RAINEX Meeting
Miami
15-17 November 2004

Meeting Report

1. Attendees:

UW: Bob Houze, Brad Smull, Stacy Brodzik
UM: Shuyi Chen, Dave Nolan, Sharan Majumdar, Melicie Des Flots, John Cangialosi, Peter Kozich, Derek Ortt, Wei Zhao, Joe Tenerelli
UM/RSMAS System Administrator: Mike Anderson
HRD: Frank Marks, Rob Rogers, Sim Aberson, John Gamache, Peter Dodge, Mike Black, Bob Black, Mark Powell, Chris Landsea, Neil Dorst, Nick Carrasco
JOSS: Jim Moore, Dick Dirks, Jose Meitin
AOC: Jim McFadden, Mike Silah, Devin Brakob
NRL: Carl Newman, Robin Kane
NHC: Ed Rappaport, James Franklin
CARCAH: John Pavone
NESDIS: Paul Chang
NCAR/EOL: Wen-Chau Lee

2. Scientific goals and experimental objectives:

RAINEX is a combined effort of four science partners: University of Miami (PI S. Chen), University of Washington (PI R. Houze), HRD (PI R. Rogers), and NCAR (PI W.-C. Lee). The scientific goal is to understand interactions between the eyewall and rainbands in relation to how these interactions affect storm intensity changes. Aircraft data will be collected to be used in conjunction with the University of Miami/RSMAS MM5, which is an atmospheric model coupled with an ocean model and a wave model. The aircraft data collection will focus on documentation of small-scale vorticity features in the rainband and the eyewall in order to provide model comparison and validation of rainband-eyewall interactions. The data need to be collected simultaneously in the eyewall and rainband regions. The three airborne Doppler radars need to be deployed in patterns that will facilitate this simultaneous Doppler coverage of both rainband and eyewall.

3. Overview of project assets and constraints on their use:

At the RAINEX planning meeting summarized here, there was extensive discussion of the participating aircraft and the ground facilities to be deployed and coordinated in RAINEX

a. P3 aircraft

The P3 aircraft (NOAA 42, NOAA 43, and NRL NR 587) will execute patterns according to the NSF proposal (Fig. 1). These legs will be designed to optimize simultaneous dual-Doppler radar coverage of a selected rainband and of the eyewall. These flights will launch dropsondes frequently in addition to collecting Doppler data. These flight legs are the principle observational objective of the project. The NRL P3 will always be assigned legs to the outside of the rainband. The NRL has 100 research hours dedicated to RAINEX. The two NOAA P3s combined have approximately 125 research hours controlled by HRD for Atlantic Storms (and a similar number tentatively allocated for Pacific storms) and 80 research hours controlled by NESDIS for Atlantic Storms. The success of the RAINEX multi-aircraft flight plan depends on cooperation and merger of goals of HRD & NESDIS with the NSF supported NRL P3 hours. The NRL P3 will be based with the NOAA P3 aircraft, wherever the operations take place. The primary base will be NOAA/AOC at McDill AFB, Florida. Scientist flying on the NRL P3 will have to be certified in a Navy swim test. The NOAA P3 flying on the inside of the rainband (module 3 in Fig. 1) will be the lead P3 aircraft. The lead RAINEX airborne scientist (usually Smull) will fly on this aircraft and will advise the RAINEX scientist on the NRL P3 (usually Lee) about where to position the track of the NRL aircraft. In addition the NRL P3 will be provided nearly real time lower fuselage radar images from one or both NOAA P3s. Data for these images will be sent to the ground operations center at RSMAS, where Zebra will be used to create a readily usable navigated lower fuselage radar image containing superimposed flight track information and possibly satellite data. This image will have to be sent at intervals of 15 min or less in order to satisfy NRL and EOL operational and safety requirements. The altitudes of the P3 aircraft will generally be in the range 8-14,000 ft, with 2000 ft vertical separation.

Radar and flight track data from the NOAA P-3s will be processed on the ground at McDill and ftp'd or hand carried to RSMAS within 48 h after landing at McDill at the end of each mission, for inclusion in mission summaries generated at the ROC.

b. ELDORA

ELDORA will be on the NRL P3 and operated under the direction of Wen-Chau Lee. All data from the NRL P-3 will be processed on the ground at McDill within 24 h after the end of each mission that the NRL P3 landed at McDill. Then the data will either be ftped or hand carried to RSMAS for inclusion in mission summary so that it is at the ROC within 48 h of landing at McDill.

c. GIV and C130 aircraft

Upper level aircraft dropsondes would be valuable to RAINEX since the dropsondes obtained by the P3 aircraft will be launched from lower altitude flight tracks. Upper level dropsonde tracks, which have been proposed to achieve RAINEX objectives are shown in red in Fig. 1. These can be achieved via collaboration with NOAA agencies. The AF C130 aircraft are "tasked" by NHC for "reconnaissance" missions at low altitude (e.g.1500-10,000 ft) into the center of systems of interest, however there is no opportunity for RAINEX objectives to accommodated on these flights. The NOAA GIV and AF C130 aircraft are also "tasked" by NHC to obtain dropsonde data in the synoptic environment during "surveillance" flights. The surveillance flight tracks cannot be modified for RAINEX. However, it may be possible to arrange to release additional dropsondes along sections of the predetermined flight track. In addition the GIV may be tasked for “inner core” missions, which would consist of either eye penetrations or eye circumnavigations at high altitude (e.g., 35-40,000 ft). AOC has indicated that in the early part of the project, the inner core missions may be restricted to storms no stronger than Category 1 or 2, but there is a possibility that this restriction might be relaxed contingent on success in the weaker storms. In addition, HRD controls 47 GIV “research” flight hours. There are definite opportunities for RAINEX objectives to be met within these hours, provided the flight planning is coordinated with HRD to ensure all other objectives are met. The modes of usage of the GIV and C130 in the reconnaissance, surveillance, and research categories are summarized in Attachment 1, provided by NHC. RAINEX can obtain dropsonde data from these GIV and/or C130 flights by appropriately partnering with the groups involved in each category—other than reconnaissance (see Sec. 4b below).

d. RSMAS ground operations center

A ground operations center at UM/RSMAS will be used to relay radar images from one or both NOAA P3 to the NRL P3 at intervals of 15 min or less in nearly real time. In addition the ground operations center will maintain a real time overview of the missions and help the RAINEX airborne scientists on the NOAA P3 and the NRL P3 with proper positioning and future flight track planning. The operations center will also produce mission summaries of each storm investigated shortly after the event. The operations center will used Zebra as its primary tool to synthesize and examine the data from each storm. Satellite, model initialization fields, RSMAS MM5 output, dropsonde data, flight level data, and preliminary Doppler radar analyses will be ingested and prepared for mission summaries and for eventual inclusion in the data archive to be organized by JOSS.

e. JOSS

JOSS will provide assistance with the data flow, data archival, and real-time planning and coordination of mission operations. An important vehicle for their data management is the web-based JOSS Data Catalog. It will be used to prepare mission summaries and to provide easy access to real time products, post mission data sets and other project information both in the field and after the field-phase.

4. Critical issues and action items:

a. Communication of radar images from NOAA P3 to NRL P3

This is a key element of the program that must function in order for the NRL P3 to participate. For this to be possible, networking and satellite link capabilities need to be available on both NOAA P3s. In addition, this will require:

- An Ethernet data feed from the radar processor to a laptop. AOC has indicated that this will be available.

- A laptop for receiving the LF data over the Ethernet. This will be provided by RAINEX. The beam data of the LF radar will be reformatted into HRD format to be transmitted to RAINEX Operation Center at RSMAS via satellite link. The software on the laptop will be provided by NCAR in collaboration with the UW.
- Software to prepare the LF data for scp transfer to the NRL P3 will be provided by NCAR Zebra operating at RAINEX Operations Center with capability to overlay flight track data on LF data and creating image files. This will be provided by UW in collaboration with NCAR.
- Capability on board the NRL P3 for scp'ing LF images from RAINEX Operations Center. This will be provided by EOL.

<u>b. Involvement of upper-level dropsonde aircraft in rainband and eyewall flights</u>

Upper level dropsonde flight tracks that would provide great value for RAINEX are shown in Fig. 1. These tracks can be accomplished in accordance with Attachment 1 via collaboration with NOAA agencies (NCEP, NHC, & HRD) as follows:

- The inner core circumnavigation of the eyewall (solid line in Fig. 1) and possible crossing of the eyewall (dashed) could be obtained by partnering with NCEP, who control 80 flight hours, some of which are for inner core soundings.
- The rainband circumnavigation in Fig. 1 can be accomplished by partnering with HRD, who control 47 research hours on the GIV.
- In addition to the flight legs in Fig. 1, RAINEX needs detailed information on the midlevel moisture affecting the outer rainbands. The surveillance flights circumnavigate the storm but have a tendency to brush up close to one side of the storm. By reaching a cooperative agreement with NHC & HRD, RAINEX can provide sondes for increased sounding frequency when the flight track is close to the outer edge of the storm. The method of communicating the locations of the extra dropsondes to the GIV remains to be specified.

<u>c. Model simulations of each storm</u>

RSMAS MM5 will be running in an ensemble mode with 2-3 different global model analysis and forecast fields as initial and lateral boundary conditions. The global model products currently available in near-real time are the NECP GFS and NAVY NOGAPS. We will contact UK Met Office in the next a few months to explore possible options to obtain their global model forecast fields. In addition, we are also in contact with GFDL to obtain the GFDL model initialization fields to add another ensemble member. Given the time required for getting the global model products (~8-10 h) and MM5 run time (~12 h), we expect to get a 24-48 hr forecast in real time.

- Ensemble MM5 track and intensity (max surface winds and min SLP) forecasts
- Rainfall and model simulated reflectivity maps
- Wind and vorticity maps to compare with the aircraft measurements
- Moist Potential Vorticity (MPV) maps

Other products can be created and made available to the RAINEX science team. This modeling plan will require additional computational resources. The PI (Chen) will discuss options with the university for possible matching funds for purchasing a 16-node linux PC cluster.

d. Setup and testing of RAINEX Operations Center

The RAINEX Operations Center (ROC) will be a vital link in the experiment design. It will be located at RSMAS. The RAINEX data flow is summarized in Fig. 2. Via a chat room capability, the ROC will be in contact with airborne mission scientists on all three P3 aircraft. The RAINEX scientist at the ROC (usually Houze) will help the airborne RAINEX scientists to position aircraft in the storm. The operations center will receive LF data from the lead NOAA P3 via scp , ingest the data in Zebra, add selected overlays (e.g. satellite, past and future aircraft tracks, storm motion), create images of the data, and make the images available for scp from the NRL P3 at intervals of <15 min. Satellite imagery will be made available via the same scp routing for each aircraft to help "fill-in" the complete picture of the storm.

Satellite imagery, model initialization fields, RSMAS MM5 output, dropsonde data, flight level data, and Doppler radar data will be ingested into Zebra. Radar data, flight level data, & dropsonde data will be ftp'd or hand-carried to the ROC following each flight . JOSS will provide pathways to these data sets and products via the JOSS Data Catalog. Using all these data sets, the RAINEX mission scientist will prepare Mission Summaries for each storm and post them via the JOSS catalog. For these functions to be carried out successfully, the computer and communications infrastructure must be in place and fully operational by the time of the first storm investigated in RAINEX. To assure that this functionality is in place a series of visits will be made to the ROC site by UW and NCAR personnel to work with RSMAS personnel to set up and test all the hardware and software. These visits for set up and testing will be done in March, May, June and July 2005.

e. Upgrade of communications on NOAA P3s

Equivalent local area network (LAN), LF data access and satellite communications are required on both NOAA P3 aircraft to achieve the required transfer of the LF radar image to the ROC from the NOAA P3s. There will be other communications needs on the NOAA P3s, including flight-level data transmission for NESDIS and airborne Doppler winds analyses for HRD. RAINEX must coordinate with these groups to ensure that adequate bandwidth is available to transmit all necessary products off the aircraft.

f. Possible modification of dropsonde capability of NRL P3

The operation of the existing dropsonde chute on the NRL P3 is possible only when the aircraft cabin is de-pressurized. This restricts the potential fordropsonde launches on the NRL aircraft to flight levels at or below about 3 km. To launch dropsondes from higher altitude (about 5 km) would require a modification to the aircraft, which would be expensive and would require a lengthy engineering certification process. NRL has assured that it is feasible technically. RAINEX must soon make a decision regarding whether this addition altitude capability would add sufficient value to the data set to justify modifying the aircraft dropsonde chute configuration.

g. Availability of Dropsonde Expendables

It is important that RAINEX make a decision within the next 90 days about the number and source of dropsondes to be used on the project. NOAA AOC has offered to include the RAINEX request with their annual order next placed in March 2005. In addition for a modest additional cost AOC will baseline check each sondes prior to launch to help assure a successful sounding. RAINEX may want to take advantage of the AOC offer.

h. Chatroom capability for aircraft coordination

Chat room capability is required for the RAINEX scientist on each P3 aircraft and at the ROC. This capability uses readily available software and has been extensively utilized in past projects like BAMEX. It will be very valuable in passing added information to help explain images, propose new way-points and discuss storm evolution (see Fig. 2).

i. Transfer of data from aircraft facility to ROC

The Doppler radar data sets and flight level data sets from all three P3 aircraft will be ftp'd or hand-carried to the ROC within 48 h of landing at McDill after each mission. EOL will support this requirement for the NRL datasets. An arrangement will be made with AOC to assure similar data access from the NOAA aircraft. Relay of dropsonde data from the GIV and USAF C130 aircraft will be available in near real time via reduced resolution satellite relay and after the flight via ftp data transfer.

j. Field program contingency plans

In the case that hurricanes are active too far east to deploy from Tampa, the P3 aircraft will move to an alternate site at St. Croix, Barbados, San Juan, or Bermuda. Briefings by Chris Landsea and Shuyi Chen indicate that the likelihood of a sharply reduced frequency of hurricanes in the Atlantic is low since the SST in the Atlantic basin remains elevated, and the developing El Nino seems weak. In this unlikely case of low frequency of Atlantic basin hurricanes during the 2005 season, the P3s could be deployed to the west coast of Mexico. The NRL P3 will always deploy from the same location as the NOAA P3s. The aircraft facilities will coordinate advance arrangements for diplomatic clearances to alternate sites to allow maximum flexibility for RAINEX operations.

Power outages at the ROC can be protected by a 2 hour UPS. If the ROC must be evacuated in the situation of a landfalling storm impacting Miami, the essential ftp and Zebra operations will be moved to another location TBD.

k. Data management

The data received in the ROC will be the first iteration of the RAINEX data set and will be available immediately via the web from the JOSS data catalog. The satellite and model initialization fields from selected operational models will be collected and posted through the JOSS Data Catalog. The mission summaries will be included in the Data Catalog. After the last flight of RAINEX, the Doppler radar, dropsonde, and flight track data sets from all the aircraft will be quality controlled and also archived by JOSS. As the UM MM5 model runs for each of the investigated storms are completed, images of selected output fields and selected model output will be provided through the JOSS Data System .

A complete RAINEX Data Management Plan will be prepared prior to the start of field operations to describe the strategy and procedures for handling RAINEX datasets and products.

JOSS and the RAINEX investigators will work with HRD to avoid duplication in the long term archive while maximizing access to the data in a timely fashion.
A concise RAINEX Data Management Plan will be prepared prior to the start of field operations to describe the strategy and procedures for handling RAINEX datasets and products.

l. Writing of the RAINEX Operations Plan

It was agreed that JOSS and the PIs would begin jointly writing a complete operations plan as soon as possible to link together all the components of RAINEX that are briefly introduced in this meeting report. A preliminary outline was discussed at the meeting.

5. Tasks organized by groups:

UW

Set up and test RAINEX Operations Center (Brodzik—collaborate with Moore, Chen, Anderson, Burghart & others). This includes wiring, connection with HRD, backup power, workstation and tape drive configurations, etc.

Conduct a series of tests of the ROC comms in March, June, and July of ’05 (Brodzik—collaborate with Rogers, Moore, Meitin, and Lee)

Acquire laptop for onboard RAINEX scientist on lead P3 aircraft. Install and test software required for chat, LF image construction, and other functions (Brodzik—collaborate with Burghart)

Obtain another laptop and 2 DAT drives for post mission processing in the ROC (Brodzik)

Work with NHC & NCEP to reach agreement on high level dropsonde plan (Houze—collaborate with Surgi, Rogers, Aberson, Franklin)

Get chat capability set up on all 3 P3 aircraft and at ROC (Brodzik—collaborate with Burghart, Smull, Meitin, & Lee)

Develop dual-Doppler processing scheme for ROC and onboard (Smull—collaborate with Gamache & Lee)

Develop complete list of products to be gathered in JOSS Data Catalog (Brodzik)

UM

Prepare and set up for the operations center at RSMAS (Anderson and Chen—in collaboration with Brodzik and Moore). Re-wire the electric outlets to handle additional PCs, clusters, laptops, tape drives. Increase Ethernet access for all machines and the data transfer in real time. Acquire additional A/C power and backup power supply/UPS for the operations center.

Set up data connections with HRD for real-time NOAA-specific satellite and model data (Anderson in collaboration with Brodzik, Moore and Rogers).

Test global observation and model data inflow for running MM5 from Unidata (LDM) and JOSS (Chen, Moore).

Organize near real time MM5 modeling program, including products sent to RAINEX Operations Center (Chen, Nolan).

HRD

HRD is a science partner in RAINEX. A crucially important contribution of HRD to RAINEX will be provision of RAINEX mission scientists aboard at least one of the NOAA P3 aircraft during each mission. The HRD RAINEX onboard scientist will help guide the RAINEX missions. If possible, the HRD RAINEX mission scientist would be separate from the overall HRD airborne mission scientist in order to focus on achieving RAINEX mission science. An overall HRD airborne mission scientist would coordinate all the HRD scientific experiments on the flight. HRD/RAINEX mission scientists aboard the NOAA P3 aircraft will be chosen among Rogers, Gamache, Dodge, M. Black, and possibly others. (Rogers—will coordinate the airborne mission scientists within HRD).

Work with UW& JOSS to arrange transmission of satellite and other synoptic products to ROC (Rogers—collaborate with Brodzik and Moore)

In coordination with NHC & RAINEX PIs develop procedures for determining location of extra dropsondes on G-IV flights (Rogers—in collaboration with NHC, Houze, & Chen).

AOC

Establish required communications on board both NOAA P3 aircraft (McFadden's representative—collaborate with Smull, Brodzik & Burghart)

Identify potential foreign bases and coordinate diplomatic clearances with NRL.

EOL

Develop software for onboard LF data retrieval and transmission to ROC (Burghart—collaborate with Brodzik, Chang).

Develop onboard dual Doppler processing (Lee—collaborate with Gamache)

JOSS

Begin drafting RAINEX Operations Plan (Moore, Meitin—collaborate with Houze & Chen)

Set up RAINEX website & email list (Meitin)

Develop preflight briefing and post-flight debrief procedures (Moore)

Develop data management plan including customization of RAINEX Field Catalog (Meitin, Moore)

Coordinate RAINEX communications strategy will all involved groups (Moore,Meitin in collaboration with many others)

NRL

Confirm/assure availability of NRL P-3 aircraft (Kane)

Establish clearances for alternate bases of operation (Newman, Kane)

Modify dropsonde chute, if required (Kane)

Identify potential foreign bases and coordinate diplomatic clearances with NRL (Kane).

Attachment 1
NHC Aircraft Tasking Grid
(provided to meeting by NHC)

Opportunities to modify flight track or sampling frequency to address RAINEX objective of maximizing inner core and rainbands measurements through great depth:

Aircraft	Operationally Tasked Reconnaissance	Operationally Tasked Inner Core	Operationally Tasked Surveillance	HRD and NESDIS Research
C-130 J	None (except psbl incr # sondes <10k ft)	N/A	Possible (limited)	N/A
WP-3D	None (except psbl incr # sondes <10k ft)	N/A	Possible (limited)	Possible through interactions with HRD and NESDIS
G-IV	N/A	Possible (TD - Cat. 1 mainly)	Very limited	Possible through interaction with HRD (45 h)

All operationally tasked missions originate at NHC (James Franklin, POC) and are passed to AOC or the AFRES via Chief Aircraft Reconassance Coordination, All Hurricanes (CARCAH) (John Pavone, POC).

For a surveillance tasking, CARCAH contacts HRD by 9 AM the day before a planned mission to put together a flight plan (Sim Aberson, POC), which is submitted to NHC and AOC for review. All surveillance flight plans must be submitted to FAA for approval 24 h prior to planned take-off. These flight track can't be modified once submitted to the FAA. Surveillance missions are usually scheduled to coincide the drops around model initialization times of 0000 or 1200 UTC. Take-off for these missions is at 0530 or 1730 UTC (1:30 AM or 1:30 PM), respectively. During storms with a potential U. S. landfall, surveillance missions can occur twice a day. HRD provides one meteorologist to do dropsonde quality control for each G-IV surveillance mission

For reconnaissance tasking, CARCAH contacts the AOC flight director or AFRES flight meteorologist with the necessary information to do the fix. The tasking is made prior to 1500 UTC (11AM) each day and is put into the Plan for the Day (POD). Flight patterns and procedures are standard and are published in chapter 5 of the National Hurricane Operations Plan (http://www.ofcm.noaa.gov/nhop/04/nhop04.htm). Slight modifications or short modules may be added to these flight plans ahead of time, provided they do not jeopardize the fix responsibility. HRD often puts at least one person on WP-3D reconnaissance missions.

For HRD or NESDIS research missions (WP-3D or G-IV) the field program director (HRD, Robert Rogers), or chief scientist (NESDIS, Paul Chang) notifies the AOC program manager (Jim McFadden) of a possible research mission at least 24 h prior to planned take-off (usually after weather briefing at 1700 UTC (1 PM) each day). Flight tracks for the proposed experiment, based on those in the field program plan put together before the season, are sent to AOC 18-24 h prior to planned takeoff for approval and submission to FAA. Modifications to these flight plans based on the storm structure or intensity are usually made.

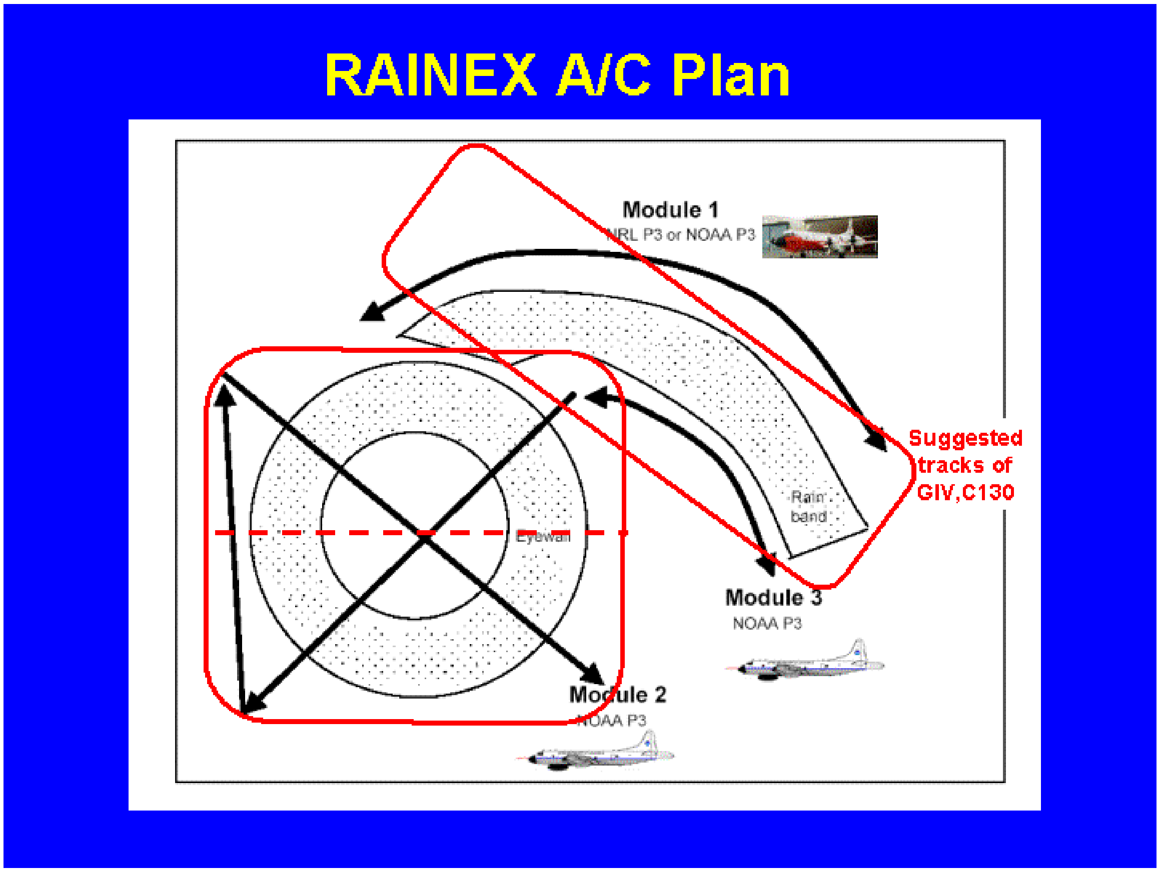

Figure 1. Proposed flight tracks for P3 (black) and dropsonde aircraft (red). Module 3 will be the position of the lead P3 aircraft. The dropsonde tracks circumnavigate the eyewall and the principal rainband. The dashed track is a desired leg across the eyewall to be conducted as and add-on to the circumnavigation.

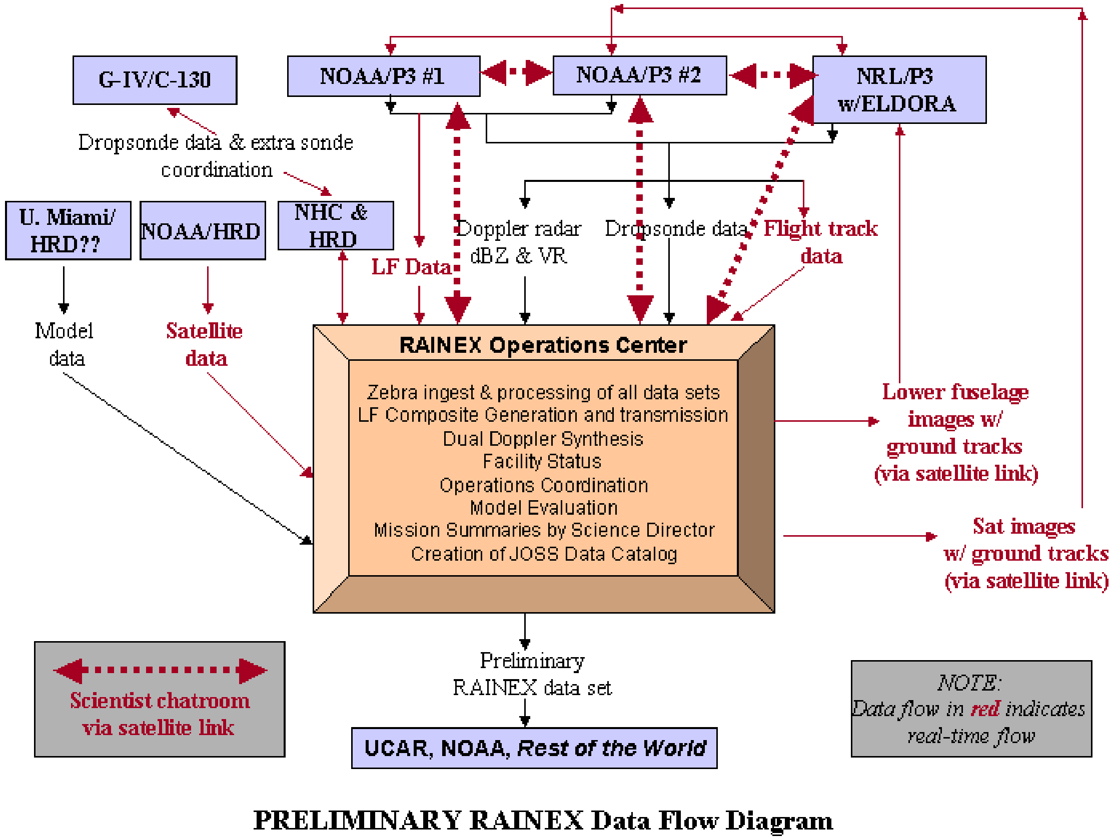

Figure 2. Preliminary data flow diagram for RAINEX.