-Feb-12	
Lim	Tim	Revelle	NCAR	16-Feb-12	23-Feb-12	
Standridge	Jen	Revelle	NCAR	16-Feb-12	23-Feb-12	
Verstraete	Lou	Revelle	NCAR	16-Feb-12	24-Feb-12	
Lindseth	Brad	Diego Garcia	NCAR			(BACKUP AND/OR MAINTENANCE AT DG)
McIntyre	Heather	Revelle	NCAR			(BACKUP FOR REVELLE)

Leadership structure (i.e., data contacts as issues arise during operations)

Kenya, Colombo, R/V *Mirai*:
Kunio Yoneyama (JAMSTEC; yoneyamak@jamstec.go.jp)
Masaki Katsumata (JAMSTEC; katsu@jamstec.go.jp)

NCAR ISSs on *Revelle* and Diego Garcia:
Bill Brown (NCAR; wbrown@ucar.edu)
Richard Johnson (CSU; Johnson@atmos.colostate.edu)

Gan Island:
Chuck Long: (PNL; Chuck.Long@pnl.gov)

Malé:
Paul Ciesielski (CSU; paulc@atmos.colostate.edu)
Pay-Liam Lin (NCU; tliam@atm.ncu.edu.tw)
Masaki Katsumata (JAMSTEC; katsu@jamstec.go.jp)

Chapter 6 NOAA P-3 Aircraft Operations

Two research aircraft will be deployed in DYNAMO: a NOAA WP-3D and a French Falcon. The NOAA WP-3D is mainly a low altitude aircraft and will be making measurements in the lower troposphere, the atmospheric boundary layer, the air-sea interface, and the upper ocean with long flight duration of 9.5-11.5 hours; the French Falcon operates mainly in the mid-troposphere and will focus on clouds above the melting level with a short duration of ~4 hours. The two aircraft thus have different science objectives and operation plans. This Chapter focuses on the operational plans of the NOAA WP-3D.

1. Overview and Objectives

The DYNAMO aircraft component is an essential part of the field program to collect high spatial resolution measurements over a relatively large region. It serves for two main purposes: to address the basic science questions/hypotheses with its unique standalone suite of measurements and to bridge observations from fixed locations on ships and islands. In addition to the existing tail and fuselage Doppler radars and the flight level in situ measurements that were available during TOGA COARE, new capabilities such as GPS dropsonde/AXBT, Step-Frequency Microwave Radiometers (SFMR), a scanning wave lidar, high-resolution infrared (IR) and visible cameras, and improved in situ sensors, will collectively produce an unprecedented datasets that will advance our understanding of the processes involved and subsequently help improve atmosphere-ocean forecasts.

Because of the complex interactions on various temporal and spatial scales over the tropical ocean, the coupled air-sea interaction and the atmospheric convective processes are closely linked through surface forcing, boundary layer transport, cloud dynamics and microphysics as well as radiation processes. Therefore, aircraft measurements will be process oriented.

With its long flight duration and a full suite of instrumentation, the aircraft measurements will facilitate process studies focusing on the interplay between air-sea fluxes, environmental moisture, and convective cloud systems. We will seek to understand the coupled feedback between the convective and boundary layer processes and the contribution of such feedback to MJO initiation. The process studies will be geared towards improving physical representations of air-sea fluxes, boundary layer flux transport, and the dynamics and thermodynamics of tropical convections in numerical models.

<u>Objectives of aircraft measurements</u>:

1) to obtain boundary layer, surface, and upper ocean measurements to address various science questions associated with coupled air-sea processes in different cloud conditions and MJO phases,

2) to characterize deep convective processes over the Indian Ocean and understand the complex feedback processes among surface forcing, cloud dynamics and thermodynamics, radiation, and atmospheric environmental conditions in various phases of the MJO,

3) to extend point measurements on island and ships to a broader area over the DYNAMO region, and

4) to obtain a suite of atmosphere, ocean, and coupled observations suitable for model evaluation/validation as well as data assimilations.

2. NOAA WP-3D Aircraft Characteristics
The NOAA WP-3D aircraft (Fig. 6.1) is one of the two P-3 aircraft supported and deployed by the NOAA Aircraft Operations Center (AOC) in Tampa FL. These aircraft have led NOAA's continuing effort to monitor and study atmospheric and oceanic systems in support of atmospheric and oceanic forecast of environmental conditions as well as other NOAA missions. Table 3.1 gives the standard specifications of the NOAA WP-3D aircraft. The N43RF ("Missy Piggy") will be deployed for DYNAMO.

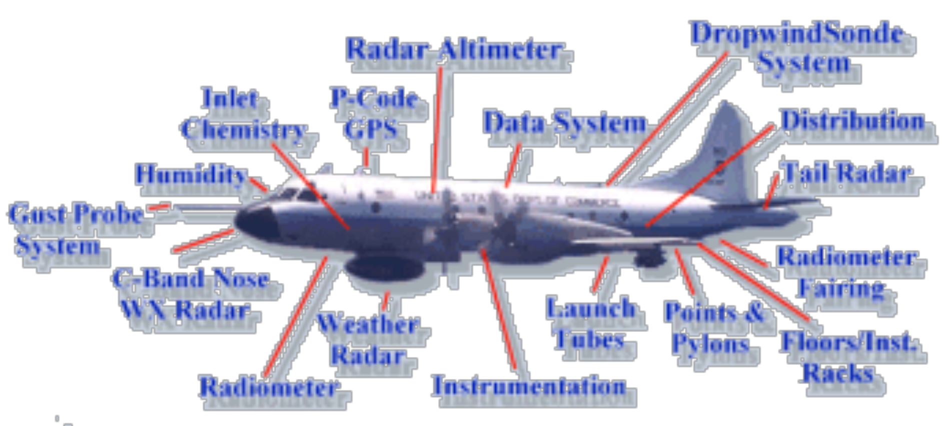


Figure 6.1. The NOAA WP-3D aircraft and location of instruments for general deployment. Information and figure obtained from http://www.aoc.noaa.gov/aircraft_lockheed.htm

Of particular interests to science mission planning are the maximum payload, flight duration, on station aircraft speed, maximum climb rate, and maximum altitude (ceiling). These properties are summarized in Table 6.1 for the NOAA WP-3D.

Table 6.1 Summary aircraft specifications relevant to mission planning. Information were obtained from http://www.aoc.noaa.gov/aircraft_lockheed.htm)

	NOAA WP-3D
Endurance	9.5-11.5 hours
Range	2,225 nm (4,100 km) low altitude (<18,000 ft or 4.8 km) 3,300 nm (6,100km) high altitude (>18,000 ft or 4.8 km)
Ceiling	27,000' (8.2 km)
Aircraft ground speed	~120 ms^{-1}
Maximum rate of climb	3000 FPM
Scientific payload	9000 lb
Max. non-crewmember	11

3. NOAA WP-3D Instrumentations

Each of the two NOAA WP-3D aircraft is equipped with a variety of scientific instrumentation, radars and recording systems for both *in-situ* and remote sensing measurements of the atmosphere, the earth, and its environment. Table 6.2 gives an overview of the standard instrumentation aboard the aircraft and a general description for each category.

Table 6.2 Overview of the NOAA P-3 instrumentation. Information were obtained from http://www.aoc.noaa.gov/aircraft_lockheed.htm)

Skywatch Collision Avoidance System (TCAS):	An airborne traffic advisory system that assists the flight crew in visual acquisition of aircraft that may pose a collision threat.
Altitude Alert System:	System that provides flight crew with visual and audio warnings about a variety of flight conditions regarding the altitude of the aircraft.
Flight Level *in situ* Sensors:	Navigational parameters Pressure, temperature, and water vapor Mean winds and turbulence Cloud physics Radiation

Radars:	Rockwell Collins C-band nose radar Lower fuselage C-band research radar – 360 deg. horizontal fan beam Tail X-band Doppler radar
Expendables:	GPS dropwindsonde atmospheric profiling system Airborne Expendable Bathythermographs (AXBTs) Airborne eXpendable Conductivity Temperature and Depth probes (AXCTDs)
Others:	C-band and Ku-band scatterometers Stepped Frequency Microwave Radiometer External Wing Store Station Mounts

The three essential instrument groups (flight level sensors, radars, and expendables) on the NOAA WP-3D are described in the following sections.

3.1 Flight level instrumentation

Table 6.3 lists all flight level measurements to be made on the WP-3D during DYNAMO. Instruments from individual research PI are listed with the PI institute name.

Table 6.3 NOAA WP-3D flight level data and instruments for DYNAMO

Parameters	*Instruments*	*Fast/Slow*
Position	INE and GPS, Oxford RT3003 GPS/INS	S
Ground Speed Vector	INE and GPS, Oxford RT3003 GPS/INS	S
Aircraft Altitude	Radar and pressure altimeters	S
Attitude Angles (heading, pitch, and roll)	INE and GPS, Oxford RT3003 GPS/INS	F
Air Temperature	Deiced Rosemount total temperature (2) UCI Rosemount temperature UCI-Modified Rosemount dual-thermistor (2)	S F F
Humidity	Edge Tech Vigilant (2) UCI LI-COR 7200 (with CO_2) UCI-modified Krypton	S F F
Static Pressure	Flush ports with Rosemount 1281AF pressure transducers	F
Dynamic Pressure	Flush ports with Rosemount 1221 F1AF pressure transducers	F

Flow Angles (sideslip and attack angles)	Rosemount 858 AJ 5-hole with Rosemount 1221F2VL transducers Radome gust system with Rosemount 1221F2VL transducers	F F
Small Cloud Droplet Spectrum	FSSP forward scattering probe	F
Cloud Droplet Spectrum	PMS 2-D Gray and/or mono probes	F
Hydrometeor Size Spectrum	PMS 2-D Gray and/or mono probes	F
Cloud Drop Size Distribution	UCSC Phase Doppler Interferometry (DPI)	F
Cloud liquid water/Total Liquid Water	SEA WCM-2000 Multi-Element Water Content System	F
Sea surface temperature	KT19.85 II	S
CO_2 air temperature	KT19.85 II	S
Shortwave Radiation	NRL-Modified Kipp & Zonen CM-22 pyranometers	S
Longwave Radiation	NRL-Modified Kipp & Zonen CG-4 pyrgeometers	S
Cloud structure; surface	Video photography (nose, side and vertical)	S

3.2 Airborne radars

AIRBORNE DOPPLER RADAR SCANNING METHODOLOGY

The characteristics of the NOAA P-3 vertical-scanning Doppler radar are listed in Table 6.4. The Doppler radar is X-band and is restricted to a maximum antenna rotation rate of ~60° s^{-1} (~10 RPM). The system employ a multiple PRF (pulse repetition frequency) scheme to extend the radial velocity Nyquist interval to > 50 m s^{-1}, greatly easing the work required to dealias (or unfold) radial velocity data sets, which is required for proper determination of the 3-D wind fields.

Table 6.4. Radar parameters for the NOAA P-3 Doppler radar.

Parameter	***Description***
Scanning Method	Vertical about the aircraft's longitudinal axis; fore/aft alternate sweep methodology
Wavelength	3.22 cm (X-band)
Beamwidth:	
Horizontal	aft: 2.07°, fore: 2.04°
Vertical	aft: 2.10°, fore: 2.10°
Polarization (along sweep axis):	Linear horizontal
Sidelobes:	
Horizontal:	aft: -57.6 dB, fore: -55.6 dB
Vertical:	aft: -41.5 dB, fore: -41.8 dB
Gain:	aft: 34.85 dB, fore: 35.9 dB
Antenna Rotation Rate	Variable 0-60° s^{-1}
Fore/Aft Tilt:	aft: -19.48°, fore: 19.25°
Pulse Repetition Frequency	Variable, 1600 s^{-1} – 3200 s^{-1}
Dual PRF ratios	Variable: 3/2 and 4/3, typical
Pulses Averaged per Radial	Variable, 32 typical
Pulse Width	0.5 μsec, 0.375 μsec, 0.25 μsec
Rotational Sampling Rate	Variable, 1° typical
Peak Transmitted Power	60 kW
Unambiguous Range with Interlaced PRT technique	38-92 km
Unambiguous Radial Velocity with Interlaced PRT technique	13-71 m/s
Along track beam spacing	~1.4 km
Range resolution	150 m

Figure 6.2 illustrates the scanning methodology. The scanning strategy is to utilize the fore/aft scanning technique to sweep out a three-dimensional volume during the aircraft's flight track. Alternative sweeps are scanned forward then aft by about 20° from a plane that is normal to the aircraft's longitudinal axis. At intersection points of the fore and aft beams a horizontal wind estimate can be made. The horizontal data spacing of those intersection points depends on the antenna rotation rate and the ground speed of the aircraft. For typical values of ground speed the

Airborne Doppler Radar Scanning Geometry

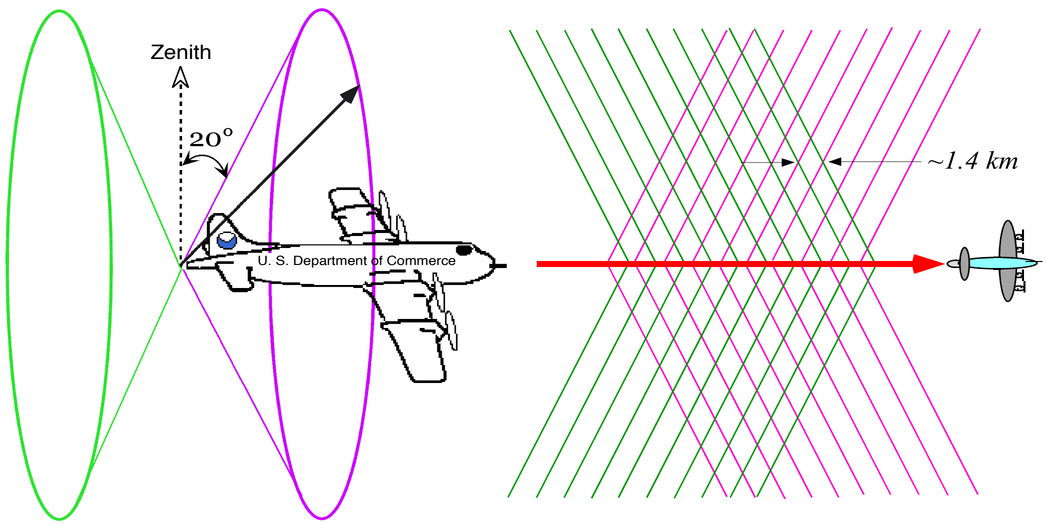


Figure 6.2. Tail radar scanning geometry. The left plot shows a schematic of the antenna scanning methodology. A horizontal projection of the beams is shown on the right.

typical data spacing is ~1.4 km. For psuedo-dual-Doppler analysis that derives 3-D winds an assumption of stationarity of processes during the data gathering must be made. The time interval between any two intersecting beams is a function of the aircraft's ground speed and antenna scanning rate, and range from the aircraft. For the P-3, with a typical ground speed of ~120 m/s and the maximum antenna rotation rate of ~10 RMP, the typical time interval between beams is ~ 1 min per 10 km range from the aircraft. The maximum effective range of the radar is ~40 km, so the time period of assumed stationarity is ~ 4 minutes.

Observations of the storms will need to encompass the entire vertical extent of the circulation in order to adequately derive three-dimensional motions from the pseudo-dual-Doppler technique. Accurate near-surface measurements of divergence are critical for the calculation of verical velocity since to derive vertical motion the continuity equation is vertically integrtated. To avoid the deleterious effects of vertical hydrometer velocity (plus vertical motion) it is desirable to contain the viewing to ±45° from the horizontal (2). A good rule of thumb is that R (the distance from the center of the intense precipitation core) should be greater that the distance the storm top is above the aircraft's altitude (or the surface is below the aircraft's height). For example, if the echo top, h, is 10 nmi (50,000 ft) and the aircraft altitude is 5 na mi (25,000 ft) then R is 5 na mi. If h is 50,000 ft and the aircraft altitude is 1 na mi (5,000 ft) then R is 9 na mi. Thus, low level flight patterns are desired to eliminate the (as much as possible) the contamination of radial Doppler velocity by terminal fallspeed.

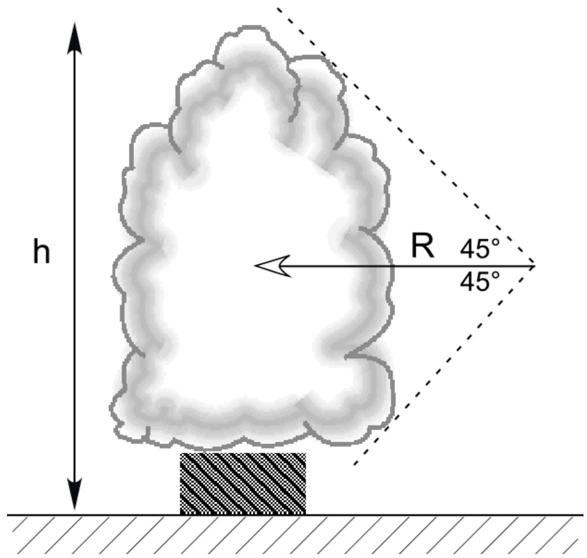


Figure 6.3. Schematic of desirable single aircraft airborne Doppler radar scanning at range R from the reflectivity maximum. Ideally the target is within the ±45° elevation angle to minimize the deleterious effects of vertical fall velocity on the measured radial velocity.

One of the potential drawbacks of the high alititude flight modules is the hazard of lightning strikes on the aircraft as the plane traverses the mixed phase region between about 0° C and –5° C. The NOAA WP-3D has a tendency to become highly electrically charged in this temperature region due to impact with ice crystals. The charging has been known to completely block VHF radio transmission and reception, making contacting air traffic control problematic. It is not known if the charging has an appreciable effect on satellite communications. Static electric discharges (i.e., lightning strikes on the aircraft) are another known hazard and those discharges have been know to damage radar antennas and radar transmitters/receivers (not to mention holes drilled in the skin of the aircraft by the discharge). Therefore, to minimize damage to the aircraft the Chief Scientists should carefully monitor the environmental conditions and be prepared to move to a lower alititude if lightning strikes threaten scientific equipment or block communications with air traffic control. Decending below the melting level is usually sufficient to bleed off the charge.

3.3 Expendables

A unique aspect of DYNAMO aircraft measurements compared to TOGA COARE is the availability of air deployable instruments such as dropsondes and Airborne eXpendable BathyThermographs (AXBT) or Airborne eXpendable Conductivity Temperature and Depth probes (AXCTD), all can be deployed from the NOAA WP-3D. Drops of expendables will be performed at variable frequencies in accord to the flight plans described in Section 6.5. Table 6.5 lists general specifications of the Vaisala RD94 dropsonde package to be used during DYNAMO.

Oceanographic instruments may be deployed from the WP-3D aircraft either from external chutes using explosive cads or from an internal drop chute. They activate upon hitting the ocean surface and radio sea temperature, salinity, and current information back to computers aboard the aircraft. Specifications of some aspects of the AXBTs and AXCTDs are also listed in Table 6.5.

Table 6.5 Dropsonde, AXBT, and AXCTD Specifications

Dropsonde System Specifications	
Sonde and receiver system	AVAPS-II multi-dropsonde unit, Vaisala RD-94
Size	41cm x 7cm (diameter)
Weight	323g
Max Deployment Airspeed	125 m/s indicated air speed
Descent speed	~11 m/s at sea level (depending on altitude)
Descent time	~15 min. from 14 km; 8 min from 7.5 km
Transmitter	RF, range 400-406 MHz
Telemetry range	325 km
Battery	2 h operating life, Lithium
Pressure	Vaisala BAROCAP, accuracy 0.4 hPa, 2Hz
Temperature	Vaisala THERMOCAP, accuracy 0.2°C, 2Hz
Relative humidity	Vaisala H-HUMIDAD thin film capacitive bead. Accuracy 2% RH, 2Hz
Horizontal winds	GPS derived, accuracy 0.5 m/s, 2Hz
Data system	Relay to aircraft. Edited and formatted message to ground following end of each drop via satcom
AXBT/AXCTD System Specifications	
AXBT/AXCTD and receiver system	
Frequencies	Sonobuoy - UHF
Channels	169.650 MHz (AXBT narrow band) 170.500 MHz (Channel 12) 172.500 MHz (Channel 14) 173.500 MHz (Channel 16)
Depth range	0-1000 m, 0.11 resolution
Ocean temperature	+/- 0.02 °C accuracy, 0.015 resolution
Conductivity (AXCTD)	+/- 0.003 Ms/CM accuracy, 0.01Ms/CM resolution
Data system	Post-flight processing and distribution via GTS

3.4 Other Sensors

Stepped Frequency Microwave Radiometer (SFMR)

The NOAA Stepped-Frequency Microwave Radiometer (SFMR) is the prototype for a new generation of airborne remote sensing instruments designed for operational surface wind estimation over the ocean. The SFMR has a downward pointing antenna, which passively reads the microwave radiation coming from the ocean surface. By making assumptions about the vertical structure of the atmosphere together with sea surface temperature measurements by a downward-looking airborne infrared radiometer, reasonable estimates of the ocean surface brightness temperature can be made at six frequencies between 4.6 and 7.2 GHz. Wind speeds are then calculated assuming linear increase in wind speed with these brightness temperatures. Since some of the frequencies are more attenuated by rainfall than others, an estimate of the rainfall rate below the airplane can also be made.

3-D surface waves field Scanning LiDAR

The University of California at Irvine (UCI) has developed a system utilizing an airborne scanning LiDAR (Light Detection and Ranging) to map the topography of ocean-surface waves to be integrated onboard the WP-3D for the DYNAMO experiment. The proven Riegl LMS Q240i – 80 eye-safe (class 1) scanning laser will be used to measure the range to the point of reflection at the surface and the scan angle with the respect to the LiDAR platform. In order to obtain the exact position of the point of reflection at the surface, highly accurate measurements of the LiDAR platform position, velocities and attitude angles are required. This will be achieved by the high end OXTS RT3003 dual antenna Navigation System / Global Positioning System (INS/GPS) unit that will be co-located with the scanning LiDAR and that will be aided with Differential GPS (DGPS) from a base station (for near base flights) and from a wide-area DGPS commercial service provided real-time by OmniSTAR Inc. This system is able to clearly resolve the omnidirectional equilibrium spectra varying as $k^{-5/2}$, as predicted by Phillips (1985).

Infrared and Visible Cameras for SST Variability and Upper Ocean Processes Characterization

Lamont-Doherty Earth Observatory of Columbia University (LDEO) is developing an airborne imaging system that utilizes both infrared and visible cameras to map the ocean surface SST and ocean surface processes. Airborne IR imagery will provide high spatial resolution calibrated SST variability. The image scale would be roughly 500 m to 1000 m (depending on altitude) with resolution of order 1 m. The IR imagery would characterize SST signatures including upper-ocean convection, freshwater lenses due to rain, Langmuir circulation, internal waves, ramping of near-surface stratification, etc. The IR and Visible imaging provide an important characterization of the wind-wave field since they are used to characterize the kinematics of wave breaking (white capping only). Analyses of the airborne IR and Visible imageries would benefit significant from over-flight over the Ship and/or mooring array for better understanding of the wave effects on the upper ocean turbulence and stratification structure and the wave effects on the air-sea fluxes.

The IR system consists of two high sensitivity thermal IR cameras. One is the JADE LWIR 750 (calibrated / 0.1K; 320 x 240 pixels; 14-bit; 240 fps; 18 mK NETD) that is sensitive to 8.0-9.3.0 micron radiation. The second is the FLIR SC655 camera (calibrated / 0.2K; 640 x 480 pixels; 14-bit; 30 fps; 35 mK NETD) that is sensitive to 8.0-12.0 micron radiation. The visible camera is an Imperx IPX-1M48-L (1000 x 1000 pixels; 48 fps programmable; 12-bit; Camera Link). This will be mounted collocated with the Riegal scanning LIDAR system. The combination of cameras will allow us to capture a multitude of scales from *O*(1m - 1000m) at resolution better than *O*(1m).

4. NOAA WP-3D Sampling Strategy

4.1 General sampling strategy

As stated in Section 1, the objectives of the DYNAMO aircraft is to quantify cloud and boundary layer dynamics and thermodynamics, air-sea interaction, and upper ocean mixing with greater details and to examine the inter-play of these components in various cloud and wind conditions and in different stages of the MJO initiation processes. DYNAMO aircraft measurements will be made differently from previous field projects in the tropics such as TOGA COARE where each flight has a single mission objective: surface flux sampling or Doppler radar measurements. We recognize that what is lacking in our understanding is the feedback between boundary layer and deep convective processes. The feedback processes occur on various temporal and spatial scales over the tropical ocean, that closely link the coupled air-sea interaction and the atmospheric convective processes through surface flux transport, boundary layer transport, cloud dynamics and microphysics, and radiation processes. The NOAA WP-3D measurements will thus focus on capturing such feedback process that calls for adequate sampling of each process in a single flight whenever weather condition permits. This is feasible due to the addition of dropsondes and AXBTs and additional remote sensors in recent years.

For the first time after TOGA COARE, DYNAMO aircraft measurements will be able to fully quantify the coupled tropical environment where all components are concurrently sampled with a combination of in situ flight level measurements, sampling from remote sensors such as C-band and X-band cloud radars, surface wave scanning lidar, and the microwave SFMR, as well as profile measurements of dropsondes and AXBTs/AXCTDs. As such, we will be able to address the coupled interaction among various processes, which is an optimal use of the combined capabilities. In addition, we should also take advantage of the mobility of the aircraft to extend point measurements on islands and ships to a broader region, which requires close coordination with and inputs from other platforms. Flight planning will also ensure that the measurements made will be suitable for model evaluation/validation as well as data assimilation.

4.2 Process-oriented flight modules

Flight modules with specific objectives are described in this section. These modules are designed to be simple and adaptable. They will obtain the desired in situ flight level data, dual-Doppler cloud and cloud dynamics, and dropsonde/AXBT data with a minimal degree of complexity, and they are readily modified in real time to accommodate cloud conditions encountered during the flight.

Boundary layer process modules:

Figure 6.4 shows three low-level flight modules aimed at quantifying boundary layer processes and air-sea exchange processes, including vertical stacks of level legs (FVS), cross-section profiling (FCS), and lawn-mowing flux mapping (FFM). The letter 'F' preceding these module names refer to flight-level measurements.

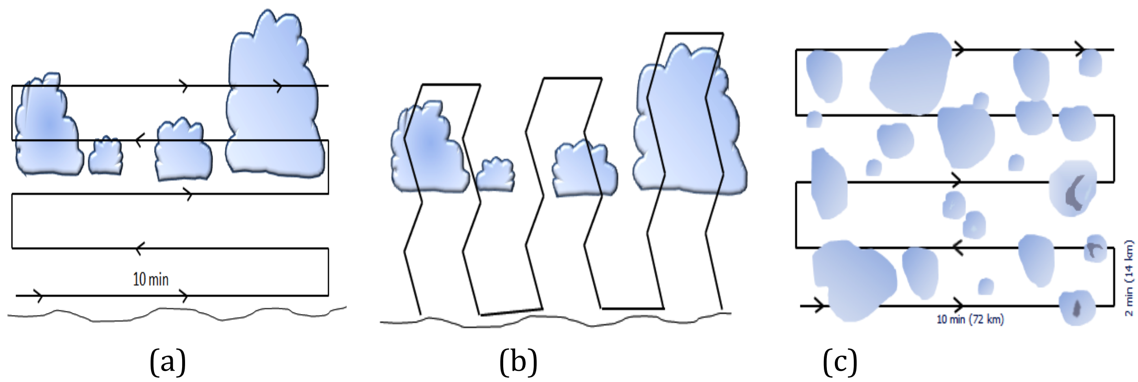


Figure 6.4. (a) Side view of flight level vertical stack (FVS) module for boundary layer turbulence flux profile sampling. (b) Side view of flight level cross-section (FCS) profiling module. (c) Top view of flight level flux mapping (FFM) module.

The FVS module (Fig. 6.4a) is designed to obtain the vertical variation of turbulence fluxes/variance and cloud dynamics and microphysics from the surface to the cloud layer. The cloud base is normally co-located with the boundary layer top. Each level leg lasts 10 min (~72 km). Three levels should be below the cloud base, one immediately above, and one through the cloud layer. For night flights or windy conditions, the lowest level is limited to be no less than 500', although it can be 200' in daytime calm conditions. Total time of the module is ~ 70 min. Preferably, two FVS modules in the along- and cross-wind directions should be made. If time only allows for one FVS measurement, the module should be done in the cross-wind direction.

The FCS module intends to sample the vertical profiles along a straight line, resulting in high-resolution measurements in a vertical cross-section. Sections of slant path ascents and descents are made at a rate of 1000'/min. Soundings go from the As-Low-As-Possible (ALAP) altitude to ~100' above the cloud top or 3 km, whichever is lower. Separation between successive soundings is about 2 min of level flight at the top or at ALAP level for the given flight conditions. Total time for this module is ~70 min for the depicted six sounding configuration. If necessary, the ascent/descent rate will be lowered to ensure proper sampling and response of various flight level sensors, in which case the number of soundings from this pattern will have to be reduced.

The FFM module in Fig. 6.4c is designed to evaluate the spatial variability of surface flux, the ocean wave field, and SST. This module should be at the ALAP altitude (200' or higher in unfavorable conditions) and be repeated at another level in the middle of the boundary layer when flight time allows. The module covers an area of 70 km×60 km and takes ~60 minutes to complete. Preferably, FFM module is done in the same region of the dropsonde/AXBT survey pattern in close time period so that the surface fluxes, surface waves, and the vertical profiles in both the atmosphere and ocean are sampled.

These patterns should be adjusted in case of deep convective clouds as flight near the surface is likely not permissible.

Deep convection process modules:

The goal of the aircraft flights for deep convection studies is to determine how convective structure and fluxes, particularly at the air-sea interface, vary as a function of environmental conditions. This goal will be achieved through obtaining statistics of the horizontal and vertical fluxes of heat, moisture, momentum, radiation, and precipitation for a representative sample of all classes of clouds frequently observed over the tropical oceans and thereby, developing an understanding of the processes involved, and how these processes respond to environmental conditions. The cloud system characteristics, combined with the logistical constraints, suggest a strategy for planning and executing the aircraft research missions. Flight modules for deep convection characterization include a radar/dropsonde cloud survey (DCS) module and a radar convective element (RCE) module.

The DCS module is illustrated in Fig. 6.5. This module is done at the highest possible altitude level. Leg lengths would scale with the "size" of the convective system as defined by, for example, the extent of the cloud shield as defined by IR satellite imagery. For suppressed conditions (cloud class of 0 or 1) the leg length may be arbitrary, for example, 100 to 200 km. The goal of the survey module is to define the large scale extent of the convective cloud population within range of the P-3's LF radar (plus any other ship or ground-based radar, if appropriate). For more convectively disturbed conditions, or whenever there is precipitation, "Purl" patterns (2 minute 360° circles) will be done every 100 km to derive highly accurate vertical profiles of vertical motion.

The DCS pattern also serves as a dropsonde survey pattern and an alternative for the Dropsonde Area Survey (DAS) pattern to be discussed later (Fig. 6.7). Dropsonde release will be made on all legs of the 'figure 6.4' pattern with even spacing at a Dropsonde Release Interval (DRI) of 5 minutes. Additional dropsondes may be needed immediately before or after each 2-minute purls so that dropsonde derived vertical velocity can be compared with the highly accurate vertical profiles of vertical motion derived from the co-located "Purl" patterns (2 minute 360° circles) done every 100 km along the legs of the figure 6.4. An estimated total of 30 sondes and 21 AXBTs (maximum number of external AXBT release above 10000') are needed to complete this module. The DCS module is particularly useful at the start of the measurements to identify the spatial variability in cloud, wind, air temperature, and water vapor and further help to identify the entry point of other process modules (FVS, FCS, FFM, or RCE).

The RCE pattern focuses on investigation of a particular convective element (e.g., linear feature) as shown in Fig. 6.6. Leg lengths are 80-100 km and consist of both line-parallel and line-perpendicular segments if there is a trailing stratiform region. Otherwise a series of straight and level legs (at 5,000 ft altitude) will be flown along a convective feature. A few dropsondes can be deployed along the line segments in both directions to document the low-level flow and thermodynamic structure (i.e., cold-pool strength) ahead of and behind the line. However, due to the relatively low drop altitude, we only anticipate meaningful sounding data below ~1200 m to allow sensor adjustment at the staring of the sounding. Nevertheless, these soundings will be useful to identify the disturbed boundary layer structure.

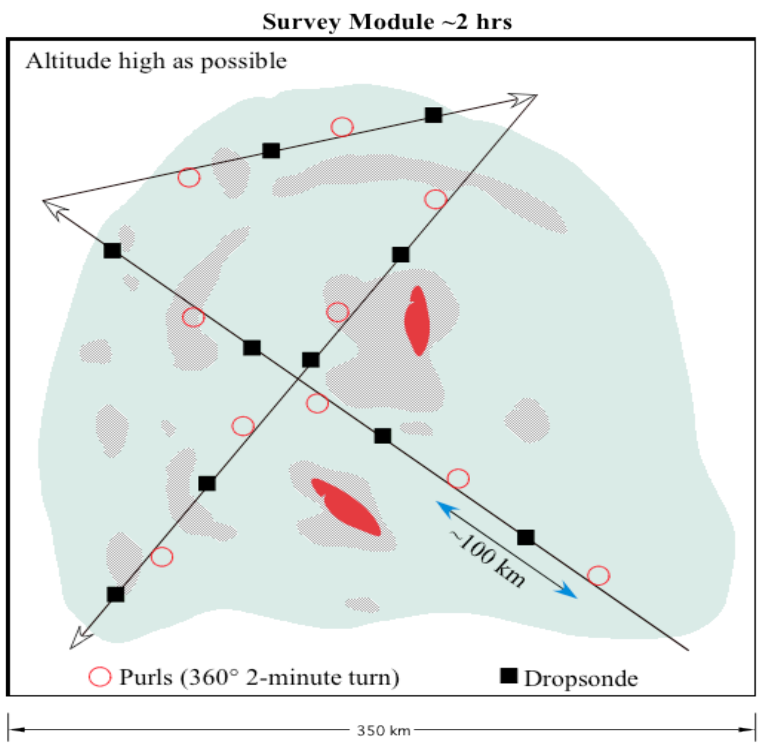


Figure 6.5. "Survey" module to sample the larger scale aspects of the convective systems. This will be done in all systems. Leg lengths will be adjusted based on the extent of the precipitation shield or 208 K contour on IR satellite imagery.

Dropsonde/AXBT/AXCTD deployment:

Dropsonde measurements are the highlight of the WP-3D measurements in DYNAMO because of its potential of 3-D coverage of the measurement area. The main objective of the P-3 dropsonde and AXBT/AXCTD deployment is to provide detailed representation of the vertical structure and its horizontal variability of the lower troposphere and the upper ocean. The general strategy for dropsonde deployment is to obtain spatially coherent vertical structure of wind and atmospheric thermodynamic variables. The basic deployment will be along a straight line, all patterns are formed by multiple straight lines in various configurations. Two major sonde deployment patterns are described here including dropsonde area survey (DAS) and dropsonde convective element (DCE) study.

A schematic of the DAS module is given in Fig. 6.7. This lawn-mowing pattern, similar to that of the flux mapping (FFM) module discussed earlier, is especially designed for mapping out the spatial variability of the lower troposphere and the ocean mixed layer with gridded sample

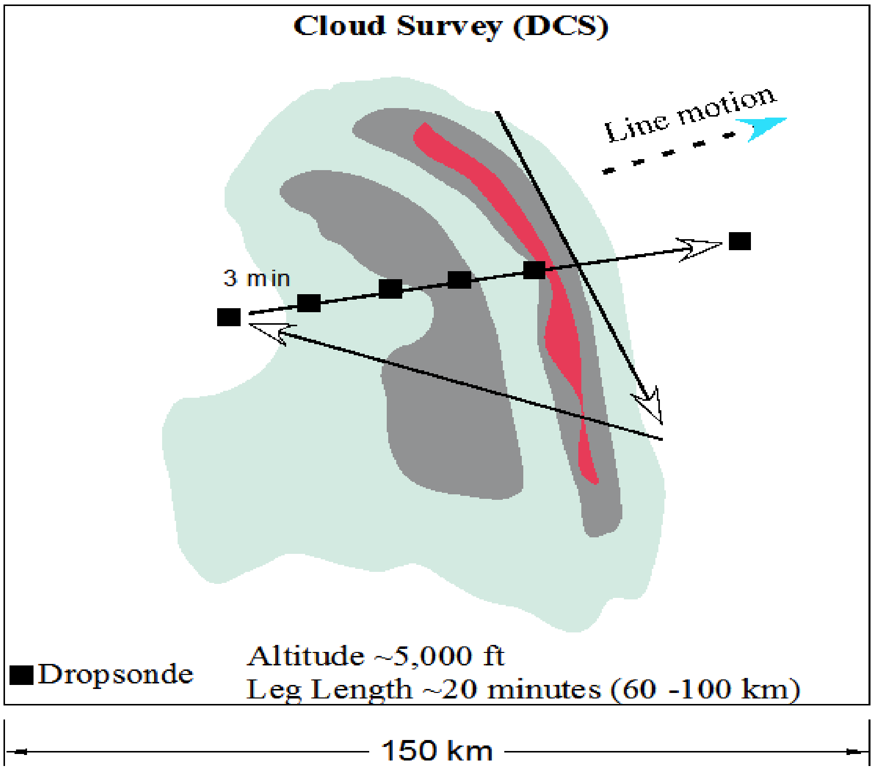


Figure 6.6. Flight module for Doppler radar documenting of convective features. Dropsondes along the back to front leg are every 3 minutes (~21 km spacing) until the convective line is penetrated. Last dropsonde ahead of the system is deployed ~50 km ahead of the line.

profiles in the measurement domain. The altitude of the DAS legs is between 10,000 and 19,000' depending on the cloud top height of the cloud population in the sample area. Depicted here are five 25-min legs (180 km), separated by 5-min (36 km) short legs. Dropsonde deployment intervals are 5 minutes (36 km spacing). Depending on the cloud scales and the scales of horizontal heterogeneity of the field, the area coverage, and the frequency of dropsonde release can be adjusted accordingly. A few general guidelines for the use of this module are listed below:

1. This pattern is used to address one of the DYNAMO objectives to quantify the

moisture environment under different cloud conditions. Hence this module should be used in multiple flights with different cloud population distribution, with special focus on cloud fields with significant spatial variability.

2. Good estimates of the cloud scales and spatial variability are essential for the planning and execution of DAS pattern to make the most effective use of the expendables. In pre-flight planning, DAS altitude, coverage area (location and size), and dropsonde release interval (DRI) will be determined using satellite observations and model forecasts to ensure that

   1) sufficient number of soundings should be made through clouds and cloud environments to allow statistical characterization of the clouds and their environment. Based on long-term tropical cloud climatology (Mapes and Houze 1992) and analyses of the cloud populations over the Western Pacific (Chen et al, 1996), five distinct “classes” of cloud systems were identified with scales of precipitation cells ranging between 10 km for class 0, 20-30 km for class-1, 100 km for class 2, and 250 km or larger for class 3-4 systems. To sample the cloud scales of class 2 and below, drop release intervals of 5 minutes or shorter are needed to yield a horizontal spacing of ~36 km or less. At a release interval of 3 minutes, the horizontal spacing is 21 km. In case of significant cloud variability, 3-minute drop release interval is preferred. DAS pattern will not be used in homogeneous cumulus cloud field and will be replaced with dropsondes along two lines, one crosswind, one along wind and intermittent soundings throughout the flight;

   2) Dropsonde release level should be at an altitude that provides meaningful sonde data from the cloud top of the most popular small clouds to the lowest possible altitude at the given environmental conditions (ALSP). Thus, the DAS altitude should be ~500-600 m above to allow time for sensor adjustment at the release of the sonde. Given an estimated cumulus top at about 2.5 km ASL, a minimum DAS level of 10,000' is needed. Adjustments to these specifics of the DAS pattern should be made during the flight based on the most current satellite information, Doppler radar scan, and in-flight visual observations.

   3) The DAS pattern can also be used as the radar survey pattern (DCS, although not in figure 6.4 configuration) if appropriate altitude is used. This is a preferred flight strategy to make the best use of the limited flight hours whenever conditions allow.

   4) The modeling group of DYNAMO prefer to have sounding profiles from higher altitude. While aircraft operation will consider this requirement for the broader DYNAMO objectives, it will be considered with all other decision making factors. One alternative to accommodate multiple objectives is to

drop from the highest feasible altitude (AHAP) at the beginning and end of the DAS pattern, or to release dropsondes intermittently while the P-3 is at higher altitudes.

5) The DAS pattern will be preceded or followed by a vertical cross-section pattern (FCS) within the DAS covered area. The in situ measurements from the aircraft sounding can be used to examine known sensor issues of dropsonde measurements when going through cloud layers. Previous research have identified sensor wetting problems that reduced dropsonde measured temperature in and below cloud layers in subtropical stratocumulus clouds. Similar problems are expected to exist in the tropical precipitating clouds, but the magnitude and the impact of such sensor issues remain to be examined using the DYNAMO measurements. Measurement design should take this into consideration.

6) There are two AVAPS systems on the P-3 that are capable of sampling 8 dropsonde simultaneously. This configuration can accommodate very aggressive dropsonde release even to a DRI of 1 minute. In contrast, we are limited by the 3 channels of AXBT/AXCTD sampling and will not be able to make all AXBTs coincident with the dropsondes. The feasible AXBT drop interval is likely 5-10 minutes. For a more frequent AXBT profiling, it is feasible to execute an AXBT only DAS pattern from a lower level, e.g., 4000'-5000'. Our past experiences with AXBT data suggest that AXBT releasing at these levels do not impact the success rate of the AXBTs, but we need to experiment with AXCTDs to find their operational limits. Ocean sampling only DAS will be denoted as DAS-O. The measurements from this level can be for flux mapping (FFM) in the cloud layer or radar cloud survey (DCS). In addition, a mixture of AXBT and AXCTD should be used to quantify freshwater layer in the upper ocean due to convective precipitation.

The DAS module may take ~1.5 hours and requires about ~30 dropsondes and ~18 AXBTs. The DAS module will be used in flights except for those in relative homogeneous cloud conditions, in which case DAS pattern will be replaced with linear deployment of sondes in the along- and cross-wind directions and a DAS-O at a lower level. The measurements in this type of cloud condition will focus on low-level turbulence, boundary layer flux transport, as well as upper ocean mixing.

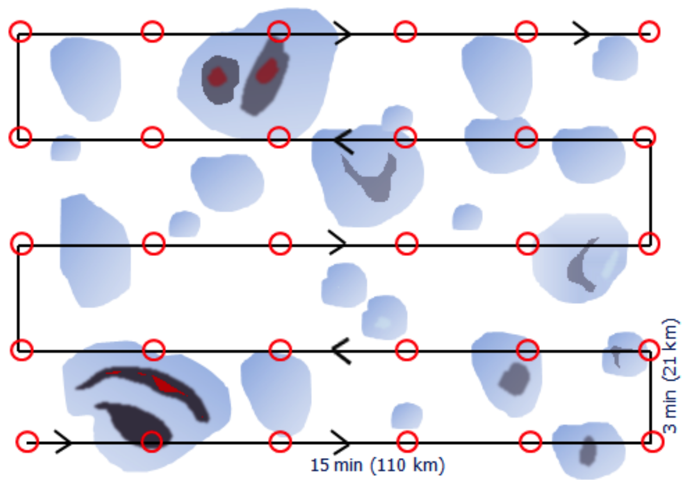


Figure 6.7. Top view of gridded dropsonde area survey (DAS) module. Altitude is high as possible.

Dropsonde measurements will also be used to target individual convective elements with more frequent sonde release. These deployment are referred to as 'dropsonde convective element' (DCE) modules. The DCE measurement is designed to quantify the kinematic and thermodynamic variations in the strong convective cloud systems with significant horizontal dimensions (several tens to 100 Km in diameter). The DCE leg should be placed relative to the convective cloud system, such as the penetrations through the linear cloud feature depicted in Fig. 6.8. This pattern supplements the radar cloud element pattern (RCE) from 5000'. The DCE drop altitude will be ~10,000'. To achieve high spatial resolution, dropsonde release interval will be ~ 3 minute, which gives a horizontal spatial spacing of about 21 km. About 70 minutes of flight time, 25 dropsondes, and 14 AXBTs are needed for this pattern.

To address the boundary layer and cloud variability in response to the large scale SST variation in the DYNAMO region, we have added another module to map out the large scale variation of the moisture field, convection and boundary layer in the larger DYNAMO domain. This module is referred to as the Dropsonde Large-scale Gradient (DLG) depicted in Fig. 6.9. Dropsondes and AXBTs will be deployed at even spacing of ~0.5° (50 Km, or 7 minutes). A flight plan has been developed for the utilization of this module (see Section 4.3) where we also

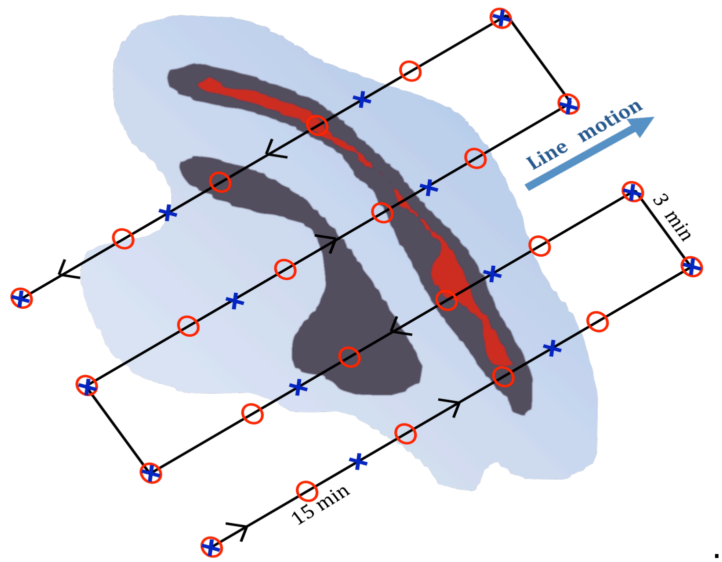


Figure 6.8. Top view of the DCE module consisting 4 15-minute legs (108 km in length) separated by ~3-min short legs.

add in radar cloud scan near Gan Island and flux mapping near the NE ship to facilitate aircraft-island and aircraft-ship inter-comparisons. Ideally, a total of 48 dropsondes and 48 AXBTs are needed for this module.

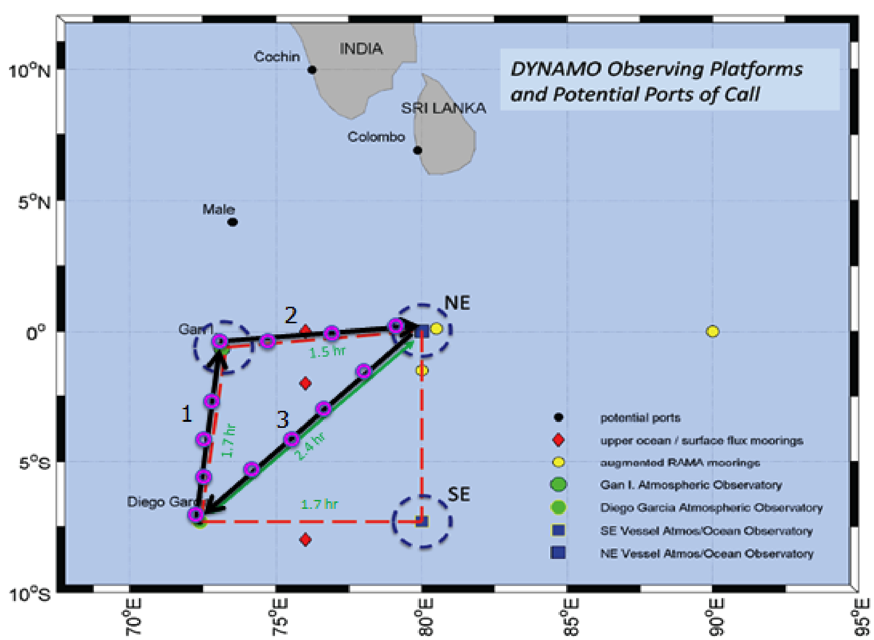
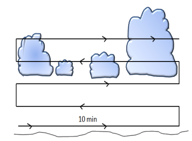
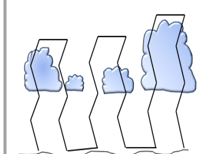
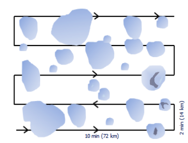
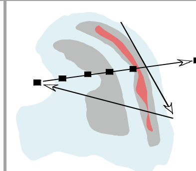
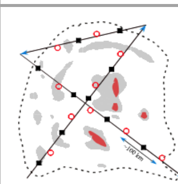
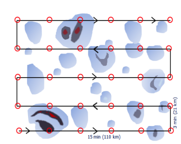
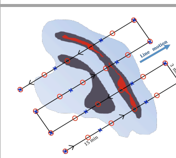
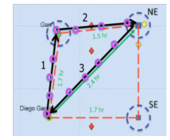


Figure 6.9. Dropsonde Large-scale Gradient (DLG) module to sample moisture, cloud, and boundary layer variability in response to large-scale variation of SST in the DYNAMO domain. Note that the NOAAWP-3D will be based at Diego Garcia at the southwest corner of the DYNAMO domain enclosed by the red dash lines. The time needed to transit to other DYNAMO sites are labeled in the figure.

Table 6.6. Summary of all flight modules. The first letter of each module ID indicate the key sensor/probe of the module: 'F' refers to flight-level sensors; 'R' refers to radar; and 'D' refers to dropsonde. DRI refers to dropsonde/AXBT release interval given in parentheses in unit of minutes.

Module ID	Name	Measurements	Horizontal range (km)	Altitude (ft) (MSL)	Approximate elapse time (minutes)	Sondes/ AXBTs (DRI)	Flight Pattern
FVS	Vertical stacks of level legs	Fluxes at multiple levels in the boundary layer	70	4-5 levels between 200' to 1000' above cloud base	70		
FCS	Cross-section profiles	Vertical cross-section of low-level profiles from in situ measurements	70	Near surface to cloud top or 3 km	70		
FFM	Flux mapping	Horizontal variability of flight level fluxes	70×60	As low as possible and 100' below cloud base	60		
RCE	Radar convective element	Radar sampling of deep convective elements	Segments of ~100 km	5000'	60	6/6 (10/10)	
DCS	Cloud field survey	Survey for cloud conditions over a large region	Varies, typically ~200×200	As high as possible	120	30/24 (5/5)	
DAS	Area survey by dropsondes and AXBTs	Fine resolution 3-D variations in the air and ocean	110×80	As high as possible	90	30/21 (5/5)	
DCE	dropsonde study of convective elements	Spatial and vertical variations near convective element	110×70	10,000'	70	25/14 (3/5)	

DLG	Large-scale SST/ moisture gradient	Large-scale survey t by dropsondes and AXBTs	Vary	24,000' (MSL) (Altitude adjustment for AXBT drops)	510	48/48 (7/7)	

AXBT deployment modules:

AXBT deployments provide a large area survey of the water column in the measurement area and provide oceanic structural data for predictive ocean models. With DYNAMO project, the NOAA P-3 can only deploy AXBT through the 18 external tubes at altitude above 10,000'. We are thus limited to 18 AXBT deployment from above 10,000' for each flight. However, we can deploy AXBT/AXCTD through internal chutes whenever altitude allows, especially during some of the dropsonde modules (DAS, DCE, and DCS). DAS-O pattern, with AXBTs/AXCTDs only, can be made in conjunction with the FFM pattern at low levels (e.g., 4000') or radar patterns (RCE at 5000') for refined sampling of the upper ocean. The combination with other patterns will be referred to as FFM/DAS-O or RCE/DAS-O.

4.3 Preliminary flight plans for typical missions

A total of 105 hours of P-3 flight time will be available for science missions of DYNAMO, which can be used in ~11 research flights each with ~9 hour duration. In this section, flight plans for certain scenarios are given to show how the modules are put together to address a specific mission objectives. Figure 6.9 depicts the DYNAMO measurement domain. Of particular interests to aircraft operation is the flight time needed for the P-3 to transit to other DYNAMO sites denoted in green in Fig. 6.9.

A) DEEP CONVECTION AND FEEDBACK WITH BOUNDARY LAYER PROCESSES

The objective of this mission is to obtain measurements in regions with active deep convective systems. Spatially coherent deployment of dropsondes and AXBTs, as well as Doppler radar observations, are crucial for this mission objective to provide fine resolution spatial variation in and around the convective system. Aircraft in situ measurements will sample the vertical cross-section across some convective element to supplement the dropsonde measurements with cloud microphysics and in situ sampled temperature and relative humidity for validation of the dropsonde measurements through precipitating clouds. Near-surface flux mapping are done ahead and behind the convective system to examine the interplay between boundary layer processes and the convective system.

Similar flights should be made in different convective cloud systems in various stages of the MJO.

Table 6.7. Tentative flight plan for sampling spatial variation near deep convective systems.

Mission type:		**Mission location:**		**Total flight time (hr)**	**# drpsnds**	**# AXBTs**	**# AXBTs (Ext)**	**# AXCTDs**
Spatial variation near convective system		**Near DGAR**		**9.3**	**64**	**16**	**17**	**11**
Item	Module	Time (min)	Altitude (ft)	Objective				
1	T/O, Ferry	20	AHAP*	Ferry and dropsonde at the highest aircraft altitude	1	1		
2	DCS	120	AHAP	Survey of cloud fields, +DRI: 5 min+ at 'purl' locations	30		17	
3	RCE	60	5000'	Convective cloud structure	7			
	DCE	70	10,000'	find mapping of spatial variability in and around convective systems, DRI:3 min	25	7		7
4	Descent sounding	10	10,000' to ALAP**	Vertical profile and reposition to at least 75 km ahead of the system at ALAP				
5	FFM	60	ALAP	Flux mapping, SST, surface wave				
6	FVS cross-wind	60	ALAP to cloud layer	Flux profile, AXBT if above 4000'		2		2
7	Radar scan+flux	20	2,000'	Cross the convective system at highest FVS level, AXBT		2		2
8	FFM	60	ALAP	Flux mapping, SST, surface wave				
9	FVS cross-wind	60	ALAP to cloud layer	Flux profile, AXBT if above 4000'		4		
10	Ferry home	20	AHAP		1			

**AHAP: as high as possible; **ALAP: as low as possible; +DRI: dropsonde release interval (min)*

b) Unorganized convection in suppressed phase of MJO

This flight plan aims to understand the dynamic and thermodynamic structure of an isolated convective system in both the suppressed and active phase of the MJO. The system may have a horizontal scale of 20-30 km (class-1 clouds). In addition to identify the thermodynamic characteristics within the cloud layer, we will also make measurements in the boundary layer and near the surface, as well as in the upper ocean. The role of boundary layer processes on cloud development will be examined using measurements from this type of flights.

As the cloud population has a broad spectrum in their size and depth and in different stages of the MJO, similar flights will take place during the extensive observation period.

Table 6.8. Tentative flight plan for sampling near single convective system in the suppressed phase.

Mission type:		**Mission location:**		**Total flight time (hr)**	**# of drpsnds**	**# AXBTs (Int)**	**# AXBTs (Ext)**	**# AXCTDs**
Single convective system in supressed phases of MJO		**Near DGAR**		**8.0**	**30**	**11**	**10**	**6**
Item	Module	Time (min)	Altitude (ft)	Objective				
1	T/O, Ferry	20	AHAP	away from island effects, identify a convective events (CE), BT+CTD	1	1		1
2	descent	10	AHAP to cloud layer	descent to start FVS legs from top level to upwind of CE				
3	crosswind FVS	70	ALAP to cloud layer	vertical flux profiles upwind of CE, AXBT at top FVS level, BT+CTD		4		2
4	FCS	70	ALAP to 10,000'	multiple soundings through CE, dropsonde for co-located soundings, cross through CE	3	3		
5	DAS	70	10,000'	mapping of variability of temp, RH, wind, and vertical velocity across the CE, radar scan of convection, DRI: 3 min	25		10	
6	crosswind and along wind FVS	140	ALAP to cloud layer	vertical flux profiles downwind of CE		2		2
7	FFM	60	ALAP	over a large area centered at the CE				
8	ascent to AHAP, dropsonde at top	20	ALAP to AHAP	ascent through cloud to ferry level, co-located dropsonde for dropsonde data evaluation, BT+CTD	1	1		1
9	ferry back	20	AHAP					

* Simultaneous AXBT and CTD drops are planned for sensor evaluation purpose.
**Dropsonde to be deployed in cloud close to aircraft ascent/descent for dropsonde evaluation

c) Air-sea interaction in shallow cumulus topped boundary layers

This scenario most likely happens in the suppressed phase of MJO with a field of cumulus clouds. Coupled air-sea interaction processes will be studied, especially to examine the interplay between turbulence mixing in the boundary layer and in the cloud layer and characterize the ocean mixed layer. To make effective use of the sondes, spatial variation of the boundary layer will made in the two long legs of a figure 6.4 pattern in along- and cross-wind directions. However, frequent dropsonde release is used (3 min DRI).

Table 6.9. Tentative flight plan for air-sea interaction missions.

Mission type:		**Mission location:**		**Total flight time (hr)**	**# drpsnds**	**# AXBTs (Int)**	**# AXBTs (Ext)**	**# AXCTDs**
Air-sea interaction in shallow Cu regime		**Near DGAR**		**6.8**	**16**	**7**	**8**	**10**
Item	Module	Time (min)	Altitude (ft)	Objective				
1	T/O, Ferry	10	AHAP	Ferry and away from island effects, dropsonde before descent to ALAP	1	1		
2	Dropsonde in fig 6.4, along- and cross-wind (DSS)	50	10,000'	Dropsonde crosswind and along wind (20 min each, 14 min on the short arm), DRI: 3 min	14		8	
3	FCS	70	ALAP-200' above cloud top	Vertical profiles along a crosswind cross-section, AXBT		2		5
4	FVS cross-wind & along-wind	140	ALAP to cloud layer	Flux profile, AXBT if above 4000'		2		5
5	FFM	60	ALAP	Flux mapping, sst, surface wave				
6	FFM	60	100' below cloud base	Flux mapping, sst, surface wave				
7	Ascent, Ferry home	20	ALAP to AHAP	dropsonde at top	1	2		

d) Large-scale SST/Moisture gradient and convective variability

This flight plan is designed to address several issues related to large-scale variability in the DYNAMO region. The extensive dropsonde/AXBT deployment is the essential part of the this measurements. Soundings are made to aid the DYNAMO sounding arrays in examining the large-scale flow divergence and convergence. Meanwhile, we will be able to examine the spatial variability of the moisture field, the convective activity, as well as the boundary layer structure in response to large scale SST variations frequently seen from satellite observations. The DLG module will be used in the flight plan, we also include a flux mapping module near the NE ship for coordinated post-experiment analyses with other DYNAMO facilities.

A variation of this flight plan is to move the DLG triangle towards northwest upwind of the DYNAMO domain, if strong SST variation is identified upstream of DYNAMO. The AXBT data will be closely monitored on the flight to identify SST gradient in the region. All dropsonde data from this flight can be incorporated into extensive case analyses for regional moisture convergence/divergence in collaboration with the sounding group. This flight mission is included in a separate table below as well.

Table 6.10. Tentative flight plan for sampling large scale variations between Diego Garcia, Gan Island, and NE ship.

Mission type:		**Mission location:**		**Total flight time (hr)**	**# drpsnds**	**# AXBTs (int)**	**# AXBTs (Ext)**	**# AXCTDs**
Large-scale SST/Moisture gradient and convective variability		**DYNAMO domain**		**7.6**	**48**	**13**	**21**	**8**
Item	Module	Time (min)	Altitude (ft)	Objective				
1	T/O, dropsonde to Gan	100	AHAP	Ferry and dropsonde at the highest aircraft altitude towards Gan, DRI: 7 min, ARI: 15 min	15		7	
3	dropsonde from Gan to NE ship	90	AHAP	dropsonde and AXBT towards NE ship, DRI: 7 min, ARI: 15	13		6	
4	FFM	60	ALAP	Flux mapping, sst, surface wave				
5	DAS-O	60	4000'	Flux mapping, sst, surface wave, DRI: 5 min		6		8
6	Ascent and ferry home*	144	AHAP	dropsonde & AXBTs, DRI: 7 min	20	7	8	

** Drop down below 10,000' for internal AXBT launches every 20 minutes.*

Table 6.11. Tentative flight plan for sampling large-scale variations near the DYNAMO domain.

Mission type:		Mission location:		Total flight time (hr)	# drpsnds	# AXBTs (Int)	# AXBTs (Ext)	# AXCTDs
deep sounding upwind of DYNAMO region		**north-west of DGAR**		**7.6**	**62**	**18**	**21**	**9**
Item	Module	Time (min)	Altitude (ft)	Objective				
1	T/O, dropsonde to NW of DGAR	60	AHAP	Ferry and dropsonde at the highest aircraft altitude to NW, DRI: 5 min	12		8	
2	Dropsonde to East	60	AHAP	dropsonde from west to east, DRI: 5 min	12		8	
3	DAS	90	10,000'	Area survey for mesoscale variability, DRI: 3 min	30	18		
4	FCS within the DAS domain	70	ALAP to 3 km	in situ vertical profiles				
5	FFM	60	ALAP	Flux mapping, sst, surface wave				
6	ascent and FFM	60	100' below cloud base	Flux mapping at 2nd level within BL, AXBT if above 4000'				9
7	Ascent	15	to AHAP	ascent, ready to leave at highest altitude				
8	dropsonde to DGAR	40	AHAP	Ferry and dropsonde towards DGAR, DRI: 5 min	8		5	

e) Ship-aircraft coordination in suppressed conditions

The flight includes a long transit flight through the middle of the DYNAMO domain with extensive dropsondes and AXBT deployments along the path. The on-station region will be west of the NE ship where patterns focusing on air-sea interaction and its interaction with the cloud fields.

Table 6.12. Tentative flight plan for mission focused on WP-3D and NE ship coordinated measurements.

Mission type:	Mission location:	Total flight time (hr)	# drpsnds	# AXBTs	# AXBTs (Ext)	# AXCTDs
AC-ship coordination	**West of NE ship**	**8.7**	**52**	**0**	**21**	**18**

Item	Module	Time (min)	Altitude (ft)	Objective				
1	T/O, Ferry and dropsonde	120	AHAP	Ferry and dropsonde towards west of NE ship, DRI: 5 min, ARI: 12 min	24		10	
2	FCS/AXBT	70	ALAP - cloud top	in situ cross-section, AXCTD whenever possible				7
3	FFM	70	ALAP	surface flux, waves, SST				
4	crosswind and along wind FVS	120	all FVS levels except ALAP	vertical flux profiles, AXCTD whenever possible				11
5	Ferry back+ dropsondes	140	AHAP	vertical profiles across DYNAMO domain, DRI: 5 min; ARI: 12 min	28		11	

Two flights are planned for this mission, one with deep convective systems near the ship, one in the suppressed phased of MJO with only small cumulus field around.

f) NOAA WP-3D and French Falcon coordinated mission

We have planned a two aircraft coordinated mission with the P-3 flying well below the French Falcon that plans to operate at 9840 feet (3,000 m) or above. To be within the range of the Falcon, the area of measurement will be about 100-200 km south of Gan Island. The P-3 will fly at its highest altitude in transit to the location with dropsonde and AXBT deployment along the transit path. As the P-3 gets closer to the measurement area, P-3 will transit near the surface, sampling surface flux, SST, and wave variability towards the designated area, where P-3 will sample the cloud and boundary layer below the melting level. Dropsonde measurements from this flight can also be used for large-scale divergence calculation in collaboration with the sounding group.

On-site initial analyses will show the value of this coordinated flight, which help us to determine on the need for more similar flights in different cloud conditions or with refined flight patterns.

Table 6.13. Tentative flight plan for mission focused on WP-3D and French Falcon coordinated measurements.

Mission type:	**Mission location:**	**Total flight time (hr)**	**# drpsnds**	**# AXBTs**	**# AXBTs (Ext)**	**# AXCTDs**
P-3 & French Falcon coordination	**100 km South of Gan**	**8.7**	**30**	**11**	**21**	**19**

Item	Module	Time (min)	Altitude (ft)	Objective				
1	T/O, Ferry	60	AHAP	Ferry and dropsonde at the highest aircraft altitude towards Gan, descend to ALAP after last dropsonde ~300 km south of Gan	12		7	
2	Level leg	30	ALAP	surface flux/low-level transit to coordinated flight location				
3	FCS	70	ALAP to 2.5 km	in situ aircraft crossection survey of boundary layer and cloud conditions+ AXBT at the top of each sounding		2		1
4	FFM	60	ALAP	surface flux mapping, wave and SST				
6	crosswind and alongwind FVS	120	ALAP to cloud layer	vertical flux profiles in crosswind direction, AXBT at highest level		4		6
7	DAS-O/RCE	90	5000'	radar cloud element and AXBT area survey, fresh water lens		5		12
8	ascent, ferry, and dropsondes	90	AHAP	Ferry and dropsonde at the highest aircraft altitude towards DGAR, DRI: 5 min; ARI: 6.5 min	18		14	

5. NOAA WP-3D Science Mission Planning and Aircraft Operations

5. 1 Decision-making protocol

The aircraft PIs will the following principles of decision-making protocol for DYNAMO aircraft operation. Decisions on flight plans will be based on:

1) Meteorological/oceanic conditions from all available resources including model forecasts and satellite observations, etc.
2) Science objectives yet to be met, priority will be given to provide a full coverage of various of MJO initiation phases
3) Conditions of aircraft instrumentations for specific science objectives
4) Readiness of other DYNAMO observational components for coordinated missions

5.2 Timing of decisions

The proper execution of aircraft missions with specific flight modules requires an established protocol for decision-making. A daily planning meeting will be conducted to make the decision on the next day's flight and details of the flight if a flight day is determined, and an outlook for possible flights in the next few days. Such decisions should be made by the science team at the end of the daily planning meeting in the form of Plan of the Day (POD). The aircraft PIs plus the NOAA/AOC project manager comprise the aircraft management team responsible for decision-making. A nominal daily schedule is shown in Fig. 6.10.

5.3 Decisions

The most important daily decision is whether to declare the following day an "up" day or "down" day. If an "up" day is declared then secondary decisions about take-off time, likely area of operations, primary and secondary flight modules to be flown, and aircraft scientific seat allocation will need to be made to allow for airspace reservations to be made by the pilots, as well as planning for expendables (dropsondes, AXBTs, AXCTDs) that will need to be loaded on the aircraft.

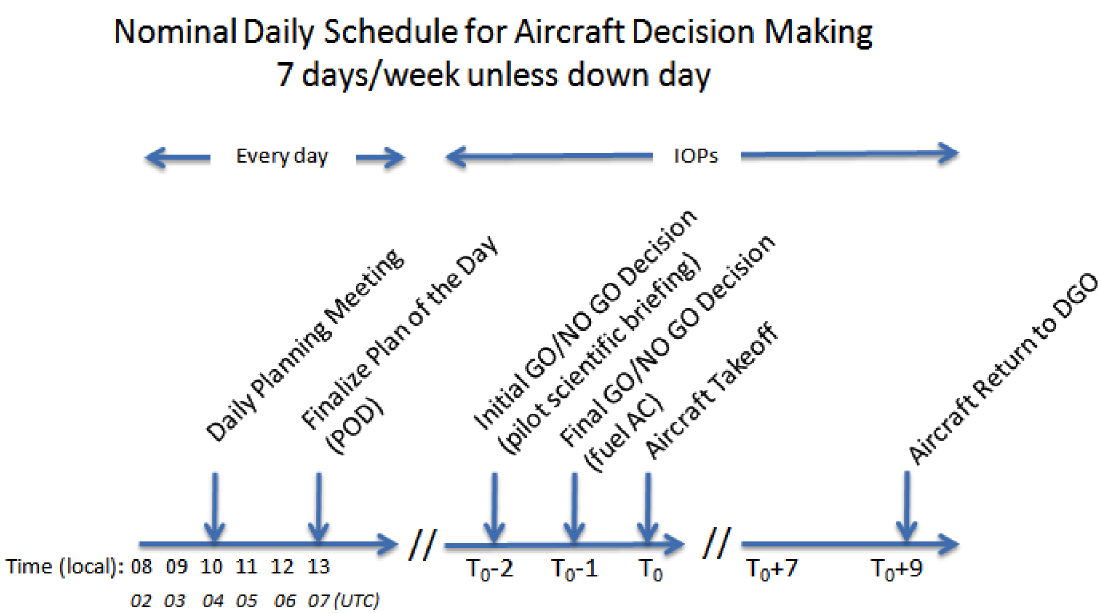


Figure 6.10. Nominal time plot of daily activities.

5.6 Operational Rules

There are several well-established rules governing aircraft operations that NOAA has developed to insure safe flight operations. The most salient of which are:

a) There are a maximum of 6 consecutive "up" days before a mandatory "down" day has to be declared. An "up" day is defined as an alert to conduct a scientific mission. Note that an "up" day is defined whether or not a particular mission is actually conducted, i.e., a flight cancellation still counts as an "up" day.

b) After approximately 50 flight hours a mandatory aircraft inspection must be performed. This inspection shall be designated a "no fly" day, but counts as an "up" day. There might be some latitude in performing the 50 hour inspection, i.e., it could conceivably be conducted a few flight hours early or late.
c) A maximum crew duty day of 16 hours. A crew duty day is defined as when an aircrew member reports to their designated place to begin mission preflight and ends when he/she departs the work location after completion of the mission. Nominally, the pre-flight period is ~3 hours, and the post flight period, following block-in, is ~1 hour. These constraints imply that the maximum possible delay in take-off for a maximum duration mission (~9 hours) would be 3 hours. Delays longer than 3 hours would shorten the mission.
d) A minimum crew rest period of 12 hours from the time the last person leaves the airplane to the time the first person reports for next mission pre-flight. A crew member cannot report for a subsequent preflight until the crew rest period is completed. This constraint implies a 16 hour period for consecutive flights between previous mission landing and next mission takeoff.
e) Takeoff times are set at least 12 hours in advance if the anticipated flight operations (i.e., alerts) are consistently in the same diurnal cycle, i.e., daytime or nighttime flights. If the takeoff alert is being shifted from predominately "daytime" to "nighttime" cycle or visa versa, then at least 24 hours notice is required.
f) Following 3 consecutive maximum endurance missions the NOAA AOC facility manager for the NOAA P-3 may authorize a 24-hour down period.

5.7 Aircraft scientific duties

<u>P-3 Mission Scientist</u>

The mission scientist will be a designated individual who is responsible for the overall scientific execution of a particular flight and acts as the primary point of contact for the AOC Flight Director. This person will communicate with the operational flight crew to execute the appropriate flight patterns and to receive real-time updates on instrument status from the instrument PIs to insure proper data gathering. This individual will keep a detailed "event log" of significant aircraft activities (e.g., starting/ending times of flight leg segments, altitude changes, significant weather etc.), as well as keep the science crew informed of mission progress. He/she will collect all relevant data logging and reporting forms from each of the instrument specialists (e.g., radar, dropsonde, cloud physics, and observers), and provide a written report about the mission accomplishments, problems, and equipment status to the NCAR data catalog following completion of the mission. He/she conducts pre-flight and post-flight briefings/debriefings of the aircraft's crew.

Boundary Layer Scientist

The boundary layer scientist is responsible for monitoring the execution of boundary layer flight modules. He/she maintains a detailed written log of significant meteorological events, interesting data, problems encountered with system performance, and instrument changes to aid in subsequent scientific analyses. This person also takes the lead in examining flight level data on the computer workstations at the operations center following the flights to prepare products for debriefings and to ensure proper equipment operation and recording.

Doppler Radar Scientist

This scientist monitors the performance of the radar systems (lower fuselage and tail Doppler radars), ensuring optimal operation for the selected mission. He/she works with the mission scientist in the design of the optimal flight patterns and scanning strategies for the radars, and operates the radar control computers to change operating modes (e.g., scanning strategies). This person also interprets the radar displays to ensure proper operation of the radars and keeps a detailed written log of significant meteorological events, interesting data, problems encountered with system performance, and radar configuration changes to aid in subsequent scientific analyses. This person also takes the lead in examining data on the computer workstations at the operations center following the flights to prepare products for debriefings and to ensure proper equipment operation and recording. He/she prepares sample imagery for transmission via the internet satellite link to the operations center when requested. It is likely the radar scientist and boundary layer scientist would take turns as mission scientist during a given mission depending on the flight module being flown.

Dropsonde Scientist

The Dropsonde scientist is responsible for monitoring dropsonde/AXBT/AXCTD data during the flight. This person monitors the data for quality assurance. He/she keeps a detailed log of the drop points, significant wind events, sensor or data recording problems, and provides a written summary to the mission scientist following the flight mission.

Cloud Physics Scientist

The cloud physics scientist is responsible for the scientific data collection from the cloud physics sensors. He/she keeps a detailed log of the cloud penetration events, significant weather, and sensor or data recording problems, and provides a written summary to the mission scientist following the flight mission. This person also monitors and interprets the particle image displays in real time to ensure system operation and to note interesting weather events.

5.8 Science Staff for Each Aircraft Mission

There are eight seats on board of the WP-3D aircraft for science staff. Seat assignments for all science and relevant AOC crew staff are shown in Figure 6.11.

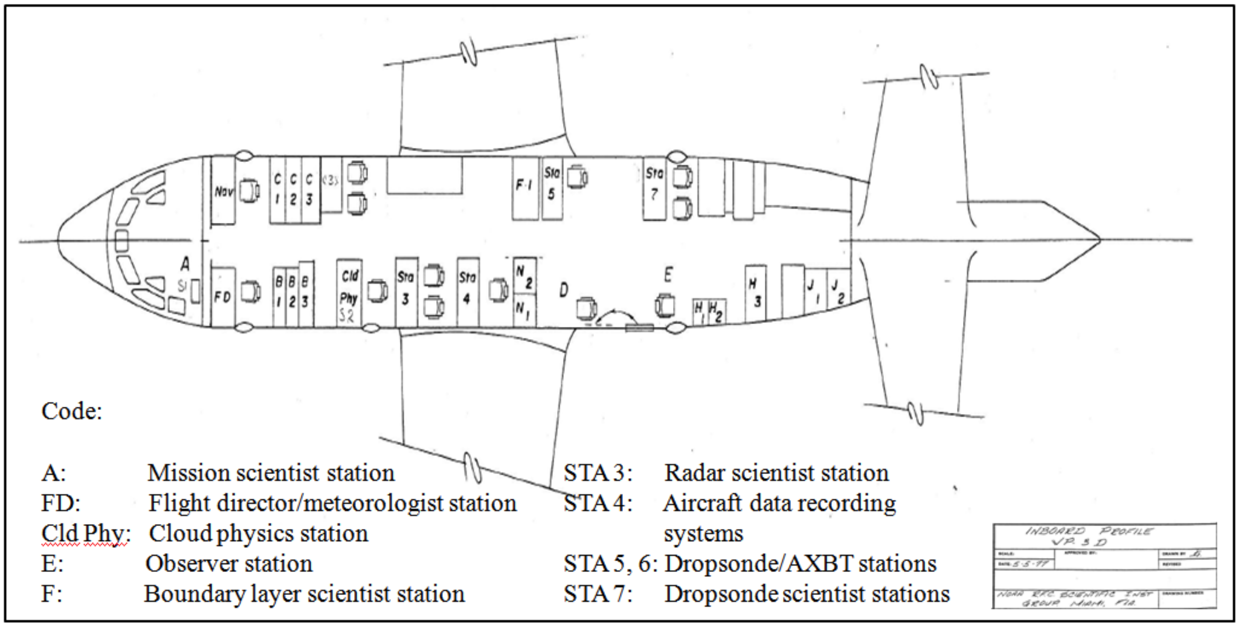


Figure 6.11. The WP-3D aircraft interior layout and seat assignments.

5.7 Aircraft Communications

Due to the rapid convective evolution and limited aircraft horizontal radar coverage, real-time communication with aircraft ground support and other DYNAMO groups (the Gan Island super radar site and ships) will be valuable to in-flight decision making. A satellite based internet link will be critical for this purpose to enable transmission and reception of emails, limited ftp of GIF imagery, and periodic transmission of aircraft position and radar information.

5.8 Post-Flight Procedures

A scientific debriefing will be held immediately after landing. The topics of debriefings are:

- operations of all research systems.
- aircraft status and instrument problems.

- any problems in coordination that hampered the mission (e.g., within the plane, between the aircraft and ships, or between the aircraft and the Gan Ops Center).
- interesting scientific aspects of the flights.
- suggestions for improvements to future flights

This information will provide input to the next planning meeting and status reports posted to the DYNAMO web catalog.

5.9 Data Processing and Product Generation

Within a few days of the completion of an aircraft mission, a concerted effort will be made to produce certain standard products such as flight tracks for various modules flown, time series of meteorological variables during interesting parts of the flights, radar reflectivity time composites, etc., to ascertain the data quality and coverage. These "quick-look" plots will be posted to the web catalog. The dropsonde scientist will provide skew-T plots of selected dropsonde/AXBT/AXCTD data to the data catalog. These preliminary results will be used for initial evaluation of aircraft mission accomplishments.

6. Coordination With Other Facilities of DYNAMO

One of the objectives of aircraft mission is to extend point measurements of DYNAMO on island and ships to a broader area within the DYNAMO region and provide in situ measurements needed for calibration and extended analyses for measurements from other facilities/platforms. Possible aircraft flights in support of other DYNAMO facilities include the suite of instruments on ships and other aircraft or islands. Preliminary flight plans are described in Section 6.3.

7. P-3 participants and their respective roles

Table 6.14. WP-3D participants(NOAA Aircraft Operational Center personnel are not included in this table).

Last Name	First Name	Affiliation	Role	Sponsoring Agency
Wang	Qing	Naval Postgraduate School	Lead PI, air-sea and boundary layer	ONR, NSF
Khelif	Djamal	UC Irvine	PI, air-sea and boundary layer	ONR
Chen	Shuyi	University of Miami	PI, convection	ONR, NOAA, NSF
Jorgensen	David	NOAA NSSL	PI, convection	NOAA
Bucholtz	Anthony	Naval Research Lab	PI, radiation	ONR
Chuang	Patrick	UC Santa Cruz	PI, cloud physics	ONR
Zappa	Christopher	University of Columbia	PI, air-sea	ONR

Meitin	Jose	NCAR EOL	Project support	NSF
Moore	James	NCAR EOL	Project support	NSF
Hornick	Heather	Naval Postgraduate School	Ph. D student, dropsonde/AXBT	ONR
Cherrett	R. Corey	Naval Postgraduate School	Ph. D student, aircraft in situ data	ONR
Trampp	David	Naval Postgraduate School	M.S. student, AXBT	ONR
Ruiz-Plancarte	Jesus	UC Irvine	Science staff, air-sea and boundary layer	ONR
Lee	Chia-Ying	University of Miami	Ph. D student, dropsonde/convection	ONR, NOAA, NSF
Judt	Falko	University of Miami	Ph. D student, convection	ONR, NOAA, NSF
Witte	Michael	UC Santa Cruz	Ph. D student, cloud physics	ONR
Brown	Scott	University of Columbia	Ph. D student, air-sea	ONR
Le Bel	Deborah	University of Columbia	Ph. D student, air-sea	ONR
Ziervogel	Charles	Office of Naval Research	Project support	ONR

Chapter 7 Other Observations

7.1 ARM AMF2 (other than radars)
The ARM second Mobile facility (AMF2) consists of a suite of instrumentation to study clouds and their radiative interactions in the atmosphere, as well as the surface radiative energy budget. Additional measurements needed for radiative transfer modeling, such as profiles of temperature and moisture (sondes), aerosol optical depth, etc. are also collected. Some other measurements of interest, such as surface latenet and sensible heat exchange, may also be included depending on the nature of the given deployment. More information about the AMF2 is available at http://www.arm.gov/sites/amf/amf2

The AMF2 will be deployed at two sites on the Addu Atoll (Fig. 2.1) during the AMIE-Gan/DYNAMO campaign. The majority of the facility will be deployed at the Gan airport adjacent to the Gan MMS offices. The scanning X/Ka band radar and the surface flux system will be deployed at the "wharf site" about 600 m north of the proposed SPolKa site. The instrument and van layout plans at the airport site are shown in Figs. 7.1 and 7.2.

The AMF2 will be collecting data beginning Oct.1, 2011 through March 31, 1012. Installation is scheduled for the month of September 2011, with packup scheduled for the month of April, 2012. Preliminary work for infrastructure (power, comms, ground preparation, etc.) is scheduled for August 2011 using local contractors. The AMF2 instrumentation includes both active and passive instrumentation, plus housing for computational resources. The Gan deployment will include about 5 seatainers located at the airport site, and an additional seatainer at the wharf X/Ka radar site. The instrumentation will include:

(1) Aerosols
(2) Cimel Sunphotometer (CSPHOT)
(3) Multi-Frequency Rotating Shadowband Radiometer (MFRSR)
(4) Atmospheric Profiling
(5) Balloon-borne Sounding System (SONDE)
(6) Microwave Radiometer, 3-channel (MWR3C)
(7) Micropulse Lidar (MPL)
(8) Microwave Radiometer (MWR)
(9) High Spectral Resolution Lidar (HSRL)
(10) Total Sky Imager (TSI)
(11) Vaisala Ceilometer (VCEIL)
(12) MHz Radar Wind Profiler at high frequency (RWP)
(13) 1290 Ka-Band Scanning ARM Cloud Radar (KASACR)
(14) X-Band Scanning ARM Cloud Radar (XSACR)
(15) Ka ARM Zenith Radar (KAZR) ñ coming soon
(16) Radiometers
(17) Atmospheric Sounder by Infrared Spectral Technology (ASSIST)
(18) Upwelling Radiation (GNDRAD)

(19) Downwelling Radiation (SKYRAD)
(20) Portable Radiation Measurement Package (PRP2)
(21) Surface Meteorology
(22) Meteorological Instrumentation at AMF (MET)
(23) Eddy Correlation System (ECOR)
(24) Surface Energy Balance System (SEBS)
(25) 2-Dimensional Video Disdrometer
(26) Rain Gauges

More information about the AMF2 instrumentation is available at http://www.arm.gov/sites/amf/amf2

The AMF2 and ARM Program will provide "quicklook" products for many of the measurements. These quicklooks are usually produced hourly and can be made available.

The nature of the AMF2 is to make continuous measurements of all instruments for the duration of the campaign. The exception is sonde launches, which are planned to occur on a 3-hourly basis for the 6 months of the EOP. Thus there are no real coordination requirements for measurements per se. Coordination for the deployment in areas such as facilities preparation and housing are recommended. Planned schedule for AMIE-Gan includes:

August 1, 2011: Commencement of site works and infrastructure preparation.
August 8, 2011: On-site supervision by ATSC personnel.
August 15, 2011: Arrival of seatainers and beginning of unpacking.
August 29 – October 1, 2011: Installation and commissioning.
September 26 - 30, 2011: Training of observations staff and final instrument verification.

The Airport and Wharf site will be installed concurrently and both sites are expected to follow the timeline outlined above.

Estimated personnel include one technician August 8 - 15. Number of personnel will increase after that to a total of 6-7 at the peak of installation activities in the month of September. Once the campaign oficially starts, there will be 2 AMF technicians manning the sites on a 6 week rotation schedule, with a few days of overlap wih the next 2-person team at handoff. Personnel numbers will again increase to about 6-7 for pack up in the month of April, 1012.

Chuck Long is the PI for AMIE-Gan, and is responsible for the scientific aspects of the campaign including liason with the larger scientific community and advocacy for using the campaign measurements to address the science issues related to the experiment.

Brad Orr is the AMF2 Site Manager, and Michael Ritsche is the AMF2 Technical Operations Manager, an both have the lead in responsibility for the deployment and operations of the AMF2 and the included instrumentation. The ARM Program operates via various "Instrument Mentors" who have responsibility and expertise for given instruments. The AMF2 Operations group is responsible for coordination with the appropriate Instrument Mentors should any instrument issues arise.

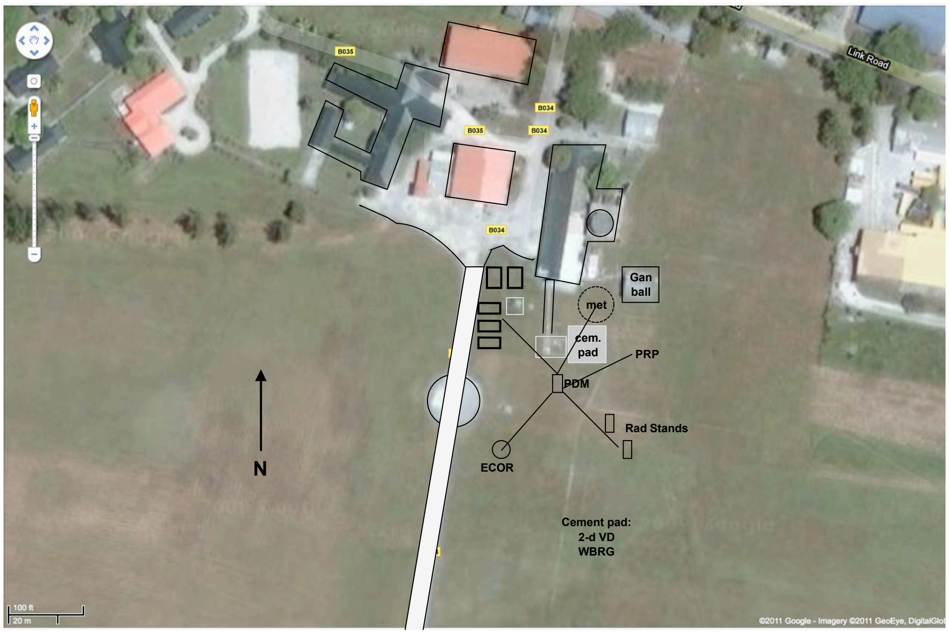


Fig. 7.1 Instrument layout at the airport site.

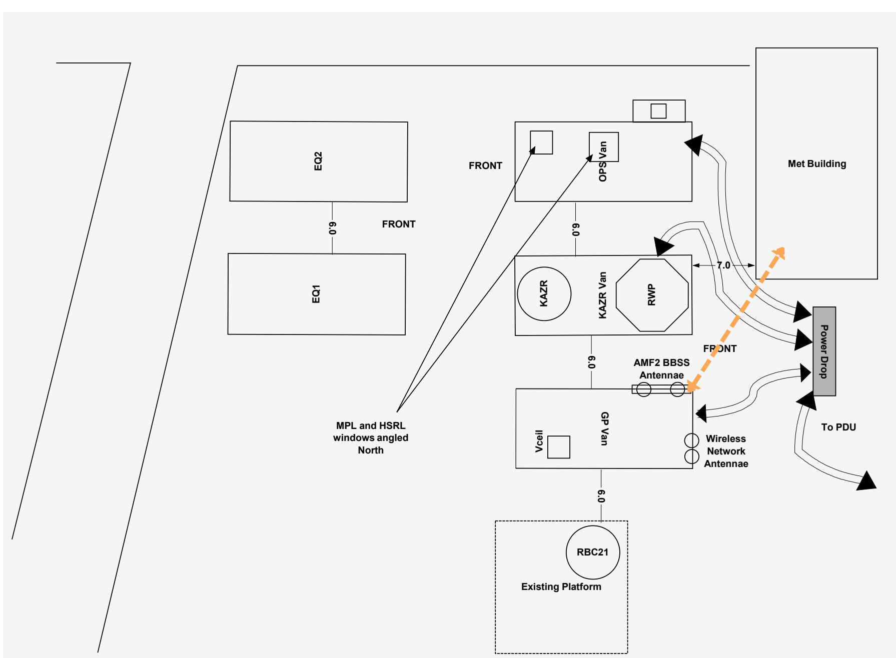


Fig. 7.2 Van layout plan at the airport site.

7.2 Diego Garcia ISS

NCAR / EOL will be operating an ISS (Integrated Sounding System) on the island of Diego Garcia, British Indian Ocean Territories (BIOT). Diego Garcia is a joint U.S./U.K. military base and access to the island is restricted. All personnel visiting the island have to be cleared by U.S. and U.K. authorities. Transfer of personnel and equipment to Diego Garcia will be via U.S. military transport, requiring an extensive clearance procedure. Logistical support is being provided by the Navy, Air Force, and military contractors. Accommodation will be in the Chagos Inn (part of the Navy Gateway Inns & Suites chain) in the village, approx 6 miles north of the site. Services such as dining mess, fast food, post office, banks, a general store, and various others are available nearby.

The ISS will be sited near the Diego Garcia airport (Fig. 7.3). The ISS will consist of a radiosonde balloon sounding system, boundary layer wind profiler radar, ceilometer, GPS Integrated Water Vapor receiver, and surface meteorological instruments such as a 10-meter tower, tipping bucket rain gauge, and solar radiation sensors (Table 7.1). Figure 7.4 outlines the instrument layout. The ISS will be shipped in a container that also serves as lab/office space. A second container will contain Helium to support sounding operations. Power, network and phone service will be provided by the military and local contractors.

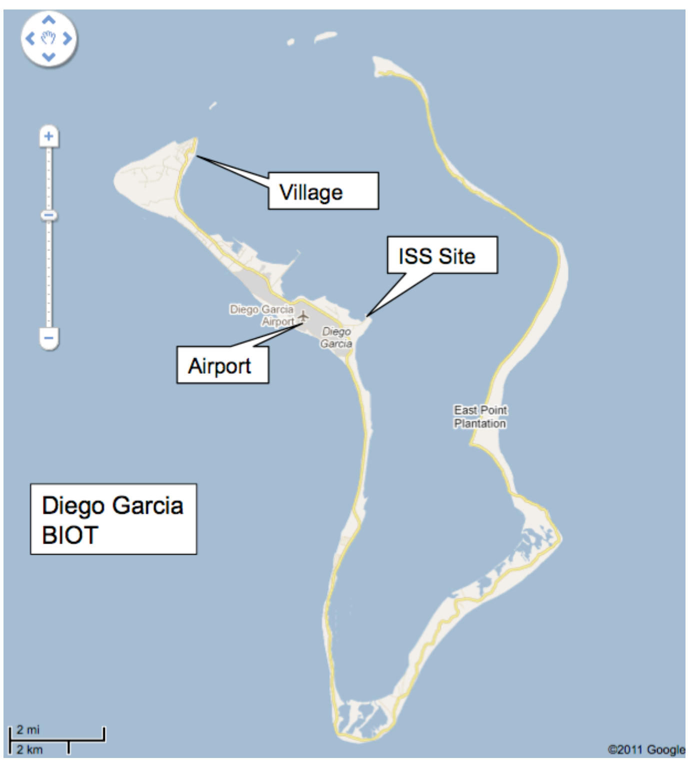


Figure 7.3 Map of Diego Garcia and location of ISS site

Soundings will be carried out every 3 hours during the SOP (Oct 1 to Nov 27), and every 6 hours for the remainder of the deployment (Nov 28 to Jan 15). Approximately 660 soundings will be launched. The wind profiler and other instruments will operate continuously. The wind profiler generates wind and virtual temperature profiles every 30 minutes, and Doppler moment data every 30 seconds. Quick look plots from most instruments will be posted on the web in near real time, however the limited network bandwidth from the island may require some parsing of the data. Significant level sounding data will be submitted to the GTS.

Table 7.1 ISS instrumentation

Instrument	Manufacturer / Model	Purpose / Measurement
Soundings	Vaisala RS92 radiosondes	Sounding of temperature, humidity, pressure, and winds (approx to tropopause)
Boundary Layer Wind Profiler Radar with RASS	Vaisala Radian LAP3000 (915 MHz, DBS)	Profiles of wind (every 30 minutes, to 2 or 3 km altitude) and virtual temperature (to 1 km); precip Doppler spectra (30 second beams)
Anemometer	R.M. Young 5103 Wind Monitor	Wind speed and direction on 10 m tower
Temperature, Humidity	Vaisala 50Y humitter	2 m level temperature and relative humidity
Pressure	Vaisala PTA427	Barometric pressure (2m)
Solar radiometer	Eppley PSP pyranometer	Incoming solar radiation
IR radiometer	Eppley PIR pyrgeometer	Infrared radiation
Net radiometer	REBS Inc Fritschen net radiometer	Sum of incoming and outgoing radiation
Rain gauge	Texas Electronics TE525 tipping bucket	Rain rate
Weather sensor	Vaisala WXT 510	Winds, temperature, humidity, rain-rate, pressure
Ceilometer	Vaisala CL31	Cloud ceiling, vertical visibility
GPS Water vapor	Trimble 4700	Integrated water vapor
Data logger	Campbell Scientific CR10x	Records data from sensors

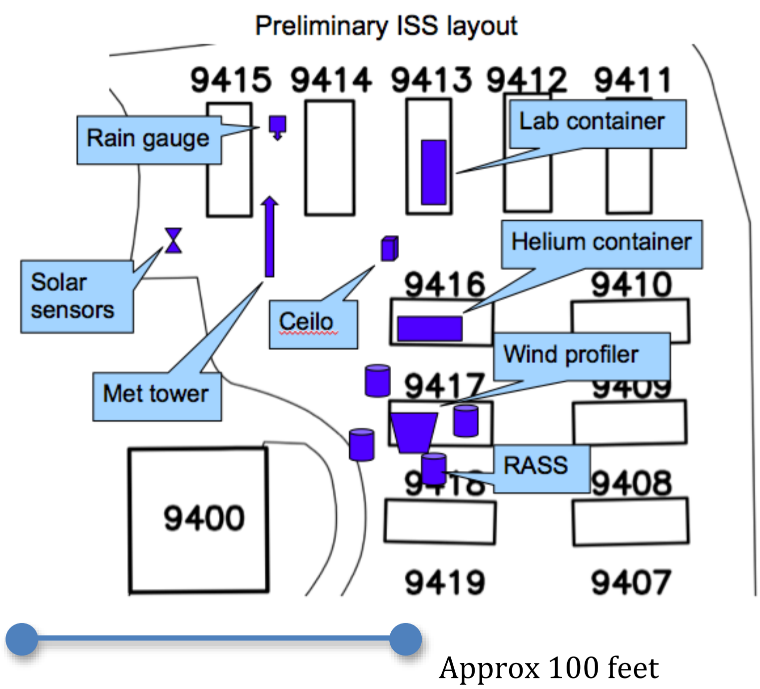
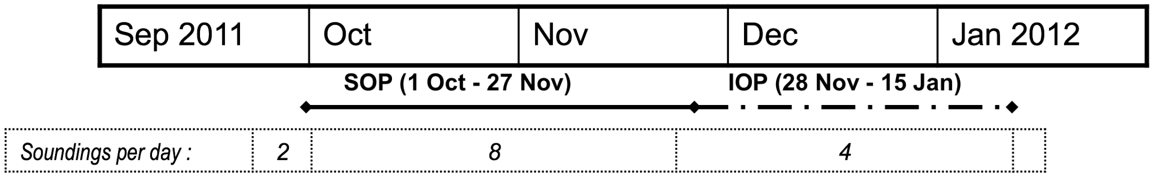


Figure 7.4 ISS instrument layout.

The preliminary staffing and sounding schedule is given in Table 7.2, although the actual staffing dates are likely to change. During operations there will generally be one NCAR staff member and 2 or 3 students. Four staff will set-up and tear-down the system, and we anticipate one or two maintenance visits.

The principle contact for the ISS is Bill Brown at NCAR/EOL (wbrown@ucar.edu).

Diego Garcia staff schedule chart



CREW	STAFF	Approx. Dates
Set-up	4 Staff	17 - 30 Sept 2011
Ops-1	1 staff + 3 students	29 Sep - 26 Oct 2011
Ops-2	1 staff + 3 students	25 Oct - 21 Nov 2011
Ops-3	1 staff + 2 students	20 Nov - 17 Dec 2011
Ops-4	1 staff + 2 students	16 Dec 2011 - 15 Jan 2012
TD (Tear-Down)	4 Staff	14 Jan - 22 Jan 2012
I (Inspection and Maintenance team)	2 Staff	TBD : Two 3-5 day visits during the Oct - Jan operations period

Figure 7.5 Schedule chart of ISS staff on Diego Garcia.

Chapter 8 Forecasting Support

1. Overview

Contained within this chapter is an outline of the planned operational forecast support for the DYNAMO field campaign. The support for the weekly briefing will be led by staff at NOAA's National Centers for Environmental Prediction (NCEP) Climate Prediction Center (CPC), but contributions and coordination will be conducted with our external partners. In some instances, these groups may provide graphics used by the forecast team.

Operational support will also include daily monitoring and model forecast products to be used by the DAYNAMO science team as needed and for additional guidance. These will include some hourly products, daily products and weekly products. It is important to note that the other operational centers will be responsible for assurance that monitoring and model forecast products from their center are properly placed in the EOL data catalog. CPC will be responsible for NCEP products only. Moreover, although the forecast operations team will make every effort to accommodate improvements and adjustments to the suite of products available to the DYNAMO science team, given time constraints and other operational tasks, we can't assure that all changes will be made. In these cases, the team will provide a timeline for if/when a change may be available.

This document outlines the format and content of the weekly briefing and gives a description of the monitoring and forecasting products available to the field PIs during the campaign. The strategy for coordination between the forecasting team components and the DYNAMO science team is also included. Finally, forecasting groups and team members are listed.

2. Weekly briefing content and format

The forecast team will provide an assessment late Tuesday afternoon/evening (U.S. Local Time) each week for recent conditions and the upcoming outlook for the region to the DYNAMO science team. The assessment will be given as a web briefing and comprise three sections,

(1) Graphics of key monitoring and forecast products that focus on the upcoming two week period, needed by the science team,

(2) Text discussion including the following parts,

(a) A review of recent conditions relevant to the campaign,
(b) Verification of recent MJO index dynamical model guidance,
(c) Verification of the most recent Global Tropics Hazards Assessment (GTH) forecast,

(d) Description of raw forecast model guidance and MJO index model forecasts

(e) Description and forecast rationale for latest GTH outlook and key forcings, and

(3) Subjective probabilities for at least moderate strength MJO activity (defined within document) during the next 1-3 weeks.

The briefing materials will be created over the Monday and Tuesday time period each week and be disseminated to DYNAMO science leadership via FTP to the EOL data catalog area for display. The briefing materials will be disseminated at 20:00 UTC on Tuesday (U.S. 15:00 EST).

3. Monitoring products available to field PIs

A number of monitoring products will be made available to the DYNAMO PIs daily. These products will be created at multiple operational centers and sent directly by these centers in realtime to the EOL data catalog for display. The current and planned products available are listed below for given operational centers.

NOAA – NCEP- Climate Prediction Center (CPC)

--Time-longitude sections of Outgoing Longwave Radiation (OLR) for the past 3 months for raw anomalies, ENSO filtered anomalies, and anomalies only associated with the MJO mode
--Spatial map of weekly averaged OLR anomalies for both raw and ENSO filtered anomalies
--Spatial map of daily OLR anomalies for both raw and ENSO filtered anomalies for the last five days
--Spatial map of pentad averaged 850-hPa total and anomalous wind vectors with shaded zonal wind magnitude for most recent two pentads
-- Spatial map of pentad averaged 200-hPa total and anomalous wind vectors with shaded zonal wind magnitude for most recent two pentads
--Spatial map of daily averaged 850-hPa anomalous wind vectors with shaded zonal wind magnitude for the last five days
--Spatial map of total and anomalous SST for the most recent week available
--Phase diagram of the WH MJO index for the last 60 days
--Vertical cross section of pentad averaged u-w vector wind and/or water vapor

These products will be updated daily (i.e., using a running time period).

National Climatic Data Center (NCDC) - Cooperative Institute for Satellite Studies (CICS)

--Time longitude diagrams of anomalous daily OLR with projections of key coherent tropical variability modes overlaid (ER-1, KW, etc.)

--Spatial maps of anomalous daily OLR associated with key coherent tropical variability modes (ER-1, KW, etc.)

ECMWF

--Analyses (daily): Time=0, 6, 12, 18, Resolution = 0.25x0.25, Global
--Plots and data for following parameters (model levels): U, V, W, T, Q, LNSP
--Plots and data for following parameters (pressure levels): Z, U, V, T, RH
--Plots and data for following parameters (surface): MSL, SSTK, SKT, STL1, SWVL1, 2T, 2D, 10U, 10V, SP, TCWV

4. Forecast products available to field PIs

A number of forecast products will be made available to the DYNAMO PIs daily. These products will be created at multiple operational centers and sent in realtime to the EOL data catalog for display. The current and planned products available are listed below for each operational center.

NOAA – NCEP- Climate Prediction Center

--Phase diagrams of WH MJO index forecasts from several models (See Appendix A)
--GTH outlook for Week-1 and Week-2 for anomalous precipitation (upper- and lower-tercile of the distribution) and tropical cyclone genesis potential

A. GFS high resolution operational model guidance for the following time periods:

--Hourly forecasts of 10 m winds overlaid with cumulative precipitation - up to 12 hours
--Hourly forecasts of total wind overlaid with RH at 1000, 850, 700, 500, 200 hPa up to 12 hours
From all four NCEP cycles (0, 6, 12, 18)

--Daily forecasts for Days 1 to 7 (all four cycles), Days 1-7, Days 8-14. Only the specifics for the weekly products are given below. Additional combination of variables and plots are available for the daily forecasts. For weekly,

(a) Total and anomalous OLR
(b) Total and anomalous vector wind overlaid with RH at 1000, 925, 850, 700, 500, 200 hPa
(c) Total and anomalous precipitation
(d) Total and anomalous precipitable water with overlaid 10 m total and anomalous wind
(e) Total and anomalous vertical wind shear (|850-hPa – 200-hPa|)

B. GFS ensemble operational model guidance for the following time periods:

Days 1 to 7, Days 1-7, Days 8-14 for:

C. CFSv2 operational model guidance for the following time periods:
Days 1-7, Days 8-14, Days 15-21, Days 22-28

Atmospheric products
(a) Total and anomalous 850-hPa vector wind
(b) Total and anomalous 200-hPa vector wind
(c) Total and anomalous precipitation

Ocean products
(a) Horizontal cross-section of salinity and w for depths of 5-300 meters
(b) Horizontal cross-section of temperature and current for depths of 5-300 meters
(c) Depth sections from 0-300 meters at 78E and 80E for salinity and zonal current, salinity and upwelling, and temperature and meridional current
(d) Depth sections from 0-300 meters at 8S and EQ for salinity and upwelling and temperature and meridional current

National Climatic Data Center (NCDC) - Cooperative Institute for Satellite Studies (CICS)

--Statistical forecasts of anomalous OLR from modes of subseasonal coherent tropical variability (ER-1, KW, etc.) in time longitude format for Weeks 1-3
--Statistical forecasts of anomalous OLR from modes of subseasonal coherent tropical variability (ER-1, KW, etc.) in spatial map format for Weeks 1-3

ECMWF

--High-resolution deterministic forecasts (daily at time=0), Resolution = 0.5x0.5, Domain: Global, Time Step = Hours 12 to 120 every 12 hours
--Plots and data for the following parameters (pressure levels): Z, U, V, T, RH
--Plots and data for the following parameters (surface): MSL, SSTK, SKT, STL1, SWVL1, 2T, 2D, 10U, 10V, SP, TCWV, TTR, TSR, SSR, STR, SSHF, SLHF, E, CP, LSP

--EPS forecasts (daily, 51 members at time=0), Resolution = 1.0x1.0, Domain: 30-150E, 30S-30N, Time step =Hours 24 to 360 every 24 hours
--Plots and data for the following parameters (pressure levels): Z, U, V, T, RH
--Plots and data for the following parameters (surface): MSL, 2T, 2D, 10U, 10V, TCWV, TTR, TP

5. Verification products available to field PIs

Verification products will be made available to the DYNAMO PIs. These products will be created and sent in realtime to the EOL data catalog for display. The current and planned products available are listed below for each operational center.

NOAA – NCEP- Climate Prediction Center (CPC)

--Phase diagrams of the most recent 1-week and 2-week verification periods for the WH MJO index for several forecast models (see Appendix A).
--Anomaly correlation plots of MJO index forecasts over the past 90 days for several forecast models (see Appendix A).
--Skill scores for the most recent GTH Week-1 and Week-2 outlook [OLR and precip (land only)]
--Verification of the operational GFS hourly wind magnitude and RH forecasts
--Comparison of 0-3 hour GFS model OLR/precipitation with Meteosat IR image
--Verification of the operational GFS weekly OLR, precipitation, wind and humidity forecasts
--Verification of the operational CFS weekly OLR, precipitation and wind forecasts

<u>6. Coordination with external partners</u>

Each Monday, CPC conducts a technical MJO-GTH conference call at 2:30 PM ET in which the MJO forecast team at CPC and external partners discuss the current conditions in the Tropics and the status of the MJO and other equatorial waves to make a forecast for MJO activity over the coming two weeks as well as produce the GTH outlooks. Drs. Paul Roundy, Carl Schreck and Matt Wheeler already do or plan to participant in this process and will be involved in our discussions. The planned outline for the conference calls is listed in Appendix B and will include accessing and reviewing forecast information from the EOL data catalog.

The draft text included in the weekly briefing for DYNAMO will be created Monday afternoon (U.S. Local Time) by 21 UTC and sent to our external partners for review and input. Overnight Monday (U.S. Local Date), input will be received by contacts from other centers. The PDF files of graphical content and text discussion will be updated and finalized Tuesday (U.S. Local Date) and then disseminated to the DYNAMO forecast team as described in Section 1 prior to the briefing.

<u>6. Forecast team and leadership structure</u>

The forecast team will consist of staff from both CPC and from external partners. The team will produce a consensus forecast for the DYNAMO team and this will serve as the “official” forecast for the campaign. A lead from the team will be designated each week to organize the thoughts of the forecast team and draft the text discussion. Depending on time availability, not all team members will be able to serve in this capacity, but it is hoped that a small rotation will be utilized. NOAA CPC will be the group that will disseminate this forecast and respond to inquiries.

NOAA

Mr. Jon Gottschalck – Head of Forecast Operations, co-lead (CPC)
Dr. Augustin Vintzileos – Research Meteorologist, co-lead (CPC/ESSIC)

Mr. Matthew Rosencrans – Meteorologist (CPC)
Ms. Michelle L'Heureux – Meteorologist (CPC)

External

Dr. Paul Roundy – Professor (SUNY, U.S.A.)
Dr. Matt Wheeler – Senior Research Scientist (BOM, Australia)
Dr. Carl Schreck – Post-doctoral fellow (NCDC-CICS)

Appendix A:

NCPO: National Centers for Environmental Prediction - Operational Global Forecast System
NCPE: National Centers for Environmental Prediction - Ensemble Global Forecast System
NCPB: National Centers for Environmental Prediction - Bias-Corrected Ensemble Global Forecast System
NCFS: National Centers for Environmental Prediction - Climate Forecast System

ECMF: European Centre for Medium Range Forecasting – Operational ensemble
EMON: European Centre for Medium Range Forecasting – Seasonal Forecast System

UKMA: United Kingdom Meteorology Office - Operational Control Run
UKME: United Kingdom Meteorology Office - Ensemble System

IMDO: India Meteorology Department - Operational Global Forecast System

CMET: Canadian Meteorology Centre - Ensemble System

TCWB: Taiwan Central Weather Bureau - Operational Prediction System

CPTC: Brazil Centre for Time and Climate Studies - Ensemble System

JMAN: Japan Meteorology Agency - Global Spectral Model Ensemble System

Appendix B:

MJO-GTH technical conference call format during the DYNAMO campaign

Section 1: (30 minutes)
1. Review recent conditions
--OLR, precipitation, circulation review
--SST review
--Review satellite imagery
--MJO indices review
--Review of KW, ER-1, etc. activity

2. Review of climate forcing predictions
--Review of ENSO and IOD
--MJO index forecasts and recent validation
--Verification of MJO index forecasts for the last 90 days
--Statistical forecasts of KW, ER-1 from NCDC-CICS, SUNY

3. Review of numerical guidance

--Review of operational model guidance from NCEP and ECMWF (data catalog)
--Review of ensemble model guidance from NCEP and ECMWF (data catalog)
--Review of statistical and dynamical TC forecast tools
--Review of raw numerical guidance

4. Additional miscellaneous predictors
--SST review
--Mid-latitude interactions, blocking, etc.

5. Discussion of preliminary GTH outlook for all areas with suggestions for any changes

Non-DYNAMO forecast team members and callers exit call

Section 2: (up to 30 minutes)

1. Additional focused discussion on the DYNAMO region

2. Finalize forecast areas for the DYNAMO region

3. Draft key talking points for the text discussion and weekly DYNAMO web briefing

Chapter 9: Other Model Operational Support Products for DYNAMO

1. Introduction

The purpose of DYNAMO real-time forecasting during the field campaign is to assist field operations (i.e., aircraft), to give field PIs a general view of past and on-going large to small-scale weather conditions, and to document weather/circulations for post-field data analyses. Coordination with the aircraft people to isolate the forecast products other than cloud related fields that are useful for aircraft operations is very important to this real-time effort. This section describes real-time modeling efforts that are planned for DYNAMO beyond the Chapter 8 efforts that describe planned DYNAMO field campaign operational support products from NOAA -NCEP-Climate Prediction Center (CPC), ECMWF, and NCDC.

2. Survey of modeling groups planning real-time forecasts

Regionally-stretched NICAM (Nasuno & Satoh):
It is intended to provide near-real-time prediction and support for CINDY/DYNAMO with the regionally stretched NICAM.
Resolution: 14~28km mesh in a 90^o x 90^o domain, centered at 80^oE, 8^oS
Length of forecasts: 7-day integrations (~6.5-day predictions)
Frequency: daily (updated at ~03UTC)

Data access:
Web access permission to CINDY/DYNAMO members will be granted for images during IOP to aid in operations on CINDY web (http://www.jamstec.go.jp/iorgc/cindy/weather.html). The possibility exists for synchronization with NCEP/CPC on RMM indices? (Weather maps, time-longitude plots and RMM indices for NICAM simulations will appear on the CINDY web).

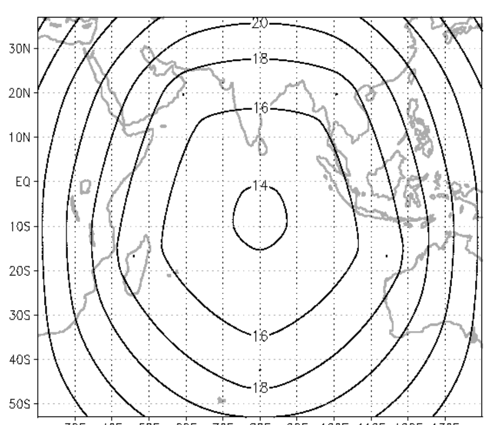


Fig. 9.1 Grid size of NICAM forecast (km).

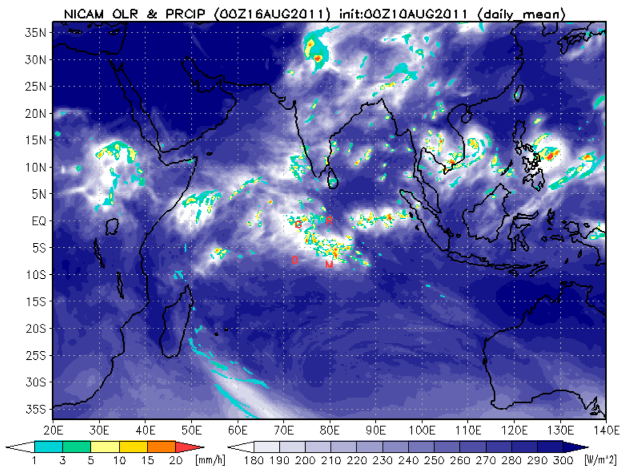


Fig. 9.2 Daily averaged OLR and precipitation after 7-day forecast (8/10/2011 00UTC started).

COAMPS/NCOM/SWAN (Sue Chen):

NRL will provide real-time COAMPS prediction up to 5 days for the CINDY/DYNAMO intensive observation period. COAMPS has continuous data assimilation in both the atmosphere (3DVAR NAVDAS) and ocean (3DVAR NCODA)

Resolution: The atmospheric model is triple nested with 27, 9, and 3 km horizontal resolution. The 60 vertical levels are terrain following that extend from 10 m above the surface to 29 km. The horizontal resolution of the ocean (NCOM) model is 1/8 degree and 60 vertical levels, including 23 sigma layers. The wave (SWAN) model resolution is ¼ degree that contains 33 freq (1-24s) and 36 directions. COAMPS model domain covers the entire Indian Ocean and Maritime Continent.
Length of forecasts: 5-days forecasts
Data assimilation Frequency: Twelve hour update cycle in the ocean and six hour update cycle in the atmosphere
Coupling: fully air-ocean-wave coupled with 6 minute coupling interval
Images: available via the DYNAMO field catalog

Data access:

Digital data can be available upon request,
Post campaign: The full set of digital model data will be archived at the HPC archiving facility. Distribution of the COAMPS digital data will follow the general Cindy-Dynamo data policy.

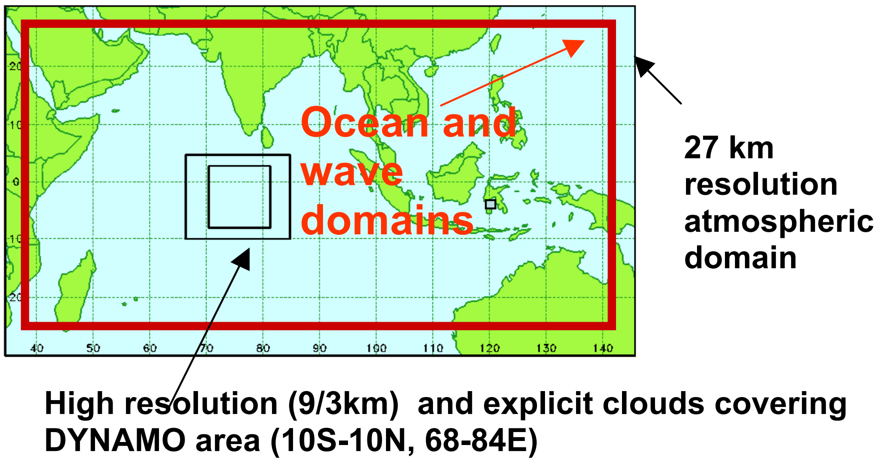


Fig. 9.3 Domain of regional model.

Météo-France model products (Duvel, Matthieu Plu):
This section describes Météo-France operational and research models, but also some ECMWF products, since France acting as the member state contact point of Cindy-Dynamo for ECMWF. The French participation is coordinated by Jean-Philippe Duvel (LMD, Paris), and the Météo-France participation is coordinated by Matthieu Plu (LACy, La Réunion). A French proposal has been submitted to the ANR and it is currently under review.
Important note : The Météo-France model outputs will be made available only if the project gets some ANR funding.

The model outputs will be useful for operations in real-time and for research purposes after the campaign.

Météo-France Arpege:
Global operational model,
Resolution: T798C2.4L70 (~35 km in the Indian Ocean),
Assimilation: 4D-Var
Forecast length: 84h
Frequency: every 6h, starting every day at 00UTC and 12UTC

Aladin-Reunion:
Limited area operational model over the South-West Indian Ocean,
Resolution: 8kmL70
Assimilation: 3D-Var, coupled with Arpege (or IFS ECMWF)
Forecast length: 54h
Frequency: every 3h, starting every day at 00UTC and 12UTC

Arome:

Cloud resolving model, initial and boundary conditions from Aladin-Réunion
Resolution: 2.5 km
Forecast length: 30h
Frequency: every 3h, starting every day at 00UTC and 12UTC

Data access:
During the campaign: Images may be provided in real-time, and they will be displayed on the Climserv webpage of IPSL. Access will be limited to the Cindy-Dynamo PIs with a password. The images may be produced at La Réunion or at Toulouse. The transfer from Météo-France to IPSL must be defined.

The images will show the following fields :

- mean-sea level pressure
- relative vorticity at 850 hPa
- accumulated rainfall over 3h (6h for Arpege)
- CAPE
- Vertical velocity at 700 hPa and 400 hPa
- Geopotential and wind barbs at different levels (850hPa, 700hPa, 500hPa, 300hPa, 200hPa)
- Wet-bulb pseudo-adiabatic potential temperature at 925 hPa
- Cloud cover at low, medium and high level
- Simulated IR and WV satellite chanels (SEVIRI-like sensor)

After the campaign: The fields displayed as described herebefore will be archived on the Climserv database from IPSL. The general Cindy-Dynamo data policy is that data are only available to the PIs before February 2013 and then they are publicly available.

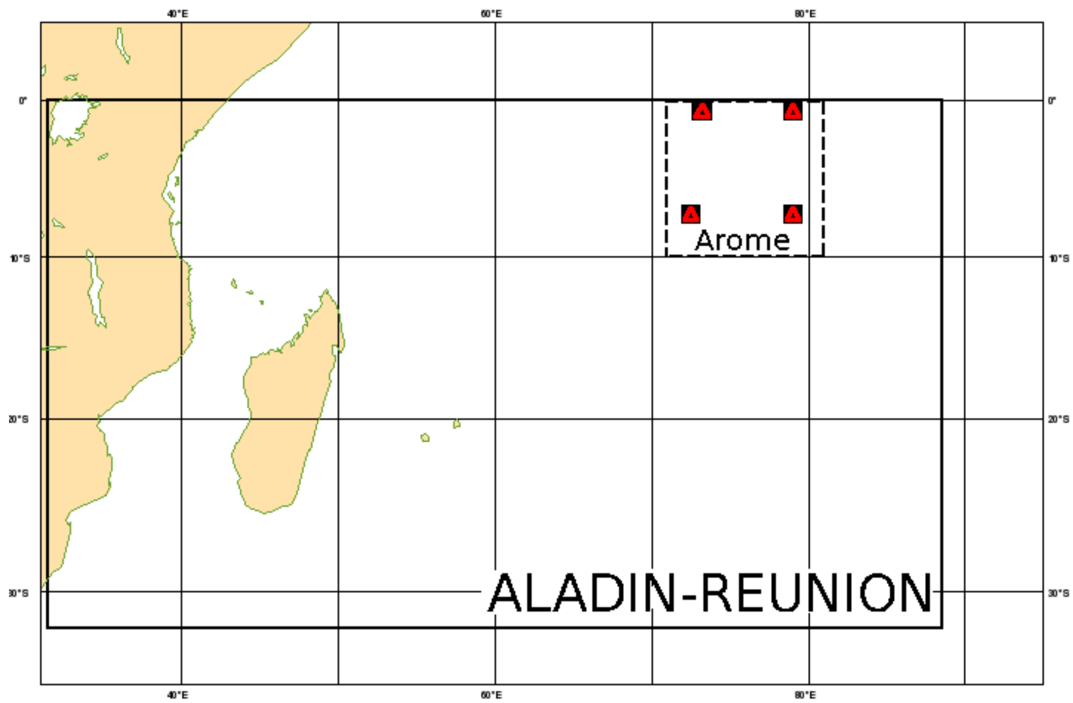


Fig. 9.4 Domain of the model Aladin-Réunion (fixed), and proposed domain for Arome (this is a proposition that may be changed before the beginning of Cindy-Dynamo, according to the needs of the PIs). The red triangles indicate the islands or ships that define the main square of observations of the Cindy-Dynamo campaign. Gan, from where the planes will fly, is the upper-left triangle.

CReSS (Shinoda):
Model: CReSS (CReSS-NHOES)
Domain: 1500 km × 1500 km or wider
Resolution: 2.5 km or less (depend on domain and resolution and Laboratory plan
Period: Oct. - Dec. (Nov.) 2011
length of forecasts: 36 hours

3. Specific Needs of PIs In-Field and Post-field

a. Aircraft Field operations:
The purpose of DYNAMO real-time forecasting during the field campaign is to assist field operations (i.e., aircraft) and to give field PIs a general view of past and on-going large-scale weather conditions. Coordination with the aircraft people to isolate the forecast products other than cloud related fields that are useful for aircraft operations is very important to this real-time effort.

Thus far, the forecast products desired for aircraft operations have been articulated as follows. Planning for aircraft missions requires a bit of downscaling to a few days. ***Specifically, the need for reliable products that convey the location and timing of convective events for Days 1, 2, and 3, and their likely areal coverage is***

desirable. At least for the P-3 there are a couple of operational constraints that need specific focus on Day 1, Day 2 and Day 3 forecasts:

1) At each daily mission planning meeting we need to set the takeoff time for any operations the next day. This constitutes an "alert". Switching between "daytime" missions (takeoff before 6 PM local) and "nighttime" missions (takeoff after 6 PM) requires a good 2 day forecast since this major change in operations might require an additional 12-24 hours notice depending on the flights that have occurred previously.

2) There's the "down time" rule which demands that an off day be declared after at most 6 consecutive "up" days (an alert or actual flight constitutes an "up" day). A down day resets the running 7 day clock so your week1 and week2 OLR forecasts would be key to forecasting a good time for an "off" day.

3) Three consecutive maximum duration missions (~9 hr) requires a down day, which does reset the 7 day clock.

4) There's a 50 hour inspection rule (after 50 flight hours an inspection is required) which would cause a "no fly day" to be declared. These inspections can be done a bit early and can also be done a bit past the 50 hour mark. Jim McFadden would have the exact rule. What this means is that if we expect several days of continuous operations we could elect to take the inspection early. A no fly day is not the same as an "day off" so the 7 day clock is not reset.

Here are some specific variable requirements provided by Qing Wang:

1) Standard variables such as the 10 m wind, air temperature, relative humidity, surface pressure, precipitation, sst, 850 mb and 500 mb wind, temperature, and geopotential height

2) less-traditional outputs such as surface momentum flux, sensible heat flux, latent heat flux, boundary layer height, cloud fraction, cloud top/base height, column integrated cloud water amount, and cloud top height (or temperature).

Output interval: About one hour?
Forecast length: at least 72 hours
Frequency: updated every 12 hours for flight planning purposes

b. Post-campaign process studies:
The real-time forecast variables to be saved for post-campaign process studies and model intercomparison are coordinated with process-modelers intending hindcast work. To date, the following model output variables have been proposed to be saved for further analysis, starting with discussions at the Fall 2010 CINDY workshop in Japan:

SST, ocean temperature, salinity, currents, mixed layer depth, surface fluxes, radiative fluxes, OLR, boundary layer processes, Q1, Q2, convective momentum transport, microphysics, vertical profiles of u, v, q, T, PS

4. Dry run plans

The purpose of the dry run is to get the PIs familiar with the data products to be employed during DYNAMO, receive feedback from the PIs, and to finalize data products well in advance of the start of the DYNAMO field stage. Dry run products will be posted on the DYNAMO website after refinement. The real-time forecasts will be included in the field data catalog.

Thus far, dry runs are currently underway at NCEP/CPC, where real-time dynamical MJO forecasts are being made based on multiple numerical model output (e.g. see Gottschalk et al. 2009). PIs have been commenting on the utility of these dry runs for aircraft and other field operations.

Dry run activities are also ongoing/planned with NICAM. These entail week-long forecasts using stretched NICAM (see above) for 11/15/2010-3/1/2011 and 23/5/2011-6/30/2011. Some initial troubles occurred with these runs (already fixed), but simulations are continuing (routinely operated every day).

NRL has conducted twenty-one day dry runs in Dec 2010 with 12 h forecast length. Images of COAMPS standard output fields will be made available at the DYNAMO web site. These fields are:

1. Precipitation, OLR, convective potential energy
2, U 200mb, 500mb, 850mb
3. V 200mb, 500mb, 850mb
3. GPH 200mb, 500mb, 850mb
4. Relative humidity 925mb, 850mb, 500mb
5. surface heat fluxes (SW, LW, LH, SH)
6. SST, ocean temperature, salinity, and currents
7. Significant wave height, dominant wave period

Chapter 10 Communication Support

This chapter describes the key nodes and links in the DYNAMO project to permit the flow of key data products and information among all participants. The communications network for DYNAMO will involve several systems to assure reliable transfer of data, relay of information for facility coordination and updating of all project participants on project activities. Figure 10.1 provides a schematic overview of the variety of communications networks and systems that will be used in support of DYNAMO operations.

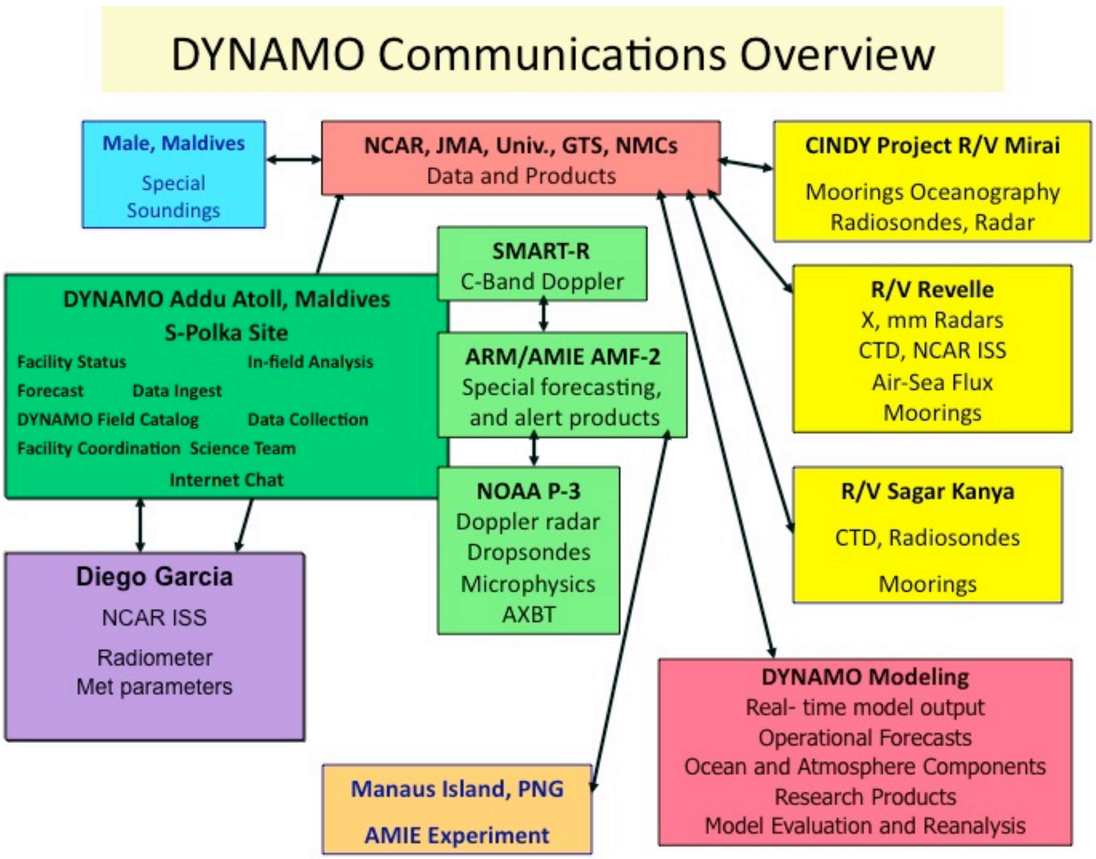


Figure 10.1. Communications overview for DYNAMO

10.1 Capabilities of DYNAMO Distributed Communications Systems

10.2 Addu Atoll Supersite Communications Network

The Addu Atoll in the Maldives Will be the location of a supersite of radars at multiple wavelengths and associated measurements. It will include facilities from the NSF (NCAR, EOL S-Polka and the TAMU SMART-R radars) and DOE/ARM (AMF-2 facility). The are unique capabilities and requirements for sharing and distributing data and products from this location. Figure 10.2 shows the data flow schematic for the Addu Supersite.

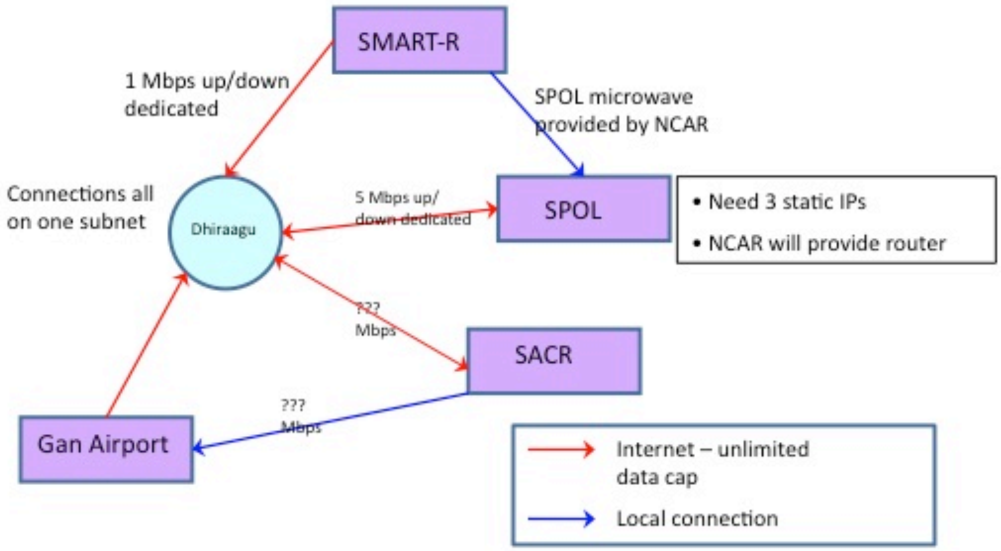


Figure 10.2. Proposed high-speed local network for the Addu Supersite connecting NSF and DOE/ARM facilities. Dhiraagu is the name of the local telephone and Internet provider on Addu Atoll. All links to the outside world will go through the Dhiraagu regional office.

The network has been laid out to enhance the ability to exchange data among the supersite facilities. This, in turn, will permit a number of value added products (e.g. parameter time series, radar composites, derived quantities) to put on the DYANMO Field Catalog and shared with all project participants worldwide.

10.3 Internet Chat Capabilities

EOL will support Internet Relay Chat (IRC) capabilities for all centers, ships, aircraft and participants, if they are interested. This is a real-time text message exchange protocol that will permit immediate messaging between centers and participants. This technology is currently used heavily by the NCAR research aircraft and ground facilities, project scientists, engineers and technicians to relay information, debug instrumentation and provide updates during mission execution (e.g. discussion between Addu Atoll, ships, aircraft or other support centers). It will also be possible for users to access chat archives to review previous messages. This may be particularly helpful because of the project operations across different time zones. EOL will support the server to host this software. Users need only install the free client on their own machine and log into the EOL chat server to participate.

Instructions for downloading and operating the chat will be included in the DYNAMO Field Catalog.

10.4 Multiple Center Communications

The several coordination centers in DYNAMO will have a variety of communications links available to them to maintain contact and exchange information. This is important because of the large distances and multiple facilities in the DYNAMO domain. Figure X.1 shows the schematic linkage of these coordination centers and facilities, extending across the eastern Indian Ocean. A combination of Internet, email, phone and IRC chat (See Section X.2) will keep key information flowing in a timely fashion among the centers. In addition, the DYNAMO Field Catalog will be a central point of information for mission planning, a daily operations summary, facility status and preliminary data products from the observing systems.

10.5 Aircraft Communications

Participating aircraft are equipped with several forms of communications that will permit the coordination needed to execute DYNAMO observational strategies. Details of individual aircraft capabilities are given in Chapter BB. These links will allow limited transmission of radio, chat text messaging, low resolution imagery and periodic relay of aircraft position and data. This includes dropsondes, flight level, and in-situ data. The satellite links also permit text messages to and from aircraft and the operations center. Chapter BB provides details of the communications capabilities of all project aircraft.

10.6 Ship Communications

Research vessels participating in DYNAMO will have modest bandwidth satellite communications for the relay of data and products to and from other DYNAMO facilities.

10.7 Provision of DYNAMO Special Products

There will be a number of specialized products and reports provided by national forecasting centers and collaborating institutions during DYNAMO. Details of special satellite imagery are described in Chapter YY and a variety of model output fields to be available are noted in Chapter ZZ. Project participants will be preparing special reports, providing facility status updates and special weather forecasts as an aid to project operations. In most cases, these products will be provided to the project via the DYNAMO Field Catalog described in Chapter AA. Products will be transmitted automatically to the Catalog or links will be set up to allow users to access the products from the Catalog.

Chapter 11 Data Management Support

Project data management support to DYNAMO includes planning assistance to the investigators prior the field phase. DYNAMO investigators have also requested support for key data management activities including the implementation of a DYNAMO Field Catalog, collection of supplementary supporting data (e.g. satellite, surface and special model products), provision of products to and receipt of products from the NOAA WP-3D and/or French aircraft, and the long-term archival of all DYNAMO research and operational datasets.

The EOL field catalog is a web-based tool that allows the project participants to post (and access) operations and mission/scientific reports, operational and preliminary research imagery/products (e.g. satellite, surface, upper air, radar), forecast products, model output fields, and project documentation. The Field Catalog will be used to make operational decisions during the field phase as well as provide a project summary and "browse" tool for use by researchers in the post-field analysis phase. The field catalog will remain as part of the long-term DYNAMO archive. EOL will customize two field catalogs for DYNAMO (primary public version in Boulder and a smaller local version in Addu Atoll) to support the PIs, and begin operating the primary version in August 2011. This will allow enough time for the PIs to review the products and make any modifications as needed before field operations begin. EOL will then implement the local version in Addu Atoll and monitor/maintain the field catalogs through the duration of the deployment as well as provide in-field support and training to the project participants.

Data Management tasks:

- Finalize the DYNAMO/CINDY_2011 data policy and protocol.
- Design, distribute and assess a questionnaire to query PIs on data requirements.
- Arrange for collection of PI-requested operational and special research datasets prior to the campaign (e.g., radar, satellite, soundings, model products, etc).
- Customize DYNAMO Field Catalog(s) in preparation for deployment. There will be a separate local field catalog running in Addu Atoll to minimize lower bandwidth internet traffic from Maldives to the main catalog running in Boulder which will increase efficiency and speed of product access to local users. An AS will be on-site in Addu Atoll at the beginning of the campaign to assist project participants with use of the catalog and to fine tune communications between the local catalog and the version running in Boulder. EOL also budgeted an additional trip to the Maldives for an AS or SE to deal with unplanned catalog problems that may occur and require on-site expertise to resolve.
- Prepare DYNAMO Data Management Plan in cooperation with science team.
- Create and maintain the DYNAMO Website (including data management pages) at EOL.
- Implement chat messaging for all DYNAMO participants.

- Coordinate with other agencies (and CINDY_2011 PIs) on data products needed for DYNAMO real time operations and research.

EOL will provide access to the DYNAMO Field Catalog, model output, and real time data displays to make operational decisions. EOL will provide web conferencing capabilities as needed.

Chapter 12 DYNAMO Project Office (DPO) Support

1. Operational Support during Field Campaign *(1 October 2011-30 March 2012)*

The Project Manager (Moore) will be located in Addu Atoll to help with the start-up of operations, coordinate with local and national government officials and assist the PIs with local logistics as needed. This support will be over the first 3 weeks of the project. FPS proposes to provide additional operational support (Meitin) during the period of aircraft operations in November taking advantage of his considerable experience with the coordination of multiple aircraft in field projects.

- Project Manager and Associate Project Manager will act as an overall site manager during their deployment period on Addu Atoll. This includes working with the PIs, facilities and local Maldivian contacts to work out arrangements.
- DPO will provide a single point of contact for MMS in the early deployment period for public outreach activities including tours and interviews with the scientists on site.
- FPS will set-up and facilitate and international conference call arrangement on a weekly basis throughout the deployment to encourage coordination of all participants throughout the long field deployment period.

EOL will provide systems administration and software engineering support in the S-Pol radar facility to manage the local computer network as well as real-time displays consisting of high-resolution satellite data. EOL will support Internet chat rooms to facilitate the coordination of the aircraft in real-time and allow remote participation in the field project. Primary EOL tasks include:

- Coordination with PIs and other cooperating project participants (CINDY_2011) regarding flight operations planning based on science objectives.
- Maintenance and updating of DYNAMO Field Catalog including assisting participants and facilities with submission of special preliminary analysis products, flight tracks, mission reports, and facility status information for presentation at the daily briefings and at other times as needed.
- Collection, preparation and provision of DYNAMO specific high-resolution satellite, radar data, operational products, soundings data etc. to the Field Catalog.
- Set up key project communication (e.g., chat rooms , secure chat server).
- Document, report and/or notify mission planning decision to all participants and related projects.
- NEED TO SET UP AN OPS CENTER AT DG DURING THE P-3 DEPLOYMENT

Networking, Systems Administration and Communications Support at the Operations Center

- Design, plan, prepare, ship and install the complete computer network services on Addu Atoll.

- Establish networking services for the project participants including wireless and wired communications to the LAN.
- Provide print services, data storage and other support functions for all participants on Abbu Atoll and Diego Garcia.
- Implement appropriate security measures to protect project data information and computers.
- Install, configure and support of EOL data and product displays in the operations center.
- Provide documentation for how to use the network for all project participants.

2. Education and Outreach Activities

DYNAMO presents a unique opportunity to provide insights into the conduct of observational research related to the study of the MJO and its relevance to general climate research, understanding and prediction. EOL proposes to develop and support several activities focused on informing the public about the project and giving interested educational groups an opportunity to learn more about this research. EOL will accomplish the following tasks in support of education and outreach:

- Expand the EOL DYNAMO website to include general information about the project (e.g., scientist profiles, instruments and facilities used, schedule and expected outcomes) tailored to the public and educators who are interested in the project. This will include pictures, video science briefing, special articles etc.
- Use existing EOL portals to the social media (e.g., Facebook, Twitter, YouTube) to regularly post updates on DYNAMO activities.
- Prepare and distribute at least five focused 3-5 minute videos featuring the project PIs highlighting the science of DYNAMO.
- In collaboration with UCAR Communications, prepare a 30 minute documentary of DYNAMO.
- Organize and conduct outreach events in the Maldives (e.g. secondary schools, local colleges) to inform the community about and increase interest and knowledge in the project.
- Prepare printed material (e.g., project brochure) to hand out at any event described above.
- Coordinate with all participating universities, national centers and laboratories, and funding agencies in preparing and issuing a press release on DYNAMO.

We propose to send the EOL E&O Specialist (Alison Rockwell) to Addu Atoll for 10 days to gather video and audio material, interview PIs, work with the local groups and develop other in-depth documentation via on-site interviews for the documentary, web and social media site.

3. Post Field Deployment Phase *(through 3 months following the end of the campaign)*

The legacy of DYNAMO will be the rich dataset obtained during the field campaign. The goal is to establish procedures and links to the other distributed project archives (including CINDY_2011 archives) so that data can be shared amongst the projects and research community in an efficient way. EOL requests support at this time to permit uninterrupted support just after the field phase to complete some critical tasks to collect field datasets and set up the final archive.
Once the full extent of the data archive requirements are defined and known closer to the field deployment, EOL will create a revised Statement of Work and Budget to accomplish these tasks beyond the 3-month post-campaign period. It is hoped this work can be accomplished with remaining NOAA funds at EOL (re-directed to help support DYNAMO Data Management) or through a follow-on special funds request to NSF.

Several initial steps will be taken in the three month period immediately following the field season to organize the longer term DYNAMO archive in order to support the long term research needs of the project. These initial steps include:

- Finalize the full set of products in the DYNAMO Field Catalog using all possible data sources.
- Develop and implement the final DYNAMO data management web pages at EOL.
- Work with the international partners (e.g. CINDY_2001, IMS, NCEP, JAMSTEC) to establish procedures for sharing products and data among the projects.
- Construct the DYNAMO 'Dataset Master Dataset List' as a way of providing distributed access to all DYNAMO and related data that will be used in the analysis phase.
- Begin to populate the DYNAMO Data Archive with available operational/research products (generally from the Field Catalog) that will be part of the archive.
- Begin receiving preliminary and final research data sets and metadata from the DYNAMO investigators and ingesting into EOL data management system (EMDAC) for long term archival and dissemination.
- Initiate planning for a post-campaign DYNAMO Data Workshop in Boulder or Miami.

CINDY/DYNAMO Sounding Data on GTS

Site Type	Sonde, Receiver, Software	Location	Period	Time (UTC)	WMO ID, Callsign	GTS Header	Routing	Archive	Backup	Contact
Research	Vaisala RS92, MW31, Digicora III	0°36' S 73°28' E (Addu Atoll)	26 – 30 September 2011 (test)	00, 03, 06, 09, 12, 15, 18, 21	43599 VRMG	USMV01	Arm DMF via Internet to MMS	DOE ORNL	none	Brad Orr (brad.orr@anl.gov)
			1 Oct 2011 – 31 Mar 2012							
	Vaisala RS92, MW31, NCAR GAUS	7°19'S 72°25'E (Diego Garcia)	26 Sep – 30 Sep 2010 (test)	00,12	KWBC (DRG: 61967)	UMXX32	ASPEN Email via satellite to EOL	NCAR EOL	NCAR GAUS	Bill Brown (wbrown@ucar.edu)
			1 Oct – 24 Nov 2011	00, 03, 06, 09, 12, 15, 18, 21						
			25 Nov 2011 – 15 Jan 2012	00, 06, 12, 18						
	Vaisala RS92, MW31, NCAR GAU	0°N 80°E (R/V R. Revelle)	29 Aug - 26 Sep 29 Sep – 30 Sep	00,12	KWBC Ship: KAOU	UMXX33	ASPEN Email via Inmarsat to EOL	NCAR EOL	NCAR GAUS	Bill Brown (wbrown@ucar.edu)
			1 Oct – 28 Nov 2011*	00, 03, 06, 09, 12, 15, 18, 21						
			29 Nov 2011 – 4 Jan 2012*	00, 06, 12, 18						
	Vaisala RS92, MW31 v3.64, Digicora III	In cruise (R/V Mirai)	26 Sep – 30 Sep 2011	Testing/ Training	Ship: JNSR	USVX01 UKVX0 ULVX01 UEVX01	Inmarsat-C, to JMA	JAMSTEC	MW21, or MW31	Masaki Katsumata (katsu@jamstec.go.jp)
		8°S 80°E (R/V Mirai)	28 Sep – 30 Nov 2011	00, 03, 06, 09, 12, 15, 18, 21						
		In cruise (R/V Mirai)	04 Dec 2011 – ??	00, 06, 12, 18						
	????	NOAA P-3 dropsondes	08 Nov – 08 Dec 2011	variable	KWBC NOAA3	????	Email via Inmarsat to NWS Gateway	NCAR EOL	none	Jose Meitin (meitin@ucar.edu)
	Vaisala RS92, MW 31 Digicora III	0°N 80°E/83° E (R/V S. Kanya)	Sept-Oct/ Oct-Nov	00, 06, 12, 18	KWBC Ship: VTJR	UMXX33	Email via Inmarsat to EOL	??		P.M. Muraleedharan (murali@nio.org)

	Vaisala RS92, MW21 v3.64.1, Digicora III	4°25′N 73°30′E (Male)	29 – 30 September 2011 (test)	00	43555 Backup: KWBC	???? Backup: UMXX32	Submit via MMS Backup: Email to EOL	CSU	Vaisala RS92, MW31, Digicora III	Paul Ciesielski (paulc@atmos.colostate.edu)
			1 Oct 2011 – 15 Dec 2012	00, 06, 12, 18						
	Vaisala RS92, MW31 v.3.??, Digicora III	In cruise (R/V Baruna Jaya)	1 Dec – 20 Dec 2011 (??)	00, 06, 12, 18	Ship: YEAU	????		JAMSTEC		Kunio Yoneyama (yoneyamak@jamstec.go.jp)
	Vaisala RS92 ?? (MW31?) Digicora III	2°04′S 99°36′E (Sipora Is.)	1 Dec – 31 Dec 2011 (??)	00, 06, 12, 18, (occasionally 03, 09, 15, 21)	No identifier (temporary site)	????		JAMSTEC		Shuichi Mori (morishu@jamstec.go.jp)
	Vaisala RS92, MW31, Digicora III	2˚05'S 147˚E (Manus)	1 Oct 2011 – 31 Mar 2012	00, 03, 06, 09, 12, 15, 18, 21	WMO ID: 92044	USMV01	ARM DMF via Inernet then to NWS	DOE ORNL	None	Brad Orr (brad.orr@anl.gov)
	Vaisala RS92 ?? (MW21?) Digicora III	0°00′S 109°37′E (Pontianak)	1 Dec – 31 Dec 2011 (??)	00, 06, 12, 18	No identifier (temporary site)	?????		JAMSTEC		Shuichi Mori (morishu@jamstec.go.jp)
Enhanced Operation	Vaisala RS92, MW15, ??	1°17′S 36°49′E (Nairobi)	1 Oct 2011 – 15 Jan 2012	00, 12	WMO ID: 63741	????				Kunio Yoneyama (yoneyamak@jamstec.go.jp)
	Vaisala RS92, MW31, ??	4°35′S 55°40′E (Seychelles)	1 Oct 2011 – 5 Nov 2011	00, 06, 12, 18	WMO ID: 63985	????				Kunio Yoneyama (yoneyamak@jamstec.go.jp)
			5 Nov 2011 – 15 Jan 2012	00, 12						
	Meisei RS06G, ??, ??	6°56′N 79°50′E (Colombo)	1 Oct – 15 Dec 2011	00, 06, 12, 18	WMO ID: 43466	????				Masaki Katsumata (katsu@jamstec.go.jp)
	Meisei RS06G ??, ??	0°53′S 100°40′E (Padang)	1 Dec – 31 Dec 2011 (??)	00, 06, 12, 18	WMO ID: 96163	????				Shuichi Mori (morishu@jamstec.go.jp)

* No data during port calls: 27 October – 6 November 2011, 6 – 15 December 2011

In transient: 25 – 30 November,

Other CINDY/DYNAMO Data on GTS

Variables	Instruments/ Software	Location	Period	Time (GMT)	Header (WMO ID, Callsign, type, etc.)	Format	Routing	Backup	Contact
Surface T, q, u, v, p; Subsurface T, S, V, P	Moorings	85˚E(?) and 0, 3, 10˚S	1 October 2011 – 15 January 2012	(10 min)					Ren-Chieh Lien (lien@apl.washington.edu)

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