ENHANCING THE WESTERN CARIBBEAN SEA OBSERVING NETWORK FOR IMPROVED DETECTION OF HURRICANE GENESIS

A proposal submitted in response to the FY 2009 Joint Hurricane Testbed (JHT) Opportunities for Transfer of Research and Technology Into Tropical Cyclone Analysis and Forecast Operations.

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Period of funding requested: August 1, 2009 to July 31, 2011

FUNDS REQUESTED:

Year 1: $286,605
Year 2: $207,900

total requested: $494,505

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ABSTRACT

This proposal requests funds to establish a semi-adaptive observing network in the western Caribbean Sea region to provide early detection of early- and late-season tropical cyclogenesis. The network will also provide better depiction of tropical wave precursors to eastern Pacific cyclogenesis events. The observational technologies are well-established; only the institutional arrangements are necessary to obtain collaboration with the international partners.

The specific activities will include:

1) Establishing an array of surface automated weather stations and pilot balloon stations on small islands in the western Caribbean Sea region and surrounding mainland sites.

2) Instituting the communications protocols and data ingest procedures (with JHT help) to receive observations in near real-time and to request special observations when required from the observing sites.

3) Developing a web page to display the special data, along with more routine observations for quality control.

The benefits of the proposed network should be:

1) improved detection of tropical cyclogenesis in the western Caribbean Sea region.

2) more accurate depiction of the synoptic environment around tropical storms and hurricanes in Caribbean Sea region throughout the hurricane season.

3) reducing the number of unnecessary U.S. Air Force operational investigative flights into weak tropical systems with an attendant cost savings.

4) better description of tropical waves propagating across the western Caribbean Sea that may improve prediction of cyclogenesis over the eastern Pacific.

Statement of work: Introduction

The western Caribbean Sea is a region of preferred hurricane genesis during both the early (late May through June) and late (Oct-Nov) hurricane season (Fig. 1). Although many of the storms that develop in these periods are weaker than mid-season storms that originate farther east, their proximity to populated areas and irregular tracks makes it important to quickly identify their genesis and estimate their initial motion. Some of the storms that develop during the early and late season are associated with extratropical features that provide suitable conditions (low-level vorticity for example) for further development. These storms move in a variety of directions (see Fig. 1) from westward into Central America to immediate recurvature ahead of extratropical troughs, though most tend to move northwestward northwestward – towards the US.

Currently, the National Hurricane Center (NHC) uses input from a variety of satellite and in situ sources to identify cyclogenesis in the western Caribbean Sea region. While satellite imagery has tended to dominate the decision-making process in recent decades it has limitations in quantifying the intensity of a developing surface circulation or in describing the vertical structure of the wind field that might limit or enhance the intensification of the circulation. Ultimately, observations of sufficient quantity and accuracy are needed as input into numerical weather prediction models to generate consistently reliable forecasts of cyclogenesis.

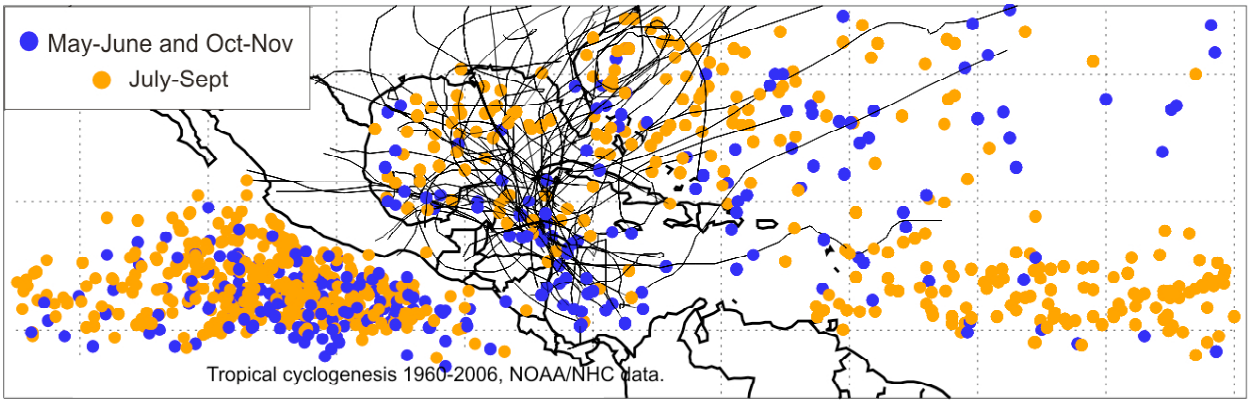

Fig 1. First position of tropical storms for May-June and Oct-Nov (blue) and July-Sept (orange); the early and late season western Caribbean cyclogenesis region is evident. Tracks of these storms (thin black lines) tend to affect the US.

Surface observations, by definition, are the ultimate validation of whether a depression or tropical storm has formed. Despite the proximity to many islands and to Central America, surface observations in the extreme western Caribbean Sea region are somewhat sparse. West of 80˚W there are few ship observations, due to the lack of major ports on the Caribbean side of Costa Rica, Nicaragua and Honduras. The very recent addition of four NBDC buoys (see Fig 3 for their locations) in the Caribbean Sea has substantially improved the surface depiction across the Central and northern Caribbean. Unfortunately, wind observations from coastal and inland sites of the major Antillean Islands and coastal sites in Central and South America are strongly affected by the topography of the islands/coasts themselves and ubiquitous sea-land breeze circulations, making it difficult to accurately infer surface winds over the open sea from those

measured on the shore (Fig. 2)[1]. Scatterometer data, such as from QuickSCAT, has helped to improve the surface windfield estimation, though there are a number of subtleties that complicate the use of these data for identifying weak or ill-defined circulation centers (Brennan and Knabb, 2006). In general, there continues to be a need for near-continuous surface winds over the Caribbean Sea to improve detecting the early stages of cyclogenesis.

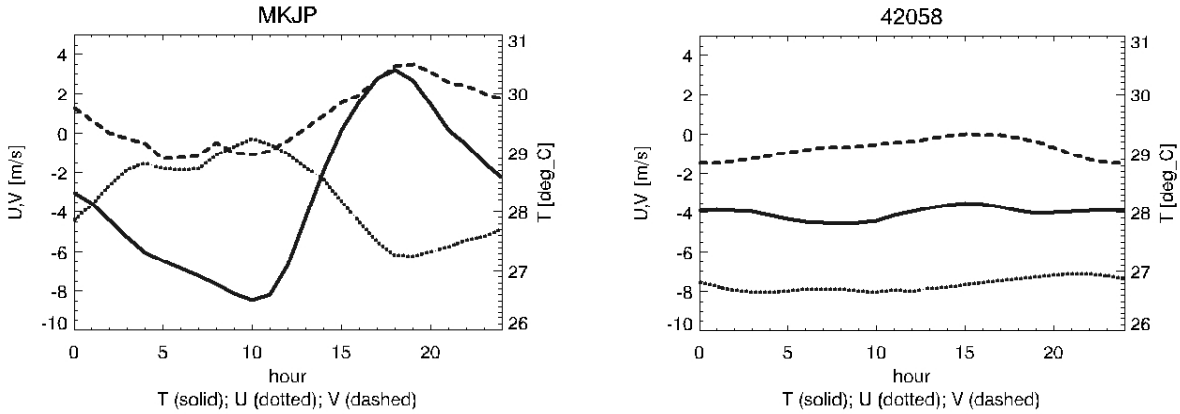

Fig. 2 Diurnal cycles of T, u and v winds at Kingston, Jamaica (left) and a NOAA buoy (~15˚N, 75˚W) showing much smaller changes at buoy. Data averaged over August-September 2008.

As for upper-air observations, the number and distribution of radiosonde stations in the Caribbean Sea region (see Figs 3 and 5 for their locations) has not changed for many years. In addition, the performance of the network is irregular, subject to many logistical and budgetary issues. The performance was particularly poor during 2008, when essentially no observations were made at San Jose, Costa Rica or at the Colombian sites of San Andres Island and Riohacha. This left a very sparse radiosonde network in the western part of the Caribbean Sea that was capable of describing only the broadest aspects of the flow over the region. While there are increasing numbers of automated aircraft reports (AMDAR), these provide sounding profiles only near major airports.

One of the specified Joint Hurricane Testbed objectives is "assessing scientific breakthroughs and new techniques to identify advanced, real- time, data-analysis techniques, forecast models, and observational systems that have potential for significantly improving the forecast guidance provided to hurricane forecasters" (JHT Terms of Reference, 2002). Examination of the projects funded by the JHT since its inception in 2001 shows that relatively few have focused on enhancing observations as an aid in real-time analysis and few in-situ efforts have been proposed. Our proposal departs from this history of projects in proposing to implement a multi-component in-situ observing system in the western Caribbean Sea and surroundings that aims at improving the detection of cyclogenesis in this region. We are specifically addressing two of the areas determined by the TPC/NHC as priorities for forecast improvement. These priorities, mentioned in the JHT FY09 call, are:

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[1] *The radiosonde observations made at Santo Domingo and Kingston are also seriously disturbed by the topography of the islands in the lowest 100 mb.*

Improved observational systems in the storm and its environment that provide data for forecaster analysis and model initialization (TPC-2 (JTWC-2))

and

Guidance for tropical cyclone genesis that exhibits a high probability of detection and a low false alarm rate, and/or provides probability of genesis (TPC-7 (JTWC-3))

Statement of work: Proposal specifics

We propose to establish a network of two complementary observing systems to provide benefits for hurricane genesis and early track forecasting. These systems use existing technology – only the actual deployment to small island sites and their planned mode of operation is novel.

Taking advantage of geography - The small islands (coral cays) of the western Caribbean Sea

Our proposal takes advantage of the geography of the western Caribbean Sea where there are many little-known islands between Jamaica and the mainland of Central America (Fig 3). Many of these have permanent garrisons of military services of the countries to which they pertain – to maintain a sovereign presence to enforce their claim to the corresponding maritime zone. These islands have critical advantages as potential sites for meteorological observations. Most important is their very small size and lack of topography. The islands, being flat (less than 3 m elevation, excluding the coconut palms on some of the islands), do not perturb the wind field like all larger islands in the Caribbean (see Fig 2 for example from Jamaica). The very small size of the islands (usually a few hundred m across) also results in negligible sea-land breezes developing, so there is no diurnal cycle apparent in the surface winds. (There may be a small diurnal cycle of temperature under weak wind conditions but this is unlikely to modify the wind field.) Thus, for most meteorological purposes the surface measurements of wind and pressure on the islands represent conditions over the open ocean, much like those from a meteorological buoy.

There are major logistical advantages of using the small Caribbean islands as observing sites. These include personnel to make observations such as balloon launches and some communications facilities to transmit the observations. Additionally, personnel help to prevent vandalism of automated weather stations – a significant problem affecting meteorological buoys. Permanently staffing of the islands also implies that regular transport is already available to the islands, which allows for low-cost site set-up and maintenance visits.

Although finding specific information about each island is not straightforward, background work towards this end has been carried out as part of a developing NOAA-funded activity known as IASCLIP (Intra-Americas Study of Climate Processes). This effort, focused towards improving climate prediction over the Inter-American Seas region, also has an interest in monitoring climate variability over the region. Suitable sites for monitoring climate variability are being sought, and the activities we are proposing here also will contribute to the IASCLIP activity. In fact, we would encourage communication with that program office (NOAA/CPO/CPPA) to

consider overlap possibilities. Our web site containing specifics on the geography of the region can be found at: http://www.nssl.noaa.gov/projects/pacs/web/IASCLIP/

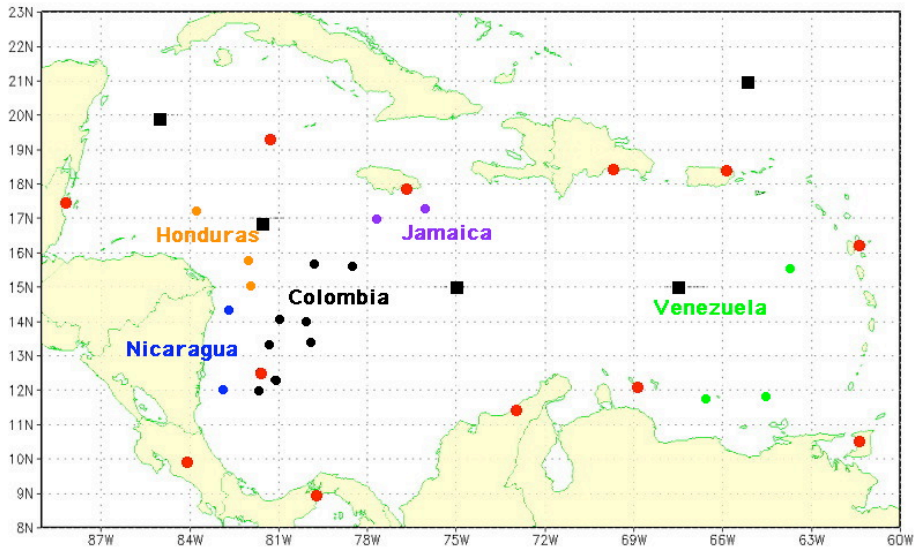

Fig 3. Map showing locations of most radiosonde stations (red dots) in Caribbean Sea region, together with selected (not all) small islands or coral banks where surface measurements could be made. Color coded by country of possession. Black squares are current NOAA buoy locations.

The tools needed for cyclogenesis detection

We propose establishing two complementary and economical observing systems, automated surface weather stations and pilot balloon stations, for improved cyclogenesis detection. These are justified below.

A. Surface automated stations

Continuous surface measurements obviously have a role to play in hurricane-related forecasting, since this was the primary rationale for installing the new NOAA buoys across the Caribbean Sea (http://www.noaanews.noaa.gov/stories2005/s2458.htm). Surface measurements, whether wind or pressure, are crucial for identifying the presence of a tropical depression. There are various possibilities for establishing a network of automated weather stations over the proposed domain. Cost is a key constraint, since stations capable of routine GOES-data transmission cost on the order of $10-15K. However, unlike ocean buoys, these should require no expensive site visits to either install or maintain, assuming the stations are installed on islands that undergo routine visits for personnel rotation. We have determined from various Internet sites that this does indeed happen every few months.

Automated surface station data, if available, should be merged with other surface data to produce a uniform surface pressure and wind analysis. The pressure data should be bias-corrected based on monthly mean values fitted to a mean pressure analysis constrained by the mean wind field determined from the meteorological buoy and small island measurements. After these biases are

removed it will be possible to produce accurate surface pressure maps (corrected also for atmospheric pressure tides) that can be used to infer whether incipient depressions are deepening with respect to their surroundings.

Siting of the AWS's is important, even on small islands, since blockage by even coconut palms, common on these islands, may have an impact on observed wind speeds. The goal would be to have measurements directly comparable with the four NOAA buoys already present in the Caribbean. However, it should be noted that AWS measurements on even the larger cays (such as Serranilla – approximately 600 by 300 m) are a vast improvement over surface measurements from coastal stations on the larger islands and along the coasts of Central and South America.

The tentative siting for the AWS's is shown in Fig 4. Some pibals sites would also have AWS's (though less expensive), with surface data being transmitted (discussed below) at the same time as pibal observations. Using GOES-transmitting AWS's at remote islands and less expensive data-logging AWS's at pibal sites where routine transmission will be required will allow for a greater number of stations for the same budget. The relative importance of each AWS data set can then be evaluated. The specific details of the AWS's will depend on funds available and discussions with TPC staff, since AWS prices range from under $1,000 to $15,000 or more.

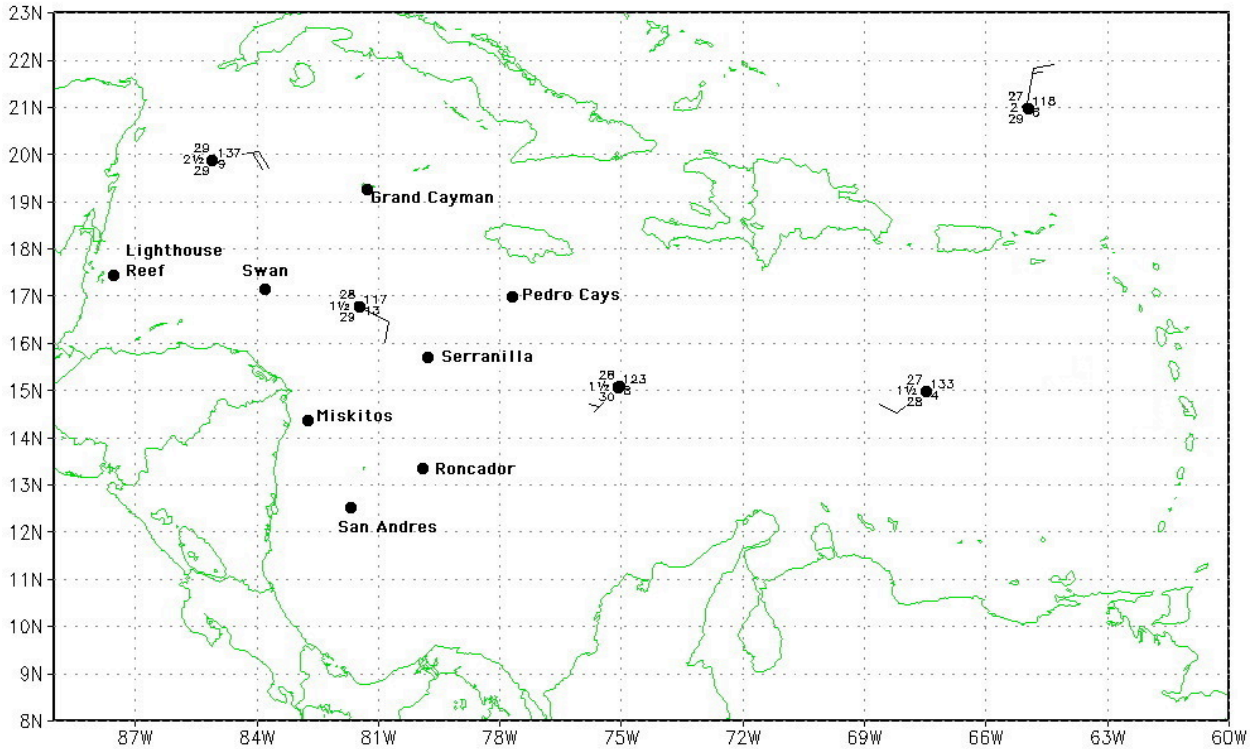

Fig 4. Proposed network of possible automatic weather station sites (labeled); NOAA buoys (black dots with data) and airport location on Grand Cayman also shown.

B. Pilot balloon stations

The influence of the environmental wind field has a large impact on the development of tropical storms (Tuleya and Kurihara, 1981, DeMaria, 1996, Frank and Ritchie, 1999). While surface

wind information can help determine whether a surface center of circulation is present, the vertical structure of the circulation gives a better indication of how well-developed is the nascent tropical storm vortex and how rapidly it is likely to develop. To *economically* obtain the vertical structure of the wind field in a depression's environment is challenging. Currently the routine radiosonde network is relied upon for background information on the vertical structure of the wind field. This is complemented with commercial aircraft (AMDAR) winds near major airports and with satellite-derived winds. If satellite imagery suggests that a depression has formed, or may be forming, then the NHC forecasters have the option of requesting an aircraft investigation to determine the actual intensity. This latter step, usually involving a US Air Force C-130 aircraft from Keesler AFB, Mississippi, is not taken lightly, since the costs involved are substantial (on order of $5K/ flight hr). The proximity of a suspected depression to land and the probability of rapid intensification are important factors in requesting an aircraft investigation. For more threatening systems the NOAA G-IV may carry out a synoptic reconnaissance with dropsondes, another valuable, but costly option.

We are proposing to establish a network of pilot balloon (pibal) stations to routinely improve the upper air wind field specification around "suspect" circulations in the western Caribbean Sea region. While pibal observations are well know for their limitations due to cloudiness, the alternative of substantially enhancing the radiosonde network is not feasible due to the high start-up costs involved. The pilot balloon stations would be operated in a manner similar to that done during the PACS-SONET project that was carried out in Latin America from 1997-2006 (Douglas and Murillo, 2008), for which the procedures are well-established. In order to minimize overall cost of the network, observations would only be made from mid-May to late October. Once-daily observations are proposed, so that observers maintain their proficiency in making the observations and because a continuous time series is valuable for improving the detection of tropical waves during the summer months. However, when requested from NHC, all stations would be able to make twice-daily observations, and selected stations would make up to 4 soundings per day. More frequent observations increase the likelihood of tracking some balloons to a relatively high level.

The tentative pibal network, shown in Figure 5, is justified on the following basis:

1) The stations at San Salvador in the Bahamas and on Grand Turk, those along the Colombian Caribbean coast, and the Central American sites at Managua and San Salvador are to enhance analysis of the synoptic-scale environment. Based on the recent poor performance from the radiosonde network over this region, these additional wind soundings should be valuable for a better depiction of the depression's environment.

2) the sites located on small islands in the western Caribbean (Swan, Serranilla, San Andres) and at Puerto Cabezas on the Nicaraguan Caribbean coast are the core stations for describing the vertical structure of the wind field closer to the depression center. Although there is a radiosonde station on San Andres, its recent unreliable performance, together with the importance of the site, necessitates a pibal site as a backup (to be operated by the Colombian Navy). These sites should have capacity for observations up to four-times daily. This should be feasible from the two sites operated by the Colombian Navy.

As for the feasibility of establishing and maintaining the proposed pilot balloon network, the key components – the theodolites, have been widely deployed as part of the PACS-SONET project. These can be obtained from the countries where they remain. Gas supplies (6 cubic meter hydrogen cylinders) can be obtained in the countries involved and the small volumes required for filling 30 gm pilot balloons indicates than only about 10-12 cylinders per station are needed each year. This simplifies the gas supply to sites – it should be feasible to transport the entire summer's supply to an island site at the beginning of the season. These can be transported easily aboard the large vessels that supply the islands and rotate island staff, or by trucks in the case of mainland sites.

Finally, we expect relatively good cooperation with the countries involved in the network, since each is affected by hurricanes and would benefit from better forecasts. Some sites, not operated by military institutions, will likely require payment to observers to make the observations. This has been done in other meteorological field programs and we have budgeted for this.

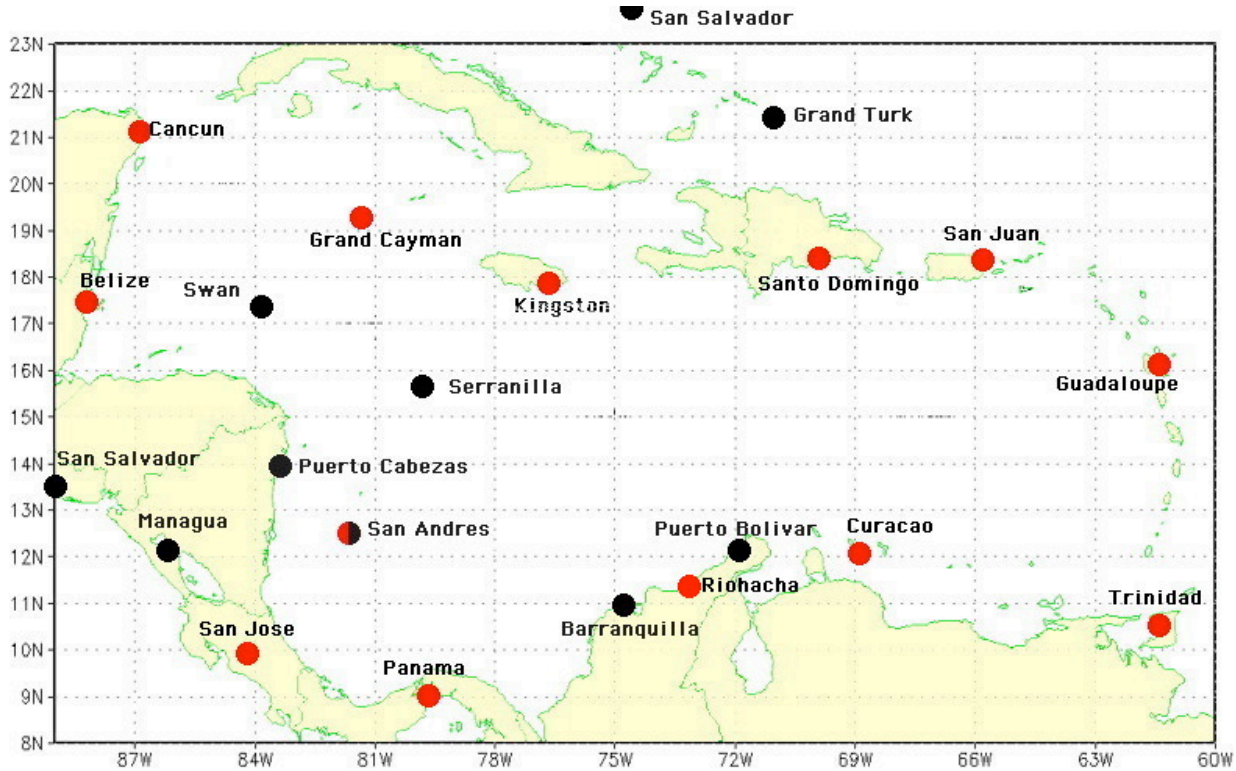

Fig 5. Proposed network of pilot balloon stations (black dots); red dots are current radiosonde sites.

Statement of work: Logistical details

Observation times and data transmission

Pibal observations are best made during daylight hours to improve the chances of obtaining a high sounding. Sunrise is ~ 1030-11:00 UTC across the central part of the proposed pibal network. For a relatively long sounding of 45 minutes duration (reaching ~10 km) with a launch

time as late as 11:15 UTC, this allows 1:45 for processing and transmission of the data to NCEP before the Eta cut-off time. Data entry of the raw angle data is the most time consuming aspect of processing the pibal data – it can take up to 10 minutes for slow data entry of a long sounding. Then processing these data with the specialized interactive software developed for PACS-SONET for correcting errors in raw pibal data takes only a few extra minutes. If the data does not arrive by the Eta cut-off time it certainly should arrive by the GFS cutoff.

Internet access should be available at some pibal stations (those in Central America, the Bahamas, and coastal Colombia) and this is the preferred method to transmit the data, with both the raw and processed sounding data being sent. However, satellite communications will be needed for both Serranilla and Swan Island. It appears that the most economical means to do this is via satellite phone with a monthly payment plan. Procedures to communicate the data files via the satellite phone need to be arranged, but this is a common application of satellite phones so the procedures should be straightforward. Islands staffed by the Colombian Navy already have communications, but the procedures for transmitting the observations would need to be carefully worked out.

Timeline of activities

The proposed start date for all JHT proposals is August 1, 2009, which complicates obtaining two full seasons of measurements. The time required for establishing the network, for arrival of funds, will be at least 3 months and more likely 6 months. Thus, observations will not begin until May 2010. It would be desirable to extend the activities through October 2011, or to begin funding in early 2009 (probably unlikely) to obtain coverage during the hurricane seasons of 2009-10. In any event, the first priority will be to arrange for permission and logistical help to install and operate the island and mainland stations. This effort would begin once approval of the project is obtained, since these coordination steps can be handled by email and telephone.

Interactions with NHC and evaluation of the new observations

If this proposal is funded we expect to discuss the overall network design with the NHC staff prior to any actual effort at implementation. We expect the NHC staff to have unique perspectives on what types of observations are likely to be most critical and from which geographical regions. In particular, we would welcome discussion of the most effective blend of high and low-cost surface stations over the region.

The JHT FY09 announcement of opportunity notes that:

A successful JHT project will result in one or both of the following: (1) A guidance product or technique leading to improved tropical cyclone analyses and/or forecasts; and/or (2) operational availability of data from a new observational system that has provided documented evidence of positive diagnostic or forecast impact.

Quantifiable measures of successful implementation of our project will include:

1) observational sites installed and personnel trained

2) requested observations made and data received within allotted time interval

3) delayed data processed and evaluated – to determine quality of the surface and upper-air data relative to other observations from the region.

More important, but also more difficult to quantify will be whether TPC staff perceive the additional observations to be a cost-effective supplement to their available tools for genesis detection and for track and intensity forecasting for mature storms. We do expect that an objective evaluation of the proposed networks will show them to be cost effective compared with other components of the current Caribbean observing network. In fact we would argue that a comprehensive evaluation of the different components of the Caribbean meteorological observation network be carried out to determine the cost effectiveness of each component.

It should be apparent that one summer of observations is not be sufficient to determine a statistically significant impact of the additional observations on the skill of predicting cyclogenesis in the western Caribbean. Even the evaluation of the impact of the daily pibal soundings from the 10 proposed sites on daily weather forecasts over the region is non-trivial, since parallel runs would be needed to evaluate the impact of the these additional data on routine forecasts. Having said this, a subjective evaluation formed by the hurricane forecasters should be possible. Current forecast discussions routinely indicate the subjectivity involved in estimating the intensity and motion of weak circulations, along with the importance of specific observations (or often the lack of them). Some means of quantifying the relative impact of the new observations in genesis and intensification forecasts needs to be identified in collaboration with TPC staff.

References:

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Tuleya, R.E., and Y. Kurihara, 1981: A Numerical Study on the Effects of Environmental Flow on Tropical Storm Genesis. *Mon. Wea. Rev.*, **109**, 2487–2506.

BUDGET JUSTIFICATION

The single largest component of the budget is salary for a full-time project manager. The work required to communicate with the relevant countries and institutions involved, travel to the sites and help with installation of equipment and training of observers, development of web page materials to help display the observations in useful forms, and to help with project summaries requires a full-time individual with technical skills and suitable experience. The automated weather station details will be determined after consultation with NHC personnel to identify the best mix of station types and their distribution. The main uncertainty in the pilot balloon observational cost is that of gas. We have used an expected upper-limit for hydrogen, actual cost may be up to 50% less. Communications from island sites would be via satellite phone (to be purchased) and monthly contracts, this appears the most feasible manner to send pilot balloon and some surface data. Travel is an approximate value, based on three 10-day trips for 2 individuals. The travel more specifically would be: trip 1: Colombia (Cartagena, Bogota) and Jamaica (Kingston), trip 2: Nicaragua (Managua), Honduras (Tegucigalpa), El Salvador (San Salvador), and Belize (Belize City), and trip 3: Bahamas (San Salvador), Turks and Caicos (Grand Turk), and Miami. One additional non-international trip would be required to Miami for consultation with JHT and Tropical Prediction Center staff.

Some sites, most likely in Central America and in the Bahamas, will require some funds for making observations. An amount of $10 per observation is included for this.

We recognize that the budget exceeds those for most JHT projects. However the scope of the project is substantial and the number of stations proposed, and countries involved, reflects an effort to partially reverse a multi-decadal decay in the in-situ measurements over the region. The program also capitalizes on a developing climate research program (the CPO/CPPA/IASCLIP) that may complement the proposed observations – or may partially support them in years ahead if they prove to be sufficiently valuable for climate monitoring activities.

YEAR 1 Budget

Automatic weather stations (2 @$ 8K ea, 5 @$2.4K ea)	$ 28,000
Pilot balloon stations (10; theodolites, computers, inflation materials)	$ 18,000
Labor	
Network supervisor (100% time) $55K salary with CIMMS benefits	$ 88,300
1 undergraduate student (25%time)	$ 6,000
observer fees ($10 per obs, 1600 obs)	$ 16,000
shipping	$ 6,000
Communications (some sat phone systems/fees, Internet connections)	$ 8,000
travel (three 10-day trips for 2 individuals)	$ 18,000
expendables:	
2400 balloons ($10K), 120 cylinders gas ($14K)	$ 24,000
subtotal year 1 costs	**$212,300**
NSSL overhead (35%)	**$ 74,305**
Total	**$286,605**

YEAR 2 Budget

Labor costs	
Network supervisor (50% time) w/benefits	$ 90,000
1 undergraduate students (25% time ea)	$ 6,000
observer fees	$ 16,000
shipping	$ 2,000
Communications (@$1K/year per site includes sat phone system)	$ 8,000
travel	$ 8,000
expendables:	
2400 balloons ($10K), 120 cylinders gas ($12K)	$ 24,000
subtotal year 2	**$154,000**
NSSL overhead (35%)	**$ 53,900**
Total	**$207,900**

Biographical Sketch - Michael W. Douglas

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Education:

Ph.D. Meteorology, Florida State University, Tallahassee, Florida, 1987. Advisor: T.N. Krishnamurti Dissertation: *Structure and dynamics of monsoon depressions*.

M.S. Atmospheric Science, University of Miami, Coral Gables, Florida, 1977. Advisor: M.A. Estoque. Thesis: *Structure and occurrence of disturbances along the ITCZ over the GATE area.*

A.B. Geophysics, University of California, Berkeley, California, 1975.

Principal Employment Experience:

10/92 - present Employed at National Severe Storms Laboratory, Norman, Oklahoma as Meteorologist. Work is principally related to explaining the warm-season circulations and rainfall patterns over the tropical Americas.

07/90 - 09/92 CIRES, Univ. of Colorado, Boulder, Colorado. Work was with the National Severe Storms Laboratory/NOAA and involved analysis of data from Mexico and southwestern U.S. (R. Maddox supervisor)

10/86 - 12/87 and 06/88-06/90 CIRES, Univ. of Colorado, Boulder, Colorado. Work with WPL/NOAA involved participation in field experiments to collect data in the vicinity of polar lows and developing oceanic cyclones and to subsequently analyze this data. (M. Shapiro supervisor)

Additional experience:

07/06 - 09/06 PI for NASA-supported measurement campaign involving pilot balloons and radiosondes in four west African countries as part of the NASA-AMMA.

04/97 - 05/06 Principal investigator for NOAA-supported pilot balloon observation network (PACS-SONET) involving ~20 stations in Latin America. Program made more than 50,000 observations since 1997 at more than 60 locations.

05/04 - 10/04 Principal investigator for 4 NOAA-supported projects associated with the North American Monsoon Experiment (NAME). Projects involved NOAA P-3 aircraft (10 flights), pilot balloon network (22 sites), vegetation monitoring and atmospheric feedbacks, and a Mexican research ship activity.

11/02 - 02/03 Principal investigator for three separate NOAA-supported projects involving a NOAA P-3 (13 flights), raingauge networks, and a 20-station pilot balloon network during the South American Low-Level Jet Experiment (SALLJEX).

06/93 - 08/93 Helped to organize the EMVER-93 observational network (9 pilot balloon and 2 special radiosonde sites) over northwestern Mexico and establish a temporary regional analysis center in Obregon, Sonora.

06/90 - 08/90 Participated in Southwest Area Monsoon Project (SWAMP). Was responsible for organizing a network of 11 pilot balloon stations in Mexico and Arizona to describe the southwest North American monsoon circulation.

02/87 - 03/89 Participated in planning and execution of four aircraft field programs using NOAA P-3 aircraft. Programs were Coordinated Eastern Arctic Research Experiment (CEAREX), Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA), Ocean Storms, and Alaska Storms Experiment.

Formal publications in the past 3 years and other relevant publications

Douglas, M.W., J. Mejia, N. Ordinola, and D. Boustead, 2008: Synoptic variability of rainfall and cloudiness along the coasts of northern Peru and Ecuador during the 1997-8 El Niño. *Mon. Wea Rev.*, **136**, in press.

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Watts, C. J., R. L. Scott, J. Garatuza-Payan, J. C. Rodríguez, J. H. Prueger, W. P. Kustas, and **M. Douglas**, 2007: Changes in vegetation condition and surface fluxes during NAME 2004. *J. of Climate*, 20, 1810-1820.

Higgins, W., …, **M. Douglas**, … and C. Zhang, 2006: The NAME 2004 Field Campaign And Modeling Strategy, *Bull. Amer. Meteor. Soc.*, **87**, 79–94.

Vera, C., Baez, J., **Douglas, M.,** …and Zipser, E., 2006: The South American Low-Level Jet Experiment, *Bull. Amer. Meteor. Soc.*, **87**, 63-77.

Current and pending support for M. Douglas

Current:

NOAA CPO/CPPA: Explaining the spatial variability of the mid-summer drought over the Inter-American Seas region. May 1, 2007 to April 30, 2010. Total requested $280,125 YEAR 1: $119,475, YEAR 2: $114,750, YEAR 3: $45,900.

NASA: Measuring the evolution of tropical waves over West Africa into tropical storms over the eastern Atlantic. March 1, 2006 – Feb 28, 2009. First year $120,000, second year $77,895, and third year $84,442.

Pending:

1) This proposal.

2) Developing international collaboration for IASCLIP, PI M.W. Douglas, submitted to

NOAA/CPO/CPPA. Period of funding requested: May 1, 2009 to April 30, 2011.

Funds requested: Year 1: $112,320, Year 2: $ 87,075, total requested: $199,395